Birla Mount Gordon

Esperanza Pit DSA and MRL Revision

Hydrogeological Response to DEHP Notice of Decision

August 2013
Table of contents

1. Introduction ...............................................................................................................................1
   1.1 Purpose of this report ......................................................................................................1
   1.2 Scope and limitations ......................................................................................................1
   1.3 Assumptions ....................................................................................................................1
   1.4 Background .....................................................................................................................2

2. Existing Conceptual Hydrogeological Model (60) .................................................................4
   2.1 General Stratigraphy .......................................................................................................4
   2.2 Alluvium Characteristics ...............................................................................................4
   2.3 Bedrock Characteristics .................................................................................................4

3. Evidence for Containment of Seepage from the Esperanza Pit .............................................9
   3.1 Condition 1 - A Groundwater Mound Providing a Hydraulic Barrier (61, 62, 63, 67) ..................................................................................................................................9
   3.2 Condition 2 - Low Permeability of Surrounding Rock and Consequent Low Groundwater Flux (58, 59) .............................................................................................14
   3.3 Condition 3 – Capture by Existing Water Management Infrastructure (64, 65) ........ 17
   3.4 Condition 4 – Ability to Detect and Manage Additional Seepage (66) .............................21

4. Conclusion ..............................................................................................................................26

Table index

Table 1 Summary of DEHP concerns and corresponding responses in this document .............3

Figure index

Figure 1 Site Geology ..................................................................................................................6
Figure 2 Existing Conceptual Hydrogeological Model ...............................................................7
Figure 3 Existing Conceptual Hydrogeological Model (Permeable Sub-vertical Fault Zone Scenario) ..................................................................................................................................8
Figure 4 Groundwater Contours July 2013 No underground mine influence ......................11
Figure 5 Groundwater Contours July 2013 – With underground mine influence ..................12
Figure 6 Plot of groundwater levels, GWMB45 and GWMB46, NE of Pit ......................... 13
Figure 7 Plot of groundwater levels, GWMB60 NE of Pit, N of TSF .....................................13
Figure 8 Plot of groundwater levels, GWB02, NE of Pit ......................................................14
Figure 9 Plot of groundwater levels, GWB02, NE of Pit ......................................................14
Figure 10 Plot of Mammoth Underground Groundwater Inflows from data monitoring ..........16
Figure 11 Mill Creek Dam Design (extract: Drawing 32-12850-C005, As Recorded issue) .....18
Figure 12  North Rock Dump seepage interception and cut-off trench (extract: Drawing 32-15847-08-C002, Rev 0, GHD) .................................................................19
Figure 13  Interception Trench (extract: Drawing 32-15847-08-C005 & C006, Rev 0, GHD)........20
Figure 14  Gunpowder Creek copper levels and Esperanza Pit water level history.................22
Figure 15  Gunpowder Creek sulphate and pit water level history........................................23
Figure 16  Mill Creek Dam sulphate, TDS and pH..............................................................24
Figure 17  Mill Creek Dam total copper (note log scale)......................................................24
Figure 18  Hoover Dam sulphate, TDS and pH.................................................................25
Figure 19  Hoover Dam total copper pH and TDS.............................................................25

Appendices

Appendix A – Plots of Groundwater Chemistry for bores in the general mine area
1. **Introduction**

1.1 **Purpose of this report**

GHD has prepared this report at the request of Birla Mount Gordon Pty Ltd (BMG) to provide additional information to assist their response to items 56 – 73 of the Department of Environment and Protection's (DEHP) *Notice of decision on review of an original decision Section 521(9) Environmental Protection Act 1994, dated 25 June 2013* (Notice of Decision). Items as discussed relate to hydrogeology between Esperanza Pit and Gunpowder Creek.

1.2 **Scope and limitations**

This report has been prepared by GHD for Birla Mount Gordon Pty Ltd (BMG) and may only be used and relied on by BMG for the purpose agreed between GHD and the BMG as set out in Section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than BMG arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were undertaken in accordance with GHD Consultancy Agreement QA010 (as defined in GHD ref: 32/09052/92/59758) and were limited to desktop review only as specifically detailed in the report, and are subject to the scope limitations set out in the report. No investigations on site or collection of data were undertaken as part of this commission.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer Section 1.3 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by BMG and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report that were caused by errors or omissions in that information.

