**Table 7-2 Design criteria from consequence category**

| Design Criteria | | Beneficiation TSF | Hydromet TSF |
|---|---|---|---|
| Stormwater Storage Capacity | | 1:5 wet season plus 1:100 AEP, 72 hr flood | 1:10 wet season plus 1:100 AEP, 72 hr flood |
| Additional Freeboard | | nil | 1:10 AEP wind runup plus 0.3 m |
| Spillway | | 1:100,000 AEP, critical flood plus 1:10 AEP wave run-up or PMF | 1:100,000 AEP, critical flood plus 1:10 AEP wave run-up or PMF |
| Seismic Loading | Operation Based Earthquake (OBE) | 1:1000 | 1:1000 |
| | Maximum Design Earthquake (MDE) | 1:10,000 | 1:10,000 |
| | Closure | MCE approximated to 1:10,000 AEP | MCE approximated to 1:10,000 AEP |

# 8. Pre-construction design details

## 8.1 Construction materials and site clearing

Prior to bulk earthworks and embankment construction, the impoundment and embankment footprint areas will be cleared, grubbed and stripped of topsoil to a nominal thickness of 200 mm and stockpiled for later use in the rehabilitation of the site.

The materials required to construct the low permeability zones within the embankments will largely be sought from external borrow pit areas but where possible from within the storages. Borrow pit areas are currently under investigation by Hastings. The select earthfill and gravel materials (structural fill) will be sought from the pit overburden material stockpiled on site. An onsite rock borrow pit (with mobile crushing plant) will be established to produce pavement materials for site access roads and the embankment crest roads.

The near surface clayey sand deposits within the Beneficiation TSF footprint will be retained to assist with seepage control.

The Hydromet TSF will incorporate a HDPE geomembrane placed across the impoundment floor and on the upstream face of containment embankments. The in situ clayey sands will be retained and reworked to form a compacted clay liner below the geomembrane. In areas lacking a suitable thickness of in situ clay, soils from an external borrow pit will be imported to form the base clay liner for the floor of the Hydromet TSF.

## 8.2 Beneficiation TSF

### 8.2.1 Storage characteristics and embankment design

The starter dam design for the Beneficiation TSF features an embankment crest width to enable light vehicle access only. The upstream face will have a 2:1(H:V) batter slope to maximise tailings storage and minimise construction material. The downstream face will have a 2.5:1 (H:V) batter slope which is considered suitably conservative to achieve geotechnical stability requirements. Sufficient space will be maintained between the dam toe and the lease boundary to allow for further design raises and the closure batter flattening works. The starter dam for the Beneficiation TSF features the geometry as listed below in Table 8-1.

**Table 8-1 Beneficiation TSF starter embankment geometry**

| Description | Design |
|---|---|
| Starter Dam Height | ~ 6.5 m |
| Minimum crest width | 7 m |
| Embankment Length | 1,600 m |
| Upstream batter slope | 1:2.0 (V:H) – Starter Dam |
| Downstream batter slope | 1:2.5 (V:H) – Starter Dam (flattened for closure, see Section 6.5) |
| Zoning | Upstream clay and downstream general selected earthfill |

The estimated total storage requirement for the Beneficiation TSF is approximately 6.5 $Mm^3$.

The estimated storage capacity of the Stage 1 starter dam is approximately 2.5 $Mm^3$, sufficient for the first 3 years only. At a filling rate of 0.65 $Mm^3$pa, the TSF would operate with conventional spigot discharge from the northern and eastern embankments for the initial 2 years, with additional capacity developed by extending spigots and discharge from higher elevations to the east and south. To achieve the necessary storage capacity for the mine life volume, the perimeter embankments will need to be raised by approximately 4.5 m. The design conservatively assumes raising using downstream construction methods.

The Pre-Construction Design Drawings presented in Appendix A provide staging drawings for the TSF over the mine life.

A storage curve for the Beneficiation TSF is presented in Figure 8-1. Note that this applies to a flat tailings surface whereas the actual volume estimates to determine the required embankment heights have considered the beach development around the TSF giving the benefit of increasing storage due to beaching around the south and east of the facility.

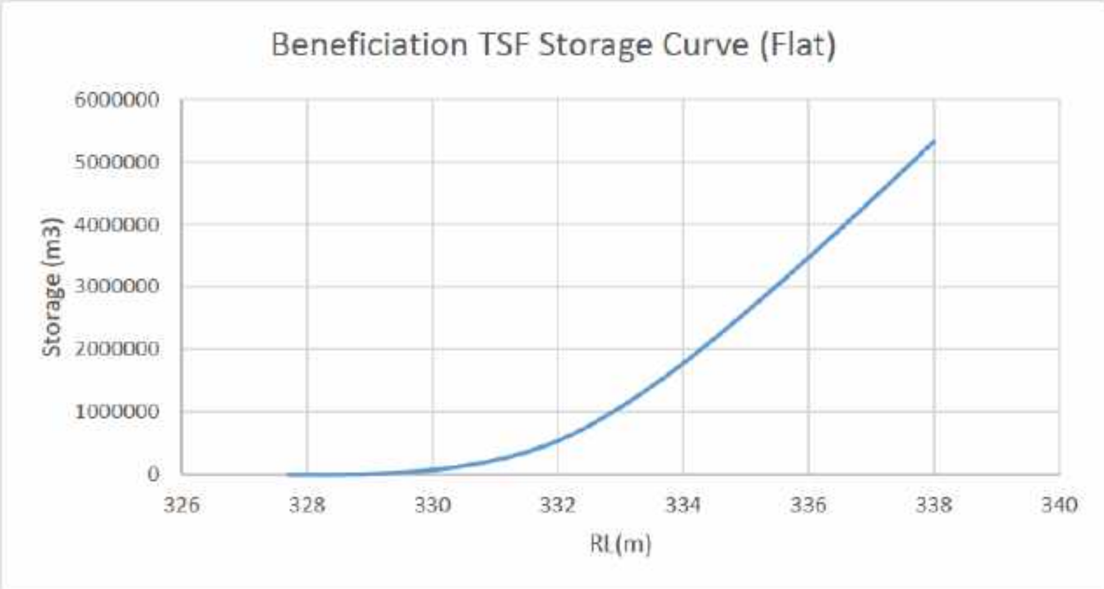


**Figure 8-1 Beneficiation TSF storage curve**

The design embankment for the Beneficiation TSF embankment incorporates three zones:

- Zone 1: Upstream sloping low permeability zone (clayey materials).
- Zone 3A: Downstream general select earthfill (general structural fill).
- Zone 2: Select sandy gravel if necessary for desiccation prevention on the surface of the upstream clay zone (subject to construction and tailings filling schedule).

A typical section of the embankment is shown in Figure 8-2 below.

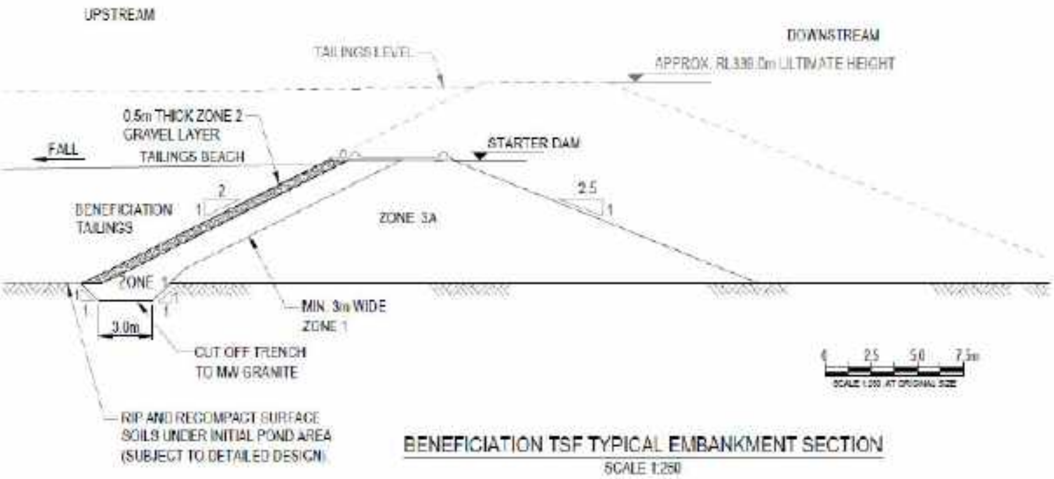


**Figure 8-2 Beneficiation TSF embankment typical section**

To reduce potential seepage beneath the embankment, the design allows for excavation of a cut-off trench at the upstream toe that is excavated to moderately weathered bedrock. The excavated trench will be backfilled with compacted Zone 1 material.

It is envisaged that Zone 1 construction material will primarily be sourced from nearby borrow pit areas where clayey sand is available at a suitable thickness. The clayey soils from borrow pit areas in the vicinity of the TSF may be supplemented by clayey (saprolitic) material recovered during stripping at the Bald Hill pit.

The in situ moisture content of the clayey borrow pit materials is generally expected to be lower than optimum moisture content at the time of construction; consequently, moisture conditioning by adding water during construction is anticipated to optimise compaction. Based on laboratory test data, in situ moisture content at the time of the investigation was generally 2% - 5% below OMC, except at the location of test pit CTTP-03 where moisture content was 4% wet of optimum.

External borrow pit sources of clayey sand typically ranged from between 1.5 m and 2.0 m in depth. ATCW geotechnical investigations found that the clayey materials in the vicinity of the TSF have moderate to low dispersion potential, inhibited to some extent by the presence of calcium carbonate (Emerson class 4). Dispersion and erosion on the upstream slopes of the embankments will be minimised by the accumulation of tailings against the low permeability zone.

Zone 3A material will be sourced from pre-stripping operations at Bald Hill and will be used to form the bulk of the embankment volume, possibly combined with residual materials excavated from borrow pit areas in the vicinity of the TSF.

### 8.2.2 Tailings deposition and decant pond

Tailings deposition within the Beneficiation TSF will involve perimeter discharge in frequent and uniform cycles around the facility via a 280PN20 HDPE pipeline with spigots nominally spaced at 50 m intervals. A new perimeter access road will need to be constructed with sufficient width to accommodate the tailings discharge pipeline so that tailings beaches can be gradually formed around all sides of the facility. The spigots would extend down the face of the embankment and reservoir slopes and depending on the beach slope achieved during operations, be extended out onto the tailings beach to develop an optimal beach shape. Towards the end of mine life, elements of Central Thickened Discharge (CTD) would be adopted to effectively fill the storage and achieve a safe closure surface.

At the commencement of operations, tailings deposition will focus on quickly pushing the pond away from the main embankment to the proposed initial decant tower location. This will be aided by a new channel excavated into the floor of the TSF to connect the decant tower with the valley low point. This will allow decant water to be returned to the plant at the earliest opportunity. Later in the operational life of the TSF, a new decant tower will be constructed towards the southern end of the facility so that the pond can be relocated to its ultimate location, where a discharge channel will be excavated through rock at closure (refer Closure and Rehabilitation Concept, Section 6.5).

The decant towers will be accessed by a new causeway construction from readily available fill materials. The decant causeway will be raised and/or relocated as part of the construction works associated with raising of the TSF, most likely at 3 years and 6 years into operation.

The proposed decant tower will be a slotted concrete ring type of decant arrangement whereby ponded water decants through slots in the side of a concrete ring tower which is raised incrementally to remain elevated above the rising tailings. A variable speed submersible pump will be installed at the base of the tower for water return to the plant.

Staged general arrangement plans are presented in the Pre-Construction Design Drawings in Appendix A.

### 8.2.3 Emergency spillway design

The Beneficiation TSF includes the initial construction of an emergency spillway excavated through natural ground on the southern side of the facility. Conceptually, the spillway is nominally set 1 m below the TSF embankment crest level with the tailings beach lowered to suit in this location.

A nominal spillway width of 50 m has been adopted which provides ample capacity to pass the PMF event. Below the spillway level there is sufficient capacity to accommodate the combined wet season storage and extreme storm storage capacity (refer Stormwater Storage Assessment, Section 9.1). The final spillway location at end of mine life will be through a granite ridgeline on the southern side of the facility to ensure long term stability.

## 8.3 Hydromet TSF

### 8.3.1 Storage characteristics and embankment design

The Hydromet TSF tailings will be of neutral pH, are not acid forming and test work has demonstrated that solution and mobilisation of dissolved metals (including radionuclides) from the tailings deposit is not expected as a result of infiltration. Nevertheless, the incorporation of a liner system for the Hydromet TSF has been adopted due to the elevated salinity of the magnesium sulphate solution, which is used to slurry the Hydromet plant residue and the Barron Liquor.

To minimise seepage the Hydromet TSF features a geocomposite lining system that comprises a minimum 300 mm thick compacted clay liner (CCL) below a HDPE liner. This is a well proven lining system that is commonly used in industry for containment of hazardous mining and landfill wastes.

The Hydromet TSF storage cell abuts the Beneficiation TSF on its western side and forms a closed storage area. Embankment construction consists of a Zone 3A select earthfill sourced from the pit overburden and a sloping impermeable Zone 1 on the upstream face and an impermeable HDPE liner. As a result, an upstream erosion protection layer is not required.

The starter dam design for the Hydromet TSF features an embankment crest width to enable light vehicle access only. The upstream face will have a 3:1(H:V) batter slope that is suitable for application of the lining system. The downstream face will have a 2.5:1 (H:V) batter slope which should be suitably conservative to achieve geotechnical stability requirements. The starter dam for the Hydromet TSF features the geometry as listed below in Table 8-2.

**Table 8-2 Hydromet TSF starter embankment geometry**

| Description | Design |
|---|---|
| Starter Dam Height | ~ 6 m |
| Minimum crest width | 7 m |
| Embankment Length | ~ 2,000 m |
| Upstream batter slope | 1:3.0 (V:H) – Starter Dam |
| Downstream batter slope | 1:2.5 (V:H) – Starter Dam (flattened for closure, see Section 6.5) |
| Zoning | Upstream clay and downstream general selected earthfill |

The estimated total storage requirement for the Hydromet TSF is approximately 1.9 Mm3.

The estimated storage capacity of the Stage 1 starter dam is 0.45 Mm3, sufficient for the first 3 years. After the initial 3 years of operation, the Hydromet TSF would be raised by approximately 3.0 m to its proposed ultimate height. Raising would be completed by downstream construction with an allowance to join and extend the lining system on the upstream face up to the ultimate height.

The design for the Hydromet TSF embankment incorporates two primary zones:

- Zone 1: Upstream sloping, low permeability zone (clayey materials) that forms part of the geocomposite lining system for the TSF.
- Zone 3A: Downstream select mine waste rock or impoundment excavation materials.

A typical section of the embankment is shown in Figure 8-3 below. This is a robust design utilising downstream construction methods to ensure a very low probability of dam failure.

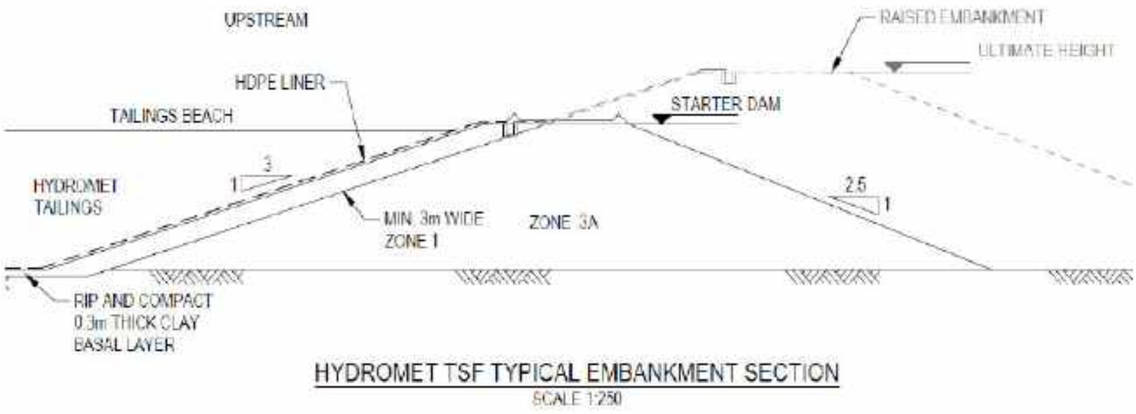


**Figure 8-3 Hydromet TSF embankment typical section**

### 8.3.2 Tailings management

The Hydromet TSF will receive the combined Hydromet waste stream in a single pipeline extending around the embankment crest access road. The TSF will be commissioned with single point discharge to fill the valley section of the TSF where the tailings deposit will be deepest and less consolidated due to the initial higher rate of rise. Within this valley section, a network of underdrains can be installed above the liner to assist with consolidation of the low density tailings. The requirement for these valley underdrains will be confirmed in detailed design.

Due to the low solids tailings, a flat beach is expected to develop within the TSF and the base is substantially covered within the first year of operation. At this point in time an evaporation balance is achieved and tailings density will be further increased by drying. At the end of mine life, the average depth of Hydromet tailings is expected to be approximately 4.5 m. This is a conservative estimate based on an assumed average 0.5 $t/m^3$ final density.

The concept design for the underdrains installed under the tailings within the valley section of the TSF comprises the use of multiple panel (e.g. Megaflo) collection drains to maximise drain surface area and promote water recovery. A collection sump would be constructed and fitted with a submersible pump for recovery and return of water to the surface of the TSF, the intent being to promote consolidation and to increase tailings density in the deeper valley section of the facility.

Figure 8-4 Megaflo panel drain examples (courtesy Geofabrics Australia)

### 8.3.3 Emergency spillway design

The Hydromet TSF includes the construction of an emergency spillway sized to safely pass a PMF event without overtopping of the embankment. The spillway will initially be excavated through rock on the northeast corner of the TSF, allowing spills to be directed to the Beneficiation TSF decant pond, which has a larger capacity to store extreme flood events.

Nominal dimensions of 20 m wide and 600 mm deep have been adopted.

Below the spillway level there is sufficient capacity to accommodate the combined wet season storage and extreme storm storage capacity (refer Stormwater Storage Assessment, Section 9.1).

### 8.3.4 Geomembrane selection and installation considerations

The Hydromet TSF design features a geocomposite liner system which comprises a geomembrane overlying a compacted clay liner. The compacted clay liner plays an important role in forming a smooth and unyielding subgrade and also restricts leakage rates due to any defects within the overlying geomembrane.

For the purpose of pre-construction design, High Density Polyethylene (HDPE) geomembrane has been selected as the preferred geosynthetic liner. HDPE geomembranes are manufactured by combining a polymer resin (>95%), with additives such as antioxidants, stabilizers, plasticizers, fillers, carbon-black, and lubricants (as a processing aid). These additives enhance the long- term performance of geomembranes by protecting the polyethylene from degradation (Ewais and Rowe 2014).

HDPE is commonly used for waste containment as it exhibits high strength and chemical resistance to a wide range of chemicals. Significant experience and data also exists relating to the long term performance and service life for HDPE liners. HDPE geomembranes are extremely durable products, designed with service lives of up to several hundreds of years under a broad range of environmental conditions.

The service life of HDPE geomembranes has historically been determined by its half-life, which is the point at which the 50% depletion level of antioxidant additives occurs. This is not considered appropriate for estimating the service life of a HDPE geomembrane for containment purposes (Rowe 2012), as although the design property, e.g., depletion of antioxidant additives, may be reduced by 50%, the mechanical properties of the geomembrane enable it to function as a hydraulic barrier for considerably longer.

In practice, a number of variables will determine the actual lifespan of any geomembrane. Factors that influence the lifespan of a geomembrane are the material properties of the geomembrane – physical, mechanical, durability and performance properties, the compatibility of the geomembrane with site-specific conditions including tailings leachate chemistry, clay liner, subgrades, foundations and applied stresses, the operating conditions of the facility including temperature, UV light from exposure, ionising radiation, installation, backfilling and construction factors.

The Hydromet TSF includes numerous factors to minimise potential degradation of the lining system as detailed below:

- **Selection of a white HDPE geomembrane**. The lifespan of HDPE geomembranes reduces drastically at elevated temperatures because higher temperatures act as catalysts that speed geomembranes' degradation reactions such as antioxidant depletion, chemical degradation and UV degradation. Even at moderate temperatures, a black geomembrane can become very hot, making it prone to wrinkling or folding, and in the process losing contact with its foundation.

  Under the recorded month average air temperature range at the proposed TSF site (21-41°C), selection of a white reflective liner should result in a liner temperature on average 21–23°C cooler than its carbon black counterpart, with correspondingly less risk of wrinkling and installation defects that may lead to developing stress cracks (Rentz et al. 2017).

  Critically, a 20°C reduction in temperature avoids thermal regimes where recrystallisation of polymers can occur which can lead to rapid onset of failure of the liner.

  For exposed portions of the HDPE liner, exposure to UV can decrease the expected or predicted lifespan by a factor of seven (GeoSynthetics Institute). Selection of a white liner (achieved by the addition of titanium dioxide and associated HALS and UV stabilisers) will reflect most of the UV light reaching the surface of the liner, ultimately prolonging its lifespan.

- **Selection of appropriate additives.** To combat geomembrane degradation at higher temperatures, selection of an appropriate additive antioxidant composition able to resist significant loss of mechanical and performance properties at elevated temperatures is proposed. It is anticipated that during detailed design, design of additive composition will include careful consideration of the tailings leachate chemistry, thermal regime and exposure to ionising radiation.

  The presence of low level ionising radiation (approximately 35Bq/g) is anticipated to have an impact on the rate of antioxidant consumption. Recent studies by Tian et al. (2017) indicate that low level radioactive leachates can promote radiative oxidation that consumes antioxidant consumption on the order of approximately 10% faster than non-radioactive leachate alone. Much of the impact of α and β radiation would be mitigated by placement of a thin layer of benign tailings on the liner prior to deposition of radioactive tailings due to the fact that radionuclides are non-mobile in the tailings.

- **Selection of an appropriate liner thickness.** All other factors considered, the thickness of the HDPE liner has a direct relationship to its service life due to increased availability of stabilisers and antioxidants and increased stress crack resistance of the liner. It is anticipated that a liner of between 1.5 and 2.0 mm in thickness will be required to achieve the desired service life.

- **Construction Methodology.** The smoothness, uniformity, and density of the subgrade and the quality of the installation – lack of wrinkles, intimate contact with subgrade, seams, penetrations, minimum extrusion welding, minimum shear stress on slopes are perhaps the most critical factor affecting liner life after material composition.

An example of a detailed construction and testing methodology is attached, which outlines the typical controls and hold point put in place to ensure development of an appropriate construction methodology and QA/QC process to ensure that it is correctly implemented.

- **QA/QC.** The QA/QC process for the HDPE liner installation will also be a critical aspect of construction involving seam testing as well as destructive testing of liner samples. Post installation of the HDPE liner, electrical leak detection testing shall be carried out involving both arc and dipole test methods as follows:
  - Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Arc Testing and/or Water Puddle Testing Method (ASTM D 7002 and/or ASTM 7953).
  - Standard Practice for Electrical Method of Locating Leaks in Geomembrane Cover with Water or Earth Materials ASTM D 7007 on the pond base.

  The attached draft geosynthetic lining specification details the typical QA/QC testing and construction supervision requirements typically implemented to supervise the construction of a composite geomembrane lining system.
- **TSF Operation.** In addition to designing specialised geomembrane polymer compositions for resisting degradation, their degradation may also be reduced by a protective thick layer tailings to take advantage of relatively lower geothermal ground temperatures (approximately 17°C). For exposed portions of the liner, leachate trickle systems may be considered to increase evaporative loss of decant water whilst simultaneously cooling the exposed portion of the liner.

Further details on the above measures to ensure the required service life of the HDPE geomembrane are detailed in the attached generic geomembrane specification (Appendix H).

It is considered that, given the anticipated physical, climatic, chemical and other constitutive factors anticipated for the proposed TSF, an appropriately selected HDPE geomembrane together with proper construction techniques (including adequate construction quality assurance), and by laying the geomembrane over a well-graded smooth foundation, service life in the hundreds of years is readily achievable.

# 9. Specific design studies

## 9.1 Stormwater storage assessment

### 9.1.1 General

Stormwater storage capacity and freeboard allowances during mine operation have been determined for the TSFs in accordance with ANCOLD requirements.

For the purpose of determining the required stormwater storage capacity, the TSF catchment system comprises both embankments and their catchments.

### 9.1.2 Storage requirements and freeboard

Freeboard and stormwater storage allowance as defined in ANCOLD 2012 is illustrated below in Figure 9-1.

