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July 29, 2016

Mount Isa Mines Limited
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Mount Isa QLD 4825

Miss. Tamara Groves
ZOPS Environmental Advisor

Dear Miss. Groves:

Black Star Open Cut Waste Rock Dump Environmental Evaluation
Environmental Evaluation Report
Final

Klohn Crippen Berger (KCB) is pleased to provide this final Environmental Evaluation report for the above mentioned project.

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Yours truly,

KLOHN CRIPPEN BERGER LTD.

Chris Strachotta
Project Manager

CK:CS:JT

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EXECUTIVE SUMMARY

The Department of Environment and Heritage Protection (DEHP) issued an Environmental Evaluation (EE) notice (Ref: 101/0008689) to Mount Isa Mines (MIM) to conduct an assessment of seepage from the Black Star Open Cut (BSOC) Waste Rock Dump (WRD). Key requirements of the EE are to:

- Identify the source, cause and extent of all seepage[1] being or likely to be released from the BSOC WRD to the receiving environment[2];
- Assess the impacts on the receiving environment and all identified environmental values (EVs) (surface water / groundwater quality, sediment quality, soils, flora and fauna);
- Determine potential options for prevention or reduction of further seepage from the BSOC WRD to the receiving environment; and,
- Identify a preferred option/s for both the remediation of identified impacts to the receiving environment and measures to prevent or limit future impacts.

Data Collation & Field Investigations

Previous investigations and historical monitoring data from the project site were reviewed, and a data gap assessment was conducted to identify additional data required to conduct the EE assessment. Based on the results of the data gap assessment, a phased field investigation program was developed and undertaken. Phase 1 comprised a site investigation program, including seepage mapping; seepage water and soil sampling; and, drill location selection for Phase 2. The Phase 2 field investigation program comprised the drilling and installation of 11 groundwater monitoring bores (5 alluvial aquifer monitoring bores and 6 bedrock aquifer monitoring bores); aquifer hydraulic testing using the installed monitoring bores and previously established bores; and, hydraulic testing of the BSOC WRD.

A concurrent assessment was undertaken to identify and/or design monitoring facilities at each of the seepage locations (BSOC WRD South Seepage, BSOC WRD North Seepage, TD3 Seepage) and within the Diversion Drain to monitor seepage from the BSOC WRD. These facilities comprised three weirs within the Diversion Drain (downstream of TD3 Seepage – Weir 1, downstream of BSOC WRD North Seepage – Weir 2 and upstream of BSOC WRD North Seepage – Weir 3); and, monitoring of pumped seepage from the BSOC WRD South Seepage trench.

Conceptualisation and Analysis

Data collected from the field investigation program was collated with the historical monitoring records and previous investigations to support the conceptualisation of the hydrogeological system across the project site (including the BSOC WRD landform) and the analysis of the seepage from the BSOC WRD.

[1] The EE notice defines "seepage" as *any liquid originating from the Black Star Waste Rock Dump footprint regardless of its contaminant concentration that has the potential to enter the receiving environment.*
[2] The EE notice defines "receiving environment" as *all groundwater and surface water that are not in disturbed areas authorised by this environmental authority and excludes land within the surface water containment areas*.

- **Hydrogeological conceptualisation**

  The groundwater system at the project site comprises three aquifers – an alluvial aquifer hosted within the unconsolidated alluvium in and adjacent to surface water courses; a weathered bedrock aquifer located to a depth of approximately 10 m comprising weathered meta-sediments of the Bortala Formation, Eastern Creek Volcanics and Whitworth Quartzite; and, a bedrock aquifer of the Bortala Formation, Eastern Creek Volcanics and Whitworth Quartzite. Groundwater levels observed in monitoring bores installed within the alluvial aquifer indicate that groundwater flow is generally towards the west (towards Hazeldene Creek) for the alluvial aquifer downstream of the BSOC WRD South and North Seepage. Groundwater flow in the alluvial aquifer downstream of the BSOC WRD North Seepage seems to be ephemeral (although this would need to be confirmed by further monitoring), as groundwater was not observed in the downstream monitoring bore (BSOC_A4), indicating a physical limit to the extent of potential seepage from the BSOC WRD North Seepage. Groundwater flow in the alluvial aquifer downstream of the TD3 Seepage is towards the east (towards the Leichhardt River), however, this flow is diverted into the KSOC Pit prior to the confluence with the Leichhardt River.

  Results from adjacent monitoring bores installed in the weathered bedrock and bedrock aquifers indicate that these aquifers are in hydraulic connection, as the groundwater levels are similar and seasonal groundwater variability is comparable. Groundwater level contours, interpreted from groundwater levels recorded on the same day from the groundwater monitoring bore network located across the project site, indicate a groundwater flow direction in the bedrock aquifer away from the BSOC WRD landform. These groundwater level contours indicate hydraulic connection between the BSOC WRD landform and the underlying bedrock aquifer. Groundwater level hydrographs from monitoring bores installed in the weathered bedrock and bedrock aquifer downstream from the BSOC WRD landform (Bore 23 and Bore 24, respectively) also support the hydraulic connection between the BSOC WRD landform and the bedrock aquifer. The regional flow direction of the bedrock aquifer is from south to north.

- **BSOC WRD conceptualisation**

  Historical project site topography (pre-BSOC WRD landform); the final configuration of TSF3 and TSF5; and, the current BSOC WRD surface were used to develop a 3D BSOC WRD landform model and to select two-dimensional Seep/W model sections for seepage assessment. The BSOC WRD landform model identified that the upstream catchments for each of the seepage locations (i.e. seepage catchment underlying the WRD) comprised both historical tailings storage (TSF3 upstream of TD3 Seepage; and, TSF5 upstream of both BSOC WRD North and South Seepages) and waste rock; indicating a potential seepage source from both tailings and waste rock.

  Hydraulic testing (test pit soak-away tests) on the current BSOC WRD surface was unsuccessful, as water was not retained in the test pits. Anecdotal information from site personnel also indicated that limited ponding on the WRD surface is observed during and following rainfall events. As a result, the majority of rainfall on the WRD surface (not including the WRD slopes) is expected to infiltrate into the landform.

- **Seepage analysis**

  Conceptualisation of the hydrogeological system and the BSOC WRD landform provided the basis for the seepage analysis. The analysis was further supported by the assessment of the waste rock and tailings geochemistry, the seepage hydrochemistry and the downstream groundwater hydrochemistry. The combined results of these assessments provided an understanding of the seepage characteristics – the seepage extent, proportion of seepage source contribution, interpreted timeframe of seepage development and predicted timeframe for seepage migration to receptors.

Seepage Source, Cause and Extent

The three seepage points located around the BSOC WRD Landform are coincident with the natural drainage locations, which are now covered by the WRD. Upstream of these seepage locations (beneath the WRD) a spillway from historical tailings dams (TSF3 and TSF5) is present, buried beneath the WRD.

A review of waste rock and tailings geochemistry and kinetic testing was undertaken, in conjunction with a review of BSOC WRD seepage chemistry, as well as historical tailings chemistry data, to assess whether a definitive source (either tailings or waste rock) is providing the seepage now observed from BSOC WRD. The MIM landfill sludge pits were also considered as a potential source.

Based on the available chemistry data, the following is concluded:

- TD3 and BSOC WRD North Seepages have similar water qualities and both have similarities to waste rock seepage and tailings seepage characteristics.
- The MIM landfill sludge pits may also contribute, although it is difficult to determine the extent of this contribution quantitatively without further constraints on the internal geochemistry of TSF3 and the WRD.
- BSOC WRD South Seepage is broadly similar to TD3 Seepage and BSOC WRD North Seepage, but reports water quality that may have some of the characteristics similar to the TD5 pit sample.
- Based on the water qualities obtained from kinetic testing of both waste rock and tailings, as well as the measured seepage, it is interpreted that there is limited basis for clear differentiation between geochemical signatures of the waste rock and tailings in the seepage.

Previous geophysical surveys were completed to determine the cause of seepage migration from the BSOC WRD Landform, and to identify potential preferential pathways for seepage. The Phase 2 field investigation program was developed to target anomalies identified from the geophysical surveys to confirm the occurrence of seepage migration. The field investigation program did not identify zones of discrete preferential seepage pathways, as previously interpreted from the geophysical surveys, rather, diffuse seepage within the alluvial aquifer and bedrock aquifer were identified.

A two dimensional modelling assessment was also undertaken to assist in determining the cause of seepage migration. This was completed using representative thicknesses of the site

infrastructure as well as the underlying geology. Sensitivity analysis for the most uncertain parameters was also undertaken to assess the potential variability in the flux estimates and movement of water.

The cause of seepage has been interpreted as the following:

- Direct seepage movement within alluvial aquifers, which originate under the BSOC WRD landform and are in connection with the alluvium beyond the extents of the landform.
- Seepage into the downstream alluvium beyond the constructed diversion drain.
- Bedrock seepage from the base of the TSFs as diffuse seepage with the bedrock aquifer, likely to be along the bedrock bedding plane (south-north orientation).

The volume of seepage that is generated, and will continue to be generated, is a function of the net percolation into the WRD and the piezometric surface within the WRD. These parameters have been established based on limited testing of the WRD surface and previous site investigations.

BSOC WRD seepage migration has been identified in the alluvial aquifer downstream of TD3 Seepage, BSOC WRD North Seepage and BSOC WRD South Seepage.

- TD3 Seepage – Downstream of this location the extent of the BSOC WRD seepage migration is to the discharge location at the KSOC open pit. The alluvial aquifer downstream of this seepage location is fully saturated as a result of flow from TD3, BSOC WRD North and South Seepages discharging into the Diversion Drain.
- BSOC WRD North Seepage – The extent of seepage migration in the alluvial aquifer downstream of the BSOC WRD North Seepage (alluvial extent to the north, beyond the diversion drain) is interpreted to be limited to ~200 m to the north of the Diversion Drain. This interpretation is based on the groundwater quality results from monitoring bore BSOC_A3 (based on an interpreted seepage extent trigger of sulphate = 1,000 mg/L[3]), and further supported by the lack of groundwater in monitoring bore BSOC_A4.
- BSOC WRD South Seepage – The extent of the seepage migration in the alluvial aquifer downstream of the BSOC WRD South Seepage (alluvial extent to the west of the seepage) is interpreted to be limited to ~300 m to the west of the BSOC WRD South Seepage. Sulphate concentrations from alluvial aquifer monitoring bores located downstream of the BSOC WRD South Seepage (BSOC_A1 and BSOC_A2) indicate that the seepage has migrated beyond BSOC_A2 (~5,500 mg/L) but has not reached BSOC_A1 (~580 mg/L).

BSOC WRD seepage migration in the bedrock aquifer was interpreted based on the groundwater quality results from monitoring bores installed in the weathered bedrock / bedrock aquifer, including bores installed as part of the field investigation program targeting discrete geological structures. As per the alluvial aquifer, a sulphate concentration of 1,000 mg/L was adopted as the extent of the seepage front. Weathered bedrock / bedrock aquifer water quality results indicate that the BSOC WRD seepage extent is generally localised to the BSOC WRD landform with two zones of seepage migration; to the north of TD3 Seepage, and to the west of BSOC WRD South

[3] Sulphate has been selected as the water quality parameter to represent seepage migration from the BSOC WRD landform due to the conservative nature of the parameter (limited influence of sorption/attenuation mechanisms in the aquifer). Therefore, the interpreted extent of the seepage migration based on sulphate is considered conservative. A sulphate concentration limit of 1,000 mg/L has been applied to correspond with the ANZECC livestock watering quality guidelines.

Seepage. Bedrock aquifer seepage migration extent to the north of TD3 Seepage is limited to ~800 m and seepage migration to the west of the South Seepage is limited to ~350 m.

The analytical results were compared to the existing groundwater quality data. Analytical contaminant transport analyses were undertaken to assess the travel time of the seepage migration front, and to predict the timing of further migration of the seepage. For conservatism sulphate was used as the contaminant parameter, while the extent of the study area was used as the receptor for the simulation. However, Spear Creek, located approximately 5.4 km north of the BSOC WRD is considered to be the nearest downstream surface water receptor from this facility since it is the location of the nearest downstream surface water monitoring point. The analytical assessment is based on the assumption that seepage commenced during the development of the underlying TSFs (i.e. TSF3 for TD3 Seepage; and, TSF5 for BSOC WRD North and South Seepages). The analytical assessment results indicate that the seepage migration in the bedrock aquifer to the north of TD3 Seepage has taken ~63 years to develop; and based on the current migration rate, the seepage front may reach Spear Creek in another 465 years.

Assessment of Impact on Receiving Environment

An assessment of impacts from the BSOC WRD seepage on the receiving environment was undertaken for surface water, groundwater, sediment / soil quality and flora / fauna based on the previously established environmental values (EVs). A summary of this assessment is outlined below:

- Surface water – seepage from the BSOC WRD occurs as surface water at each of the three seepage locations where the seepage discharges into the Diversion Drain, or seepage collection trench for BSOC WRD South Seepage. The occurrence of the seepage as surface water is managed by the Diversion Drain, which discharges the seepage water into KSOC pit, mitigating flow into the downstream water course (i.e. Leichhardt River, Hazeldene Creek). Therefore, potential impacts to the receiving environment surface water EVs from the BSOC WRD landform seepage is not anticipated.
- Groundwater – areas of potential impact to the alluvial and bedrock aquifers are defined by the interpreted plume extents. The groundwater levels in both aquifers are generally below the surface and inaccessible to fauna for consumption. During periods of high rainfall, groundwater may rise to the surface and flow as surface water within the water course, however, this water is likely to be diluted.

  Groundwater usage for industrial use, livestock watering and/or small scale irrigation (groundwater EVs) is not observed within the vicinity of the study area. Additionally, discharge of groundwater to waterways supporting existing fauna and flora communities has not been identified within the vicinity of the study area. Therefore, potential impacts on the groundwater EVs as a result of BSOC WRD landform seepage is not anticipated.
- Sediment / soil quality – specific EVs for sediment / soil quality have not been developed for ML8058, however, in this absence the established EVs for Land Use have been adopted. The extent of potential impact to sediment quality in the study area as a result of BSOC WRD seepage is limited to the ~300 m downstream of BSOC WRD South Seepage and ~200 m downstream of BSOC WRD North Seepage within the alluvium extent of the downstream watercourse. No observable or interpreted impacts to the ecosystem

biodiversity, health and significance (e.g. vegetation die-back); or, the integrity of the land surface for associated land use has been identified.

- Flora – groundwater levels in the alluvial aquifer fluctuate relative to seasonal variability, with higher groundwater levels anticipated during the wet season and lower groundwater levels during the dry season. It is anticipated that vegetation within the alluvial extent downstream of the BSOC WRD North and South Seepages may source water from the alluvial aquifer. Therefore, potential impact to flora from the BSOC WRD seepage may occur, limited to the extent of the interpreted seepage within the alluvial aquifer. Current impacts to flora within the extent of the seepage plume have not been observed.
- Fauna – consumption of seepage influenced water by fauna is considered the pathway for the BSOC WRD seepage to impact fauna. Groundwater is considered inaccessible by fauna, therefore, consumption of seepage water is not anticipated outside of the Diversion Drain. Access to the Diversion Drain and seepage locations by livestock is currently managed by the mining lease boundary fence located along the western boundary of the study area. Therefore, potential impacts to livestock from the BSOC WRD landform seepage is not anticipated.

Potential Options for Prevention or Reduction of Further Seepage

Three potential options have been identified to prevent or reduce further seepage into the alluvial aquifer. These conceptual options include a groundwater interception borefield, groundwater collection trench and an alluvial aquifer cut-off wall. A summary of these potential options are provided in the table below.

Mitigation Option	Summary Description	Cost Estimate	Implementation Timeframe
Interception Borefield	▪ Series of production bores installed along an alignment perpendicular to groundwater flow in the alluvial aquifer downstream of BSOC WRD South and North Seepages – located downstream of diversion drain ▪ Bores to be completed into bedrock, below the alluvium profile ▪ Collected water to be reticulated and discharged into diversion drain for management in KSOC pit ▪ Drilling and hydraulic testing required to confirm borefield configuration and operational requirements	$773,500	11 months
Groundwater Collection Trench	▪ Excavation of a trench aligned perpendicular to alluvial groundwater flow across the extent of the alluvium and to the base of the alluvial profile ▪ Due to the depth of excavation and the requirement to keep excavation open a “cut-back” on the trench slopes will be required ▪ Seepage water collected in the trench will be reticulated and discharged into the diversion drain for management in KSOC pit ▪ Testing of the alluvial material will be required to support the detailed design of the trench and operational requirements for the system.	$942,500	10 months
Cut-off Wall	▪ Location of the cut-off walls will be subject to site investigations to confirm extent of the alluvium and the depth to bedrock.	$1,222,000	12 months

Mitigation Option	Summary Description	Cost Estimate	Implementation Timeframe
	▪ Cut-off walls will be installed using low permeability cement / bentonite slurries, with installation conducted concurrently with excavation to the base of the alluvium and across the alluvium extent. ▪ Management of seepage water mounded upstream of the cut-off walls will be undertaken via surface drainage reconfiguration, or transfer pumping, into the diversion drain. This management option will be confirmed as part of the subsequent site investigation and detailed design.		

For the bedrock aquifer, the prevention or reduction of further seepage during mine operations could be mitigated by the installation of a groundwater seepage interception borefield. A summary of this option is provided in the following table.

Mitigation Option	Summary Description	Cost Estimate	Implementation Timeframe
Interception Borefield	▪ Series of production bores installed along an alignment perpendicular to groundwater flow in the bedrock aquifer downstream of TD3 Seepage ▪ Bores completed to below 60 mbgl (identified depth of seepage) ▪ Collected water to be reticulated and discharged into diversion drain for management in KSOC pit ▪ Drilling and hydraulic testing required to confirm borefield configuration and operational requirements	$988,000	12 months

Preferred Remediation Option/s and Measures to Prevent or Limit Future Impacts

Currently, no impacts to the receiving environment EVs for surface water, groundwater, sediment / soil quality and flora / fauna have been identified. There may be potential future impacts to these EVs, however, this could only be verified through ongoing monitoring, which has been captured as part of an adaptive management strategy. The adaptive management strategy comprises ongoing monitoring, impact assessment and, if required, implementation of a preferred mitigation option/s. Therefore, the immediate implementation of a preferred impact mitigation option/s is not considered necessary.

The ongoing monitoring program for the adaptive management strategy includes:

- Surface water monitoring in water courses downstream of the BSOC WRD North and South Seepages prior to the confluence with Hazeldene Creek – event based surface water quality (rising-stage samplers)
- Alluvial aquifer – groundwater levels, groundwater quality
- Bedrock aquifer – groundwater levels, groundwater quality
- BSOC WRD Landform seepage – seepage flow rates, seepage water quality

- Flora –monitoring of vegetation condition was considered, it is considered that any mitigation measures proposed as a result of the water quality monitoring program would be appropriate.

At the completion of each monitoring round, and following the collation of the monitoring data, a review of the monitoring data set, including historical monitoring results, should be conducted. The objective of this review will be to identify potential changes to the BSOC WRD landform seepage characteristics; the seepage plume characteristics; and, potential impacts to the receiving environment (as a result of the surface water monitoring, groundwater monitoring and/or seepage plume characteristics). The review is expected to identify future impacts and, if required, recommend the implementation of seepage mitigation option/s.

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Appendix I: Environmental Evaluation Outline Approach

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Appendix III: Seepage Weir Design Report

Appendix IV: Receiving Environment (Flora and Fauna) Assessment

1 INTRODUCTION

Mount Isa Mines Limited (MIM) was issued with a *Notice to conduct an environmental evaluation* (EE Notice) investigation by the Department of Environment and Heritage Protection (EHP) in December 2014 (Reference No. 101/0008689). The grounds for issuing the EE Notice is in accordance with Section 326B (1)(b) of the *Environmental Protection Act 1994* whereby 'an activity or proposed activity is causing or likely to cause environmental harm' and states the following:

> *'Mount Isa Mines Limited (MIM) are likely to have caused or be causing environmental harm through a release of contaminated material via surface and predominantly sub-surface flow / seepage from the Black Star Open Cut Waste Rock Dump (BSOC WRD) in three locations known as the BSOC WRD North Seepage Point, BSOC WRD South Seepage Point and TD3 Seepage Point.'*

The EE Notice includes a summary of EHP's concerns and states that:

> *EHP has concerns on the volume, location and quality of seepage[4] that is occurring and the associated environmental harm that is likely to occur to environmental values.*

MIM's Environmental Authority EPML00977513 (the EA) authorises environmental harm to environmental values where mining activities are undertaken in accordance with the conditions of the EA. EA Condition A1 states:

> *This environmental authority authorises environmental harm caused by the carrying out of mining activities by the holder of this environmental authority. Where mining activities are undertaken in accordance with the conditions of this environmental authority, environmental harm caused in compliance with the conditions is taken to be authorised. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence shall not be construed as authorising environmental harm.*

This Environmental Evaluation (EE) Report provides the results of the investigation of the volume, location and quality of seepage[4] that is occurring and includes an assessment of environmental harm that is likely to occur to the receiving environment[5] and all identified environmental values.

The BSOC WRD contains waste rock material from the BSOC lead-zinc mining operations, both of which are located on ML8058. Construction of the WRD over the historical Tailings Storage Facility 3 (TSF3) commenced in 2004 and the WRD also now partially covers the northern extent of Tailings Storage Facility 5 (TSF5). Seepage from the WRD has been identified at three locations – TD3 Seepage, BSOC WRD North Seepage and BSOC WRD South Seepage.

MIM commissioned Klohn Crippen Berger Limited (KCB) to undertake the investigation in response to EHP's EE Notice. This EE Report serves as the final deliverable for the environmental evaluation.

[4] The EE Notice defines "seepage" as *any liquid originating from the Black Star Open Cut Waste Rock footprint regardless of its contaminant concentration that has the potential to enter the receiving environment.*
[5] The EE Notice defines "receiving environment" as *all groundwater and surface water that are not in disturbed areas authorised by this environmental authority and excludes land within the surface water containment areas*.

1.1 Environmental Evaluation Requirements

This EE report has been prepared in accordance with the EE Notice requirements, as detailed in Table 1-1. The table also provides details of the sections within this document where each of the items within the EE Notice have been addressed.

Table 1-1: Environmental Evaluation Notice Requirements

EE Notice Requirement	Section Addressed in this Document
1. Identify the source, cause and extent of all seepages that are being, or are likely to be released from the Black Star Waste Rock Dump (BSOC WRD) to the receiving environment. This must include:	Section 5
a. the current preferential pathways/ mechanisms/ fault lines for release of seepage from the BSOC WRD to the receiving environment; and,	Section 5.2
b. the current and expected volume and rate of any seepage released from the BSOC WRD to the receiving environment; and,	Section 5.3
c. the current concentration of seepage released from the BSOC WRD to the receiving environment.	Section 5.4
2. The investigation required under item 1 must,	
a. be in accordance with ANZECC (2000) methodology; and,	Section 2.3.2
b. assess impacts on the receiving environment and all identified environmental values, the assessment must include consideration of:	Section 6
i) Water quality for surface and groundwater's (including any shallow ephemeral aquifers));	Section 6
ii) Sediment Quality;	Section 6
iii) Soils;	Section 6
iv) Flora and Fauna	Section 6
3. Determine all potential options for the prevention or reduction of any further release of seepage from the BSOC WRD to receiving environment; for all options, provide:	Section 7
a. A detailed description of each option; and,	Sections 7.1 and 7.2
b. Costs for implementation of each option; and	Section 7.3
c. A timeframe for implementation of each option.	Section 7.4
4. Identify a preferred option/s for both the remediation of identified impacts to the receiving environment, and measure to prevent or limit any future impacts. Provide justification for the nominated option/s, which includes assessment against best practice environmental management; and, identify a time-frame for implementation and completion of the nominated option/s.	Section 8

1.2 Environmental Evaluation Approach

Upon commissioning KCB were requested to provide a conceptual environmental evaluation outline that summarised the approach to undertake the EE investigation. This outline was provided to MIM on July 20, 2015 and is provided in Appendix I. This approach to the Environmental Evaluation was presented to EHP at the Environmental Evaluation Outline Meeting on July 22, 2015.

A summary of the conceptual EE outline is provided in a flow chart presented in Figure 1-1.

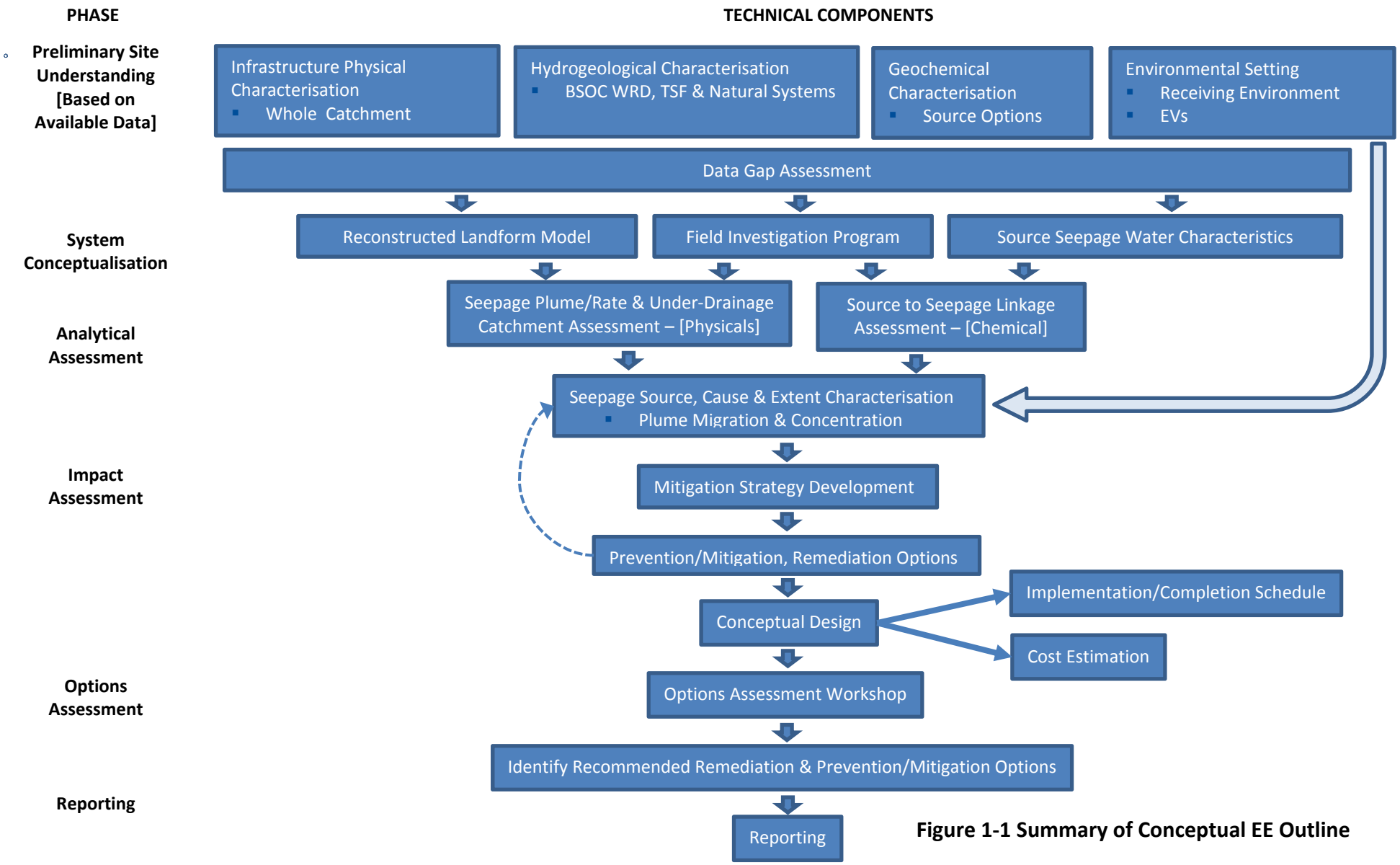

Figure 1-1 Summary of Conceptual EE Outline

1.3 EE Report Structure

This document comprises a main text component and supporting information / studies. An overview of the main text sections is presented below:

- Section 1 Introduction
- Section 2 Environmental Assessment Criteria
- Section 3 Environmental Setting
- Section 4 Site Infrastructure
- Section 5 BSOC WRD Source, Cause and Extent
- Section 6 Impact Assessment
- Section 7 BSOC WRD Seepage Prevention / Reduction
- Section 8 Preferred Impact Area Remediation Option/s
- Section 9 Conclusions and Recommendations
- Section 10 Closing

Appendices I to IV provide the supporting information / studies as follows:

- Appendix I Environmental Evaluation Outline Approach
- Appendix II Site Investigation Report
- Appendix III Seepage Weir Design Report
- Appendix IV Receiving Environment (Flora and Fauna) Assessment

2 ENVIRONMENTAL ASSESSMENT CRITERIA

2.1 Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) was established with the objective to protect Queensland's environment while allowing for development that improves the quality of life, both now and in the future, in a way that maintains ecological processes on which life depends.

Sections 326B to 326DA of the EP Act outlines the process for when an environmental investigation is required to be undertaken to assess an activity / event causing, or likely to cause, environmental harm. Under the EP Act, if EHP is satisfied on reasonable grounds that an activity is causing or likely to cause environmental harm, or a proposed activity is likely to cause environmental harm, they may request that the proponent undertaking the activity conduct / commission an investigation (an environmental evaluation) about the activity / event and submit an environmental report about the investigation to EHP. A written notice from EHP (an investigation notice) will be issued informing the proponent of the requirement to undertake an environmental investigation.

2.2 Mount Isa Mines Environmental Management Requirements

2.2.1 Environmental Authority EMPL00977513

Mining activities conducted on ML8058 have been authorised by an Environmental Authority (EA) (EMPL00977513) issued under the Chapter 5 of the EP Act.

As stated in Section 1, the EA authorises environmental harm to environmental values where mining activities are undertaken in accordance with the conditions of the EA. EA Condition A1 states:

> *This environmental authority authorises environmental harm caused by the carrying out of mining activities by the holder of this environmental authority. Where mining activities are undertaken in accordance with the conditions of this environmental authority, environmental harm caused in compliance with the conditions is taken to be authorised. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence shall not be construed as authorising environmental harm.*

Other key sections of the EA relevant to this EE investigation include:

- Schedule C – Land and Rehabilitation;
- Schedule E – Mining, Mineral Processing and Smelting Waste; and,
- Schedule H – Water.

General conditions associated with Schedule C and Schedule E, relevant to this EE investigation, relate to the management of contaminants and/or surface seepage to prevent release to the receiving environment and to prevent environmental harm. Schedule H provides the monitoring, compliance and reporting requirements for surface water and groundwater systems across ML8058. These include the:

- surface water monitoring network (contaminant release points, downstream compliance points, reference sites and other monitoring locations – Schedule H – Table 1 and Table 8)

and associated water quality release limits for controlled and uncontrolled releases (Schedule H Table 5 and Table 6, respectively); and,

- groundwater monitoring network and frequency (Schedule H – Table 10) and aquifer groundwater trigger levels and contaminant limits (Schedule H – Table 11a to 11d).

MIM are currently undertaking an investigation to establish the groundwater trigger levels and contaminant limits for or the groundwater aquifers across ML8058, and as a result trigger level and contaminant limit concentrations are not included in Schedule H – Table 11a to 11d.

2.2.2 Environmental Values

Of importance to this investigation are the established Environmental Values (EVs) for relevant receiving environment receptors, which are provided in the MIM Rehabilitation Plan (MIM, 2014), the EA EPML00977513 – Amendment Application Supporting Documentation version number 1.6 (MIM, 2015a) and EA EPML00977513 – Amendment Application Supporting Documentation version number 1.2 (MIM, 2015b). A summary of the EVs for surface water, groundwater, sediment / soil quality and flora / fauna are provided in Section 6.1.

2.2.3 Mount Isa Mines Rehabilitation Plan

The MIM Rehabilitation Plan (Revision number 1.1, 16 December 2014) has been established to provide an understanding of key components of rehabilitation requirements for disturbed land on ML8058. The key components of the Rehabilitation Plan include:

- Regulatory and policy framework;
- Rehabilitation goals, objectives, indicators and completion criteria;
- Geotechnical, geochemical and hydrological and hydrogeological studies;
- Conceptual final landform designs;
- Revegetation criteria and methods; and,
- Rehabilitation monitoring program.

Specific to the BSOC WRD, the Rehabilitation Plan provides the conceptual final landform design for the BSOC WRD, which includes the final landform surface contouring, drainage and erosion management strategy. Revegetation methods and criteria and the anticipated monitoring program for surface water, groundwater, erosion, cover system integrity / effectiveness and vegetation health/resilience are also provided in the Rehabilitation Plan.

2.3 Relevant Assessment Guidelines

2.3.1 Queensland Government Guidelines

Two guidelines released by EHP relevant to this EE investigation include:

- Guideline – Environmentally Relevant Activities Compliance and Enforcement (EHP, 2015b); and,
- Guideline – Notice to conduct or commission an environmental evaluation (EHP, 2015c).

The Guideline – Environmentally Relevant Activities Compliance and Enforcement (EHP, 2015b) was developed to assist Environmental Officers to act on Environmental reports under Section 326 of the EP Act. This guideline provides a summary of an EE including who can issue a notice to conduct or commission an EE, when EHP requires an EE, the environmental investigations associated with an EE and the requirements of an EE.

The Guideline – Notice to conduct or commission an environmental evaluation (EHP, 2015c) provides information to proponents who have been issued a notice to conduct or commission environmental evaluations under Section 321 to 329 of the EP Act. Specific to this EE investigation, this guideline provides:

- A summary of why a notice to conduct or commission an environmental investigation has been issued;
- Information that is provided in an investigation notice;
- Responsibilities upon receiving a notice to conduct or commission an EE;
- Penalties for failing to comply with a notice to conduct or commission an EE; and,
- The process EHP undertakes following receipt of the environmental report.

2.3.2 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000)

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 developed by the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) provides guidance on the undertaking of environmental assessments relating to the measurement and evaluation of water quality. This document provides a framework for the monitoring and assessment of water quality, which comprises:

- Develop hypothesis – create a conceptual model of ecosystem processes and interactions, make assumptions against which monitoring results are tested;
- Study design – select water quality indicators relative to conceptual model, identify water quality objectives, determine sampling locations;
- Sampling – undertaking sampling program;
- Sample processing and analysis – analysis selection and documentation;
- Data analysis and interpretation – analytical assessment and interpretation of data;
- Evaluation and reporting; and,
- Management action.

This environmental evaluation investigation has been conducted in accordance with the ANZECC (2000) methodology to address item 2(a) of the EE Notice.

In the absence of groundwater trigger limits and contaminant values in the current MIM EA (EMPL00977513), the ANZECC water quality guidelines for livestock watering (ANZECC, 2000) has been adopted for comparison as part of this investigation. These guidelines have been selected as beef cattle are one of the main mammal groups present in this area.

Sediments / soil have been compared against the ANZECC (2000) provisional sediment quality low trigger and high guideline values. These guidelines were used to take into consideration the adsorption of soluble contaminants and deposition of particulate-bound contaminants leading to storage in alluvial sediments.

ANZECC (2000) guidelines were also used as part of the impact assessment (Section 6), where a screening-level risk assessment was undertaken. For both groundwater and sediment, the measured environmental filtered concentration for each contaminant was divided by the guideline values to calculate the Hazard Quotient (HQ). If the HQ was <1 that contaminant was considered to be of 'low risk' and was not considered further. If the HQ was >1, the contaminant was identified as a 'contaminant of potential ecological concern' (CPEC) (ANZECC 2000). ANZECC (2000) livestock (beef cattle) guidelines and ANZECC (2000) sediment quality guidelines were used for the calculation of the HQ for the measured water and sediment concentrations.

3 ENVIRONMENTAL SETTING

3.1 Site Investigation Location

ML8058 and the associated mine infrastructure is located immediately to the west of the Mount Isa township in northwest Queensland. The focus area of this investigation, shown in Figure 3-1, was presented to EHP at the Environmental Evaluation Outline Meeting on July 22, 2015, and was based on a geographic extent beyond the anticipated current BSOC WRD landform seepage impacts. It is acknowledged that downstream surface water receptors, Hazeldene Creek, Spear Creek, Leichhardt River and Lake Moondarra are located beyond the extent of the focus area, however these have been taken into account for the assessment of potential impacts.

3.2 Topography

The topography of the Mount Isa area is characterised by rolling hills with a series of prominent north-south ridges of moderate relief dissected by linear alluvial-filled valleys. These ridges are formed from outcrop of steeply dipping bedrock. The topography across ML8058 generally ranges in elevation between 300 and 450 mAHD.

3.3 Hydrology

The study area is partially located within the sub-catchment of the Leichhardt River catchment. Major surface water drainages downstream of the study focus area include:

- The Leichhardt River, which generally flows from south to north and is located approximately 2.5 km east of the BSOC WRD;
- Spear Creek, a tributary of the Leichhardt River, flows towards the east and is located ~5.3 km north of the BSOC WRD; and,
- Hazeldene Creek, which is a tributary of Spear Creek, flows south to north and is located approximately 1.5 km west of the BSOC WRD.

The location of these surface water drainage features are shown in Figure 3-1. Minor creeks / gullies are also located within the study area. These watercourses are ephemeral, with the size and duration of flows dependent on the variable wet season.

The only permanent water bodies in the region exists in man-made structures such as large impoundments (Lake Moondarra, Lake Julius and Rifle Creek Dam), tailings dams, open pits and seepage collection ponds.

A key watercourse in the study area is King Gully, which is located directly north of BSOC WRD and is now used as a diversion channel to manage runoff and seepage from the BSOC WRD. Further information about King Gully diversion is provided in Section 4.1.1.

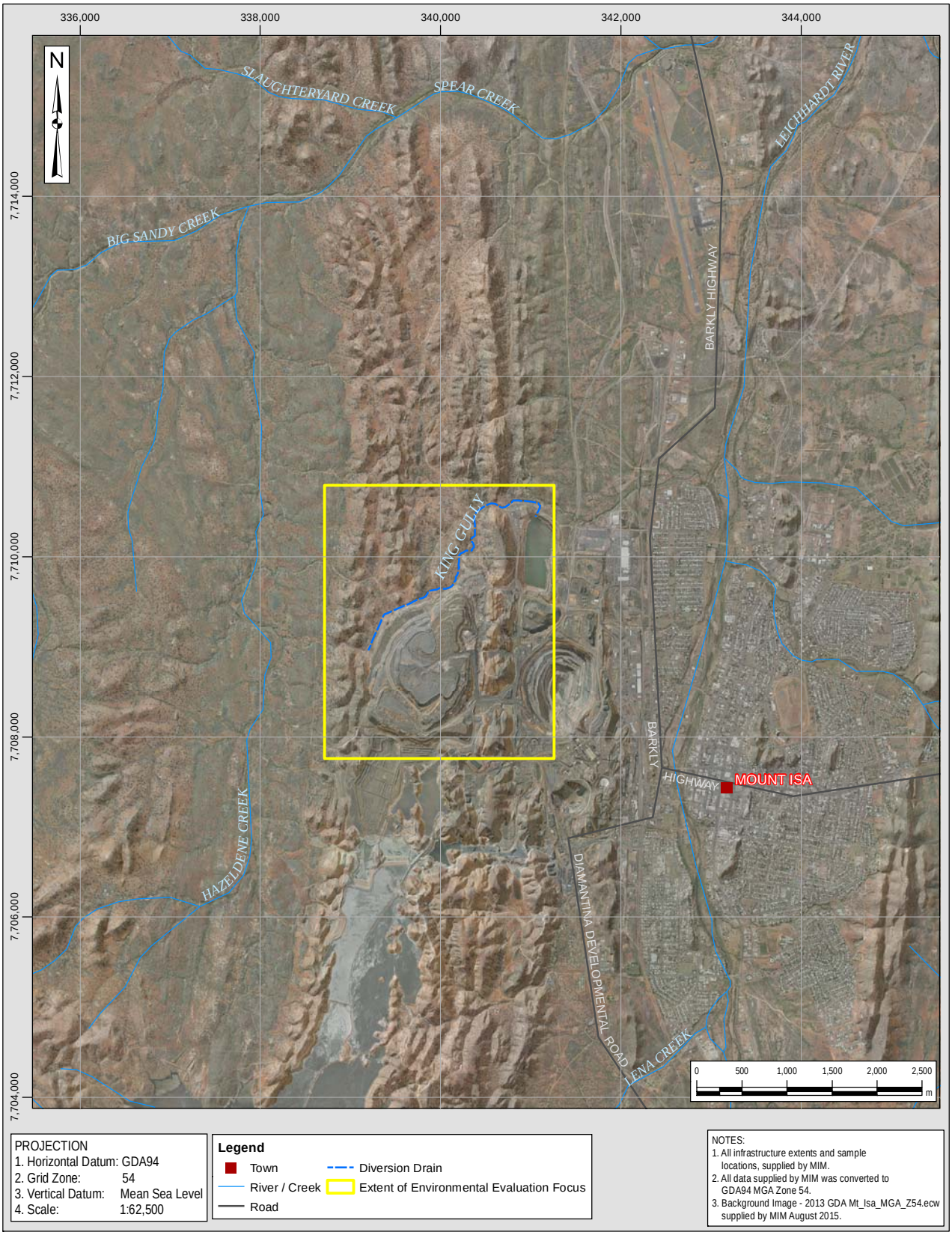

Figure 3-1: Regional setting and environmental evaluation focus area

3.4 Meteorological Conditions

The Mount Isa region is classified as being in the 'Grassland' climate group, based on the Köeppen classification system (Bureau of Meteorology, 2016), which consists of two distinct seasons: wet season from December to March; and the dry season from April to November. Table 3-1 presents monthly and annual climate statistics for rainfall, evaporation for the Mount Isa Mine (#029126) weather station and temperature for the Mount Isa Aero (#029127) weather station.

Table 3-1: Mount Isa climate statistics (Bureau of Meteorology, 2016)

Statistic	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean rainfall (1932 to 2015)	mm	97.3	91.5	60.4	15.7	15.9	10.9	6	3.1	6.7	18.7	31.4	63.7	424.3
Mean daily evaporation (1965 to 1992)	mm	10	9.3	9.1	8.1	6.1	5.1	5.3	6.6	8.5	10.2	11.2	11.3	8.4
Mean max temperature (1966 to 2015)	°C	36.4	35.4	34.3	31.9	27.9	24.9	24.8	27.3	31.3	34.8	36.5	37.1	31.9
Mean min temperature (1966 to 2015)	°C	23.7	23.3	21.8	18.5	13.8	10	8.7	10.2	14.2	18.5	21.5	23.1	17.3

In summary:

- Mean annual rainfall for records between 1932 and 2015 is 424.3mm, with around 74% of the mean annual rainfall occurring between December and March.
- During the wet season, monthly mean maximum temperature range between ~34°C and 37°C with monthly mean minimum temperatures ranging between ~21.8°C and 23.7°C.
- During the dry season, the monthly mean maximum temperature ranges between ~24.9°C and 36.5°C, with monthly mean minimum temperatures ranging between 10.0°C and 21.5°C.
- High evaporation rates are observed in the Mount Isa region throughout the year with distinct seasonal patterns and low variability. The average annual evaporation is 3,066 mm/year with a range in mean daily evaporation of between 5.1 and 11.3 mm/day, with highest evaporation occurring during the wet season months.

Figure 3-2 presents the daily rainfall for the weather station at MIM (#029126) and the associated rainfall excess / deficit trend between 1960 and 2016. Rainfall excess / deficit trends are used to depict long term rainfall trends, which can be difficult to interpret from raw rainfall totals alone. They are based on actual rainfall comparison to long term average conditions, and are used to show seasonality in data, as well as long term trends, which may in some cases persist for decades. This presentation of data can also be used for comparison against groundwater level hydrographs, discussed further in Section 5.2.2.2 The graph shows the annual seasonality of the rainfall, as well as long periods of decline, where rainfall is lower than the long-term average and periods of recovery, for example between 1997 and 2012.

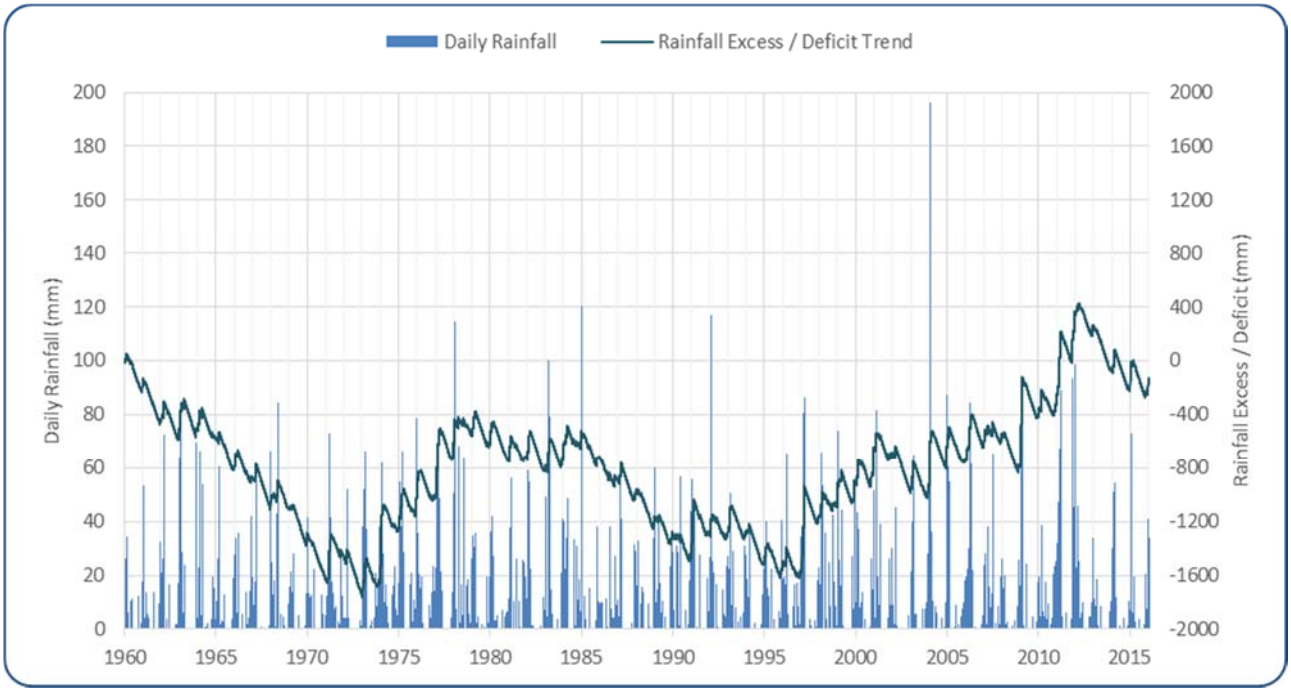

Figure 3-2: Daily rainfall and excess / deficit trend (Mount Isa Mine #029126)

3.5 Geological Setting

3.5.1 Regional Geology

Regionally, the Mount Isa Inlier encompasses the majority of the Mount Isa region. The Inlier comprises Early to Middle Proterozoic rocks and covers an area of approximately 50,000 km^2. Geological units of the Inlier have been subdivided into three broad north-south trending Provinces, namely:

- The Western Fold Belt Province;
- The Kalkadoon-Ewen Province; and,
- The Eastern Fold Belt.

The EE Study Area is located on the western portion of the Inlier within a sedimentary sequence regionally referred to as the Leichhardt River Fault Trough of the Western Fold Belt complex. The Mount Isa Group and Haslingden Group (Myally Subgroup) of geological units are present within the EE Study Area.

The sequence of rocks are interpreted to have been deposited in a rift-basin setting and comprises a series of upward fining and increasing carbonate sedimentary sequences. The Mount Isa Group comprises several formations in 5 km thick sequences of weakly metamorphosed mid-Proterozoic carbonate siltstones, mudstones and shales with basal sandstone and conglomerate units zone (Forrestal, 1990).

Regional deformation has tilted this sequence producing uniform westerly dipping (approx. 65°) bedding throughout the area. This pattern is modified at the site by parasitic folding. Asymmetrical folding on all scales occurs, the largest in the area being the Mount Isa Fold, with the majority of ore resources on the western limb of this fold system. Urquhart shears are axial

planar to the Mount Isa Fold, and form the eastern limits of the ore zone (Forrestal, 1990). The western extent of the ore zone is defined by the north-south striking Mount Isa Fault; a major structural lineament, steeply dipping towards the east.

The hydrostratigraphy of the localised geological units underlying and within the vicinity of the EE Study Area are outlined in Table 3-2, with the regional geological map shown in Figure 3-3. Geological formations located within the immediate EE Study Area are highlighted in bold text. Nomenclature presented in the table has been updated based on the Geology of Queensland (Jell, 2012).

3.5.2 Weathering

Weathering across the Mount Isa region is variable and influenced by the presence of sulphide minerals within geological structures. The weathering profile is divided into two distinct horizons classified based on the degree of oxidation and leaching. These horizons are separated by distinct boundaries, and include:

- The base of complete oxidation (BOCO) – which is represented by a level where all the sulphide minerals are completely oxidised, and the lithologies have been leached of readily soluble minerals; and,
- The base of moderate leaching (BOML) – is defined by the appearance of ore minerals and below which comprises of a zone where the lithologies are variably leached resulting in secondary porosity.

Beyond the mine area, these surfaces are not as easily distinguished and occur at approximately 15m below ground surface (KCB, 2013b).

3.5.3 Alluvium

Quaternary alluvial deposits are generally associated with drainage features across the Mount Isa area. These deposits typically comprise coarse sand and gravel deposits derived from the surrounding rock ridges, and are associated with streambed and active channel margins. These sediments are typically shallow and range from less than 3 m thick in smaller water courses to up to 15 m thick in larger drainage systems (e.g. Leichhardt River).