1.3 **Assumptions**

As previously mentioned in Section 1.2, this report is based on data provided by BMG including:

- Surface topography – LiDAR, 2011 ALS data.
- Shape files of surface geology mapping (faults).
- *Gunpowder Creek Monitoring Data – Master.xls* spread sheet as received 23/07/2013. This contains raw surface and ground water monitoring data as collected by BMG.
- Model data in .dxf format for the open cut, underground mine workings and the Pit shell;
  - `amh_abf_mam_ex_f.dxf`
  - `amh_abf_mam_f.dxf`
Hydrogeological reports prepared by previous consultants as referenced throughout this report. These reports have been used as a source of hydrogeological parameters used in the assessment. Only the summary data were available and the original permeability test data were not available.

Surface water and sulphates discharge data spread sheets received 01/08/2013:
- BMG_Results_Surface Water Database 02-Jan-98 to 30-Mar-10_2012.xls
- BMG_Results_Surface Water database 13-Mar-98 to 11 May-11(SGS)_23-10-11.xls
- Gunpowder flows discharge and sulphats levels.xls

GHD has not independently verified or checked the information provided beyond the agreed scope of work. It is therefore assumed that all of the information provided, in particular the numerous model input files and .xls spread sheets, are free from errors and omissions that could affect the outcomes of the current study.

1.4 **Background**

The current maximum Design Storage Allowance (DSA) for water stored in the former Esperanza open cut mine pit is approximately 10 m below the typical dry season water level in Gunpowder Creek or 184 m AHD. It is assumed that this was chosen as a conservative level to prevent any migration of contaminated water from the Pit to Gunpowder Creek. While this water level allows for containment no matter how permeable the surrounding material, it is overly conservative where the surrounding rock has a low permeability or where water levels around the pit are higher than the contained water, hence providing a hydraulic barrier to outward flow from the Pit. GHD also understands that having the DSA set 10 m below Gunpowder Creek is not a requirement of the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams, February 2012*.

As additional water storage is required in the Pit to cope with increased site water, due to recent extreme wet seasons, the highly conservative approach is no longer achievable given the operation’s water balance. A revised Design Storage Allowance (DSA) of 204.5 mAHD and mandatory reporting level (MRL) of 216.5 mAHD are being sought to provide additional temporary storage. A more realistic water level limit is required, which should be based on the hydrogeological conditions identified at the site and the overall likelihood of discharge from the Pit to Gunpowder Creek representing a significant risk to the receiving environment in Gunpowder Creek.

In GHD’s opinion, a raised water level would be acceptable if any one of the following four conditions could be met:

1. Ambient groundwater levels around the pit are higher than the water level in the pit, providing a hydraulic barrier to outward flow.
2. The permeability of the rock surrounding the Pit, below the Pit water level, is so low that seepage from the Pit to Gunpowder Creek would not result in a significant increase in contaminant loading to Gunpowder Creek.
3. Should seepage occur, it will be adequately captured by existing water management systems.
4. Should seepage occur and it is not captured by existing systems, it can be detected early and intercepted or otherwise be managed to prevent impact on Gunpowder Creek.

This document seeks to present available evidence to demonstrate that at least one of the above is the case. The points have been presented to address specific numbered items listed in DEHP’s Notice of decision on review of an original decision Section 521 (9) Environmental Protection Act 1994 (dated 25 June 2013). The referenced section numbers are noted in the section headings of this document as numbers in brackets e.g. (25). The various DEHP hydrogeological concerns and the location of their corresponding responses are summarised in Table 1 below.