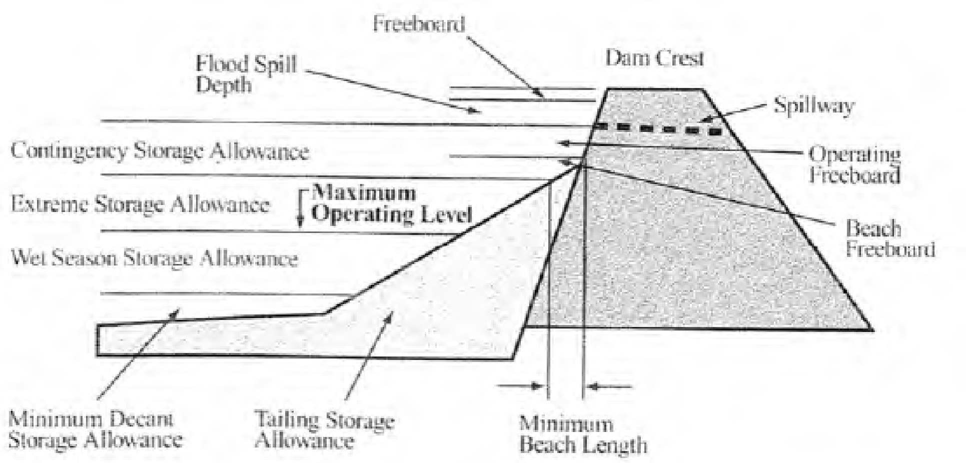


Figure 9-1 ANCOLD freeboard definition

For the Beneficiation TSF, the 86 ha catchment comprises of the upstream impoundment area accounting for construction of the upstream diversion drain. This catchment area is applicable from commissioning until closure.

For the Hydromet TSF, the catchment incudes the full impoundment area defined by the downstream crest of the final embankments. The catchment area for the storage is 36 ha for the TSF.

For stormwater storage and freeboard assessment it is conservatively assumed that there is zero infiltration loss during rainfall and wet season events.

To mitigate the risk of environmental spill, the freeboard for each of the TSFs in the initial three years has been assessed assuming no decant recovery during a 1:100 year, 72 hr storm event.

The calculated stormwater storage and freeboard requirements for the respective TSFs are given in Table 9-1. This shows that the Normal Maximum Operating Level (NMOL) for the Beneficiation TSF and Hydromet TSF decant pond is 2.0 m and 1.15 m respectively below the spillway level in each facility.

**Table 9-1 Freeboard and stormwater storage requirements**

| TSF | Freeboard Component | Freeboard Volume ($m^3$) | Freeboard Depth (m) |
|---|---|---|---|
| **Beneficiation TSF** Spill Consequence Category = Low | Wet Season Storage Allowance (1:5 AEP) | 260,000 | 1.4 |
| | Extreme Storm Storage (1:100 AEP, 72 hr) | 215,000 | 0.6 |
| | Contingency Storage (Contingency including waves) | 0 | 0 |
| | **Total** (depth/capacity between spillway and Normal Minimum Operating Level (NMOL)) | **475,000** | **2.0** |
| **Hydromet TSF** Spill Consequence Category = Significant | Wet Season Storage Allowance (1:5 AEP) | 105,000 | 0.3 |
| | Extreme Storm Storage (1:100 AEP, 72 hr) | 90,000 | 0.25 |
| | Contingency Storage (Contingency including waves) | 210,000 | 0.6 |
| | **Total** (depth/capacity between spillway and NMOL) | **405,000** | **1.15** |

## 9.2 Flood hydrology

### 9.2.1 Hydrological modelling

Hydrological modelling was undertaken to assess the capacity requirements of the water management structures associated with the TSF including spillways and diversion drain.

This section summarises the process used in determining the capacity requirements. Modelling of the rainfall routing through the storages was undertaken utilising RORB software to determine the critical duration, expected flows and height of water in the storages.

#### *Design rainfall events*

In order to determine design rainfall events, the Generalised Short Duration Method (GSDM) and the Revised Generalised Tropical Storm Method (GTSMR) were used, as outlined in 'Australian Rainfall and Runoff: A Guide to Flood Estimation' (Ball et al., 2016), in conjunction with Intensity Frequency Duration (IFD) data obtained from the Bureau of Meteorology.

Figure 9-2 presents design rainfall events for various AEPs and storm durations.

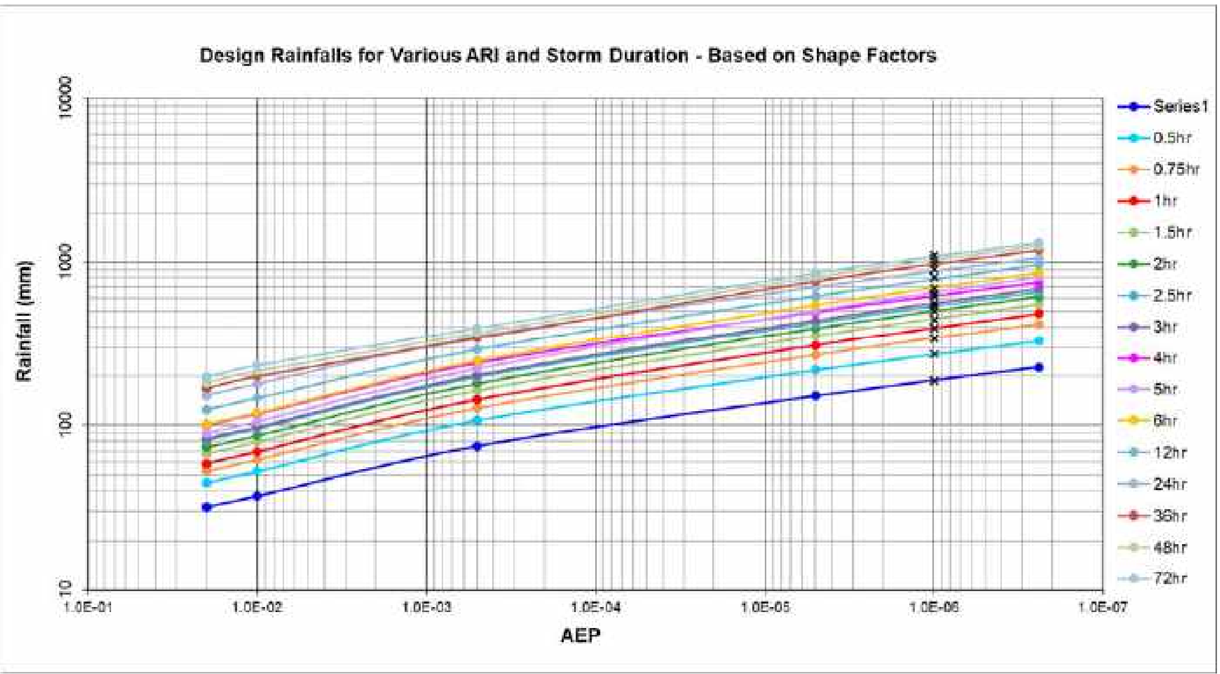


Figure 9-2 Design rainfall IFD curves

### *Hydromet TSF*

Due to the arrangement of the facility, the catchment of the Hydromet TSF is limited to the internal area and external crest footprint, equating to 36.2 ha.

A graphical representation of the modelling results is presented in Figure 9-3.

The operational level of the TSF was modelled as 250 mm above the tailings level to allow for the 1:100 AEP 72 hour rainfall event at the commencement of the design flood event. This is in excess of the Normal Maximum Operating Level which ensures a conservative estimate of spillway discharge.

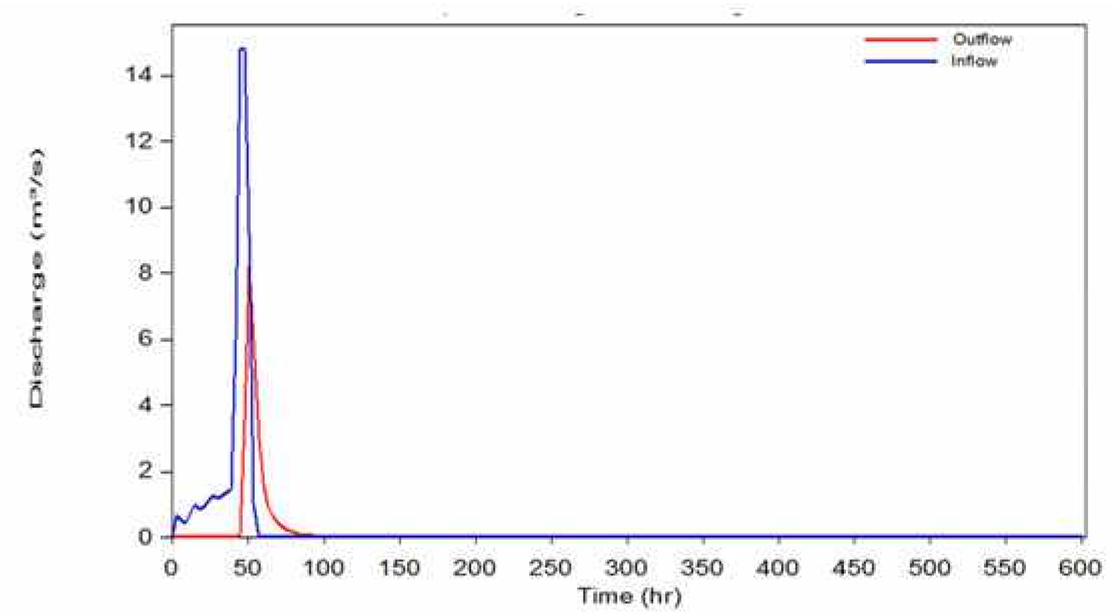


Figure 9-3 Hydromet TSF hydrograph (critical duration)

As per the Consequence Category assessment (see Section 7.3), the TSF is required to pass a PMF flood event. The modelling completed found the critical event to be 12 hours, with a peak inflow of 15.4 $m^3$/s and a peak outflow of 8.5 $m^3$/s. The proposed spillway arrangement ensures adequate capacity to pass a PMF rainfall event without overtopping of the TSF embankment.

### *Beneficiation TSF*

Due to the arrangement of the facility, the catchment of the TSF is limited to the internal area of the facility and the external catchment upstream of the footprint, equating to 106 ha.

A graphical representation of the modelling results is presented in Figure 9-4.

The operational level of the TSF decant pond was conservatively modelled as 1.0 m below the spillway crest at the commencement of the design flood event. This is in excess of the Normal Maximum Operating Level which ensures a conservative estimate of spillway discharge.

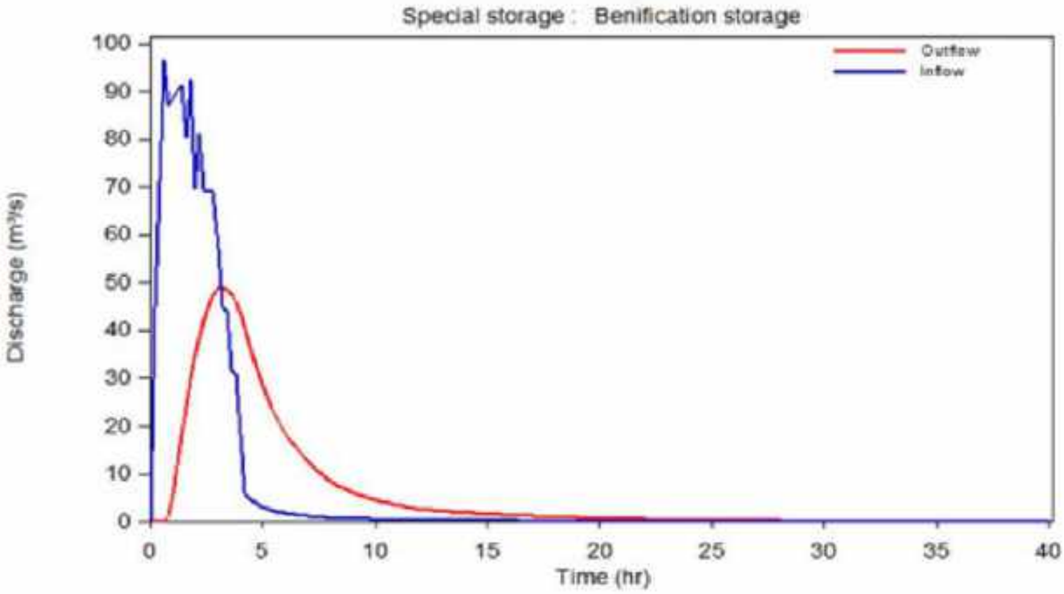


**Figure 9-4 Beneficiation TSF hydrograph (critical duration)**

As per the Consequence Category assessment (see Section 7.3), the TSF is required to pass a PMF flood event. The modelling completed found the critical event to be 4 hours, with a peak inflow of 95.16 $m^3$/s and a peak outflow of 49.08 $m^3$/s. The proposed spillway depth of 1000 mm ensures the PMF is passed without overtopping of the TSF embankment.

### *Upstream cut-off drain*

The catchment area upstream of the Beneficiation and Hydromet TSF is limited by the topography of the local area and equates to a total of 41 ha, this was then split equally between the two TSFs. The sizing of the drain has been developed to meet the requirements of 1:100 AEP rainfall event using mannings equations for open channels. The parameters used in the development of the drain size can be found below.

**Table 9-2 Cut-off drain design parameters**

| Parameter | Value |
|---|---|
| Area | 3 m |
| Perimeter | 4.8 m |
| Slope | 1:500 m |
| Mannings n | 0.025 |

The drain design allows for flow from each sub-catchment to flow in separate directions minimising the size of the required drain. Further details on the design of the external diversion drain can be found in the Pre-Construction Design Drawings in Appendix A.

## 9.3 Water balance

A basic spreadsheet water balance model (WBM) was developed by GHD to assess the storage behaviour and test the capacity of the Hydromet TSF for rainfall and tailings storage. The model will be used as a preliminary check and may be used as a basis for a more detailed version in GoldSIM in the future.

### 9.3.1 Input data

#### *Hydromet TSF*

The physical parameters relating to the Hydromet TSF were based on the current design and are outlined in Table 9-3.

**Table 9-3 Hydromet TSF data**

| Input | Values |
|---|---|
| Maximum Operating Level | 339.35 m |
| Spillway Level | 340.5 m |
| Full Supply Volume | ~ 1900 ML |

Data relating to the volumes and flow rates of tailings material and bleed water entering the Hydromet TSF appear in Table 9-4.

**Table 9-4 Tailings material and bleed water data**

| Input | Values |
|---|---|
| Annual Production Solids | 72,000 tonnes |
| Flow of Tailings Solids | 62,500 m3/day |
| Flow of Tailings Water | Retained Water 0.3 ML/day<br>Free water 1.2 ML/day |

#### *Catchment area*

There is no external catchment reporting to the Hydromet TSF due to the upstream diversion drain, as such, the catchment area for the Hydromet TSF is 36.2 hectares.

#### *Climate data*

Climate data, including rainfall and evaporation were used for the development of the WBM. The details and sources of the data are outlined in Table 9-5.

**Table 9-5 Climate input data**

| Climate Data | Source of Data |
|---|---|
| Historical Rainfall Data | SILO Data drill (Lat -23.95, Long: 116.30) – QLD Government |
| Historical Evaporation Data | SILO Data drill (Lat -23.95, Long: 116.30) – QLD Government |

### 9.3.2 Assumptions

The following assumptions were made in the development of the WBM:

- No external catchments report to the Hydromet TSF
- All spill from the Hydromet TSF reports to the Beneficiation TSF
- The available water shall be evaporated from the Hydromet TSF including free bleed water from the deposited tailings and rainfall

- The Hydromet TSF was assumed to be empty at the start of the WBM (elevation 331.5 m)
- No seepage losses occurred from the Hydromet TSF due to lining

### 9.3.3 Methodology

***Scenario modelling***

The scenario tested in the WBM simulates the current plant operational settings to assess the viability and likely performance of the Hydromet TSF over a 10 year operational mine life. The scenario was run for three rainfall scenarios, namely, 20 percentile rainfall, 50 percentile rainfall and 80 percentile rainfall.

***Model settings***

The settings and corresponding parameters used in the water balance model for the Hydromet TSF are detailed in Table 9-6.

**Table 9-6 Simulation settings**

| Settings | Parameter |
|---|---|
| Time Step | Monthly |
| Data Range | 20 percentile rainfall: 01/07/1889 to 30/06/1906<br>50 percentile rainfall: 01/07/1938 to 30/06/1948<br>80 percentile rainfall: 01/07/2009 – 31/12/2018/, to 01/01/1889 – 30/06/1889 |
| Number of Simulation Years | 10 Years |
| Hydromet TSF Initial Water Level | 331.5 m |

***Methodology***

The following steps were undertaken in order to model the water balance across the Hydromet TSF:

- 20, 50, 80 percentile rainfall scenarios were determined across a 10 year period with monthly time steps.
  - The 20th percentile 10-year rainfall is the volume corresponding at which only 20% of the record is lower.
  - To find a 20th percentile rainfall volume, the entire rainfall record was grouped in windows of 10 years starting at 1 Jul 1889 to 30 Jun 1898, continuing with 1 Jul 1890 to 30 Jun
  - 1899, "wrapping around" at 1 July 2018 to 30 Jun 1897, etc.
  - The 10-year window sums are ranked and solved for 20% higher than the lowest rainfall sum.
  - The same procedure is done for the other percentiles.
- Monthly average evaporation was determined based on SILO data from 1889 to 2019.
- The Hydromet TSF volume was calculated for each time step using the following equation:
  - Volume (ML) = $P - E + Q_T$

Whereby:

  - P = Precipitation

– E = Evaporation
– $Q_T$ = Flow of tailings solids, free water and retained water

### 9.3.4 Model Results

The overall inventory of the Hydromet TSF appears in Figure 9-5.

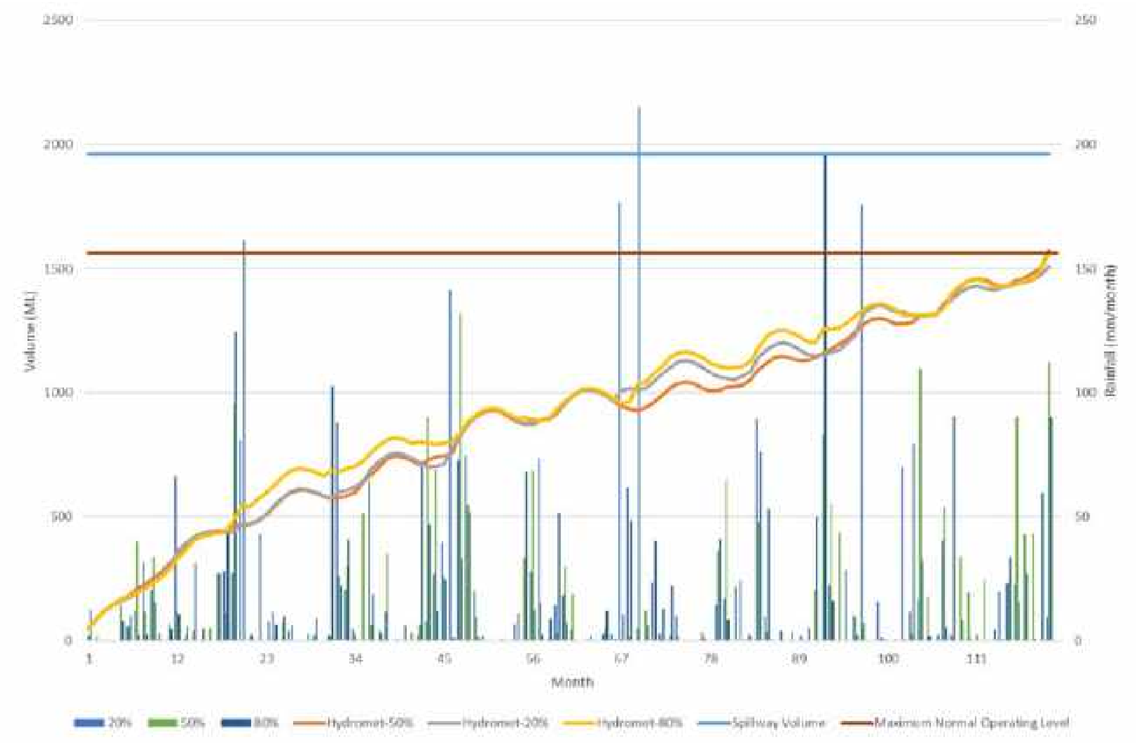


Figure 9-5 Overall hydromet TSF inventory

From the water balance analysis it was found that the storage volume for the Hydromet TSF could support the total volume of tailing solids, free water and retained water for a 20, 50 and 80 percentile rainfall over a 10 year period, starting empty.

A detailed whole site GoldSim water balance will be undertaken during detailed design to confirm the site requirements and confirm the findings of the preliminary water balance.

## 9.4 Seepage analysis

### 9.4.1 Methodology

A concept level 2-D seepage analysis using the finite element software, Rocscience Slide, was carried out to assess the potential for seepage development from the refined TSF arrangement. Only the Beneficiation TSF was considered in the analysis. The Hydromet TSF design features a geocomposite liner system that ensures very small rates of seepage, hence negating the need for seepage modelling at this stage.

The seepage modelling completed by GHD was carried out to supplement previous seepage modelling presented in ATCW 2019. For the originally proposed arrangement (refer Section 3), ATCW found that "*the presence of confined water pressure in the aquifer below approximately 50 m depth and the presence of a very low permeability, unsaturated granite rock mass above this depth, the likelihood of significant downward seepage of water contained in saturated, very low permeability tailings stored at the ground surface is considered very low*". Seepage modelling by ATCW was limited to considering the Return Water Pond (RWP) and TSF2 since these were considered to have higher seepage potential relative to the other TSFs.

Key changes between the previous concept design presented in ATCW 2019 and the refined TSF arrangement is that both TSF2 and the RWP have been eliminated from the design which significantly reduces the risk of seepage related impacts.

Seepage analysis completed by GHD for the Beneficiation TSF involved developing an idealised cross-section through the TSF with a hydrogeological setting similar to that presented by ATCW 2019 (see Section 2.6) but with sensitivity analysis on layer thickness and hydraulic permeability to assess the effects of varying conditions.

A transient model was established to estimate the rates of seepage into the foundation due to development of a pond on the Beneficiation TSF and also assessing the benefit of developing a layer of low permeability tailings below the pond. The fate of seepage with time (0 – 1000 years) within the foundation was then assessed for the various model runs.

The seepage analysis considered a range of permeability values listed in Table 9-7 based on ATCW inferred values and site investigation works.

**Table 9-7 Model hydraulic conductivity values**

| Material | Average $k_{sat}$ (m/s) | Sensitivity model $k_{sat}$ (m/s) |
|---|---|---|
| Beneficiation Tailings | $1 \times 10^{-8}$ | |
| Zone 1 Clay Core | $1 \times 10^{-9}$ | |
| Zone 3A Fill Material | $1 \times 10^{-8}$ | |
| Sandy Clay Foundation | $1 \times 10^{-7}$ | |
| HW / MW Granite | $1 \times 10^{-7}$ | $1 \times 10^{-6}$ |
| SW / FR Granite | $1 \times 10^{-8}$ | $5 \times 10^{-8}$ |
| Fractured SW / FR Granite Aquifer | $1 \times 10^{-6}$ | |

### 9.4.2 Results

The results of the seepage analysis shown in Appendix D, illustrates that the seepage expected over the life of the facility is expected to remain within the TSF footprint with the majority of the ponding expected in the highly weathered to moderately weathered granite.

The vertical seepage through the highly weathered to moderately weathered granite is illustrated below in Figure 9-6 using the flux generated in the seepage modelling. Importantly, the conceptual modelling indicates that seepage flux exiting the TSF footprint is negligible.

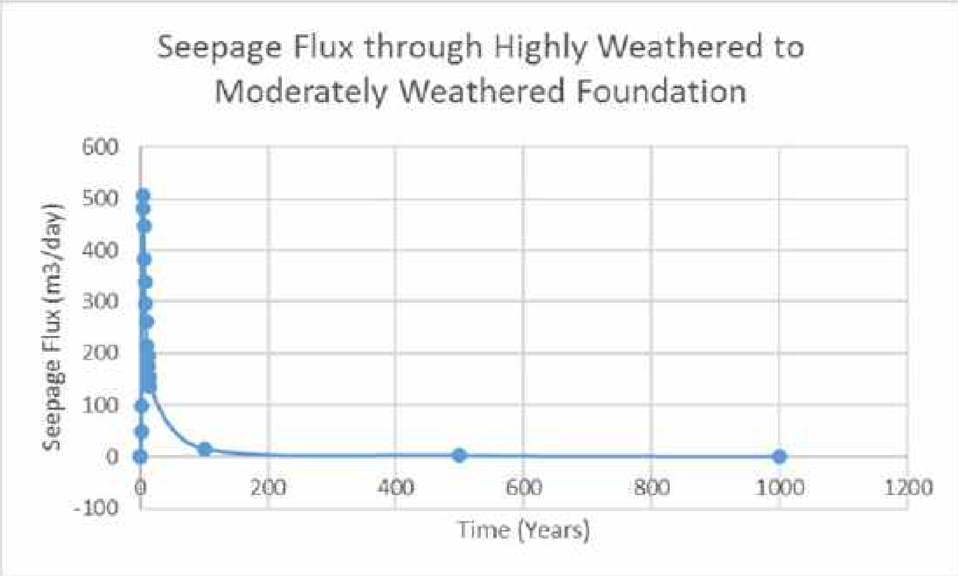


Figure 9-6 HW/MW vertical seepage rates

## 9.5 Stability analysis

This Section presents the results of preliminary stability analysis to support the proposed design of the TSF embankments.