Table 3-2: Summary of the regional geology

Location	Parent Group	Unit Name	Unit Thickness (m)	Lithology Summary	Dominate Rock Types	Hydrostratigraphy
East of Mount Isa Fault	Mount Isa Group	Magazine Shale	unknown	Thin bedded calcareous sericitic shale, minor greenstone	Shale to siltstone, carbonaceous calcareous to dolomitic	Aquitard – generally forms ridges, only minor oxidation and leaching, minor storage potential in greenstone
		Kennedy Siltstone	300	Coarse bedded sequence of dolomitic and siliceous siltstone; sedimentary structure – cross-bedding, flute and load cast, slumping	Carbonaceous dolomitic and siliceous siltstone	Aquitard – generally siliceous, relatively unleached and unoxidised, strongly jointed and fractured
		Spear Siltstone	170	Thin (laminated) to medium bedded siltstone and shale	Carbonaceous calcareous to dolomitic siltstone	Aquitard – generally siliceous, relatively unleached and unoxidised, strongly jointed and fractured
		Urquhart Shale	920	Thin to coarse bedded, typically laminated, dolomitic and carbonaceous shale and siltstone with pyritic bands, deeply weathered and iron stained.	Carbonaceous dolomite shale and siltstone	Aquifer – oxidation and leaching enhance secondary porosity creating zones of high water storage, faulting also provides increased water storage conduits for groundwater movement and further leaching and oxidation
		Native Bee Siltstone	780	Bedded and laminated dolomitic, siliceous siltstone with interbeds of shale	Carbonaceous calcareous to dolomitic siltstone	Aquifer – faulting and weathering increases potential water storage and provide conduits for groundwater movement
		Breakaway Shale	600 – 1000	Laminated to thinly bedded pyritic to micaceous shale with minor siltstone	Carbonaceous and siliceous shale or siltstone	Aquitard – siliceous shales and slate, unleached and unoxidised.
		Moondarra Siltstone	1200	Medium to coarse bedded siltstone, dolomite minor shale with pyrite	Carbonaceous calcareous to dolomitic siltstone	Aquitard – siliceous minor leaching and oxidation
West of Mount Isa Fault	**Haslingden Group (Myally Subgroup)**	**Whitworth Quartzite**	**unknown**	**Massive medium to coarse feldspathic to quartzose sandstone, fine purple sandstone and mudflake conglomerate**	**Sandstone, conglomerate**	**Aquifer – faulting and weathering increases potential water storage, with some primary porosity**
		Bortala Formation (Judenan Beds)	**unknown**	**Flaggy, fine feldspathic sandstone, siltstone, micaceous siltstone, dolomitic sandstone, tuffaceous siltstone, grey-green chert**	**Conglomerate, sandstone, siltstone**	**Aquitard – occasionally quartzose shale may be locally permeable but is virtually unleached and unoxidised**
	Haslingden Group	**Eastern Creek Volcanics**	**>1000**	**Metamorphosed basalt, intercalated with silty and sandy sediments, quartzite tuff, pelitic schist, which is only minimally leached and oxidised**	**Metamorphosed basalt, silty and sandy sediments**	**Within the ECV, the Lena Quartzite forms an impervious groundwater barrier where relatively unsheared.**

*Blue fill indicates geological units which are within the immediate study area, underlying the BSOC WRD and TSF's.

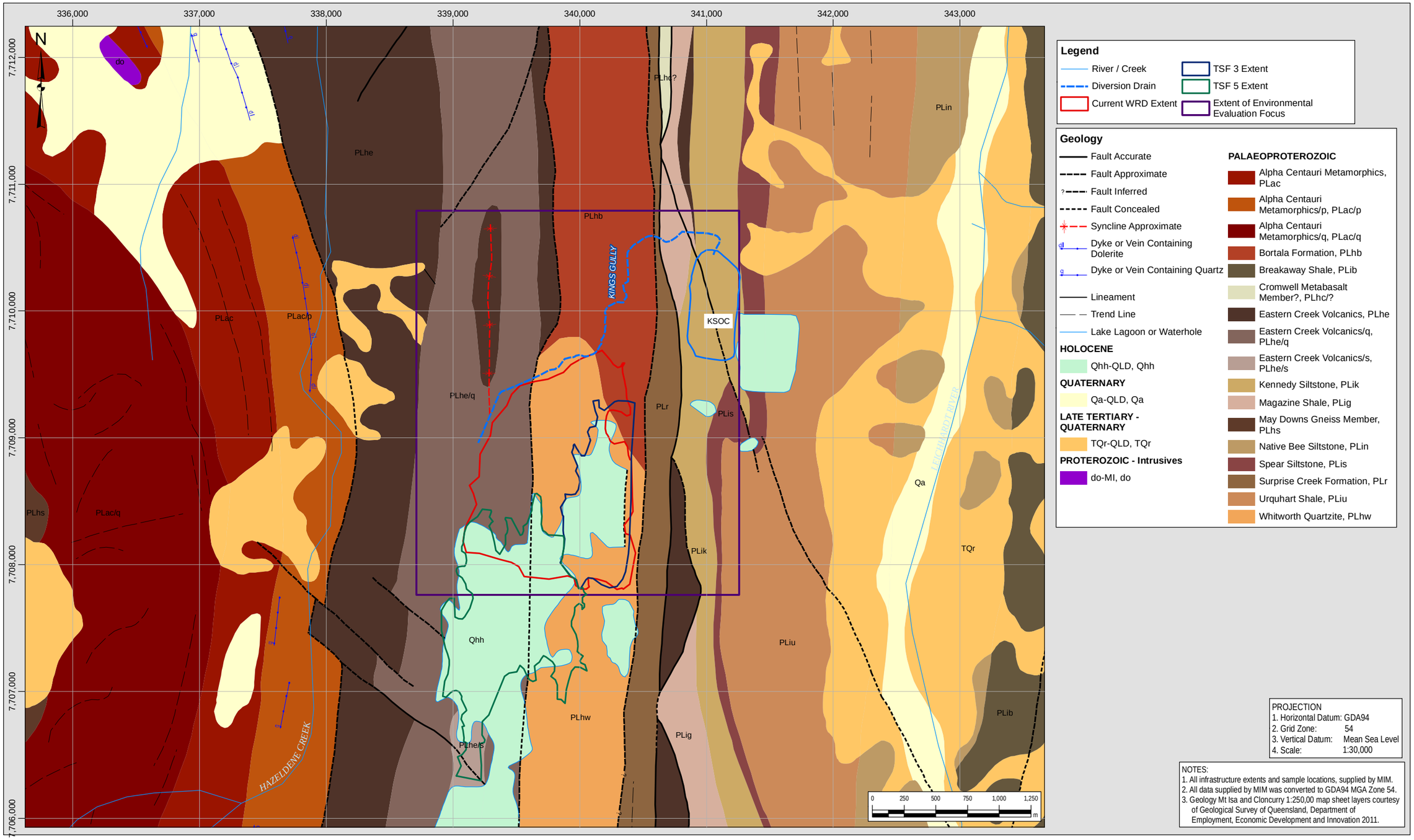

Figure 3-3: Regional geology map

3.6 Hydrogeological Setting

3.6.1 Aquifer Systems

In general, two aquifer systems are identified in the Mount Isa area.

- **Bedrock Aquifers** – are typically hosted in meta-sediment / meta-volcanics, comprising the Bortala Formation (Judenan Beds), Whitworth Quartzite, and Eastern Creek Volcanics (ECVs). Groundwater storage in this aquifer is typically limited to secondary porosity associated with localised zones of leaching, alteration and / or structural deformation (fracturing, bedding planes and brecciation). Of relevance to this assessment are the aquifer systems to the west of the Mount Isa Fault hosted within the Judenan Beds, Whitworth Quartzite and ECVs. Limited weathering / leaching and faulting / fracturing are observed within these stratigraphic units and primary porosity is low. Differential weathering in stratigraphic units of this aquifer has previously been estimated to a depth of 15 m. Previous investigations indicate that mine dewatering has a limited impact on groundwater levels in these aquifers west of the Mount Isa Fault due to limited hydraulic connectivity across the fault zone, as a result of the low permeability of the fault zone. The Mount Isa Fault behaves as a barrier to groundwater flow.
- **Alluvial Aquifers** – are interpreted as perched, unconfined aquifers associated with unconsolidated alluvial sediments adjacent to the Leichhardt River and other minor drainage systems across the project site. These aquifers are shallow and develop as a result of rainfall recharge and / or stream / river leakage. Due to the distinct seasonality of rainfall across the Mount Isa region, the majority of the watercourses across the region are ephemeral. As a result, for some minor water course the associated alluvial aquifers may also be ephemeral (i.e. no groundwater during the dry season).

3.6.2 Recharge

Generally, recharge to the bedrock aquifer is from direct rainfall infiltration. Recharge rates will be influenced by geological structures and the degree of weathering, with higher recharge rates anticipated for zones with increased porosity (higher weathering) and surface exposure of geological structures. Where more competent or unfractured rocks occur at the surface limited recharge is anticipated.

Localised recharge to the bedrock aquifers may also occur from infiltration from stream bed leakage of surface water features where watercourses and associated alluvial deposits overlie fractured bedrock units. However, since the local creeks flow intermittently and areas of streambed are frequently dry, the potential for connectivity between surface and groundwater is limited, with the exception of larger watercourses which comprise saturated / partially saturated alluvial profiles (e.g. Leichhardt River).

For the alluvial aquifers recharge would occur via a combination of direct rainfall infiltration and creek / river leakage. Due to the relatively high porosity of the unconsolidated alluvial sediments, the recharge rate for the alluvial aquifer would be relatively high. The recharge rate would decrease as the alluvial aquifer saturates and reaches storage capacity. Once at aquifer capacity, direct rainfall would only result in surface water runoff.

3.7 Ecological Setting

The Mount Isa Mine is located in the Northwest Highlands bioregion. The highly seasonal nature of the environment affects biodiversity and environmental cues within ML8058, particularly post-wet season when rainfall results in higher botanical recruitment and increased fauna species and populations recorded during biodiversity surveys (Amec Foster Wheeler, 2015).

ML8058 is characterised by rugged, rocky hills and poor shallow soils. The vegetation reflects the complex geology, infertile soil and semi-arid climate. Low open woodland with Eucalyptus, Corymbia and Acacia species predominates, with a ground layer of Triodia species (spinifex). ML8058 is surrounded by (and overlays) neighbouring pastoral leases, which are used for rangeland grazing. Conditions are unsuitable for improved pasture so clearing of native vegetation has generally been limited to areas required for mining and supporting infrastructure.

MIM has commissioned various biodiversity studies and surveys across ML8058 over the past few years, and this has included the mapping and ground-truthing of regional ecosystems (Amec Foster Wheeler, 2015). These investigations identified that overall native vegetation communities across ML8058 are in moderate to good condition, meeting remnant status and close to benchmark values.

A more detailed summary of the terrestrial flora and fauna, and the aquatic flora and fauna, within the EE investigation area is provided in Sections 2.2, 2.3 and 2.4 of the BSOC Environmental Evaluation Receiving Environment (Flora and Fauna) Assessment report (Amec Foster Wheeler, 2016), which is provided in Appendix IV.

4 SITE INFRASTRUCTURE

MIM currently operates two separate mining and processing operations for copper and lead-zinc on ML8058 and includes crushing plants, mills, two concentrators, and lead and copper smelters. The main infrastructure relevant to this study include:

- BSOC WRD – construction commenced in 2004 and stores waste rock from the BSOC Pit.
- Tailing Storage Facilities (TSF): TSF3 and TSF5, commissioned and operated between 1946 and 1955 (TSF3) and 1958 and 1964 (TSF5) (Forsyth, 2014).
- The MIM landfill, which has been in operation for more than 30 years and is located to the east of the BSOC WRD.

The following sections 4.1 to 4.3 provide further details on these facilities, respectively, with the location of these facilities presented in Figure 4-1.

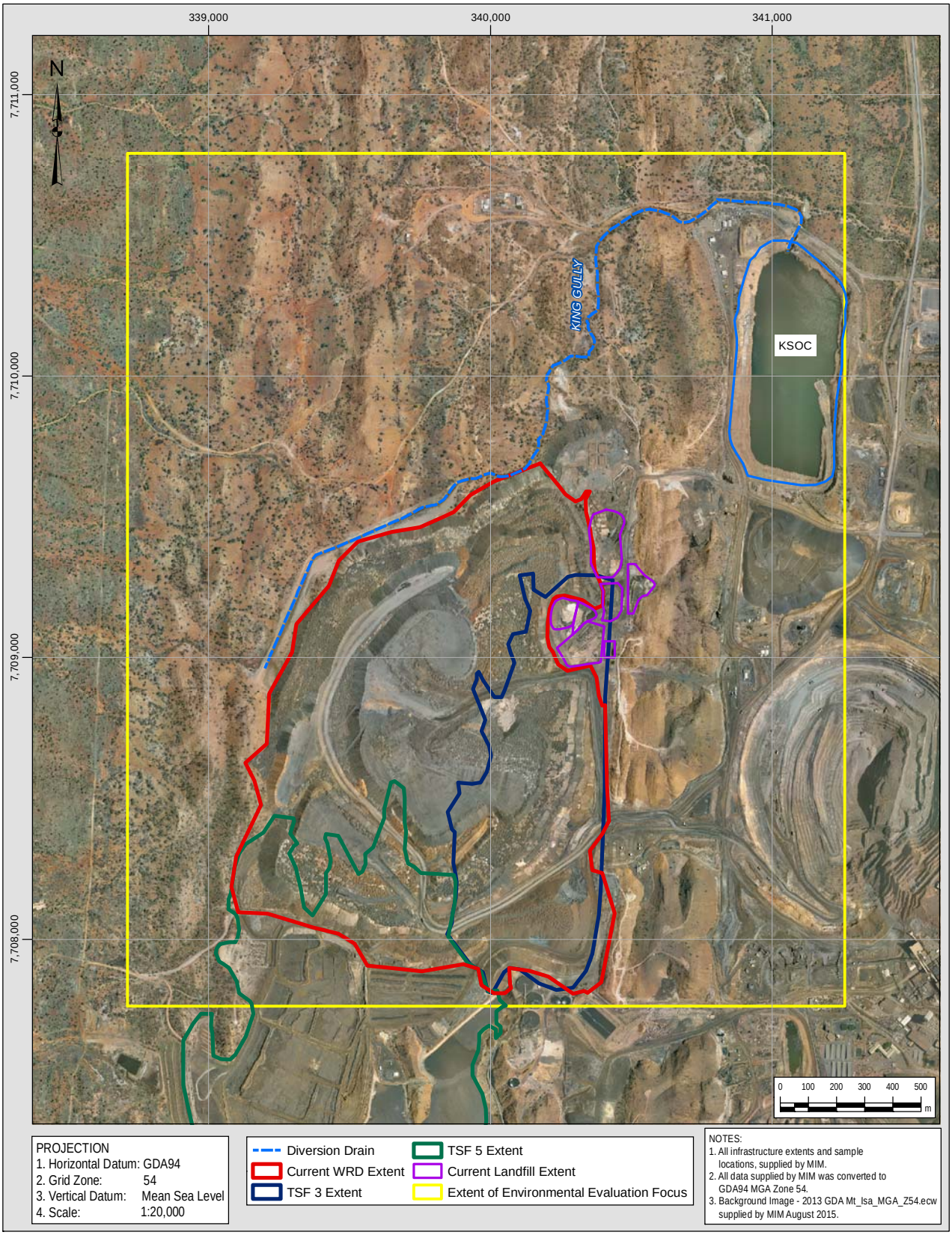

Figure 4-1: Location of BSOC WRD (current extent), TSF3, TSF5 and Landfill extent (current)

4.1 Black Star Open Cut (BSOC) Waste Rock Dump (WRD)

4.1.1 Physical Characteristics

The BSOC WRD is a valley-fill waste rock storage facility and has been in construction since 2004 containing material from the BSOC pit zinc-lead mining operations. The WRD was constructed entirely over the existing TSF3 and partially over the northern extent of TSF5. Figure 4-2 shows a photograph of the current construction of BSOC WRD (August, 2015), facing to the north.

Figure 4-2: BSOC WRD, facing north (August, 2015)

The WRD design was based on the principal of progressive encapsulation of Potentially Acid Forming (PAF) waste rock material by Non Acid Forming (NAF) waste material, resulting in PAF cells. A basal layer of NAF, of 10 m thickness, was placed on top of TSF3 to form the base of the PAF cell, while a 20 m buffer of NAF was placed onto the natural topography along the WRD base prior to the placement of PAF material. The 20 m NAF buffer was retained along the sides of the WRD adjacent to the natural topography. The design capacity of the BSOC WRD is 147 Mt, which equates to a height of 87 m above the original surface level. Currently, the WRD is scheduled to be placed in care-and-maintenance in H2 2016 (MIM, 2014a).

In 2011, a Diversion Drain was constructed along the western and northern margin of the BSOC WRD. The intent of the Diversion Drain was to manage runoff and seepage water discharging from the BSOC WRD to the Kennedy Siltstone Open Cut (KSOC) process water pit via King Gully and the King Gully "first-flush" diversion weir. The Diversion Drain is referred to within the EA as the 'BSOC WRD West Diversion Drain' and is listed as a 'Regulated Dam' in the Mount Isa East Containment Area (EA, *Appendix 1, Table 1*). The Diversion Drain and transfer of seepage water is therefore included as an 'Authorised Mining Activity' under the EA.

In 2014, the King Gully Dam and associated infrastructure were installed within King Gully to collect the seepage water and pipe it to KSOC Pit as part of the clean and dirty water separation project, as shown in Figure 4-3.

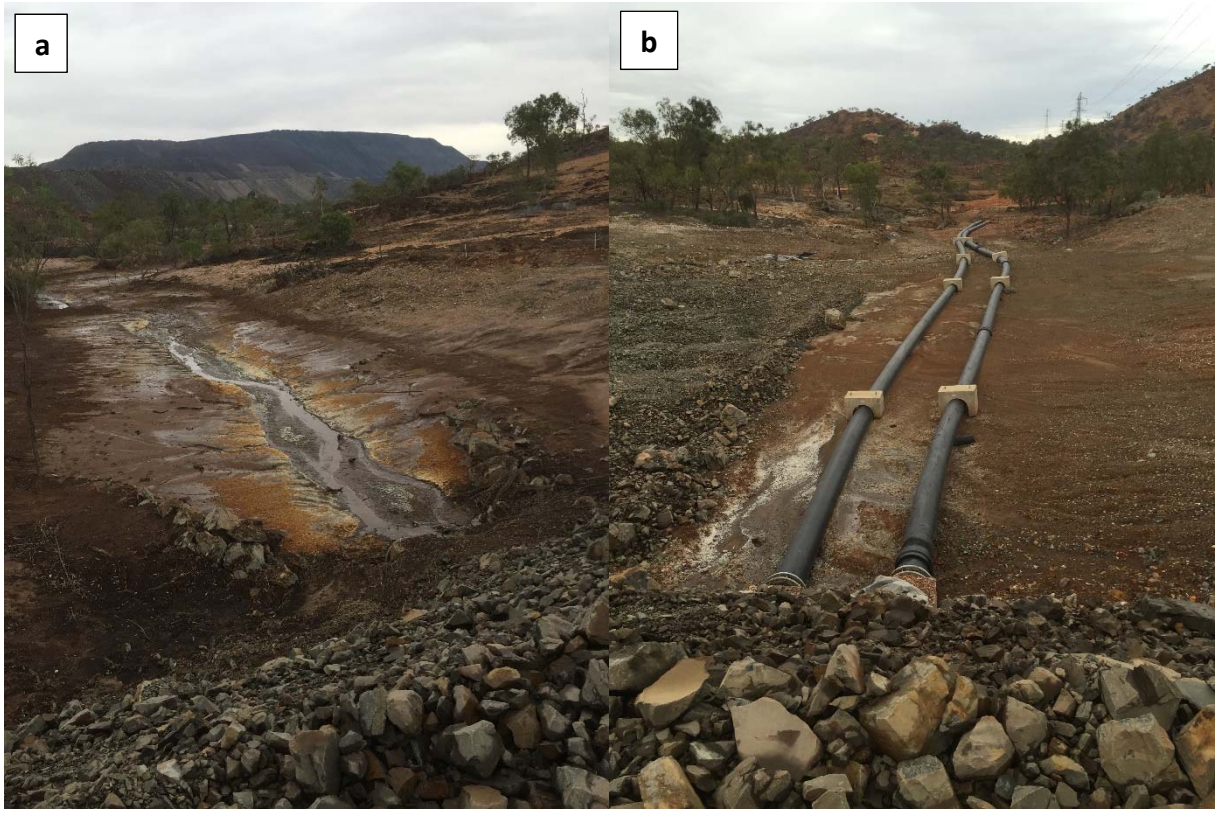

Figure 4-3: King Gully Dam. a) upstream facing south, with BSOC WRD in the background, b) downstream, facing north, where seepage is piped to KSOC (August, 2015)

4.1.2 Geochemical Characteristics

Waste rock from the BSOC pit placed within the WRD includes Urquhart Shale, Kennedy Siltstone, Spear Siltstone and Eastern Creek Volcanics. The acid-base characteristics of the waste rock in the BSOC WRD have been described extensively in a number of reports and research work (e.g. KCB 2011, 2012, 2013, 2014; Forsyth 2014, unpublished thesis) and are summarised in Table 4-1 which includes ore samples for comparison. These samples were chosen based on previous studies, which have identified (from a large dataset) these samples to be representatives of the waste rock (and ore) and are therefore considered appropriate to this study. A number of the samples have high sulphur concentrations and are considered as PAF.

Table 4-1: Acid-base accounting summary statistics for representative BSOC waste rock samples

Lithology	Statistics	Total S %	ANC (kg H_2SO_4/t)	MPA (kg H_2SO_4/t)	NAPP (kg H_2SO_4/t)	NPR
Eastern Creek Volcanics (ECV)	*Mean*	0.0026	60.96	0.08	-60.88	789.02
	Median	0.0025	54	0.08	-53.92	705.88
	Maximum	0.006	310	0.18	-2.42	4052.29
	Minimum	0.0025	2.5	0.08	-309.92	32.68
	Standard Deviation	0.0006	58.56	0.02	58.56	770.3
	Count	51	51	51	51	51
Kennedy - Spears	*Mean*	0.35	133.51	10.69	-122.83	1114.74
	Median	0.0025	110	0.08	-99.92	124.43
	Maximum	8	900	244.8	134.8	11764.71
	Minimum	0.0025	0.5	0.0765	-899.92	0.05
	Standard Deviation	1.19	143.16	36.27	150	1921.3
	Count	153	153	153	153	153
Urquhart	*Mean*	3.22	111.2	98.55	-12.65	315.3
	Median	0.21	9.5	6.43	-0.82	1.48
	Maximum	22	520	673.2	472	6274.51
	Minimum	0.0025	0.25	0.0765	-489.76	0.001
	Standard Deviation	5.54	160.14	169.4	210.1	1209.45
	Count	212	212	212	212	212

ANC – Acid Neutralisation Capacity
MPA – Maximum Potential Acidity
NAPP – Net Acid Producing Potential
NPR – Neutralisation Potential Ratio
Mean NPR – Calculated from individual samples.

Comparison of whole-sample concentration has been undertaken for the main waste rock types in BSOC WRD using data from previous studies. Whole-sample refers to analysing the entire sample of a particular waste rock or tailings material. For solid samples, this is achieved by either dissolving the entire sample with acid and analysing the composition using mass spectrometry, or fusing a portion of the sample into a 'glass' disk and analysing using X-ray fluorescence (XRF) spectroscopy. The comparisons are shown in Figure 4-4 and Figure 4-5. The following observations are made:

- In general, Urquhart Shale waste rock samples have the highest zinc, iron and lead, as would be expected in material that contains the majority of the ore bodies.
- The Kennedy-Spears waste rock samples have higher zinc and iron concentrations than the Eastern Creek Volcanic (ECV) samples.
- Kennedy-Spears waste rock samples also have greater concentrations of lead compared to the ECV samples (at least one order of magnitude greater in most cases.
- Manganese and cadmium concentrations are comparable between the waste rock types, although some Urquhart Shale samples exhibit increased cadmium (Figure 4-5).
- Kennedy-Spears and Urquhart Shale samples have comparable sulphur concentrations but Urquhart Shale waste rock samples generally have far higher iron concentrations (Figure 4-5).

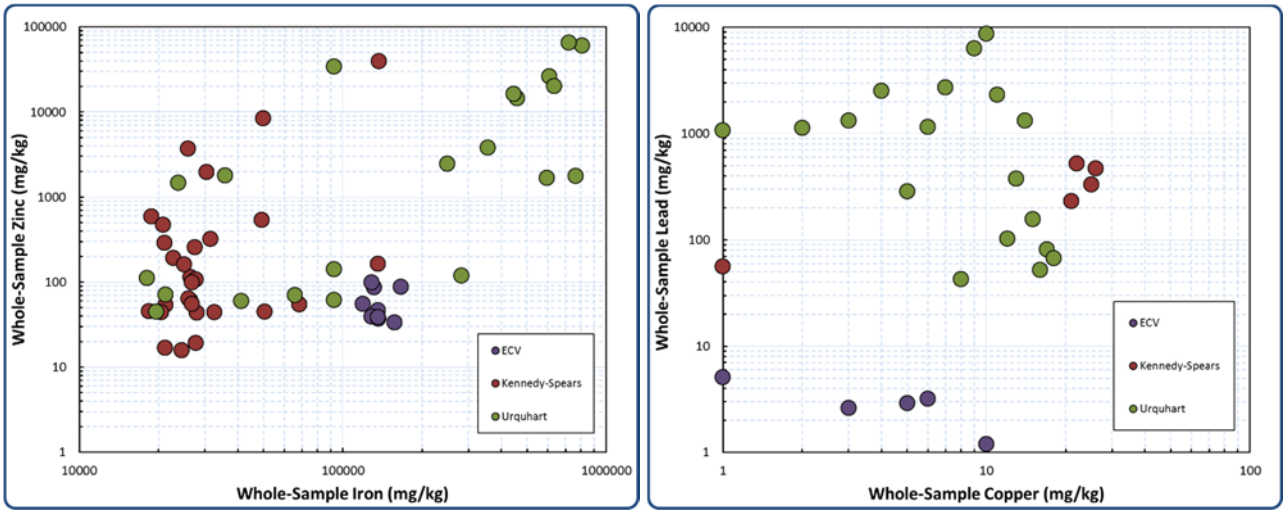

Figure 4-4: Whole-sample concentrations of the main waste rock samples a) iron and zinc concentrations, b) copper and lead concentrations

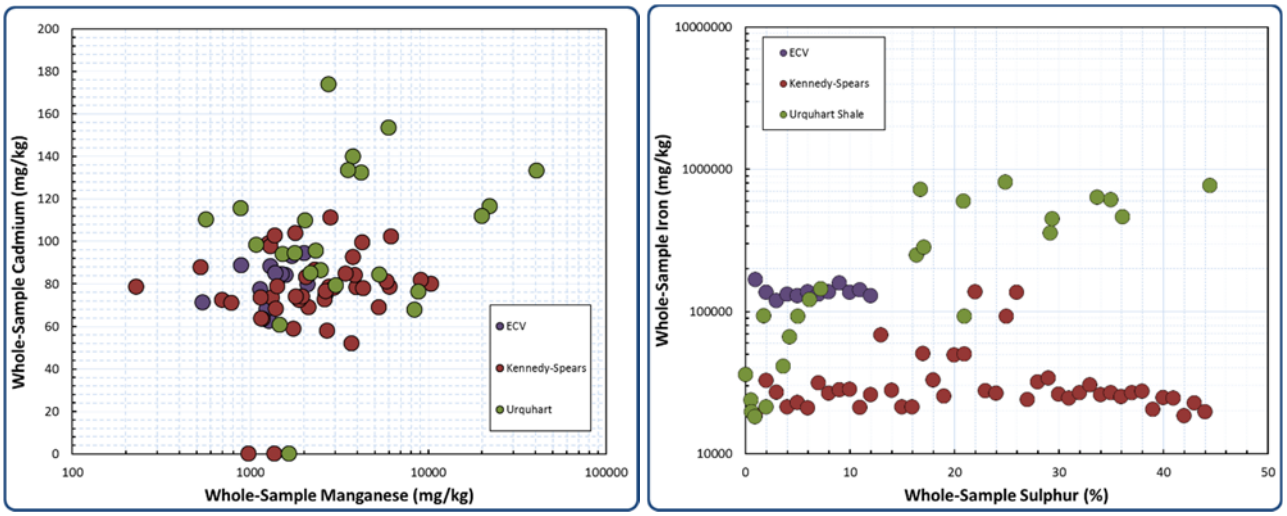

Figure 4-5: Whole-sample concentrations of the main waste rock samples a) manganese and cadmium concentrations, b) sulphur and iron concentrations

4.2 Tailings Storage Facilities

4.2.1 Physical Characteristics

Tailings Storage Facilities (TSF) 3 and 5 cover an area of approximately 182 Ha and 189 Ha, respectively. These TSFs are unlined valley-fill facilities and have been inactive for many years; TSF3 was in operation between 1946 and 1955, and TSF5 was in operation between 1958 and 1964 (Forsyth, 2014).

From the 1970s, a portion of the northern end of TSF3 was partially buried by the MIM landfill, as shown in Figure 4-1. Historical photographs provided by MIM, dated 1997 (Figure 4-6) show that the southern end of TSF3 was rehabilitated (revegetated).

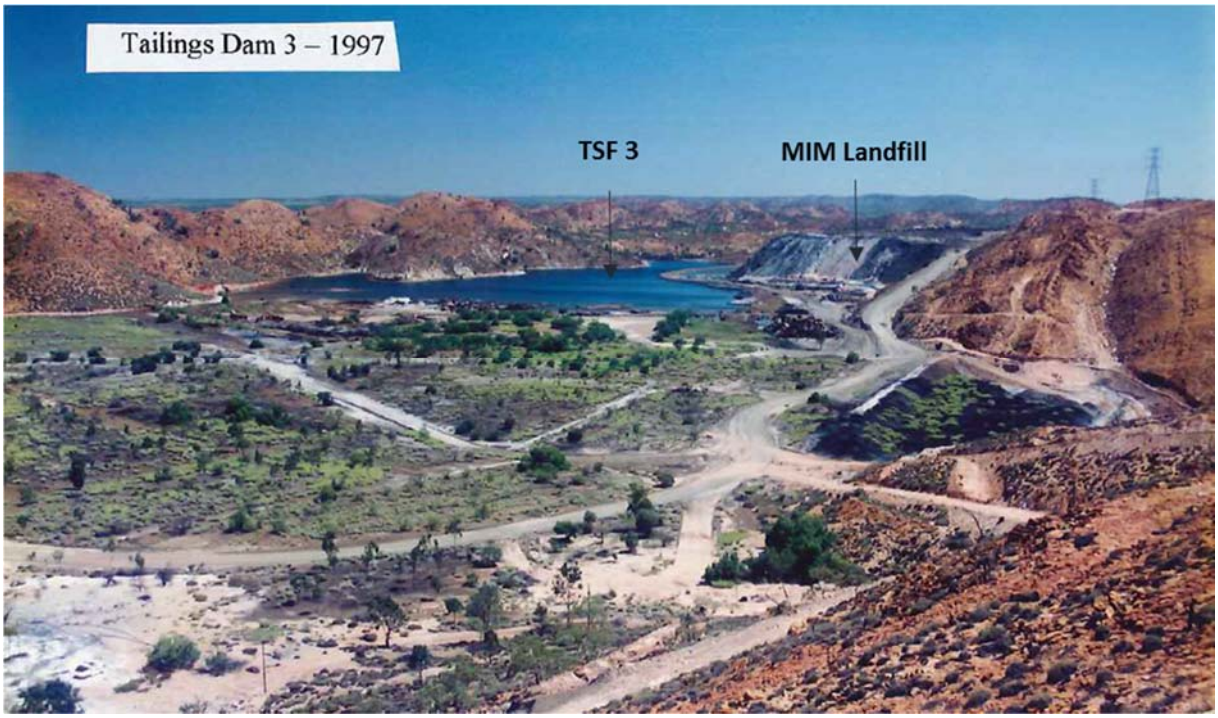

Figure 4-6: TSF3 historical photograph from 1997 facing north and shows the partially rehabilitated TSF3 and MIM landfill to the east

Construction of the BSOC WRD, which began in 2004, resulted in the progressive burial of the remainder of TSF3 and a northern portion of TSF5. During construction of the WRD, a 3 m gravel cap was placed on three-quarters of the TSF3 surface. At the commencement of the WRD construction tailings in TSF3 was estimated to have been up to 25 m thick.

Figure 4-7 shows a photograph of BSOC WRD and TSF5 where it is not covered by the WRD, facing south. Mining of tailings materials from TSF5 has been undertaken since 2011 to be used as paste fill underground at the George Fisher Mine. Mining of these tailings has resulted in the exposure of the base of TSF5 and ponding of tailings water, resulting from the desaturation of the adjacent tailings profile. This occurs within the northern area of TSF5, adjacent to the southern extent of BSOC WRD. The ponded tailings water is managed via a sump and pump-back system, with ponded water pumped back to the KSOC Pit.

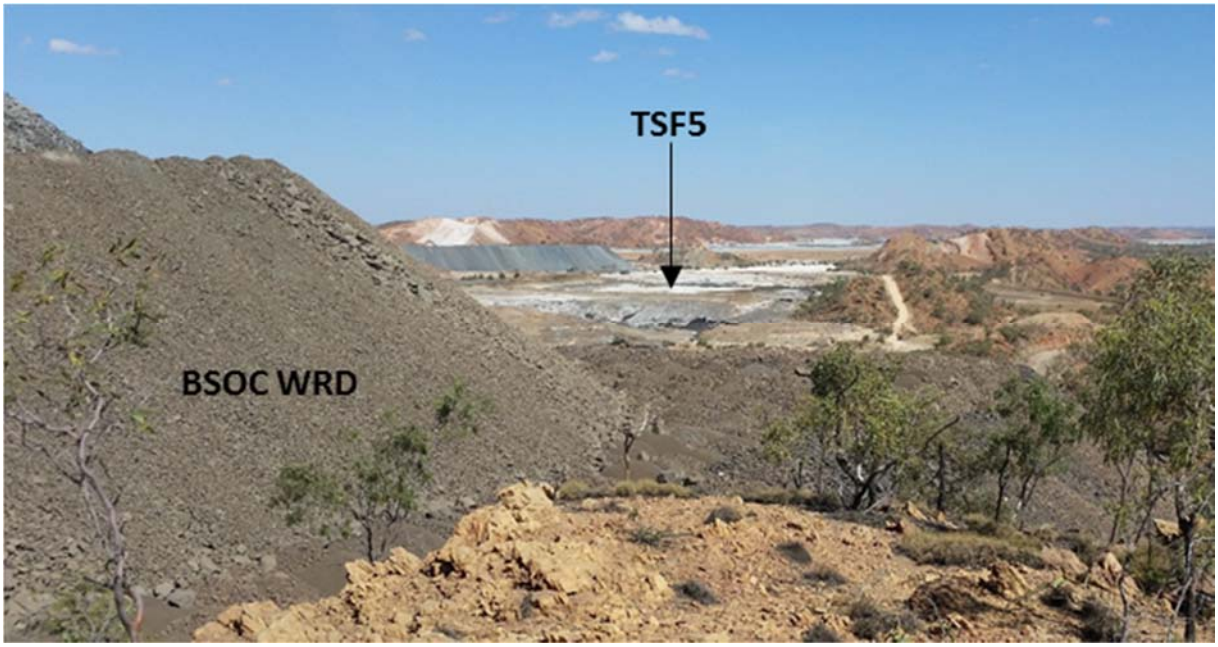

Figure 4-7: Photograph facing south showing BSOC WRD and TSF5 where it is not covered by BSOC WRD (August, 2015)

4.2.2 Geochemical Characteristics

The acid-base characteristics of the tailings have been described in a number of reports and research work (e.g. KCB 2011, 2012, 2013, 2014; Forsyth 2014, unpublished thesis) and are summarised in Table 4-2. Subsequent descriptions in this section make use of the 'historic' data found in these reports. The copper, lead-zinc-silver and mixed copper and lead-zinc samples have high sulphur concentrations and are described as PAF.

Table 4-2: Summary of MIM Tailings Characteristics

Sample	pH	EC	MPA	ANC kg H_2SO_4	NPR (ANC/MPA)	NAPP (MPA-ANC)	Total sulphur %	Oxidisable sulphur	NAG pH
84 Copper (401)	6.8	2000	94.95	90	0.95	4.95	3.1	3	7.3
86 Copper (413)	7.5	2400	116.39	100	0.86	16.39	3.8	3.7	6.9
85 Copper (407)	7.8	2600	119.46	100	0.84	19.46	3.9	3.8	7.6
84 Mixed (403)	7.2	2100	248.10	100	0.40	148.10	8.1	7.4	7.6
85 Mixed (409)	7.5	2500	336.93	110	0.33	226.93	11	10	7.7
86 Mixed (415)	7.8	2600	266.48	110	0.41	156.48	8.7	8.2	7.8
84 Lead-Zinc (405)	7.5	2300	398.19	230	0.58	168.19	13	10	7.9
85 Lead-Zinc (411)	7.7	2500	367.56	220	0.60	147.56	12	8.9	7.8
86 Lead-Zinc (417)	7.9	2700	398.19	230	0.58	168.19	13	10	7.9
Minimum	**6.8**	**2000**	**94.95**	**90**	**0.33**	**4.95**	**3.1**	**3**	**6.9**
Maximum	**7.9**	**2700**	**398.19**	**230**	**0.95**	**226.93**	**13**	**10**	**7.9**
Median	**7.5**	**2500**	**266.48**	**110**	**0.58**	**148.10**	**8.7**	**8.2**	**7.7**

ANC – Acid Neutralisation Capacity
MPA – Maximum Potential Acidity
NAPP – Net Acid Producing Potential
NPR – Neutralisation Potential Ratio
NAG – Net Acid Generation

Figure 4-8 and Figure 4-9 compare the whole-sample sulphur and iron concentrations of copper tailings, lead-zinc-silver tailings, mixed tailings and samples from TSF3 and TSF5, which were analysed prior to construction of BSOC WRD over the TSF's (URS, 2004). Also shown are concentrations from the Urquhart Shale (waste rock), which contains the majority of the zinc-ore bodies.

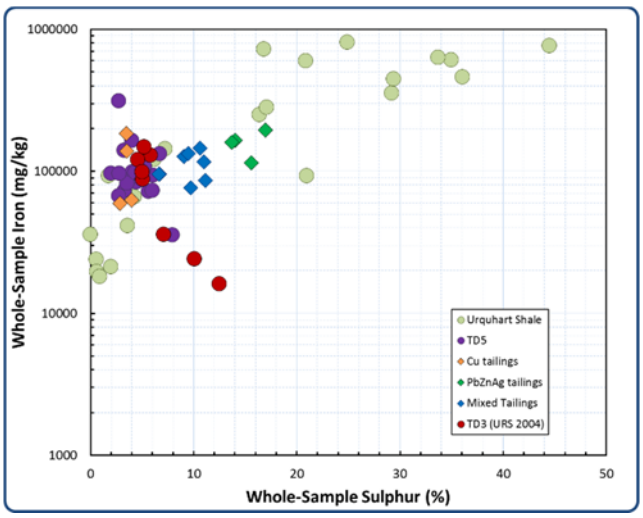

Figure 4-8: Whole-sample sulphur and iron concentrations of the copper, lead-zinc-silver and mixed tailings, compared to concentrations taken from TSF3 and TSF5.

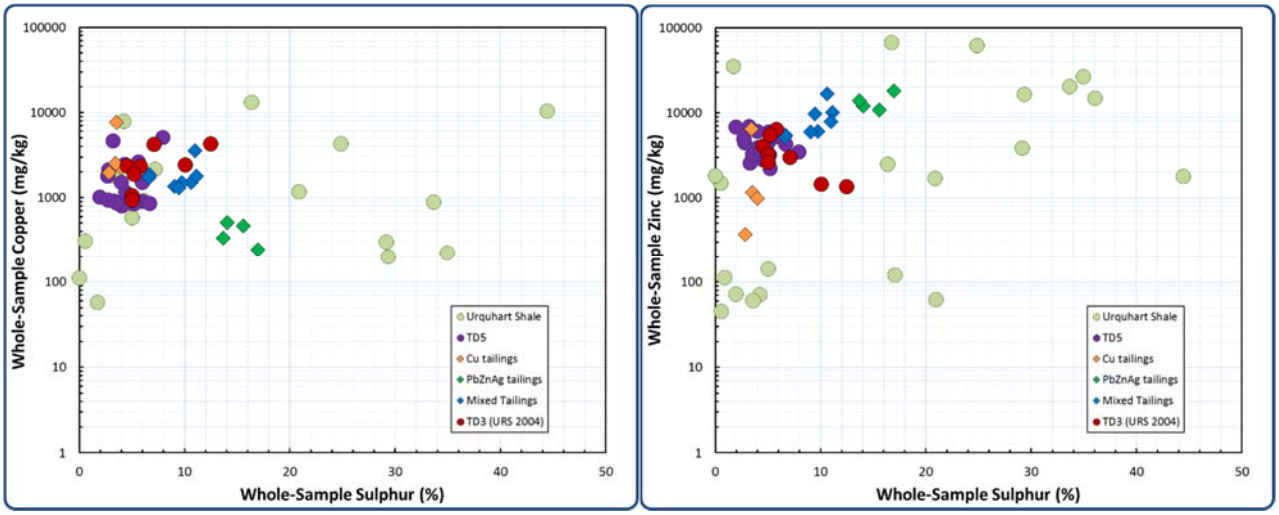

Figure 4-9: Whole-sample concentrations of the copper, copper-zinc and mixed tailings, compared to concentrations taken from TSF3 and TSF5, a) sulphur and copper concentrations, b) sulphur and zinc concentrations

As may be expected, all tailings samples have similar iron concentrations; the lead-zinc-silver and mixed tailings have higher sulphur concentrations. Whole-sample copper and zinc concentrations follow the tailings type; TSF3 and TSF5 have similar copper and zinc contents.

4.3 Mount Isa Mines Landfill Facility

The MIM landfill has been in operation for more than 30 years and was partially constructed over the existing TSF3. The site is located to the east of the BSOC WRD, as shown in Figure 4-1.

Waste disposal within this facility is authorised by the EA, which provides criteria for waste disposal and acceptance and states that the waste disposal must not extend beyond the boundary of the Mount Isa Mines Landfill.

The MIM landfill is authorised by the EA to accept the following waste types:

- Domestic waste;
- Commercial waste;
- Industrial waste;
- Regulated waste (subject to hazardous characteristics,Table 4-3);
- Construction and demolition waste; and
- Liquid waste and wastes yielding free liquid must only be disposed of in a dedicated cell (sludge pit).

Table 4-3: Waste Hazard Characteristics (Schedule F – Table 1)

Hazard Characteristic	Description of the Hazard Characteristic
Ignitability	Regulated wastes that are capable of causing a fire when ignited through friction, absorption of moisture, or spontaneous chemical changes under standard temperature and pressure
Corrosivity	Regulated wastes which on dissolution exhibit a pH of 2 or less or 12.5 or greater
Reactivity	Regulated wastes that have any of the following properties: ▪ React violently with water; and/or, ▪ Form potentially explosive mixtures with water and other substances likely to be disposed of in the landfill facility; and/or, ▪ Generate toxic gases, vapours, or fumes dangerous to human health or the environment when mixed with water and other substances likely to be disposed of in the landfill facility; and/or, ▪ Contain substances which generate toxic gases, vapours or fumes when exposed to pH conditions between 2 and 12.5; and/or, ▪ Are capable of detonation or explosive reaction when subjected to a strong initiating sources or if heated under confinement; and/or, ▪ Are readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.

The location of each of the EA authorised waste types are shown on Figure 4-10, with the outline of the landfill area. The figure also shows BSOC WRD to the west of the landfill area. The waste cells directly overlying TSF3 are the general waste, tyre cell and contaminated cells, as well as the sludge pits. Regulated wastes which exhibit the hazard characteristics outlined in Table 4-3 can only be disposed of in the sludge pit or contaminated cells at the MIM Landfill, as shown on Figure 4-10.

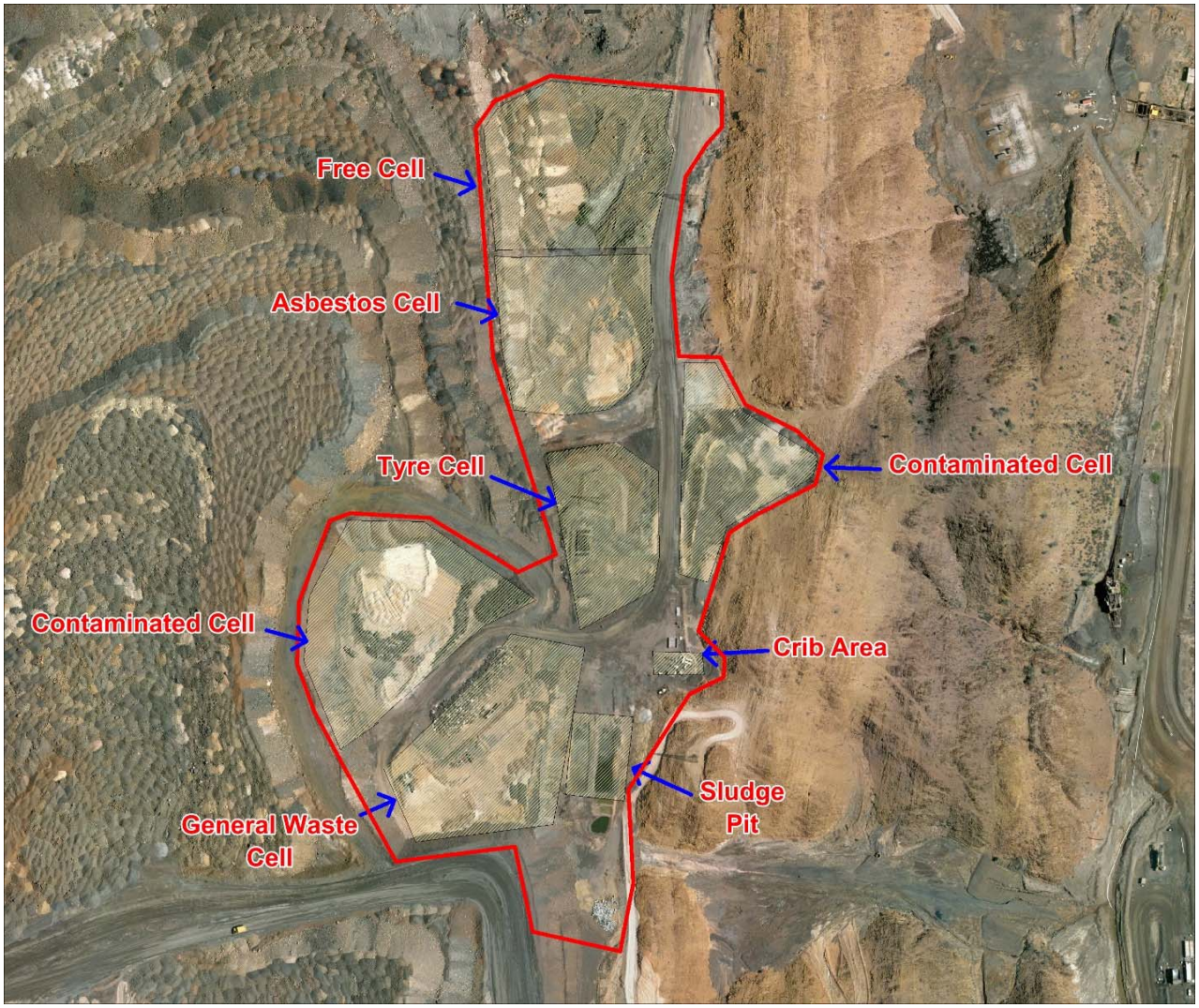

Figure 4-10: Outline of Mount Isa Landfill and associated authorised waste cells from the EA Schedule K (Figure 11)

The two sludge pits, shown in Figure 4-11, are unlined and used to dispose of liquid wastes from the MIM site and some external facilities. A landfill register of liquid waste placed in the sludge pits has been maintained since September 2009. This register indicates approximately 3.4 ML of liquid waste is placed in the sludge pits each year.

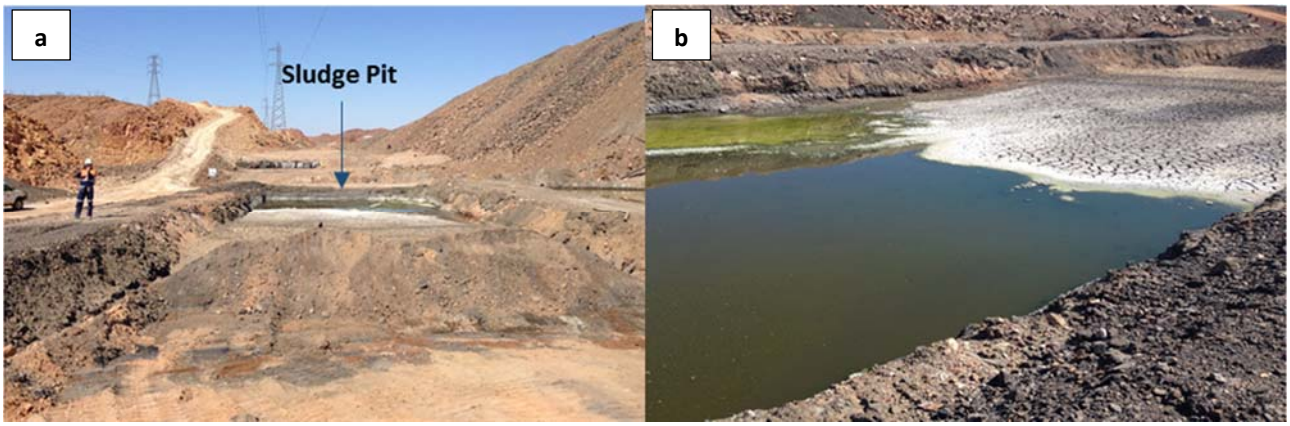

Figure 4-11: Sludge Pits. a) Sludge pit facing south, b) Sludge pit east wall facing west (August, 2015)

5 BSOC WRD SEEPAGE SOURCE, CAUSE AND EXTENT

This section of the report provides information on the source, cause and extent of the seepage associated with the BSOC WRD and addresses item 1 (a, b, c) of the EE Notice.

An overview of each of the seepage locations identified in the EE Notice is also provided in this section (section 5.1) of the report.

To provide additional understanding of the seepage associated with BSOC WRD and the underlying site infrastructure, site investigations were undertaken in August and December, 2015 by KCB personnel (Appendix II). These site investigations also aimed to address data gaps identified as part of the preliminary site understanding and data gap assessment (KCB, 2016). Two phases of site investigation were undertaken:

- Phase 1: Site inspection and field mapping, undertaken in August, 2015 by KCB Hydrogeologists.
- Phase 2: Drilling, testing and sampling, undertaken in December, 2015 by KCB Hydrogeologists and January, 2016 by MIM personnel.

The methods and results of these site investigations are further outlined below.

It should be noted that the following terminology is used in the following sections:

> ***BSOC WRD Landform:*** *Refers to all infrastructure within the footprint of BSOC WRD, including BSOC WRD, MIM Landfill, TSF3 and part of TSF5.*

5.1 BSOC WRD Landform Seepage

Seepage associated with the BSOC WRD landform generally occurs at three locations around the landform, as shown in Figure 5-1. The seepage locations were identified within the EE Notice and referred to as:

- BSOC WRD South Seepage;
- BSOC WRD North Seepage; and
- TD3 Seepage.

A description of each of the seepage points is provided in the following section.