**Table 1 Summary of DEHP concerns and corresponding responses in this document**

<table>
<thead>
<tr>
<th>DEHP Response Section</th>
<th>Sections in this Document</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>57,58,59,60</td>
<td>2, 3.2</td>
<td>Fractured rock, faulting, connectivity, conceptualisation</td>
</tr>
<tr>
<td>61,62,63,67</td>
<td>3.1</td>
<td>Contours, mound, risk, hydrographs</td>
</tr>
<tr>
<td>64,65</td>
<td>1, 3.3</td>
<td>Seepage</td>
</tr>
<tr>
<td>66</td>
<td>3.4</td>
<td>Detection and management</td>
</tr>
</tbody>
</table>

This document is a supplementary document to previous documents as submitted to DEHP by BMG and builds on existing information as presented in those reports. It is noted that Items 56, 68, 69 and 70 - 73 have not been specifically been addressed in this document, rather, where appropriate these are addressed with other items throughout this document.
2. Existing Conceptual Hydrogeological Model (60)

2.1 General Stratigraphy

The Esperanza open cut (Pit) area lies within a region of regionally metamorphosed sedimentary rocks, (originally mudstones to sandstones with some limestone) and igneous rocks (metabasalts) (Figure 1). The strata have been deformed by a long history of tectonic activity and now dips steeply to the west-northwest. This bedrock is overlain in some areas, such as the major drainage lines and Gunpowder Creek, by relatively thin layers of alluvium. There are several areas of waste rock and tailings resulting from current and historical mining activities overlying both bedrock and alluvium.

2.2 Alluvium Characteristics

The frequent presence of bedrock outcrop in the creeks suggest that the alluvium is relatively thin - probably less than 10 m, although some thicker alluvium may be present above the stream bed in stranded river terraces. The alluvium appears to comprise a mix of sands and gravels, with thick silty deposits associated with river terraces and overbank flood deposits. Given the elevation of the alluvium and relatively shallow bedrock depth, the saturated thickness of the alluvium is likely to be limited and it is unlikely that the alluvium represents a significant aquifer in the Esperanza area, although it represents pathway for some down-valley groundwater flow.

2.3 Bedrock Characteristics

Due to the pervasive recrystallisation associated with the post-tectonic regional metamorphism and alteration associated with mineralisation, any intergranular (primary) porosity has been sealed, with only secondary porosity, such as fracturing or dissolution remaining.

Fracturing occurs in crystalline rock due to two main processes:

Stress relief fracturing caused by the expansion of the rock as overlying material is removed by erosion, which tends to result in sub-horizontal fracturing.

Tectonic fracturing, which is caused by regional rock stresses, such as shearing which tends to result in sub-vertical fracturing and faulting, or compression or tension, which tends to result in moderately dipping faults and fractures.

In the Mt Gordon area, the zone of intense stress-relief fracturing tends to be limited to the upper 10 m (although may be thinner in some areas, with a fairly rapid transition to an intermediate zone of weaker fracturing to a depth of approximately 20-30 m. The stress relief fracturing is relatively permeable due to its geologically recent formation, with the exception of a shallow zone where the jointing and fracturing may be filled with clay formed from weathering of the rock mass. The permeability of the stress relief fracturing gradually decreases with depth as hydrostatic pressure keeps joints closed. AGE (1999) quoted hydraulic conductivity of siltstones and shales near the surface at 3x10^{-5} m/s (2.6 m/d) with the highest permeability occurring in the upper 10 m, decreasing to 1x10^{-7} to 1x10^{-9} m/s (1x10^{-2} to 1x10^{-4} m/d) at about 30 m depth.

Fracturing due to tectonic stress is present within the metasediments and metavolcanics, which also caused the various faults mapped at surface and intersected within the pit and underground workings. Due to post-tectonic metamorphism and alteration, however, these tectonic fractures have been almost totally sealed by haematite/chlorite/quartz mineralisation. This has been noted in the Mammoth underground workings (M. Thomas 2013 pers. comm.).
where faults are filled with soft chlorite/haematite mineralisation and groundwater inflow is distributed throughout the workings as general seepage, with no significant areas or preferential inflow. Observations of short-term flows from some faults for a few days immediately after rain, indicate that any connectivity of the faults with shallow aquifers or surface is local only. It is also likely that there is localised interconnection of the faults immediately adjacent to the mine to the surface through the numerous exploration holes drilled through the ore body.