In general the proposed embankment geometry and zoning provides geotechnically stable embankments in accordance with ANCOLD requirements. The design conservatively assumes staged embankment raising using downstream construction methods.

Geotechnical investigations indicate foundation conditions across the TSF area comprise dense superficial soils and weathered rock at shallow depth. Any low strength or potentially liquefiable soils will be stripped from the foundation prior to embankment construction.

### 9.5.1 Approach and methodology

A preliminary geotechnical stability analysis has been completed for the maximum (highest) section of the Beneficiation TSF embankment at its ultimate height as shown in Figure 9-7. This is considered the critical section for all proposed TSF embankments.

The embankment was modelled with the Slope/W software package to perform Limit Equilibrium slope stability analysis. Bishop's Simplified Method was adopted in calculating the factor of safety values against sliding.

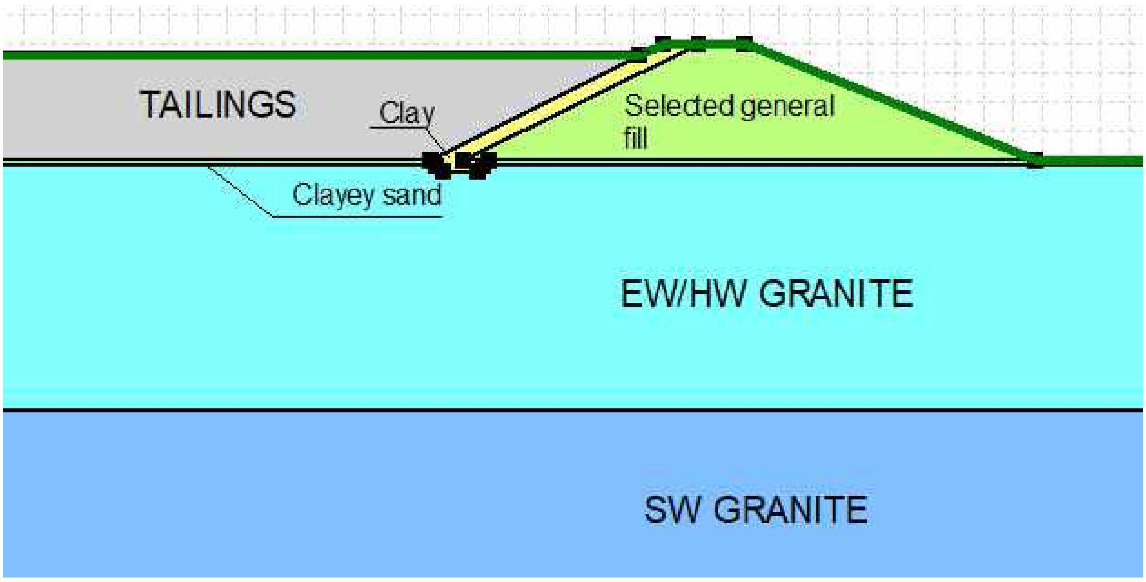


Figure 9-7 Stability model section

### 9.5.2 Load cases and factors of safety

Load cases considered for stability analysis are listed in Table 9-8. The ANCOLD "Guidelines on Tailings Dam Design, Construction, Operation and Closure" (ANCOLD 2012) state that there are no "rules" for acceptable factors of safety. However, they suggest the recommended Factors of Safety (FoS) as shown in Table 9-8 which have been adopted for this preliminary analysis.

**Table 9-8 Stability analysis FOS acceptance criteria**

| Condition | Minimum Recommended FoS | Target Minimum FoS |
|---|---|---|
| Long term drained conditions | 1.5 | 1.5 |
| For short term undrained conditions (potential loss of containment) | 1.5 | 1.5 |
| For short term undrained conditions (no potential loss of containment) | 1.3 | 1.3 |

Given the absence of any potentially liquefiable soils within the embankment and foundation as well as the proposed use of downstream construction methods for raising of the TSF, a post-seismic slope stability case is not considered critical and has been excluded from the preliminary analysis. Seismic assessment based on simplified deformation analysis is subsequently presented in Section 9.6.

### 9.5.3 Soil and rock strength parameters

The parameters adopted for the constructed embankments and deposited tailings are based on laboratory testing and are presented in Table 9-9.

**Table 9-9 Parameters used for stability analyses**

| Material | Unit Weight | Undrained | | | Effective (Drained) | |
|---|---|---|---|---|---|---|
| | $kN/m^3$ | c (kPa) | φ (°) | $S_u$ | c (kPa) | φ (°) |
| Zone 1 Clay | 19 | 100 | 0 | | 10 | 20 |
| Zone 3A Selected general fill | 21 | 0 | 35 | | 0 | 35 |
| Tailings | | | | 0.3 | See Note 1 | See Note 1 |
| Clayey sand (foundation) | 19 | 80 | 0 | | 0 | 20 |
| EW/HW Granite (foundation) | 22 | 13000 | 35 | | 500 | 38 |
| SW Granite (foundation) | 22 | 20000 | 43 | | 500 | 43 |
| Fresh Granite (foundation) | 22 | 23000 | 46 | | 500 | 46 |

Note 1: Undrained tailings properties were adopted for the drained analysis conservatively assuming that the tailings are contractive and likely to generate significant pore pressures on shearing. The use of drained parameters in stability analyses for contractive tailings is not appropriate as the pore pressure state along the failure surface is unknown.

### 9.5.4 Model pore pressure

For all analyses, it was assumed that decant water is able to pond against the perimeter embankment resulting in a phreatic surface developing through the embankment. In practice, this is not allowed to occur and is therefore a very conservative assumption used to allow a simplified but conservative preliminary analysis. The modelled phreatic surface is presented in the model outputs within Appendix E.

### 9.5.5 Analyses results

A summary of the minimum Factor of Safety (FoS) achieved for each load condition is provided in Table 9-10. For the proposed embankment design, it can be seen that the minimum target Factor of Safety is achieved in all cases. Figures showing the critical analysis outputs are given in Appendix E.

**Table 9-10 Results of stability analysis**

| Loading Conditions | Calculated FOS | Target Minimum FOS |
|---|---|---|
| Short term undrained (no loss of containment), Downstream | 1.9 | 1.3 |
| Short term undrained (no loss of containment), Upstream | 2.2 | 1.3 |
| Long term, Undrained | 1.9 | 1.5 |
| Long term, Drained | 1.9 | 1.5 |

## 9.6 Seismic assessment

### 9.6.1 Seismic risk

The risk posed to the TSF embankments from rare or extreme seismic events is considered to be Low due to:

- The relatively low seismicity of the site
- The batter slopes achieve factors of safety above 1.5 for static stability
- The embankment and foundations soils are not prone to seismic liquefaction

Based on the above factors, a seismic assessment was limited to simplified deformation analysis. Two empirical analysis methods have been used including the Swaisgood Method and Pells and Fell Method as described below. These are simplified screening methods that are suitable for pre-construction design to confirm that excessive deformation and damage to the embankment will not occur following an extreme earthquake.

### 9.6.2 Deformation analysis

ATCW 2019 presented the results of a simplified empirical method using Swaisgood (2003) to assess the likely magnitude of crest settlement under seismic loading. This previous assessment is still valid for the current proposed design (i.e. similar embankment and foundation characteristics). ATCW predicted a maximum crest settlement of 90 mm for the 1:10,000 MCE. This magnitude of embankment settlement is considered acceptable and well within the freeboard allowance for the TSF. Additionally, when assessed according to the Pells and Fell (2003) method a "Minor" damage class is expected with associated cracking and settlement unlikely to result in risk of breach and loss of containment.

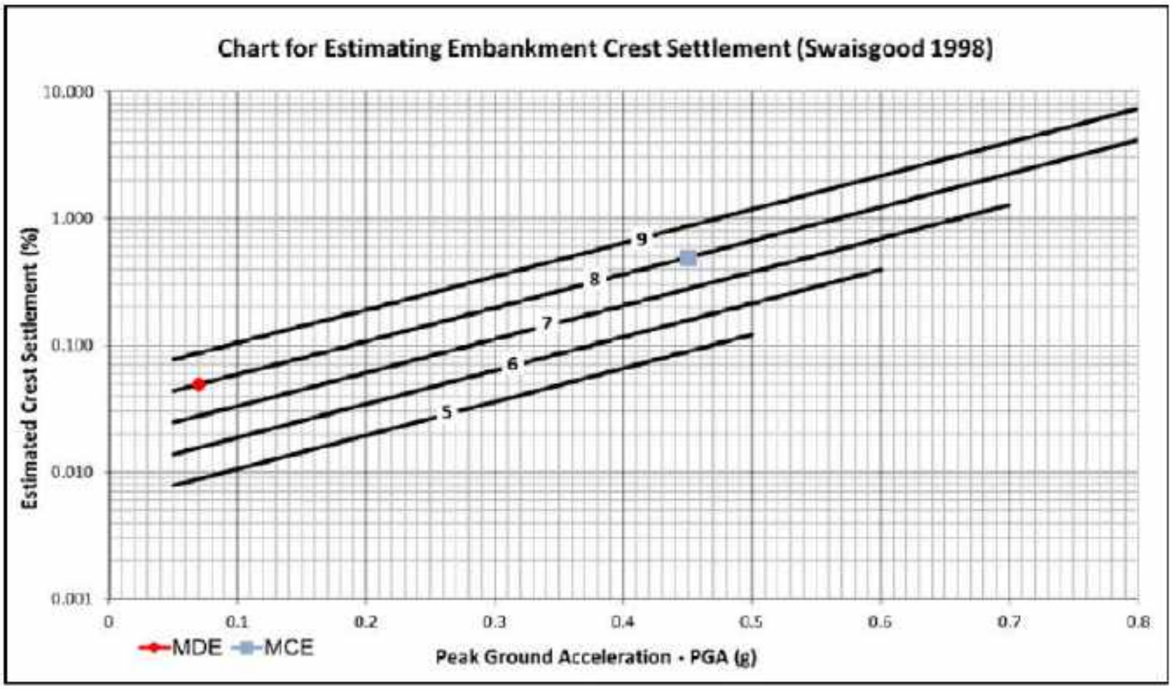


**Figure 9-8 Relative crest settlement versus peak ground acceleration (ATCW, 2019)**

## 9.7 Hydromet TSF ammonia gas air emissions study

To inform the pre-construction design of the Hydromet TSF based on combining of the Hydromet waste streams, Hastings advised GHD of the need to consider the potential health and safety risks associated with potential for ammonia gas evolving at the TSF.

In April 2019, Hastings provided GHD with a worst case scenario, whereby the Hydromet TSF receives a tailings stream at 76 t/h containing approximately 0.04 g/L of ammonium bicarbonate and 6.28 g/L of ammonium hydroxide solution. Based on this "worst case scenario" condition, GHD completed modelling to assess the potential evolution of ammonia gas (NH3) from the proposed TSF. The results of this modelling were presented in a GHD Technical Memorandum, 15th April 2019 (refer Appendix I), that included predictions of daily ammonia gas generation under a range of pH conditions including a worst case condition with an elevated pH of 11.3. The estimated daily ammonia gas generation for this "worst case scenario" was estimated at 5,300 kg/day NH3.

Hastings subsequently engaged consultants ERM to undertake an air quality modelling assessment of ammonia emissions from the Hydromet TSF. The ERM report is attached as Appendix I. The model assessed the emission rate for ammonia under the "worst-case scenario" described above. Ground level concentrations were evaluated at numerous onsite and offsite receptor locations. These concentrations were then compared against Ambient and OHS assessment criteria for NH3. ERM provided the following summary of observations from their modelling:

- *No exceedances of air quality criteria were predicted at the identified offsite sensitive receptors.*
- *One exceedance (25.75 mg/m3) of the 15-min OHS criteria was predicted at an onsite receptor (TSF receptor 1) located within 250 m from the centre of the source (Figure 4-1). This exceedance occurred under worst-case conditions. The next worst case scenario predicted a concentration of 12.89 mg/m3 at this same receptor. This concentration is well within the criteria (50% of the criteria).*
- *In summary, the modelling results indicate that the maximum concentration is of low likelihood to occur and dependent on concurrence of worst case emission rate and worst case dispersion conditions (i.e., prevalence of calm conditions, transition from stable to unstable meteorological conditions, and winds blowing towards this receptor).*

Subsequent to completion of the above respective GHD and ERM studies, Hastings advised of further refinements to the plant design which suggested a revised set of chemistry in offgas absorbing and dual alkali caustic regeneration. Mass Balance assumptions were updated accordingly with a key change being a significant lowering of pH under the worst case scenario from pH 11.3 (basis of above studies) to below pH 9. This change to the "worst case scenario" is significant, since the amount of ammonia gas generation is proportional to the pH. The reduced pH to below 9 will significantly reduce the generation of NH3 under the worst case scenario, as is demonstrated in Figure 9-9 below (extract from GHD Technical Memorandum).

Based on the above updates, there is assurance that the modelling completed by GHD and ERM is very conservative and hence the risks associated with ammonia gas evolution from the Hydromet TSF are suitably low and manageable.

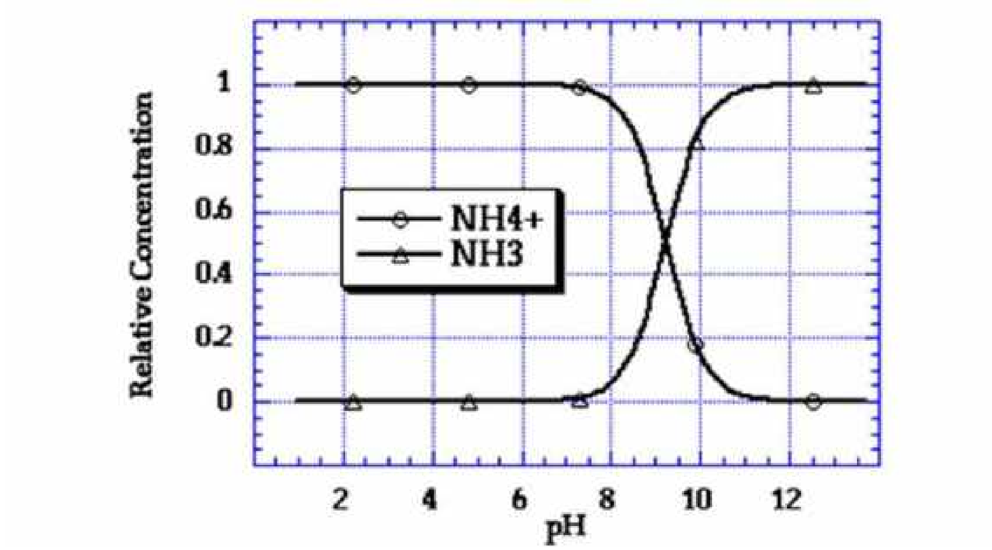


Figure 9-9 Ammonia/ammonium concentration vs pH (Richard, 1996)

# 10. Operations, maintenance and surveillance

## 10.1 Observational approach

In accordance with ANCOLD 2012, the design and management of the TSF shall utilise the observational approach. The observational approach allows the TSF to be optimised over time as monitoring information becomes available and the design and construction methodologies evolve. The observational approach allows any changes that might occur during the life of the TSF to be accommodated whilst meeting the design criteria and objectives over the entire life of the TSF.

The key risks that could result in design and operation modifications during commissioning and operation of the project are:

- Life of mine and tailings production rate
- Physical properties of the tailing including solids content and rheology
- Geochemical properties of the materials
- Variation in geological or hydrogeological conditions across the site
- Variations in geotechnical properties of embankment materials following borrow pit area investigations

Further studies and investigations being carried out as part of Detailed Design will assist in mitigating the risks through greater understanding of the TSF areas.

Critical Operating Parameters (COPs) should be developed for the TSF against which the performance of the TSF can be evaluated. The indicators address key functional, dam safety and environmental requirements. The TSF Operating, Maintenance and Surveillance (OMS) manual is regularly updated to reflect the COP's and incorporate Trigger Action Response Plans (TARPs) to ensure that intervention occurs well in advance of nearing any unsafe trigger event.

## 10.2 Monitoring and surveillance

ANCOLD (2003) provides guidance on the surveillance requirements and frequency for dams based on their Consequence Category. Regular inspections and monitoring of instrumentation, by suitably trained operators, is critical in ensuring structural integrity is maintained, and any indications of failure are identified early and acted on appropriately. Instrumentation is also important in monitoring the management of tailings against design assumptions, to determine if any design changes are required during operations, or for closure.

The recommended inspection and monitoring types and frequencies are presented in Table 10-1 and Table 10-2.

**Table 10-1 TSF inspection types and frequency**

| Inspection Type | Recommended Frequency (ANCOLD, 2003) |
|---|---|
| | High C |
| Routine Visual | Daily to Tri-Weekly |
| Intermediate | Annual |
| Comprehensive | On Commissioning then 5 Yearly |
| Special | As Required |

**Table 10-2 TSF monitoring types and frequency**

| Monitoring Type | Recommended Frequency (ANCOLD, 2003) |
| --- | --- |
| | High C |
| Rainfall | Daily to Tri-Weekly |
| Storage Level | Daily to Tri-Weekly |
| Seepage | Daily to Tri-Weekly |
| Chemical Analysis of Seepage | ANCOLD recommend this be considered. The environmental monitoring plan for the site incorporates this requirement. |
| Pore Pressure | Monthly to 6-Monthly |
| Surface movement | 2 Yearly |

The following instrumentation / monitoring is recommended at the site:

- Rainfall gauge
- V-notch weirs for environmental flow monitoring and seepage (if observed)
- Vibrating wire piezometers (VWPs) for pore pressure monitoring
- Settlement markers on embankments for movement monitoring
- Regular tailings beach surveys for density reconciliation and comparing actual beach development against design assumptions
- Level gauge boards and / or automated level sensors for monitoring water levels
- Monitor slurry density at the plant to compare against design assumptions
- Monitoring of beach saturation via either routine sampling/testing or instrumentation

### 10.2.1 Instrumentation

This section outlines likely instrumentation that would be required, for monitoring safety and performance of the storages.

*Groundwater monitoring*

A series of groundwater monitoring bores are proposed around the TSFs, to monitor groundwater level and quality. These bores will be monitored up to 12 months prior to commencement of deposition of tailings to provide baseline data for the project and then quarterly throughout the life of the project.

To intercept groundwater in the confined aquifer, the bores will need to be approximately 70 m deep with a nested bore approximately 20 m deep to confirm upward seepage from the confined aquifer is not taking place.

The deeper bores should be constructed in accordance with the Minimum Construction Requirements for Water Bores in Australia and screened across the first water strike encountered. Gravel pack should be installed to at least one metre above the top of the screen followed by a bentonite seal not less than two metres thick. The remainder of the well annulus should be cement grouted to the surface.

A number of Vibrating Wire Piezometers (VWP) are also proposed to be installed under the embankments to identify seepage development within the underlying foundation.

The proposed monitoring bore and VWP layout is presented in Drawing DWG-C010.

### *Movement monitoring*

Surface movement monuments are recommended on the crest of the storages, to monitor potential movement / settlement over the life of the facility, particularly following significant rainfall events, spill events, and earthquake events.

Additional monuments may be installed on areas where ground conditions would lead to increased risk of differential settlement.

Permanent survey pillars will need to be located on natural ground at strategic locations outside the embankment to allow routine movement monitoring of the embankments.

## 10.3 Operation, maintenance and surveillance manual

An Operations Maintenance and Surveillance (OMS) Manual (operating manual) should be prepared as part of the TSF Detailed Design. The principal objective of this manual is to provide a documented operation procedure to assist in the safe and efficient storage of tailings and water management in the TSF cells.

The OMS manual shall be prepared to meet the minimum regulatory requirements (ANCOLD, 2003 and DME, 1998) and include:

- Roles and responsibilities
- Design intent
- Regular operations and inspections
- Water and tailings management procedures
- Operational requirements for mechanical equipment and instrumentation
- Maintenance schedules and procedures
- Surveillance requirements
- Examples of potential damages and associated repair works
- Definition of Critical Operating Parameters and associated Trigger Action Response Plans

The OMS manual should outline key monitoring activities which will include:

- Routine reconciliation of tailings discharge tonnage and solids concentration
- Tailings beach scans (nominally quarterly) to provide up to date pond storage characteristics
- Routine monitoring of tailings beach levels
- Routine monitoring of pond water levels and process plant return water rates
- Routine monitoring of groundwater level fluctuations
- Routine assessment of groundwater and decant pond water quality
- Underdrainage system return rates and volume
- Annual field evaluation of tailings beach density

## 10.4 Dam safety emergency plan

ANCOLD (2003) states a Dam Safety Emergency Plan (DSEP) be prepared where any persons, infrastructure or environmental values could be at risk if the dam were to fail. A DSEP is therefore recommended for both TSFs.

The DSEP should include (but not be limited to) the following:

- Critical contact details
- Trigger Action Response Plans (TARPs)
- Procedures in specific failure events
- Emergency muster points
- Dam break inundation maps

Training of site personnel, whom will be responsible for dam inspections, operation and management, is recommended; this would include familiarisation with the OMS and DSEP.

## 10.5 Annual audits

Fundamental to the design of the TSF is the proposed Observational Approach and ongoing Dam Safety Program as described throughout this document, by which there is a means of monitoring and measuring the safe and environmentally responsible management of the TSF throughout the full TSF life cycle. Annual Operational Reviews/Audits aim to:

- Evaluate the implementation and effectiveness of the tailings management system
- Reduce risk, and to drive continuous improvement
- Provide assurance to company and regulatory stakeholders that the TSF is being effectively managed in conformance with design, operational and management commitments

Once indicators and targets are set they must be routinely monitored and reviewed to identify any changes and areas for improvement. It is proposed that routine annual reviews are conducted to identify trends in the data that might cause concern as early as possible. It is essential to react to these concerns well before they impact on the integrity and performance of the structure or the receiving environment and become increasing difficult to resolve. As modification effort could span several years to reduce its impact on the overall operation, addressing a major problem at a later stage might be operationally difficult, expensive, and could even be impractical. The observational method provides the ability to address concerns through a proactive rather than reactive approach.

Indicators and targets should be reviewed and if necessary updated during the reviews to ensure they remain a valid and useful way of evaluating TSF performance.

## 10.6 TSF operator training

Effective operations and maintenance of the TSF is dependent on the staff achieving an acceptable level of competency. To enable staff to perform their duties to this standard, staff need to undergo training specifically addressing the operation and maintenance of tailings facilities, which should include:

- Occupational health and safety responsibilities
- Operations and maintenance of the dams and outlet works components
- Familiarity with the COPs and TARPs

- Dam surveillance
- Emergency procedures

## 10.7 Temporary mining and plant shutdown provisions

In the event of a temporary mining and plant shut down, there may be an extended period without tailings deposition into the Beneficiation and Hydromet TSFs. As discussed in Section 5.3, all tailings are Non-Acid Forming and hence there is a very low risk associated with AMD development on the tailings beaches. Normal TSF operations, surveillance and maintenance activities would need to continue for these shutdown periods however the lack of tailings discharge will require special provisions to control the generation of dust. The necessary mitigation measures would depend on the period of shut-down however may include measures such as:

- Irrigation of tailings beaches with mine make-up water;
- Application of dust suppression chemicals using a LGP water cart or by aerial spraying;
- Temporary capping of tailings beaches with locally won earthfill.

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Refer also to the Basis of Design documentation listed in Table 4-1 and Table 4-2 of this report.