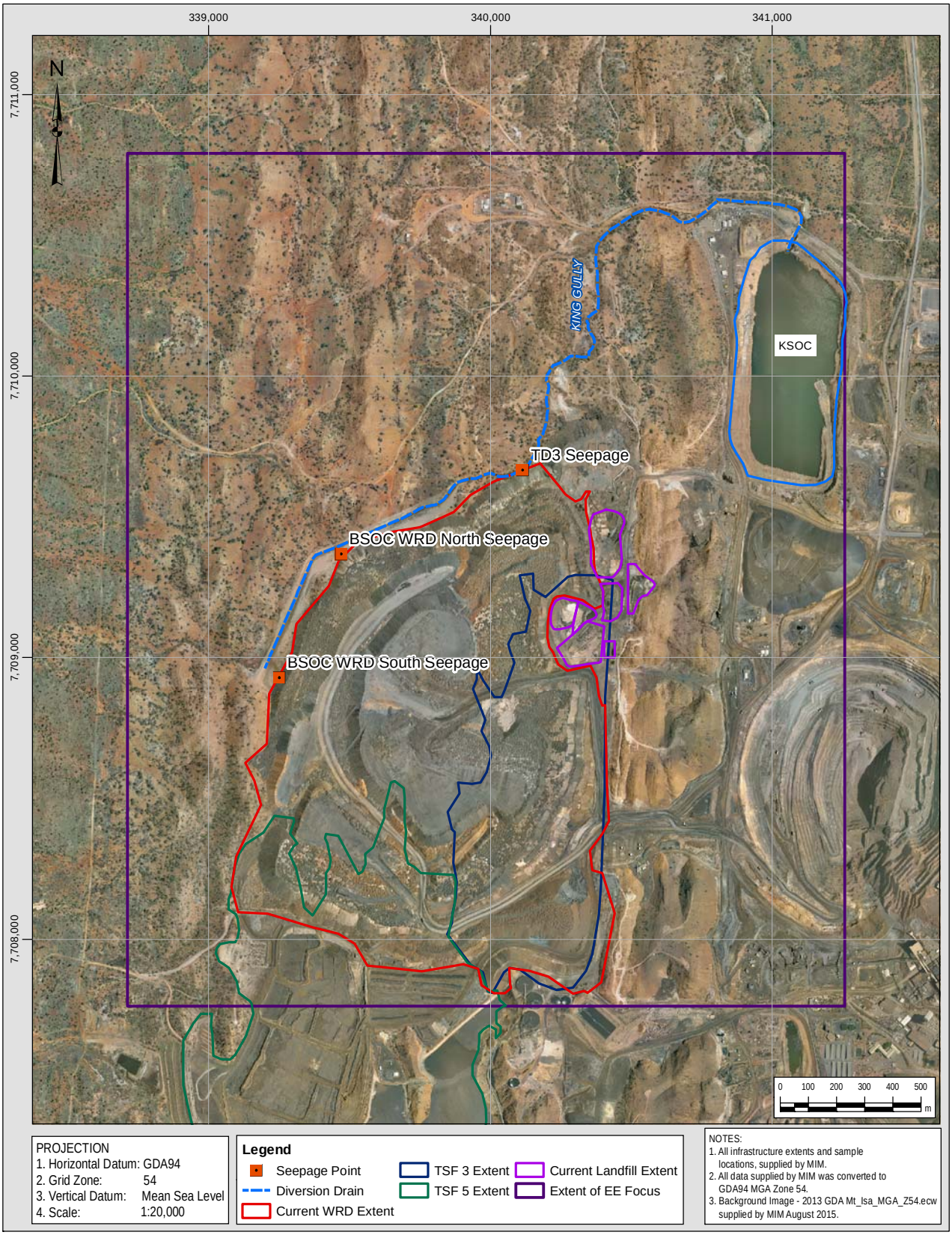

Figure 5-1: Location of Seepage associated with BSOC WRD Landform

5.1.1 BSOC WRD South Seepage

BSOC WRD South Seepage has been monitored by MIM since 2011. The location of the south seepage aligns with a natural drainage line now covered by the WRD. Prior to construction of the WRD, a dam wall / spillway for TSF5 was installed at the headwaters of this watercourse and historical aerial photographs indicate the presence of salt precipitation, which may suggest that seepage occurred downstream from the TSF5 spillway (Figure 5-2). However, natural occurrence of mineral precipitation on the ground surface has been identified during previous investigations undertaken at the MIM site (CMLR, 2009; AGE, 2002).

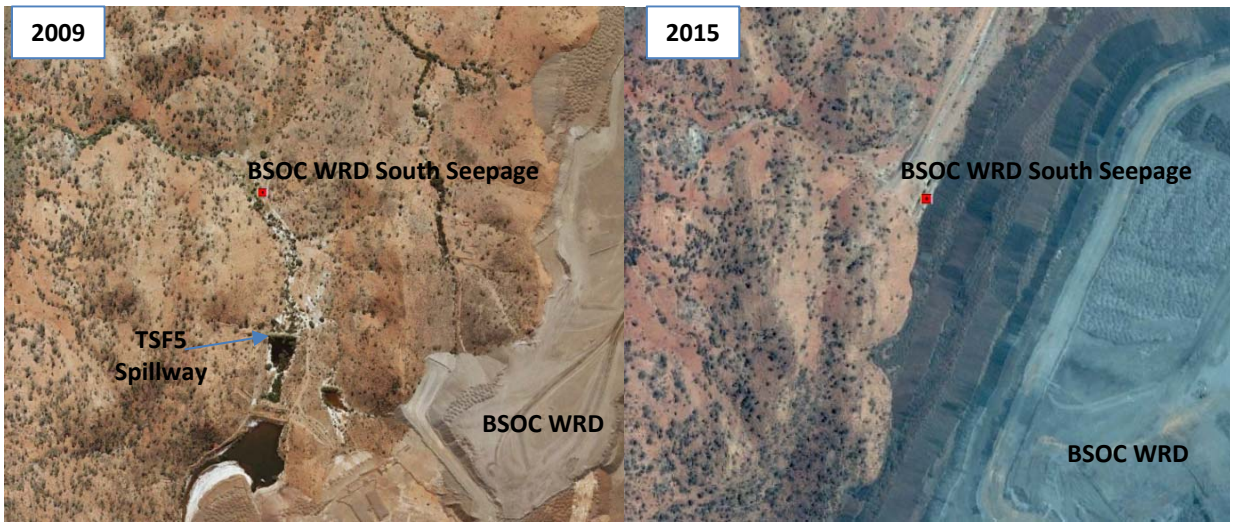

Figure 5-2: Aerial photographs of BSOC WRD South Seepage point in 2009 prior to WRD construction (left) and after WRD construction (right) in that area

Prior to the installation of the Diversion Drain, surface water flow at the BSOC WRD South Seepage location was towards the west, with the original watercourse being a tributary of Hazeldene Creek.

Multiple seepage points are observed at the BSOC WRD South Seepage, and as a result MIM have excavated a trench to allow the collection of seepage from each of these sources (Figure 5-3 and Figure 5-4). The collected seepage is mechanically transferred into the Diversion Drain, also shown in Figure 5-3, via a transfer pump, which is manually operated when the water level in the collection trench rises.

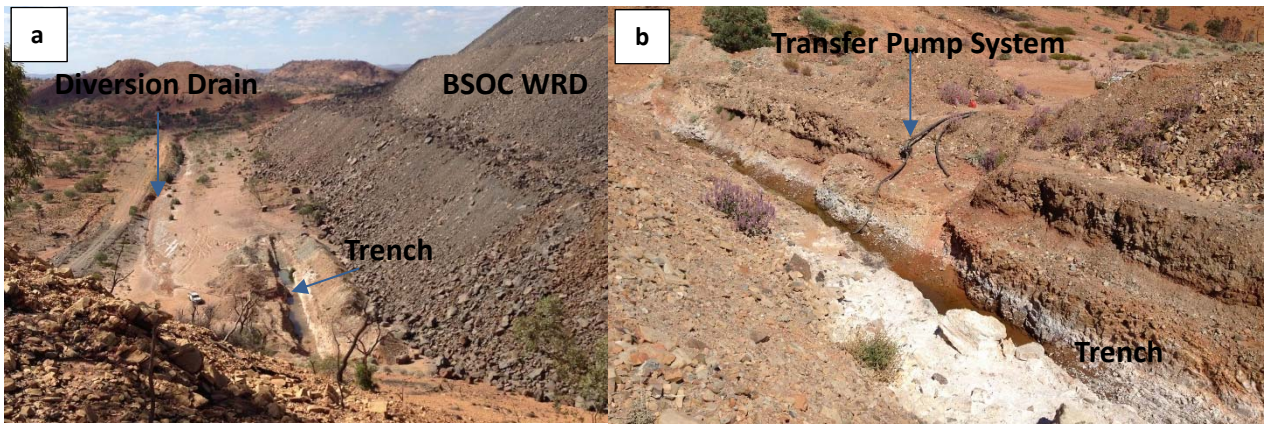

Figure 5-3: BSOC WRD South Seepage. a) Facing north, with the Diversion Drain, WRD and trench shown, b) Trench and transfer pump system (August, 2015)

Figure 5-4: BSOC WRD South Seepage. a) Facing north, toe seepage behind the trench, b) Collection of seepage within the trench (facing south) (August, 2015)

Seepage at the BSOC WRD South Seepage point occurs throughout the year, however, visual inspections indicate some seasonality influence in the flow rates (increased rates during the wet season). Monitoring of seepage rates / volumes had not been undertaken prior to this investigation, however, flow monitoring facilities have been installed in the Diversion Drain as part of this investigation to allow future monitoring (discussed further in Section 5.3.1).

5.1.2 BSOC WRD North Seepage

BSOC WRD North Seepage has also been monitored by MIM since 2011. The location of the north seepage aligns with a natural drainage line, which is now covered by BSOC WRD. Surface water flow from this watercourse, prior to the installation of the diversion, was towards the north, before flowing towards the north-west and joining Hazeldene Creek. Historical aerial photographs (Figure 5-5) before the construction of the WRD provide an indication of salt precipitation along this watercourse, which could be associated with seepage from TSF5; however as discussed previously, natural occurrence of mineral precipitation on the ground surface in this area has been identified during previous investigations (CMLR, 2009; AGE, 2002).

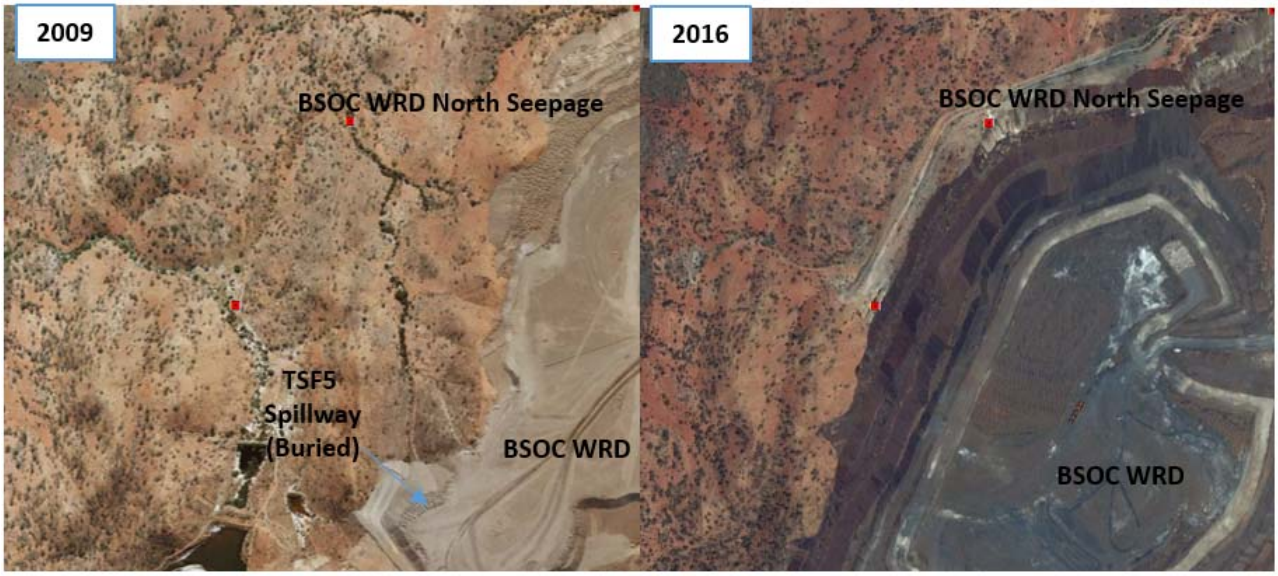

Figure 5-5: Aerial photographs of BSOC WRD North Seepage. 2009 – Prior to WRD construction, 2016 – after WRD construction

Historical monitoring of seepage at the BSOC WRD North Seepage indicates that the seepage is ephemeral, with seepage occurring during the wet season and the early dry season. Recent visual inspection of the Diversion Drain within the vicinity of this location (Phase 1 site investigation; August, 2015 (dry season)) has identified minor seepages downstream of the main seepage location, as shown in Figure 5-6. Monitoring of seepage rates / volumes had not been undertaken prior to this investigation, however, flow monitoring facilities have been installed in the Diversion Drain as part of this investigation to allow future monitoring (discussed further in Section 5.3.1).

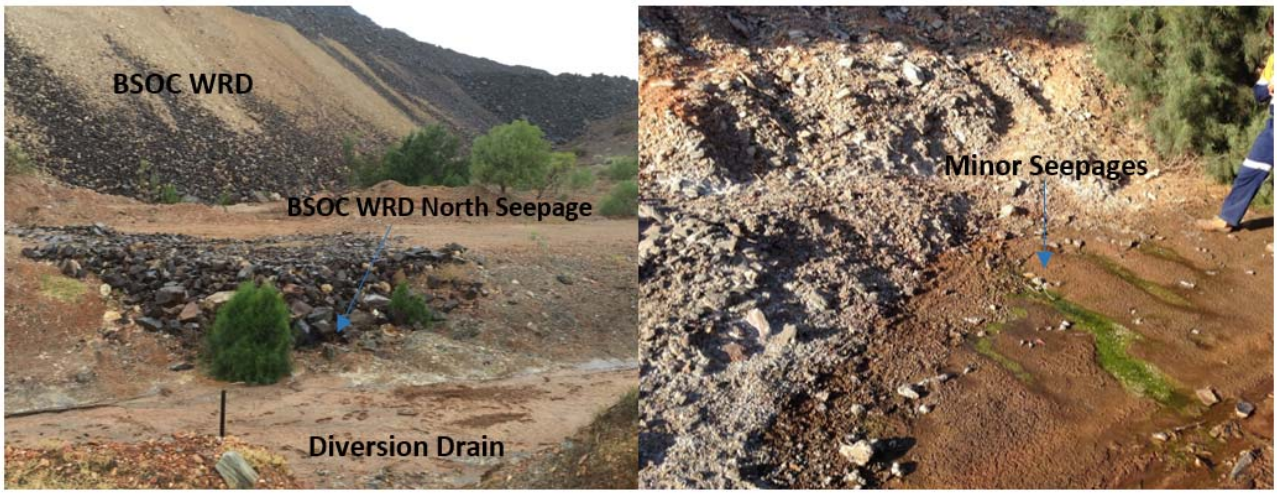

Figure 5-6: BSOC WRD North Seepage. a) Facing south, with BSOC WRD and the Diversion Drain shown, b) Minor seepages identified downstream of the main BSOC WRD North Seepage location (August, 2015)

5.1.3 TD3 Seepage

TD3 Seepage is located along the northern edge of the BSOC WRD and was identified in September 2014. The seepage location aligns with a natural drainage line underlying the WRD, which can be traced upstream to the TSF3 spillway / dam, as shown in Figure 5-7. Prior to installation of the WRD, surface water flow along this drainage line was from south to north prior to the drainage joining King Gully.

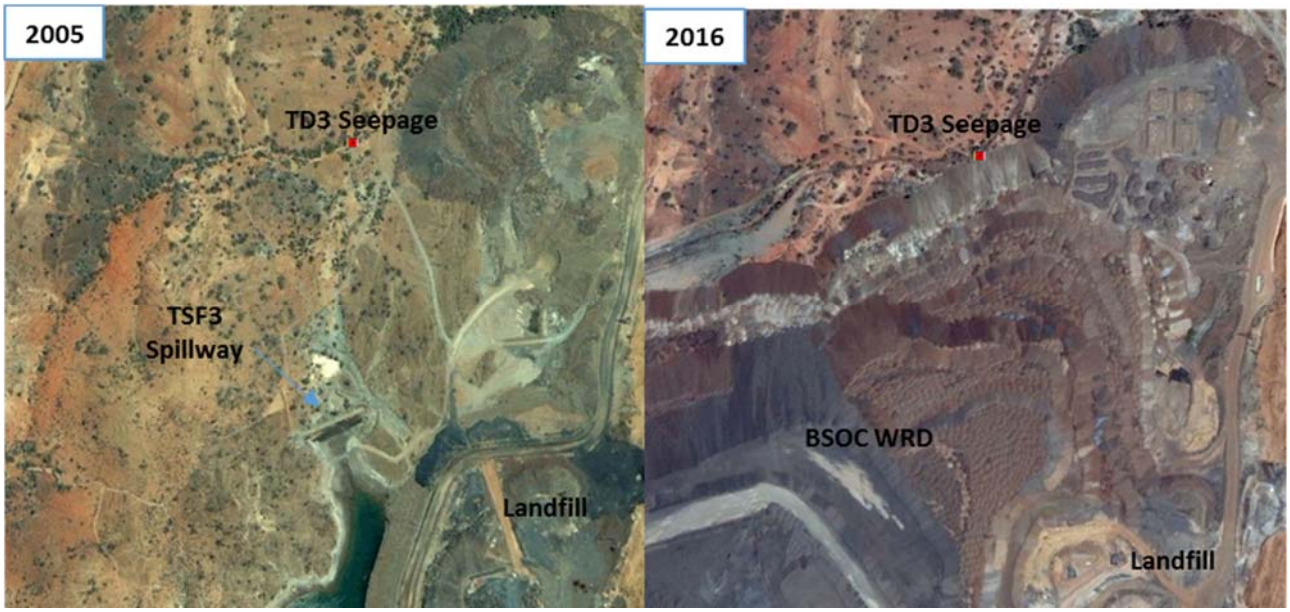

Figure 5-7: Aerial photographs of TD3 Seepage. 2005 – Prior to WRD construction, 2016 – after WRD construction

TD3 Seepage is a perennial seepage from the BSOC WRD landform, and comprises the highest seepage rate of the three seepages. The seepage discharges directly into the Diversion Drain at the BSOC WRD toe, which flows into King Gully to the King Gully Dam and eventually discharges

into KSOC Pit (Figure 5-8). Monitoring of seepage rates / volumes had not been undertaken prior to this investigation, however, flow monitoring facilities have been installed in the Diversion Drain as part of this investigation to allow future monitoring (discussed further in Section 5.3.1).

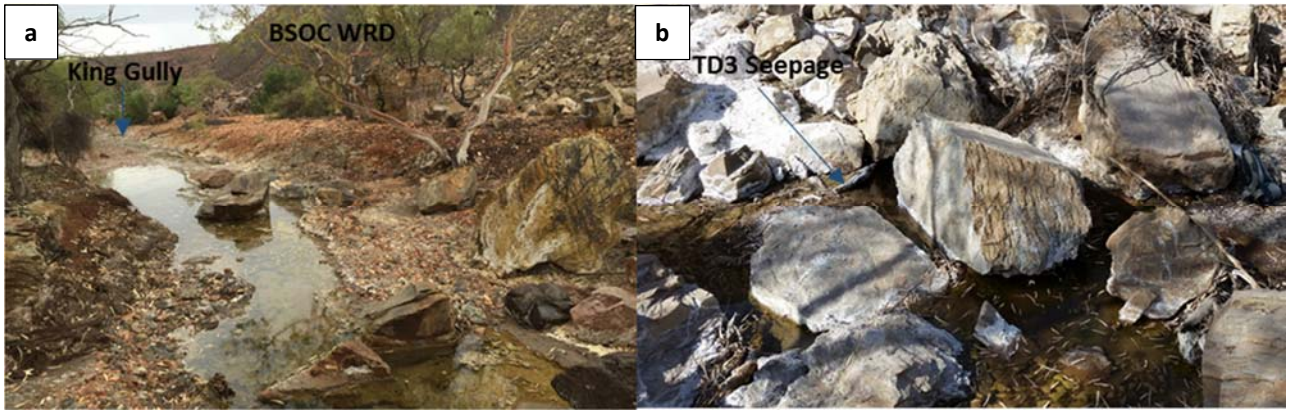

Figure 5-8: TD3 Seepage. a) Facing east at TD3 Seepage, with BSOC WRD and King Gully / Diversion Drain shown, b) Main TD3 Seepage point (August, 2015)

5.2 Current Preferential Pathways / Mechanisms / Fault Lines for Seepage

In order to determine the current preferential pathways / mechanisms / fault lines for the release of seepage from the BSOC WRD to the receiving environment (1 (a) of the EE Notice), the following tasks were undertaken:

- Development of a Reconstructed Landform Model:
  - Sub-catchment mapping of original topography underlying the BSOC WRD, prior to WRD and TSF construction.
- Development of a Conceptual Hydrogeological Model:
  - Identifying the aquifer systems associated with the BSOC WRD;
  - Drilling of 11 new investigation bores into both alluvium and bedrock;
  - Determining groundwater levels and movement;
  - Hydraulic conductivity testing of newly installed bores and existing bores;
  - Determining the hydraulic properties of waste materials, including infiltration testing on the BSOC WRD; and
  - Collection of surface water, groundwater, seepage and soil samples.

The methods and results of these investigations are presented in the following sections.

5.2.1 Reconstructed Landform Model

As part of system conceptualisation, a Reconstructed Landform Model has been generated for the area surrounding and including the BSOC WRD landform; this included the following surfaces:

- Original topographic surface before construction of TSF's and the WRD, which was interpreted based on historical topographic maps.
- Topographic surface of the TSF's, prior to construction of the WRD, provided by MIM, however the date of this is surface is unknown.
- Current topography, which was provided by MIM for Q2, 2015.

The three surfaces are presented in Figure 5-9 and also show the location of current seepage (BSOC WRD South, BSOC WRD North and TD3 Seepages), as well as an interpretation of the original drainage lines and sub-catchments.

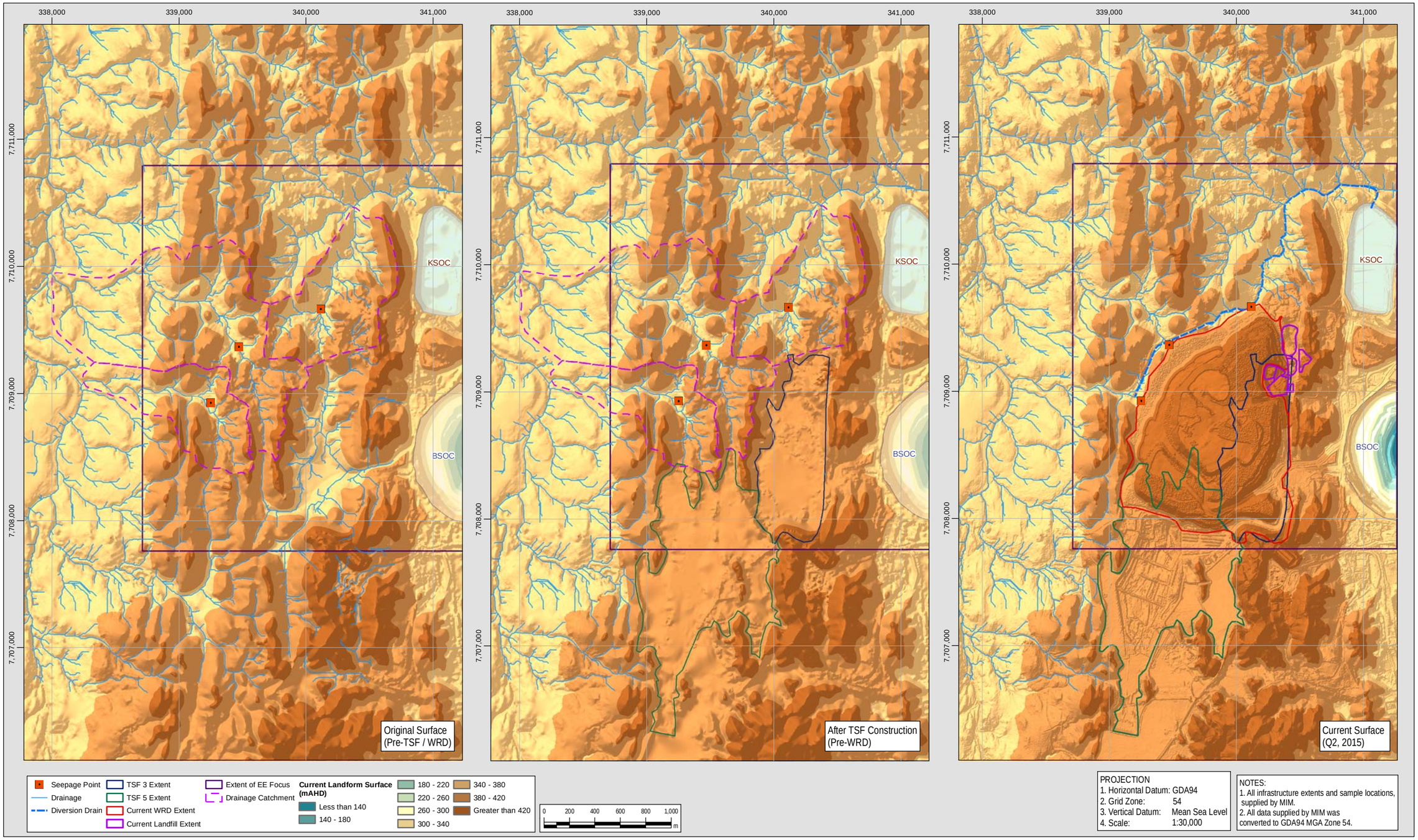

Figure 5-9: Reconstructed landform surfaces and current seepage locations. a) Original drainage / catchments – prior to TSF construction, b) After TSF construction, c) Current surface (Q2, 2015)

5.2.2 Hydrogeological Conceptualisation

This section provides the hydrogeological understanding of the groundwater system in the EE Study Area. The hydrogeological conceptual model has been developed from existing background information and studies as well as the data / information obtained during the site investigations. The conceptualised hydrogeological system forms the basis for the assessment of hydraulic connection between the BSOC WRD landform and underlying groundwater system; and, the assessment of potential seepage in the groundwater system.

5.2.2.1 Aquifer Systems

Two aquifer systems are identified in the investigation area: alluvial aquifer and bedrock aquifer.

Alluvial Aquifers

The alluvial aquifer is identified as an unconfined system associated with unconsolidated alluvial sequences adjacent to watercourses across the project site. These aquifers are shallow and develop as a result of rainfall recharge and / or stream / river leakage. The alluvial aquifers within these areas have limited effective storage, due to the presence of the lower permeability clays and silts and the lack of coarse grain material. As a result this reduces the potential for these aquifers to provide baseflow during the dry season (AGE, 2002; URS, 2011).

Mapping of the alluvial aquifer system within the Study Area was undertaken in the Phase 1 site investigation. The location of the mapped alluvium is presented in Figure 5-10. Also shown is the inferred location of the alluvium underlying the WRD which has been inferred based on the reconstructed landform model, as discussed in Section 5.2.1 (Figure 5-9).

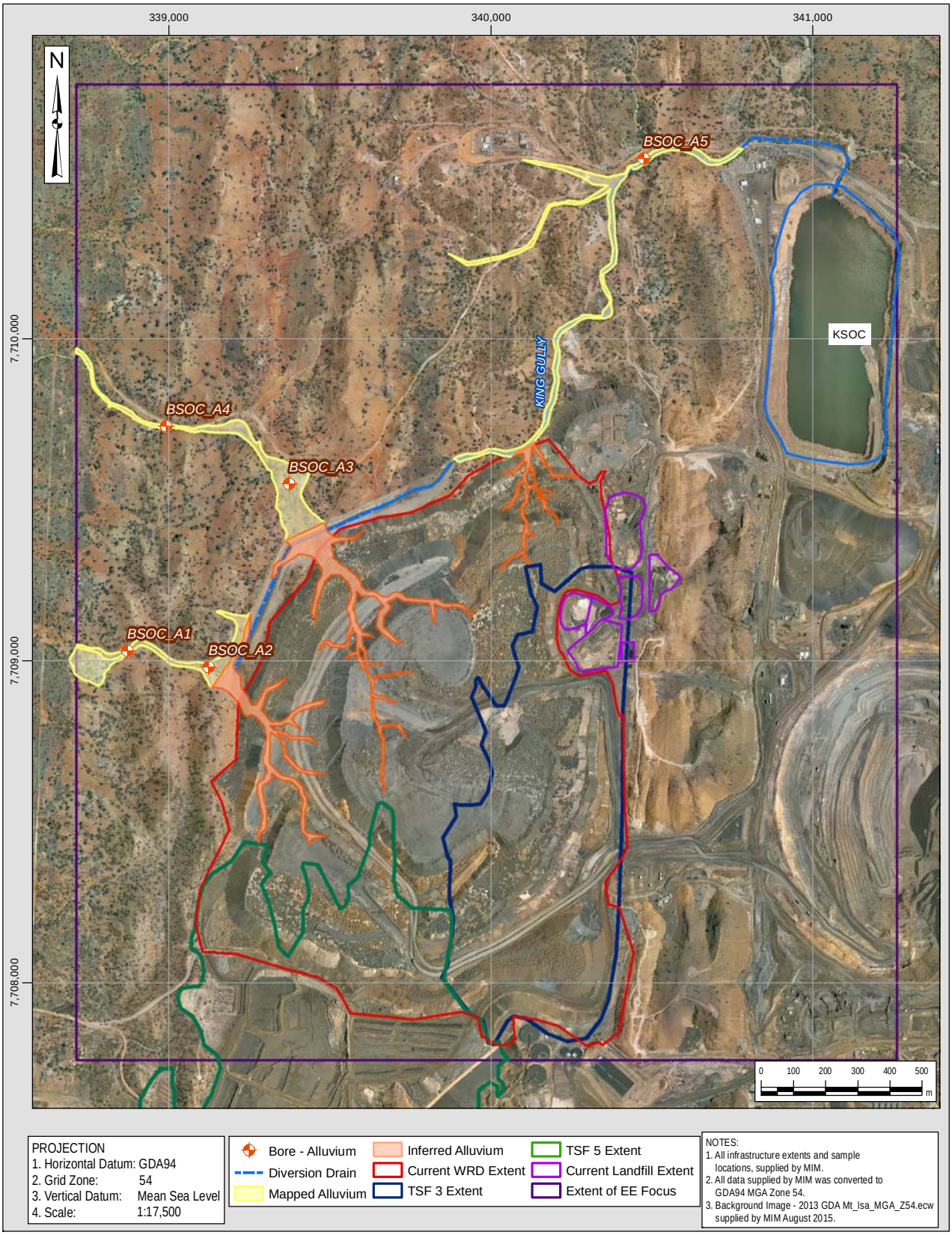

Figure 5-10: Location of mapped alluvium, inferred alluvium and alluvial monitoring bores

During the alluvium mapping exercise, a pathway for seepage was identified within the Diversion Drain, where the drain has been constructed across the alluvium. Figure 5-11 shows a conceptual schematic of the Diversion Drain from its origin close to BSOC WRD South Seepage to downstream of King Gully Dam. An inset focusing on BSOC WRD North Seepage shows the seepage water flowing down the Diversion Drain and when the seepage reaches where the drain is constructed over the alluvium, seepage water infiltrates into the alluvium, which will then flow downgradient towards the west.

Based on the Phase 1 site investigation findings, drilling and construction of five alluvial bores was undertaken during the Phase 2 site investigation. Location and Completion details for these bores are provided in Table 5-1, with the location of the bores shown in Figure 5-10. Further information on these bores is provided in Appendix II.

All bores were constructed in accordance with the *'Minimum Construction Requirements for Water Bores in Australia'* (NUDLC, 2012), under the supervision of a KCB Hydrogeologist. Airlift development of the installed bores was completed by licenced water bore drillers (Tulla Drilling), under the supervision of MIM personnel.

Table 5-1: Location and Completion Details for Alluvial Monitoring Bores

Target Aquifer	Bore ID	GDA94 MGA Zone 54 (m)		Ground Elevation (mAHD)	Stick up (m)	Drilled Depth (mbGL)	Screened Interval (mbGL)	Screened Geology	Water Level (mbGL)
		Easting	Northing						
Alluvium	BSOC_A1	338873	7709022	368	0.94	4.0	1.3 to 2.8	Alluvium, clayey gravel	0.61
	BSOC_A2	339122	7708981	375	0.70	10.0	3.6 to 9.6	Alluvium, silty gravel	1.97
	BSOC_A3	339373	7709550	378	0.94	5.5	0.8 to 2.8	Alluvium, clayey gravel	0.80
	BSOC_A4	338990	7709729	366	0.84	5.0	0.7 to 1.7	Alluvium, gravel and sand	1.19
	BSOC_A5	340475	7710561	362	0.85	5.0	0.5 to 1.5	Alluvium, gravel and sand	0.43

Bores surveyed using MIM handheld GPS
Water level measured on 21st December prior to development

The alluvium encountered was generally no deeper than 3 mbGL, with the exception of BSOC_A2, where alluvium was intersected to a depth of 9 mbGL and corresponds with the location of the confluence of two watercourses, and where the alluvium is approximately 100 m wide (perpendicular to watercourse drainage line). The alluvium generally comprised silty, sandy gravel, with angular grains. No groundwater was intersected during the drilling, however shortly after bore construction groundwater was observed in all bores. At BSOC_A3 in the period between drilling and construction, groundwater was observed flowing into the bore, which may be a result of the dewatering of a perched layer (groundwater on a low permeability layer within the alluvium profile), indicating the presence of groundwater in the alluvium. It should also be noted that groundwater in BSOC_A4 was removed during development in January, 2016 and has since not recharged.

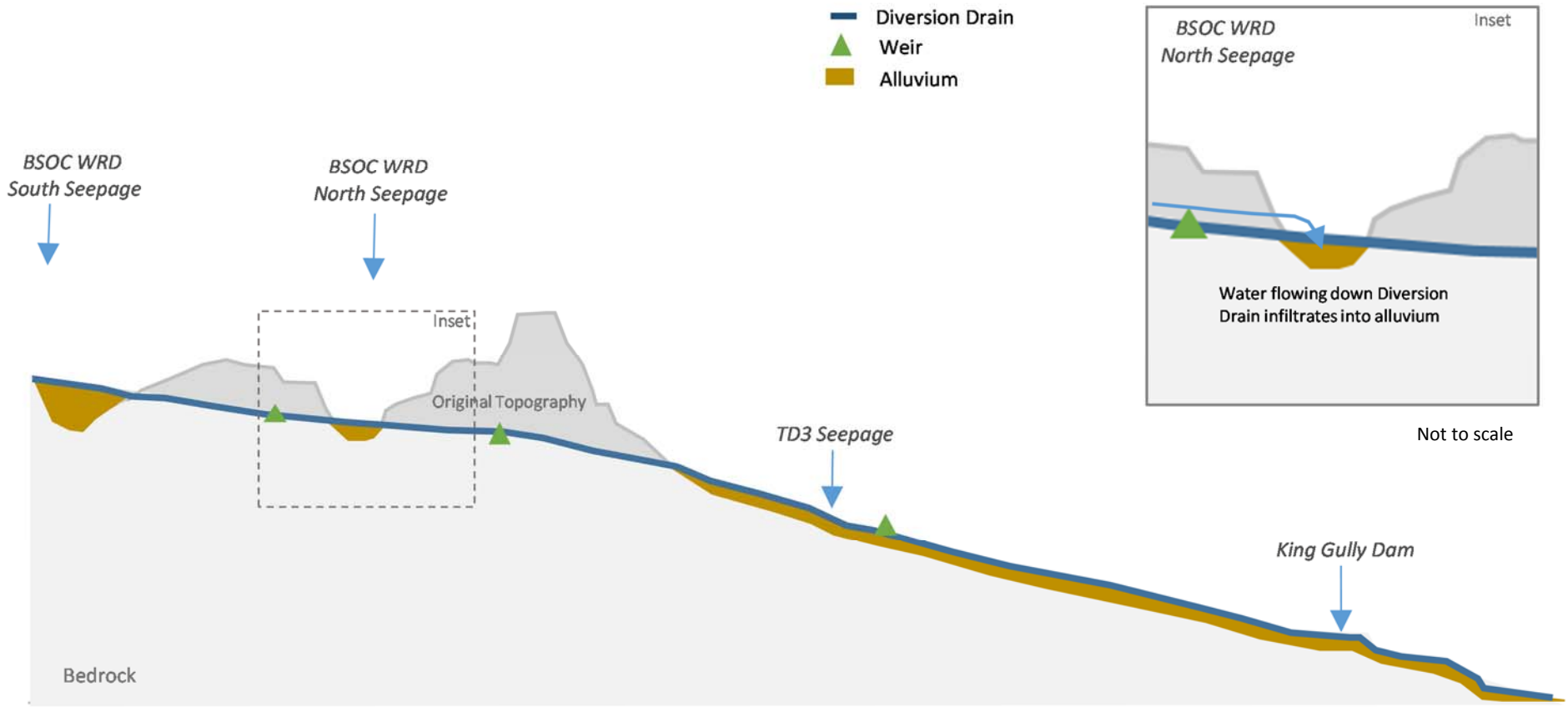

Figure 5-11: Conceptual schematic of the Diversion Drain and alluvium

Bedrock Aquifers

Within the vicinity of the BSOC WRD landform, the bedrock aquifer is hosted in meta-sediment / meta-volcanics, comprising the Bortala Formation (Judenan Beds) and Eastern Creek Volcanics (ECVs). These formations are considered to be 'fractured rock' aquifers. Groundwater storage in this aquifer is generally limited to secondary porosity associated with the formation bedding planes. Limited weathering / leaching and faulting / fracturing are observed within these stratigraphic units, and hence primary porosity is low. Differential weathering in stratigraphic units of this aquifer is observed to be between 7 and 13 mbGL.

Previous investigations indicate that mine dewatering has a limited impact on groundwater flow in the bedrock aquifer at the project site due to the limited hydraulic connectivity across the low permeability Mount Isa Fault, which is located to the east of the BSOC WRD Landform.

Figure 5-12 presents the location of geological structures (Stoker geology) in relation to the BSOC WRD Landform. Also shown are the interpreted conductive zones (electrical) from a Hummingbird Electromagnetic Survey (HEM), which was undertaken in 2002 by AGE Consultants and Fugro Airborne Surveys. The HEM system is designed to provide information on the spatial conductivity (electrical) variations. Over a survey region, these changes may be related to lithology, porosity, or surficial fluids. This survey was conducted with the aim of mapping the location of potential conductive trends, which may be indicative of contaminant migration.

From the figure, the following observations are made:

- Three north-south faults are located within the EE study area:
  - The Mount Isa Fault, located east of the BSOC WRD landform;
  - On the western boundary of the study area; and
  - Underlying TSF5, which corresponds to the geological change from the ECV to the Bortala Formation / Whitworth Quartzite.
- Zones of conductance, associated with the underlying TSF3, have been interpreted as being located from the TSF3 dam wall towards the north, which appears to discontinue at the intersection with a southeast-northwest trending structure. These were previously interpreted as being significant seepage, which is occurring at the northern end of TSF3. The report stated that this was evident by a moderate to high conductivity zone extending approximately 700 m to the north of the TSF3.
- A zone of conductance was identified from the TSF5 north dam wall towards the north. The original survey (2002) indicated that it was not clear whether this conductive trend was all the result of fluid migration, or whether the northern end of the trend is responding to a lithological cause.
- Faults within the study area have also been considered in the context of providing a pathway or barrier for seepage. The majority of these faults are north-south trending. Of significance is the fault which is underlying TSF5 and also corresponds with the change in geology to the ECVs in the west.

This information and field observations were used to determine bore locations to target and investigate further groundwater flows in the bedrock within the study area.

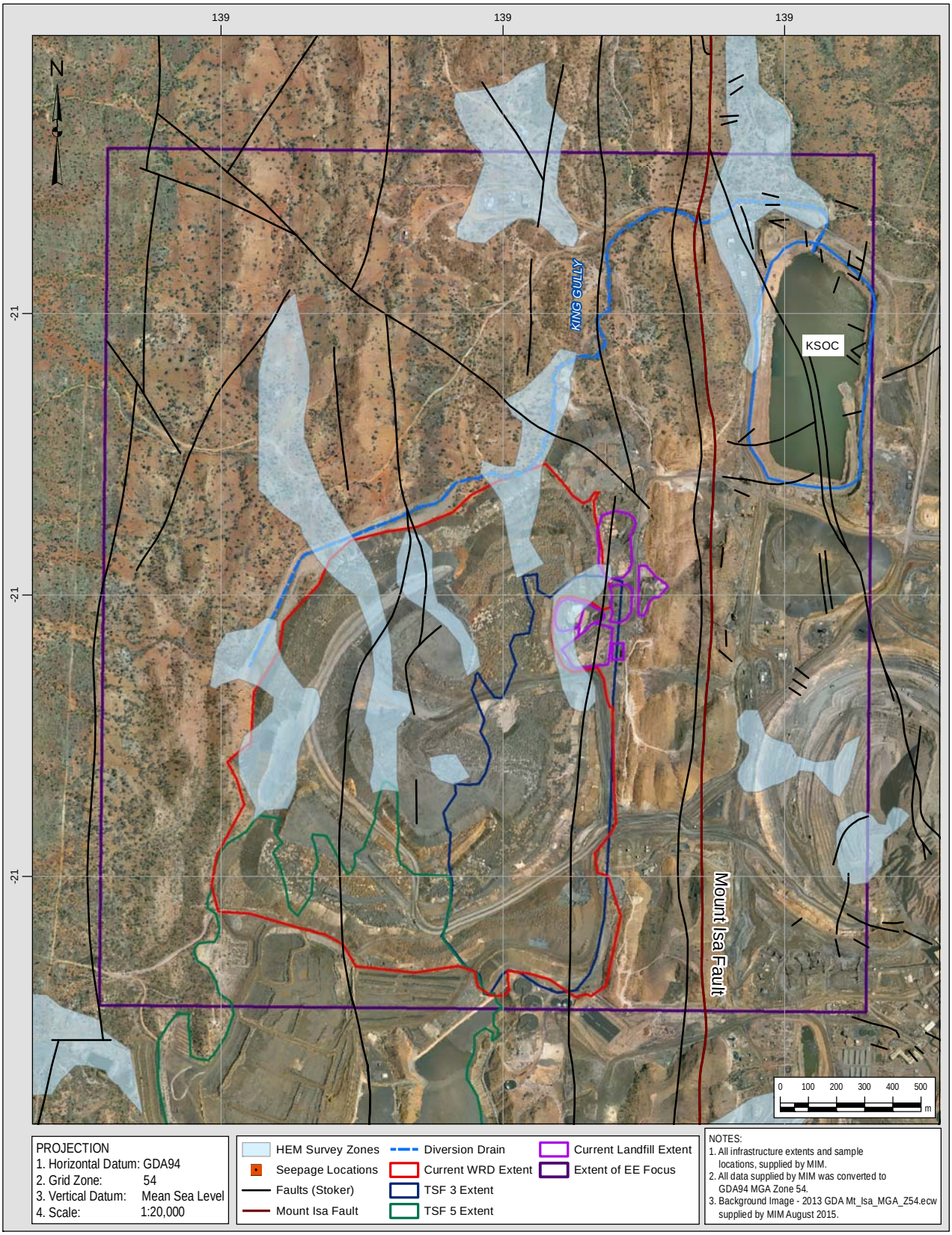

Figure 5-12: Location of faults / structures and inferred conductive zones

Drilling and construction of six bedrock bores was undertaken during the Phase 2 site investigation. Location and completion details for these bores are provided in Table 5-2, with the location of the bores shown in Figure 5-13. Further information on these bores is provided in Appendix II.

As with the alluvial bores, all bedrock bores were constructed in accordance with the *'Minimum Construction Requirements for Water Bores in Australia'* (NUDLC, 2012), under the supervision of a KCB Hydrogeologist. Airlift development of the installed bores was completed by licenced water bore drillers (Tulla Drilling), under the supervision of MIM personnel.

Table 5-2: Location and Completion Details for Bedrock Bores

Target Aquifer	Bore ID	GDA94 MGA Zone 54*(m)		Ground Elevation* (mAHD)	Stick up (m)	Drilled Depth (mbGL)	Water Strike (mbGL)	Screened Interval (mbGL)	Screened Geology
		Easting	Northing						
Bedrock	BSOC_B1	339153	7708920	384	0.75	29.2	9	11.0 to 29.0	Meta-sediments, fresh
	BSOC_B2	339177	7709783	388	1.06	26.2	9	7.8 to 25.8	Meta-sediments, fresh
	BSOC_B3	339446	7709681	381	0.29	35.3	20	17.2 to 35.2	Meta-sediments, fresh
	BSOC_B4	339676	7709695	386	1.11	36.3	20	18.3 to 36.3	Meta-sediments, fresh
	BSOC_B5	340255	7710381	367	1.07	35.0	14	14.3 to 32.3	Meta-sediments, fresh
	BSOC_B6	340189	7710685	369	0.75	72.0	42	37.0 to 55.0	Meta-sediments, fresh

* Bores surveyed using MIM handheld GPS

Some observations made during the drilling of the bedrock bores are provided in the following:

- Meta-sediments were encountered within all drill holes, generally comprising of siltstones and sandstones with varying degrees of metamorphism. Schist was common throughout, as was significant chlorite alteration in some locations.
- The base of the weathered profile was encountered at depths between 7 and 13 m.
- BSOC_B2 was drilled at a location of high conductance identified during the HEM in 2002 (as reported in URS, 2011). Some primary porosity within a meta-sandstone was observed in the drill cuttings from BSOC_B2, which may reflect a zone of increased groundwater flow. Based on the lithology and groundwater encountered during drilling, this conductive zone can be interpreted as a geological anomaly rather than an area impacted by seepage.
- Evidence of oxidation / leaching (possible fracturing) was observed in all drill holes, and generally decreased with depth.
- Groundwater was generally intersected at transition between the weathered zone and fresh bedrock, at depths of between 6 and 12 mbGL.
- Airlift yields ranged between 0.1 and 1.6 L/s, with the highest yield observed in BSOC_B2, where both matrix porosity and increased oxidation / leaching was evident.

Figure 5-13: Location of new monitoring bores

5.2.2.2 Groundwater Levels and Flow

Groundwater movement in the bedrock aquifers predominantly occurs along structural defects (faults, fractures, joint, bedding and foliation) with the rate of flow governed primarily by defect characteristics (frequency, length, aperture and orientation). Generally, these discrete structural features across the MIM site are orientated along a south to north strike. Therefore, regional groundwater movement in the bedrock aquifer is likely to be from south to north, with previous studies estimating the regional hydraulic gradient as 0.00025 (KCB, 2013b).

Limited historical data exists for groundwater levels within the alluvial aquifer within the vicinity of the BSOC WRD landform, however, groundwater level measurements from the new alluvial bores (BSOC_A1 to BSOC_A5) indicate that groundwater movement in the alluvial aquifer is a general reflection of the surface water flow regime, with movement within these unconsolidated sediments occurring as a function of gravity drainage within intergranular pore spaces.

Within the vicinity of the BSOC WRD Landform, MIM have a number of monitoring bore facilities installed within the bedrock aquifer. These have been used to assess the current and historical groundwater conditions. Some of these facilities are monitored as part of the EA (Schedule H – Table 10). Other facilities installed as part of previous (unrelated) investigations have been considered where data is available. Data from the bores drilled as part of this investigation are also included.

The location of bores discussed in the following sections are presented in Figure 5-14.

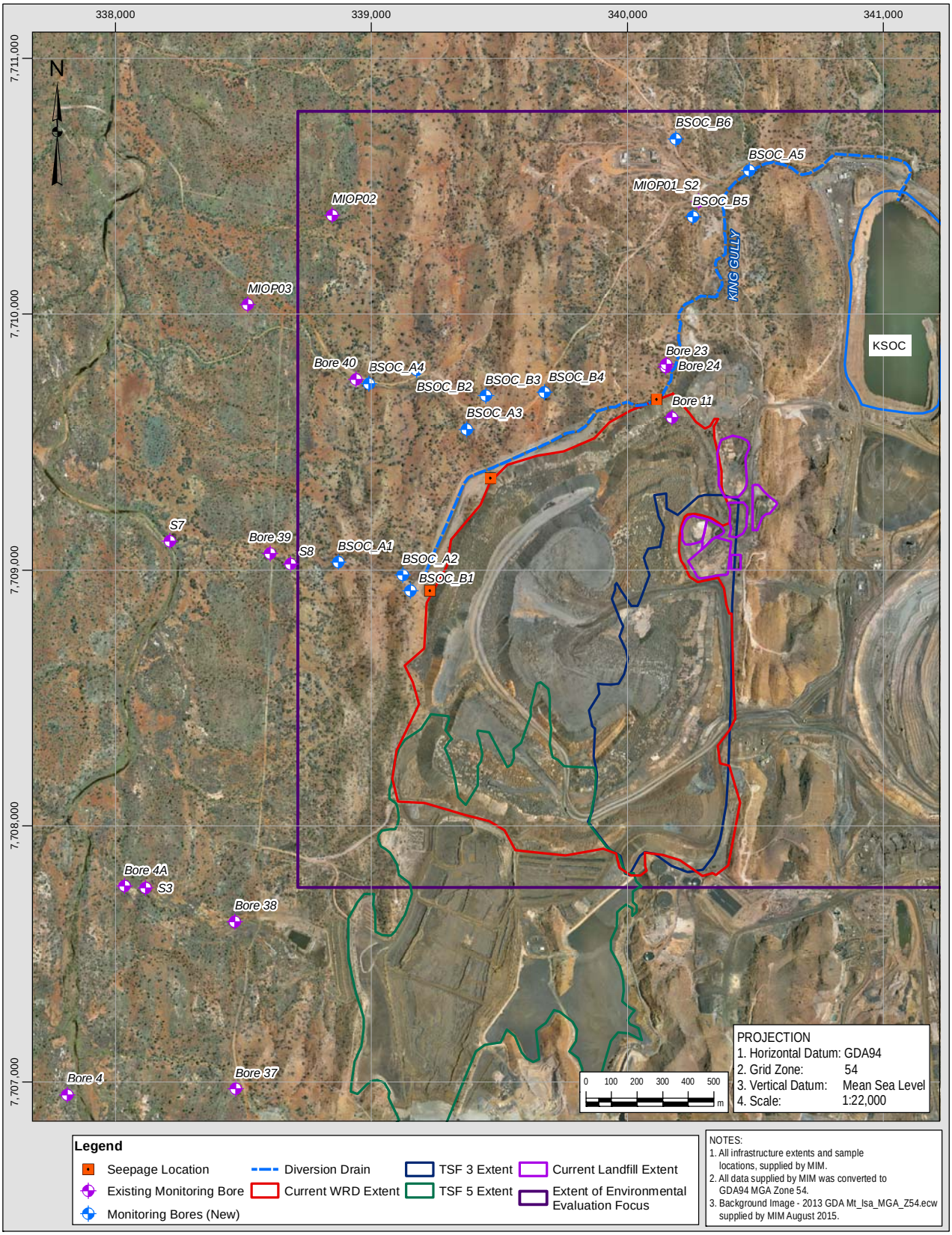

Figure 5-14: Location of bores with groundwater level records

Groundwater hydrographs are presented and discussed in the following sections, including historical data and recent data-logger data collected during this investigation (August, 2015 and February, 2016). All bore hydrographs in the following section are compared to the regional rainfall trends at the MIM site using the rainfall excess / deficit trend over the period 1995 to 2016 (Figure 3-2).