A conceptual hydrogeological model is presented as Figure 2. It is based on existing Pit water level of 208 m AHD (as at July 2013), the cross-section and interpolated groundwater levels through the Pit and the North Rock Dump to Gunpowder Creek (no vertical exaggeration). A second scenario (Figure 3) is presented with a permeable sub-vertical fault zone inserted, which would result in reversal of flows adjacent to the mine workings (note that this scenario is not supported by any geological observations, rather it presents a hypothesised conservative scenario).

In summary, the site is characterised by possible narrow alluvial aquifers along Gunpowder Creek and larger drainage channels, which are potentially connected to a surficial aquifer in bedrock with secondary porosity due to by stress relief fracturing, in the upper 10 - 20 m of bedrock below natural ground surface. There is no “deep aquifer”,¹ as bedrock below the surficial aquifer, including faulted zones, is relatively impermeable, due to pervasive recrystallisation of primary porosity and mineralisation of fault zones and joints. There are, however, localised, disconnected voids and drillholes that are rapidly dewatered when pumped out or when intersected by mine development and as such do not result in long distance flow paths.

¹ This term has been informally used in previous correspondence to discuss potential flow paths through deep bedrock, but should not be used as the very low permeability of the bedrock prevents storage or transmission of significant quantities of water.
Figure 2  Existing Conceptual Hydrogeological Model
Figure 3  Existing Conceptual Hydrogeological Model (Permeable Sub-vertical Fault Zone Scenario)
3. Evidence for Containment of Seepage from the Esperanza Pit

The following section seeks to detail the constraints on groundwater flow from the Esperanza Pit to Gunpowder Creek that restrict seepage flow and expands on the four conditions for containment of seepage from the Esperanza Pit introduced in Section 1.4 of this report.

3.1 Condition 1 - A Groundwater Mound Providing a Hydraulic Barrier (61, 62, 63, 67)

Since the previous letter issued by GHD on this topic, *BMG regulated Dams EA Amendment Response to DEHP Queries, dated 8 March 2013* (GHD ref 42/17564/111423), further data have been collected and provided by BMG (refer section 1.3 for received information). Figure 4 below shows contours of groundwater levels recorded in July 2013. The water levels have been interpolated using simple Krigging, with dummy water level points used to represent approximate July 2013 water levels directly beneath the tailings dam (280 m), the open pit (208 mAHD) and the Mill Creek dam (213 m). This method is applicable, conservatively assuming the water bodies are connected to any fracture zones and there is limited vertical hydraulic gradient. Influence of the underground workings and the seepage interception systems around the TSF have not been included in Figure 4. This is conservative as these would further constrain flow.

The contours in Figure 4 (2 m) show a ridge approximately 12 m above the existing level of the water in the pit, running between GWMB45 and GWMB2 (indicated by a dashed red line) at approximately 220 mAHDD with a ridge of at least 8 m above the pit water level remaining around the spill point to Mill Creek. This ridge would prevent flow of groundwater out of the pit. The 2013 dry season ridge is also above the proposed DSA and MRL, and is likely to remain so, even allowing for seasonal fluctuations, given that wet and dry season water levels in the deep rock generally vary by less than 1 m (Figure 6 to Figure 8). Although GEMB45 and GWMB46 vary by around 8 m, the value used is assessing the groundwater mound was at the lower end of the bores' water level range. The minimum groundwater elevations observed in these two bores were 218.50 mAHD in October 2012 and 217.81 in October 2008 respectively. Pit levels were lower than these levels in both cases at approximately 210 mAMD and 182 mAHD respectively.

Another significant observation from the various water level and rainfall plots is that the shallow bores show a rapid response to rainfall events but with a water level range of approximately 1 m. The deep bores also show only a limited change in water levels over time, but with a significant lag time after rainfall, of approximately 2-3 months, suggesting very low permeability.

If the drainage influence of the Mammoth underground mine is taken in to account (Figure 5), with drainage levels set at approximately 700 m below surface, all seepage from the pit should be captured by the underground workings.