# Appendices

# Appendix A
## Design Drawings

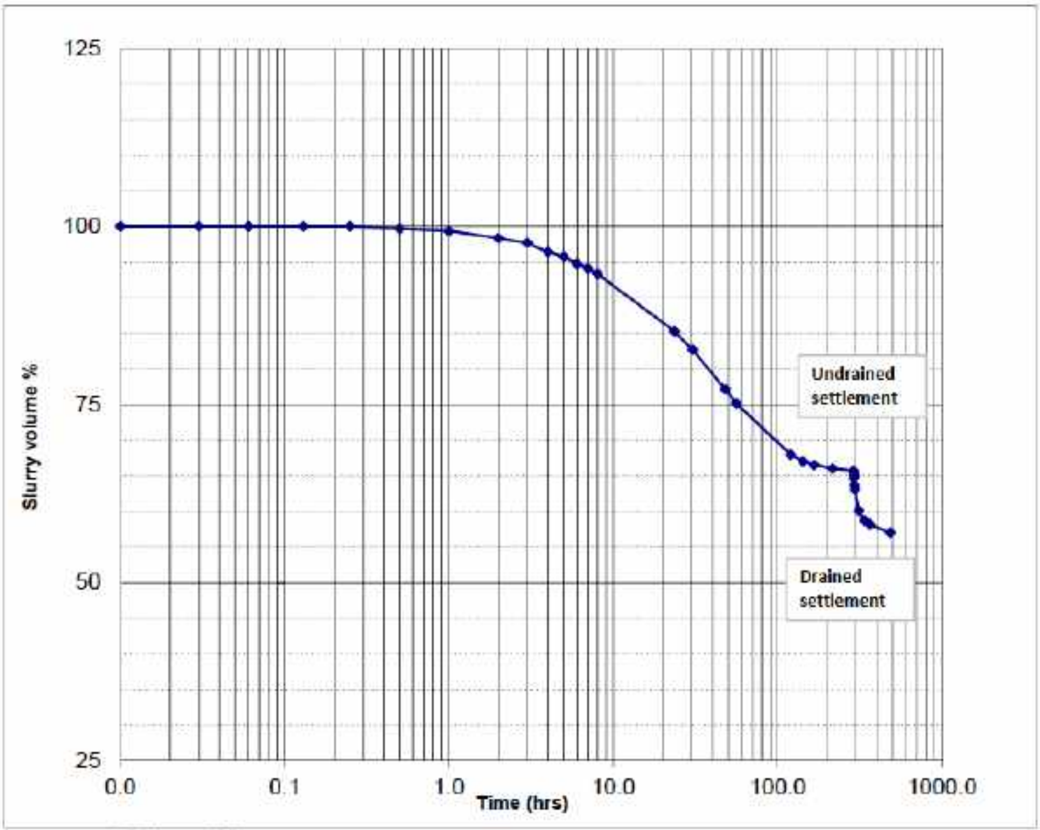
# Appendix B
## Tailings Test Results, Geotechnical

## Column Sedimentation Test - Results

**SYD1900567.3**

Client: Hastings Technology Metals Ltd
Project: Yangibana
Location: Option Study

Job No: 3219134
GHD Sample No: SYD19-0110-01
**Client ID: Pilot Plant Combined Beneficiation Tailings**




**Settlement data**

| Time (hrs) | Slurry Height (mm) | Volume (%) | |
|---|---|---|---|
| 0.01 | **306** | 100 | |
| 0.03 | 306 | 100 | |
| 0.06 | 306 | 100 | |
| 0.13 | 306 | 100 | |
| 0.25 | 306 | 100 | |
| 0.50 | 305 | 100 | |
| 1.00 | 304 | 99 | |
| 2.00 | 301 | 98 | |
| 3.00 | 299 | 98 | |
| 4.00 | 295 | 96 | |
| 5.00 | 293 | 96 | |
| 6.00 | 290 | 95 | |
| 7.00 | 288 | 94 | |
| 8.00 | 285.5 | 93 | |
| 23.50 | 261 | 85 | |
| 30.33 | 253 | 83 | |
| 48.00 | 236 | 77 | |
| 56.00 | 230 | 75 | |
| 120.00 | 208 | 68 | |
| **143.00** | **205** | **67** | **end primary** |
| 167.25 | 203.5 | 67 | |
| 216.00 | 202 | 66 | |
| 288.25 | 201 | 66 | |
| **290** | 200 | 65 | |
| 292.00 | 199 | 65 | |
| 290.43 | 198 | 65 | |
| 292.50 | 195 | 64 | |
| 294.50 | 193 | 63 | |
| 311.50 | 184 | 60 | |
| 337.00 | 179.5 | 59 | |
| 362.75 | 178 | 58 | |
| 485.00 | 174.5 | 57 | |

**Test Data**

| | |
|---|---|
| Total mass of tailings+cylinder (g): | 19390 |
| Mass cylinder (g): | 7551 |
| Mass tailings (g): | **11839** |
| Initial Volume tailings (cm³): | 8675.98 |
| Volume of tailings at NC (cm3): | 5812.34 |
| Final Volume of tailings (cm3): | 4947.58 |

| | |
|---|---|
| Date Commenced: | 20/03/2019 |
| Date Completed: | |
| Tested by: | ZK |
| Checked By: | |

**INITIAL TEST CONDITIONS**

| | |
|---|---|
| Solids: | 40 |
| Saturation: | 100% |
| $e_o$: | 4.643 |
| γ sat: | 1.365 |
| γdry: | 0.546 |
| w: | 150% |

**ESTIMATED NORMALLY CONSOLIDATED TEST CONDITIONS**

| | |
|---|---|
| Solids: | 75 |
| Saturation: | 100% |
| ef: | 2.780 |
| γ sat: | 2.037 |
| γdry: | 0.815 |
| w: | 33% |

**ESTIMATED FINAL UNDRAINED TEST CONDITIONS**

| | |
|---|---|
| Solids: | 86 |
| Saturation: | 100% |
| ef: | 2.218 |
| γ sat: | 2.393 |
| γdry: | 0.957 |
| w: | 16% |

**TEST CONDITIONS**

| | |
|---|---|
| Cylinder Diameter (mm): | 190 |
| Initial Ht of Test (mm): | 306.0 |
| Final height of Sediment (mm): | 201.0 |
| Water Type: | As received |
| Apparent Particle Density: | 3.08 |
| Initial Mass of Tailings (g): | 11839 |
| Initial Moisture content calculated from densities (%): | 150 |
| NC Moisture content calculated from densities (%): | 33 |
| Final Moisture content calculated from densities (%): | 16 |


GHD Geotechnics
Unit 5, 43 Herbert St Artarmon NSW
p: (02) 9462 4860
f: (02) 9462 4710

## *Column Sedimentation Test Permeability Stage*

## *Report No: SYD1702548*

**Client: Hastings Technology Metals Ltd**

**Job No : 3219134.00**

**Sample No: SYD19-0110-01**
**Client ID:**

**Project: Yangibana**

**Report No : SYD1900567.3**

Area m2 0.0284

| *Date & time* | *Time* | *Elapsed Time (hrs)* | *1 Soil height (mm)* | *1 Water Height (mm)* | *Hydraulic Gradient* | *Flow rate mls / hr* | *2 k (m/s) from Water Height Change* | *Collected Seepage (mls)* | *Seepage Flow Rate ($m^3$/s)* | *2 k (m/s) from Collected Seepage* | *Comment* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/04/2019 | 1:57:00 AM | 0 | 201 | 306 | 1.52 | | | 0 | | | |
| 1/04/2019 | 4:30:00 PM | 4.55 | 193 | 292 | 1.51 | 59.8 | 5.6E-07 | 272 | 1.7E-08 | 3.9E-07 | Draining |
| 2/04/2019 | 9:30:00 AM | 21.55 | 184 | 281 | 1.53 | 18.2 | 1.2E-07 | 309.8 | 5.1E-09 | 1.2E-07 | Draining |
| 3/04/2019 | 11:00am | 47.05 | 179.5 | 269 | 1.50 | 12.5 | 8.6E-08 | 318.8 | 3.5E-09 | 8.1E-08 | Draining |
| 4/04/2019 | 12:45:00 PM | 72.8 | 178 | 259 | 1.46 | 11.5 | 7.3E-08 | 295.7 | 3.2E-09 | 7.6E-08 | Draining |
| 5/04/2019 | 3:00:00 PM | 99.05 | 177 | 249 | 1.41 | 10.9 | 7.4E-08 | 284.9 | 3.0E-09 | 7.4E-08 | refill to 291 |
| | | 99.05 | 177 | 291 | 1.41 | 10.9 | 7.4E-08 | | 3.0E-09 | 7.4E-08 | |
| 8/04/2019 | 12:40:00 PM | 168.72 | 175 | 263.5 | 1.51 | 11.9 | 7.5E-08 | 826.2 | 3.3E-09 | 8.0E-08 | |
| 9/04/2019 | 3:00:00 PM | 195.05 | 174.5 | 253 | 1.45 | 11.3 | 7.5E-08 | 296.9 | 3.1E-09 | 7.5E-08 | |
| | | | | | | | | | | 3 k= 7.5E-08 | |

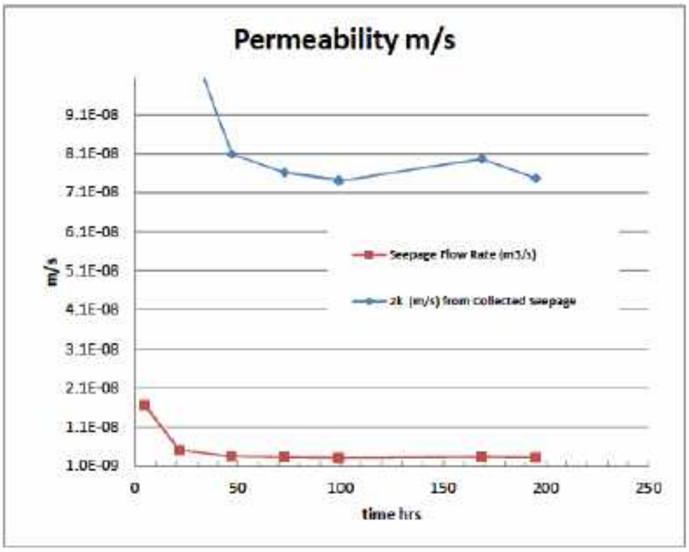
**Notes**

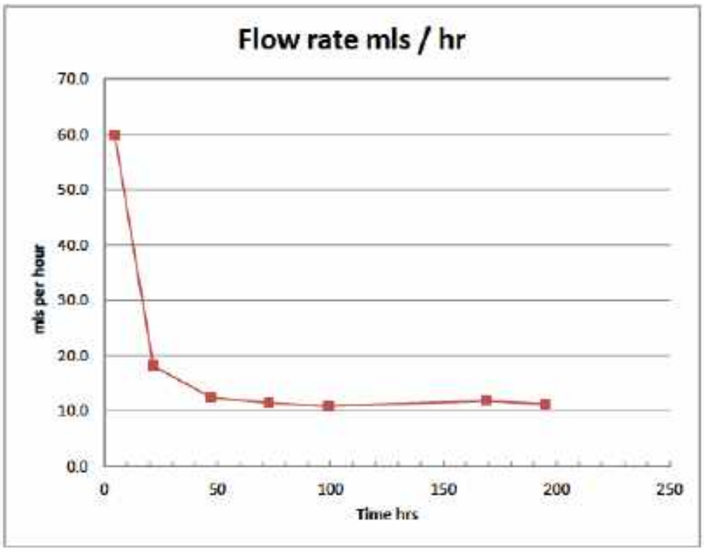
Shearvane tests at end of test

Vane size: 50mm (readable to 0.07 kPa)

| | Upper Test | Lower Test |
|---|---|---|
| Peak (kPa): | | |
| Residual (kPa): | | |

Notes
1. From base of sample
2. Between consecutive records
3. From change in water height



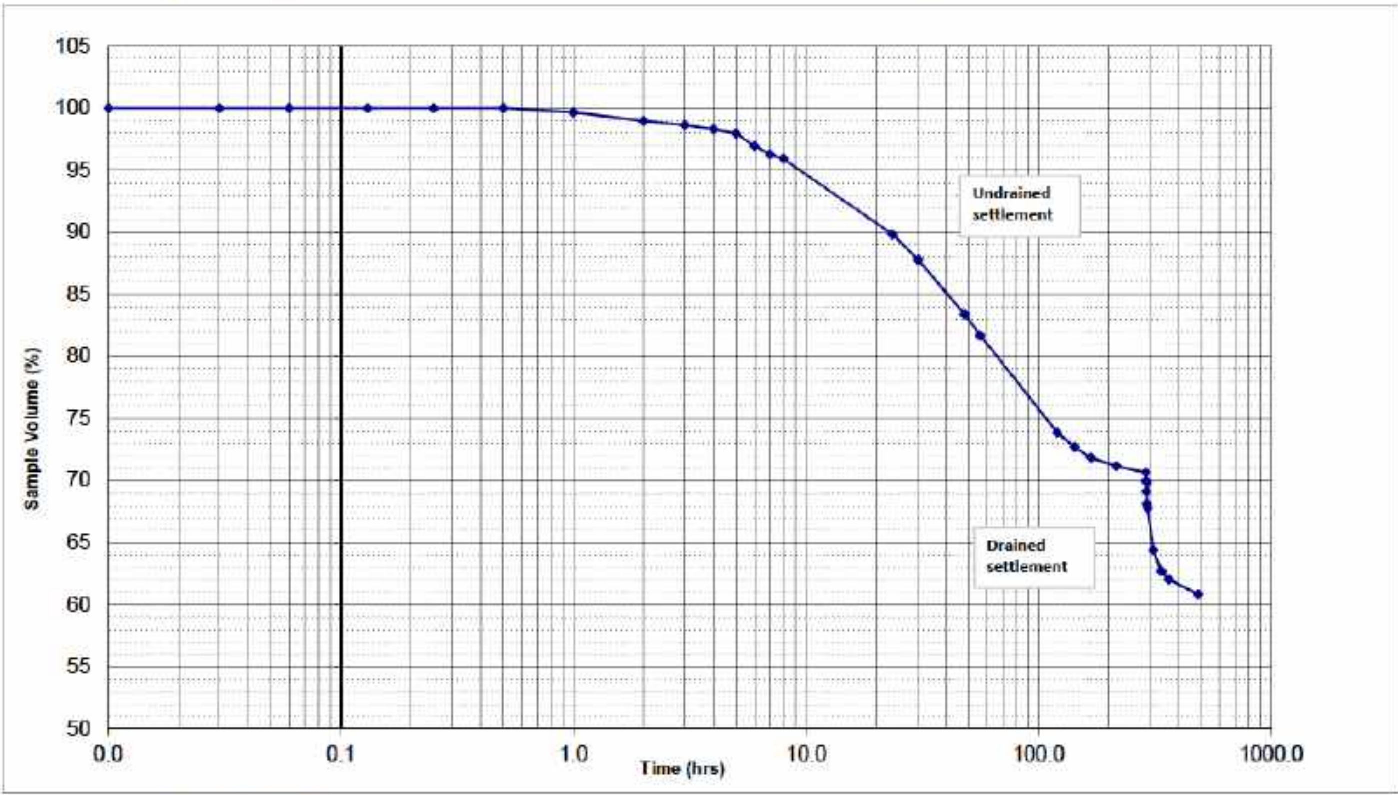

GHD Geotechnics
Unit 5 / 43 Herbert St Artarmon NSW
p: (02) 9462 4700
f: (02) 9462 4710

## *Column Sedimentation Test - Report*

## *Report No: SYD1900567.2*

Client: Hastings Technology Metals Ltd
Project: Yangibana
Location: Option Study

Job No: 3219134
GHD Sample No: SYD19-0110-02
**Client ID: Pilot Plant**




**Settlement data**

| | Time (hrs) | Slurry Height (mm) | Volume (%) | |
|---|---|---|---|---|
| 20/03/2019 | 0.01 | 295 | 100 | |
| | 0.03 | 295 | 100 | |
| | 0.06 | 295 | 100 | |
| | 0.13 | 295 | 100 | |
| | 0.25 | 295 | 100 | |
| | 0.50 | 295 | 100 | |
| | 1.00 | 294 | 100 | |
| | 2.00 | 292 | 99 | |
| | 3.00 | 291 | 99 | |
| | 4.00 | 290 | 98 | |
| | 5.00 | 289 | 98 | |
| | 6.00 | 286 | 97 | |
| | 7.00 | 284 | 96 | |
| | 8.00 | 283 | 96 | |
| | 23.50 | 265 | 90 | |
| | 30.33 | 259 | 88 | |
| | 48.00 | 246 | 83 | |
| | 56.00 | 241 | 82 | |
| | 120.00 | 218 | 74 | |
| | 143.00 | 214.5 | 73 | |
| | **167.25** | **212** | **72** | **end primary** |
| | 216.00 | 210 | 71 | |
| | 288.25 | 208.5 | 71 | |
| Drained | **290** | 206.5 | 70 | |
| | 292.00 | 206 | 70 | |
| | 290.43 | 204 | 69 | |
| | 292.50 | 201 | 68 | |
| | 294.50 | 200 | 68 | |
| | 311.50 | 190 | 64 | |
| | 337.00 | 185 | 63 | |
| | 362.75 | 183 | 62 | |
| | 485.00 | 179.5 | 61 | |

**SAMPLE AERATED WHEN MIXED, AIR REMOVED INSITU & SAMPLE PLUNGED TO REMIX**

**Test Data**

| | |
|---|---|
| Total mass of tailings+cylinder (g): | 23842 |
| Mass cylinder (g): | 12717 |
| Mass tailings (g): | **11125** |
| Initial Volume tailings (cm³): | 8364.10 |
| Volume of tailings at NC (cm3): | 6010.81 |
| Final Volume of tailings (cm3): | 5089.34 |

| | |
|---|---|
| Date Commenced: | 20/03/2019 |
| Date Completed: | 10/05/2019 |
| Tested by: | ZK |
| Checked By: | DB |

| INITIAL TEST CONDITIONS | | ESTIMATED NORMALLY CONSOLIDATED TEST CONDITIONS | | ESTIMATED FINAL UNDRAINET TEST CONDITIONS | |
|---|---|---|---|---|---|
| Solids: | 37 | Solids: | 68 | Solids: | 80 |
| Saturation: | 100% | Saturation: | 100% | Saturation: | 100% |
| $e_o$ | 5.310 | ef. | 3.534 | ef. | 2.839 |
| γ sat: | 1.330 | γ sat: | 1.851 | γ sat: | 2.186 |
| γdry: | 0.488 | γdry: | 0.679 | γdry: | 0.802 |
| w: | 172% | w: | 47% | w: | 24% |

Shearvane after draining: 1.0 kPa, 50mm vane

Moisture content after draining: 56.2%

**TEST CONDITIONS**

| | |
|---|---|
| Cylinder Diameter (mm): | 190 |
| Initial Ht of Test (mm): | 295.0 |
| Final height of Sediment (mm): | 179.5 |
| Water Type: | As received |
| Apparent Particle Density: | 3.08 |
| Initial Mass of Tailings (g): | 11125 |
| Initial Moisture content calculated from densities (%): | 172 |
| NC Moisture content calculated from densities (%): | 47 |
| Final Moisture content calculated from densities (%): | 24 |


GHD Geotechnics
Unit 5, 43 Herbert St Artarmon NSW
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## Column Sedimentation Test Permeability Stage

## Report No: SYD1702548

**Client:** Hastings Technology Metals Ltd

**Job No :** 3219134.00

**Sample No:** SYD19-0110-02
**Client ID:**
**Project:** Yangibana
**Report No :** SYD1900567.2

Area m2 0.0284

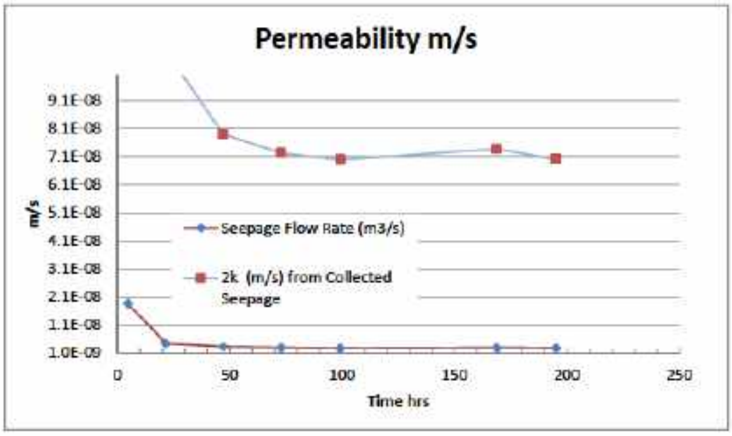
| Date | Time | Elapsed Time (hrs) | [1] Soil height (mm) | [1] Water Height (mm) | Hydraulic Gradient | Flow rate mls / hr | [2] k (m/s) from Water Height Change | Collected Seepage (mls) | Seepage Flow Rate ($m^3$/s) | [2] k (m/s) from Collected Seepage | Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/04/2019 | 11:57:00 PM | 0 | 208.5 | 295 | 1.41 | | | 0 | | | Draining |
| 1/04/2019 | | 4.55 | 200 | 284.5 | 1.42 | 67.1 | 4.5E-07 | 305.3 | 1.9E-08 | 4.6E-07 | Draining |
| 2/04/2019 | | 21.55 | 190 | 273 | 1.44 | 15.9 | 1.3E-07 | 269.9 | 4.4E-09 | 1.1E-07 | Draining |
| 3/04/2019 | | 47.05 | 185 | 262 | 1.42 | 11.5 | 8.4E-08 | 293.8 | 3.2E-09 | 7.9E-08 | Draining |
| 4/04/2019 | | 72.8 | 183 | 253 | 1.38 | 10.3 | 6.9E-08 | 266.2 | 2.9E-09 | 7.2E-08 | Draining |
| 5/04/2019 | | 99.05 | 182 | 244 | 1.34 | 9.7 | 7.0E-08 | 255.3 | 2.7E-09 | 7.0E-08 | refill to 286 |
| | | 99.05 | 182 | 286 | 1.34 | 9.7 | | | 2.7E-09 | 7.0E-08 | |
| 8/04/2019 | | 168.72 | 180 | 259 | 1.44 | 10.5 | 7.7E-08 | 729.7 | 2.9E-09 | 7.4E-08 | |
| 9/04/2019 | | 195.05 | 179.5 | 248 | 1.38 | 10.1 | 8.2E-08 | 265.8 | 2.8E-09 | 7.0E-08 | |
| | | | | | | | | | | [3] k= 8.2E-08 | |

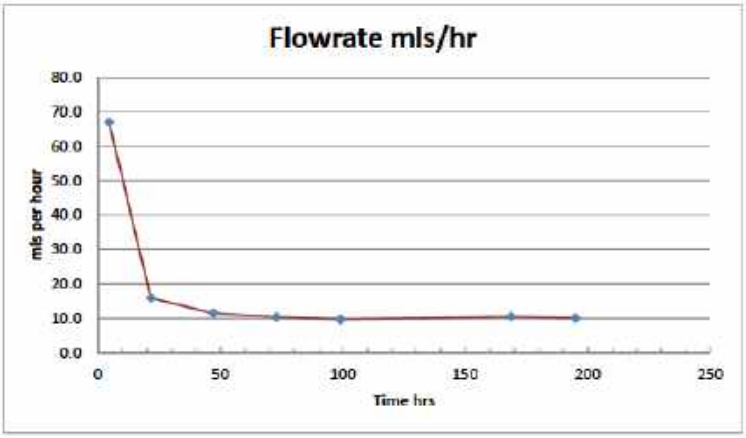
<u>Notes</u>

Shearvane tests at end of test
Vane size: 50mm (readable to 0.07 kPa)

| | Upper Test | Lower Test |
|---|---|---|
| Peak (kPa): | 1 | - |
| Residual (kPa): | - | - |

Notes
1. From base of sample
2. Between consecutive records
3. From change in water height



ALS Environmental

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| Work Order | : **ES1909306** | Page | : 1 of 2 |
| Client | : **GHD PTY LTD** | Laboratory | : Environmental Division Sydney |
| Contact | : [redacted] | Contact | : Customer Services ES |
| Address | : [redacted] | Address | : [redacted] |
| Telephone | : ---- | Telephone | : [redacted] |
| Project | : 3219134 Yangibana TSF Option Study | Date Samples Received | : 27-Mar-2019 12:50 |
| Order number | : | Date Analysis Commenced | : 28-Mar-2019 |
| C-O-C number | : ---- | Issue Date | : 29-Mar-2019 09:40 |
| Sampler | : ---- | | |
| Site | : | | |
| Quote number | : EN/005/18 | | |
| No. of samples received | : 1 | | |
| No. of samples analysed | : 1 | | |

NATA Accreditation No. 825
Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

**Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.**

## *Signatories*

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| [redacted] | | Sydney Inorganics, Smithfield, NSW |

## General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | Yangibana Decant | ---- | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 22-Mar-2019 00:00 | ---- | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | ES1909306-001 | -------- | -------- | -------- | -------- |
| | | | | Result | ---- | ---- | ---- | ---- |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | |
| Suspended Solids (SS) | ---- | 1 | mg/L | 88 | ---- | ---- | ---- | ---- |