Historical groundwater level data for bores in the vicinity of BSOC WRD are presented in Figure 5-15 to Figure 5-19 based on their spatial location.

Hydrographs for bores located north of BSOC WRD and the TD3 Seepage location are shown in Figure 5-15, including Bore 23, Bore 24, MIOP01/S2 and Bore 11, which is now decommissioned and covered by BSOC WRD. Measurements taken from the new bores BSOC_B5 and BSOC_B6 are also included, however there is only one measurement.

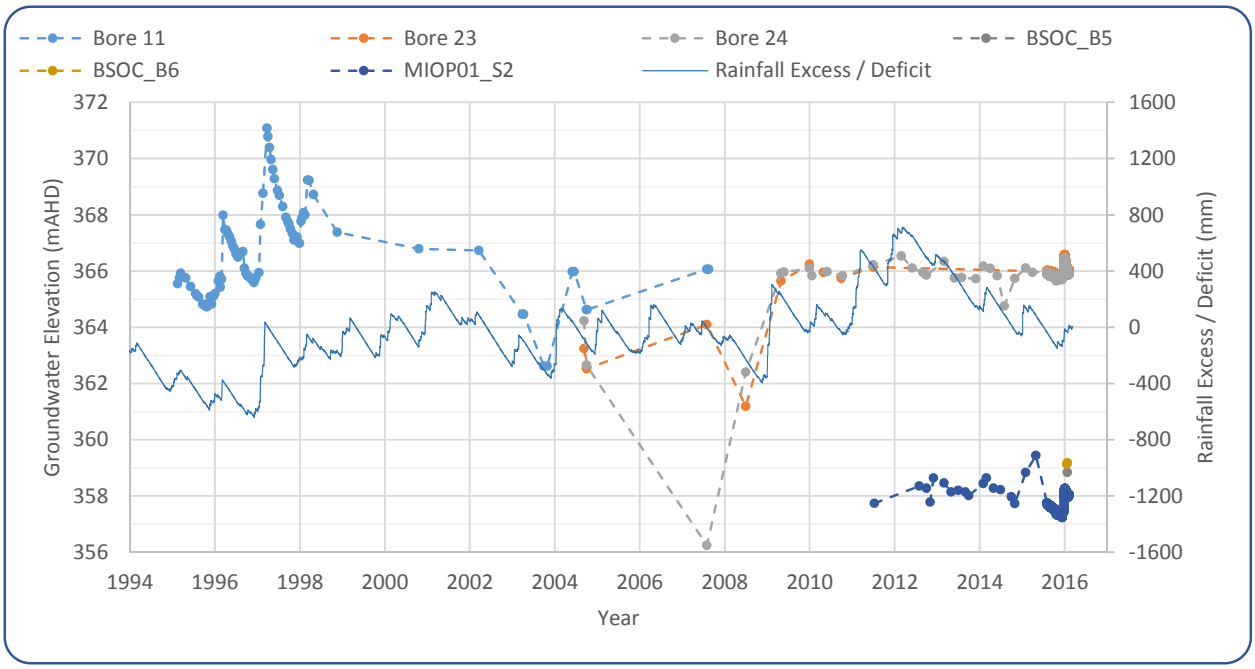

Figure 5-15: Groundwater hydrograph – bores located north of BSOC WRD and TD3 Seepage

Bore 11 has the oldest monitoring record, commencing in 1995, and ending in 2007 when it was covered by BSOC WRD. Prior to 1999, frequent measurements were collected at this location. Groundwater levels are seasonal in their response, comparable to the rainfall excess / deficit trend. After 1999 it is difficult to comment on the water level trend due to the decreased frequency of measurements.

Of the other bedrock aquifer bore monitoring records, there are limited and infrequent measurements prior to 2015 to provide a detailed interpretation of the long term groundwater trend, however some comments are made in the following:

- MIOP01/S2 is located north of BSOC WRD and screened to a depth of 5.5 mbGL. The water level hydrograph shows a very good correlation with the rainfall excess / deficit trend. Increases in the groundwater level occur as a result of large rainfall events, which suggests that recharge at this location is almost instantaneous and that groundwater levels are controlled by the rainfall conditions.

- Bore 23 and Bore 24 can be considered as a nested monitoring site, with screens located within the weathered bedrock and fresh bedrock respectively. These sites are located the closest to the BSOC WRD and show a similar water level response to each other, indicating connection between the weathered and fresh bedrock at this location and a downward gradient (discussed further later in this section).

Based on the available historical data for Bore 23 and Bore 24, groundwater levels do not correlate with the long term excess / deficit trend, showing a relatively stable groundwater levels observed when compared against the decline in the rainfall trend. This is highlighted further in Figure 5-16, which shows the difference in the change in water level for Bore 24 relative to two other sites, Bore 39 and Bore 40, which correlate with the overall rainfall trend. The graph shows that since 2011, although there have been seasonal responses, these are of a lower magnitude than observed in the other monitoring sites. The overall change (for the period presented) has been a decline of ~0.5 m for Bore 24, whereas the decline is ~6 m in Bore 40 and ~4.5 m in Bore 39. This response differs to those observed at other sites and potentially indicates a secondary source of recharge (BSOC WRD Landform) at Bore 23 / Bore 24.

The recent data-logger data for Bore 23 and Bore 24 also supports this in the response to the wet season rainfall. Following the large rainfall event in December 2015 / January 2016, groundwater levels increase by ~0.7 m and decline to close to pre-event levels by February 2016. The other bores water levels do not respond in the same way to Bore 23 and Bore 24 and are still at their peak at the time of data-logger removal.

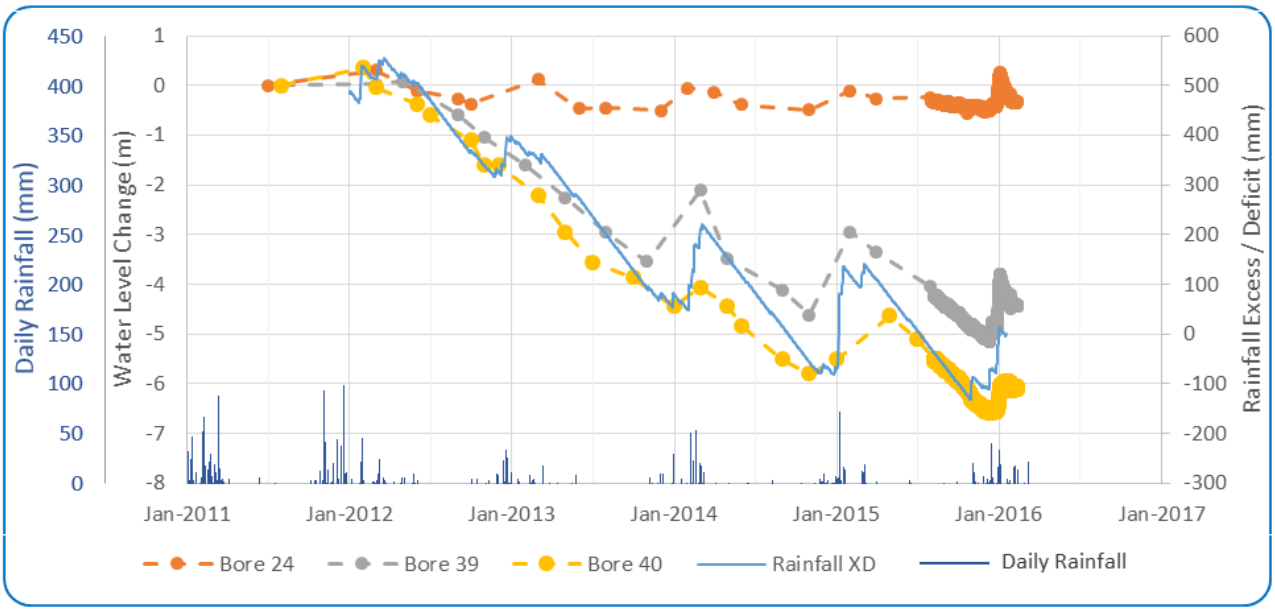

Figure 5-16: Change in groundwater level at Bore 24, Bore 39 and Bore 40 from July, 2011 to February, 2016, with rainfall excess / deficit trend and daily rainfall

Hydrographs for bores located along the creek line west of the BSOC WRD (and BSOC WRD South Seepage) are presented in for Figure 5-17, including Bores 39, S7 and S8. New bore BSOC_B1 is also included, however, there is only one measurement.

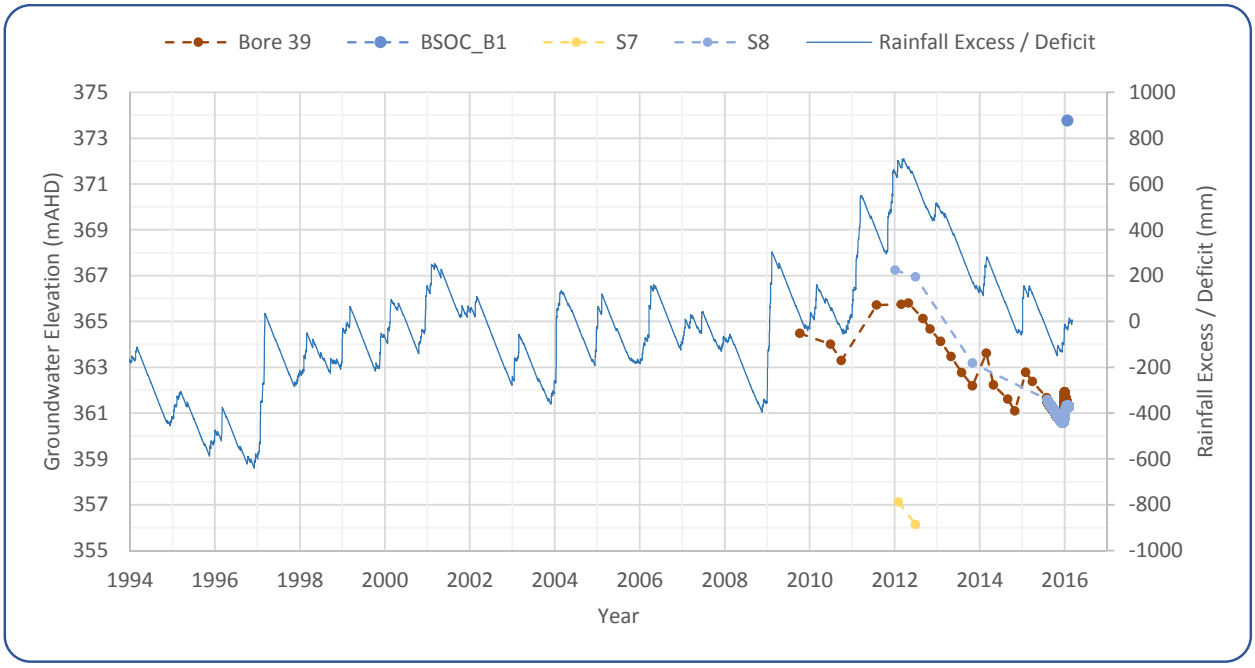

Figure 5-17: Groundwater Hydrograph – Bores located west of BSOC WRD South Seepage

The groundwater level monitoring record commences after 2009 for these monitoring sites. Generally it can be observed that the water levels in these locations are seasonal in their response and the decline in groundwater levels between 2012 and 2016, which correlates with the rainfall excess / deficit trend during the same period. Bore specific observations from the recent data-logger data include:

- Bore 39 and S8 are located to the west of BSOC WRD and the BSOC WRD South Seepage. The two bores are located ~80 m apart and based on available geology information the bores are screened within different formations. Although relatively close together these sites are also located on opposite sides of a north-south trending fault. The hydrograph also shows that the water levels observed in the bores are considerably different.
    - Bore 39 correlates well with the rainfall excess / deficit trend, with rises in groundwater level observed following rainfall events. The large rainfall event in December 2015 / January 2016 results in an increase of over 1 m in Bore 39, with a steady decline in the following month.
    - Water levels from S8 show a much more subtle response to rainfall events, with a lag time of 20 days before groundwater levels peak following the December 2015 / January 2016 event.

Hydrographs for bores located north and northwest of BSOC WRD North Seepage are shown in Figure 5-18, including Bore 40, MIOP02 and MIOP03. Measurements taken from the new bores BSOC_B2, BSOC_B3 and BSOC_B4 are also included, however, there is only one measurement.

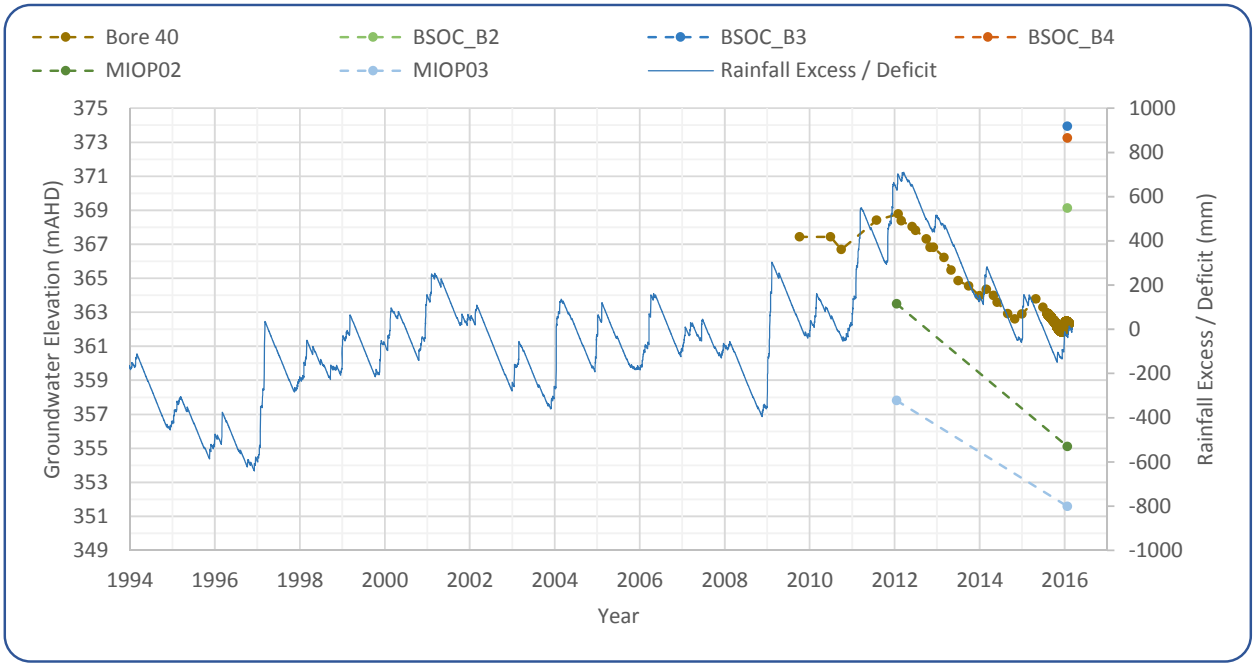

Figure 5-18: Groundwater Hydrograph – Bores located north and northwest of BSOC WRD North Seepage

Limited data exists at these bores, as they were drilled for investigative purposes rather than monitoring, with the exception of Bore 40, which is monitored as part of the EA, with records commencing in 2009. The hydrograph for Bore 40 shows an overall declining trend between 2009 and 2016, which corresponds with the trend observed in the rainfall / excess deficit plot. The water levels are similar to that of S8, located to the south of Bore 40, however there is less of a lag in response to the rainfall event. Based on the two points available for MIOP02 and MIOP03, both these sites have also experienced a decline in groundwater level, however no further comment can be made due to the limited data.

Hydrographs for bores located to the southwest of BSOC WRD are shown in Figure 5-19, including Bore 37, 38, 4, 4A and S3.

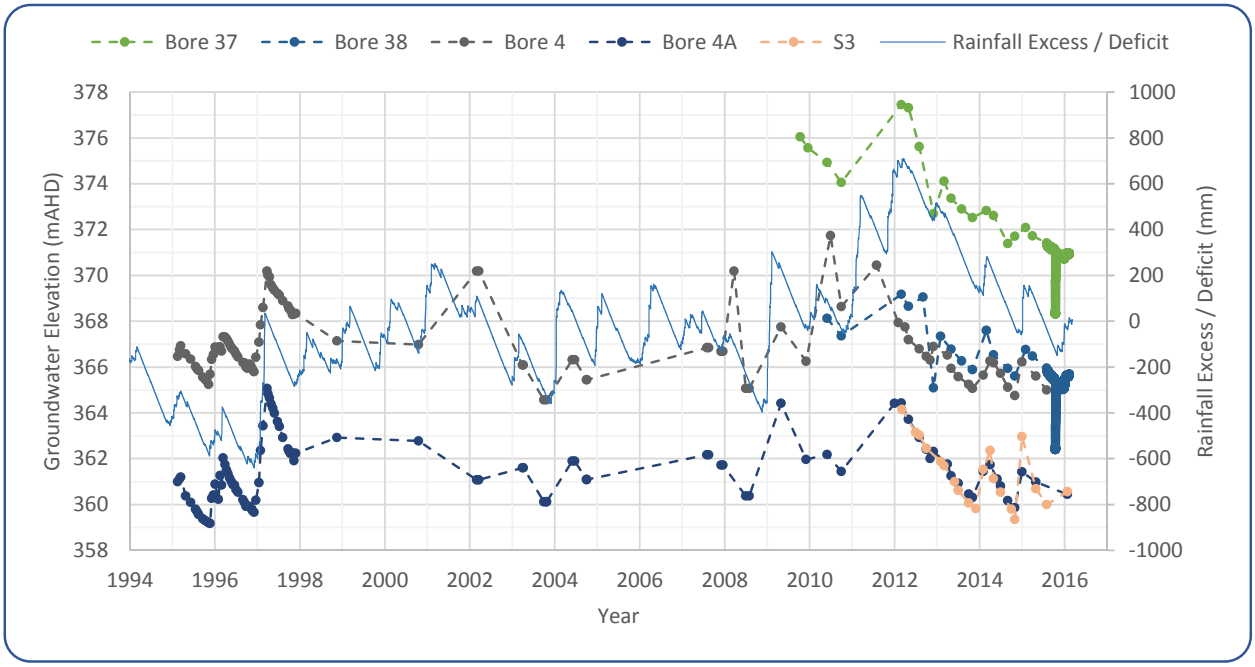

Figure 5-19: Groundwater Hydrograph – Bores located south-west of BSOC WRD and west of TD5

The records for two sites (Bore 4 and Bore 4A) have a good frequency of data between 1995 and 1998 and the water levels between this period show a good correlation with the rainfall excess / deficit trend. A rise of ~4 m in the groundwater level at both sites is observed following large rainfall events during the 1996 / 1997 wet season. Between 1998 and 2012, the available groundwater data is infrequent and therefore no comment is able to be made in reference to trends during this period.

From 2012 groundwater levels across all monitoring sites show a general decline, which correlates to the decline observed in the rainfall excess / deficit trend. Bore 4A and S3 appear to have greater fluctuations associated with the wet / dry seasons, while bores such as Bore 37 have a more tempered response. It should also be noted that the water level records for Bore 37 and Bore 38 show a drawdown response in late 2015, which may relate to pumping associated with quarterly groundwater sampling of these bores required by the EA *Schedule H (Table 10)*.

Groundwater Level Summary

Based on the available groundwater level data presented and discussed in the previous sections, the following comments are made relating to the groundwater system:

- Across most sites, there is a good correlation with the rainfall excess / deficit trend, particularly post 2012, where the majority of data exists.
- Wet / dry season fluctuations are also observed, varying in the magnitude of response across the monitoring sites, likely to be a function of variable hydraulic conductivities in the bedrock aquifer (driven by variable lithologies).
- The groundwater level response to large rainfall events is often almost instantaneous, indicating that there is direct infiltration from rainfall.

- Hydrographs for Bore 23 and Bore 24 indicate a secondary recharge mechanism for the bedrock aquifer at this location, and is likely to be the BSOC WRD Landform, given their proximity to the landform.

Groundwater Flow Contours

Previous studies have interpreted the regional groundwater flow direction within the Myally Sub-group and Eastern Creek Volcanics as being in a north to north-westerly direction (CMLR, 2010), based on topography.

Groundwater level contours have been produced to provide an understanding of the groundwater flow regime within the immediate vicinity of the BSOC WRD Landform and provide an indication of the direction of groundwater flow. The contours have been generated for the bores screened within the weathered and fresh bedrock for the wet season in January 2016; insufficient data was available to produce contours for the dry season.

Figure 5-20 shows the inferred groundwater level contours, which indicate a general radial pattern around the BSOC WRD, with groundwater flowing away from the BSOC WRD Landform towards the west and north. This radial groundwater flow adjacent to the BSOC WRD Landform is indicative of a higher hydraulic head within the BSOC WRD Landform, which is in hydraulic connection / influencing the underlying bedrock piezometric surface. It should be noted that at the groundwater levels were collected on January 26, 2016 and if a comparison is made for that period between the inferred contour pattern to the response presented in the hydrographs; the contrasting response after the rainfall event, which is seen in Bore 23 and Bore 24, is also observed in the contours.

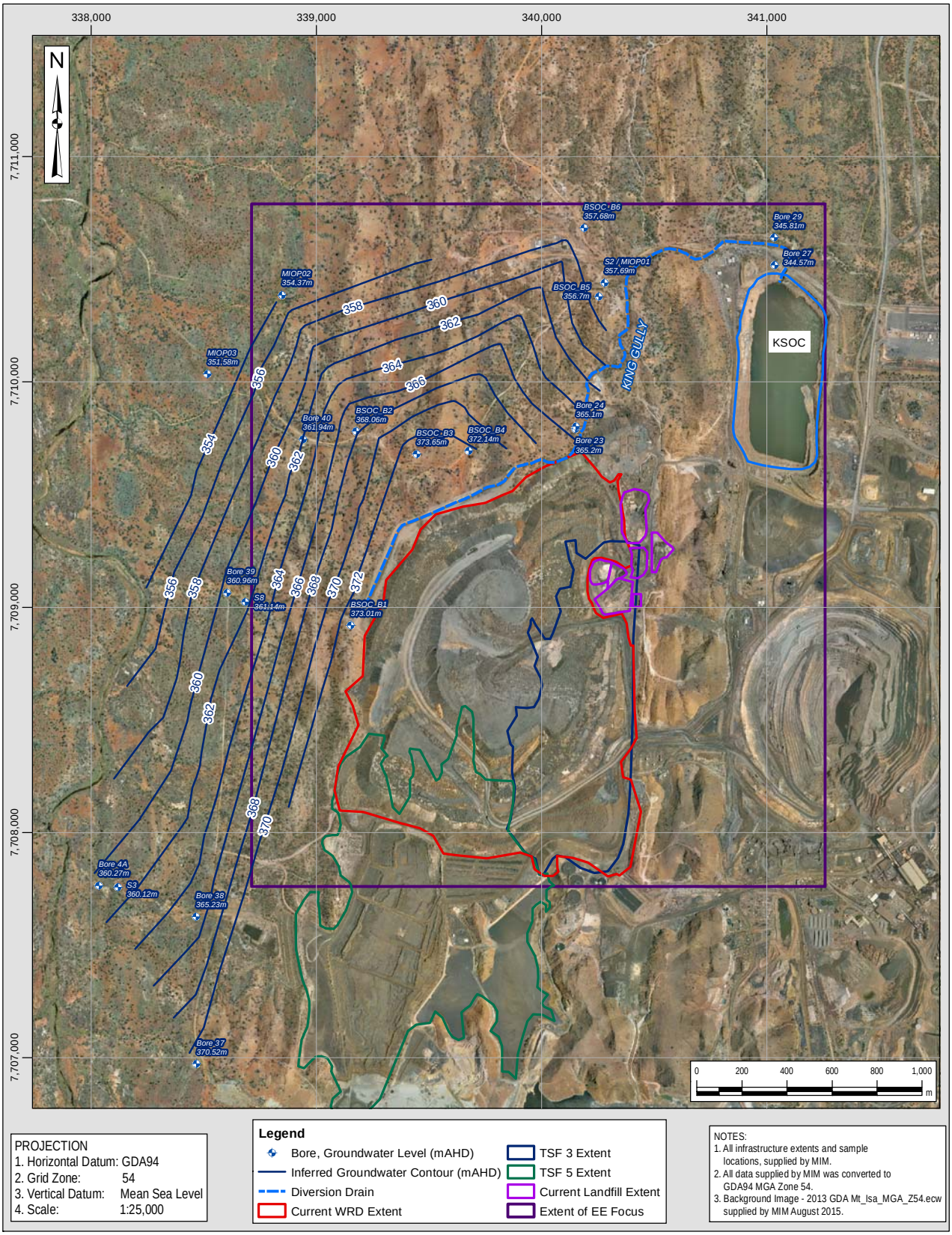

Figure 5-20: Bedrock groundwater level contours (January, 2016)

Groundwater Flow Gradients

Based on the groundwater level contours presented in Figure 5-20 and groundwater level measurements for the alluvial aquifers, groundwater flow gradients (horizontal) have been estimated. Gradients are estimated based on the change in hydraulic head over a distance. These are presented in Table 5-3.

Table 5-3: Groundwater Flow Gradients

Flow Path	Estimated Hydraulic Gradient
Alluvial aquifer underlying the drainage associated with BSOC WRD South Seepage to the west	0.015
Alluvial aquifer underlying the drainage associated with BSOC WRD North Seepage to the west	0.013
Bedrock / weathered bedrock to the west	0.022
Bedrock / weathered bedrock to the north	0.024

Previous studies have indicated the regional groundwater flow gradient as being north-south, and estimated the flow gradient as 0.00025 (KCB, 2013b). A steeper hydraulic gradient is observed in the bedrock aquifer adjacent to the BSOC WRD in comparison to the regional groundwater flow gradient.

Vertical Groundwater Gradients

Vertical groundwater gradients between the alluvial and bedrock aquifers were not able to be assessed as limited bore pairs are installed within the Study Area.

While the direct assessment of the hydraulic connectivity between the waste materials, alluvium and basement rocks is not possible, conceptually it can be inferred that vertical leakage from the overlying waste rock / tailings to the alluvium would occur. Additional, vertical leakage from the overlying waste rock / tailings and alluvium to the underlying bedrock may also occur (provided the water level in the bedrock is lower than the water level in the overlying alluvium / waste material), however, this infiltration is rate limited by the low permeability of the underlying bedrock units.

In contrast, upward seepage from the bedrock aquifer into the alluvial aquifer along drainage depression may occur. This can occur where upward hydraulic gradients due to confining conditions associated with structural features are present, however, due to limited nested groundwater monitoring facilities this could not be confirmed.

The vertical gradient between the weathered zone and bedrock aquifer is able to be assessed using the groundwater levels from Bore 23 and Bore 24. Based on the data-logger data collected between August, 2015 and February, 2016, water levels in the weathered zone are higher than the bedrock, indicating a downwards vertical gradient at all times (during the record). The downwards vertical gradient at this location has been calculated as 0.002. This indicates that groundwater within the weathered zone is in hydraulic connection with groundwater in the bedrock aquifer as the groundwater levels from these aquifers are relatively similar.

5.2.2.3 Hydraulic Conductivity

Literature values for a range of hydraulic conductivity for different geology are provided in Driscoll (1986). The following are relevant to this study for comparison against site testing values:

- Unfractured igneous and metamorphic rocks – 1 x 10^{-5} to 1 x 10^{-9} m/d
- Fractured igneous and metamorphic rocks – 100 to 0.001 m/d

Hydraulic testing to obtain site specific estimates of hydraulic conductivity was completed during the Phase 2 site investigation on new and selected existing monitoring bores. Testing was undertaken through packer testing and slug testing techniques, and is discussed in the following sections. The purpose of the testing was to provide additional understanding of the ability of the groundwater / seepage to move within the aquifers across the study area.

Packer Testing on New Bedrock Bores

Packer testing was completed in the bedrock drill holes prior to bore construction. Borehole inflatable packers are designed to enable permeability (hydraulic conductivity) testing in open holes and/or discrete test sections, with the packers used to seal off (isolate) the desired section of the hole prior to testing. To carry out the test, drill rods with the packer assembly attached were inserted to the selected test interval depth, where the packers were inflated using nitrogen gas. Following the packers inflation, hydraulic testing of the sealed interval was undertaken by injecting water into the formation under constant pressure, with a measurement of the average stabilised flow rate (or water consumption) at the test pressure. This was repeated at a number of different pressure steps to measure the formation response at different pressures (Lugeon Tests). The resulting data was used to calculate a transmissivity of the test interval and consequently the hydraulic conductivity of the formation, which will provide an indication of the ease of which fluid can move through rock media.

Testing was undertaken on five of bedrock drill holes, with between two to three tests carried out per hole. Testing was not completed on BSOC_B6 due to problems with the packer equipment. The test intervals were selected based on the encountered drill cuttings and airlift yields or water inflow zones identified during drilling. The tests were analysed using solutions by Houslby (1976) and Thiem (1906). Details of the packer testing results can be found in Appendix II. A summary of the packer testing intervals and estimates of hydraulic conductivity are presented in Table 5-4.

Table 5-4: Summary of Packer Testing Intervals and Average Hydraulic Conductivity

Bore ID	Test Interval Depth (mbGL)	Inferred Geology	Interval Description	Average Hydraulic Conductivity (m/d)
BSOC B1	12.9 to 14.9	Weathered Bedrock	Water inflow zone, with yield increase observed during drilling at ~14m	0.29
	22.9 to 24.9	Bedrock	Fresh bedrock, with little or no fracture evidence	0.006
BSOC B2	7.9 to 9.9	Weathered Bedrock	First water strike, less than 0.2 L/s. Meta-sediments, moderately weathered, strong evidence of water contact	1.41
	13.9 to 15.9	Bedrock	Increase in yield observed at this depth and continuous flow from airlift sustained	1.16
	20.9 to 22.9	Bedrock	Quartzite with potential matrix flow and an increase in yield to 1.6 L/s observed during airlifting.	0.04
BSOC B3	19.9 to 21.9	Bedrock	First water strike interval	0.08
	24.4 to 26.4	Bedrock	Fresh bedrock with limited fracturing	0.003
BSOC B4	18.9 to 20.9	Bedrock	First water strike interval	0.37
	27.2 to 29.2	Bedrock	Fresh bedrock with no evidence of fracturing	0.001

Bore ID	Test Interval Depth (mbGL)	Inferred Geology	Interval Description	Average Hydraulic Conductivity (m/d)
	32.2 to 34.2	Bedrock	Fresh bedrock, with schist (very weak) layers. No evidence of fracturing or matrix flow	0.004
BSOC B5	12.8 to 14.8	Weathered Bedrock	First water strike interval	0.1
	18.9 to 20.9	Bedrock	Fresh rock with no evidence of fracturing	0.004
	28.7 to 30.7	Bedrock	Significant water inflow zone identified during drilling at ~30m.	0.61

The following observations on the packer testing program / results are made:

- Testing of the fresh bedrock, where there was little or no evidence of fracturing was conducted in four of the five holes. The average hydraulic conductivity across all the tests in this horizon is ~0.003 m/d.
- Testing horizons within the weathered bedrock were completed across three of the bores, with a range of hydraulic conductivity of 0.1 to 1.4 m/d.
- Values estimated within BSOC_B2 are generally higher than other bores which is a reflection of the geology encountered at this location, with some matrix porosity observed in the drill cuttings.
- The deepest zone tested in BSOC_B5 (28.7 to 30.7 mbGL) has an estimated hydraulic conductivity of 0.6 m/d, which is higher than observed at similar depths in other holes and was tested as an inflow zone, which was identified during drilling.

In-situ Hydraulic Testing of Existing Monitoring Bores

Hydraulic (slug) testing was completed on selected existing monitoring bores by MIM personnel between 2 February and 25 February, 2016, to provide estimates of hydraulic conductivity. The location of the bores tested are presented in Figure 5-21.

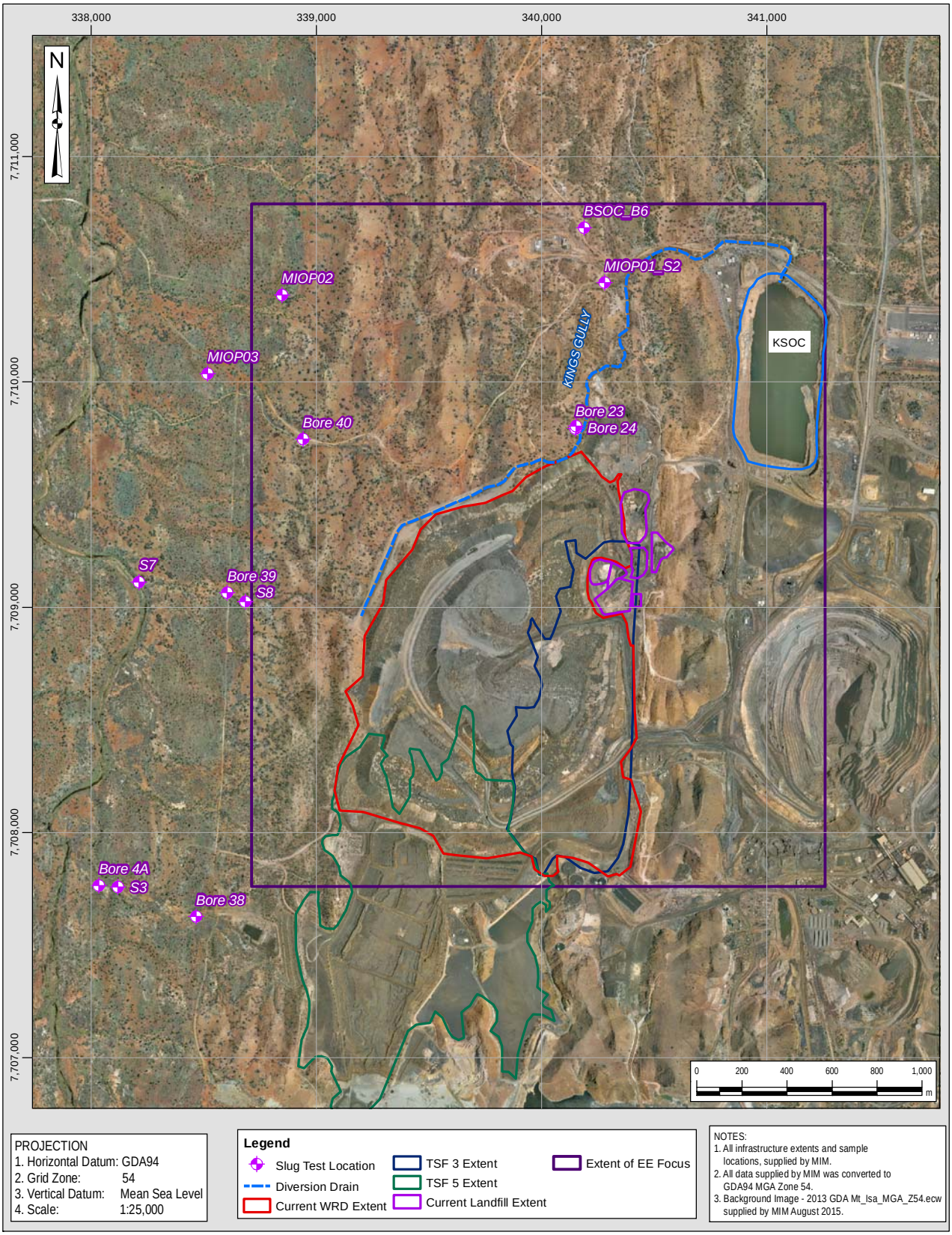

Figure 5-21: Location of Hydraulic Testing on existing bores

Data from the slug tests were reviewed and hydraulic conductivity values calculated using AQTESOLV Pro v4.5 software. Analytical solutions were selected based on underlying analytical assumptions, specific well conditions, and aquifer responses (Butler, 1998). The majority of tests were analysed using the Bouwer and Rice (1976), KGS Model (Hyder et al., 1994) methods and Hvorslev (1951). If bores are screened across the water table these required additional compensation to account for the effective screened interval using Bouwer and Rice (1976) as described in Butler (1998). Table 5-5 presents the estimates of hydraulic conductivity at each of the bores, with the full results provided in Appendix II.

Table 5-5: Estimates of Hydraulic Conductivity from In-situ Permeability Tests

Bore ID	Screened Interval (mbGL)	Assumed Geology	Aquifer Model	Analysis Method	Average Hydraulic Conductivity (m/day)
BSOC_B6	37.0 to 55.0	Bedrock	Confined	KGS Model	0.0006
Bore 23	4.0 to 8.0	Weathered Bedrock	Unconfined	KGS Model	2.0
Bore 24	40.0 to 58.0	Bedrock	Confined	Hvorslev	0.07
Bore 38	29.0 to 37.0	Bedrock	Confined	Hvorslev	0.0006
Bore 39	18.5 to 24.5	Bedrock	Confined	KGS Model	2.4
Bore 40	19.0 to 25.0	Bedrock	Confined	KGS Model	2.0
Bore 4A	10.0 to 47.5	Bedrock	Confined	KGS Model	0.03
MIOP01/S2	2.5 to 5.5	Weathered Bedrock	Unconfined	Bouwer and Rice, corrected	0.04
MIOP02	10.0 to 15.0	Weathered Bedrock	Unconfined	Bouwer and Rice, corrected	0.1
S3	11.0 to 14.0	Weathered Bedrock	Confined	KGS Model	0.1
S7	8.0 to 13.0	Weathered Bedrock	Confined	Hvorslev	0.6
S8	11.0 to 14.0	Bedrock	Confined	KGS Model	0.003

The following observations on the in-situ permeability test program / results are made:

- Estimates of hydraulic conductivity ranged between 0.0006 m/d and 2.4 m/d.
- Higher values were observed in Bore 23, Bore 39 and Bore 40:
  - Bore 23 is likely to be screened within the weathered zone, which is considered to have a higher hydraulic conductivity than the fresh bedrock due to the weathered geology at this location.
  - Bore 39 is likely to be screened below the weathered zone, with the geological log indicating the screen is located within meta-basalt (Eastern Creek Volcanics), with the potential that there is some primary porosity remaining as well as a degree of fracturing. The water level hydrograph for this bore also shows a rapid response to and following the large rainfall event which is likely a result of this higher hydraulic conductivity.
  - Bore 40 is also described as being screened within meta-basalt (Judenan Beds) and is screened below the weathered zone. The closest bore to Bore 40 is BSOC_B2, which also has some higher hydraulic conductivity values due to potential matrix porosity

(observed during drilling), which could also be present at Bore 40, however detailed geological descriptions from the time of drilling Bore 40 are not available to confirm.

- The lowest values of hydraulic conductivity were estimated from the tests were observed at BSOC_B6[6], Bore 38 and S8.
  - BSOC_B6 is a relatively deep bore, with limited oxidation / fracturing and primary porosity observed during drilling, therefore a value of 0.0006 m/d is representative of the conditions observed.

Hydraulic Conductivity versus Depth

A comparison of the hydraulic conductivity values and the testing depth (screen mid-point) is presented in Figure 5-22 for values obtained during the packer testing and in-situ permeability testing. The figure shows there is a general decrease in hydraulic conductivity with depth, which is to be expected for this geological environment, where secondary porosity (structural deformation and weathering) is more prevalent at shallow depths. With the exception of three results, all other results are indicative of fractured igneous and metamorphic rocks as reported in literature.

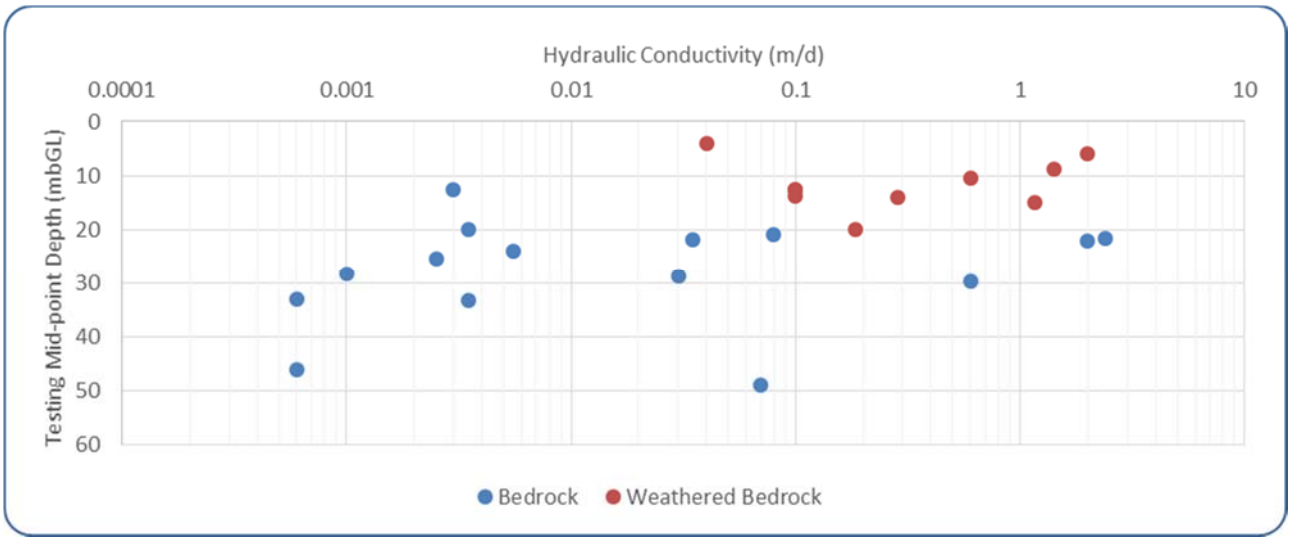

Figure 5-22: Weathered Bedrock and Bedrock Hydraulic Conductivity versus Depth

5.2.3 Hydrogeology of the BSOC WRD Landform

Limited hydraulic testing of waste rock and tailings has been undertaken across the MIM site. A summary of hydraulic parameters for waste rock and tailings, obtained from available background information, is provided Table 5-6.

[6] Packer testing was planned at this location, however due to issues with the packer testing equipment, in-situ testing was completed instead.

Table 5-6: Waste Material Hydraulic Parameters from Previous Studies

Waste Material Description	Compaction	Hydraulic Conductivity (m/d)	Source
BSOC waste rock – oxide waste rock	Compacted	0.05	O'Kane (2007)
	Relatively unconsolidated (one compaction cycle)	2.3	O'Kane (2007)
BSOC waste rock – primary material	Compacted	0.07	O'Kane (2007)
BSOC waste rock – primary material (Modelled)	Non-compacted	86.4	O'Kane (2007)
BSOC waste rock – cover surface material	Unknown	0.0004	O'Kane (2011)
BSOC waste rock (trafficked)	Compacted	0.07 to 0.45	Schneider (2012)
BSOC waste rock – cover trial material	Compacted	0.36 to 0.47	Schneider (2012)
BSOC waste rock – cover trial material	Non-compacted	0.21 to 0.73	Schneider (2012)
Tailings	n/a	0.0001 – 0.18	Forsyth (2014)

Estimation of the saturated hydraulic conductivity of the tailings material was completed by Forsyth (2014) as part of a column leaching test program. Relevant to this assessment is the testing completed for TSF5, with TSF3 already covered by the WRD at the time of testing. Four tailings samples were tested for TSF5, with the range of results provided in Table 5-6. A mean hydraulic conductivity value of 0.027 m/d was calculated from these results.

Field saturated hydraulic conductivity testing was completed by O'Kane Consultants in 2007, reporting that values were obtained for compacted waste rock surface and primary waste rock. Testing was reported to be unsuccessful on the compacted coarse-grained material and therefore the study states that these values (presented in Table 5-6) represent the lower range of values expected. O'Kane (2007) also undertook in-situ consolidation hydraulic conductivity tests where they reported a value for a relatively unconsolidated oxide waste rock, which had undergone one compaction cycle. Modelling within the same study for development of a cover design system used a value of 86.4 m/d for the saturated hydraulic conductivity of the WRD primary waste rock and a porosity of 0.32.

Particle size distribution (PSD) was also undertaken by O'Kane (2007) and they report that the PSD of the BSOC materials are approximately 60% gravel, 25% sand and 15% silt and clay sized particles according to the Unified Soil Classification System.

A cover trial program at MIM was completed between 2008 and 2011 as part of a PhD thesis and reported in Schneider (2012). During the cover trial program measurements of hydraulic conductivity were obtained for waste rock, both compacted and uncompacted, through infiltration tests using disc and hood infiltrometers. The values obtained from the testing are provided in Table 5-6. The thesis also details limitations and issues encountered during the infiltration testing, which indicate that the values presented represent lower end (minimum) hydraulic conductivity values. This is as a result of unsuccessful testing of the coarser material as the rate of infiltration was too high. Also due to limitations with the instruments used, testing was only able to be undertaken on even surfaces where smaller sized rocks were present, excluding

areas of protruding stones / boulders. The thesis also concludes that when comparing the hydraulic conductivity values obtained with the results from the cover trials, the hydraulic conductivity is likely to be higher than values obtained from the infiltration testing.

As part of the Phase 2 field program, infiltration testing was planned to be carried out on the current WRD surface using a 'soakaway' style test to estimate the hydraulic conductivity of the WRD. A test was attempted in the centre of the WRD (Figure 5-23), however, the rate of infiltration was greater than the rate of filling from the water truck (approximately 150 L/min) and the test was abandoned. The size range of waste rock at this location was highly variable, with the observed rocks on the surface greater than 10 cm in diameter.

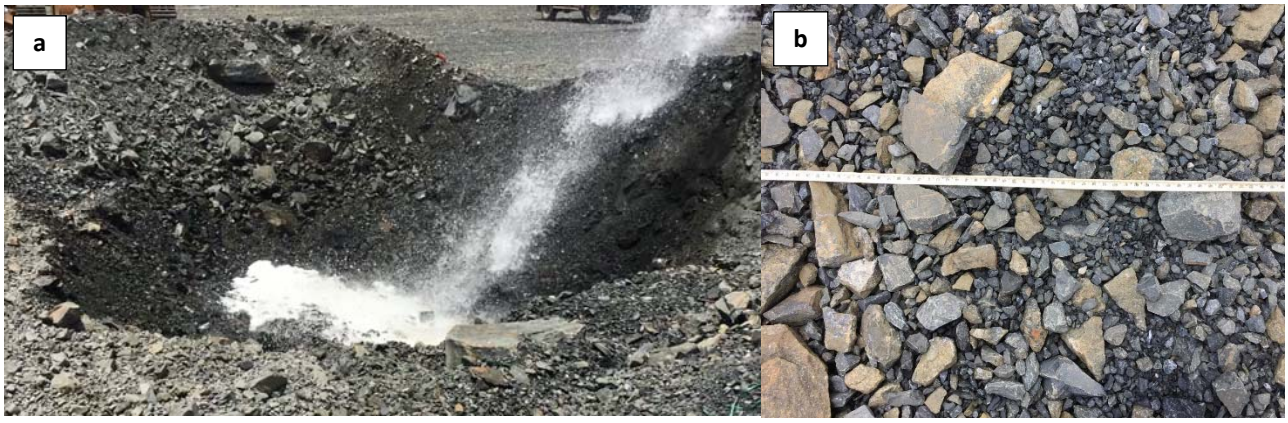

Figure 5-23: WRD Infiltration 'Soakaway' Testing. a) water infiltrating test pit, b) Typical WRD surface material (December, 2015)

As a result, observational evidence was collected across the WRD surface, which included observing the rate of infiltration on a heavily compacted / trafficked area of the WRD (Figure 5-24). Water was observed to pool on the surface and run off. Generally the size of the rocks in this area is no greater than 2 cm diameter and are compacted.

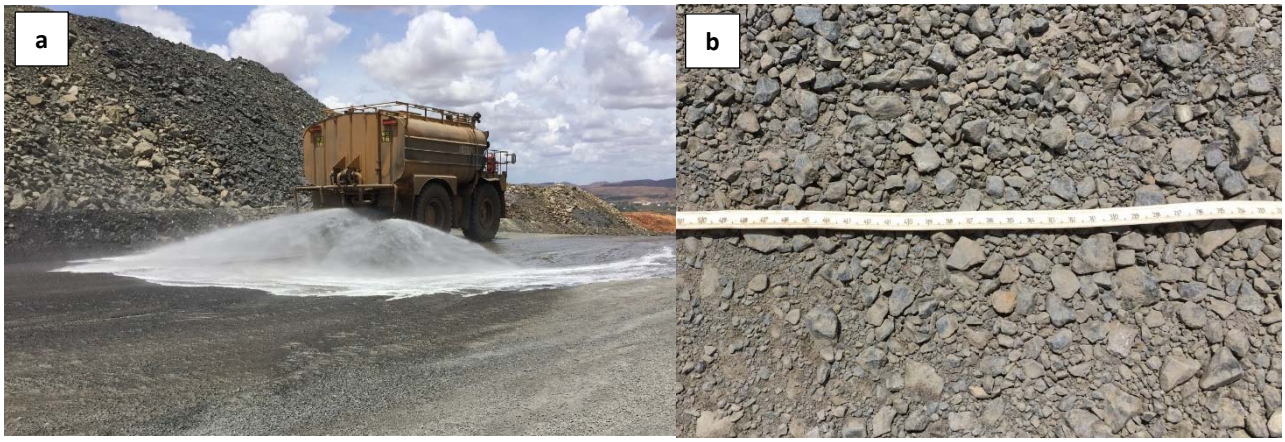

Figure 5-24: Infiltration observations on highly trafficked / compacted area. a) water infiltration test, b) compacted waste rock surface (December, 2015)

Additional observational evidence was collected across the WRD surface to assess potential areas where the rate of infiltration may vary and run-off may occur. Further details are provided in Appendix II, with some commentary provided below:

- Heavy metals rejects (HMR) are also deposited on the waste rock dump surface for use in traffic areas. The rock size in this area is relatively uniform and no greater than 3 cm diameter, with little or no compaction observed.
- Within a highly compacted area of the BSOC WRD, located at a trafficked section, the size of waste rock ranges between 1 cm and 5 cm and shows evidence of salt precipitation. Silt-sized particles were also present as a result of erosion and compaction of the rock.
- Anecdotal information from site personnel also indicate that during / after rain events, ponding of water is not observed on the flat surface of the WRD.