Given the above data either one of the two scenarios as present below is in effect:
• If the underground workings are not well connected to the surficial aquifer, seepage from the Pit at current levels around 208 mAHD or the requested DSA of 204.5 mAHD is prevented from discharging to Gunpowder Creek by a surrounding groundwater ridge; or

• If the surficial aquifer and underground mine are connected through pervasive fracturing or faulting, any Pit water level up to the spill level at approximately 226 mAHD would be captured by the underground mine drainage.

Concern has been raised (63) that if deposition to the Esperanza TSF ceases, additional head applied by the TSF will dissipate and remove the hydraulic barrier. In GHD’s opinion, this is an unlikely scenario, as drainage of the tailings and reduction in the hydrostatic load would only occur following the closure and remediation of the TSF on mine closure. This would also mean that mine inflow and excess process water would not be discharged to the pit and thus the pit water level would be dropping to its ultimate post closure level.
Figure 4  Groundwater Contours July 2013 No underground mine influence.

Note Blue to green dots represent theoretical water levels associated with major water level features; blue lines are groundwater flow directions; black lines are mapped faults; and red dotted line is the hypothesised groundwater divide line – i.e. no-flow line)
Figure 5  Groundwater Contours July 2013 – With underground mine influence

Note: Red dots are location set at 700 m below surface to represent drainage to the underground mine
Figure 6  Plot of groundwater levels, GWMB45 and GWMB46, NE of Pit

Figure 7  Plot of groundwater levels, GWMB60 NE of Pit, N of TSF
3.2 Condition 2 - Low Permeability of Surrounding Rock and Consequent Low Groundwater Flux (58, 59)

3.2.1 Low Permeability of Fault Zones (58, 59)

Although faults such as the Mammoth Fault have been noted as being “potential conduits” (AGE 1999 and Geocompute 2001) this observation is based on conditions often associated with faults in general rather than any site-specific testing. In contrast, however, wherever faults have been intersected at depth via exploration drilling or during the extensive underground workings in the Mammoth Mine, they have been found to be filled with haematite/chlorite mineralisation, with the exception of localised open zones, which are rapidly drained and do not produce...
significant long-term inflows. Based on these observations, the faults do not represent zones of preferential groundwater flow, and any groundwater flow through the deep rock would be through relatively uniform minor fracturing and jointing.

Some additional fracturing may be present within a few metres of the surface of the open cut and underground workings due to;

- blasting and localised stress relief; and
- the many exploration and mine resource drillholes.

They may also represent a pathway for shallow groundwater to enter the underground and open cut workings. Water cannot move from the mine voids, however, until water levels rise above the base of the stress-relief fracturing. This can be thought of as groundwater spilling out of the voids once it reaches the shallow fracture zone.

In summary, in GHD’s opinion, there is no evidence for any faults acting as conduits other than for very localised flow. There is, however, abundant evidence for the faults and general bedrock being relatively impermeable in the form of the very low observed mine inflows discussed below.

3.2.2 Low Mine Inflows (60)

Figure 10 shows net groundwater inflows to the mine, calculated by subtracting process water delivered to the mine from the total volume extracted from dewatering sumps. Net flows range from approximately -5 L/s (less water was extracted than was injected) to 5 L/s. The average monitored inflow, was generally around 1 L/s. Short-term inflow spikes occurred immediately following heavy rainfall, due to increased seepage in shallow in mine portal areas as well as a decreased evaporation of water in the mine due to increased humidity. Given that base of the mine is some 700 m below the level of Gunpowder Creek, the water-filled Esperanza pit and the water storage dam to the east, this is an extremely low inflow rate by any measure and supports the understanding that the bedrock is almost impermeable below the surficial aquifer.
3.2.3 **Estimation of Bedrock Permeability**

Very limited permeability data is available for the deep bedrock, with most investigations focussing on shallow groundwater in the surficial stress-relief fracturing zone. Given the extensive tunnelling and stoping within the underground mine zone, deep bedrock permeability can, however, be estimated from underground mine inflows modelled as an “equivalent well”\(^2\).

While this method is aimed at estimating inflows where flow is primarily horizontal, it can be used to provide an estimate of hydraulic conductivity in this case to within an order of magnitude.