**Sydney Laboratory**
Unit 5/43 Herbert St
Artarmon NSW 2064
email: artarmon@ghd.com.au
web: www.ghd.com.au/ghdgeotechnics
Tel: (02) 9462 4860
Fax:(02) 9462 4710

# Aggregate/Soil Test Report

**Report No: SYD1900567**
**Issue No: 2**
*This report replaces all previous issues of report no 'SYD1900567'.*

**Client:**
Hastings Technology Metals Limited
167 St George Terrace
Perth WA 6000

**Project:** 3219134

Accredited for compliance with ISO / IEC 17025 - Testing
[redacted]
NATA Accredited Laboratory Number: 679
Approved Signatory [redacted]
Date of Issue: 10/05/2019


## Sample Details

| | |
|---|---|
| **GHD Sample No** | SYD19-0110-01 |
| **Date Sampled** | 01/03/2019 |
| **Sampled By** | Sampled By Client |
| **Location** | Yangibana TSF Option Study |
| **Soil Description** | SILT: brown (Tailings) |

## Test Results

| Description | Method | Result | Limits |
|---|---|---|---|
| Moisture Content (%) | AS 1289.2.1.1 | 150 | |
| Date Tested | | 12/03/2019 | |
| Coef of Permeability (m/sec) | AS 1289.6.7.3 | 2 E-09 | |
| Mean Stress Level (kPa) | | 30 | |
| Permeant Used | | Syd tap water | |
| Length (mm) | | 67.7 | |
| Diameter (mm) | | 62.8 | |
| Length/Diameter Ratio | | 1.08 | |
| Laboratory Moisture Ratio (%) | | 0.0 | |
| Laboratory Density Ratio (%) | | 0.0 | |
| CompactiveEffort | | Standard | |
| Method of Compaction | | Remoulded | |
| Surcharge Applied (Kg) | | 0.0 | |
| Pressure Applied (Kpa) | | 10 | |
| Oversize Sieve (mm) | | 6.3 | |
| Percentage Oversize (%) | | 0.0 | |
| Moisture Content (%) | | 25.9 | |
| Date Tested | | 22/03/2019 | |

## Comments

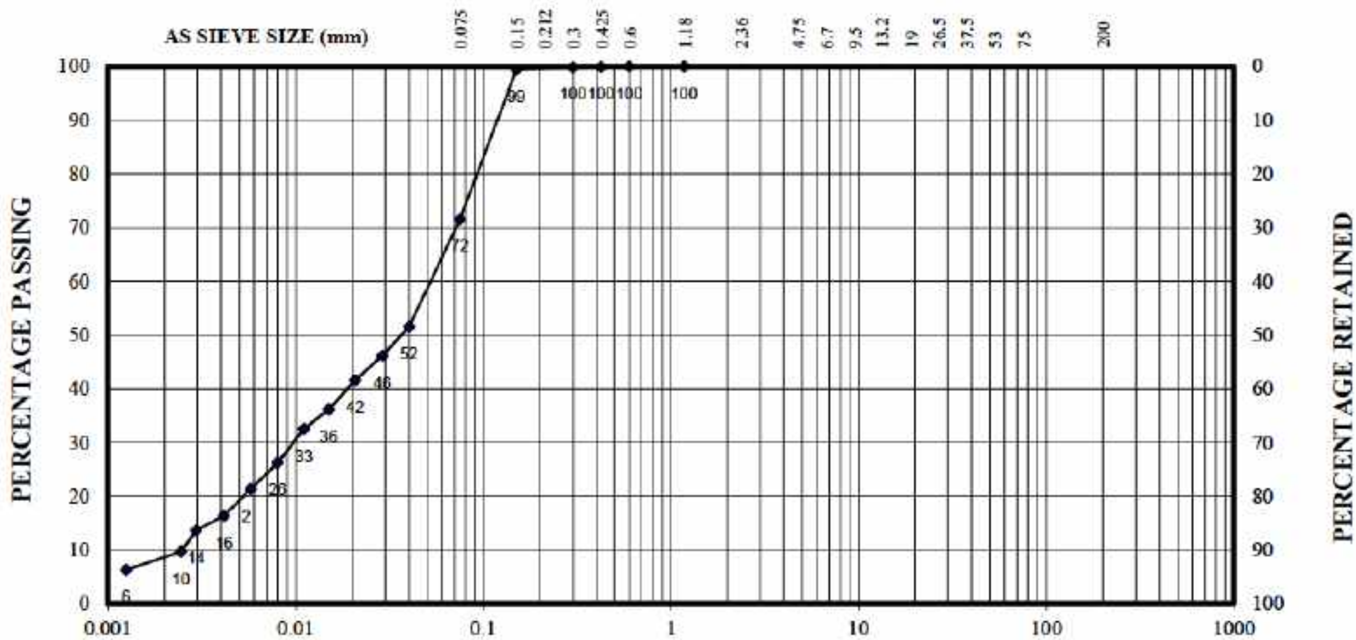
Moisture and Density Ratio's not applicable.
Sample intial dry density = 1.825 t/m³ and MC = 21.9 %
Sample final dry density = 1.821 t/m³ and MC = 25.9 %

# SOIL CLASSIFICATION REPORT

| | |
|---|---|
| **Trial Hole:** | - |
| **Depth (m):** | - |
| **Sample No:** | SYD19-0110-01 |

**Client:** Hastings Technology Metals Limited
**Project:** Yangibana TSF
**Location:** Options Study

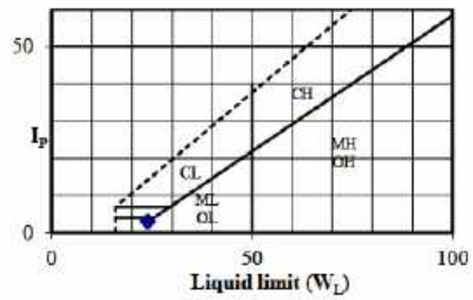
**Client Sample No.:** -
**Sample History:** Sampled By GHD




| CLAY | SILT FRACTION | | | SAND FRACTION | | | GRAVEL FRACTION | | | COBBLES | BOULDERS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fine | Medium | Coarse | Fine | Medium | Coarse | Fine | Medium | Coarse | | |

0.002 0.006 0.02 0.075 0.2 0.6 2.36 6 20 63 200

**PARTICLE SIZE (mm)**




**TEST METHODS**
Particle size AS1289.3.6.3

**OTHER TESTS** AS1289.3.1.1
AS1289.3.2.1 AS1289.3.3.1 AS1289.3.4.1 AS1289.3.5.1

**GRADING**
$C_u = D_{60} / D_{10} =$ 22.02
$C_c = D_{30}^2 / (D_{10} \times D_{60}) =$ 0.71

**PARTICLE DENSITY** 3.08 (measured)

**PRE-TREATMENT HYDROMETER** No

**TEST CONDITION** Washed sieve with dispersing agent

**GROUP SYMBOL:**

**SOIL NAME:** SILT: brown

**REMARKS:**

**INDEX PROPERTIES (%)**
Liquid Limit = 24 Plastic Limit = 21
Plasticity Index = 3 Linear Shrinkage % = 4.0

**Atterberg Limits** (History/Preparation) Oven Dried
**Liquid Limit** (type of test) 4 Point
**Linear Shrinkage** (mould size) 125 mm

**Tested by:** [redacted]
**Date tested:** 27.03.19
**Checked by:** [redacted]
**Date checked:** 10/05/2019
**Approved Signatory:**
[redacted]
[redacted] 10/05/2019


**GHD Pty Ltd**
Unit 5, 43 Herbert St, Artarmon NSW, 2064
Tel: (02) 9462 4700 Fax: (02) 9462 4710


Accredited for compliance with ISO/IEC 17025 - Testing

Laboratory Accreditation Number - 679

| | |
|---|---|
| JOB No. | 3219134 |
| REPORT No. | SYD1900567.1 |

Ref Document F9.1.16 issue 1.2

# Appendix C
Combined Beneficiation Tailings Test Results, Geochemical

ALS Environmental

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| Work Order | : **ES1907149** | Page | : 1 of 16 |
| Amendment | : **1** | | |
| Client | : **GHD PTY LTD** | Laboratory | : Environmental Division Sydney |
| Contact | [redacted] | Contact | : [redacted] |
| Address | [redacted] | Address | : [redacted] |
| Telephone | : ---- | Telephone | [redacted] |
| Project | : 3219134 | Date Samples Received | : 08-Mar-2019 08:15 |
| Order number | : 3219134 | Date Analysis Commenced | : 11-Mar-2019 |
| C-O-C number | : ---- | Issue Date | : 23-Apr-2019 10:50 |
| Sampler | : [redacted] | | |
| Site | : Hasting's Yangibana Project | | |
| Quote number | : ME/158/19 | | |
| No. of samples received | : 14 | | |
| No. of samples analysed | : 14 | | |

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

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- Analytical Results

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## *Signatories*

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| [redacted] | Inorganic Chemist | Sydney Inorganics, Smithfield, NSW |
| | Analyst | Sydney Inorganics, Smithfield, NSW |
| | Senior Acid Sulfate Soil Chemist | Brisbane Acid Sulphate Soils, Stafford, QLD |
| | Inorganics Coordinator | Sydney Inorganics, Smithfield, NSW |

## General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

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Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ED041G: LOR raised for Sulfate on samples 10 and 12 due to sample matrix.
- EN055: Ionic Balance out of acceptable limits for various samples due to analytes not quantified in this report.
- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.
- (ADD METHOD): NATA accreditation does not cover performance of this service.
- EA016: Calculated TDS is determined from Electrical conductivity using a conversion factor of 0.65.
- EA046 ABCC: NATA Acreditation does not cover the performance of this service.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

## Analytical Results

Sub-Matrix: LEACHATE
(Matrix: WATER)

| Compound | CAS Number | LOR | Unit | 2018 bene combined tailings T01 - pH 13.0 | 2018 bene combined tailings T02 - pH 12.0 | 2018 bene combined tailings T03 - pH 10.5 | 2018 bene combined tailings T04 - pH 9.0 | 2018 bene combined tailings T05 - pH 8.0 |
|---|---|---|---|---|---|---|---|---|
| Client sampling date / time | | | | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 |
| | | | | ES1907149-002 | ES1907149-003 | ES1907149-004 | ES1907149-005 | ES1907149-006 |
| | | | | Result | Result | Result | Result | Result |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | 12.8 | 11.9 | 10.0 | 9.09 | 8.10 |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 32800 | 1070 | 213 | 259 | 341 |
| **EA016: Calculated TDS (from Electrical Conductivity)** | | | | | | | | |
| Total Dissolved Solids (Calc.) | ---- | 1 | mg/L | 21300 | 696 | 138 | 168 | 222 |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | <1 | <1 | <1 | 284 | 36 |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | 6140 | 103 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | 761 | 340 | 20 | 7 | <1 |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | <1 | <1 | 64 | 38 | 42 |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 6900 | 443 | 84 | 45 | 42 |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | 4 | 5 | 6 | <1 | <1 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | 23 | 11 | 11 | <1 | <1 |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | <1 | <1 | <1 | 3 | 11 |
| Magnesium | 7439-95-4 | 1 | mg/L | <1 | <1 | <1 | <1 | 2 |
| Sodium | 7440-23-5 | 1 | mg/L | 3710 | 223 | 54 | 58 | 66 |
| Potassium | 7440-09-7 | 1 | mg/L | 9 | 2 | 2 | 2 | 3 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | 15.7 | 2.37 | 4.33 | 0.02 | 0.02 |
| Dysprosium | 7429-91-6 | 0.001 | mg/L | <0.001 | <0.001 | 0.007 | <0.001 | <0.001 |
| Silver | 7440-22-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | 0.021 | 0.007 | 0.006 | <0.001 | <0.001 |
| Bismuth | 7440-69-9 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Erbium | 7440-52-0 | 0.001 | mg/L | <0.001 | <0.001 | 0.002 | <0.001 | <0.001 |
| Boron | 7440-42-8 | 0.05 | mg/L | 0.08 | 0.06 | 0.28 | <0.05 | <0.05 |
| Europium | 7440-53-1 | 0.001 | mg/L | <0.001 | <0.001 | 0.007 | <0.001 | <0.001 |
| Strontium | 7440-24-6 | 0.001 | mg/L | 0.006 | 0.002 | 0.044 | 0.019 | 0.076 |
| Barium | 7440-39-3 | 0.001 | mg/L | 0.182 | 0.144 | 1.51 | 0.158 | 0.483 |

## Analytical Results

Sub-Matrix: **LEACHATE**
(Matrix: **WATER**)

| Compound | CAS Number | LOR | Unit | 2018 bene combined tailings T01 - pH 13.0 | 2018 bene combined tailings T02 - pH 12.0 | 2018 bene combined tailings T03 - pH 10.5 | 2018 bene combined tailings T04 - pH 9.0 | 2018 bene combined tailings T05 - pH 8.0 |
|---|---|---|---|---|---|---|---|---|
| Client sampling date / time | | | | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 |
| | | | | ES1907149-002 | ES1907149-003 | ES1907149-004 | ES1907149-005 | ES1907149-006 |
| | | | | Result | Result | Result | Result | Result |
| **EG020T: Total Metals by ICP-MS - Continued** | | | | | | | | |
| **Gadolinium** | 7440-54-2 | 0.001 | mg/L | <0.001 | <0.001 | **0.019** | <0.001 | <0.001 |
| **Titanium** | 7440-32-6 | 0.01 | mg/L | <0.01 | <0.01 | **0.14** | <0.01 | <0.01 |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | **0.003** | <0.001 | <0.001 |
| **Gallium** | 7440-55-3 | 0.001 | mg/L | **0.005** | **0.003** | **0.013** | <0.001 | <0.001 |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | **0.0003** | **0.0001** | <0.0001 |
| **Hafnium** | 7440-58-6 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Tellurium** | 22541-49-7 | 0.005 | mg/L | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | <0.001 | <0.001 | **0.008** | <0.001 | <0.001 |
| **Holmium** | 7440-60-0 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Uranium** | 7440-61-1 | 0.001 | mg/L | **0.064** | **0.002** | **0.006** | **0.002** | **0.002** |
| **Caesium** | 7440-46-2 | 0.001 | mg/L | <0.001 | <0.001 | **0.005** | <0.001 | <0.001 |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | **0.004** | **0.001** | **0.013** | <0.001 | <0.001 |
| **Indium** | 7440-74-6 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Copper** | 7440-50-8 | 0.001 | mg/L | **0.004** | **0.002** | **0.017** | **0.004** | **0.004** |
| **Lanthanum** | 7439-91-0 | 0.001 | mg/L | <0.001 | **0.002** | **0.084** | <0.001 | <0.001 |
| **Rubidium** | 7440-17-7 | 0.001 | mg/L | **0.016** | **0.003** | **0.059** | **0.003** | **0.005** |
| **Lithium** | 7439-93-2 | 0.001 | mg/L | <0.001 | <0.001 | **0.022** | **0.004** | **0.009** |
| **Lutetium** | 7439-94-3 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Thorium** | 7440-29-1 | 0.001 | mg/L | <0.001 | <0.001 | **0.044** | <0.001 | <0.001 |
| **Cerium** | 7440-45-1 | 0.001 | mg/L | **0.002** | **0.009** | **0.349** | **0.002** | **0.001** |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | **0.005** | **0.061** | **2.35** | **0.054** | **0.034** |
| **Neodymium** | 7440-00-8 | 0.001 | mg/L | **0.001** | **0.008** | **0.273** | **0.001** | <0.001 |
| **Molybdenum** | 7439-98-7 | 0.001 | mg/L | **0.064** | **0.037** | **0.010** | **0.024** | **0.020** |
| **Praseodymium** | 7440-10-0 | 0.001 | mg/L | <0.001 | **0.002** | **0.060** | <0.001 | <0.001 |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | <0.001 | <0.001 | **0.012** | <0.001 | <0.001 |
| **Samarium** | 7440-19-9 | 0.001 | mg/L | <0.001 | <0.001 | **0.031** | <0.001 | <0.001 |
| **Lead** | 7439-92-1 | 0.001 | mg/L | **0.005** | **0.003** | **0.127** | **0.001** | <0.001 |
| **Terbium** | 7440-27-9 | 0.001 | mg/L | <0.001 | <0.001 | **0.002** | <0.001 | <0.001 |
| **Antimony** | 7440-36-0 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Thulium** | 7440-30-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Ytterbium** | 7440-64-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Tin** | 7440-31-5 | 0.001 | mg/L | **0.054** | **0.002** | <0.001 | <0.001 | <0.001 |

## Analytical Results

| Sub-Matrix: LEACHATE (Matrix: WATER) | | | Client sample ID | 2018 bene combined tailings T01 - pH 13.0 | 2018 bene combined tailings T02 - pH 12.0 | 2018 bene combined tailings T03 - pH 10.5 | 2018 bene combined tailings T04 - pH 9.0 | 2018 bene combined tailings T05 - pH 8.0 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 |
| Compound | CAS Number | LOR | Unit | ES1907149-002 | ES1907149-003 | ES1907149-004 | ES1907149-005 | ES1907149-006 |
| | | | | Result | Result | Result | Result | Result |
| **EG020T: Total Metals by ICP-MS - Continued** | | | | | | | | |
| Yttrium | 7440-65-5 | 0.001 | mg/L | <0.001 | <0.001 | **0.018** | <0.001 | <0.001 |
| Thallium | 7440-28-0 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Zirconium | 7440-67-7 | 0.005 | mg/L | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Vanadium | 7440-62-2 | 0.01 | mg/L | **0.21** | **0.10** | **0.05** | <0.01 | <0.01 |
| Zinc | 7440-66-6 | 0.005 | mg/L | **0.075** | **0.196** | **0.291** | **0.019** | **0.167** |
| Iron | 7439-89-6 | 0.05 | mg/L | **0.07** | **0.50** | **16.1** | **0.07** | <0.05 |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| Mercury | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | |
| Fluoride | 16984-48-8 | 0.1 | mg/L | **4.8** | **0.5** | **0.6** | **0.6** | **0.6** |

## Analytical Results

| Sub-Matrix: LEACHATE (Matrix: WATER) | | | Client sample ID | 2018 bene combined tailings T06 - pH Neutral | 2018 bene combined tailings T07 - pH 5.5 | 2018 bene combined tailings T08 - pH 4.0 | 2018 bene combined tailings T09 - pH 2.0 | 2018 bene combined tailings B01 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 |
| Compound | CAS Number | LOR | Unit | ES1907149-007 | ES1907149-008 | ES1907149-009 | ES1907149-010 | ES1907149-011 |
| | | | | Result | Result | Result | Result | Result |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | 6.44 | 5.63 | 3.52 | 1.96 | 6.64 |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 658 | 702 | 1020 | 8260 | <1 |
| **EA016: Calculated TDS (from Electrical Conductivity)** | | | | | | | | |
| Total Dissolved Solids (Calc.) | ---- | 1 | mg/L | 428 | 456 | 663 | 5370 | <1 |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | 122 | 138 | 225 | 253 | <1 |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | 15 | 8 | <1 | <1 | <1 |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 15 | 8 | <1 | <1 | <1 |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | 6 | <1 | <1 | <10 | <1 |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | 12 | <1 | <1 | 11 | <1 |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | 34 | 39 | 62 | 65 | <1 |
| Magnesium | 7439-95-4 | 1 | mg/L | 9 | 10 | 17 | 22 | <1 |
| Sodium | 7440-23-5 | 1 | mg/L | 70 | 73 | 76 | 73 | <1 |
| Potassium | 7440-09-7 | 1 | mg/L | 5 | 6 | 10 | 17 | <1 |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | 0.03 | 0.01 | 4.39 | 19.5 | 0.01 |
| Dysprosium | 7429-91-6 | 0.001 | mg/L | <0.001 | <0.001 | 0.010 | 0.057 | <0.001 |
| Silver | 7440-22-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | <0.001 | 0.004 | 0.034 | <0.001 |
| Bismuth | 7440-69-9 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Erbium | 7440-52-0 | 0.001 | mg/L | <0.001 | <0.001 | 0.003 | 0.015 | <0.001 |
| Boron | 7440-42-8 | 0.05 | mg/L | 0.18 | 0.07 | 0.34 | 0.53 | <0.05 |
| Europium | 7440-53-1 | 0.001 | mg/L | <0.001 | <0.001 | 0.008 | 0.051 | <0.001 |
| Strontium | 7440-24-6 | 0.001 | mg/L | 0.295 | 0.378 | 0.737 | 0.886 | 0.005 |
| Barium | 7440-39-3 | 0.001 | mg/L | 1.38 | 1.04 | 5.18 | 13.8 | 0.088 |

## Analytical Results

Sub-Matrix: LEACHATE
(Matrix: WATER)

| Compound | CAS Number | LOR | Unit | 2018 bene combined tailings T06 - pH Neutral | 2018 bene combined tailings T07 - pH 5.5 | 2018 bene combined tailings T08 - pH 4.0 | 2018 bene combined tailings T09 - pH 2.0 | 2018 bene combined tailings B01 |
|---|---|---|---|---|---|---|---|---|
| Client sampling date / time | | | | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 |
| | | | | ES1907149-007 | ES1907149-008 | ES1907149-009 | ES1907149-010 | ES1907149-011 |
| | | | | Result | Result | Result | Result | Result |
| **EG020T: Total Metals by ICP-MS - Continued** | | | | | | | | |
| **Gadolinium** | 7440-54-2 | 0.001 | mg/L | <0.001 | <0.001 | **0.024** | **0.143** | <0.001 |
| **Titanium** | 7440-32-6 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | **0.01** | <0.01 |
| **Beryllium** | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | **0.054** | **0.076** | <0.001 |
| **Gallium** | 7440-55-3 | 0.001 | mg/L | <0.001 | <0.001 | **0.013** | **0.094** | <0.001 |
| **Cadmium** | 7440-43-9 | 0.0001 | mg/L | **0.0004** | **0.0004** | **0.0033** | **0.0042** | <0.0001 |
| **Hafnium** | 7440-58-6 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Tellurium** | 22541-49-7 | 0.005 | mg/L | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| **Cobalt** | 7440-48-4 | 0.001 | mg/L | <0.001 | **0.004** | **0.059** | **0.141** | <0.001 |
| **Holmium** | 7440-60-0 | 0.001 | mg/L | <0.001 | <0.001 | **0.001** | **0.007** | <0.001 |
| **Uranium** | 7440-61-1 | 0.001 | mg/L | <0.001 | <0.001 | **0.023** | **0.265** | <0.001 |
| **Caesium** | 7440-46-2 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | **0.001** | <0.001 |
| **Chromium** | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | **0.006** | **0.080** | <0.001 |
| **Indium** | 7440-74-6 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Copper** | 7440-50-8 | 0.001 | mg/L | **0.004** | **0.004** | **0.030** | **0.198** | <0.001 |
| **Lanthanum** | 7439-91-0 | 0.001 | mg/L | <0.001 | **0.003** | **0.103** | **0.860** | <0.001 |
| **Rubidium** | 7440-17-7 | 0.001 | mg/L | **0.011** | **0.016** | **0.043** | **0.148** | <0.001 |
| **Lithium** | 7439-93-2 | 0.001 | mg/L | **0.022** | **0.024** | **0.044** | **0.103** | <0.001 |
| **Lutetium** | 7439-94-3 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | **0.001** | <0.001 |
| **Thorium** | 7440-29-1 | 0.001 | mg/L | **0.002** | <0.001 | <0.001 | **0.053** | <0.001 |
| **Cerium** | 7440-45-1 | 0.001 | mg/L | **0.001** | **0.006** | **0.329** | **2.36** | <0.001 |
| **Manganese** | 7439-96-5 | 0.001 | mg/L | **1.03** | **2.40** | **13.3** | **35.0** | **0.014** |
| **Neodymium** | 7440-00-8 | 0.001 | mg/L | <0.001 | **0.004** | **0.290** | **2.15** | <0.001 |
| **Molybdenum** | 7439-98-7 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Praseodymium** | 7440-10-0 | 0.001 | mg/L | <0.001 | <0.001 | **0.064** | **0.555** | <0.001 |
| **Nickel** | 7440-02-0 | 0.001 | mg/L | **0.005** | **0.012** | **0.045** | **0.080** | <0.001 |
| **Samarium** | 7440-19-9 | 0.001 | mg/L | <0.001 | <0.001 | **0.035** | **0.238** | <0.001 |
| **Lead** | 7439-92-1 | 0.001 | mg/L | <0.001 | <0.001 | **0.014** | **1.04** | <0.001 |
| **Terbium** | 7440-27-9 | 0.001 | mg/L | <0.001 | <0.001 | **0.003** | **0.015** | <0.001 |
| **Antimony** | 7440-36-0 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| **Thulium** | 7440-30-4 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | **0.001** | <0.001 |
| **Selenium** | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | **0.04** | <0.01 |
| **Ytterbium** | 7440-64-4 | 0.001 | mg/L | <0.001 | <0.001 | **0.002** | **0.008** | <0.001 |
| **Tin** | 7440-31-5 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