Based on site observations and the infiltration test which was attempted in the centre of the BSOC WRD on the recently placed primary waste rock (non-compacted), the maximum hydraulic conductivity of the surface material is approximated to be ~100 m/d[7]. This approximation indicates that the non-compacted surface material is highly permeable, which has allowed maximum infiltration at surface to occur in the non-compacted areas of the WRD following rainfall events. However, it is anticipated that the hydraulic conductivity approximation would not be uniform across the whole WRD surface due to compaction (trafficked areas) and also within the internal structure of WRD, where potential traffic compaction may have also occurred.

As well as rainfall infiltration, the water balance of the WRD will also include evaporation and run-off. As previously discussed, there was little impediment on the typical WRD surface to rainfall infiltration (based on the testing) and no ponding of water observed after rainfall events. Evaporation is high in the Mount Isa region, exceeding rainfall in every month of the year, however there is no testing to confirm the impact evaporation would have on infiltration (or net percolation) into the WRD.

Schneider (2012) also provides a site specific estimate of 'net percolation' into the WRD material following three wet seasons. These rates are measured as seepage from the base of 2 m thick cover materials trial plot (comprising both compacted and non-compacted waste rock), across six plots. Issues were encountered with the measurement equipment, however the most complete trial indicated that up to 95% of the rainfall over the three wet seasons percolated into the WRD. It was also concluded from the trials that runoff from the trial plots does not occur and that all incident rainfall percolated into the WRD material.

Based on the results from Schneider (2012) and the observations made during the Phase 2 field investigation, the net percolation into BSOC WRD is likely to be high, although it is not possible to estimate an exact value. Literature values have been reviewed for a number of mines within Australia and rates are reported as high as 86% of rainfall (Harries, 1990; Rodhe & Williams, 2009) for the net percolation into WRDs.

Water levels, and the associated interpreted piezometric surface, within the BSOC WRD is unknown due to the lack of groundwater monitoring facilities within the WRD. However, due to the interpreted radial groundwater contours adjacent to the BSOC WRD landform it is interpreted that a saturated head is present within the WRD and underlying TSFs which is in hydraulic connection / influencing the underlying bedrock piezometric surface.

[7] Calculation based on flow rate entering test pit, divided by approximate area where the water was placed during the test

5.2.4 Summary of Current Preferential Pathways / Mechanisms / Fault Lines for Seepage

The above investigations concluded that the potential pathways for seepage from the BSOC WRD landform include:

- Groundwater flow through alluvial aquifers;
- Surface water flow along the Diversion Drain infiltrating into the higher permeability alluvial aquifer; and,
- Groundwater flow within bedrock aquifers, either through primary matrix, fractures / faults / structural defects / structural anomalies.

Alluvial Aquifer

Movement through the alluvium is dependent on the hydraulic properties of the aquifer and groundwater flow gradients. Based on the evidence collected during the Phase 2 site investigation and reported in the preceding sections, the following interpretations are made relating to seepage pathways within the alluvial aquifers:

- Mapping on the alluvium during the Phase 1 site investigation and the inferred location of the alluvium underlying BSOC WRD, developed using the reconstructed landform models and historical aerial photographs, indicates that a connection exists between the alluvium underlying the WRD and the alluvium beyond the dump toe. Seepage may directly enter groundwater within the alluvial aquifer underlying the WRD and flow downgradient.
- Historical aerial images indicate the presence of salt precipitation prior to construction of the WRD which may have originated from dams / spillways associated with TSF3 and TSF5, which when correlated with the HEM survey, indicates zones of conductance along the creek lines.
- Groundwater flow gradients indicate groundwater moves towards the west within the alluvium associated with BSOC WRD North and BSOC WRD South seepages.
- Observational evidence from the Phase 1 site investigation also confirmed that seepages occur within the Diversion Drain where the alluvium is exposed at surface due to the construction of the drain.
- As the seepage within the Diversion Drain flows towards King Gully and passes over the alluvium (e.g. at BSOC WRD North Seepage), it was observed that seepage on the surface infiltrated into the alluvium at these locations. This seepage then joins the groundwater system within the alluvium and flows towards the north-west, away from the drainage alignment.

Bedrock Aquifer

Groundwater movement through the bedrock is more complex. Based on the site investigation results, primary matrix flow is limited and therefore seepage movement of this nature is limited, with long term migration rates. Evidence of oxidation and potential fracturing and bedding planes, indicating presence of water within the bedrock aquifer, was encountered within the majority of the drill holes and there is potential for seepage through the bedrock, should extensive connectivity exist. As well as within fractures, groundwater flow within the area may also occur within faults and structural lineaments.

Zones of conductance (seepage plumes) identified from previous HEM survey investigations have been disproved and inferred as a geological anomaly rather than seepage plumes.

5.3 Current and Expected Volume and Rate of Seepage

In order to determine the current and expected volume and rate of seepage from the BSOC WRD to the receiving environment (1 (b) of the EE Notice), the following tasks were undertaken:

- Design and installation of flow monitoring weirs within the Diversion Drain; and
- Completion of a two-dimensional seepage modelling assessment.

5.3.1 Seepage Weir Design and Installation

5.3.1.1 Overview and Design Basis

A site visit was carried out as part of this assessment by a KCB Senior Civil Engineer to inspect the seepage points and provide feedback on recommended flow measurement methods. A concept design and construction requirements for flow gauging weirs and pump flow meters to estimate seepage volumes from BSOC WRD was then undertaken. This component of the investigation also included recommendations for the installation of flow gauges to develop an understanding of the emergent seepage volumes and flow patterns. The design basis for the seepage monitoring weirs is outlined in Table 5-7. The full seepage design report is provided in Appendix III, with a summary provided in the following sections.

Table 5-7 Seepage Monitoring Weirs Design Basis

Item	Design Criteria	Reference
Design Intent	To estimate the seepage volumes and flow rates, from the BSOC WRD at each of three discharge points.	(KCB, 2015)
Design Life	Intended as semi-permanent structures, to gauge flows for a duration of 5 – 10 years with ongoing maintenance during this time	
Hydrology		
Rainfall	IFD for the Mount Isa Region	BOM, 1987 ARR based IFD generated at www.bom.gov.au
Runoff estimation method	Rational method Bransby-Williams Time of concentration	(Pilgram, 1987; TMR, 2010)
Runoff Coefficient estimate	Table 5.9.1 – Runoff coefficient estimation in rural areas	(TMR, 2010)
Weir		
Flow Gauging Range	Able to monitor low flows (seepage) and higher, wet season flows. *Assume: maximum gauging of 5 year ARI (Average Recurrence Interval) flows*	KCB Assumption
Location	Defined channel with sufficient longitudinal grade in the channel to provide some vertical drop between the weir and the downstream channel section. Bedrock channel base, avoid alluvium materials.	
Construction Materials	Concrete and steel plate	

5.3.1.2 Flow Monitoring Design and Construction

Three flow monitoring weirs were proposed as part of the EE investigation, and were constructed in December 2015. The location of the weirs is shown in Figure 5-25.

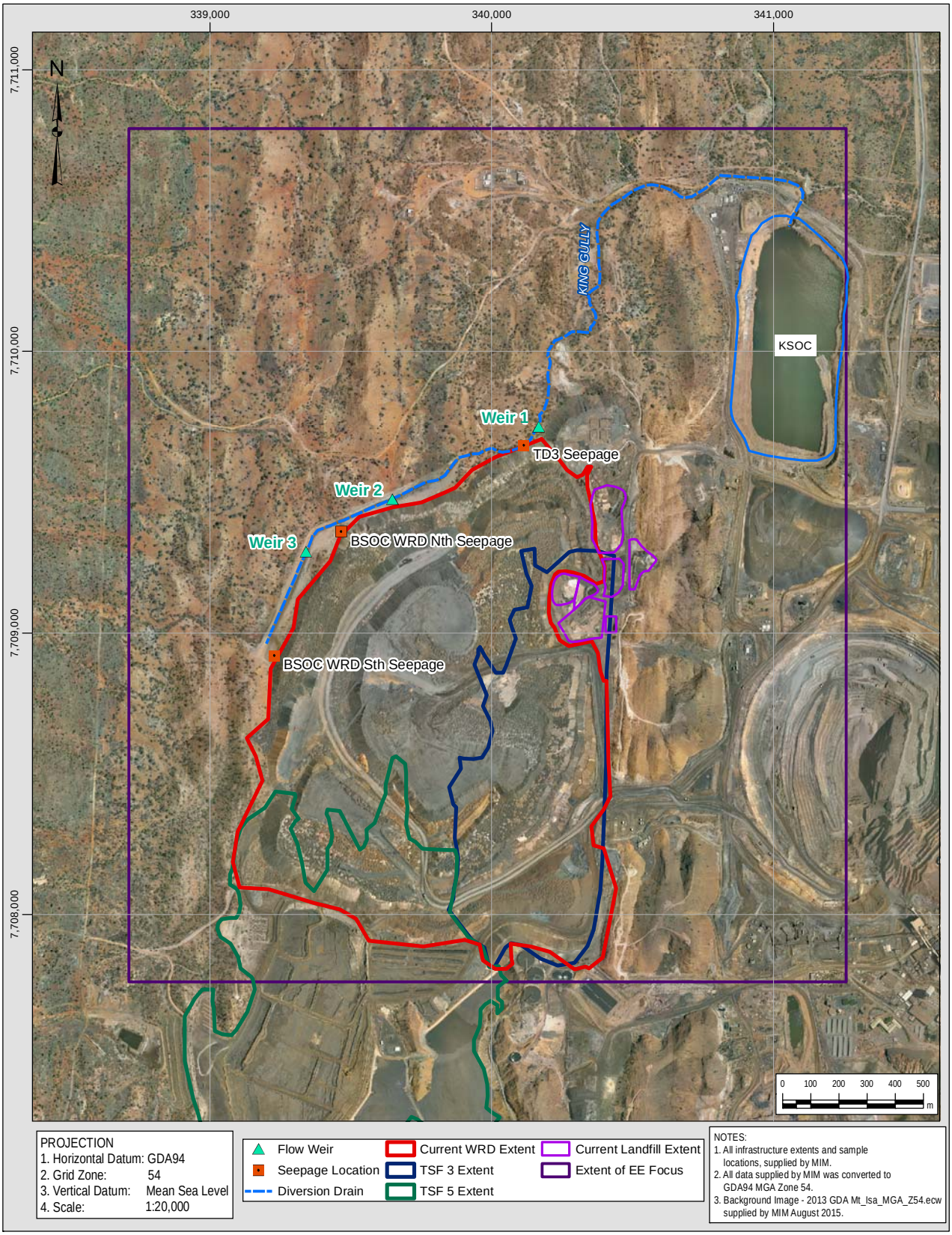

Figure 5-25: Location of flow monitoring weirs

The weirs were proposed at locations along the Diversion Drain where the depth to bedrock was relatively shallow (to allow the weir structure to be “keyed” into the bedrock), and between seepage points along the Diversion Drain. The weirs were constructed as concrete structures with a v-notch steel weir plate to measure the low flows, primarily from seepage, with the higher flows estimated based on the channel cross section. A summary of the weirs is provided below.

BSOC WRD Weir 1 (Figure 5-26) is located immediately downstream of the TD3 Seepage and was installed to estimate total seepage from the BSOC WRD, and provide inputs to calculate the seepage at the TD3 Seepage.

Figure 5-26: BSOC WRD Weir 1 after construction (January, 2016)

BSOC WRD Weir 2 (Figure 5-27) is located downstream of the BSOC WRD North Seepage, and was installed to provide inputs to calculate the seepage at the BSOC WRD North Seepage.

Figure 5-27: BSOC WRD Weir 2 after construction (January, 2016)

BSOC WRD Weir 3 (Figure 5-28) is located upstream of the BSOC WRD North Seepage and was installed to estimate the flow prior to the BSOC WRD North Seepage. Flows monitored at BSOC WRD Weir 3 will include surface water runoff from the catchment as well as seepage from BSOC WRD South Seepage, which is pumped into the Diversion Drain from the trench.

Figure 5-28: BSOC WRD Weir 3 after construction (January, 2016)

Recommendations were also made for water level loggers, which were installed adjacent to the Weirs 1 and 3 in March, 2016. Installation of a water level logger at Weir 2 is yet to be completed, due to issues with the automated flow monitoring equipment. Information from MIM site personnel is that since construction there has been no water flowing over Weir 2, however pools of water have been observed upstream of the weir.

Flow monitoring equipment has also recently been installed (July, 2016) on the transfer pump at the BSOC WRD South Seepage trench (Figure 5-29) and will be used in conjunction with the flow monitoring at Weir 3 in the future.

Figure 5-29: BSOC WRD South Seepage transfer pump flow monitoring equipment (July, 2016)

5.3.1.3 Diversion Drain Flow Monitoring

Flow data was recorded for Weirs 1 and 3 between March and May 2016 following installation of the water level loggers.

The hydrograph for Weir 1 is shown in Figure 5-30 and Weir 3 is shown in Figure 5-31. Rainfall recorded during the same period was sourced from the Bureau of Meteorology for the rain gauge at Mount Isa Mine (#029126) and is included for comparison against the Weir 1 hydrograph.

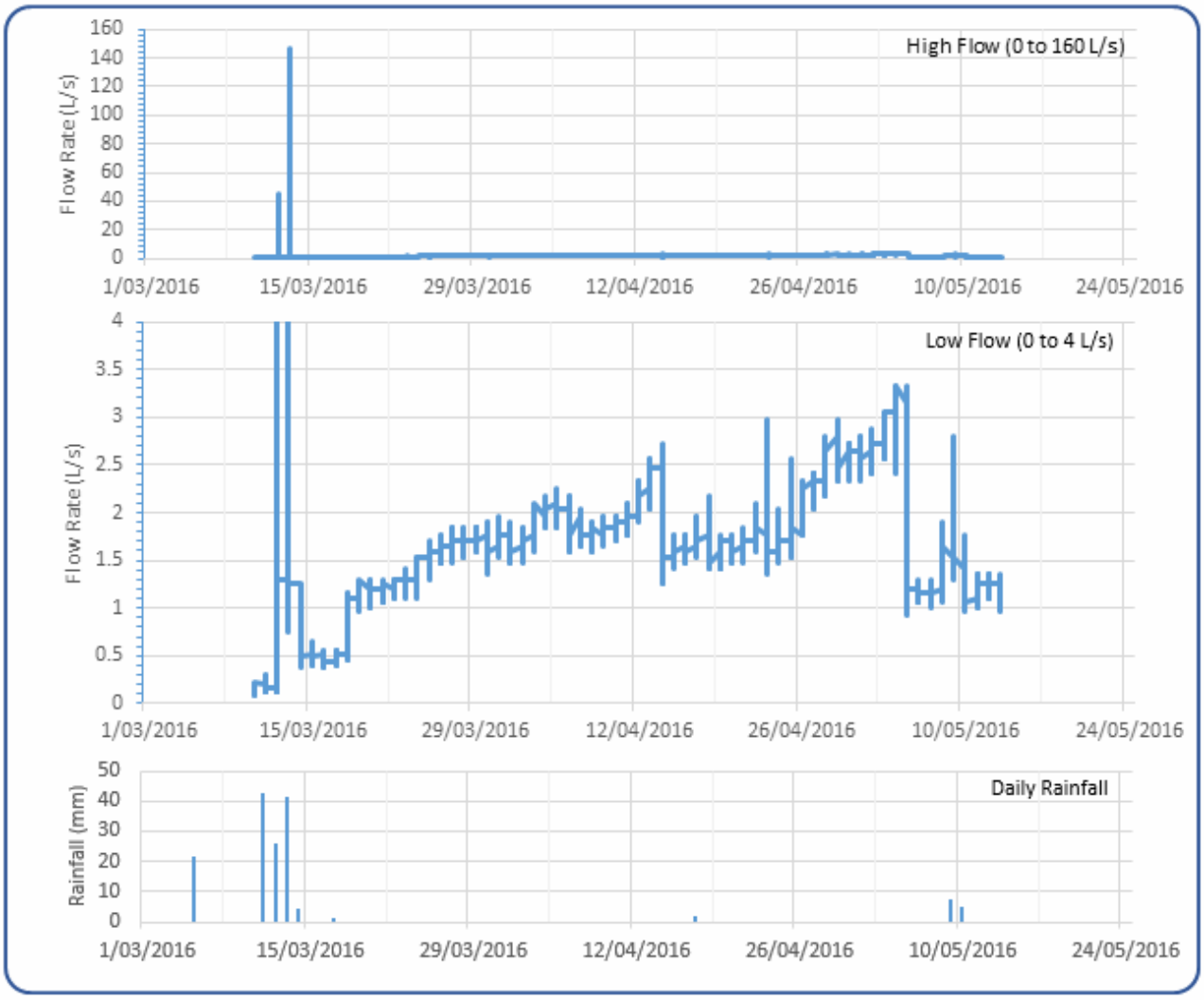

Figure 5-30: Weir 1 hydrographs from March to May 2016, shown as high flow graph, low flow graph and rainfall

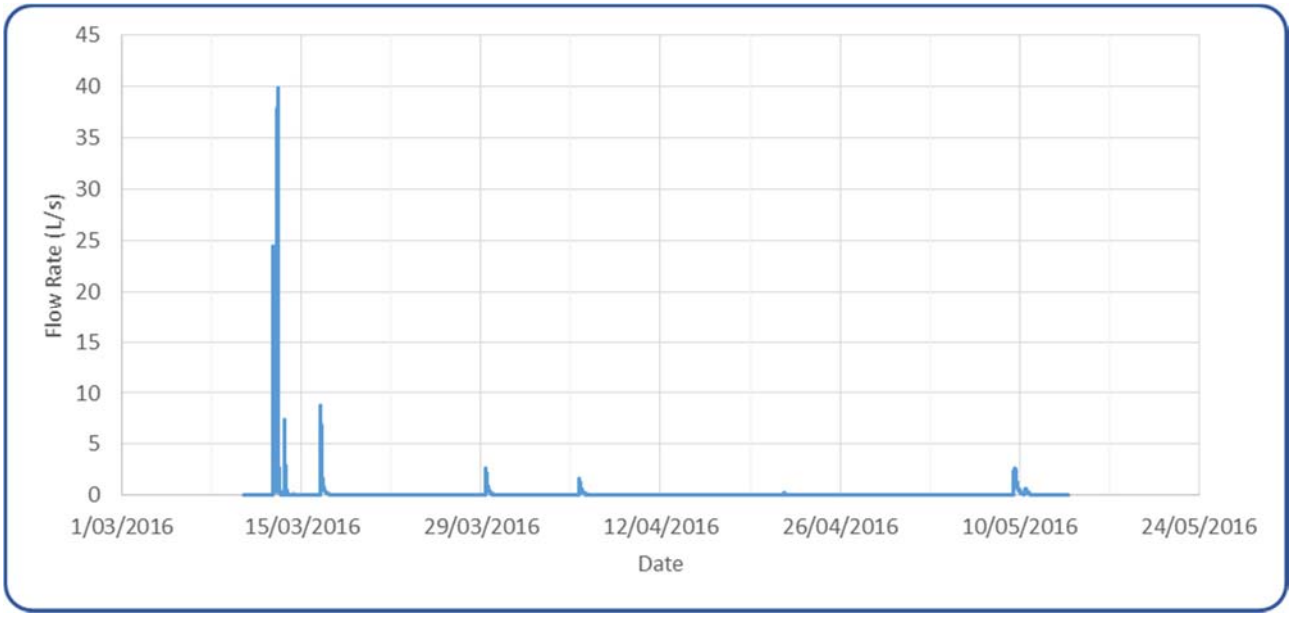

Figure 5-31: Weir 3 hydrograph – March to May 2016

Based on the short period of record available, the following observations are made:

- Weir 1, located downstream of TD3 Seepage, has recorded a flow for the full period of record:
  - Higher flow rates were recorded in March in response to rainfall events, with 115mm of rain falling between March, 11 and March, 17 (BOM, 2016). Two smaller rainfall events occurred on April, 17 (1.6mm) and May 9/10 (12.2mm).
  - The average flow rate over the period of record at Weir 1 is 1.83 L/s.
  - The hydrograph shows an increasing trend following the rainfall event at the beginning of the record, which may be indicative of an increase in seepage at TD3 in response to the large rainfall event.
- Weir 3, located downstream of BSOC WRD South Seepage, has recorded limited flow across the period of record.
  - Based on the above rainfall, flow at this weir correlates with the rainfall events, with the exception of the three smaller flows within the middle period of the record (March, 29 and April 5, 25).
  - In the absence of rainfall in these periods, these smaller flows are likely to have occurred as a result of the transfer of water from the BSOC WRD South Seepage collection trench into the Diversion Drain. The maximum flow for these events was ~2.7 L/s (March, 29).

5.3.2 Two-Dimensional Seepage Modelling

5.3.2.1 Overview

Two-dimensional seepage modelling was undertaken as part of this assessment using the modelling platform Seep/W (Geo-Slope International; September, 2013 release). Seep/W allows the numerical representation of two-dimensional flow, representing variability in material hydraulic properties and the capacity to model a wetting front through unsaturated materials. The seepage modelling comprised the following:

- Construction of three 2D models through each of the seepage locations (TD3, BSOC WRD North Seepage and BSOC WRD South Seepage), which included representative thicknesses of the BSOC WRD, TSFs and underlying geology (alluvium, weathered bedrock and bedrock);
- Assignment of material properties, based on both literature values and analysed field testing values (where available);
- Assessment of the wet / dry season flux variation using average monthly rainfall;
- Estimation of unit seepage volumes at each of the seepage locations;
- Estimation of the water flux between site infrastructure (WRD, TSF) and the underlying geology;
- Estimation of groundwater flux through the alluvium, weathered bedrock and bedrock;
- Model scenarios to assess the sensitivity of the model to parameters of uncertainty; and,
- Conversion of fluxes / seepage rates from two-dimensions to three-dimensions to be representative of the study area.

5.3.2.2 Model Domain and Layers

Three representative 2D cross sections through the BSOC WRD landform were selected for the seepage modelling, with their locations shown in Figure 5-32. These sections are located through each of the seepage points and the upstream and downstream interpreted catchments. Alluvial material was included in each of the sections, as well as a representative thickness of weathered zone and bedrock material.

A summary of each of the seepage model domains is provided in the following sections.

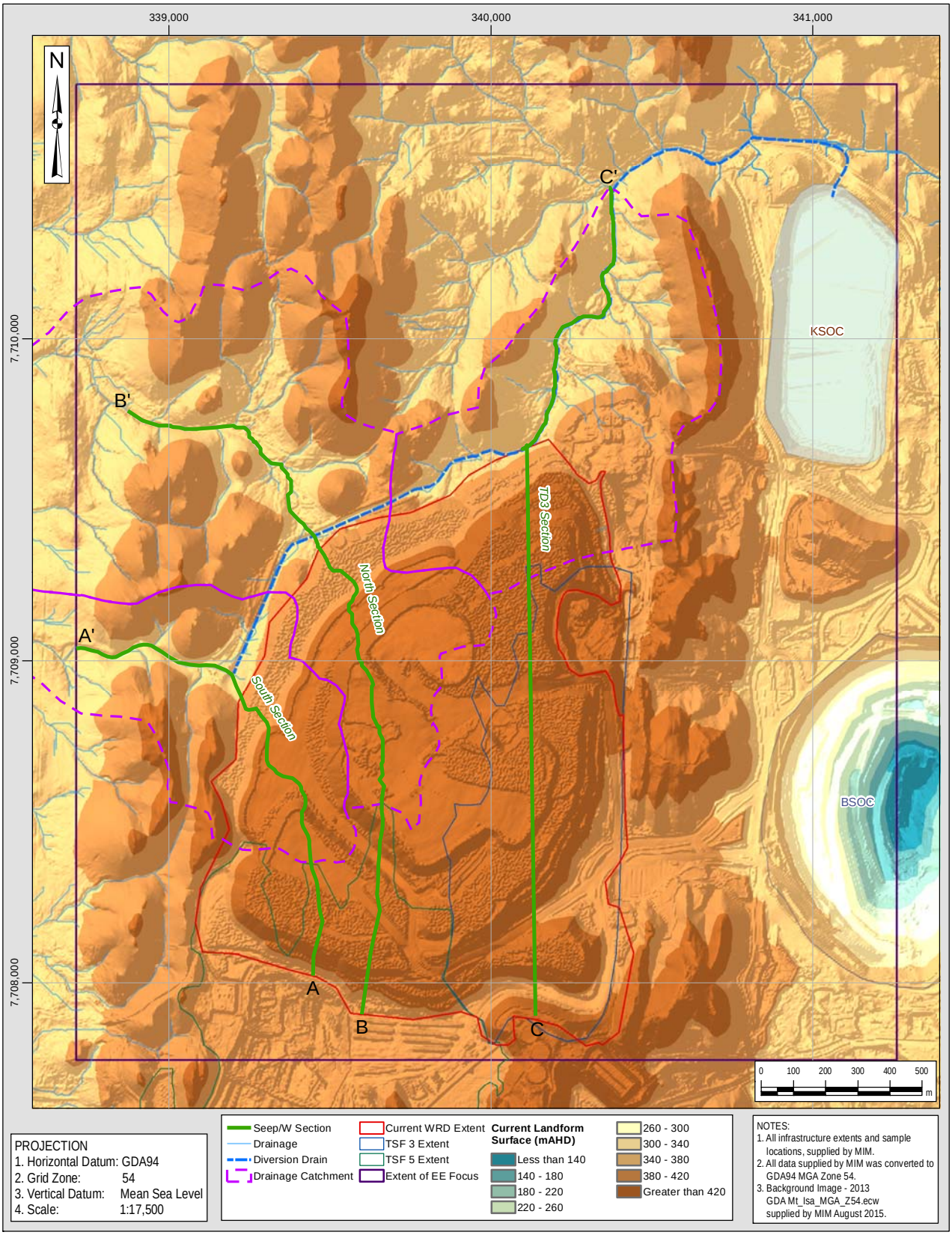

Figure 5-32: 2D Model Locations

TD3 Seepage Model Domain

The TD3 Seepage 2D model domain, as shown in Figure 5-33 is orientated in a general south to north direction and includes the full length of TSF3, which is approximately 1,100 m in length. BSOC WRD overlies TSF3 and ranges in width from ~1,600 m where the WRD overlies TSF3 and underlying geology; and, ~1,000 m at the top of the dump.

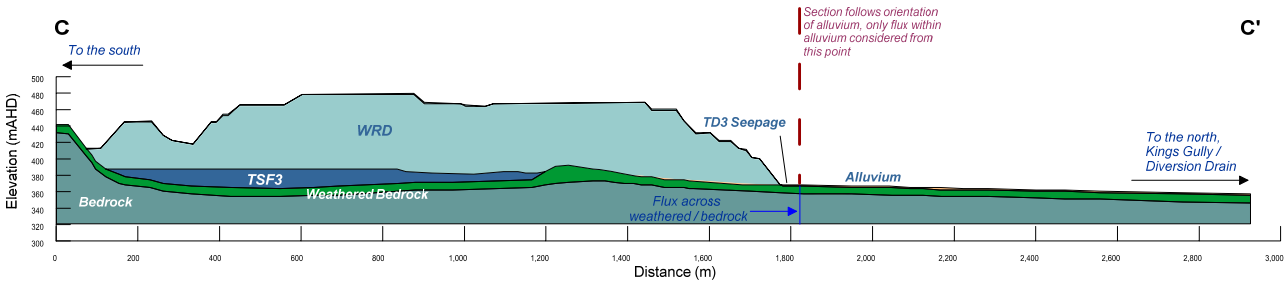

Figure 5-33: TD3 Seepage slice model section

At the TD3 seepage point, the section is orientated to follow the creek towards King Gully Dam. Alluvium is included underlying the BSOC WRD to the north of TSF3. Seepage nodes are placed at the toe of the WRD and within the Diversion Drain (constructed within the alluvial system), before flowing into King Gully downstream. Seepage nodes represent zones where groundwater flow can leave the model (i.e. discharge as surface water flow)

Conceptually, this two-dimensional section has been scaled to represent seepage from TD3 and any discharge to groundwater within the bedrock or alluvium flowing towards the north.

BSOC WRD North Seepage Model Domain

The BSOC WRD North Seepage 2D model domain is shown in Figure 5-34 and includes the footprint of TSF5 covered by the WRD, which is approximately 700 m in length. BSOC WRD overlies TSF5 and is ~1,500 m wide at the base and ~1,000 m at the top of the section.

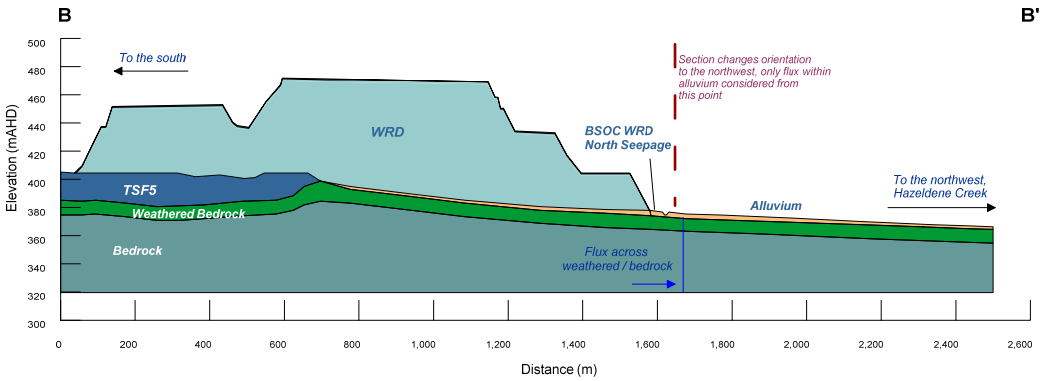

Figure 5-34: BSOC WRD North Seepage 2D Model Section

The 2D section is orientated in a general south to north direction, up to the North Seepage point, at which point the section follows the alignment of the creek to capture potential seepage through the alluvium.

Seepage nodes are placed at the toe of the WRD and within the Diversion Drain which has been constructed within the alluvial layer.

Conceptually, this section can be scaled to represent the catchment underlying the dump associated with north seepage and any discharge flowing west towards the study area boundary. Within the bedrock, regionally groundwater is flowing from south to north and therefore any fluxes estimate from the model will be estimated from directly underlying the BSOC WRD North seepage point.

BSOC WRD South Seepage Model Domain

The BSOC WRD South Seepage model domain is presented in Figure 5-35 and includes the western dam of TSF5, which is covered by the WRD. TSF5 is approximately 400 m in length within the model domain. The WRD is ~850 m in length along the base of the model domain and ~540 m across the top.

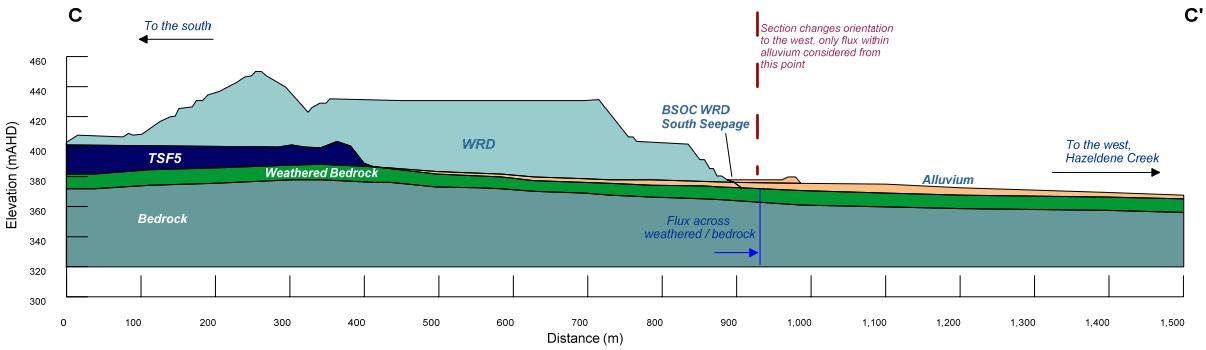

Figure 5-35: BSOC WRD South Seepage 2D model section

The 2D model section is orientated south to north from the southern extent of the WRD to the BSOC WRD South Seepage point, at which point the section follows the alignment of the creek to capture potential seepage through the alluvium.

Adjacent to the BSOC WRD South Seepage point is the start of the Diversion Drain. To encourage surface water flow in the northerly direction into the Diversion Drain, this area was built up to provide the surface gradient required for the flow. A trench was also excavated into the bedrock at this location, however this has not been included in the model as the extent of the underlying alluvium is beyond the length of the trench and migration of seepage in the alluvial aquifer can bypass the collection trench. All seepage exiting the WRD within this section is captured at the WRD toe through the placement of seepage nodes.

Conceptually, this section can be scaled to represent the catchment underlying the dump associated with BSOC WRD South Seepage and any discharge entering the groundwater system flowing towards the west for the alluvial aquifer and a flux line to represent flow towards the north (measured directly underneath the dump) in the bedrock aquifer.

5.3.2.3 Model Boundary Conditions and Material Properties

Boundary Conditions and Assumptions

The following boundary conditions were established in the SEEP/W models. Assumptions and limitations of the modelling are also included in this section.

- No flow boundary conditions were established along the bottom of the model (no flow bedrock conditions) representing the extent of encountered groundwater in the bedrock aquifer during the site investigation;
- Rainfall recharge was applied across the WRD top surface at a rate equivalent to 80% (Model A) and a rate equivalent to 50% (Model B) of average monthly precipitation to allow for water lost due to evaporation and runoff from heavily trafficked areas. A rate of 30% was applied to the WRD slopes to accommodate runoff.
  - The 80% rate was selected based on values presented in Schneider (2012), literature values (Section 5.2.3) and observational evidence collected during the Phase 2 site investigation, whereby site personnel indicated little or no ponding of water on the dump surface during and following rainfall events.
  - The 50% rate was utilised to assess variability in the model should significant evaporation occur as a result of water storage within the upper near-surface layers of the WRD.
- A seepage face (represented by seepage nodes) was applied to the toe of the WRD and within the Diversion Drain (if applicable).
- Flux boundaries were established to assess the transfer of water within areas of the model, e.g. the volume of water leaving the base of TSF3 or TSF5, and the flux of water flowing within the alluvium aquifer.
- The through-flow of water down-gradient was specified using a constant head boundary at the model edges. The values chosen where taken from the groundwater contours interpreted from January 2016 groundwater levels.
- The WRD has been modelled as a single unit, however it is acknowledged that there would be variability within the WRD due to compaction / trafficked areas during various stages of its construction. Sensitivity of the WRD hydraulic conductivity has been included to address this.
- The models do not take into consideration any flow of water which enters the alluvium as a result of flow along the Diversion Drain where the drain crosses the alluvium.
- Measured and calibrated flow data from Weir 1 (downstream of TD3 seepage), which is indicative of seepage volumes, is available for period between March and May 2016. This data was used to compare against predicted results from the TD3 Seepage Model (Section 5.3.2.5).
- Each model is simulated within the Seep/W transient platform based on daily time steps for a period of 20 years to allow the model to establish static conditions. This option was selected as the dump is simulated as the current landform and does not allow for the construction of the dump over time. On reaching static conditions, a second model run was simulated for 365 days to assess total flux during a 1 year period.

Material Properties

Each hydrostratigraphic unit in the models has a unique hydraulic function of conductivity (m/d) versus pore-water pressure and volumetric water content versus pore-water pressure (soil-water characteristic curve or SWCC). Table 5-8 summarises the various materials used in the modelling

and lists the adopted material properties, used for the 'base case' scenario. In the absence of site-specific SWCC functions, default sample functions were used (from SEEP/W) for each typical material.

Table 5-8: Range of Hydraulic Conductivity Values (m/d)

Slice Model	Material	Saturated Hydraulic Conductivity (m/d)	Source
All	Waste Rock	10	Observational Evidence
	Tailings	0.027	Forsyth (2014) – TSF5
	Alluvium	1	Literature
TD3	Weathered Zone	0.28	Phase 2 Testing
North		0.16	Phase 2 Testing
South		0.28	Phase 2 Testing
TD3	Bedrock	0.008	Phase 2 Testing
North		0.015	Phase 2 Testing
South		0.01	Phase 2 Testing

5.3.2.4 Model Scenarios

For each model section a base case scenario has been modelled with some additional model runs to assess the sensitivity of certain model parameters. For each model section the following scenarios have been modelling:

- Base Case, using model input parameters as discussed in the previous sections.
- Sensitivity 1: A decrease of half an order of magnitude in the saturated hydraulic conductivity of the alluvium (0.5 m/d).
- Sensitivity 2: An increase of half an order of magnitude in the saturated hydraulic conductivity of the alluvium (5 m/d).
- Sensitivity 3: A decrease of half an order of magnitude in the saturated hydraulic conductivity of the WRD (2 m/d).
- Sensitivity 4: An increase of half an order of magnitude in the saturated hydraulic conductivity of the WRD (50 m/d).
- Sensitivity 5: An increase in the saturated hydraulic conductivity of the WRD (50 m/d) and a decrease in the saturated hydraulic conductivity of the alluvium (0.5 m/d).

All of the above scenarios were run using the 80% (model A) and 50% (model B) infiltration rates.

5.3.2.5 Modelling Results

Results of each scenario from the three models are presented in the following sections. The two-dimensional flux lines / nodes have been 'scaled up' to represent water flow / seepage across those locations in three-dimensions (i.e. incorporating the lateral extent of the WRD landform). This area, representing the 'scale up' is also provided. The results are presented as a rate of m^3/d, which has been extracted from the 1 year static condition model for both the 50% and 80% infiltration scenarios. Discussion of the results for each seepage model is provided in the following sections, with some discussion common to the three models provided below.

Across the three 2D seepage models, varying the infiltration rate within the models (50% and 80% of average monthly rainfall) resulted in similar flux volume transfers, which is a result of simulating seepage under static conditions. Generally slightly lower volumes are observed in the 50% model, which is to be expected as there is less water available within the model. This also impacted the rates of seepage, which were lower in the 50% model than the 80% model.

The sensitivity of the alluvial K_{sat} was significant, with the higher value (5 m/d) resulting in the smallest seepage volumes across all of the models and in most cases this resulted in no seepage at all. The lower K_{sat} of the alluvium (0.5 m/d) increased the rate of seepage, which was as a result of limiting this pathway for seepage.

Modifying the K_{sat} of the BSOC WRD also resulted in variation across the flux and seepage estimates. A lower K_{sat} of the WRD increased the amount of water within the WRD and subsequently modelled a larger head of water overlying the TSF's. The higher K_{sat} scenario generally resulted in higher seepage rates which is as a result of water being able to move more quickly through the WRD following infiltration.

Seasonality in the seepage rates was also predicted across the three 2D models, with peak seepage generally occurring after 60 to 90 days, equivalent to a time period at the end of February / March (end of wet season); and, the minimum seepage after ~240 days, equivalent to a time period at the end of July (dry season).

TD3 Seepage Model

Results for the TD3 seepage model are provided in Table 5-9 for both the 80% and 50% infiltration rate models for all sensitivity scenarios.

Table 5-9: TD3 Seepage 2D Model – Seepage Modelling Results (m^3/d)

Model	Flow Path	Flux Type	Representative Flux (Q) Area (m^2)	Model Scenario (m^3/d)					
				Base Case	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
Model A (80% Infiltration)	TSF3 to Weathered Bedrock	Horizontal Flux	701,220	13.0	13.0	13.0	33.9	3.6	3.6
	Bedrock to North	Vertical Flux	23,200	5.4	5.5	5.1	13.8	4.3	4.2
	Weathered Bedrock to North	Vertical Flux	5,800	15.2	15.2	15.1	15.2	15.1	15.2
	Alluvium to North	Vertical Flux	46	0.4	0.2	2.4	0.4	0.4	0.2
	TD3 Seepage	Flux Node	580	307.2	427.7	-	143.2	358.3	479.6
	Seepage into Diversion Drain / Alluvium Daylighting	Flux Node	23	15.6	11.0	25.8	17.0	13.6	9.0
Model B (50% Infiltration)	TSF3 to Weathered Bedrock	Horizontal Flux	701,220	9.4	9.4	9.4	30.5	2.1	9.4
	Bedrock to North	Vertical Flux	23,200	4.5	4.4	5.4	11.3	3.1	4.4
	Weathered Bedrock to North	Vertical Flux	5,800	15.2	15.2	15.1	15.2	15.1	15.2
	Alluvium to North	Vertical Flux	46	0.4	0.2	2.4	0.4	0.4	0.2
	TD3 Seepage	Flux Node	580	112.3	227.2	-	38.1	195.5	228.8

Model	Flow Path	Flux Type	Representative Flux (Q) Area (m^2)	Model Scenario (m^3/d)					
				Base Case	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
	Seepage into Diversion Drain / Alluvium Daylighting	Flux Node	23	14.4	10.1	17.0	15.6	11.1	12.0

Model refers to the infiltration rate used
Flow path refers to the flux section or node
Flux type provides a description of the orientation of the flux or if it's a node
Representative flux (Q) area is the cross sectional area which has been used to 'scaled up' from two-dimensions to three-dimensions

Results from the TD3 seepage model estimates that the volume of seepage at this location is between 143 and 480 m^3/d (1.6 and 5.5 L/s) for the 80% model and between 38 and 229 m^3/d for the 50% model (0.4 and 2.7 L/s). Both these estimates are deemed appropriate based on the observed flow within the Diversion Drain / King Gully and the data obtained from Weir 1 downstream of this seepage location.

A summary of the fluxes from the TD3 Seepage model is provided as follows:

- TD3 Seepage:
  - 1.6 to 5.5 L/s (Model A - 80%) and 0 to 2.7 L/s (Model B - 50%)

    91.4% (Model A) and 82.3% (Model B) of total flux from BSOC WRD landform at TD3 Seepage point for Base Case simulation.
- Seepage to alluvium:
  - 0.002 to 0.03 L/s (both Model A and B)

    0.1% (Model A) and 0.3% (Model B) of total flux from BSOC WRD landform at TD3 Seepage point for Base Case simulation.
- Diversion Drain (daylighting) seepage:
  - 0.05 to 0.4 L/s (Model A- 80%) and 0.12 to 0.2 L/s (Model B - 50%)

    4.6% (Model A) and 10.5% (Model B) of total flux from BSOC WRD landform at TD3 Seepage point for Base Case simulation
- Seepage into bedrock from BSOC WRD Landform (BSOC WRD and TSF3):
  - 0.05 to 0.16 L/s (Model A- 80%) and 0.02 to 0.35 L/s (Model B - 50%)

    3.9% (Model A) and 6.9% (Model B) of total flux from BSOC WRD landform at TD3 Seepage point for Base Case simulation

Potential Sludge Pond Contribution to TD3 Seepage

Infiltration from the landfill sludge ponds to the BSOC WRD landform has been hypothesised as a contribution flux to the TD3 Seepage. The potential contribution of the sludge ponds can be conservatively estimated based on a flux balance of the sludge ponds, which comprises:

- Direct waste water placement in the sludge ponds – 3.4 ML/year;
- Evaporation from the sludge ponds
  - Average evaporation rate = 3,066 mm/year
  - Pond size = 10 m x 25 m (2 ponds); and
- Conservative infiltration rate into the underlying formation – difference between the direct waste water placement rate and evaporation rate.

Based on the above fluxes, a conservative infiltration rate into the underlying formation is 0.06 L/s. Assuming all of the sludge pond infiltration contributes to the total flux in the TD3 Seepage catchment, the proportion of the sludge pond flux is conservatively estimated at 1% to 3% of the total flux in the catchment. Based on this proportion of sludge pond flux contribution, it is interpreted that the water quality signature of the sludge pond would be "over-printed" by, and would be negligible compared to, the BSOC WRD landform seepage water quality signature.

BSOC WRD North Seepage Model

Results for the BSOC WRD North seepage model are provided in Table 5-10 for both the 80% and 50% infiltration rate models for all sensitivity scenarios.

Table 5-10: BSOC WRD North Seepage 2D Model - Seepage Modelling Results (m^3/d)

Model	Flow Path	Flux Type	Representative Flux (Q) Area (m^2)	Model Scenario (m^3/d)					
				Base Case	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
Model A (80% Infiltration)	TSF5 to Weathered Bedrock	Horizontal Flux	168,300	22.4	19.8	22.1	12.3	20.1	20.0
	Bedrock to North-West	Vertical Flux	11,825	2.9	3.0	2.7	3.0	2.9	3.0
	Weathered Bedrock to North-West	Vertical Flux	2,750	3.6	3.6	3.6	3.6	3.6	3.7
	Alluvium to North-West	Vertical Flux	50	0.7	0.4	3.5	0.7	0.7	0.4
	North Seepage	Flux Node	275	123.2	152.7	0	111.5	131.1	160.9
	Seepage into Diversion Drain / Alluvium Daylighting	Flux Node	25	8.9	6.0	19.6	9.2	8.6	5.7
Model B (50% Infiltration)	TSF5 to Weathered Bedrock	Horizontal Flux	168,300	23.0	20.2	26.0	18.5	20.7	20.7
	Bedrock to North-West	Vertical Flux	11,825	3.0	2.9	2.7	3.0	2.7	2.9
	Weathered Bedrock to North-West	Vertical Flux	2,750	3.6	3.6	3.5	3.5	3.6	3.7
	Alluvium to North-West	Vertical Flux	50	0.7	0.4	3.6	0.7	0.7	0.4
	North Seepage	Flux Node	275	57.3	87.0	0	52.3	63.6	93.3
	Seepage into Diversion Drain / Alluvium Daylighting	Flux Node	25	8.6	5.8	12.5	8.8	8.4	5.6

Model refers to the infiltration rate used
Flow path refers to the flux section or node
Flux type provides a description of the orientation of the flux or if it's a node
Representative flux (Q) area is the cross sectional area which has been used to 'scaled up' from two-dimensions to three-dimensions

Similarly to the TD3 seepage model, both models with variable infiltration (50% and 80%) resulted in similar flux rates of seepage, with the main difference in the two models being the volume of seepage.

The results from the BSOC WRD North Seepage model indicates that the volume of seepage from the WRD toe ranges between 0 and ~161 m^3/d (0 to 1.8 L/s) across the model scenarios. Actual seepage rates were not available to compare against model results, however based on observational evidence from site personnel, seepage at the BSOC WRD North Seepage does not flow all year round and therefore the lower estimates obtained with the higher k_{sat} alluvium scenario would seem most appropriate for this model.

A summary of the fluxes from the BSOC WRD North Seepage model is provided as follows:

- BSOC WRD North Seepage:
  - 1.3 to 1.9 L/s (Model A - 80%) and 0 to 1.1 L/s (Model B - 50%)

    79.4% (Model A) and 42% (Model B) of total flux from BSOC WRD landform at BSOC WRD North Seepage point for Base Case simulation
- Seepage to alluvium:
  - 0.005 to 0.04 L/s (Model A - 80%) and 0.004 to 0.04 L/s (Model B - 50%)

    0.5% (Model A and B) of total flux from BSOC WRD landform at BSOC WRD North Seepage point for Base Case simulation
- Diversion Drain (daylighting) seepage:
  - 0.07 to 0.2 L/s (Model A - 80%) and 0.07 to 0.01 L/s (Model B - 50%)

  5.7% (Model A) and 6.3% (Model B) of total flux from BSOC WRD landform at BSOC WRD North Seepage point for Base Case simulation
- Seepage into bedrock from BSOC WRD Landform (BSOC WRD and TSF5):
  - 0.1 to 0.3 L/s (Model A - 80%) and 0.2 to 0.3 L/s (Model B - 50%)

    14.4% (Model A) and 25.7% (Model B) of total flux from BSOC WRD landform at BSOC WRD North Seepage point for Base Case simulation

BSOC WRD South Seepage Model

Results for the BSOC WRD South seepage model are provided in Table 5-11 for both the 80% and 50% infiltration rate models for all sensitivity scenarios.

Table 5-11: BSOC WRD South Seepage 2D Model - Seepage Modelling Results (m^3/d)

Model	Flow Path	Flux Type	Representative Flux (Q) Area (m^2)	Model Scenario (m^3/d)					
				Base Case	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
Model A (80% Infiltration)	TSF5 to Weathered Bedrock	Horizontal Flux	89,010	35.8	35.6	38.8	27.1	46.5	48.6
	Bedrock to North-West	Vertical Flux	16,500	4.7	4.8	4.3	8.1	3.1	3.1

Model	Flow Path	Flux Type	Representative Flux (Q) Area (m^2)	Model Scenario (m^3/d)					
				Base Case	Sensitivity 1	Sensitivity 2	Sensitivity 3	Sensitivity 4	Sensitivity 5
	Weathered Bedrock to North-West	Vertical Flux	3,375	17.2	18.0	15.8	17.2	17.2	18.0
	Alluvium to West	Vertical Flux	300	4.9	2.6	22.5	4.9	4.9	2.6
	South Seepage	Flux Node	375	152.5	173.0	0.9	136.8	179.1	200.3
Model B (50% Infiltration)	TSF5 to Weathered Bedrock	Horizontal Flux	89,010	32.1	31.9	35.9	27.5	44.7	44.7
	Bedrock to North-West	Vertical Flux	16,500	4.2	4.2	4.2	7.0	2.9	2.9
	Weathered Bedrock to North-West	Vertical Flux	3,375	18.0	18.0	15.4	18.0	18.0	19.5
	Alluvium to West	Vertical Flux	300	4.9	2.6	21.2	4.9	4.9	2.3
	South Seepage	Flux Node	375	103.8	123.7	0	95.5	130.5	152.1

Model refers to the infiltration rate used
Flow path refers to the flux section or node
Flux type provides a description of the orientation of the flux or if it's a node
Representative flux (Q) area is the cross sectional area which has been used to 'scaled up' from two-dimensions to three-dimensions

A summary of the fluxes from the BSOC WRD South Seepage model is provided as follows:

- BSOC WRD South Seepage:
  - 0.01 to 2.3 L/s (Model A- 80%) and 0 to 1.1 L/s (Model B - 50%)

    78.2% (Model A) and 72.8% (Model B) of total flux from BSOC WRD landform at BSOC WRD South Seepage point for Base Case simulation
- Seepage to alluvium:
  - 0.03 to 0.26 L/s (Model A – 80%) and 0.03 to 0.25 L/s (Model B – 50%)

    2.6% (Model A) and 3.4% (Model B) of total flux from BSOC WRD landform at BSOC WRD South Seepage point for Base Case simulation
- Seepage into bedrock from BSOC WRD Landform (BSOC WRD and TSF5):
  - 0.3 to 0.6 L/s (Model A – 80%) and 0.3 to 0.5 L/s (Model B – 50%)

    18.3% (Model A) and 22.5% (Model B) of total flux from BSOC WRD landform at BSOC WRD South Seepage point for Base Case simulation

Model Results Discussion

The model results provided in the above three sections are based on analytical assessments using field tested, and assumed (in the absence of field testing), hydraulic parameters; and, the conceptualised flow systems for the underlying groundwater regime and the BSOC WRD landform These results comprise a summary of predicted fluxes leaving the BSOC WRD landform via toe seepage, seepage into the Diversion Drain, infiltration into the alluvial aquifer and infiltration into the bedrock aquifer, for each of the model sections. Verification of these predicted fluxes have been undertaken based on results of the field investigation program, historical monitoring results and operational anecdotal observations. A summary of these verifications include:

- Seepage monitoring facilities (v-notch weirs installed in the Diversion Drains) were established as part of this investigation. Monitoring records were collected between March and May 2016, and these records were used to compare against the predicted model results.
  - TD3 Seepage is a perennial seepage discharging directly into the Diversion Drain. Observational estimates of the seepage rate from TD3 Seepage, during the Phase 1 field investigation program (middle of the dry season) was ~1.5 to 2 L/s. Limited monitoring of flow at Weir 1 between March to May 2016 identified an average flow rate of 1.8 L/s.
  - Historically BSOC WRD North Seepage was observed as an ephemeral seepage that flows following the commencement of the wet season and ceases to flow during the dry season. During the Phase 1 field investigation program (dry season) minor seepages at BSOC WRD North Seepage were observed in the Diversion Drain.
  - Two points of seepage are observed at BSOC WRD South Seepage, within the excavated seepage collection trench and at the toe of the WRD. Seepage in the seepage collection trench occurs throughout the year with lower seepage rates are observed during the dry season. Seepage at the WRD toe is ephemeral with seepage flow occurring during the wet season and ceasing during the dry season.
  - These seepage observations are comparable with the results from the 2D modelling.
- Seepage from the BSOC WRD landform into the alluvial aquifer is predicted in each model. This prediction is supported by the results of the Phase 2 field investigation program (alluvial aquifer monitoring bore installation), with groundwater observed in the alluvial aquifer downstream of each seepage location.
- The predicted seepage rates into the alluvial aquifer are also supported by the field investigation results. Monitoring bores installed in the alluvial aquifer downstream of the BSOC WRD North Seepage indicate that the alluvial aquifer has a limited saturated thickness and is dry (no groundwater observed) at BSOC_A4 (~800 m downstream of BSOC WRD North Seepage). Limited groundwater in the alluvial aquifer downstream of the BSOC WRD North Seepage is supported by the predicted low seepage rates from the BSOC WRD landform to the alluvial aquifer.
- Seepage into the bedrock aquifer is predicted for each of the model slices. However, results from the field investigation program indicate that the downstream migration of BSOC WRD landform seepage in the bedrock aquifer is relatively limited, with the exception of TD3 Seepage. Groundwater quality results from monitoring bores installed in the bedrock aquifer downstream of BSOC WRD North and South Seepages do not indicate the presence of BSOC WRD Landform seepage in the groundwater (BSOC_B2, B3 and B4). Therefore, although modelling has indicated seepage into the bedrock aquifer at the BSOC WRD North and South Seepages, targeted field investigations have indicated that evidence of seepage is not present in the bedrock aquifer at the downstream bore locations, which is likely a function of the groundwater flow velocity, which is considered further within the one-dimensional analytical assessment, discussed in Section 5.4.8.
- Seepage contribution from the landfill sludge ponds to the TD3 Seepage catchment has been conservatively assessed to contribute 1% to 3% of the total flux from the TD3

Seepage catchment. Based on the estimated proportion of sludge pond flux contribution to TD3 Seepage, this contribution would be negligible compared to the seepage contribution from the BSOC WRD landform.