Using:

- a radius of influence of 600 m;
- mine dimensions of 600 length, 200 m width and 700 m depth; and
- aquifer thickness of 1000 m.

an inflow rate of 1 L/s requires a hydraulic conductivity of approximately \(1 \times 10^{-7}\) m/d, which is equivalent to compacted clay typically used in landfill liners. This is an average value and takes in to account variability in faulting and fracturing over the extensive underground workings.

3.2.4 **Deep Groundwater Seepage Rates**

In the event that the hydraulic barrier noted in Section 3.1 is not present (unlikely until post mine closure) the volume of seepage through deep bedrock can be estimated using the maximum possible hydraulic gradient, the approximate cross sectional area of the pit and the permeability of the deep bedrock.

---

Using:

- a triangular cross-sectional area of 100 m deep by 300 m wide (15,000 m²),
- hydraulic gradient of 0.12 (228 mAHD – 108 mAHD over 1000 m distance to Gunpowder creek); and
- a hydraulic conductivity (K) of 1x10⁻⁷ m/d

the Darcy seepage rate is estimated at approximately 1.8x10⁻⁴ m³/d (2x10⁻⁶ L/s). This is equivalent to approximately 60 L of pit water per year. By any measure, this is not a significant seepage rate. Consequently, no significant seepage of pit water can occur through the deep bedrock, below the surficial aquifer. Significant seepage can only occur if the water level in the pit rises above the base of the surficial aquifer which, assuming a depth of 10 m below the bedrock surface at 222 mAHD, would be at approximately 212 mAHD in the saddle to the northeast of the pit (refer Section 3.3).

In summary, there is no deep aquifer and significant groundwater flow is only likely through the surficial stress-relief fracture zone above 212 mAHD in the saddle top the northeast of the pit.

3.3 Condition 3 – Capture by Existing Water Management Infrastructure (64, 65)

In the event that a hydraulic barrier is not present (unlikely until post mine closure) and water levels in the pit rise above the base of the surficial aquifer, even to the point of spilling out of the pit, the only pathway for seepage out of the pit is through the surficial aquifer, which is generally limited to approximately 10 m below natural ground surface. The only area where this occurs between the Esperanza pit and Gunpowder Creek is in the northeast corner of the pit, where is spills to Mill Creek. As the ridges either side of Mill Creek are more than 20 m above the creek bed, there is no pathway for groundwater flow other than down Mill Creek. Given the presence of the lake behind the Mill Creek Dam, seepage from the base of the lake would form a hydraulic barrier to downstream flow, forcing the seepage arriving at the lake from upstream to discharge to surface on the edges of the lake. Any such seepage discharging to the lake would react with and be diluted by the water in the lake, and managed as part of the controlled release from Mill Creek dam. Furthermore, it would represent only a very small proportion of overall discharge from the dam.

The Mill Creek Dam was constructed between March and December 2007. The works comprised the construction of an 81,000m³ earth and rockfill structure. Mill Creek Dam replaced the existing smaller Hoover Dam immediately downstream of the current site on Mill Creek, approximately 300m upstream of the confluence with Gunpowder Creek. In this location, the dam is able to intercept contaminated runoff from the catchment of Mill Creek and Esperanza Creek during high rainfall events and allow the contaminated water to be transferred to other storages, treated, evaporated, reused or released.

The dam wall comprises of the following material zones (Figure 11). The very low permeability of the structure has been design to mitigate seepage:

- Zone 1: clay material.
- Zone 1A gravelly clay.
- Zone 2A and 2B: filter materials with a horizontal thickness of 1.2 metres.
- Zones 3 rockfill.
- Zone 4: selected coarse rockfill. This zone was constructed with a 3 metres thickness.
Figure 11 Mill Creek Dam Design (extract: Drawing 32-12850-C005, As Recorded issue)
Although the Mill Creek Dam is constructed with a foundation grout curtain and a core with very low permeability, minor seepage may occur below and around this grout curtain. However, should this occur this seepage will be of treated water from within the lake near to the dam wall. As noted above, seepage from the Esperanza Pit cannot flow directly to beneath the Mill Creek dam embankment, as the flow naturally will be directed to the upstream end of the lake.