## Analytical Results

Sub-Matrix: **LEACHATE**
(Matrix: **WATER**)

| | | | Client sample ID | 2018 bene combined tailings T06 - pH Neutral | 2018 bene combined tailings T07 - pH 5.5 | 2018 bene combined tailings T08 - pH 4.0 | 2018 bene combined tailings T09 - pH 2.0 | 2018 bene combined tailings B01 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 |
| Compound | CAS Number | LOR | Unit | ES1907149-007 | ES1907149-008 | ES1907149-009 | ES1907149-010 | ES1907149-011 |
| | | | | Result | Result | Result | Result | Result |
| **EG020T: Total Metals by ICP-MS - Continued** | | | | | | | | |
| **Yttrium** | 7440-65-5 | 0.001 | mg/L | <0.001 | <0.001 | **0.033** | **0.162** | <0.001 |
| **Thallium** | 7440-28-0 | 0.001 | mg/L | <0.001 | <0.001 | <0.001 | **0.004** | <0.001 |
| **Zirconium** | 7440-67-7 | 0.005 | mg/L | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | **0.585** | **0.689** | **1.21** | **1.58** | **0.014** |
| **Iron** | 7439-89-6 | 0.05 | mg/L | <0.05 | <0.05 | <0.05 | **26.7** | <0.05 |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | **0.3** | **0.2** | **1.2** | **1.0** | <0.1 |

## Analytical Results

Sub-Matrix: LEACHATE
(Matrix: WATER)

| Compound | CAS Number | LOR | Unit | 2018 bene combined tailings B02 | 2018 bene combined tailings B03 | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | ---- | ---- | ---- |
| | | | | ES1907149-012 | ES1907149-013 | -------- | -------- | -------- |
| | | | | Result | Result | ---- | ---- | ---- |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | **1.74** | **12.9** | ---- | ---- | ---- |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | **13300** | **35600** | ---- | ---- | ---- |
| **EA016: Calculated TDS (from Electrical Conductivity)** | | | | | | | | |
| Total Dissolved Solids (Calc.) | ---- | 1 | mg/L | **8640** | **23100** | ---- | ---- | ---- |
| **EA065: Total Hardness as CaCO3** | | | | | | | | |
| Total Hardness as CaCO3 | ---- | 1 | mg/L | <1 | <1 | ---- | ---- | ---- |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | <1 | **6120** | ---- | ---- | ---- |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | <1 | **1050** | ---- | ---- | ---- |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | <1 | <1 | ---- | ---- | ---- |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | <1 | **7180** | ---- | ---- | ---- |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | <10 | <1 | ---- | ---- | ---- |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | <1 | **11** | ---- | ---- | ---- |
| **ED093F: Dissolved Major Cations** | | | | | | | | |
| Calcium | 7440-70-2 | 1 | mg/L | <1 | <1 | ---- | ---- | ---- |
| Magnesium | 7439-95-4 | 1 | mg/L | <1 | <1 | ---- | ---- | ---- |
| Sodium | 7440-23-5 | 1 | mg/L | <1 | **3800** | ---- | ---- | ---- |
| Potassium | 7440-09-7 | 1 | mg/L | <1 | **1** | ---- | ---- | ---- |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Aluminium | 7429-90-5 | 0.01 | mg/L | **0.02** | **0.17** | ---- | ---- | ---- |
| Dysprosium | 7429-91-6 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Silver | 7440-22-4 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Arsenic | 7440-38-2 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Bismuth | 7440-69-9 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Erbium | 7440-52-0 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Boron | 7440-42-8 | 0.05 | mg/L | <0.05 | <0.05 | ---- | ---- | ---- |
| Europium | 7440-53-1 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Strontium | 7440-24-6 | 0.001 | mg/L | <0.001 | **0.011** | ---- | ---- | ---- |
| Barium | 7440-39-3 | 0.001 | mg/L | **0.020** | **0.453** | ---- | ---- | ---- |

## Analytical Results

Sub-Matrix: LEACHATE
(Matrix: WATER)

| | | | Client sample ID | 2018 bene combined tailings B02 | 2018 bene combined tailings B03 | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | ES1907149-012 | ES1907149-013 | -------- | -------- | -------- |
| | | | | Result | Result | ---- | ---- | ---- |
| **EG020T: Total Metals by ICP-MS - Continued** | | | | | | | | |
| Gadolinium | 7440-54-2 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Titanium | 7440-32-6 | 0.01 | mg/L | <0.01 | <0.01 | ---- | ---- | ---- |
| Beryllium | 7440-41-7 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Gallium | 7440-55-3 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Cadmium | 7440-43-9 | 0.0001 | mg/L | <0.0001 | <0.0001 | ---- | ---- | ---- |
| Hafnium | 7440-58-6 | 0.01 | mg/L | <0.01 | <0.01 | ---- | ---- | ---- |
| Tellurium | 22541-49-7 | 0.005 | mg/L | <0.005 | <0.005 | ---- | ---- | ---- |
| Cobalt | 7440-48-4 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Holmium | 7440-60-0 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Uranium | 7440-61-1 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Caesium | 7440-46-2 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Chromium | 7440-47-3 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Indium | 7440-74-6 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Copper | 7440-50-8 | 0.001 | mg/L | <0.001 | **0.005** | ---- | ---- | ---- |
| Lanthanum | 7439-91-0 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Rubidium | 7440-17-7 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Lithium | 7439-93-2 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Lutetium | 7439-94-3 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Thorium | 7440-29-1 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Cerium | 7440-45-1 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Manganese | 7439-96-5 | 0.001 | mg/L | **0.009** | **0.003** | ---- | ---- | ---- |
| Neodymium | 7440-00-8 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Molybdenum | 7439-98-7 | 0.001 | mg/L | <0.001 | **0.002** | ---- | ---- | ---- |
| Praseodymium | 7440-10-0 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Nickel | 7440-02-0 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Samarium | 7440-19-9 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Lead | 7439-92-1 | 0.001 | mg/L | **0.002** | **0.002** | ---- | ---- | ---- |
| Terbium | 7440-27-9 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Antimony | 7440-36-0 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Thulium | 7440-30-4 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Selenium | 7782-49-2 | 0.01 | mg/L | <0.01 | <0.01 | ---- | ---- | ---- |
| Ytterbium | 7440-64-4 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| Tin | 7440-31-5 | 0.001 | mg/L | <0.001 | **0.039** | ---- | ---- | ---- |

## Analytical Results

Sub-Matrix: **LEACHATE**
(Matrix: **WATER**)

| | | | Client sample ID | 2018 bene combined tailings B02 | 2018 bene combined tailings B03 | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | ---- | ---- | ---- |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **ES1907149-012** | **ES1907149-013** | -------- | -------- | -------- |
| | | | | Result | Result | ---- | ---- | ---- |
| **EG020T: Total Metals by ICP-MS - Continued** | | | | | | | | |
| **Yttrium** | 7440-65-5 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Thallium** | 7440-28-0 | 0.001 | mg/L | <0.001 | <0.001 | ---- | ---- | ---- |
| **Zirconium** | 7440-67-7 | 0.005 | mg/L | <0.005 | <0.005 | ---- | ---- | ---- |
| **Vanadium** | 7440-62-2 | 0.01 | mg/L | <0.01 | <0.01 | ---- | ---- | ---- |
| **Zinc** | 7440-66-6 | 0.005 | mg/L | **0.010** | **0.072** | ---- | ---- | ---- |
| **Iron** | 7439-89-6 | 0.05 | mg/L | **1.10** | <0.05 | ---- | ---- | ---- |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| **Mercury** | 7439-97-6 | 0.0001 | mg/L | <0.0001 | <0.0001 | ---- | ---- | ---- |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | |
| **Fluoride** | 16984-48-8 | 0.1 | mg/L | <0.1 | **3.8** | ---- | ---- | ---- |

## Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

| Compound | CAS Number | LOR | Unit | 2018 bene combined tailings | 2018 bene combined tailings T01 - pH 13.0 | 2018 bene combined tailings T02 - pH 12.0 | 2018 bene combined tailings T03 - pH 10.5 | 2018 bene combined tailings T04 - pH 9.0 |
|---|---|---|---|---|---|---|---|---|
| Client sampling date / time | | | | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 |
| | | | | ES1907149-001 | ES1907149-002 | ES1907149-003 | ES1907149-004 | ES1907149-005 |
| | | | | Result | Result | Result | Result | Result |
| **EA002: pH 1:5 (Soils)** | | | | | | | | |
| pH Value | ---- | 0.1 | pH Unit | 10.1 | ---- | ---- | ---- | ---- |
| **EA009: Nett Acid Production Potential** | | | | | | | | |
| Net Acid Production Potential | ---- | 0.5 | kg H2SO4/t | -7.3 | ---- | ---- | ---- | ---- |
| **EA010: Conductivity (1:5)** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 276 | ---- | ---- | ---- | ---- |
| **EA011: Net Acid Generation** | | | | | | | | |
| pH (OX) | ---- | 0.1 | pH Unit | 8.9 | ---- | ---- | ---- | ---- |
| NAG (pH 4.5) | ---- | 0.1 | kg H2SO4/t | <0.1 | ---- | ---- | ---- | ---- |
| NAG (pH 7.0) | ---- | 0.1 | kg H2SO4/t | <0.1 | ---- | ---- | ---- | ---- |
| **EA013: Acid Neutralising Capacity** | | | | | | | | |
| ANC as H2SO4 | ---- | 0.5 | kg H2SO4 equiv./t | 7.3 | ---- | ---- | ---- | ---- |
| ANC as CaCO3 | ---- | 0.1 | % CaCO3 | 0.7 | ---- | ---- | ---- | ---- |
| Fizz Rating | ---- | 0 | Fizz Unit | 0 | ---- | ---- | ---- | ---- |
| **EA055: Moisture Content (Dried @ 105-110°C)** | | | | | | | | |
| Moisture Content | ---- | 1.0 | % | <1.0 | ---- | ---- | ---- | ---- |
| **ED042T: Total Sulfur by LECO** | | | | | | | | |
| Sulfur - Total as S (LECO) | ---- | 0.01 | % | <0.01 | ---- | ---- | ---- | ---- |
| **EG005(ED093)T: Total Metals by ICP-AES** | | | | | | | | |
| Aluminium | 7429-90-5 | 50 | mg/kg | 3920 | ---- | ---- | ---- | ---- |
| Boron | 7440-42-8 | 50 | mg/kg | <50 | ---- | ---- | ---- | ---- |
| Iron | 7439-89-6 | 50 | mg/kg | 43600 | ---- | ---- | ---- | ---- |
| **EG020T: Total Metals by ICP-MS** | | | | | | | | |
| Arsenic | 7440-38-2 | 0.1 | mg/kg | 7.8 | ---- | ---- | ---- | ---- |
| Selenium | 7782-49-2 | 1 | mg/kg | 16 | ---- | ---- | ---- | ---- |
| Silver | 7440-22-4 | 0.1 | mg/kg | 0.7 | ---- | ---- | ---- | ---- |
| Barium | 7440-39-3 | 0.1 | mg/kg | 1020 | ---- | ---- | ---- | ---- |
| Thallium | 7440-28-0 | 0.1 | mg/kg | 0.8 | ---- | ---- | ---- | ---- |
| Beryllium | 7440-41-7 | 0.1 | mg/kg | 3.4 | ---- | ---- | ---- | ---- |
| Cadmium | 7440-43-9 | 0.1 | mg/kg | 0.2 | ---- | ---- | ---- | ---- |
| Bismuth | 7440-69-9 | 0.1 | mg/kg | 0.3 | ---- | ---- | ---- | ---- |
| Cobalt | 7440-48-4 | 0.1 | mg/kg | 12.8 | ---- | ---- | ---- | ---- |

## Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

| | | | Client sample ID | 2018 bene combined tailings | 2018 bene combined tailings T01 - pH 13.0 | 2018 bene combined tailings T02 - pH 12.0 | 2018 bene combined tailings T03 - pH 10.5 | 2018 bene combined tailings T04 - pH 9.0 |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 |
| Compound | CAS Number | LOR | Unit | ES1907149-001 | ES1907149-002 | ES1907149-003 | ES1907149-004 | ES1907149-005 |
| | | | | Result | Result | Result | Result | Result |
| **EG020T: Total Metals by ICP-MS - Continued** | | | | | | | | |
| Chromium | 7440-47-3 | 0.1 | mg/kg | 58.5 | ---- | ---- | ---- | ---- |
| Copper | 7440-50-8 | 0.1 | mg/kg | 25.0 | ---- | ---- | ---- | ---- |
| Thorium | 7440-29-1 | 0.1 | mg/kg | 153 | ---- | ---- | ---- | ---- |
| Manganese | 7439-96-5 | 0.1 | mg/kg | 3210 | ---- | ---- | ---- | ---- |
| Strontium | 7440-24-6 | 0.1 | mg/kg | 58.1 | ---- | ---- | ---- | ---- |
| Molybdenum | 7439-98-7 | 0.1 | mg/kg | 4.7 | ---- | ---- | ---- | ---- |
| Nickel | 7440-02-0 | 0.1 | mg/kg | 33.4 | ---- | ---- | ---- | ---- |
| Lead | 7439-92-1 | 0.1 | mg/kg | 255 | ---- | ---- | ---- | ---- |
| Antimony | 7440-36-0 | 0.1 | mg/kg | <0.1 | ---- | ---- | ---- | ---- |
| Uranium | 7440-61-1 | 0.1 | mg/kg | 8.4 | ---- | ---- | ---- | ---- |
| Zinc | 7440-66-6 | 0.5 | mg/kg | 86.6 | ---- | ---- | ---- | ---- |
| Lithium | 7439-93-2 | 0.1 | mg/kg | 17.7 | ---- | ---- | ---- | ---- |
| Vanadium | 7440-62-2 | 1 | mg/kg | 20 | ---- | ---- | ---- | ---- |
| Tin | 7440-31-5 | 0.1 | mg/kg | 3.4 | ---- | ---- | ---- | ---- |
| **EG035T: Total Recoverable Mercury by FIMS** | | | | | | | | |
| Mercury | 7439-97-6 | 0.1 | mg/kg | <0.1 | ---- | ---- | ---- | ---- |
| **EN58-2: Leaching Environmental Assessment Framework (LEAF) Method 1313** | | | | | | | | |
| Particle Size (>85 wt% passing through) | ---- | 0.1 | mm | ---- | 2.0 | 2.0 | 2.0 | 2.0 |
| Acid | ---- | - | - | ---- | 4N HNO3 | 4N HNO3 | 4N HNO3 | 4N HNO3 |
| Volume of acid | ---- | 0.1 | mL | ---- | <0.1 | <0.1 | <0.1 | 0.1 |
| Base | ---- | - | - | ---- | 1N NaOH | 1N NaOH | 1N NaOH | 1N NaOH |
| Volume of base | ---- | 0.1 | mL | ---- | 70.0 | 4.0 | <0.1 | <0.1 |
| Volume of water | ---- | 1 | mL | ---- | 330 | 396 | 400 | 400 |
| Extraction Contact Time | ---- | 0.5 | hours | ---- | 48.0 | 48.0 | 48.0 | 48.0 |
| Ambient Temperature | ---- | 0.5 | °C | ---- | 22.4 | 22.4 | 22.4 | 22.4 |
| Mass of "as tested" solid | ---- | 0.1 | g | ---- | 40.0 | 40.0 | 40.0 | 40.0 |
| Target pH | ---- | 0.1 | pH Unit | ---- | 13.0 | 12.0 | 10.5 | 9.0 |
| Ambient Temperature during extraction | ---- | 0.1 | °C | ---- | 22.4 | 22.4 | 21.9 | 23.1 |

## Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

| Compound | CAS Number | LOR | Unit | 2018 bene combined tailings T05 - pH 8.0 | 2018 bene combined tailings T06 - pH Neutral | 2018 bene combined tailings T07 - pH 5.5 | 2018 bene combined tailings T08 - pH 4.0 | 2018 bene combined tailings T09 - pH 2.0 |
|---|---|---|---|---|---|---|---|---|
| Client sampling date / time | | | | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 |
| | | | | ES1907149-006 | ES1907149-007 | ES1907149-008 | ES1907149-009 | ES1907149-010 |
| | | | | Result | Result | Result | Result | Result |
| **EN58-2: Leaching Environmental Assessment Framework (LEAF) Method 1313** | | | | | | | | |
| **Particle Size (>85 wt% passing through)** | ---- | 0.1 | mm | **2.0** | **2.0** | **2.0** | **2.0** | **2.0** |
| **Acid** | ---- | - | - | **4N HNO3** | **4N HNO3** | **4N HNO3** | **4N HNO3** | **4N HNO3** |
| **Volume of acid** | ---- | 0.1 | mL | **0.2** | **0.5** | **0.6** | **0.9** | **3.0** |
| **Base** | ---- | - | - | **1N NaOH** | **1N NaOH** | **1N NaOH** | **1N NaOH** | **1N NaOH** |
| **Volume of base** | ---- | 0.1 | mL | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| **Volume of water** | ---- | 1 | mL | **400** | **400** | **399** | **399** | **397** |
| **Extraction Contact Time** | ---- | 0.5 | hours | **48.0** | **48.0** | **48.0** | **48.0** | **48.0** |
| **Ambient Temperature** | ---- | 0.5 | °C | **22.4** | **22.4** | **22.4** | **22.4** | **22.4** |
| **Mass of "as tested" solid** | ---- | 0.1 | g | **40.0** | **40.0** | **40.0** | **40.0** | **40.0** |
| **Target pH** | ---- | 0.1 | pH Unit | **8.0** | **7.0** | **5.5** | **4.0** | **2.0** |
| **Ambient Temperature during extraction** | ---- | 0.1 | °C | **22.3** | **22.4** | **23.1** | **22.3** | **22.4** |

## Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

| | | | Client sample ID | 2018 bene combined tailings B01 | 2018 bene combined tailings B02 | 2018 bene combined tailings B03 | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | 26-Nov-2018 00:00 | ---- | ---- |
| Compound | CAS Number | LOR | Unit | ES1907149-011 | ES1907149-012 | ES1907149-013 | -------- | -------- |
| | | | | Result | Result | Result | ---- | ---- |
| **EN58-2: Leaching Environmental Assessment Framework (LEAF) Method 1313** | | | | | | | | |
| **Particle Size (>85 wt% passing through)** | ---- | 0.1 | mm | **2.0** | **2.0** | **2.0** | ---- | ---- |
| **Acid** | ---- | | | **4N HNO3** | **4N HNO3** | **4N HNO3** | ---- | ---- |
| **Volume of acid** | ---- | 0 1 | mL | 0 1 | **3.0** | 0 1 | ---- | ---- |
| **Base** | ---- | | | **1N NaOH** | **1N NaOH** | **1N NaOH** | ---- | ---- |
| **Volume of base** | ---- | 0 1 | mL | 0 1 | 0 1 | **70.0** | ---- | ---- |
| **Volume of water** | ---- | 1 | mL | **400** | **397** | **330** | ---- | ---- |
| **Extraction Contact Time** | ---- | 0.5 | hours | **48.0** | **48.0** | **48.0** | ---- | ---- |
| **Ambient Temperature** | ---- | 0.5 | °C | **22.4** | **22.4** | **22.4** | ---- | ---- |
| **Mass of "as tested" solid** | ---- | 0.1 | g | <0.1 | <0.1 | <0.1 | ---- | ---- |
| **Target pH** | ---- | 0.1 | pH Unit | **Natural** | **2.0** | **13.0** | ---- | ---- |
| **Ambient Temperature during extraction** | ---- | 0.1 | °C | **22.4** | **22.4** | **22.4** | ---- | ---- |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | Hastings pilot plant filtrate | ---- | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Nov-2018 00:00 | ---- | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | ES1907149-014 | -------- | -------- | -------- | -------- |
| | | | | Result | ---- | ---- | ---- | ---- |
| **EA005P: pH by PC Titrator** | | | | | | | | |
| pH Value | ---- | 0.01 | pH Unit | 11.8 | ---- | ---- | ---- | ---- |
| **EA010P: Conductivity by PC Titrator** | | | | | | | | |
| Electrical Conductivity @ 25°C | ---- | 1 | µS/cm | 5220 | ---- | ---- | ---- | ---- |
| **EA016: Calculated TDS (from Electrical Conductivity)** | | | | | | | | |
| Total Dissolved Solids (Calc.) | ---- | 1 | mg/L | 3390 | ---- | ---- | ---- | ---- |
| **EA025: Total Suspended Solids dried at 104 ± 2°C** | | | | | | | | |
| Suspended Solids (SS) | ---- | 5 | mg/L | 16 | ---- | ---- | ---- | ---- |
| **ED037P: Alkalinity by PC Titrator** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | DMO-210-001 | 1 | mg/L | 703 | ---- | ---- | ---- | ---- |
| Carbonate Alkalinity as CaCO3 | 3812-32-6 | 1 | mg/L | 213 | ---- | ---- | ---- | ---- |
| Bicarbonate Alkalinity as CaCO3 | 71-52-3 | 1 | mg/L | <1 | ---- | ---- | ---- | ---- |
| Total Alkalinity as CaCO3 | ---- | 1 | mg/L | 914 | ---- | ---- | ---- | ---- |
| **ED041G: Sulfate (Turbidimetric) as SO4 2- by DA** | | | | | | | | |
| Sulfate as SO4 - Turbidimetric | 14808-79-8 | 1 | mg/L | 182 | ---- | ---- | ---- | ---- |
| **ED045G: Chloride by Discrete Analyser** | | | | | | | | |
| Chloride | 16887-00-6 | 1 | mg/L | 285 | ---- | ---- | ---- | ---- |
| **EK040P: Fluoride by PC Titrator** | | | | | | | | |
| Fluoride | 16984-48-8 | 0.1 | mg/L | 2.6 | ---- | ---- | ---- | ---- |

ALS Environmental

# *Acid Buffering Characteristic Curve (ABCC) REPORT*

**Batch: ES1907149**

| | | | |
|---|---|---|---|
| **CONTACT:** | [redacted] | **LABORATORY:** | Brisbane |
| **CLIENT:** | GHD PTY LTD | **DATE SAMPLED:** | 26/01/2018 |
| **ADDRESS:** | [redacted] | **DATE RECEIVED:** | 8/03/2019 |
| | | **DATE COMPLETED:** | 22/03/2019 |
| | | **SAMPLE TYPE:** | Soil |
| | | **No. of SAMPLES:** | 1 |

## COMMENTS

**EA046 : NATA accreditation does not cover performance of this service.**

## ISSUING LABORATORY: ALS BRISBANE

| | | | |
|---|---|---|---|
| **Address:** | [redacted] | **Telephone:** | [redacted] |
| | | **Facsimile:** | [redacted] |
| | | **E-mail:** | [redacted] |

**Signatory**

[redacted]

*Australian Laboratory Services Pty Ltd (ABN 84 009 936 029)*

| Work Order : | ES1907149 | Client ID: | GHD PTY LTD |
|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| | Sub Matrix | | | Soil |
| | Client Sample Identification 1 | | | 2018 bene combined tailings |
| | Client Sample Identification 2 | | | |
| | Sample Date | | | 26/01/2018 |
| Method | Analyte | Units | LOR | 1<br>ES1907149 |

***EA046 - A Titration information***

| | | |
|---|---|---|
| **HCl Molarity:** | **M** | **0.1** |
| **Increments:** | **mL** | **0.1** |
| **Weight** | **(g)** | **2** |
| **ANC** | **kgH2SO4/t** | **7.3** |