5.4 Current Concentration and Extent of Seepage

In order to determine the current concentration of seepage released from the BSOC WRD to the receiving environment (1 (c) of the EE Notice), the following tasks were undertaken:

- Analysis of recent and historical WRD seepage water quality chemistry,
- Analysis of recent and historical tailings seepage water quality chemistry,
- Analysis of sludge pit water quality chemistry from the MIM Landfill Facility,
- Analysis of groundwater quality chemistry from newly installed investigation bores,
- Analysis of surface water quality chemistry,
- Analysis of isotope samples from groundwater and seepage water,
- Analysis of mineral precipitation observed downstream of the WRD,
- A one-dimensional analytical contaminant transport assessment (Ogata-Banks).

The information compiled from these investigations was then used to interpret the extent of seepage water to the receiving environment.

The approach adopted in the geochemistry investigation was as follows:

- Section 5.4.1: Describe the observed seepage water chemistry. This section describes and compares the major and trace-element seepage chemistry of BSOC WRD South seepage, BSOC WRD North seepage and TD3 seepage;
- Section 5.4.1: Compare the observed seepage water chemistry at TD3 to historical and recent seepage associated with TSF5. This section describes the historical and more recently observed seepage water quality associated with TSF5 to provide a useful comparison with the seepage observed at TD3, BSOC WRD South and BSOC WRD North. Time-series diagrams show the variations in water quality over the sampling periods;
- Section 5.4.1.1: Describe the leachate chemistry from waste rock and tailings humidity cells. Kinetic testing (humidity cell testing) is currently being undertaken for a range of waste rock and tailings samples. Humidity cell tests are conducted under controlled laboratory conditions and as a result are not strictly representative of the seepage chemistry observed in the field. However, they do provide an indication of which chemical species *may* be mobilised and appear in seepage water. This section compares the results of the kinetic tests to the BSOC WRD seepage chemistry;
- Section 5.4.2: Describe the observed seepage chemistry of the landfill/sludge pit. This section describes the water chemistry from the sludge pit seepage and compares the results to the seepage chemistry observed at TD3, BSOC WRD South and BSOC WRD North;
- Section 5.4.3: Describe the observed groundwater chemistry. This section provides descriptions of water from monitoring bores in the alluvial aquifer and bedrock aquifer and compares the results to the seepage locations TD3, BSOC WRD South and BSOC WRD

North. Together with time-series diagrams, these results should provide an indication of which monitoring bores are likely to be impacted by the seepage(s);

- Section 5.4.4: Describe the isotope chemistry of seepage and groundwater samples. Stable isotopes of hydrogen, oxygen and sulphur may provide some additional insight into potential seepage sources. This section describes the results from the analysis of a number of water samples that were selected to undergo stable isotope investigation and compares these to the previous isotope investigation (Forsyth, 2014);
- Section 5.4.5: Describe the observed surface water chemistry. This section provides descriptions of the King Gully surface water quality and compares the results to TD3 seepage;
- Section 5.4.6: Describe mineral precipitation calculations. This section describes the results of hydrogeochemical modelling the observed seepage water quality. The Geochemist's Workbench and PHREEQC were used to determine the minerals that are likely to be in equilibrium with the seepage water and to then simulate precipitation of these minerals from the seepage water. This was then compared to mineral precipitates observed downstream from the seepage points (see KCB site investigation report) to provide an indication of whether the downstream sites may have experienced influx from seepage water; and,
- Section 5.4.7: Provide a summary of the water chemistry.

The geochemical dataset consists of the following main types of recent and historical information that have been used to assess the nature of the seepage water and the potentially impacted sites:

- Major element parameters (major anions, major cations, EC, pH). These have been used to provide the main characteristics of the water samples;
- Trace elements have allowed further insight into the water types, where appropriate; and
- Isotopes have been used to provide additional information on possible source(s).

5.4.1 Seepage Water Chemistry

Seepage concentrations are presented below for the three BSOC WRD landform seepage locations. The location of the seepage, along with historical seepage locations, groundwater samples and the TD5 pit water sample (collected in February, 2016) are shown in Figure 5-36.

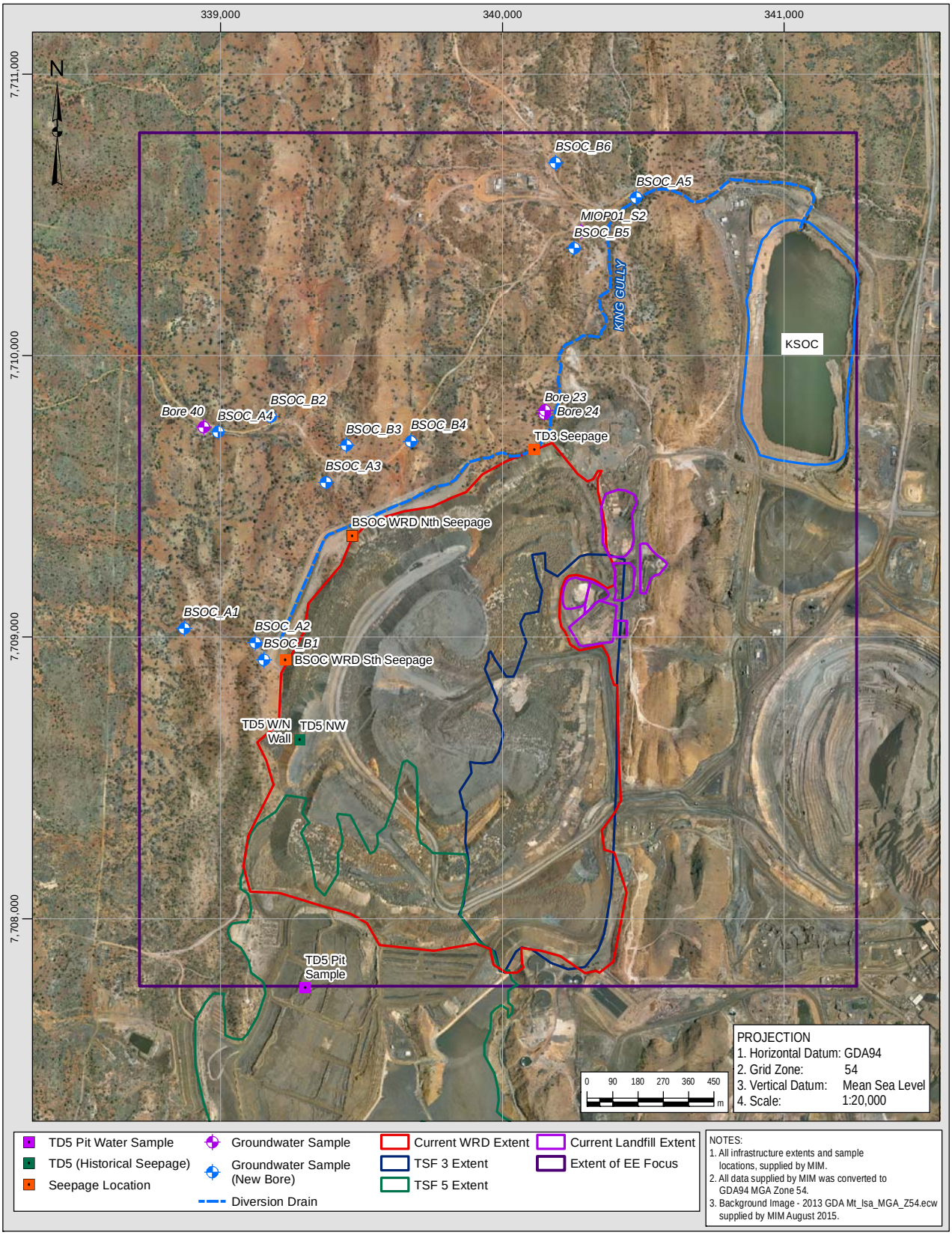

Figure 5-36: Location of water chemistry samples including seepage, groundwater and TD5 pit water sample

BSOC WRD South Seepage

Figure 5-37 presents a multi-element diagram (also known as a Schoeller plot) showing the concentration of a number of trace elements and dissolved metals for the BSOC WRD South Seepage. The purpose of this diagram is to provide an overview of the potential dissolved trace element 'signatures' that may be characteristic of the seepage point and may allow the identification of potential source(s) characteristics. BSOC WRD South Seepage has relatively low concentrations of zinc (~0.001 – 0.1 mg/L), cadmium (~0.0001 – 0.01 mg/L), manganese (~1 mg/L) and nickel (~0.01 mg/L; Figure 5-37). BSOC WRD South Seepage concentrations are superficially similar to those for BSOC WRD North seepage and TD3 (cf. Figure 5-37, Figure 5-38 and Figure 5-39). However, BSOC WRD South Seepage is generally lower in zinc and manganese; and, contains cadmium and nickel around two orders of magnitude lower in concentration.

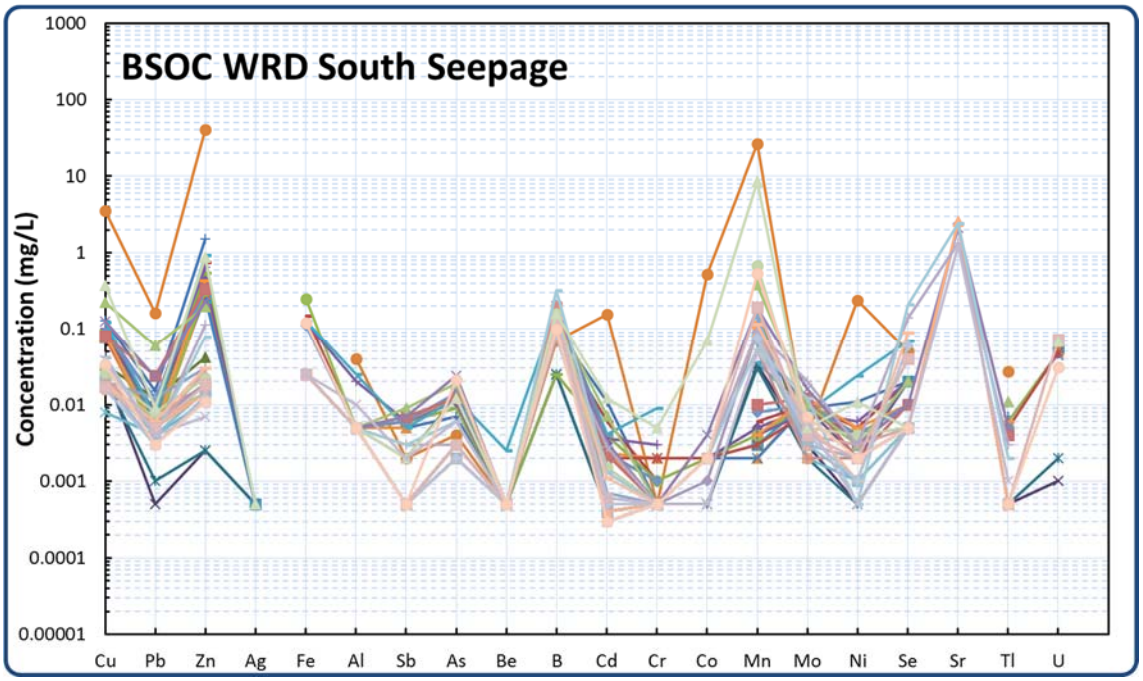

Figure 5-37: Multi-element plot showing BSOC WRD South Seepage trace element concentrations

BSOC WRD North Seepage

BSOC WRD North seepage (Figure 5-38) has a similar trace element 'signature' to TD3 seepage (Figure 5-39), with relatively high zinc and manganese concentrations and moderate cadmium, cobalt and nickel concentrations.

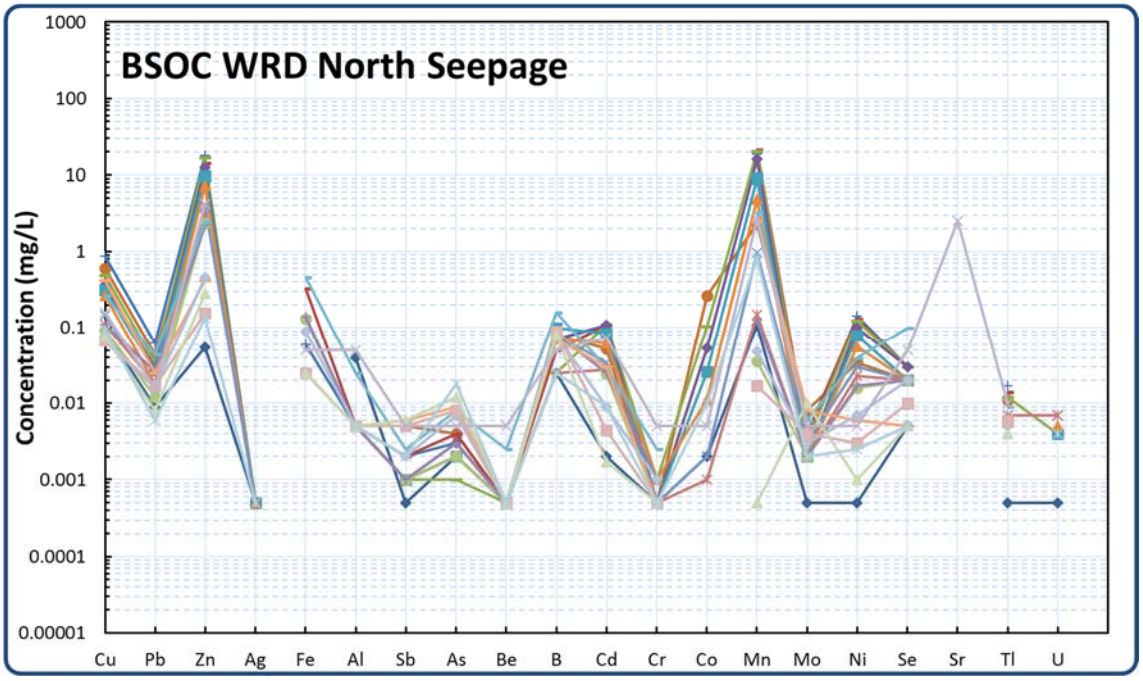

Figure 5-38: Multi-element plot showing BSOC WRD North Seepage trace element concentrations

TD3 Seepage

Figure 5-39 shows the dissolved trace element pattern for TD3 seepage. The diagram shows that the seepage contains relatively high zinc and manganese concentrations (~10 mg/L) and moderate cadmium, cobalt and nickel concentrations (~0.1 mg/L). TD3 seepage contains roughly one order of magnitude more copper than lead.

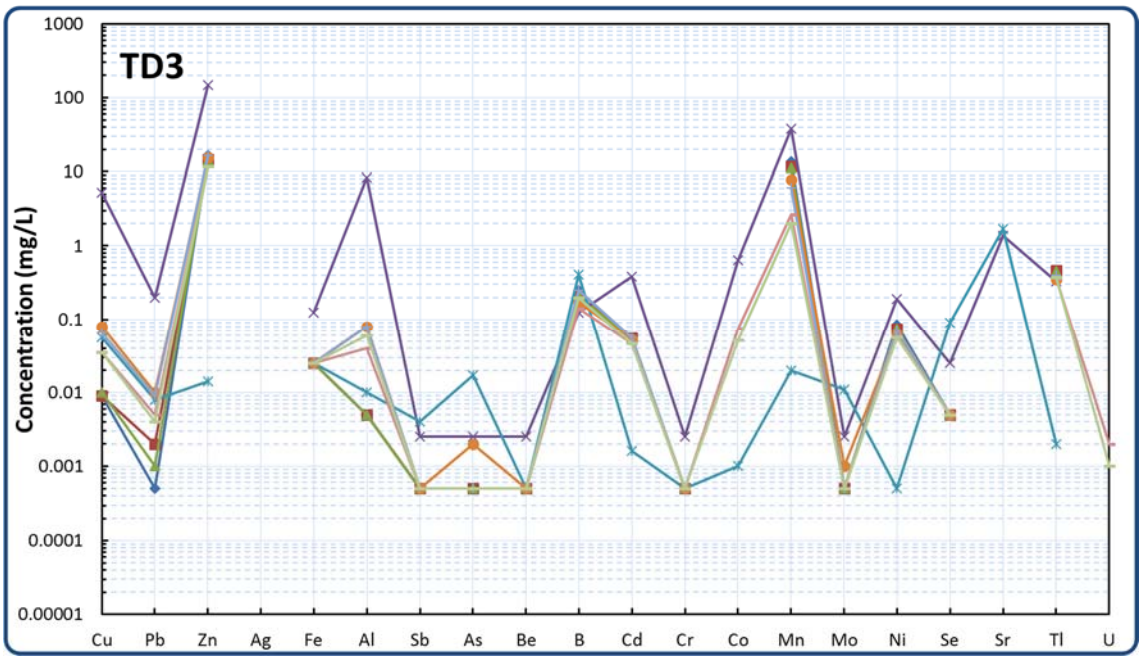

Figure 5-39: Multi-Element Plot Showing TD3 Seepage Trace Element Concentrations

Major Parameter Seepage Characteristics

Major element characteristics of the BSOC WRD landform seepage water samples are shown in Figure 5-40. BSOC WRD North Seepage has slightly higher calcium and similar sulphate concentrations compared to seepage from BSOC WRD South Seepage, which tends to be slightly richer in sodium, potassium and chloride, which may reflect differences in the waste material deposited. TD3 Seepage generally falls within the field of BSOC WRD North Seepage samples. Seepage water from all sources displays a wide range of electrical conductivities (EC), but a generally narrow range of pH.

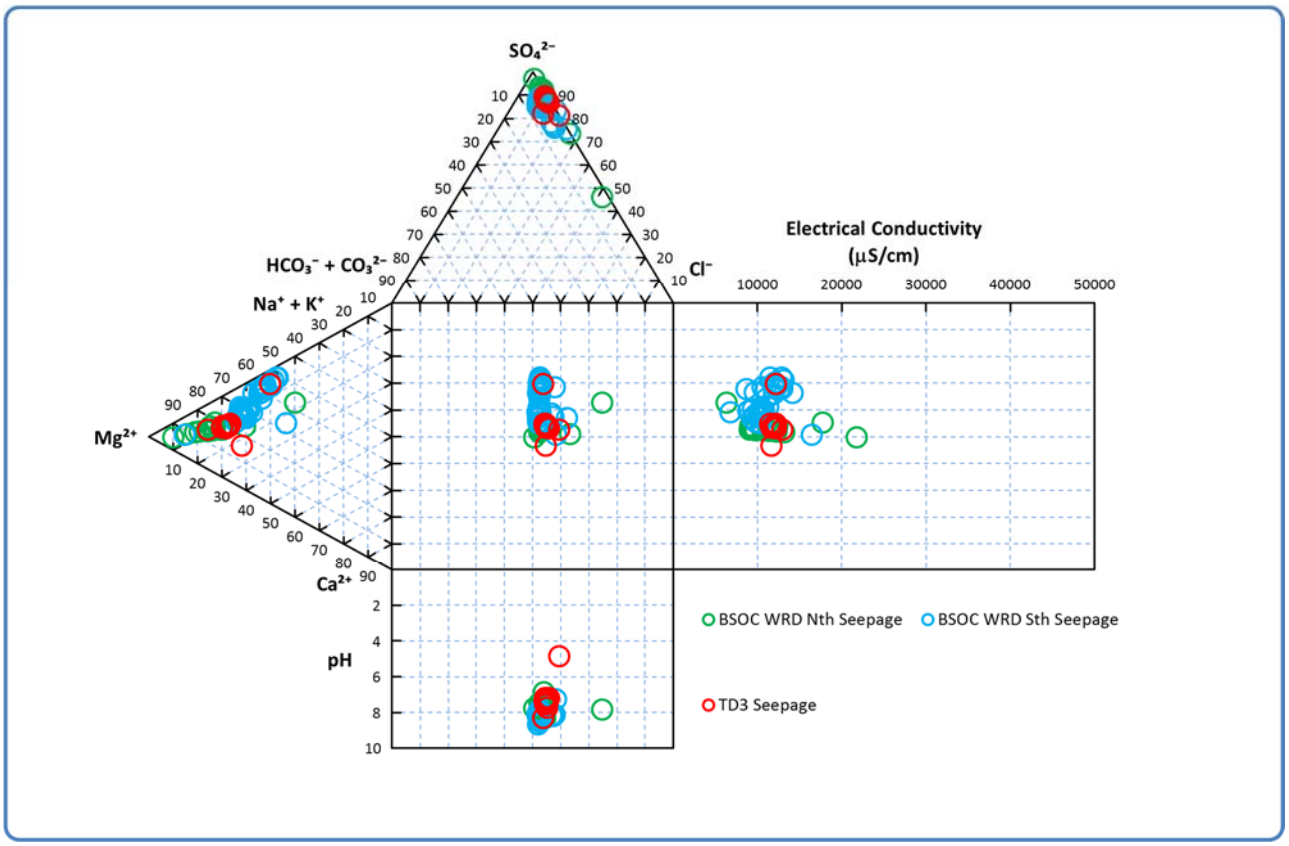

Figure 5-40: Durov diagram showing the dissolved major element contents, pH and electrical conductivity of seepage from BSOC WRD North, BSOC WRD South and TD3.

BSOC WRD landform seepage water chemistry is likely to be influenced by gypsum solubility, with most of the TD3 Seepage samples and BSOC WRD North and South Seepage samples saturated in gypsum (Figure 5-41). Despite some high salinity reported in some of the seepages, they are likely to remain under-saturated in halite (Figure 5-42).

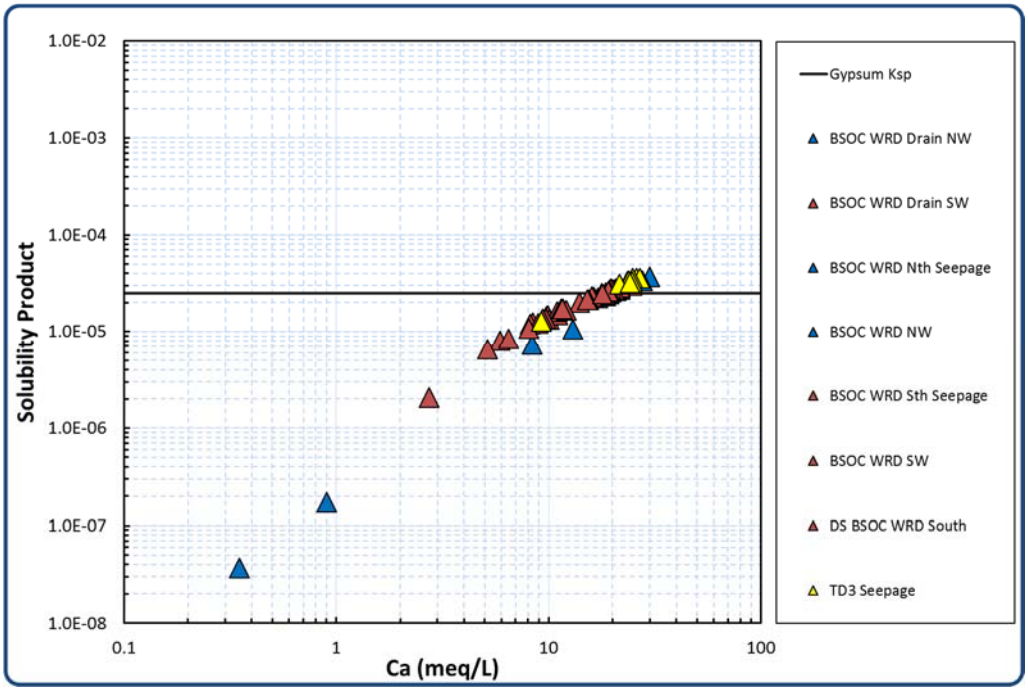

Figure 5-41: Calculated gypsum ($CaSO_4$) solubility product for BSOC samples plotted against calcium concentration (meq/L)

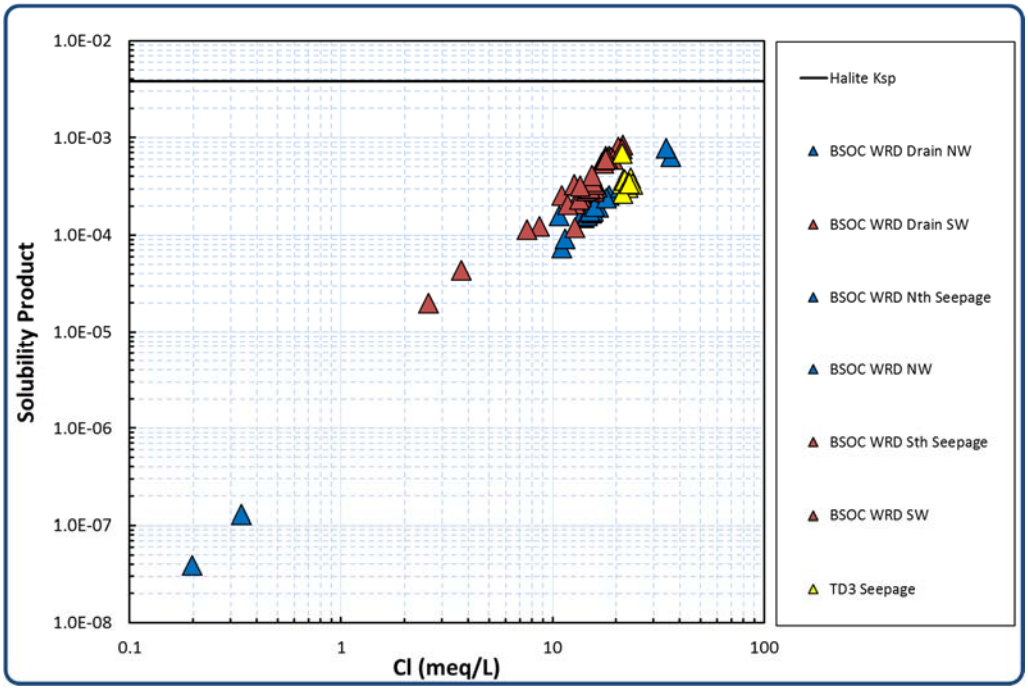

Figure 5-42: Calculated halite (NaCl) solubility product for BSOC samples plotted against chloride concentration (meq/L)

Comparison of Current BSOC WRD Landform Seepage to Historical Tailings Seepage Water Chemistry

Previous investigations of TSF3 and TSF5 indicate that the tailings materials are generally alkaline and contain high salinity water with elevated concentration of some metals. Historical sampling of TSF3 seepage at the East Wall from January 2001 to February 2004 (Forsyth & Edraki, 2010) indicates slightly alkaline pH, elevated EC and elevated concentration of total cadmium, total copper, fluorine, total lead, total zinc and sulphate.

Time series graphs for selected parameters were used to see the variation in these parameters over the sampling periods. The plots may be useful to observe long-term trends, or potential seasonal responses in the geochemistry. Figure 5-43 shows the variation of sulphate, alkalinity, pH and zinc over time[8], for recent quality monitoring of TD3 Seepage, BSOC WRD North Seepage and BSOC WRD South Seepage. A water sample was collected from within TSF5, where mining of the tailings is occurring, as part of this investigation (February, 2016; Figure 5-36) to provide additional context against current and historical seepage concentrations. This is also included within the following graphs.

Also shown, as a useful comparison of changes over time, are time series parameters from the TD5W seepage collection point as presented in Forsyth (2014).

[8] These parameters were chosen because sulphate, pH and alkalinity represent major characteristics of the seepage water, whereas zinc concentrations may be indicative of the zinc source, since mixed and lead-zinc tailings are present.

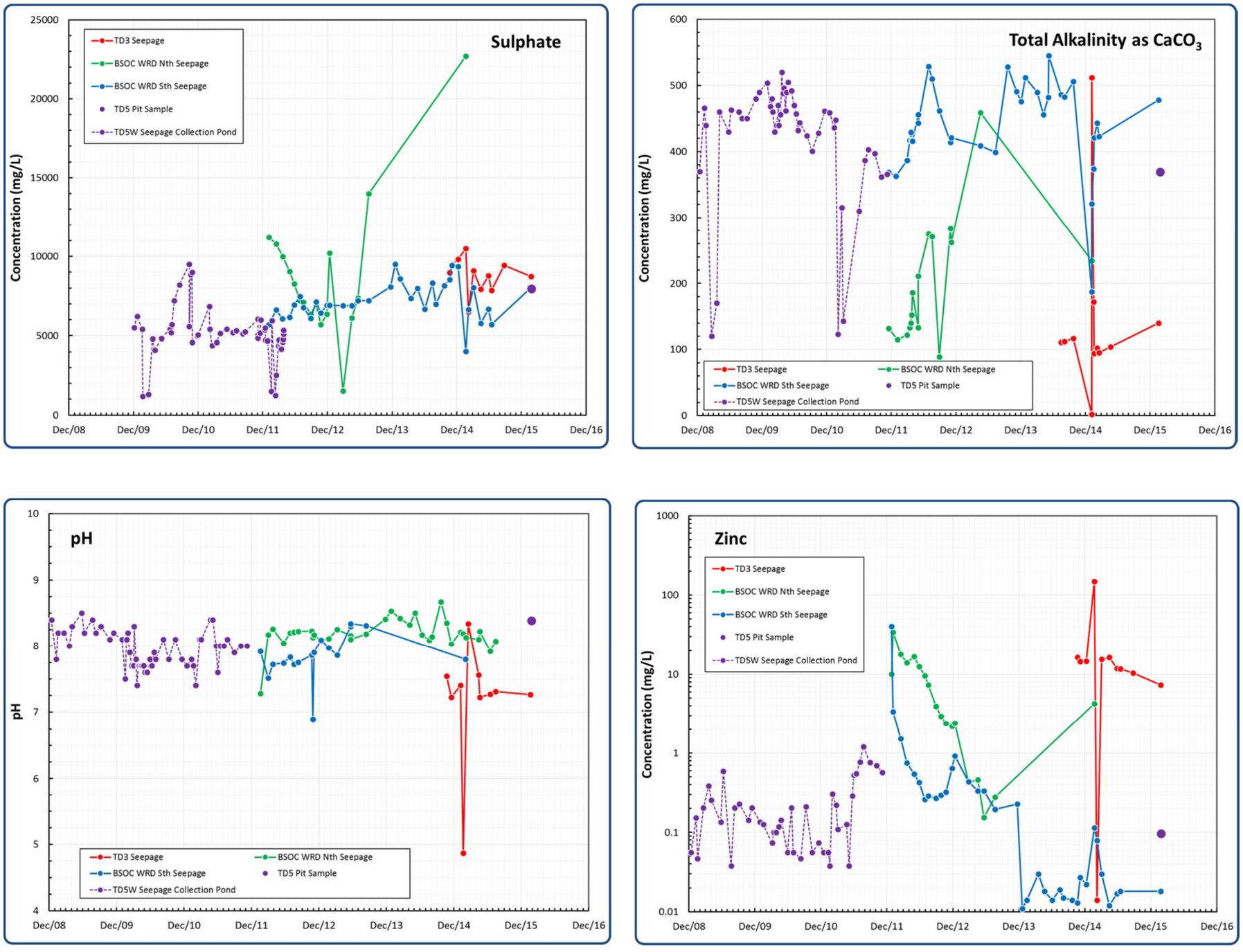

Figure 5-43: Time series for selected seepage locations a) sulphate, b) alkalinity, c) pH, d) zinc

TSF5 Seepage (Historical)

TSF5 seepage water quality has remained relatively constant throughout the years it has been monitored: the recent TSF5 pit sample (location shown on Figure 5-36) collected in 2016 has similar concentrations to the data monitored prior to 2012. Sulphate concentrations might be showing a slight increase and alkalinity may be showing a slight decrease, but the pH values reported for the TSF5 pit sample are ~8, suggesting that the water quality is not experiencing a drop in pH. Multi-element plots of TSF5 seepage samples give a reasonably tightly defined locus of concentrations. The trace element 'fingerprint' of TSF5 appears to be similar to that for BSOC WRD South Seepage (cf. Figure 5-37 and Figure 5-44). Parameter values are generally consistent with 'historical' values (e.g. sulphate ~5000 mg/L and pH ~ 8 (Forsyth & Edraki, 2010).

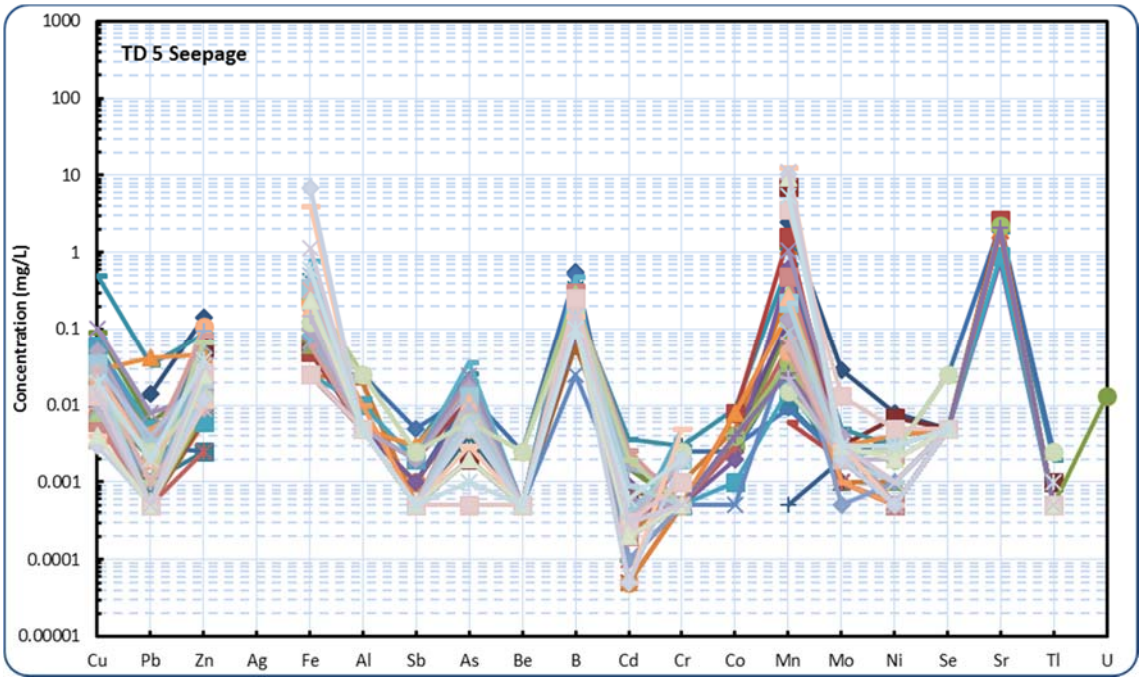

Figure 5-44: Multi-Element Plot Showing TSF5 Seepage Trace Element Concentrations

TSF3 Seepage (Historical)

TSF3 seepage water quality differs from the other seepage water qualities and exhibits higher concentrations of sulphate and zinc and lower pH, which may be due to contributions of historical disposal of acidic wastes (MIM Waste Management Register). TD3 seepage is similar to those from BSOC WRD North Seepage and broadly similar to BSOC WRD South Seepage and TSF5 (cf. Figure 5-38, Figure 5-39, Figure 5-44). Although TD3 seepage water quality has exhibited spikes in concentrations over time (e.g., sulphate), these are potentially isolated events and may represent outliers. A pH value of ~7, is similar to that reported prior to 2009 (Forsyth and Edraki, 2010).

The trace element 'signature' of TSF3 samples is shown in Figure 5-45. Relatively high zinc and manganese concentrations are similar to those seen in the tailings humidity cell leachate (cf. Figure 5-50, Figure 5-51 and Figure 5-52 with Figure 5-45), which would be expected for seepage that may have some influence from tailings chemistry.

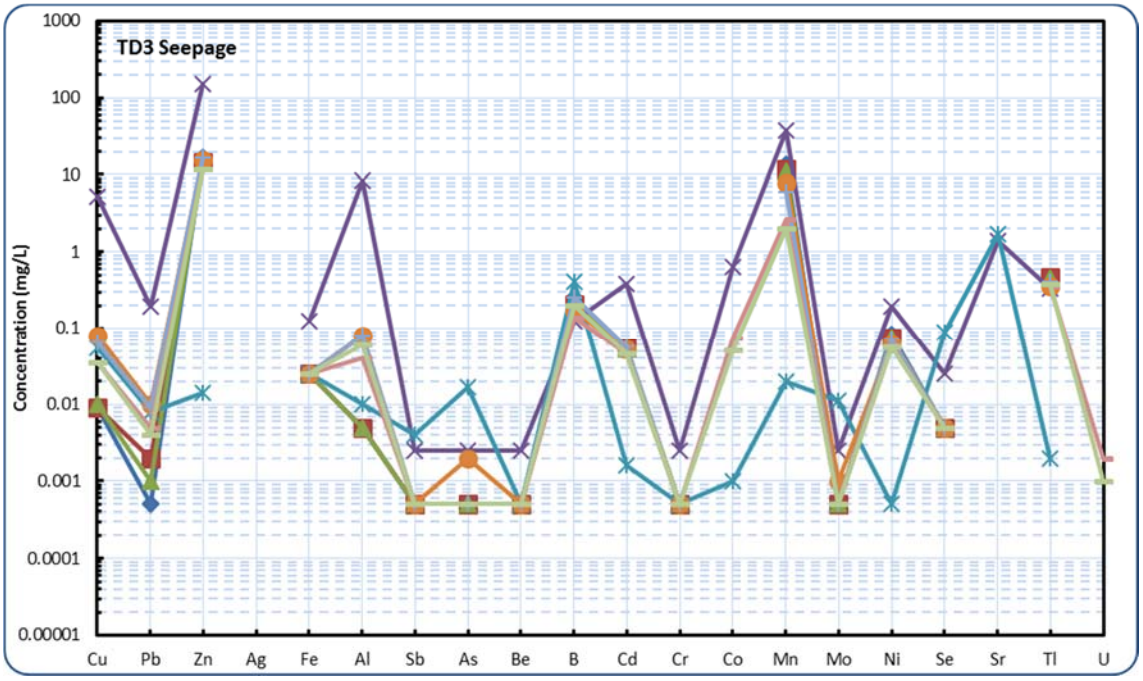

Figure 5-45 Multi-element plot showing TD3 seepage trace element concentrations

Major water quality parameters show the similarities between the seepage locations, although when compared with the TD5 pit sample (collected 2016), the TD5 pit sample is higher in sodium and slightly higher in chloride.

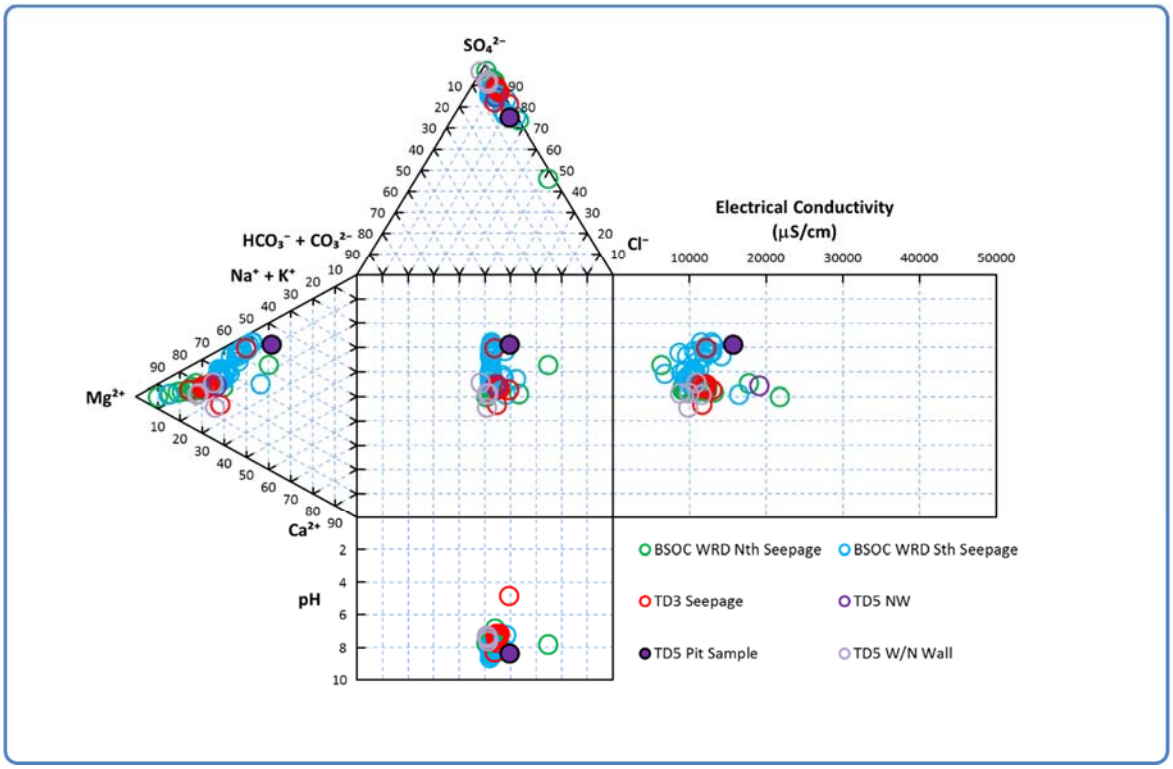

Figure 5-46: Durov diagram showing the dissolved major element contents of seepage from BSOC WRD North, BSOC WRD South,TD3, TD5 Pit Sample, TD5 NW and TD5 W/N Wall. Also shown are seepage pH and EC

5.4.1.1 Kinetic Testing Leachate Chemistry

Humidity cell testing provides an indication of which parameters of a particular waste material are likely to be mobilised under aerobic conditions. Humidity cells are designed to simulate weathering of the waste material under carefully controlled laboratory conditions and leachate chemistry is therefore not intended to provide the absolute concentrations of solutes when scaled to the waste rock or TSF. The tests do, however, provide an indication of the relative reactivity and mobility of elements of concern and are useful to assess the expected proportions of these parameters from waste material subjected to weathering.

BSOC waste rock and tailings (see below) are currently undergoing an extensive kinetic testing program (humidity cell testing) to assess their weathering characteristics (see KCB, 2014). Detailed information on sample selection, humidity cell testing and results can be found in KCB (2014) BSOC Humidity Cell Testing Interim MEMO. The sample tests consist of ECV, Kennedy-Spears and Urquhart Shale waste rock types and Copper, Copper-Lead-Zinc mixed and Lead-Zinc tailings (see below for tailings). Three waste rock types and all three tailings samples are classified as potentially acid forming and should give some indication on the mobilisation and nature of metals due to weathering.

Waste Rock Humidity Cell Leachate Chemistry

Dissolved trace elements in leachate from the humidity cell tests on the waste rock types are shown in Figure 5-47, Figure 5-48 and Figure 5-49. Leachate concentrations for both the ECV and the Kennedy-Spears samples are generally low (≤ ~0.1 mg/L) for most trace element parameters. Urquhart Shale leachate from humidity cell tests reports higher concentrations of zinc and manganese (~1 mg/L) and low copper/zinc ratios.

With the caveat above in mind, the humidity cell leachate chemistry of the Urquhart Shale waste rock does somewhat resemble the leachate chemistry observed at BSOC WRD North, which may be expected since the BSOC WRD North leachate should be influenced by the waste deposited at the waste rock dump. Humidity cell Urquhart Shale leachate also bears some similarities to TD3 seepage (cf. Figure 5-39 and Figure 5-48).