To add further security, any seepage below or around the grout curtain at the embankment would report to the downstream dam, which is regularly monitored prior to release.

In the unlikely event that seepage occurs to the north of the Pit, through the impermeable bedrock and through the hydraulic barrier, and was at a rate that could be measured above the seepage already occurring through the North Rock dump, it would be captured by the recently installed interception/cut-off trench at the northern end of the dump Figure 12 and Figure 13.

![Figure 12 North Rock Dump seepage interception and cut-off trench](Drawing 32-15847-08-C002, Rev 0, GHD)

Note: This photo is from prior to trench installation when the seepage dam was collecting seepage from waste rock dump to the south.
Figure 13 Interception Trench (extract: Drawing 32-15847-08-C005 & C006, Rev 0, GHD)
The design layout for the North Rock Dump interception/cut-off trench is shown above. The trench was constructed in accordance with the intent of the design which included a grout curtain wall and an HDPE liner along the base and downstream face, keyed in to the grout curtain, to restrict flow underneath or around the trench; together with, the use of additional gravel-filled drains upstream, to capture shallow seepage and direct it into the trench. The trench included the installation of additional monitoring bores. The North Rock interception trench was certified by RPEQ Engineer Malcolm Barker in the subsequent report GHD, *Esperanza TSF Interception Trenches, Constructed Report, December 2012.*

Both management of seepage via Mill Creek Dam and the North Rock Interception Trench is detailed further in the report GHD, *Esperanza Master Seepage Report, May 2012.*

### 3.4 Condition 4 – Ability to Detect and Manage Additional Seepage (66)

Whilst the potential for preferential flows cannot be definitely eliminated, given the observations discussed in this section, preferential flow through the deep bedrock resulting in a significant increase in contaminant loading to Gunpowder Creek is considered by GHD to be highly unlikely.

In the highly unlikely event that there is some, as yet unidentified, discrete, zone of high permeability, and seepage is not:

- intercepted by drainage to the underground workings (Condition 1);
- blocked by the surrounding hydraulic barrier (Condition 2); or
- intercepted by the Mill Creek dam or North Rock Dump Interception Trench (Condition 3);

then it could only report to Gunpowder Creek if it can reach the creek before hydraulic gradients are reversed once the pit water levels returned to below the base of Gunpowder Creek post mining. Such seepage should be readily identifiable by the detailed water quality and groundwater level monitoring program now in place at the mine. If detected, detailed site-specific investigation could be carried out to identify and delineate such a discrete flow path and to manage seepage either by sealing the conduit by grouting, or active drainage through interception trenches if shallow or bores if deep. It is worth noting, however, that if such a flow path exists, water would have just as easily flowed in the other direction when the pit was drained and would have been observed as a discrete inflow zone during open cut mining, where the difference between the head in the drained pit and Gunpowder Creek would have been far great than any possible gradient from the filled pit to Gunpowder Creek.

In addition to an arbitrary reporting level based on the MRL and DSA, an additional trigger for investigation could be the dropping of groundwater levels in bores within the groundwater mound below the pit level or a nominal height above the Pit level (66).

A more appropriate program of water treatment and release is being negotiated as part of a revised Court Order, and receiving water monitoring remains in place. Consequently, it is expected that sulfate elevations that previously occurred towards the end of the dry season, through evaporative concentration of water impacted by mine discharges at the end of the wet season, should be significantly reduced by a revised treated water release regime, all contaminant limits within the current EA limits are expected to be meet, without exceedance.

Examples of the current monitoring data are presented as Figure 14 to Figure 19 Note in Figure 14. The copper levels in gunpowder Creek Figure 15
Figure 14 Gunpowder Creek copper levels and Esperanza Pit water level history
Figure 15 Gunpowder Creek sulphate and pit water level history
Figure 16 Mill Creek Dam sulphate, TDS and pH

Figure 17 Mill Creek Dam total copper (note log scale)
The data above and attached as appendices demonstrate that detailed monitoring is in place and a good history of data against which to compare future monitoring has been collected.