***EA046 -B - Curve information***

| Addition | mLs added (total) | kg H2SO4/t | pH | Addition | mLs added (total) | kg H2SO4/t | pH |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 8.44 | 36 | 3.6 | 8.82 | 3.08 |
| 1 | 0.1 | 0.245 | 7.86 | 37 | 3.7 | 9.065 | 3.05 |
| 2 | 0.2 | 0.49 | 7.46 | 38 | 3.8 | 9.31 | 3.03 |
| 3 | 0.3 | 0.735 | 7.23 | 39 | 3.9 | 9.555 | 3.00 |
| 4 | 0.4 | 0.98 | 7.08 | 40 | 4 | 9.8 | 2.97 |
| 5 | 0.5 | 1.225 | 6.94 | 41 | 4.1 | 10.045 | 2.95 |
| 6 | 0.6 | 1.47 | 6.78 | 42 | 4.2 | 10.29 | 2.93 |
| 7 | 0.7 | 1.715 | 6.58 | 43 | 4.3 | 10.535 | 2.91 |
| 8 | 0.8 | 1.96 | 6.36 | 44 | 4.4 | 10.78 | 2.89 |
| 9 | 0.9 | 2.205 | 6.15 | 45 | 4.5 | 11.025 | 2.87 |
| 10 | 1 | 2.45 | 5.95 | 46 | 4.6 | 11.27 | 2.85 |
| 11 | 1.1 | 2.695 | 5.66 | 47 | 4.7 | 11.515 | 2.83 |
| 12 | 1.2 | 2.94 | 5.32 | 48 | 4.8 | 11.76 | 2.81 |
| 13 | 1.3 | 3.185 | 5.00 | 49 | 4.9 | 12.005 | 2.80 |
| 14 | 1.4 | 3.43 | 4.80 | 50 | 5 | 12.25 | 2.79 |
| 15 | 1.5 | 3.675 | 4.64 | 51 | 5.1 | 12.495 | 2.77 |
| 16 | 1.6 | 3.92 | 4.50 | 52 | 5.2 | 12.74 | 2.76 |
| 17 | 1.7 | 4.165 | 4.33 | 53 | 5.3 | 12.985 | 2.74 |
| 18 | 1.8 | 4.41 | 4.20 | 54 | 5.4 | 13.23 | 2.73 |
| 19 | 1.9 | 4.655 | 4.08 | 55 | 5.5 | 13.475 | 2.71 |
| 20 | 2 | 4.9 | 3.98 | 56 | 5.6 | 13.72 | 2.70 |
| 21 | 2.1 | 5.145 | 3.89 | 57 | 5.7 | 13.965 | 2.69 |
| 22 | 2.2 | 5.39 | 3.79 | 58 | 5.8 | 14.21 | 2.67 |
| 23 | 2.3 | 5.635 | 3.70 | 59 | 5.9 | 14.455 | 2.66 |
| 24 | 2.4 | 5.88 | 3.67 | 60 | 6 | 14.7 | 2.65 |
| 25 | 2.5 | 6.125 | 3.59 | 61 | 6.1 | 14.945 | 2.63 |
| 26 | 2.6 | 6.37 | 3.52 | 62 | 6.2 | 15.19 | 2.62 |
| 27 | 2.7 | 6.615 | 3.46 | 63 | 6.3 | 15.435 | 2.61 |
| 28 | 2.8 | 6.86 | 3.40 | 64 | 6.4 | 15.68 | 2.59 |
| 29 | 2.9 | 7.105 | 3.35 | 65 | 6.5 | 15.925 | 2.59 |
| 30 | 3 | 7.35 | 3.30 | 66 | 6.6 | 16.17 | 2.57 |
| 31 | 3.1 | 7.595 | 3.26 | 67 | 6.7 | 16.415 | 2.56 |
| 32 | 3.2 | 7.84 | 3.22 | 68 | 6.8 | 16.66 | 2.55 |
| 33 | 3.3 | 8.085 | 3.18 | 69 | 6.9 | 16.905 | 2.54 |
| 34 | 3.4 | 8.33 | 3.15 | 70 | 7 | 17.15 | 2.53 |
| 35 | 3.5 | 8.575 | 3.11 | 71 | 7.1 | 17.395 | 2.52 |

| Work Order : | ES1907149 | Client ID: | GHD PTY LTD |
|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| | Sub Matrix | | | Soil |
| | Client Sample Identification 1 | | | 2018 bene combined tailings |
| | Client Sample Identification 2 | | | |
| | Sample Date | | | 26/01/2018 |
| Method | Analyte | Units | LOR | |
| | | | | 1<br>ES1907149 |

*EA046 - A Titration information*

| | | |
|---|---|---|
| **HCl Molarity:** | **M** | **0.1** |
| **Increments:** | **mL** | **0.1** |
| **Weight** | **(g)** | **2** |
| **ANC** | **kgH2SO4/t** | **7.3** |

*EA046 -B - Curve information*

| Addition | mLs added (total) | kg H2SO4/t | pH | Addition | mLs added (total) | kg H2SO4/t | pH |
|---|---|---|---|---|---|---|---|
| 72 | 7.2 | 17.64 | 2.51 | | | | |
| 73 | 7.3 | 17.885 | 2.50 | | | | |

| Work Order : | ES1907149 | Client ID: | GHD PTY LTD |
|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| | Sub Matrix | | | Soil |
| | Client Sample Identification 1 | | | 2018 bene combined tailings |
| | Client Sample Identification 2 | | | |
| | Sample Date | | | 26/01/2018 |
| Method | Analyte | Units | LOR | |
| | | | | 1 Check<br>ES1907149 |

***EA046 - A Titration information***

| | | |
|---|---|---|
| **HCl Molarity:** | **M** | **0.1** |
| **Increments:** | **mL** | **0.1** |
| **Weight** | **(g)** | **2** |
| **ANC** | **kgH2SO4/t** | **7.3** |

***EA046 -B - Curve information***

| Addition | mLs added (total) | kg H2SO4/t | pH | Addition | mLs added (total) | kg H2SO4/t | pH |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 8.78 | 36 | 3.6 | 8.82 | 3.11 |
| 1 | 0.1 | 0.245 | 7.91 | 37 | 3.7 | 9.065 | 3.09 |
| 2 | 0.2 | 0.49 | 7.54 | 38 | 3.8 | 9.31 | 3.07 |
| 3 | 0.3 | 0.735 | 7.35 | 39 | 3.9 | 9.555 | 3.04 |
| 4 | 0.4 | 0.98 | 7.17 | 40 | 4 | 9.8 | 3.02 |
| 5 | 0.5 | 1.225 | 6.97 | 41 | 4.1 | 10.045 | 3.01 |
| 6 | 0.6 | 1.47 | 6.72 | 42 | 4.2 | 10.29 | 2.99 |
| 7 | 0.7 | 1.715 | 6.40 | 43 | 4.3 | 10.535 | 2.97 |
| 8 | 0.8 | 1.96 | 6.04 | 44 | 4.4 | 10.78 | 2.96 |
| 9 | 0.9 | 2.205 | 5.70 | 45 | 4.5 | 11.025 | 2.94 |
| 10 | 1 | 2.45 | 5.40 | 46 | 4.6 | 11.27 | 2.93 |
| 11 | 1.1 | 2.695 | 5.14 | 47 | 4.7 | 11.515 | 2.91 |
| 12 | 1.2 | 2.94 | 4.88 | 48 | 4.8 | 11.76 | 2.90 |
| 13 | 1.3 | 3.185 | 4.68 | 49 | 4.9 | 12.005 | 2.89 |
| 14 | 1.4 | 3.43 | 4.50 | 50 | 5 | 12.25 | 2.87 |
| 15 | 1.5 | 3.675 | 4.36 | 51 | 5.1 | 12.495 | 2.86 |
| 16 | 1.6 | 3.92 | 4.23 | 52 | 5.2 | 12.74 | 2.85 |
| 17 | 1.7 | 4.165 | 4.10 | 53 | 5.3 | 12.985 | 2.84 |
| 18 | 1.8 | 4.41 | 3.99 | 54 | 5.4 | 13.23 | 2.83 |
| 19 | 1.9 | 4.655 | 3.90 | 55 | 5.5 | 13.475 | 2.82 |
| 20 | 2 | 4.9 | 3.82 | 56 | 5.6 | 13.72 | 2.81 |
| 21 | 2.1 | 5.145 | 3.74 | 57 | 5.7 | 13.965 | 2.80 |
| 22 | 2.2 | 5.39 | 3.67 | 58 | 5.8 | 14.21 | 2.79 |
| 23 | 2.3 | 5.635 | 3.60 | 59 | 5.9 | 14.455 | 2.78 |
| 24 | 2.4 | 5.88 | 3.54 | 60 | 6 | 14.7 | 2.77 |
| 25 | 2.5 | 6.125 | 3.49 | 61 | 6.1 | 14.945 | 2.75 |
| 26 | 2.6 | 6.37 | 3.45 | 62 | 6.2 | 15.19 | 2.74 |
| 27 | 2.7 | 6.615 | 3.40 | 63 | 6.3 | 15.435 | 2.74 |
| 28 | 2.8 | 6.86 | 3.36 | 64 | 6.4 | 15.68 | 2.73 |
| 29 | 2.9 | 7.105 | 3.32 | 65 | 6.5 | 15.925 | 2.72 |
| 30 | 3 | 7.35 | 3.28 | 66 | 6.6 | 16.17 | 2.72 |
| 31 | 3.1 | 7.595 | 3.25 | 67 | 6.7 | 16.415 | 2.71 |
| 32 | 3.2 | 7.84 | 3.22 | 68 | 6.8 | 16.66 | 2.70 |
| 33 | 3.3 | 8.085 | 3.19 | 69 | 6.9 | 16.905 | 2.69 |
| 34 | 3.4 | 8.33 | 3.16 | 70 | 7 | 17.15 | 2.68 |
| 35 | 3.5 | 8.575 | 3.14 | 71 | 7.1 | 17.395 | 2.68 |

| Work Order : | ES1907149 | Client ID: | GHD PTY LTD |
|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| | Sub Matrix | | | Soil |
| | Client Sample Identification 1 | | | 2018 bene combined tailings |
| | Client Sample Identification 2 | | | |
| | Sample Date | | | 26/01/2018 |
| Method | Analyte | Units | LOR | |
| | | | | 1 Check ES1907149 |

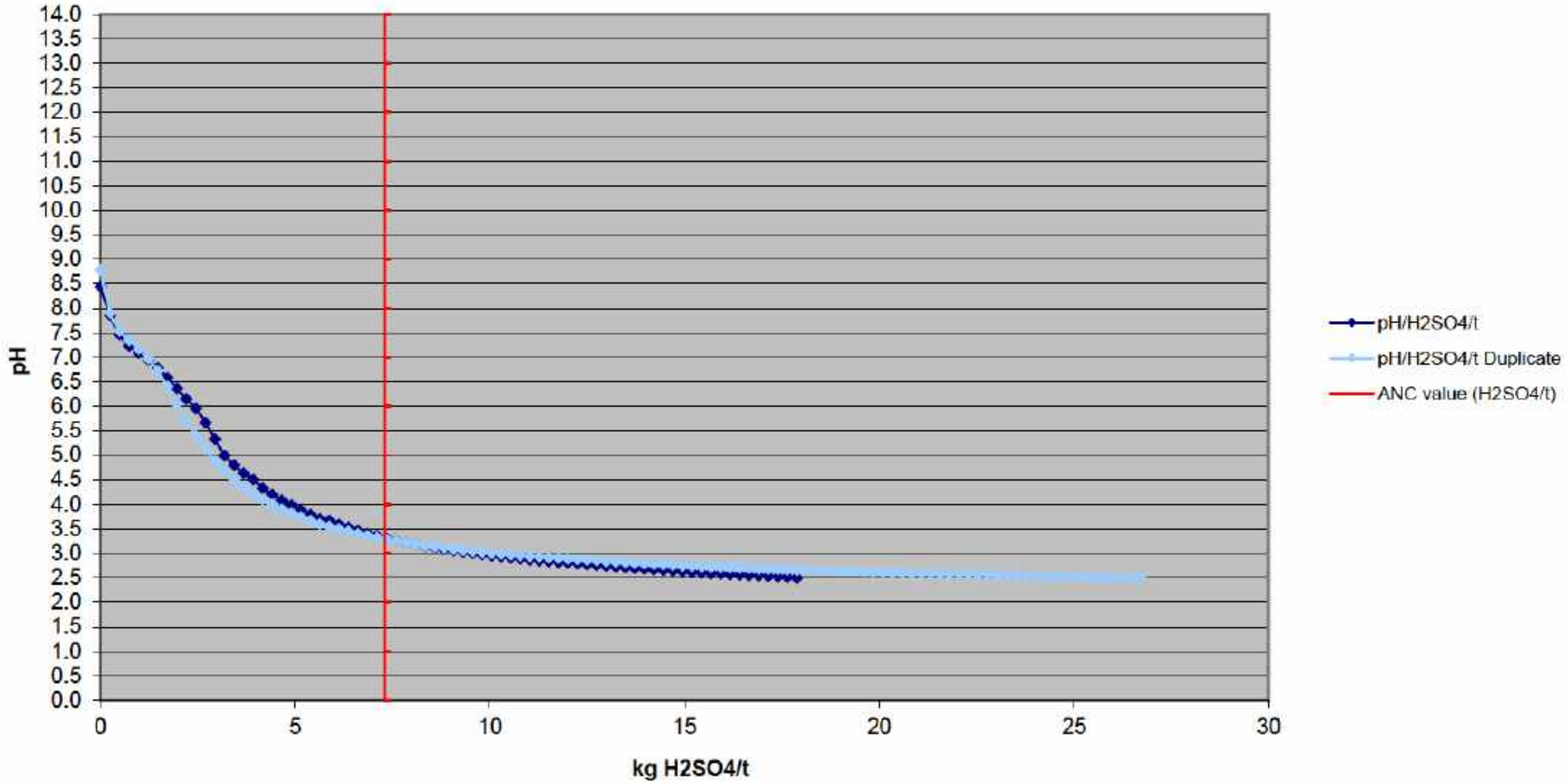
## *EA046 - A Titration information*

| | | |
|---|---|---|
| **HCl Molarity:** | **M** | **0.1** |
| **Increments:** | **mL** | **0.1** |
| **Weight** | **(g)** | **2** |
| **ANC** | **kgH2SO4/t** | **7.3** |

## *EA046 -B - Curve information*

| Addition | mLs added (total) | kg H2SO4/t | pH | Addition | mLs added (total) | kg H2SO4/t | pH |
|---|---|---|---|---|---|---|---|
| 72 | 7.2 | 17.64 | 2.67 | 108 | 10.8 | 26.46 | 2.50 |
| 73 | 7.3 | 17.885 | 2.66 | 109 | 10.9 | 26.705 | 2.50 |
| 74 | 7.4 | 18.13 | 2.66 | | | | |
| 75 | 7.5 | 18.375 | 2.65 | | | | |
| 76 | 7.6 | 18.62 | 2.64 | | | | |
| 77 | 7.7 | 18.865 | 2.64 | | | | |
| 78 | 7.8 | 19.11 | 2.63 | | | | |
| 79 | 7.9 | 19.355 | 2.62 | | | | |
| 80 | 8 | 19.6 | 2.62 | | | | |
| 81 | 8.1 | 19.845 | 2.61 | | | | |
| 82 | 8.2 | 20.09 | 2.61 | | | | |
| 83 | 8.3 | 20.335 | 2.60 | | | | |
| 84 | 8.4 | 20.58 | 2.60 | | | | |
| 85 | 8.5 | 20.825 | 2.59 | | | | |
| 86 | 8.6 | 21.07 | 2.59 | | | | |
| 87 | 8.7 | 21.315 | 2.58 | | | | |
| 88 | 8.8 | 21.56 | 2.57 | | | | |
| 89 | 8.9 | 21.805 | 2.57 | | | | |
| 90 | 9 | 22.05 | 2.57 | | | | |
| 91 | 9.1 | 22.295 | 2.56 | | | | |
| 92 | 9.2 | 22.54 | 2.56 | | | | |
| 93 | 9.3 | 22.785 | 2.55 | | | | |
| 94 | 9.4 | 23.03 | 2.55 | | | | |
| 95 | 9.5 | 23.275 | 2.55 | | | | |
| 96 | 9.6 | 23.52 | 2.54 | | | | |
| 97 | 9.7 | 23.765 | 2.54 | | | | |
| 98 | 9.8 | 24.01 | 2.53 | | | | |
| 99 | 9.9 | 24.255 | 2.53 | | | | |
| 100 | 10 | 24.5 | 2.53 | | | | |
| 101 | 10.1 | 24.745 | 2.52 | | | | |
| 102 | 10.2 | 24.99 | 2.52 | | | | |
| 103 | 10.3 | 25.235 | 2.51 | | | | |
| 104 | 10.4 | 25.48 | 2.51 | | | | |
| 105 | 10.5 | 25.725 | 2.51 | | | | |
| 106 | 10.6 | 25.97 | 2.51 | | | | |
| 107 | 10.7 | 26.215 | 2.50 | | | | |

## ES1907149 - 1 and Check 1 (2018 bene combined tailings)
## Acid Buffering Characteristic Curve
Titrating with 0.1M HCl, in increments of 0.1 mLs every 1000 seconds



ALS Environmental

# *Kinetic Net Acid Generation (NAG) Report*

**Batch: ES1907149**

| | | | |
|---|---|---|---|
| **CONTACT:** | [redacted] | **LABORATORY:** | Brisbane |
| **CLIENT:** | GHD PTY LTD | **DATE SAMPLED:** | 26/11/2018 |
| **ADDRESS:** | [redacted] | **DATE RECEIVED:** | 8/03/2019 |
| | | **DATE COMPLETED:** | 20/03/2019 |
| | | **SAMPLE TYPE:** | Soil |
| | | **No. of SAMPLES:** | 1 |

## COMMENTS

**EA011K: This method is not NATA accredited**

## ISSUING LABORATORY: ALS BRISBANE


| | | | |
|---|---|---|---|
| **Address:** | [redacted] | **Telephone:** | [redacted] |
| | | **Facsimile:** | [redacted] |
| | AUSTRALIA | **E-mail:** | [redacted] |


**Signatory**

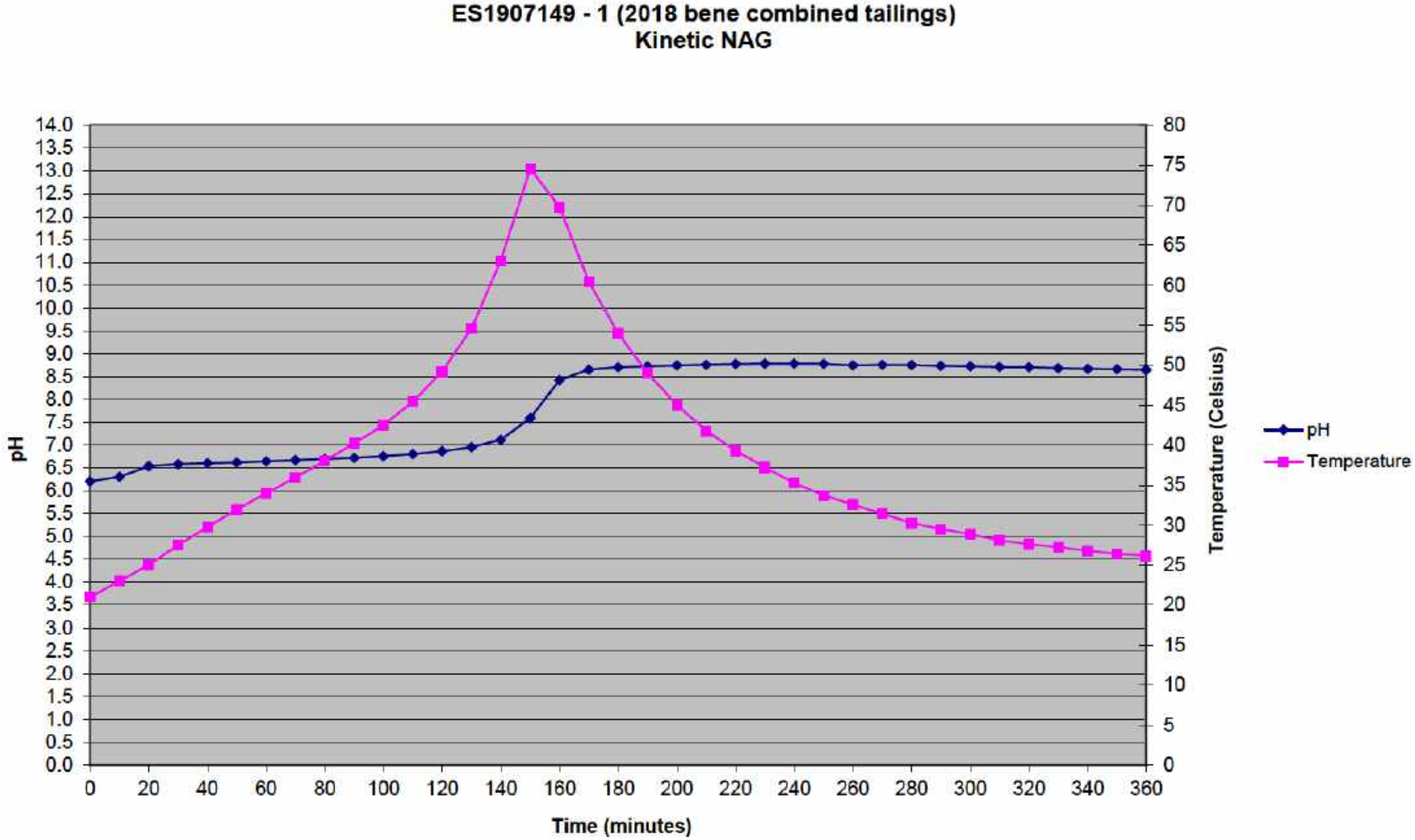
[redacted]

| Work Order : | ES1907149 | Client ID: | GHD PTY LTD |
|---|---|---|---|

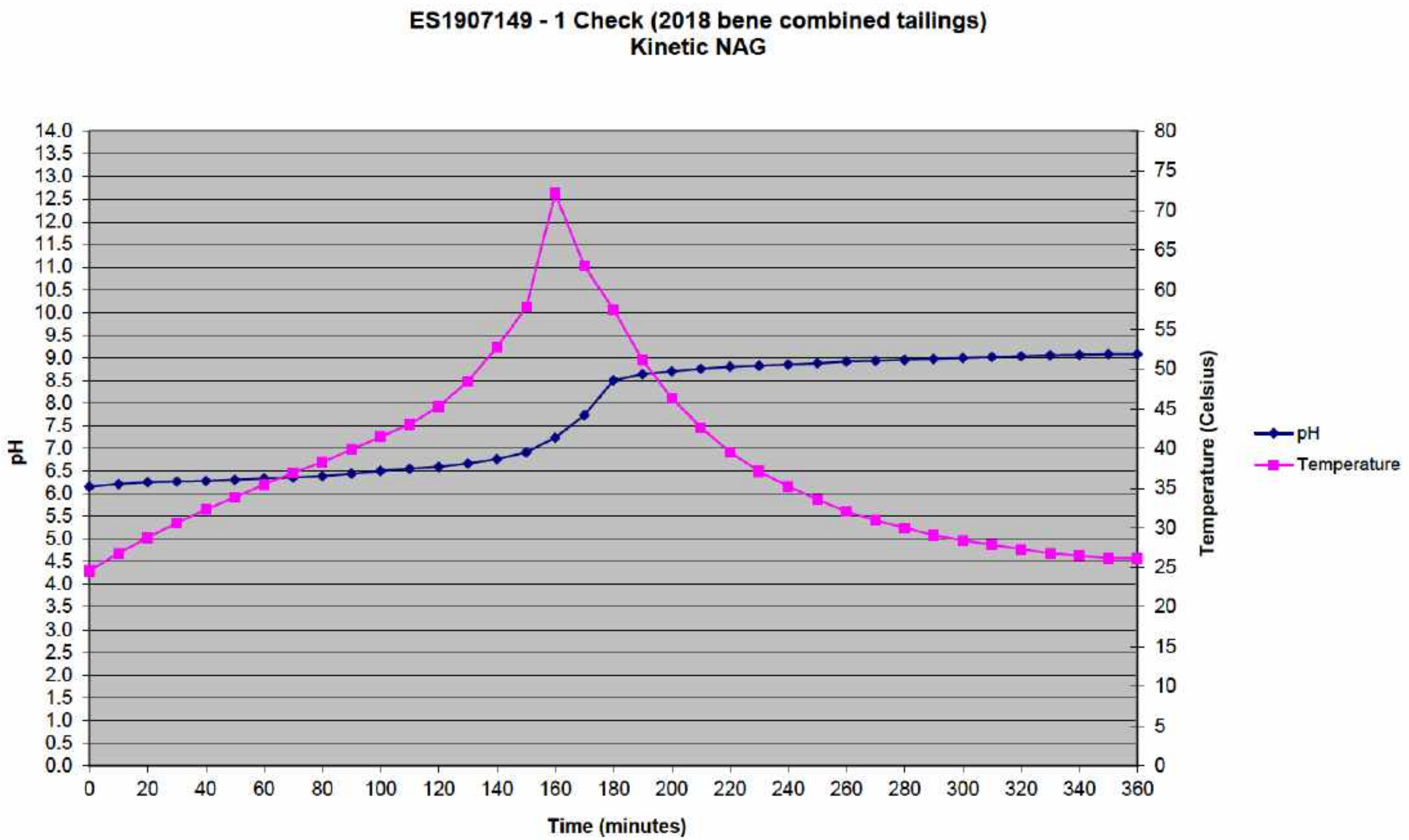
| | | | |
|---|---|---|---|
| Sub Matrix | Soil | Soil | |
| Client Sample Identification 1 | **2018 bene combined taili** | **2018 bene combined tailings** | |
| Client Sample Identification 2 | | | |
| Sample Date | 26/11/2018 | 26/11/2018 | |
| | | | |
| | **ES1907149 1** | **ES1907149 1 Check** | |