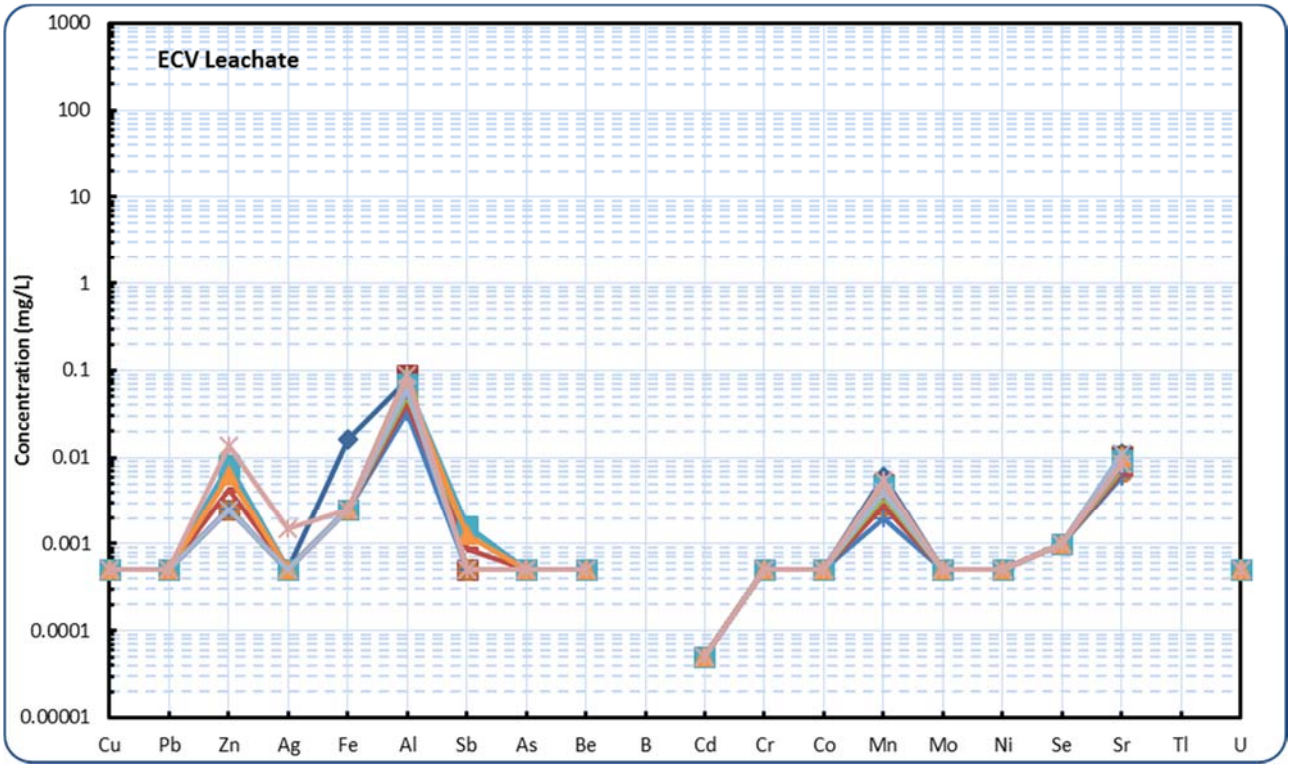

Figure 5-47: Multi-element leachate concentrations from ECV samples subjected to humidity cell testing

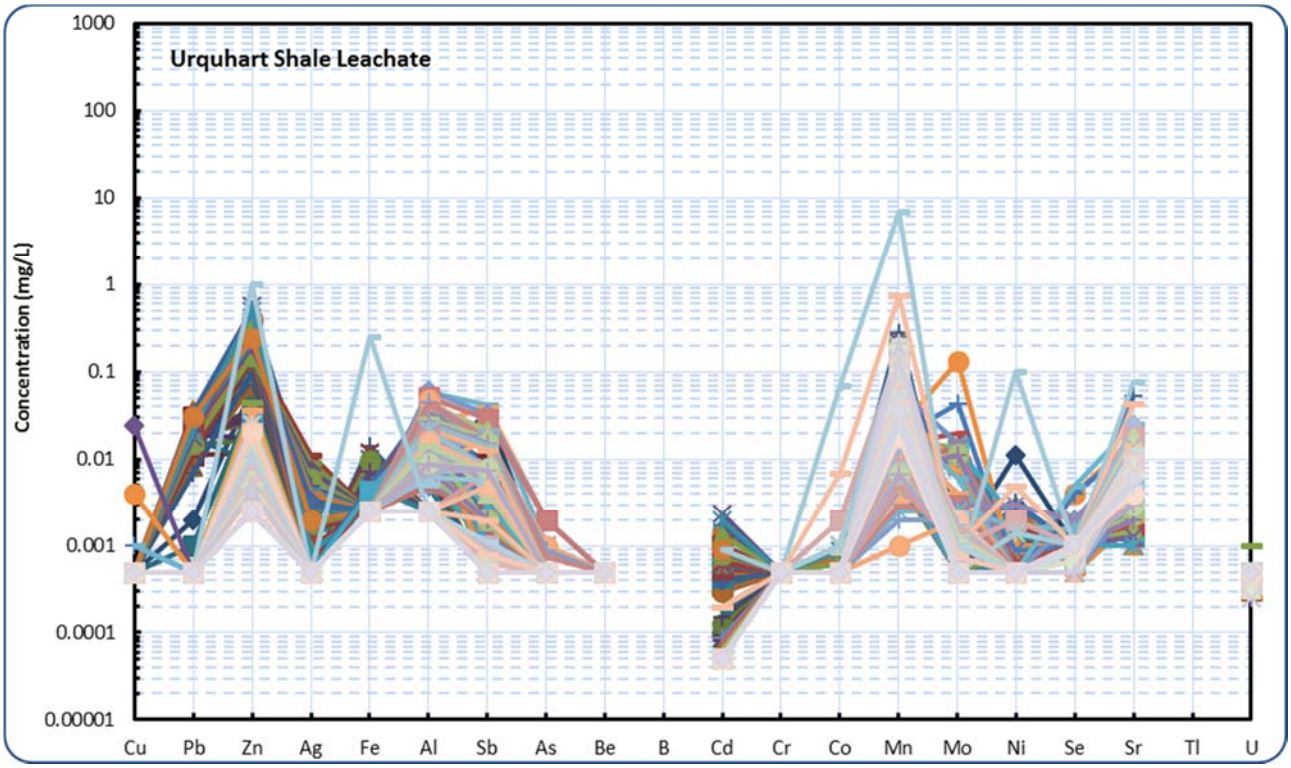

Figure 5-48: Multi-element leachate concentrations from Urquhart Shale samples subjected to humidity cell testing

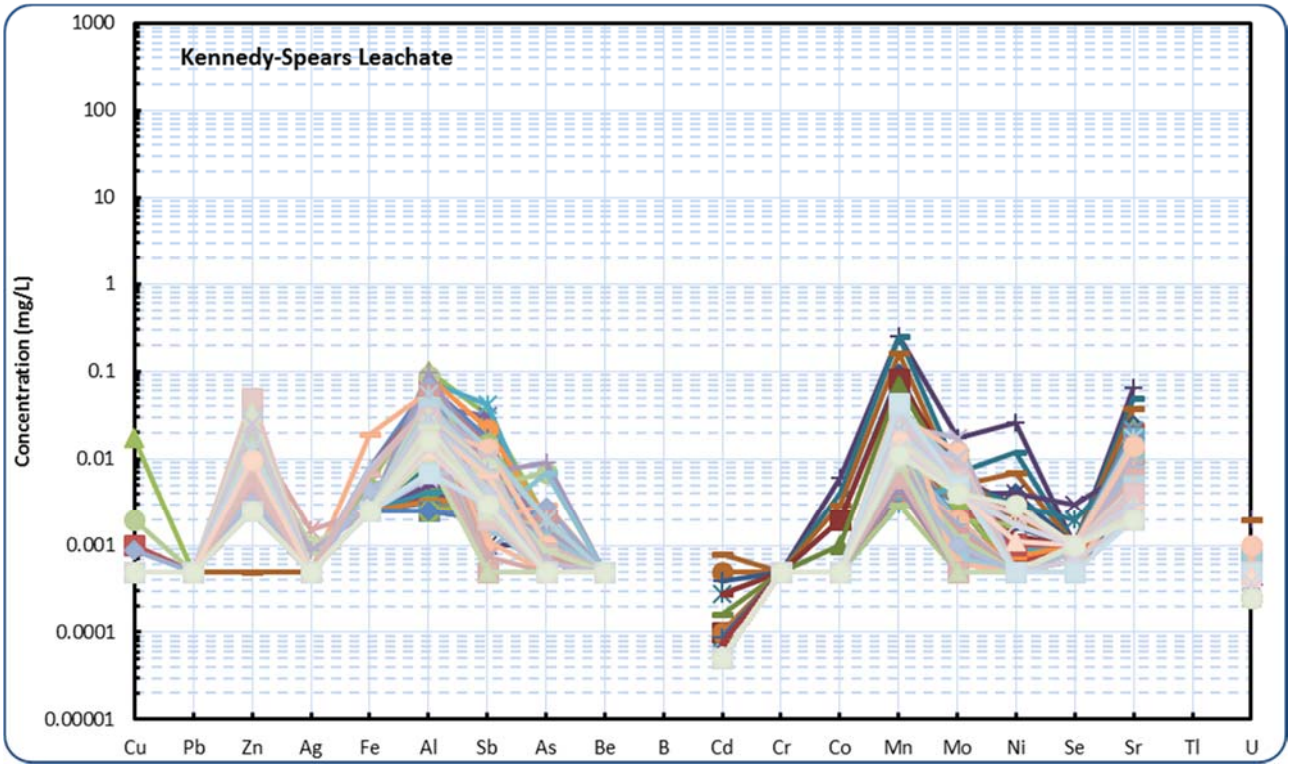

Figure 5-49: Multi-element leachate concentrations from Kennedy-Spears samples subjected to humidity cell testing

Tailings Humidity Cell Leachate Chemistry

As stated above, humidity cell tests *may* provide a useful indication of which parameters are likely to leach from, in this case, the tailings samples. Leachate concentrations from humidity cell tests on copper tailings (Figure 5-50), mixed copper and lead-zinc tailings (Figure 5-51) and lead-zinc tailings (Figure 5-52) have greater concentrations of most trace elements, as would be expected, when compared to those from similar tests on waste rock (see Section 0). In particular, manganese and cadmium concentrations are relatively high in leachate from the mixed and lead-zinc tailings. Also, and as expected, the copper tailings reports leachate with high copper-zinc ratios, whereas the mixed and lead-zinc tailings have low copper-zinc ratios. The copper tailings (and some of the leachate samples from the mixed tailings) have relatively high cobalt concentrations, such that the manganese-cobalt ratio is close to ~1, whereas the manganese-cobalt ratio for the lead-zinc tailings is below ~1. All tailings leachates have nickel concentrations at or below 0.01 mg/L.

As for the waste rock humidity cells (see above), comparison of the tailings humidity cell leachate with BSOC WRD North and TD3 seepage suggests some similarities (cf. Figure 5-50, Figure 5-51, Figure 5-52, Figure 5-38, Figure 5-39).

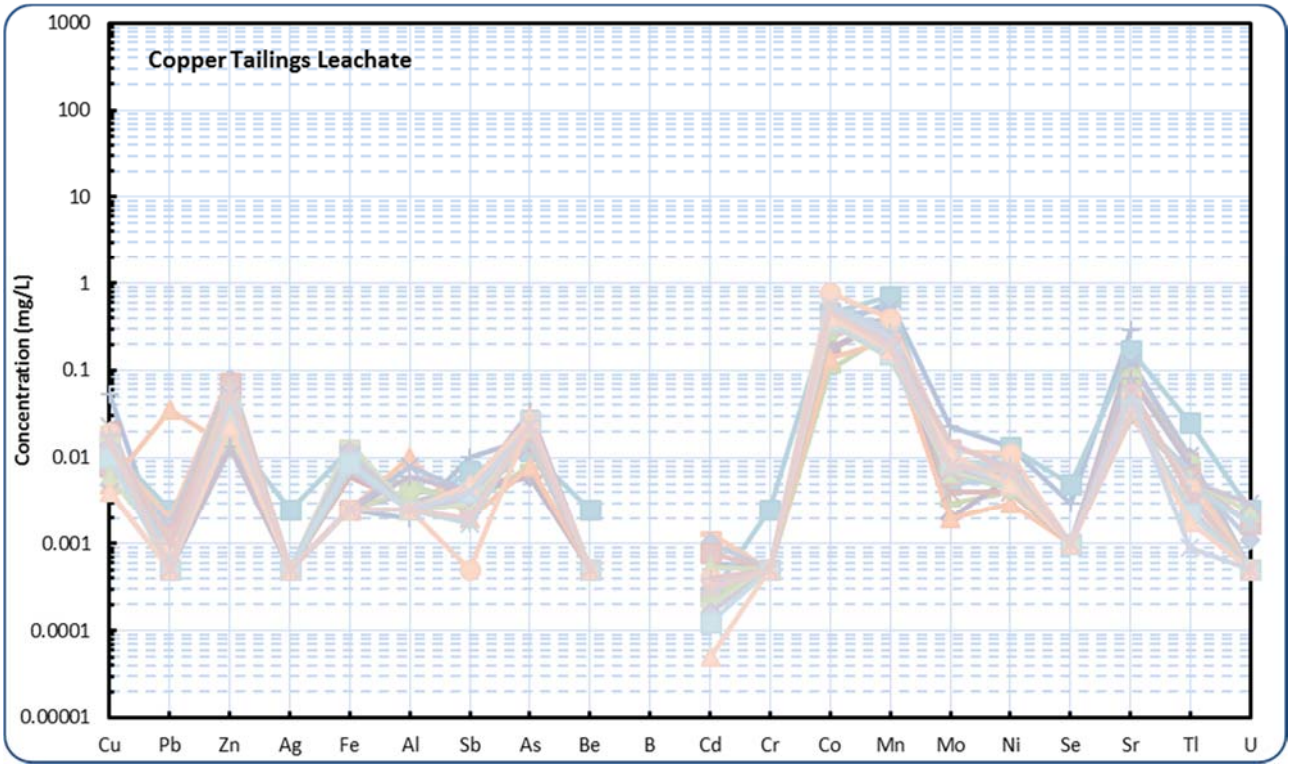

Figure 5-50: Multi-element leachate concentrations from Copper Tailings samples subjected to humidity cell testing

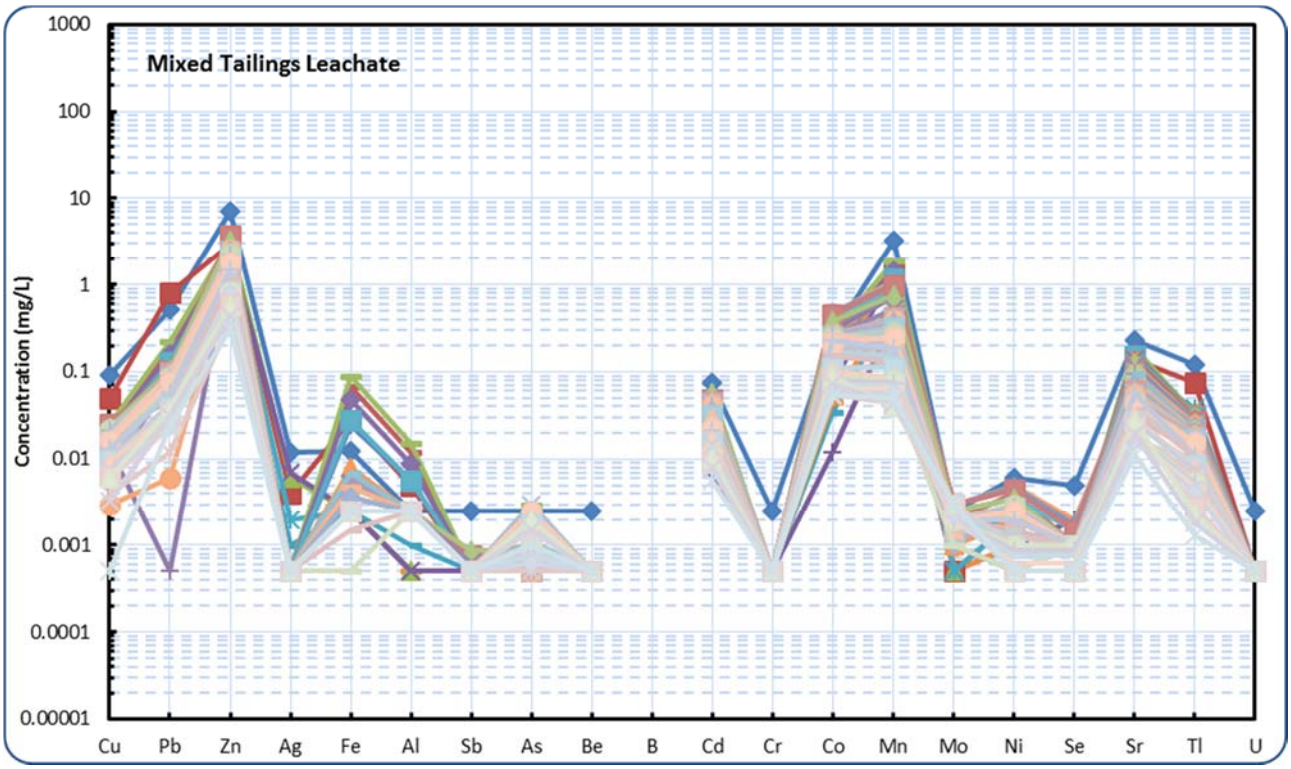

Figure 5-51: Multi-element leachate concentrations from Mixed Tailings samples subjected to humidity cell testing

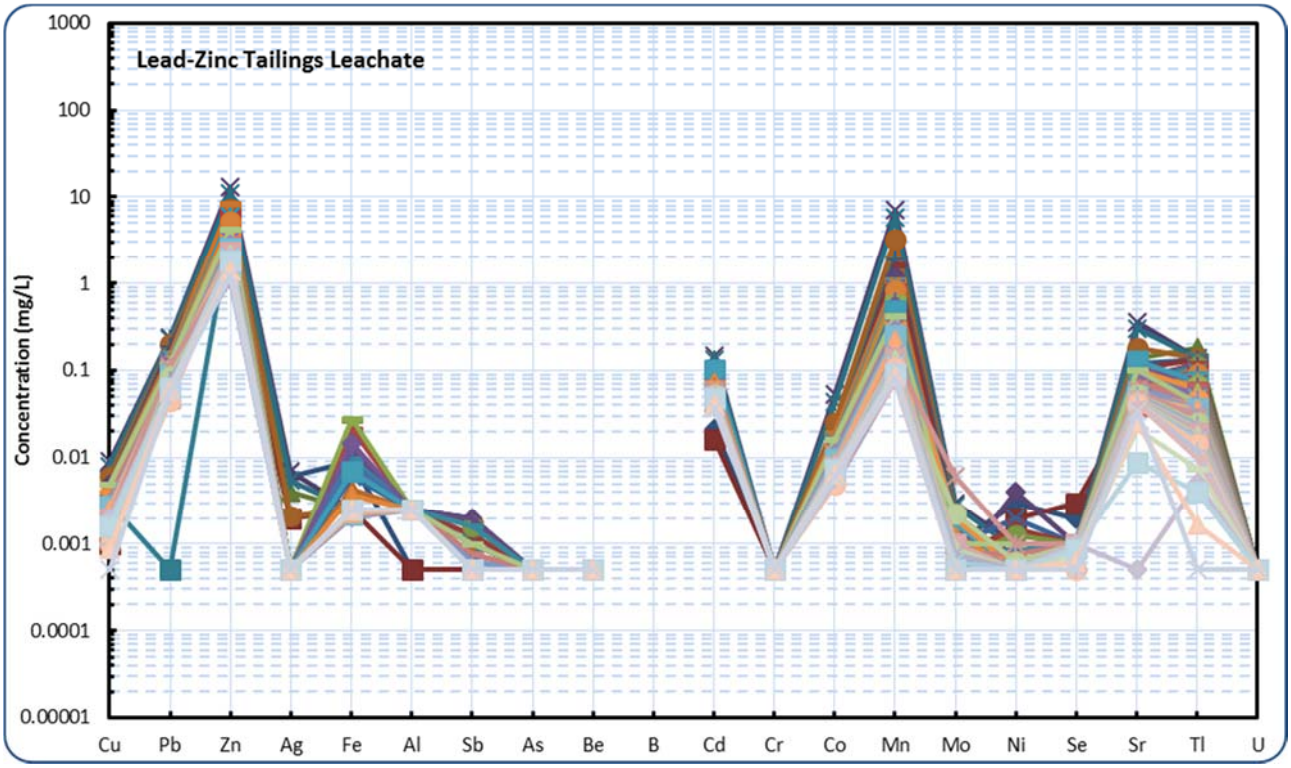

Figure 5-52: Multi-element leachate concentrations from Lead-Zinc Tailings samples subjected to humidity cell testing

5.4.2 Landfill / Sludge Pit Water Chemistry

Limited historical chemical data exists for the sludge pits, with one historical sample available.

The landfill and sludge pits were visited on August 25, 2015 as part of the Phase 1 site investigation and a water sample was collected from both sludge pits. Figure 5-53 shows the location of the landfill, sludge pits and samples.

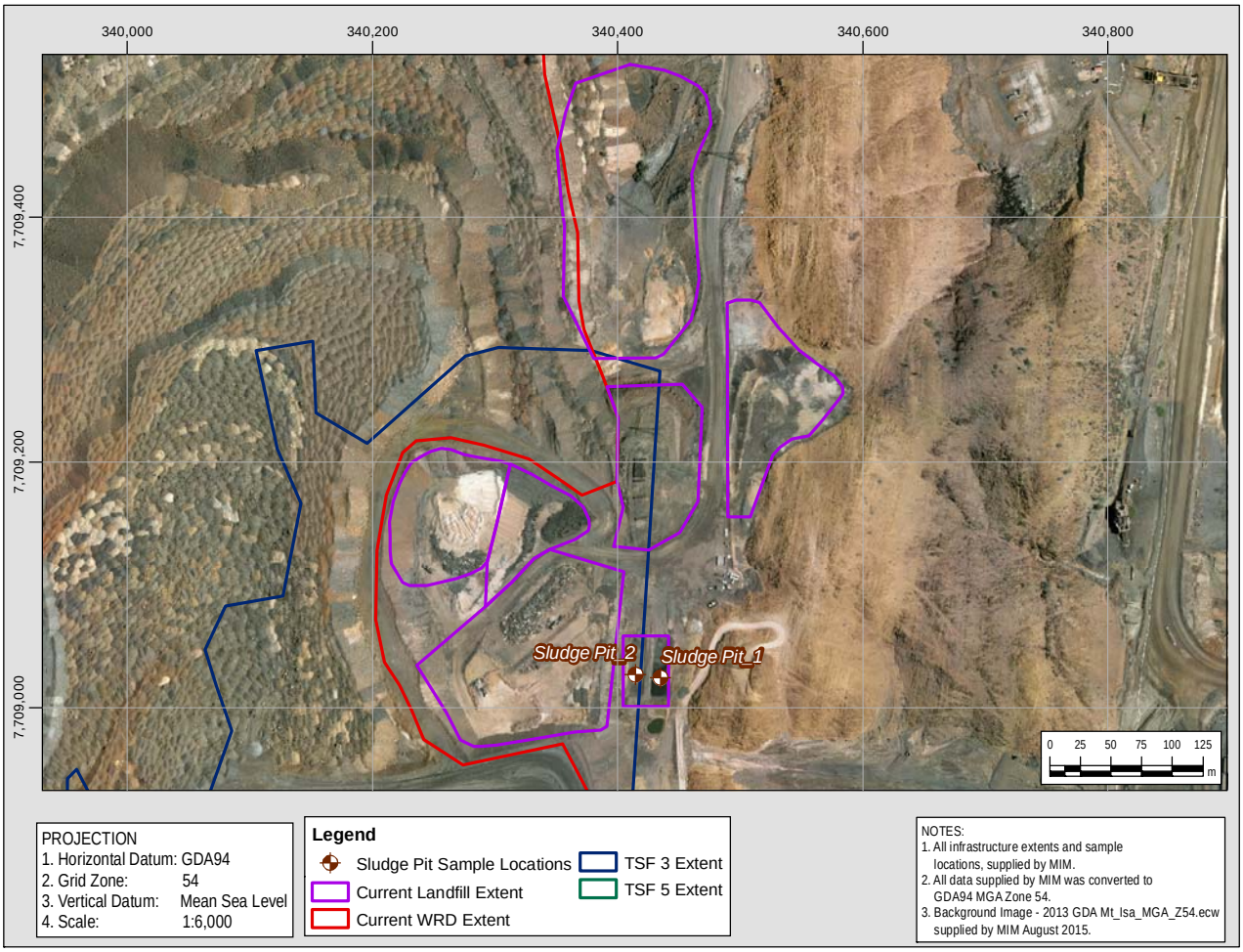

Figure 5-53: MIM Landfill General Waste Cell and Sludge Pits and Location of Sample Collection

Table 5-12 presents a summary of the water sample results from the sludge pits. Certificate of analysis for these samples are presented in Appendix II.

Table 5-12: Summary of Sludge Pit Sample Results

Parameter	Unit	SludgePit_1	SludgePit_2
		Date Sampled	
		25/08/2015	25/08/2015
Laboratory pH	pH_Units	9.03	5.43
Electrical conductivity	µS/cm	28700	4650
Total Dissolved Solids	mg/L	34500	3870
Magnesium	mg/L	1240	222
Calcium	mg/L	70	406
Alkalinity (Bicarbonate as $CaCO_3$)	mg/L	5340	4
Alkalinity (Carbonate as $CaCO_3$)	mg/L	1990	1
Alkalinity (total) as $CaCO_3$	mg/L	7340	4
Sodium	mg/L	7090	301
Potassium	mg/L	501	56
Sulphate	mg/L	13400	2540
Chloride	mg/L	3080	399
Fluoride	mg/L	3.3	6.3
Ammonia as N	µg/L	120	27700
Nitrate (as N)	mg/L	0.01	0.01
Nitrite (as N)	mg/L	0.01	0.01
Total Organic Carbon	mg/L	2	11.3
Phosphorus	mg/L	7.5	0.83
Aluminium	mg/L	0.11	2.59
Antimony	mg/L	0.023	0.017
Arsenic	mg/L	1.45	0.858
Barium	mg/L	0.163	0.016
Beryllium	mg/L	0.005	0.001
Bismuth	mg/L	0.005	0.008
Boron	mg/L	1.85	0.27
Cadmium	mg/L	0.15	2.66
Chromium (III+VI)	mg/L	0.004	0.002
Cobalt	mg/L	0.027	0.568
Copper	mg/L	0.187	44.2
Iron	mg/L	0.94	8.62
Lead	mg/L	1.12	3.51
Manganese	mg/L	0.511	4.05
Mercury	mg/L	0.0001	0.0001
Molybdenum	mg/L	0.081	0.001
Nickel	mg/L	0.124	0.446
Selenium	mg/L	0.05	0.04
Silver	mg/L	0.005	0.001
Strontium	mg/L	0.591	0.588
Thallium	mg/L	0.05	1.5
Thorium	µg/L	5	1
Titanium	mg/L	0.05	0.01
Uranium	µg/L	16	1
Vanadium	mg/L	0.05	0.01
Zinc	mg/L	0.607	15.3

Metals as filtered
EC and pH – lab values

Figure 5-54 presents the multi-element diagram for sludge pit water concentrations, for the samples collected during the Phase 1 site investigation and a historical sample from 2011.

Based on these samples, TD3 seepage may also contain a minor component of sludge pit water (cf. Figure 5-54 and Figure 5-45); cadmium and manganese concentrations show some similarities between the samples shown here, however this is inconclusive as it is based on comparison of two sample events only.

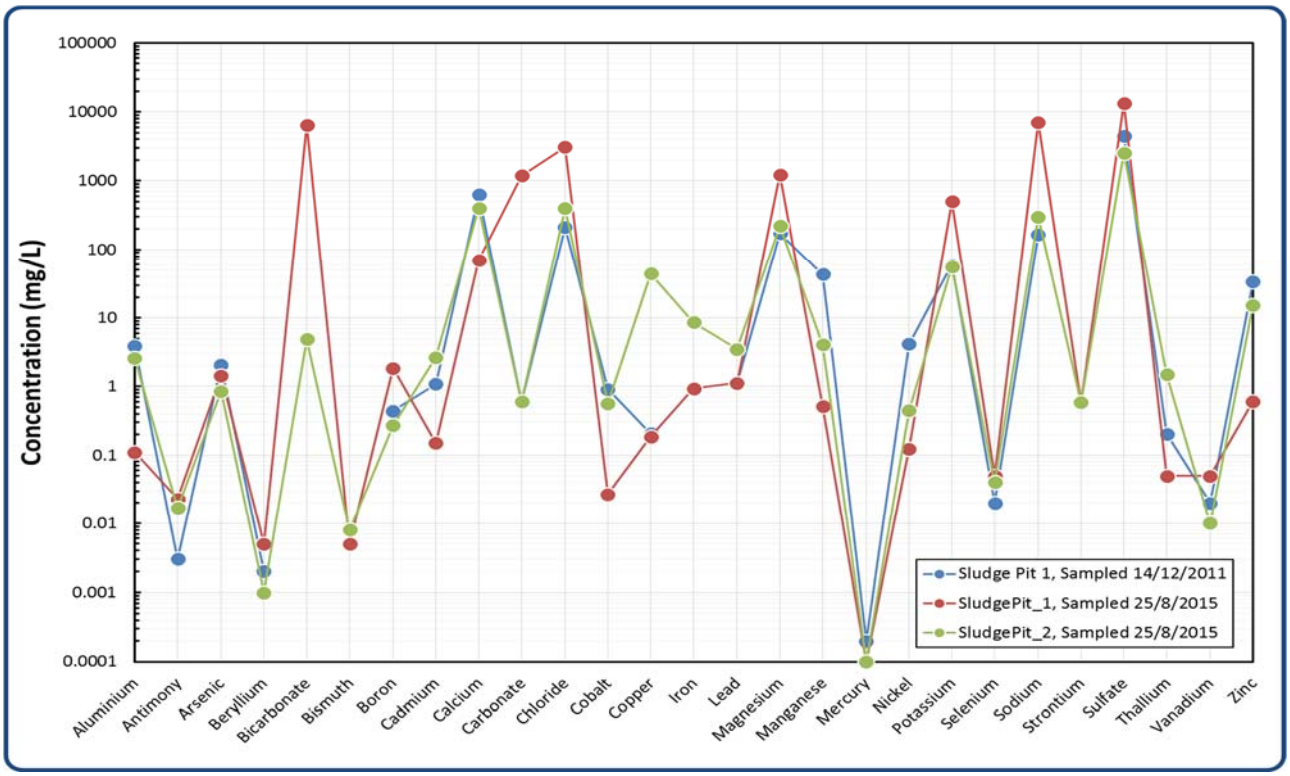

Figure 5-54: Multi-element diagram showing concentrations in sludge pit water

5.4.3 Groundwater Chemistry

Historical groundwater chemistry data is available for a number of existing MIM bores which are monitored as part of the EA *Schedule H*.

As part of this investigation, groundwater samples were collected by MIM personnel from the new monitoring bores, following completion of airlift development and dispatched under chain of custody protocol to ALS for analysis. It should be noted that BSOC_A4 was dry at the time of sample collection and therefore a sample was not collected.

A summary of the field water quality parameters and results of the water quality analysis are presented in Table 5-13, with the complete water quality analysis results presented in Appendix II. Samples were also collected from BSOC WRD South Seepage and TD3 Seepage. BSOC WRD North Seepage was not flowing at the time of sample collection.

Table 5-13: Summary of Phase 2 groundwater and seepage sample results

Sample Type	Sample ID	Date Sampled	Field Parameters*			Laboratory Results									
			Temp	pH	EC	SO_4	F	Al	As	Cd	Co	Cu	Pb	Ni	Zn
	Unit			-	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Groundwater	BSOC_A1	19/1/16	32.9	8.66	3,933	576	2.3	0.9	0.003	<0.0001	<0.001	0.005	<0.001	<0.001	<0.005
	BSOC_A2	19/1/16	29.4	7.18	12,753	5,580	6.4	2.20	0.002	<0.0001	<0.001	0.005	0.002	0.002	0.006
	BSOC_A3	21/1/16	33.7	8.23	5,830	727	3.4	25.8	0.007	<0.0001	<0.001	0.049	0.002	<0.001	<0.005
	BSOC_A4	Dry	-	-	-	-	-	-	-	-	-	-	-	-	-
	BSOC_A5	19/1/16	34.8	7.39	16,048	4,870	5.1	18.5	0.014	0.0001	0.004	0.002	0.002	0.003	0.015
	BSOC_B1	20/1/15	30.7	7.28	5,372	1,760	5.3	1.51	<0.001	<0.0001	<0.001	0.001	<0.001	<0.001	0.007
	BSOC_B2	20/1/15	30.1	6.93	1,346	152	1.8	0.35	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.006
	BSOC_B3	20/1/15	30.0	7.13	3,926	182	5.3	0.39	<0.001	<0.0001	<0.001	0.005	0.004	<0.001	0.022
	BSOC_B4	21/1/16	36.7	8.33	3,699	320	4.1	0.68	0.010	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005
	BSOC_B5	20/1/16	30.6	7.13	6,364	1,410	6.1	0.35	0.011	<0.0001	<0.001	<0.001	<0.001	<0.001	0.006
	BSOC_B6	21/1/16	35.0	8.79	6,224	413	4.7	4.15	0.012	<0.0001	<0.001	0.038	0.004	0.001	0.005
Seepage	BSOC WRD South Sump	25/1/16	32.2	8.57	18,600	11,900	3.9	0.1	0.092	<0.0001	0.002	0.067	0.004	0.002	0.008
	BSOC WRD South Seepage	25/1/16	30.8	8.31	12,000	8,030	4.6	0.12	0.005	0.0011	0.002	0.051	0.019	0.002	0.036
	TD3 Seepage	25/1/16	28.3	7.76	11,900	8,720	1.4	0.03	0.002	0.0344	0.002	0.026	0.009	0.036	7.59
	TD5 Pit	29/1/16	-	8.38	15,700	7,920	5.3	0.07	0.02	0.0011	0.046	0.034	0.039	0.013	0.126

*Seepage Samples – EC / pH laboratory values
Metal as total

Alluvial Aquifer

Limited historical data exists for the groundwater quality within the alluvial aquifer, with this interpretation relying solely on the groundwater samples collected as part of this investigation.

Figure 5-55 shows the average major water quality parameters for alluvial aquifer groundwater. Also shown, for comparison, are the seepage water qualities, including those from the TSF5 pit water sample.

Water quality from the alluvial monitoring bores is generally more sodium and potassium rich than seepage water. Of the alluvial monitoring bores in Figure 5-55, BSOC_A2 and BSOC_A5 have higher sulphate concentrations and higher ECs than BSOC_A3 and BSOC_A1. BSOC_A2, located closest to the BSOC WRD South Seepage, reports water that has similar major parameter characteristics to the seepage samples, although all alluvial bores have lower magnesium concentrations than the BSOC WRD seepages. BSOC_A1 and BSOC_A3 appear to be only slightly similar to the seepage water from any of the sources. Values of pH remain slightly to mildly alkaline at ~7 – 8.

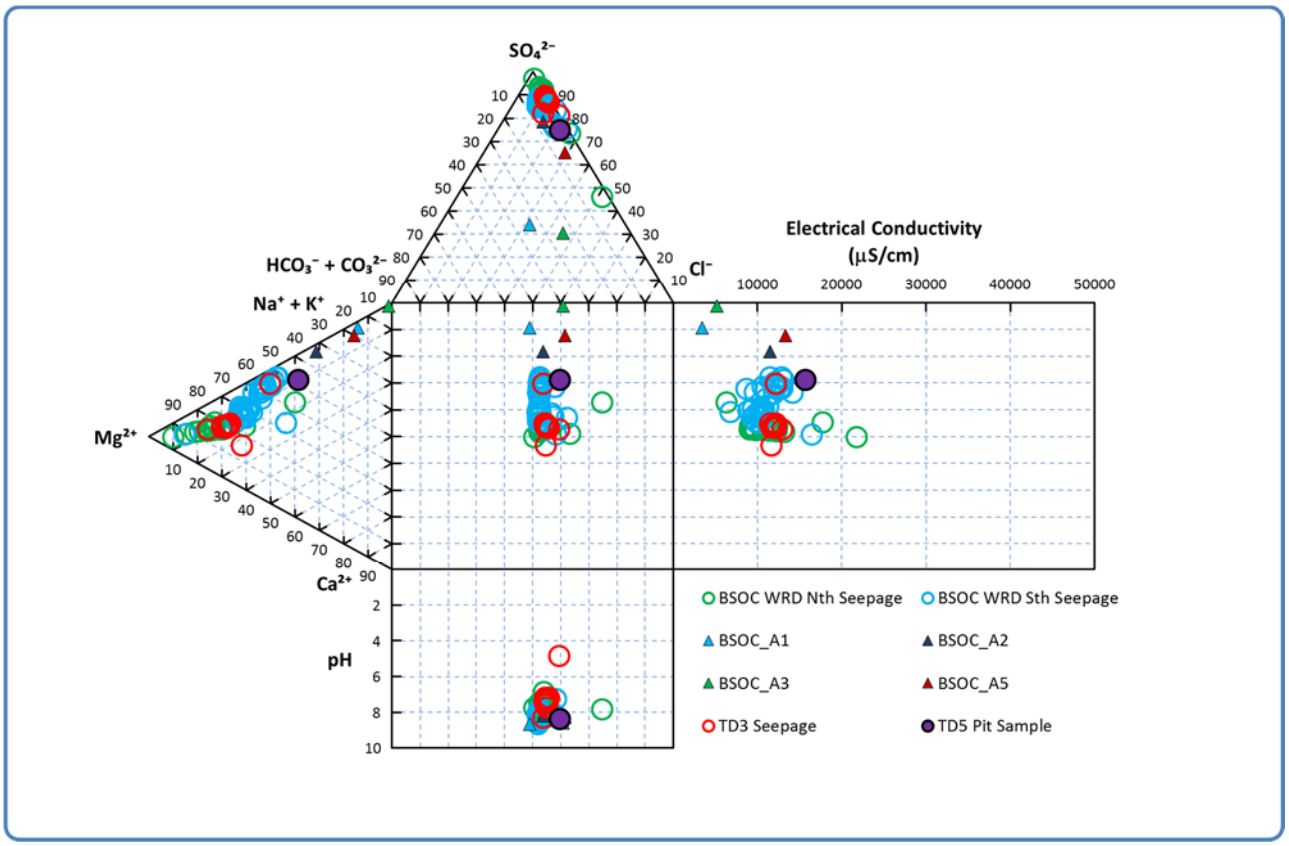

Figure 5-55: Major water quality parameters for alluvial groundwater. Also shown are seepage water qualities from BSOC WRD North, BSOC WRD South and TD3 and parameter values from the TD5 seepage pit

Bedrock Aquifer

Figure 5-56 shows the average major water quality parameters for bedrock groundwater, including the recently installed bores and the longer-term monitoring bores (Bores 23, 24, 39 and

40). Also shown, for comparison, are the seepage water qualities, including those from the TD5 pit sample.

With the exception of Bores 23 and 24, all monitoring bores in Figure 5-56 have lower sulphate concentrations, higher sodium and potassium concentrations and lower EC values. Bores 23 and 24 are close to the TD3 seepage point and may be exhibiting some influence from this water.

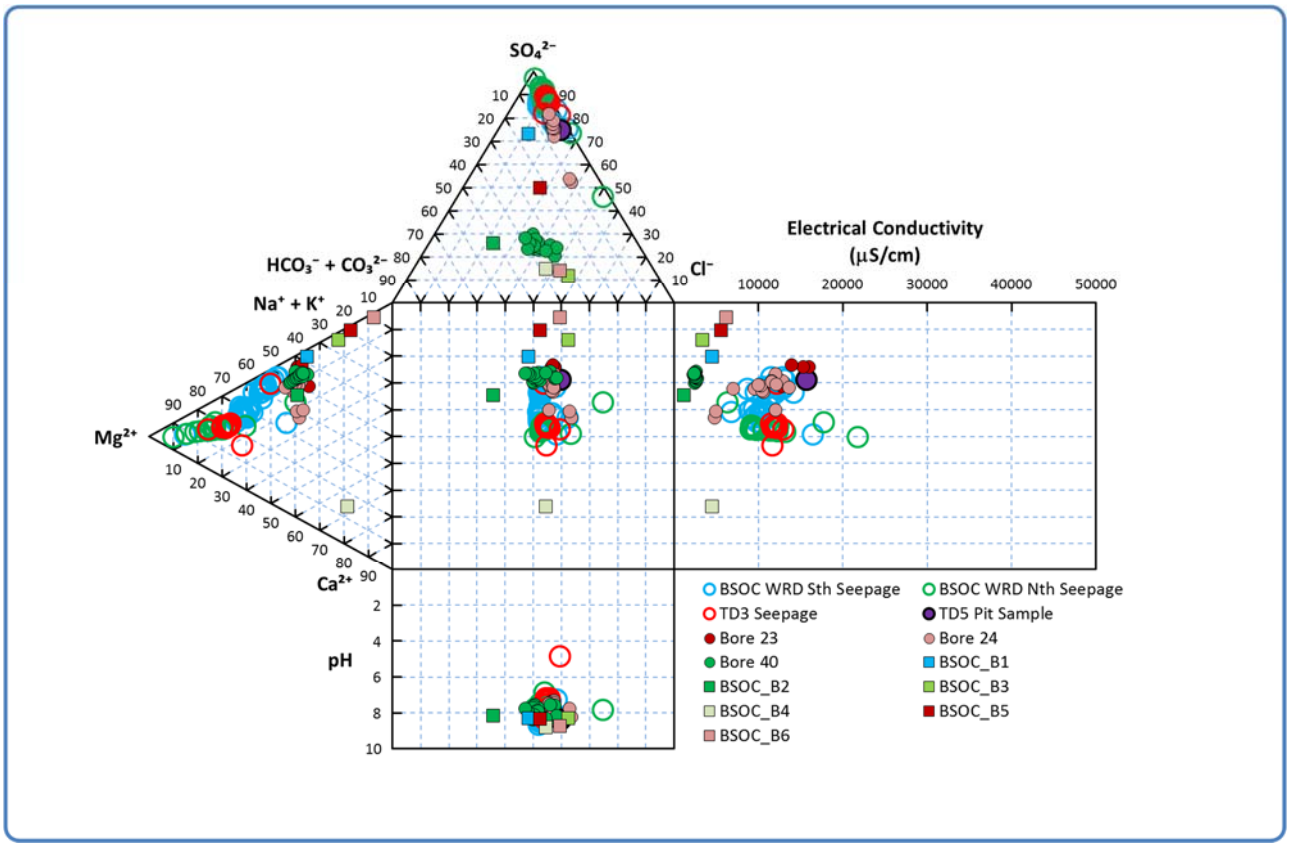

Figure 5-56: Major water quality parameters for bedrock groundwater, including the long-term groundwater monitoring bores 23, 24, 39 and 40. Also shown are seepage water qualities from BSOC WRD North, BSOC WRD South and TD3 seepage and parameter values from the TD5 seepage pit

Time-Series Diagrams

Figure 5-57 shows the variation over time of sulphate, chloride, pH, alkalinity, zinc and copper, respectively, in alluvial and bedrock aquifers[9]. Also shown in these figures are values collected for Bore 40 from the study of Forsyth (2014), to provide a comparison of the variations over a longer timescale.

Concentrations for a given sample have remained relatively consistent over the monitoring periods. For sulphate, the highest concentrations over time are found in Bore 24, which is the closest bore downgradient of TD3 Seepage. For a given area (e.g., in the vicinity of TD3 seepage), the alluvial monitoring bores report higher concentrations than the bedrock bores. In the vicinity of BSOC WRD North Seepage (green symbols), Bore 40 has reported sulphate consistently ~ 300

[9] Colours represent 'areas' of bores: red symbols are in the vicinity of TD3 Seepage, green symbols are in the vicinity of BSOC WRD North Seepage and blue symbols are in the vicinity of BSOC WRD South Seepage

mg/L, which is comparable to the nearby bores BSOC_B2, BSOC_B3 and BSOC_B4, which were drilled as part of this investigation.

Chloride concentrations show the same relatively consistent trends over time, with bores in the vicinity of TD3 Seepage reporting the highest concentrations. Values of pH have remained relatively consistent at ~ 7 to ~ 9, whereas alkalinity for all bores varies by ~ 1500 mg $CaCO_3$/L. Zinc and copper concentrations have remained below ~ 0.1 mg/L throughout the monitoring period.

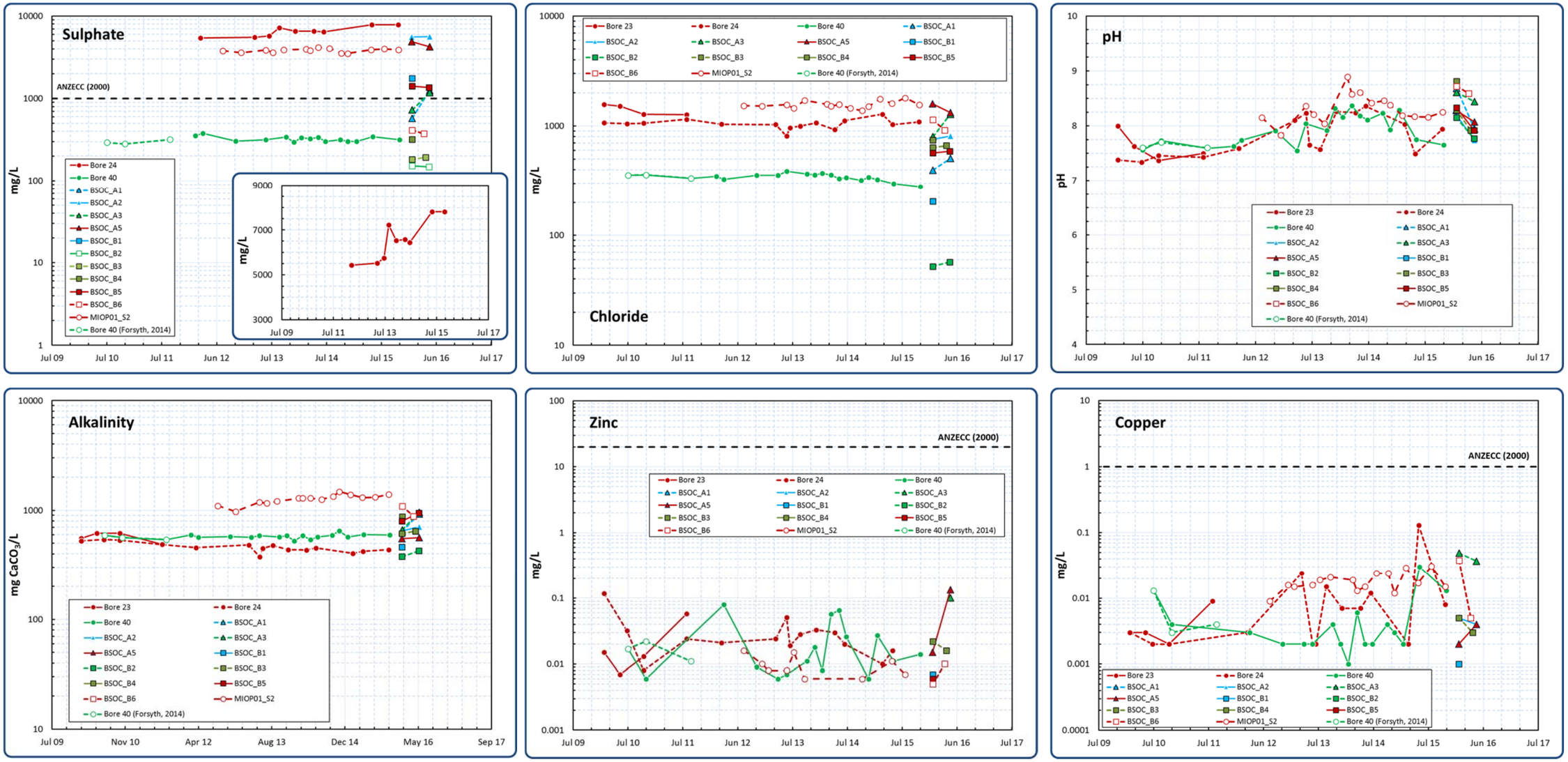

Figure 5-57: Time-series concentrations for alluvial and bedrock bores, a) Sulphate, b) Chloride, c) pH, d) Alkalinity, e) Zinc, f) Copper

5.4.4 Isotope Samples

Water samples from the seepage locations and groundwater samples were collected from a selection of existing monitoring bores and the monitoring bores installed during the Phase 2 field investigation program were analysed for hydrogen, oxygen and sulphur stable isotopes. The analysis was performed at the University of Queensland, using the methods described in Forsyth (2014).

Oxygen and hydrogen isotopes were chosen because they are the constituents of H2O (i.e., water); sulphur stable isotopes were chosen because sulphide / sulphate is ubiquitous throughout the mine site. In addition, these isotopes were investigated by Forsyth (2014) and it is useful to compare the previous results with information gleaned in this study. Subtle changes in the ratios of O18 and O16 and H1 and H2 (Deuterium, D) may reflect differences in water source(s) or the conditions the water samples may have been subjected to. Differences in S32 and S34 stable isotopes may reflect redox conditions.

Results from sulphate δS^{34}, referenced to Canyon Diablo troilite, show that TD5 pit seepage is almost 4 ‰ enriched in S^{34} compared to TD3 seepage (Figure 5-58). Enrichment of sulphate S^{34} may be caused by reduction of sulphate to sulphide (bacterial), or by oxidation of sulphide to sulphate. This may also be consistent with the fact that TSF3 tailings has been buried for a longer duration than TSF5 as less sulphide oxidation is a mechanism for lower sulphate S^{34}. The results show that BSOC_A5 and BSOC_A2 may have been influenced by components of TSF3 and TSF5, respectively.

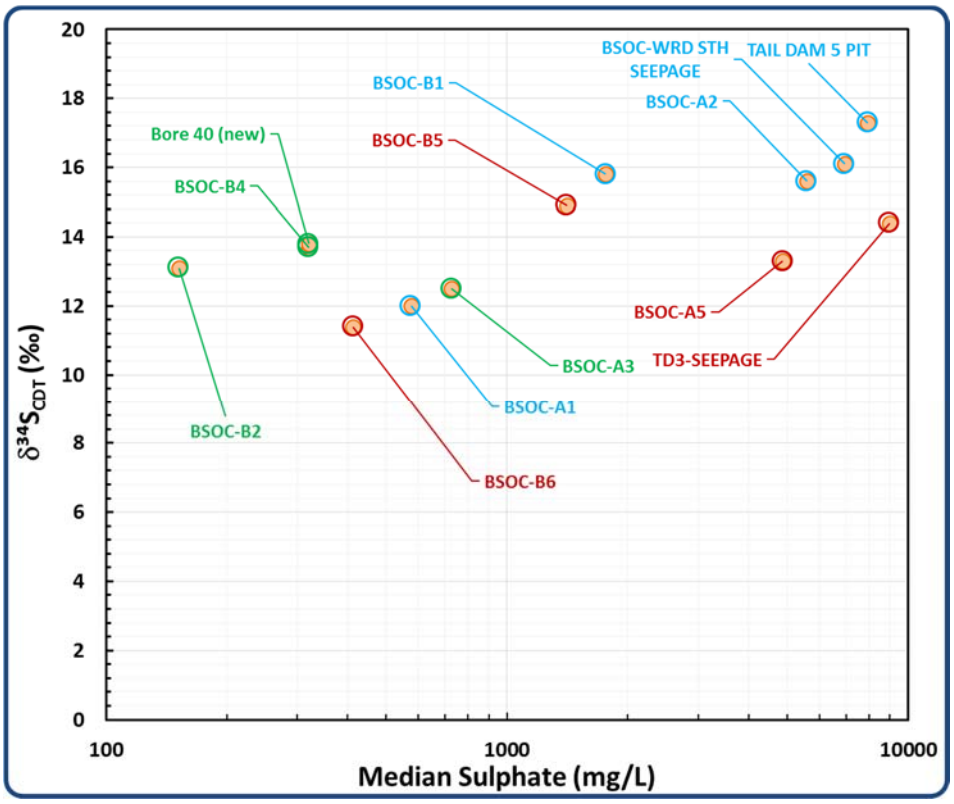

Figure 5-58: $\delta^{34}S$, referenced to Canyon Diablo troilite, against median sulphate for alluvial and bedrock groundwater bores, TD3 Seepage, TD5 pit sample and BSOC WRD South Seepage

Figure 5-59 shows the variation in stable isotopes of oxygen and hydrogen (Deuterium, D), referenced to Vienna Standard Mean Ocean Water (VSMOW). Figure 5-59 shows the global meteoric water line (GMWL) and a local meteoric water line (LMWL), calculated by regression of rainfall values δ18O and δD at Mount Isa collated by CSIRO between 2008 and 2010 (Crosbie et al., 2012). The slope of the LMWL is ~ 5 and is comparable to that calculated by Forsyth (2014). Compositions plotting to the right of the LMWL are likely, at Mount Isa, to have experienced evaporative events, which favour loss of the lighter isotopes of oxygen (O16) and hydrogen (H1) resulting in the enrichment of the residual water in O18 and H2(D).