The data for pit water levels and Gunpowder Creek copper concentrations show a significant decrease in copper levels after levels in the pit begin to rise while, conversely, sulfate levels increase. If the change was due to pit seepage, then both would be expected to rise and there would be a strong correlation between copper and sulfate levels. As discussed in the Esperanza TSF seepage report, the increase in sulfate is most likely attributable to a change in treated water discharge, which has since been modified and sulfate is expected to decrease significantly over the next dry season.
Another point of note is that despite variations in copper concentrations in Mill Creek Dam samples, due to changes in the treatment process, the concentrations in the downstream Hoover dam have remained relatively stable and below the limit, demonstrating that copper contamination is being successfully managed and sulfate levels are relatively stable.

Further to the above monitoring activities, the following monitoring actions will be adopted to enable early detection of seepage and maintain hydraulic containment of seepage (Cases 1 and 4):

Regular, monthly, inspections of Mill Creek will be carried out, between the pit and the treated water discharge point, to identify any increased seepage;

Seepage collection data from the North Rock dump interception trench will be regularly reviewed for any indication of an increase in seepage not attributable to rainfall events (this is required as part of the TSF management).

Regular monitoring of water level to confirm that water levels in GWMB 45/46 and GWMB2 remain above the pit water level. Exceedance of the level in the bores by the Pit water level will be reported to DEHP and suitable management options developed on a case-by-case basis.

Regular monitoring of the chemistry and water levels in the groundwater monitoring bores around the pit. If either sulfate, Cu, pH or TDS/EC exceed historical values or they or water levels show an increasing trend not reflected in other bores at the site and attributable to rainfall variation DEHP shall be notified, the cause investigated and appropriate remedial action taken.

4. **Conclusion**

In GHD’s opinion, based on the above discussion, for pit water levels at the current water level of approximately 208 mAH, the proposed DSA of 204.5 m and proposed MRL of 216.5 m, all four criteria as defined in section 1.4 are likely to be met, being:

1. Observed ambient groundwater levels around the pit are higher than the current and proposed water levels in the pit, providing a hydraulic barrier to outward flow or else flow is captured by flow to the Mammoth underground mine;

2. The permeability of the deep bedrock surrounding the pit is considered so low that even in the absence of a hydraulic barrier and with elevated pit water levels, deep seepage from the pit to Gunpowder Creek is highly unlikely to be measurable, nor is it likely to result in a significant increase in contaminant loading to Gunpowder Creek;

3. Should seepage occur through the surficial aquifer, it is highly likely to discharge to the Mill Creek lake and cannot discharge untreated below the Mill Creek Dam embankment due to the hydraulic barrier formed by the ponded water behind the dam. Additional safety is provided by the Hoover dam downstream. If seepage can flow, through some as yet unidentified pathway, to the north, it is highly likely to be intercepted by the North Rock dump interception trench. As noted in Point 2, any diffuse deep seepage is highly likely to be captured by the underground mine dewatering system;

4. Monitoring systems presently in place, including regular groundwater level and surface and groundwater quality monitoring, together with monitoring of the various seepage management and water treatment systems, along with additional monitoring proposed above, is likely to identify any significant change in seepage. If detected, seepage could be delineated through further investigations, including drilling and installation of monitoring bores if required, and managed through the use of recovery bores or interception trenches if required or lowering water levels in the Pit if spare storage capacity is available such as MCD.
On this basis, at least one, but most likely all four conditions are likely to have been met and hence of raising the water levels in the pit to the proposed DSA and MRL is not a significant risk, in terms of both likelihood and consequence, to water quality in Gunpowder Creek. Thus; management of contaminated water at the site by storage in the former Esperanza open cut Pit, allowing mine operation and gradual improvement of environmental management of other legacy issues at the site represents the best outcome for the environment.

Given the improved water management systems at the site, including controlled discharge of treated water to Gunpowder Creek, it is expected that water quality in Gunpowder Creek, when similar seasons are compared, is highly likely to gradually improve over the next year.

In conclusion, it is GHD’s opinion that, since multiple containment criteria can be met, raising water levels in the pit to the proposed levels is highly unlikely to pose a significant risk or threat of irreversible impact to water quality in Gunpowder Creek.
Appendix A – Plots of Groundwater Chemistry for bores in the general mine area