***EA011-K: (A) Titration information***

| Time (mins) | pH | Temp | pH | Temp | pH | Temp |
|---|---|---|---|---|---|---|
| 0 | 6.21 | 21.0 | 6.16 | 24.6 | | |
| 10 | 6.31 | 23.0 | 6.22 | 26.8 | | |
| 20 | 6.54 | 25.0 | 6.25 | 28.8 | | |
| 30 | 6.58 | 27.5 | 6.27 | 30.6 | | |
| 40 | 6.60 | 29.7 | 6.28 | 32.3 | | |
| 50 | 6.62 | 32.0 | 6.31 | 33.8 | | |
| 60 | 6.64 | 34.0 | 6.34 | 35.5 | | |
| 70 | 6.67 | 35.9 | 6.36 | 36.9 | | |
| 80 | 6.69 | 38.1 | 6.39 | 38.3 | | |
| 90 | 6.72 | 40.2 | 6.44 | 39.9 | | |
| 100 | 6.76 | 42.5 | 6.51 | 41.4 | | |
| 110 | 6.81 | 45.4 | 6.55 | 43.1 | | |
| 120 | 6.87 | 49.2 | 6.59 | 45.3 | | |
| 130 | 6.96 | 54.6 | 6.67 | 48.5 | | |
| 140 | 7.12 | 63.1 | 6.76 | 52.8 | | |
| 150 | 7.59 | 74.6 | 6.91 | 57.8 | | |
| 160 | 8.42 | 69.8 | 7.24 | 72.2 | | |
| 170 | 8.65 | 60.5 | 7.73 | 63.0 | | |
| 180 | 8.70 | 54.0 | 8.50 | 57.5 | | |
| 190 | 8.73 | 49.0 | 8.64 | 51.1 | | |
| 200 | 8.75 | 45.0 | 8.70 | 46.4 | | |
| 210 | 8.76 | 41.8 | 8.76 | 42.7 | | |
| 220 | 8.78 | 39.3 | 8.80 | 39.6 | | |
| 230 | 8.78 | 37.2 | 8.83 | 37.1 | | |
| 240 | 8.79 | 35.3 | 8.85 | 35.3 | | |
| 250 | 8.78 | 33.8 | 8.88 | 33.6 | | |
| 260 | 8.75 | 32.6 | 8.92 | 32.1 | | |
| 270 | 8.76 | 31.4 | 8.94 | 30.9 | | |
| 280 | 8.75 | 30.3 | 8.96 | 30.0 | | |
| 290 | 8.73 | 29.5 | 8.98 | 29.1 | | |
| 300 | 8.73 | 28.9 | 9.00 | 28.4 | | |
| 310 | 8.71 | 28.1 | 9.02 | 27.9 | | |
| 320 | 8.71 | 27.6 | 9.04 | 27.3 | | |
| 330 | 8.68 | 27.3 | 9.05 | 26.8 | | |
| 340 | 8.67 | 26.8 | 9.07 | 26.5 | | |
| 350 | 8.66 | 26.4 | 9.08 | 26.2 | | |
| 360 | 8.65 | 26.2 | 9.08 | 26.2 | | |



ES1907149 - 1 (2018 bene combined tailings)
Kinetic NAG
pH
Temperature (Celsius)
Time (minutes)
pH
Temperature
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
12.0
12.5
13.0
13.5
14.0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360



ES1907149 - 1 Check (2018 bene combined tailings)
Kinetic NAG
pH
Temperature (Celsius)
Time (minutes)
pH
Temperature
14.0
13.5
13.0
12.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360

# CERTIFICATE OF ANALYSIS

| | | | |
|---|---|---|---|
| Work Order | : **ES1909328** | Page | : 1 of 6 |
| Client | : GHD PTY LTD | Laboratory | : Environmental Division Sydney |
| Contact | : [redacted] | Contact | : [redacted] |
| Address | : [redacted] | Address | : [redacted] |
| Telephone | : ---- | Telephone | : [redacted] |
| Project | : 3219134 | Date Samples Received | : 27-Mar-2019 14:00 |
| Order number | : | Date Analysis Commenced | : 28-Mar-2019 |
| C-O-C number | : ---- | Issue Date | : 18-Apr-2019 18:26 |
| Sampler | : ---- | | |
| Site | : | | |
| Quote number | : EN/005/18 | | |
| No. of samples received | : 4 | | |
| No. of samples analysed | : 4 | | |

NATA Accreditation No. 825
Accredited for compliance with ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

**Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.**

## *Signatories*

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

| *Signatories* | *Position* | *Accreditation Category* |
|---|---|---|
| [redacted] | Analyst | Sydney Inorganics, Smithfield, NSW |
| | Instrument Chemist | Sydney Inorganics, Smithfield, NSW |
| | Metals Teamleader | Radionuclides, Fyshwick, ACT |

## General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- Gross Alpha and Beta Activity analyses are performed by ALS Fyshwick (NATA Accreditation number 992).
- LOR for gross alpha and beta in sample 4 raised due to the high amount of solid present.
- LOR for gross alpha and beta in sample  raised due to the high amount of solid present.

## Analytical Results

Sub-Matrix: **ASLP LEACHATE**
**(Matrix: WATER)**

| | | | Client sample ID | **2018 bene combined tailings ASLP PH 5** | **2018 bene combined tailings ASLP PH 9** | **----** | **----** | **----** |
|---|---|---|---|---|---|---|---|---|
| | | | *Client sampling date / time* | 26-Mar-2019 00:00 | 26-Mar-2019 00:00 | ---- | ---- | ---- |
| *Compound* | *CAS Number* | *LOR* | *Unit* | **ES1909328-001** | **ES1909328-004** | **--------** | **--------** | **--------** |
| | | | | Result | Result | ---- | ---- | ---- |
| **EA250: Gross Alpha and Beta Activity** | | | | | | | | |
| **Gross alpha** | ---- | 0.05 | Bq/L | **0.96** | <0.05 | **----** | **----** | **----** |
| **Gross beta activity - 40K** | ---- | 0 10 | Bq/L | **0.65** | 0 10 | **----** | **----** | **----** |

## Analytical Results

| Sub-Matrix: **DI WATER** (Matrix: **WATER**) | | | Client sample ID | **2018 bene combined tailings ALSP DI** | **----** | **----** | **----** | **----** |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Mar-2019 00:00 | ---- | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | **ES1909328-003** | **--------** | **--------** | **--------** | **--------** |
| | | | | Result | ---- | ---- | ---- | ---- |
| **EA250: Gross Alpha and Beta Activity** | | | | | | | | |
| **Gross alpha** | ---- | 0.05 | Bq/L | <0.05 | ---- | ---- | ---- | ---- |
| **Gross beta activity - 40K** | ---- | 0 10 | Bq/L | 0 10 | ---- | ---- | ---- | ---- |

## Analytical Results

Sub-Matrix: SOIL
(Matrix: SOIL)

| | | | Client sample ID | 2018 bene combined tailings ASLP PH 5 | 2018 bene combined tailings ALSP DI | 2018 bene combined tailings ASLP PH 9 | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Mar-2019 00:00 | 26-Mar-2019 00:00 | 26-Mar-2019 00:00 | ---- | ---- |
| Compound | CAS Number | LOR | Unit | ES1909328-001 | ES1909328-003 | ES1909328-004 | -------- | -------- |
| | | | | Result | Result | Result | ---- | ---- |
| **EN60: ASLP Leaching Procedure** | | | | | | | | |
| Extraction Fluid pH | ---- | 0.1 | pH Unit | **4.9** | ---- | **9.2** | ---- | ---- |
| Final pH | ---- | 0 1 | pH Unit | **5.0** | ---- | **9.5** | ---- | ---- |
| **EN60: Bottle Leaching Procedure** | | | | | | | | |
| Final pH | | 0.1 | pH Unit | ---- | **9.8** | ---- | ---- | ---- |

## Analytical Results

| Sub-Matrix: WATER (Matrix: WATER) | | | Client sample ID | Hastings pilot plant filtrate | ---- | ---- | ---- | ---- |
|---|---|---|---|---|---|---|---|---|
| | | | Client sampling date / time | 26-Mar-2019 00:00 | ---- | ---- | ---- | ---- |
| Compound | CAS Number | LOR | Unit | ES1909328-002 | -------- | -------- | -------- | -------- |
| | | | | Result | ---- | ---- | ---- | ---- |
| **EA250: Gross Alpha and Beta Activity** | | | | | | | | |
| **Gross alpha** | ---- | 0.05 | Bq/L | <0.05 | ---- | ---- | ---- | ---- |
| **Gross beta activity - 40K** | ---- | 0.10 | Bq/L | <0.10 | ---- | ---- | ---- | ---- |

| | |
|---|---|
| **SUBJECT:** | **Mo and F levels in Recycled Process Water testwork** |
| **DATE:** | 17/5/2019 |
| **DOCUMENT NO. & REV:** | YGB-20-000-ENG-PRO-TCN-0001 Rev 01 |
| **AUTHOR:** | [redacted] |

## SUMMARY

A review of the recycled process water quality was undertaken after queries from DWER on the tailings leach testwork. Specifically Molybdenum (Mo) and Fluorine (F) levels in the tailings leach test were initially high and then declined rapidly with flushing. The question was asked whether repeated contact with fresh ore would result in Mo and F concentrations significantly above those seen in the tailings leach testwork.

Locked cycle testwork has been carried out to assess the water quality and impact on metallurgical performance of recycled process water chemistry. Mo and F were not measured initially, however some results were able to be measured in the last 3 cycles of the locked cycle testwork (out of a total of 15 cycles). TDS levels were around 2600 to 3100 mg/L, with associated Mo and F assays at 2-2.5 mg/L and 4-5mg/L respectively.

## BACKGROUND

This technical filenote discussed water quality from testwork intended to simulate process water recycle within this Yangibana Beneficiation flowsheet.

This is an interim report associated with the testwork, specifically discussing the deportment of elements Mo and F queried by DWER during the works approval process.

## TEST DETAILS

The Yangibana beneficiation flowsheet is in open circuit, with the tailings from each of the flotation stages reporting to final tailings. The locked cycle testwork was designed to look at the recycle of water within the process. The initial plan was to complete 8 rougher only cycles to produce the process water that would then be tested on the full rougher and 4-stage cleaner circuit. However additional cycles were added in order to optimise the reagent dose rates with the new water chemistry. The ore sample used for this testwork was the 2016 blended pilot plant feed (sourced from the Bald Hill and Fraser's mineralisation).

A total of 15 cycles have been completed in the locked cycle testwork. Regardless of cycle performance the water from each test was recovered by adding the coagulation reagent proposed in the full scale operation – lime. The supernatant was then decanted. Additional water was recovered by collecting the filtrate from pressure filtration, in order to maximise the amount of recycled water available for subsequent tests.

Samples from each cycle were analysed for a limited suite of elements. F and Mo were added late in the program to address the query from DWER.

## RESULTS

The results of water analysis from each cycle of testing are shown in Figure 1 below. This graph shows the levels of Ca, Cl, Mg, Na, SiO2 and total dissolved solids (TDS) for the initial raw site water, as well as water analysis at the end of each flotation test. TDS of the water rose rapidly from 1150mg/L in the raw site water, up to a maximum of 3615 mg/L in the testwork. With Sodium (Na) being a major driver of TDS levels. Sodium levels are being increased by the addition of sodium silicate and caustic soda (NaOH) reagents in the process. Increased levels in the process water can be of assistance in the processing circuit, acting as recycled reagents, reducing the amount of fresh caustic soda required by the process.

A more detailed analysis was complete on the final testwork sample from Test P, the results are shown in Appendix A.

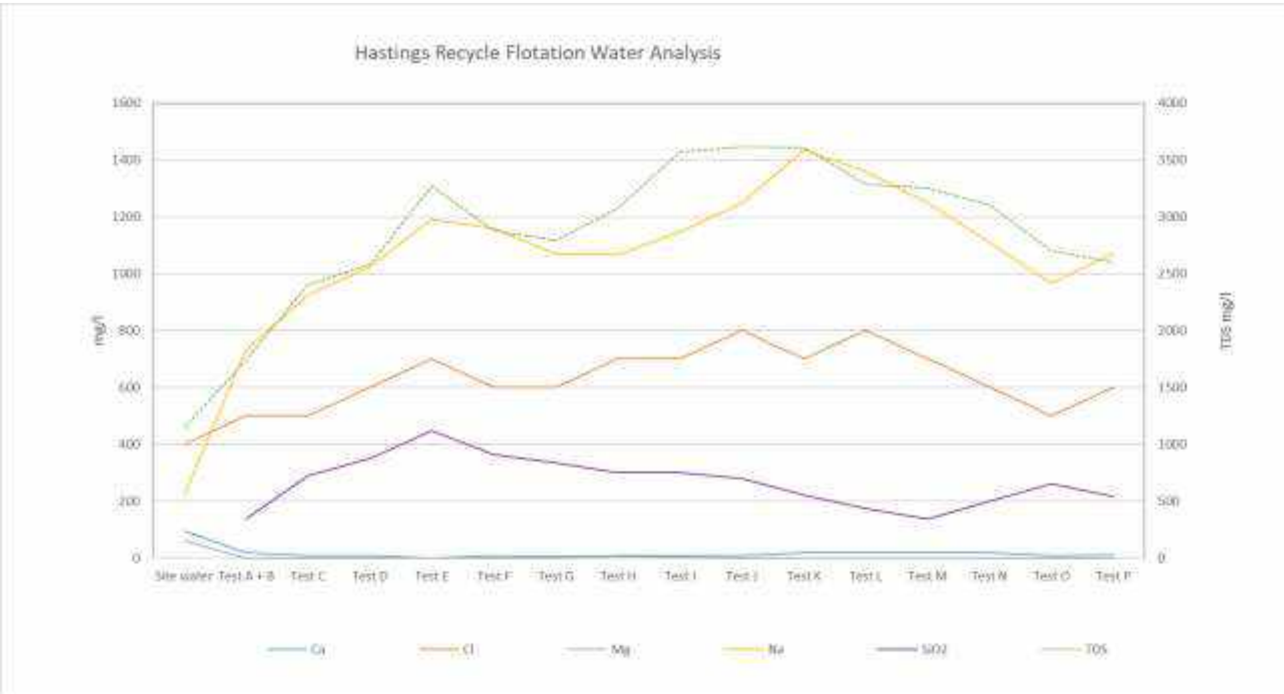



Figure 1 - Graph of recycled process water TDS and key dissolved element concentrations

Additional analyses of the water were undertaken after the levels of F and Mo in the tailings leach testwork were questioned.

From the Tailings Characterisation Report (GCA Nov 2017) the observation was made that analysis of TSF 1 and 2 slurry water indicates they are alkaline, brackish and likely to be enriched in fluorine (F) and molybdenum (Mo) against the ANZECC Stock Quality Guideline (ANZECC, 2000). Pb was less than detection-limit in the slurry water despite elevated levels of Pb in TSF 1 and 2 solids. Radionuclides concentrations in the TSF 1 and 2 Slurry Waters were below 1Bq/g and not considered radioactive.

Further Leach testing detailed in in "180621 - Yangibana Tailings Leach Study Report - R0" June 2018, has suggested that the enrichments of Mo and F are temporary artefacts of the process water. These enrichments rapidly decline with flushing. This indicates that the Mo and F elevations were largely due to 'operational time-scales' and are not a long term feature of the tailings leachate.

The question was raised regarding what level of Mo and F would be seen on multiple contacts between fresh ore and recycled process water during the operation. Figure 2 below shows the results from 3 cycles of testing, at the end of the testwork program. TDS levels were around 2600 to 3100 mg/L, with associated Mo and F assays at 2-2.5 mg/L and 4-5mg/L respectively.

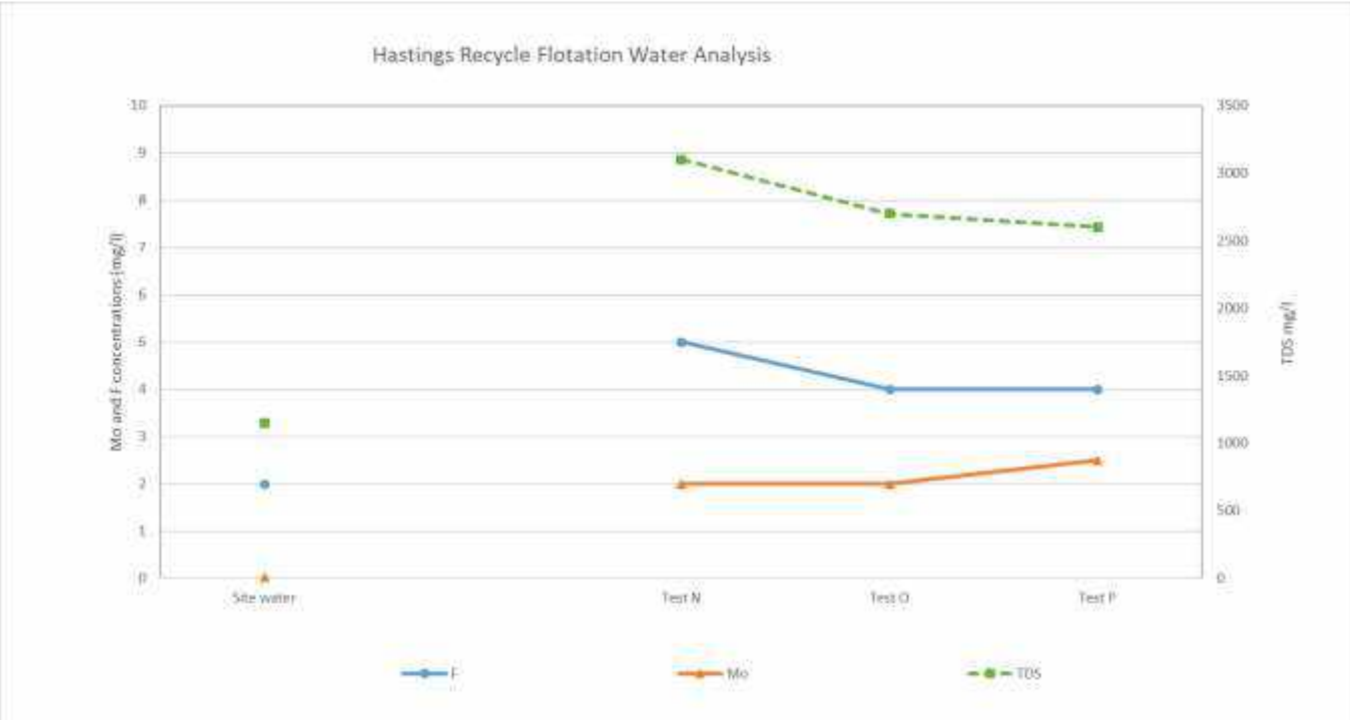



Figure 2 – Molybdenum and Fluorine analysis of recycled process water from last 3 cycles of testing

Note that no fresh water was added to the locked cycle testwork, however the current water modeling for site indicates that in steady state the process will operate on a mix of 80:20 recycled water to fresh raw water, with some water lost to the hydromet circuit, evaporation, water losses in the concentrate dryer and to the settled solids in the TSF.

The leach testwork leachate Mo levels were 1.072 to 1.154 mg/L for TSF 1 liquor and 1.953 mg/L for TSF 2 liquor.

The leach testwork leachate F levels were 7-11mg/L for the tailings leach testing.

# APPENDIX A – DETAILLED WATER ANALYSIS (TEST P)

**Job No: A17449**
**Project: Hastings Recycled Water Evaluation**

ALS

**Date: 03/04/2019**

**Detailed Analysis - Pilot Composite 2016 Recycled water**

| Analyte | Grade | Site Water | Reclaimed water from test RDA2622 'P' |
|---|---|---|---|
| Ag | mg/l | 0.10 | <0.02 |
| Al | mg/l | <0.20 | 1.60 |
| Ba | mg/l | 0.10 | <0.05 |
| Bi | mg/l | <0.10 | <0.10 |
| Ca | mg/l | 96.5 | 6.00 |
| Cd | mg/l | <0.05 | <0.05 |
| Co | mg/l | <0.05 | <0.05 |
| Cr | mg/l | <0.10 | <0.10 |
| Cu | mg/l | 0.08 | 0.02 |
| Fe | mg/l | <0.10 | 0.60 |
| K | mg/l | 9.0 | 21.00 |
| Li | mg/l | <0.05 | <0.05 |
| Mg | mg/l | 61.2 | <0.20 |
| Mn | mg/l | <0.05 | <0.05 |
| Mo | mg/l | <0.05 | 2.00 |
| Na | mg/l | 223 | 1018.00 |
| Ni | mg/l | <0.05 | <0.05 |
| OH | mg/l | | 600.00 |
| P | mg/l | <1.0 | <1.0 |
| Pb | mg/l | 0.45 | <0.05 |
| Si | mg/l | | 111.00 |
| Sr | mg/l | 0.78 | 0.10 |
| Ti | mg/l | <0.10 | <0.10 |
| V | mg/l | <0.02 | 0.14 |
| Y | mg/l | <0.01 | <0.01 |
| Zn | mg/l | 0.04 | <0.02 |
| Zr | mg/l | <0.05 | <0.05 |
| *HCO3 | | 300 | <100 |
| *CO3 | | <100 | 400.00 |
| Cl | mg/l | 400 | 600.00 |
| SO4 | mg/l | 100 | 360.00 |
| TDS | mg/l | 1150 | 2810.00 |
| pH | | 8.2 | 11.86 |
| **Cond | | 1.929 | 5.79 |

Data is in mg/l unless otherwise stated
*Data is in mg/l CaCO3
** Data is in ms/cm

Filtrate was allowed to settle and only clear filtrate was submitted for analysis

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ALS METALLURGY

# Appendix D – Seepage Analysis

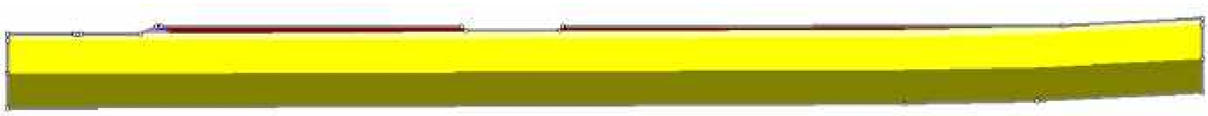

Figure D-12-1 Seepage model arrangement

Figure D-12-2 Seepage model – Year 1

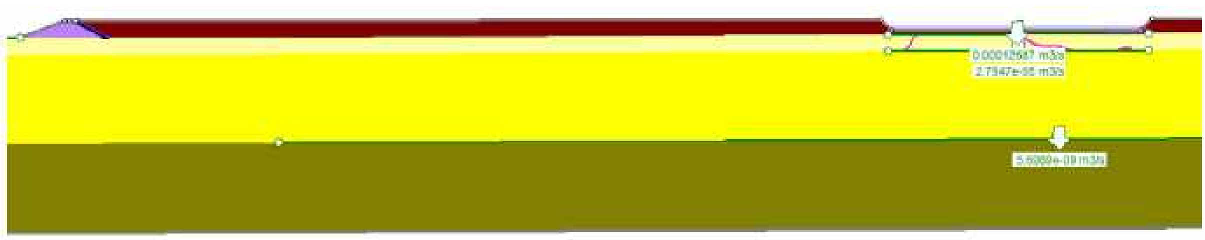

Figure D-12-3 Seepage model – Year 4

Figure D-12-4 Seepage model – Year 6

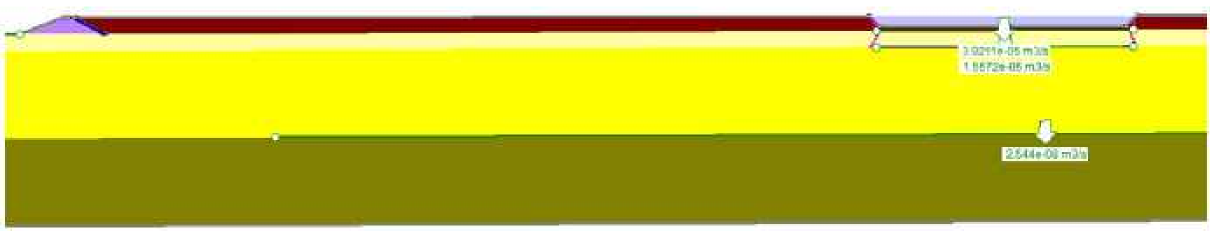

Figure D-12-5 Seepage model – Year 10