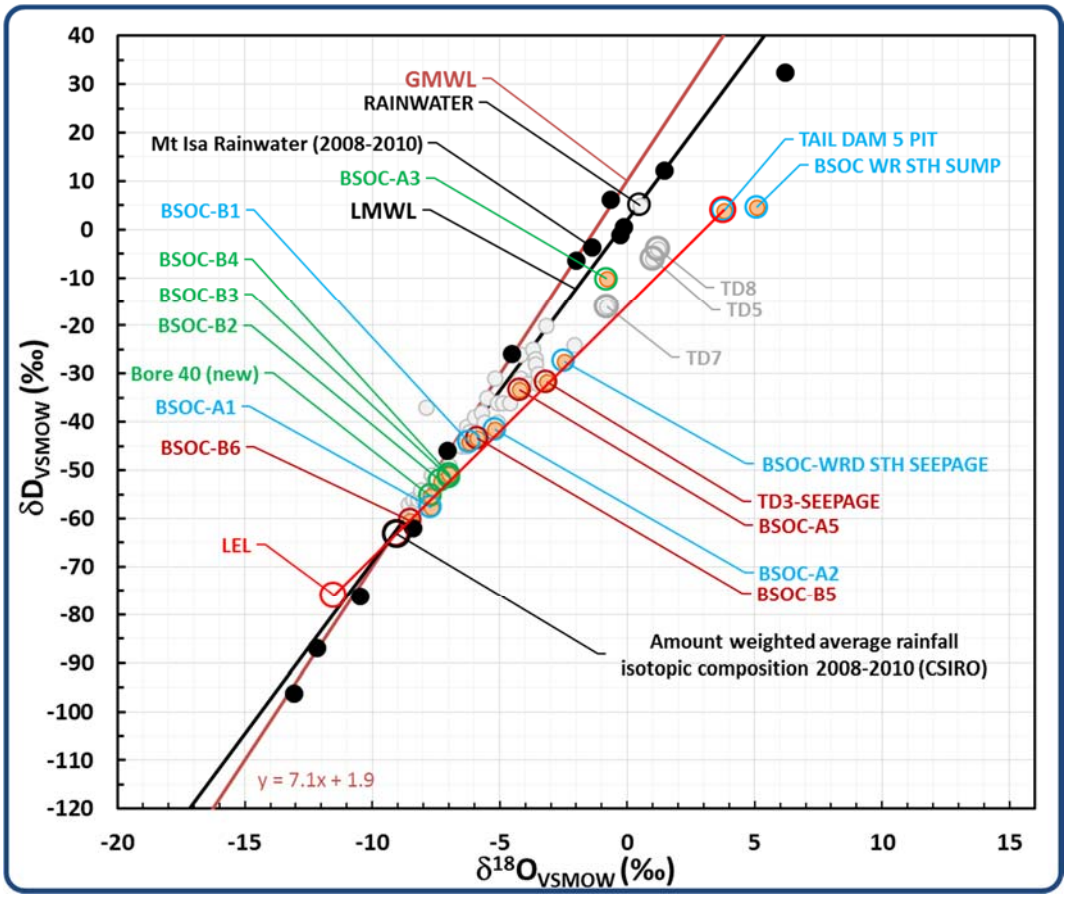

Figure 5-59: $\delta^{18}O$ and δD, referenced to Vienna Standard Mean Oceanic Water (VSMOW), for alluvial and bedrock groundwater bores and seepage water

A Local Evaporation Line (LEL) is thus calculated between the isotopically 'heavy' TD5 pit water and an average weighted rainfall value (CSIRO). The TD5 pit sample water is perhaps expected to have among the heaviest isotopic signature since it is exposed to the air and may experience extensive evaporation. Other seepage compositions generally fit on the similar trends as the LEL, which may indicate influence between the samples – i.e., similar compositions – with differences simply being due to different levels of evaporation. Of the bore samples, the alluvial bores BSOC_A2 and BSOC_A5 may exhibit some impact from the seepage(s), whereas the bedrock groundwater bores show little impact. Interestingly, the isotopic signature of BSOC_A3 is comparable to the seepage water, although this may be due to high levels of evaporation.

5.4.5 Surface Water Chemistry

Historically, surface water samples have been collected by MIM for a number of sites within the study area, with the majority of these in the vicinity of the King Gully and the Diversion Drain. Limited data is available for water chemistry relating to the gullies associated with the BSOC WRD North and South Seepages, which is a function their ephemeral nature and limited water flow.

During the Phase 1 site investigation, water samples were collected from selected locations across the study area. The sample locations shown on Figure 5-60 and were collected from the seepage points, collection trenches and any pooling water that was observed during the field mapping exercise. These samples were dispatched to ALS Environmental Division in Brisbane for analysis. Table 5-14 presents a summary of the water sample results for selected parameters.

Table 5-14: Summary of Phase 1 site investigation water sample results

Sample ID	Temp	pH	EC	SO_4	F	Al	As	Cd	Co	Cu	Pb	Ni	Zn
	°C	*-*	*µS/cm*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
WRD_Sth_2	19.7	8.64	12,828	9,460	2.7	0.06	0.018	0.0026	0.002	0.158	0.03	0.002	0.245
WRD_Sth_3	28.1	8.24	7,099	3,130	5.7	0.18	0.003	0.0003	<0.001	0.018	0.008	<0.001	0.01
WRD_Sth_4	23.0	8.64	15,630	9,820	4.5	0.02	0.008	0.0018	0.002	0.048	<0.05	0.001	0.015
WRD_Nth_1	29.4	8.69	15,161	6,240	3.9	0.06	0.011	0.0017	<0.001	0.048	0.07	<0.001	0.032
TD3_Sth_1	29.5	8.80	5,535	1,130	1.8	0.02	0.003	0.0006	<0.001	0.032	0.009	<0.001	0.012
TD3_Sth_2	34.7	8.98	20,040	6,320	3.9	2.17	0.058	0.0048	0.007	0.825	0.272	0.005	0.476
TD3_Seepage	28.6	7.32	15,306	9,440	1.3	<0.05	<0.005	0.0426	0.007	0.019	<0.005	0.0045	9.57
TD3_Nth_4	19.0	8.42	24,339	16,700	2.4	<0.05	0.024	0.0035	<0.005	0.211	0.075	<0.005	0.092
KG_DS_1	23.8	9.24	8,924	900	6.2	0.05	0.054	0.0011	0.002	0.217	0.064	<0.001	0.031

Metals as total
Temperature, pH and EC measured in the field

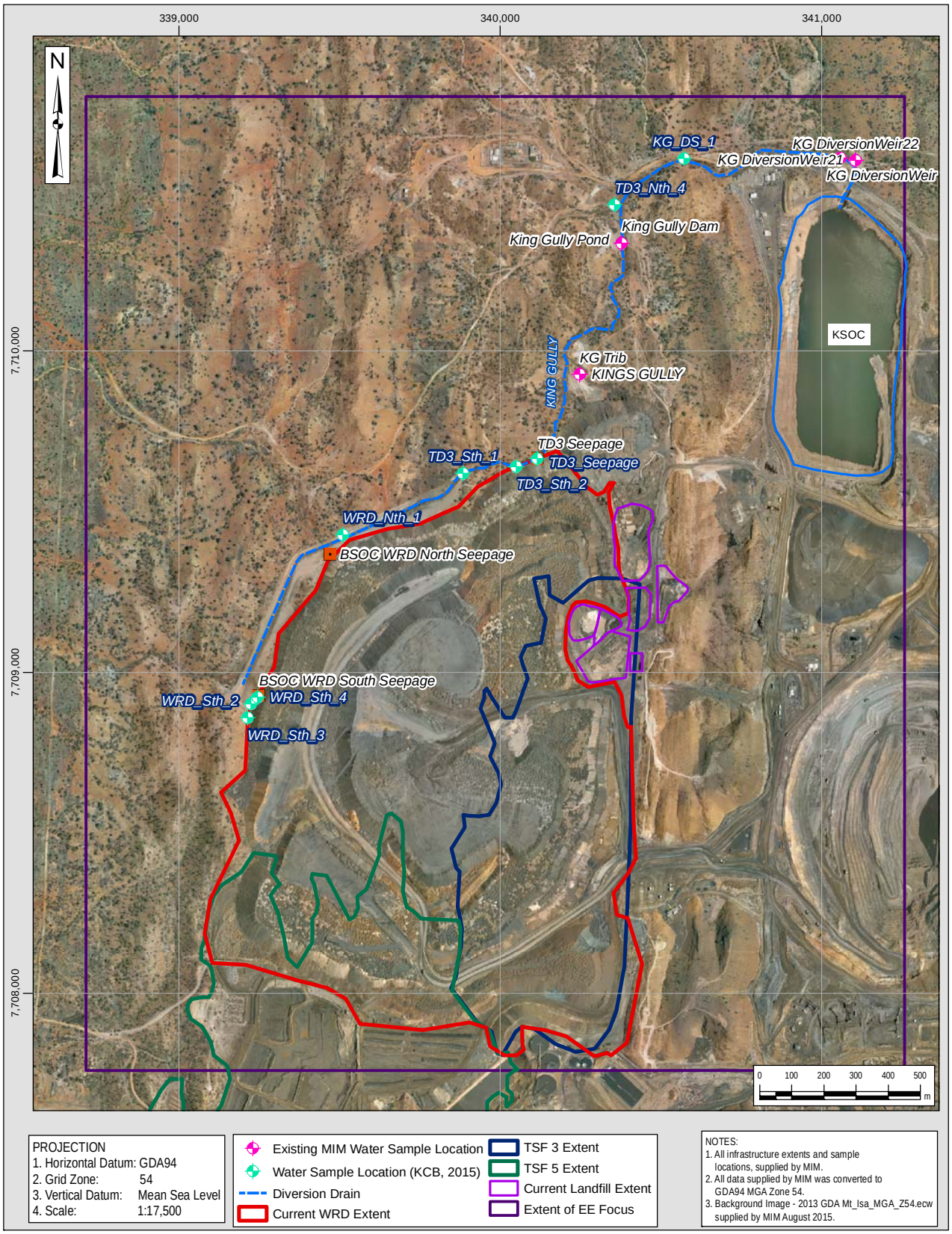

Figure 5-60: Location of water samples collected during Phase 1 site investigation and existing MIM sampling locations

Major water quality parameters are shown for selected surface water locations in Figure 5-61. For clarity, only a selected sample set is shown in Figure 5-60, although it is important to note that the entire dataset was used for this investigation. Samples chosen include: KG_Trib and KING GULLY (close to TD3 seepage), King Gully Pond and King Gully Dam (further along the Diversion Drain) and KG Diversion Weir (furthest away). Water from locations closest to the TD3 Seepage has a similar range of major parameters. In general, the furthest away, KG Diversion Weir samples, show fewer similarities: water from this location is lower in sulphate, higher in sodium and potassium and has a lower EC. A small number of Diversion Weir samples exhibit high EC, which may reflect some influence from the TD3 seepage.

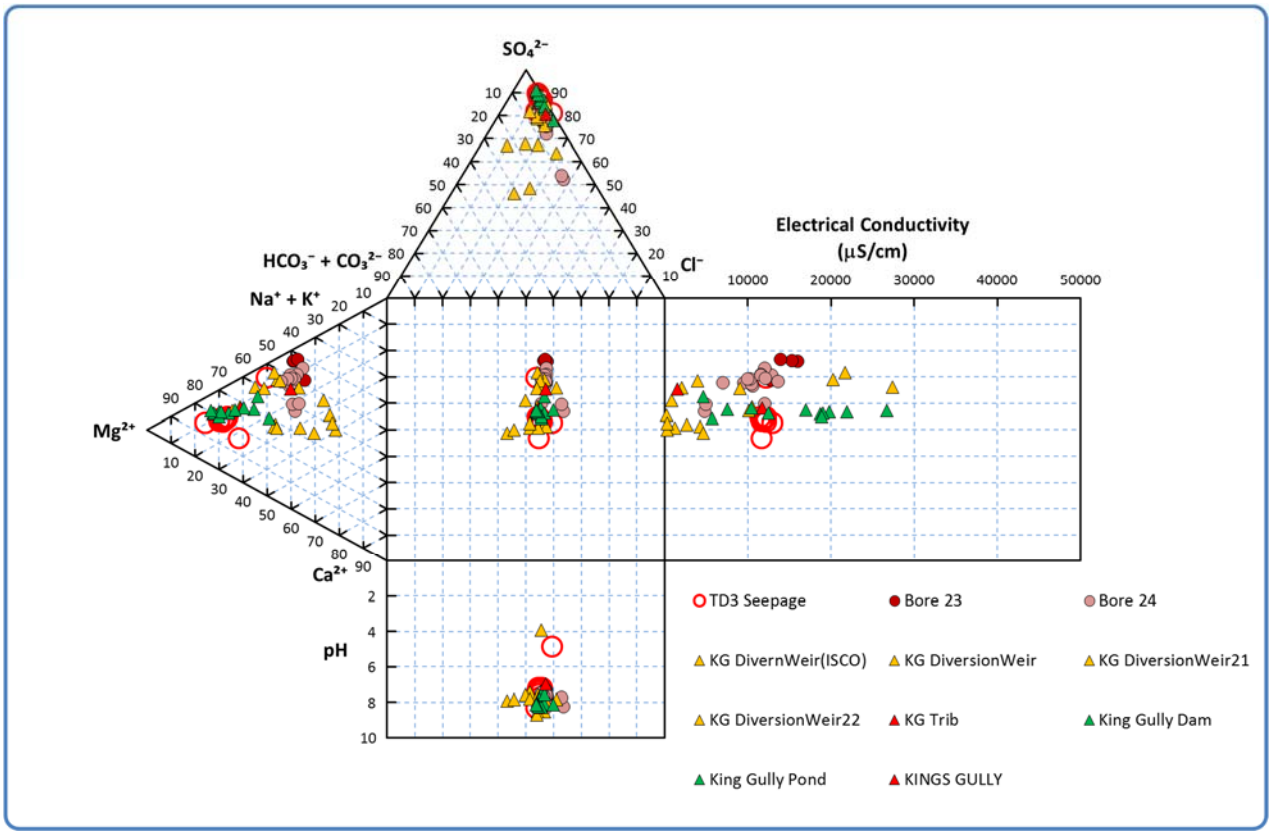

Figure 5-61: Major water quality parameters for selected surface water locations and water quality from TD3 Seepage

As expected, surface water quality is generally poorer the closer the sampling location is to the seepage source. For monitoring points along the Diversion Drain, the samples closest to the TD3 (and/or BSOC WRD North Seepage) Seepage have the highest sulphate concentrations, highest EC and lowest sodium and potassium concentrations. Some distal samples, at the King Gully Diversion Weir have high sulphate (and EC). Geochemical modelling of the seepage water suggests that the 'improvement' in water quality along the Diversion Drain is consistent with precipitation of minerals such as gypsum and zinc: this may explain why the trace element patterns show that BSOC WRD South Seepage, BSOC WRD North Seepage and TD3 Seepage water have high zinc concentrations (> ~ 10 mg/L), whereas most of the groundwater and surface water samples report zinc contents of ~ 0.1 mg/L or less. These results are consistent with the nature of the soil samples collected in the downstream zones of the seepage points.

5.4.6 Mineral Precipitation

Mineral precipitation on the alluvium and bedrock surfaces were observed across the study area. The presence of precipitation may represent evidence of WRD seepage, however, natural precipitation on bedrock surfaces has previously been identified across the MIM site (CMLR, 2009). As a result, soil samples were collected from the identified precipitation locations and from background locations to support the assessment of the BSOC WRD seepage extent.

The location of where the soil samples were collected is shown in Figure 5-62, with a summary of the soil sample results provided in Table 5-15.

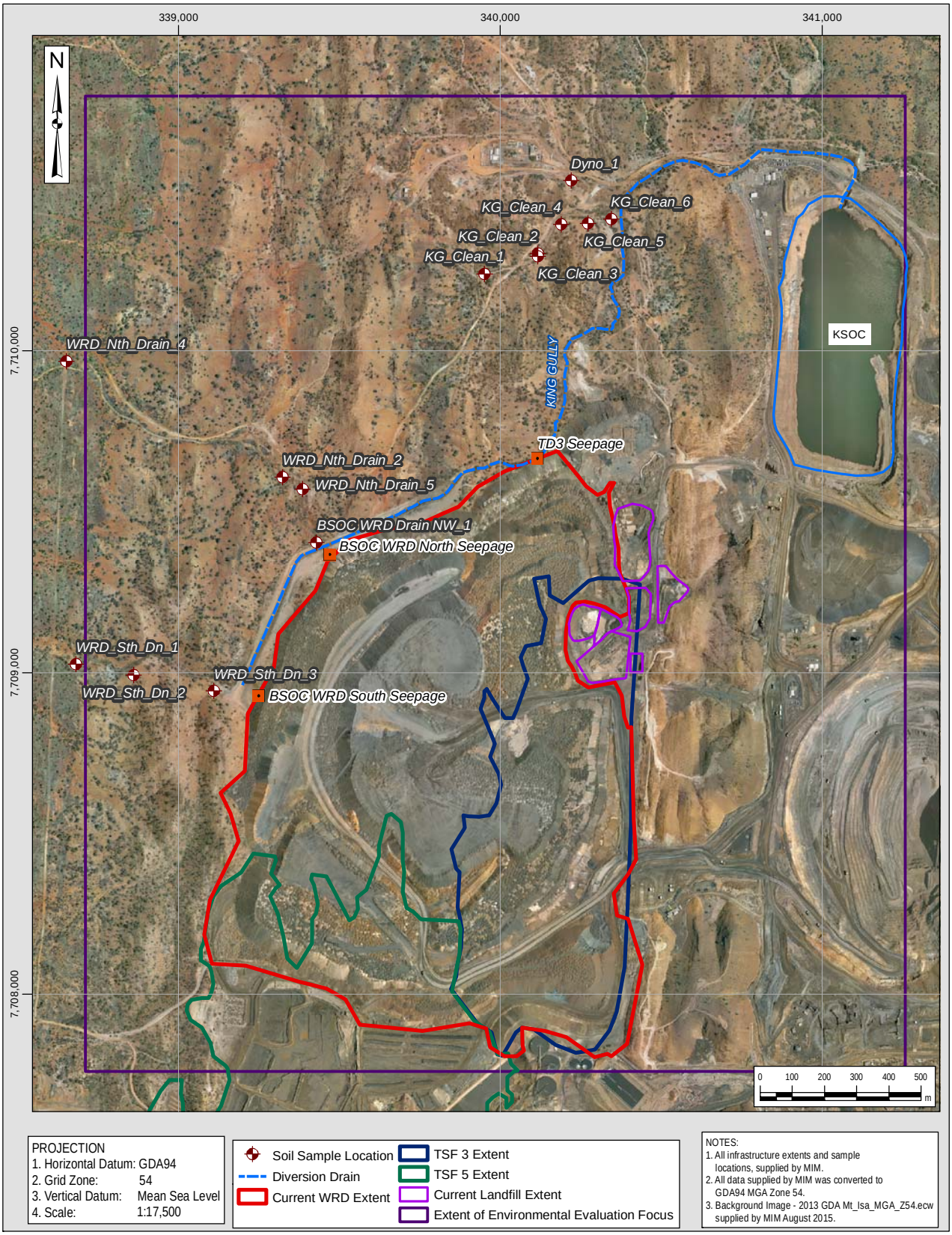

Figure 5-62: Location of soil samples in relation to site infrastructure and seepage locations

Table 5-15: Summary of Phase 1 Soil Sample Results

Sample ID	pH	EC	SO_4	Ca	Mg	Na	K	Cu	Pb	Zn
	-	*µS/cm*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
WRD_Sth_Dn_1	8.6	90	90	30	30	10	10	489	145	97.9
WRD_Sth_Dn_2	8.9	3,290	7,920	80	1,520	3,510	700	2,110	609	356
WRD_Sth_Dn_3	7.8	43,900	245,000	1660	33,600	63,800	7,160	400	635	813
WRD_Nth_Drain_2	9.4	14,300	55,000	700	6,840	15,200	430	222	104	103
WRD_Nth_Drain_4	8	79	120	40	60	90	20	241	102	80
WRD_Nth_Drain_5	8.5	168	270	90	30	40	10	373	138	119
BSOC WRD Drain NW_1	6.8	31,000	61,500	4,040	18,500	21,800	300	1,210	634	410
KG_Clean_1	9.3	97	190	60	30	50	10	261	82	69
KG_Clean_2	10.5	38,800	91,500	30	10	73,400	920	534	132	162
KG_Clean_3	10.2	7,430	17,600	160	190	10,300	320	443	149	144
KG_Clean_4	9.8	17,900	45,300	40	60	25,700	1,540	1,660	505	530
KG_Clean_5	9.8	6,730	17,200	580	490	7,740	130	364	142	146
KG_Clean_6	9.2	24,100	91,700	2,420	8,300	27,300	1,170	495	173	145
Dyno_1	9.9	28,800	44,000	30	10	53,600	1,530	438	137	113

A full description of the sample locations is provided in Appendix II. A summary of the soil sampling results is provided in the following:

- The WRD Nth and Sth samples were collected from the alluvial tributaries downstream of the respective seepage locations (BSOC WRD North and South Seepages).
- WRD_Nth_Drain_4 was collected from the study area boundary and has since been considered as a 'background' soil sample.
- Samples were collected from the King Gully clean catchment (KG_Clean) where notable precipitation was observed.
- Dyno_1 was taken from a bedrock / alluvial interface with observable precipitation, adjacent to the Dyno Nobel facility.

As noted during the Phase 1 site investigation (Appendix II), precipitates were observed along the Diversion Drain that are postulated to derive from the BSOC WRD seepage water. Accordingly, the hydrogeochemical software, Geochemist's Workbench, was used to 'reverse model' the water chemistry that would be expected to be in equilibrium with soil samples with the composition in Table 5-15. In addition, PHREEQC was used to 'forward model' the minerals most likely to precipitate from seepage with a water quality equivalent to that of TD3 Seepage, BSOC WRD North Seepage and BSOC WRD South Seepage. Both methods suggest that gypsum is likely to be saturated in such water, with smithsonite ($ZnCO_3$) also likely to be near saturation. This is in agreement with Forsyth (2014). Figure 5-63 shows the modelled sulphate and zinc concentrations that may be expected if gypsum and smithsonite precipitate from a water with the composition of TD3 Seepage. This suggests that some of the soil samples may be impacted by the influx of seepage water, although this influence is unlikely in the distal samples, such as WRD_Sth_Dn_1, WRD_Nth_Drain_4 and KG_Clean_1.

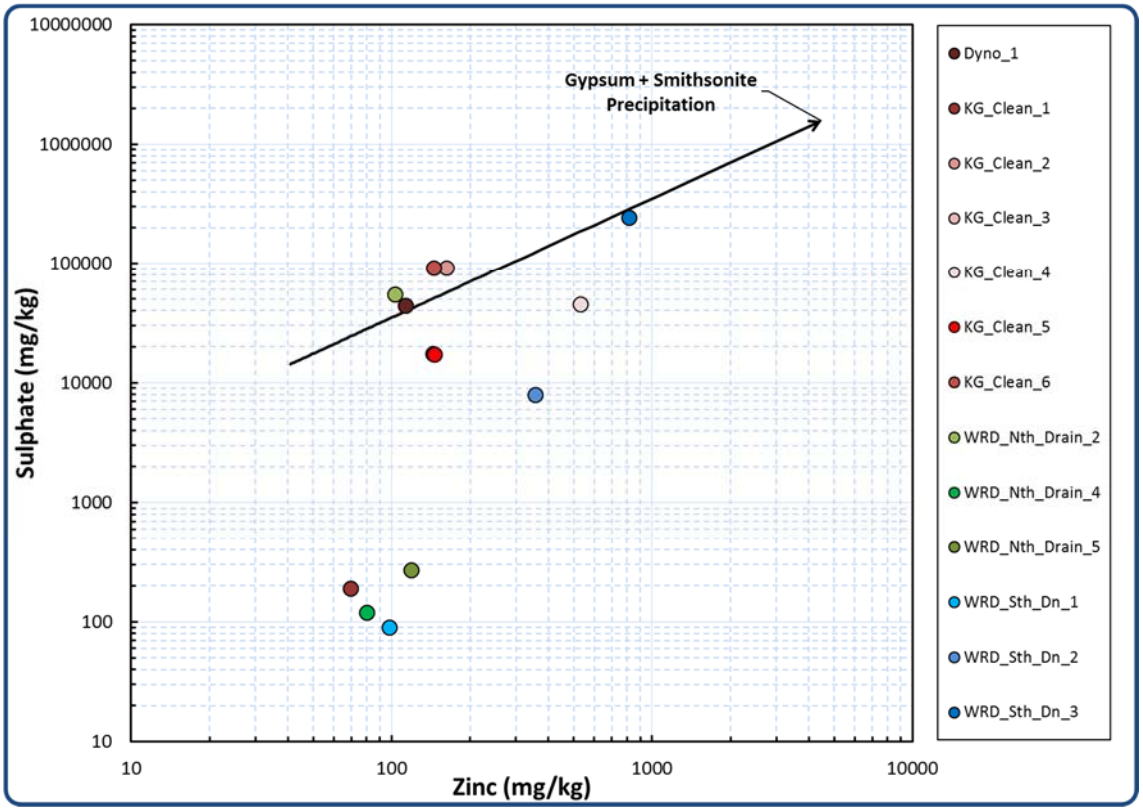

Figure 5-63: Soil zinc and sulphate concentrations. Also shown is the locus of concentrations that may be expected when gypsum and smithsonite precipitate from water with the same composition as TD3 Seepage water

5.4.7 Summary of Water Chemistry

WRD Seepage Water Chemistry

Major and trace element parameters suggest that TD3 Seepage has some similarities to BSOC WRD North Seepage and, while there are slight differences in the levels of certain parameters, both seepage waters are similar to BSOC WRD South Seepage. This suggests that the overlying waste rock has an influence on the TSF3 chemistry and the seepage observed at TD3 and/or BSOC WRD North Seepage is a result of this influence. Stable isotopes provide a hint that TSF5 water chemistry may have an influence on the seepages to the north, but further sampling and testing would be required to confirm this.

Based on the water qualities obtained from kinetic testing of both waste rock and tailings, as well as the measured seepage, there is no basis for clear differentiation between geochemical signatures in the tailings and waste rock seepage.

TSF Seepage Water Chemistry

The trace element 'fingerprint' of TSF5 appears to be similar to that for BSOC WRD South Seepage (cf. Figure 5-37 and Figure 5-44).

TSF3 trace element concentrations, represented here by TD3 seepage, are similar to those from BSOC WRD North Seepage and broadly similar to those from BSOC WRD South Seepage and TSF5 (cf. Figure 5-38, Figure 5-39, Figure 5-44).

Landfill Chemistry

Certain parameters, such as cadmium and manganese, have similar relative proportions in the sludge pit seepage and TD3 seepage. It is possible that there may be some influence from the sludge pit on TD3 seepage, but the extent of any influence is difficult to determine quantitatively without further constraints on the internal geochemistry of TSF3 and the WRD. Further assessment of the groundwater flow system underlying the sludge pits would also be required to confirm the potential seepage contribution to the BSOC WRD landform from sludge pit infiltration.

Groundwater Chemistry

The bedrock bores show little major parameter and isotopic evidence of being impacted by the seepage at any of the three seepage points. Alluvial bores BSOC_A2, BSOC_A3 and BSOC_A5, however, are likely to be impacted. For BSOC_A2, the likely source is BSOC WRD South Seepage; For BSOC_A3, the likely source is BSOC WRD North Seepage; for BSOC_A5, the source of the impact is likely to be TD3 Seepage.

Time-series data show that the long-term monitored bores (e.g. Bore 40) have relatively consistent water chemistry throughout the monitoring period. Of the bores assessed in this report, Bores 23 and 24 are likely to have been impacted by seepage. Distal bores, such as Bore 40, are not impacted. No bedrock monitoring bores in the vicinity of BSOC WRD North Seepage (e.g. BSOC_B3) show geochemical evidence of being impacted, which may suggest that BSOC WRD North Seepage does not migrate to the north-northwest in the bedrock aquifer.

Surface Water Chemistry

Surface water quality appears to deteriorate the closer to TD3 the water is sampled, which may be expected. Some distal surface water samples (e.g., at the King Gully Weir) report high sulphate and EC.

5.4.8 One-Dimensional Analytical Assessment

A one-dimensional analytical assessment was completed using the Ogata-Banks Analytical Solution for 1D advection-dispersion, including retardation. The basis for the analytical assessment is provided in Equation 1 (Ogata and Banks, 1961).

Equation 1:

$$C(x,t) = \frac{1}{2}Co\left[\operatorname{erfc}\left(\frac{x - \frac{v}{R}t}{\sqrt{4\frac{D}{R}t}}\right) + e^{v\frac{x}{D}}\operatorname{erfc}\left(\frac{x + \frac{v}{R}t}{\sqrt{4\frac{D}{R}t}}\right)\right]$$

Where:

x = down-gradient location of interest
t = time of interest
C_o = source concentration
v = groundwater velocity

D = dispersion
R = retardation
erfc = complementary error function
C = concentration at a specific location and time

The Ogata-Banks equation was used to determine concentration breakthrough curves at the study area boundary with consideration of advection and dispersion. Sulphate was used as the tracer/ migration parameter for this analysis due to the conservative nature of the parameter (i.e. prone to secondary reactions and attenuation / adsorption mechanisms along the flow path). Analyses were undertaken for each of the aquifers and seepage sources, with selected results discussed below. The following assumptions are made to support the analyses:

- the alluvium and bedrock aquifers act as separate hydraulic units;
- the aquifer systems are represented as intergranular, homogeneous and isotropic (i.e. no lateral or vertical variation in parameter values).
- groundwater flow is steady-state,
- groundwater flows towards the north (bedrock aquifer) and west (alluvial aquifer) of the WRD as indicated by the groundwater contours and groundwater level measurements;
- source concentrations of sulphate is assumed to be constant and to be representative of the seepage concentrations from the corresponding seepage locations,
- the timing for each model starts from the corresponding TSF (i.e. TSF3, TSF5) mid-date of operations; and,
- parameters reported in the previous sections were used where available and where not available suitable parameters from other locations were adopted. It is acknowledged that these parameters are representative of current conditions.

The results for the 1D analysis of the alluvium aquifer associated with the BSOC WRD North and South Seepages are presented in Figure 5-64 and Figure 5-65, respectively. TD3 Seepage was not included for analysis as the alluvium in this area is subject to additional seepage contribution from seepage transferred along the Diversion Drain. Additionally, seepage in the alluvium downstream of TD3 Seepage is managed by the Diversion Drain / King Gully, which directs the seepage to discharge into KSOC.

Figure 5-64 and Figure 5-65 also presents the distance to the study area boundary as well as the ANZECC (2000) livestock guideline concentration for sulphate of (1,000 mg/L). The sulphate livestock guideline concentration was selected for this analysis to represent the extent of potential impact to the groundwater system. TSF5 was used as the source for both assessments based on the historical evidence of seepage / precipitation prior to the placement of the WRD. The source term was applied as a constant in the assessment (i.e. constant sulphate concentration since the establishment of TSF5), which is considered conservative as the source term would have likely increased over time to the concentration that is currently being applied. For the purposes of this assessment it is assumed that seepage commenced at the mid-point of TSF5 operation (1961), however it is unknown when seepage may have commenced. Sulphate concentrations from the respective downstream monitoring bores (BSOC_A3 – BSOC WRD North Seepage; BSOC_A2 and

BSOC_A1 – BSOC WRD South Seepage) are also shown with the breakthrough curves to allow verification of the simulation. The following observations are made from the alluvial assessment:

- Migration of seepage beyond the diversion drain (sulphate plume) in the alluvium aquifer downstream of the BSOC WRD North Seepage to reach Hazeldene Creek (2,000 m downgradient of seepage location) is predicted to occur in 2170 (204 years since the mid-point of TSF5 operation).
- The breakthrough curve for the BSOC WRD South Seepage downstream alluvium aquifer indicates that the unmitigated sulphate plume could potentially reach Hazeldene Creek, (1,100 m downstream of BSOC WRD South Seepage), by 2122 (156 years since the mid-point of TSF5 operation).

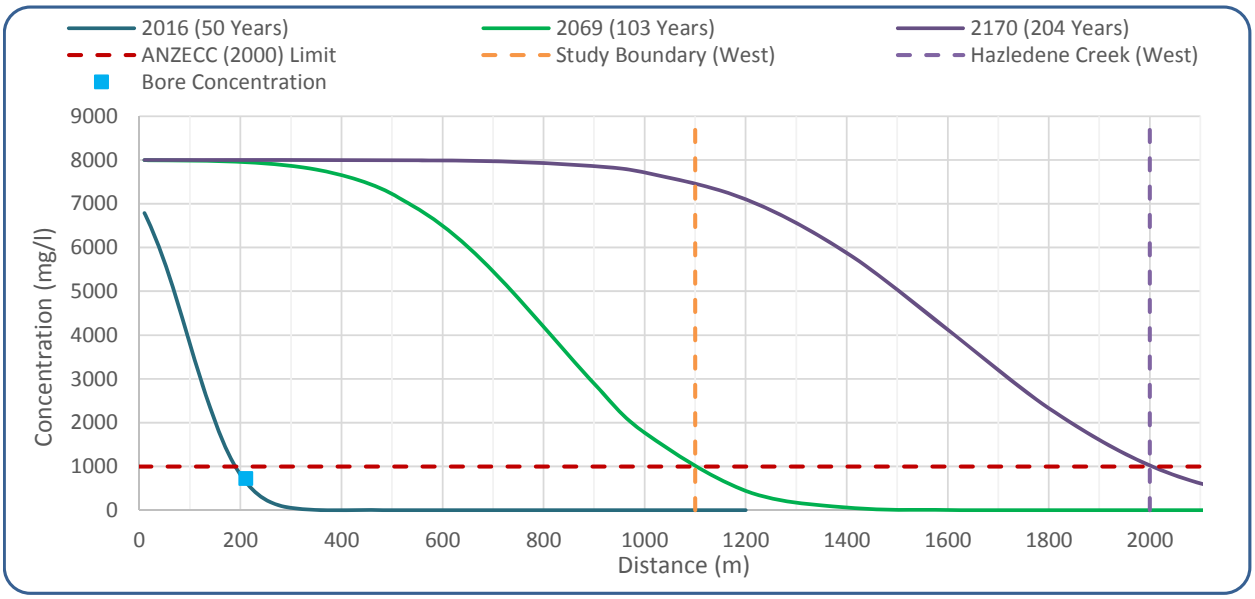

Figure 5-64: Ogata-Banks breakthrough curve for the BSOC WRD North Seepage (alluvium), with sulphate bore concentration from BSOC_A3

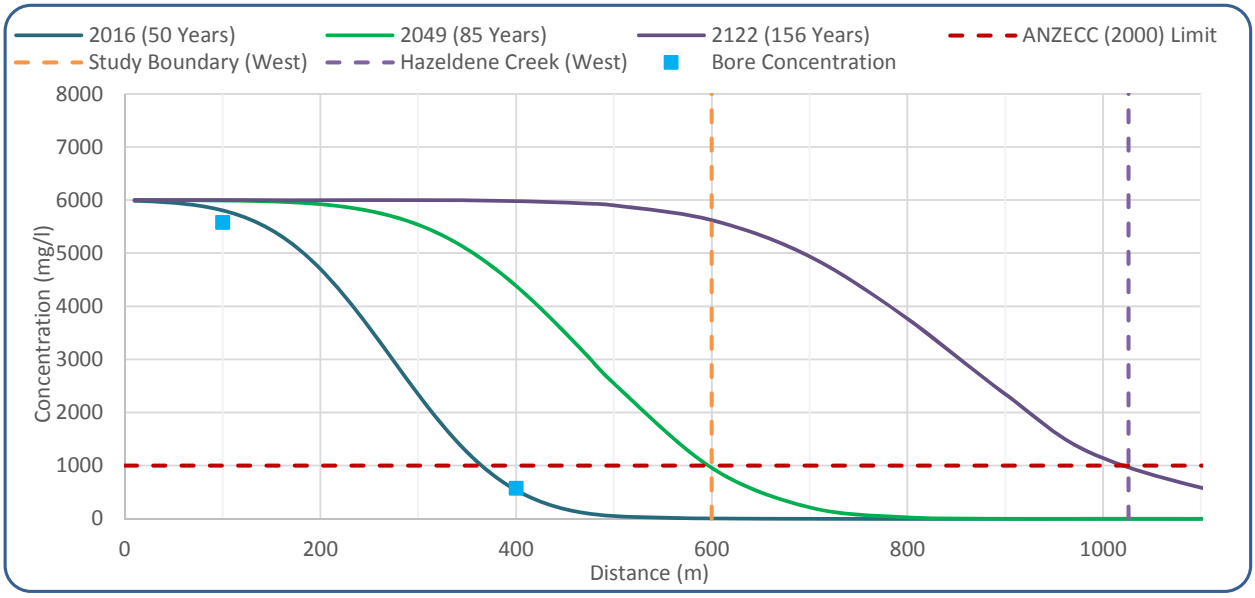

Figure 5-65: Ogata-Banks breakthrough curve for the BSOC WRD South Seepage (alluvium), with sulphate bore concentration from BSOC_A2 and BSOC_A1

The breakthrough curve for the weathered bedrock associated with the TD3 Seepage is presented in Figure 5-66, along with the downstream northern extent of the study boundary (1,125 m north of TD3 Seepage). Sulphate concentrations from downstream weathered bedrock monitoring bores (Bore 23, MIOP_02) have been used to verify the TD3 weathered bedrock breakthrough curve, and are included in Figure 5-66. The results from the Ogata-Banks analysis indicate that the 1,000 mg/L Sulphate plume in the weathered bedrock may reach the northern study area boundary by 2029 (in 13 years, and 76 years from the mid-point of TSF3 operation).

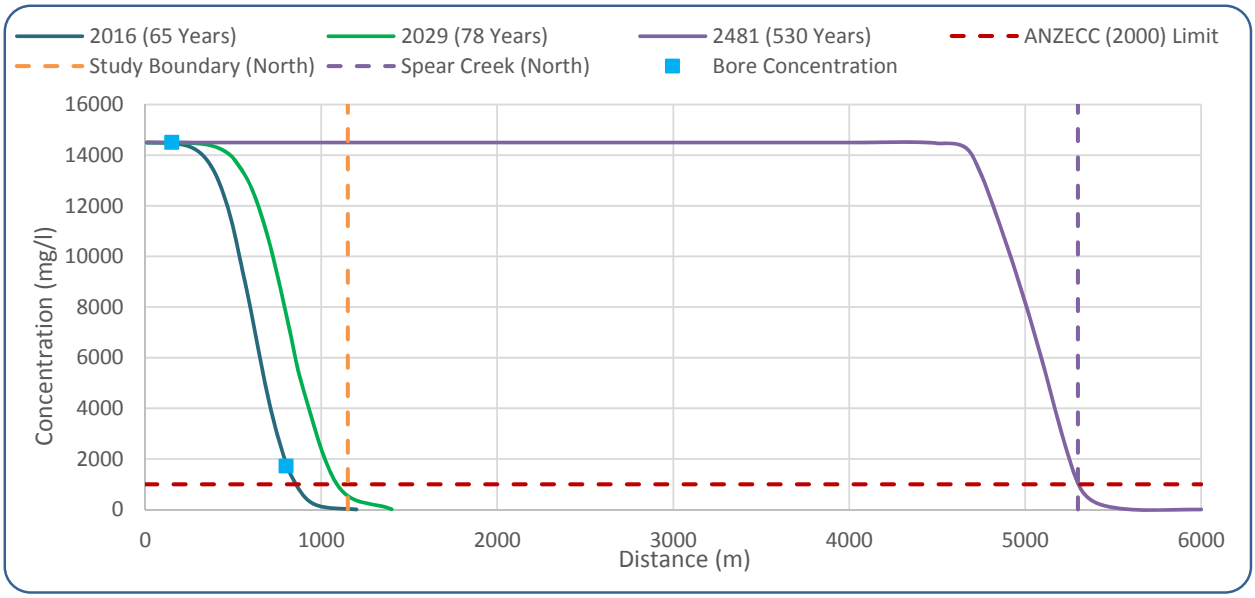

Figure 5-66: Ogata-Banks breakthrough curve for the TD3 Seepage (weathered bedrock), with sulphate bore concentrations from Bore 23 and MIOP_02

The breakthrough curve for the bedrock aquifer associated with the TD3 Seepage is presented in Figure 5-67, along with the downstream northern extent of the study boundary (1,125 m north of TD3 Seepage). Sulphate concentrations from downstream bedrock monitoring bores (Bore 24, BSOC_B5, BSOC_B6) have been used to verify the TD3 bedrock aquifer breakthrough curve, and are included in Figure 5-67. The results from the Ogata-Banks analysis indicate that the 1,000 mg/L sulphate plume in the bedrock aquifer could potentially reach the northern study area boundary by 2061 (in 45 years, and 111 years from the mid-point of TSF3 operation).

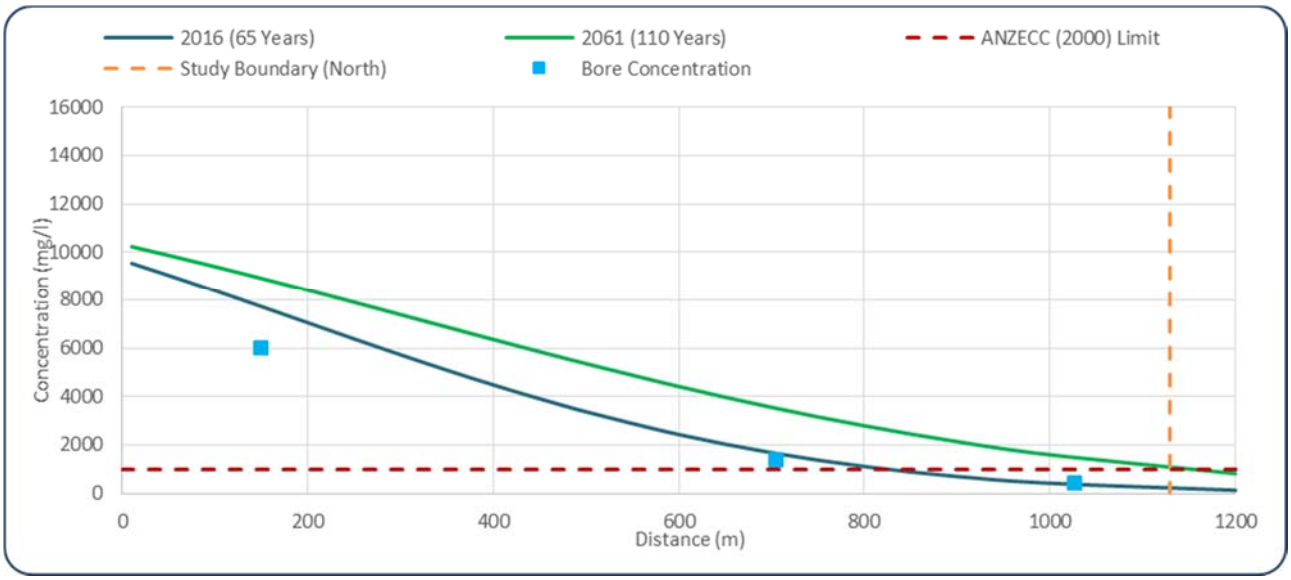

Figure 5-67: Ogata-Banks breakthrough curve for the TD3 Seepage (bedrock), with sulphate bore concentrations from Bore 24, BSOC_B5 and BSOC_B6

BSOC WRD landform seepage into the weathered bedrock and bedrock aquifer, and further downstream migration towards the north of the study area has been predicted using 1D advection-dispersion modelling and support with water quality monitoring records. For the purposes of this investigation, the prediction of future downstream migration to the northern study area extent (~1,125 m north of TD3 Seepage) has been undertaken. However, the northern extent of the study area does not represent a downstream receiving environment receptor for the weather bedrock / bedrock aquifer seepage. Based on the regional groundwater flow direction of the weathered bedrock / bedrock aquifer (towards the north), the downstream receiving environment receptor is interpreted to be Spear Creek. Spear Creek flows in a west to east direction and flows into the Leichhardt River prior to discharging into Lake Moondarra. Spear Creek is approximately 5.5 km north of the TD3 Seepage (4.3 km north of the northern extent of the study area). One dimensional advection-dispersion modelling indicates that the 1,000 mg/L sulphate plume will reach Spear Creek in 2481 (in 465 years, and 530 years from the mid-point of TSF3 operation).

5.5 Summary of BSOC WRD Seepage Source, Cause and Extent

Item 1 (a),(b) and (c) of the EE notice stated that this investigation should:

> *Identify the source, cause and extent of all seepage that are being, or likely to be released from the Black Star Open Cut Waste Rock Dump (BSOC WRD) to the receiving environment.*

Based on the information presented in this report thus far, a summary of the interpreted (and inferred) source, cause and extent is provided.

5.5.1 Seepage Source

Seepage from the BSOC WRD Landform occurs at three locations around the WRD footprint. These align with natural drainage locations, which are now covered by the WRD. At each of the 'headwaters' of these drainages, spillways from the historical tailings dams (TSF3 and TSF5) were present and are now buried by the WRD.

A review of waste rock and tailings geochemistry and kinetic testing was undertaken in conjunction with a review of BSOC WRD seepage chemistry, as well as historical tailings chemistry data to assess whether a definitive source (either tailings or waste rock) is providing the seepage now observed from BSOC WRD. The MIM landfill sludge pits were also considered as a potential source.

Based on the available chemistry data, the following is concluded:

- TD3 and BSOC WRD North Seepages have similar water qualities and both have similarities to waste rock seepage and tailings seepage characteristics.
- The MIM landfill sludge pits may also contribute, although it is difficult to determine the extent of this contribution quantitatively without further constraints on the internal geochemistry of TSF3 and the WRD. Further assessment of the groundwater flow system underlying the sludge pits would also be warranted to confirm the potential seepage contribution to the BSOC WRD landform from sludge pit infiltration.
- BSOC WRD South Seepage is broadly similar to TD3 Seepage and BSOC WRD North Seepage, but reports water quality that may have some of the characteristics similar to the TD5 pit sample.
- Based on the water qualities obtained from kinetic testing of both waste rock and tailings, as well as the measured seepage, it is interpreted that there is limited basis for clear differentiation between geochemical signatures of the waste rock and tailings in the seepage.

5.5.2 Seepage Cause

To determine the cause of seepage migration from the BSOC WRD Landform, preferential pathways were identified using the available hydrogeological information, historical geophysical surveys and field data collected as part of this investigation.

A two dimensional modelling assessment was also undertaken to assist in determining the cause of seepage migration. This was completed using representative thicknesses of the site infrastructure as well as the underlying geology. Sensitivity analysis for the most uncertain

parameters was also undertaken to assess the potential variability in the flux estimates and movement of water.

The cause of seepage has been interpreted as the following:

- Direct seepage movement within alluvial aquifers, which originate under the BSOC WRD landform and are in connection with the alluvium beyond the extents of the landform.
- Seepage into the alluvium, where the diversion drain is constructed across the alluvial aquifers.
- Bedrock seepage from the base of the TSFs as diffuse seepage within the bedrock aquifer, likely to be along the bedrock bedding plane (south-north orientation).

The volume of seepage that is generated, and will continue to be generated, is a function of the net percolation into the WRD and the anticipated piezometric surface within the WRD.

5.5.3 Seepage Extent

The extent of seepage within the alluvium and bedrock aquifers beyond the extent of the BSOC WRD landform has been interpreted (and inferred) based on the understanding of the source and cause of seepage, as well as the site observations and the available water quality data.

Figure 5-68, which presents the seepage within the alluvial aquifers, indicates that the seepage has migrated within the alluvium downstream of both the BSOC WRD North and South Seepages, however, the seepage plumes have not migrated to the study area boundary. The alluvium associated with King Gully, downstream of TD3, is considered to be saturated with BSOC WRD landform seepage due to the use of King Gully as a seepage management facility, which ultimately diverts seepage into KSOC open pit. As a result of the alluvium associated with King Gully being saturated, certain tributary watercourses, which join from the west, are also partially saturated with BSOC WRD landform seepage.

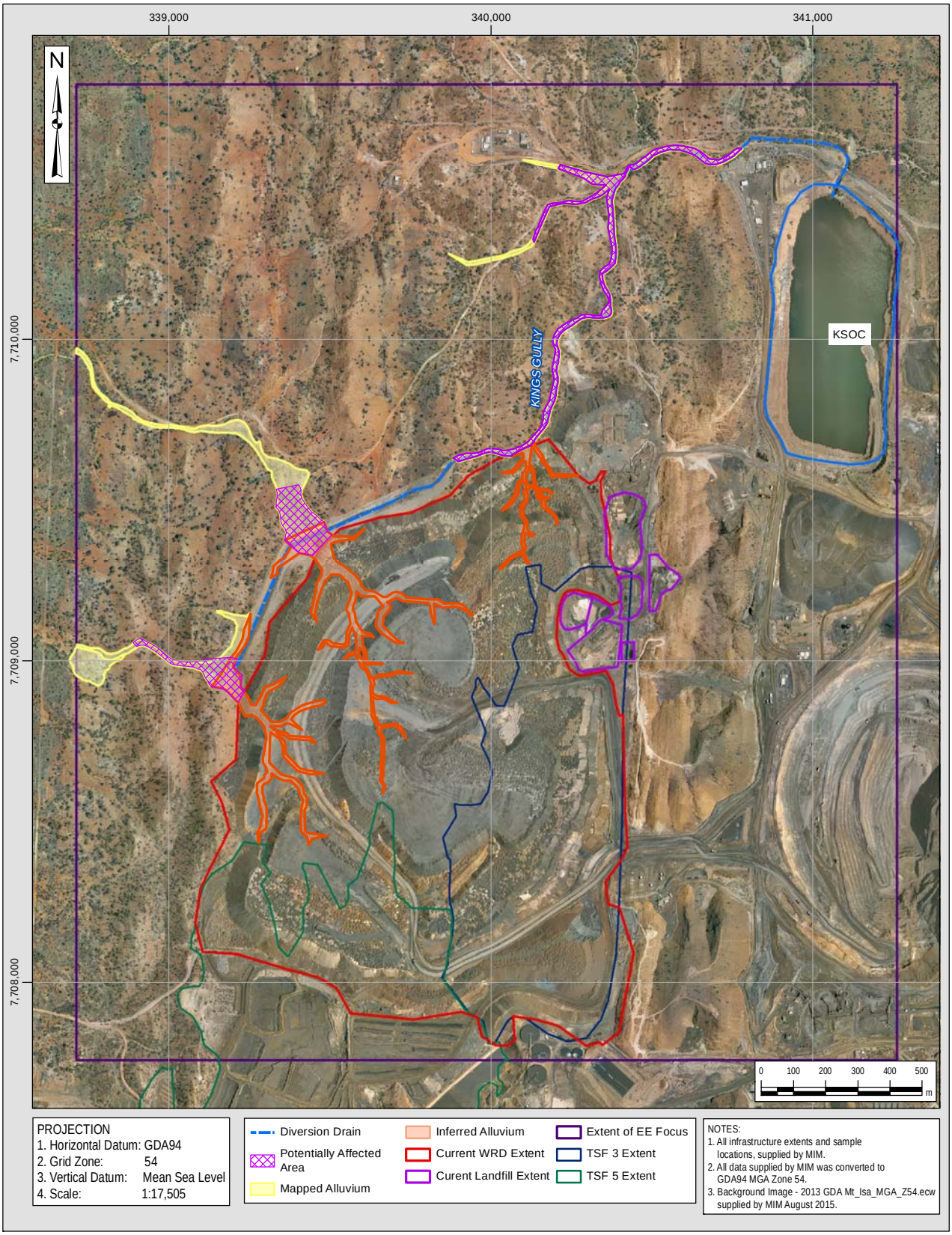

Figure 5-68: Interpreted and Inferred Extent of Seepage within the Alluvium

Figure 5-69 presents the seepage extent within the bedrock aquifers, with both interpreted and inferred extents shown (dashed line for inferred). Inferred extents have been included due to limited groundwater level and groundwater quality data available for interpretation in these areas where monitoring bores are not present. The seepage plume within the bedrock aquifer extends to the north of TD3 Seepage and the underlying TSF3, however the plume has not yet reached the study area boundary in the north.

The seepage within the bedrock aquifer in the area northwest of the WRD, downgradient of TSF5, is of a much smaller extent, with seepage contributions to groundwater observed at BSOC_B1 (adjacent to BSOC WRD South Seepage). However, the interpreted seepage plume (based on a sulphate concentration of 1,000 mg/L) has not been identified in the three new monitoring bores (BSOC_B2, BSOC_B3, BSOC_B4) and Bore 40; located to the north of the BSOC WRD landform.

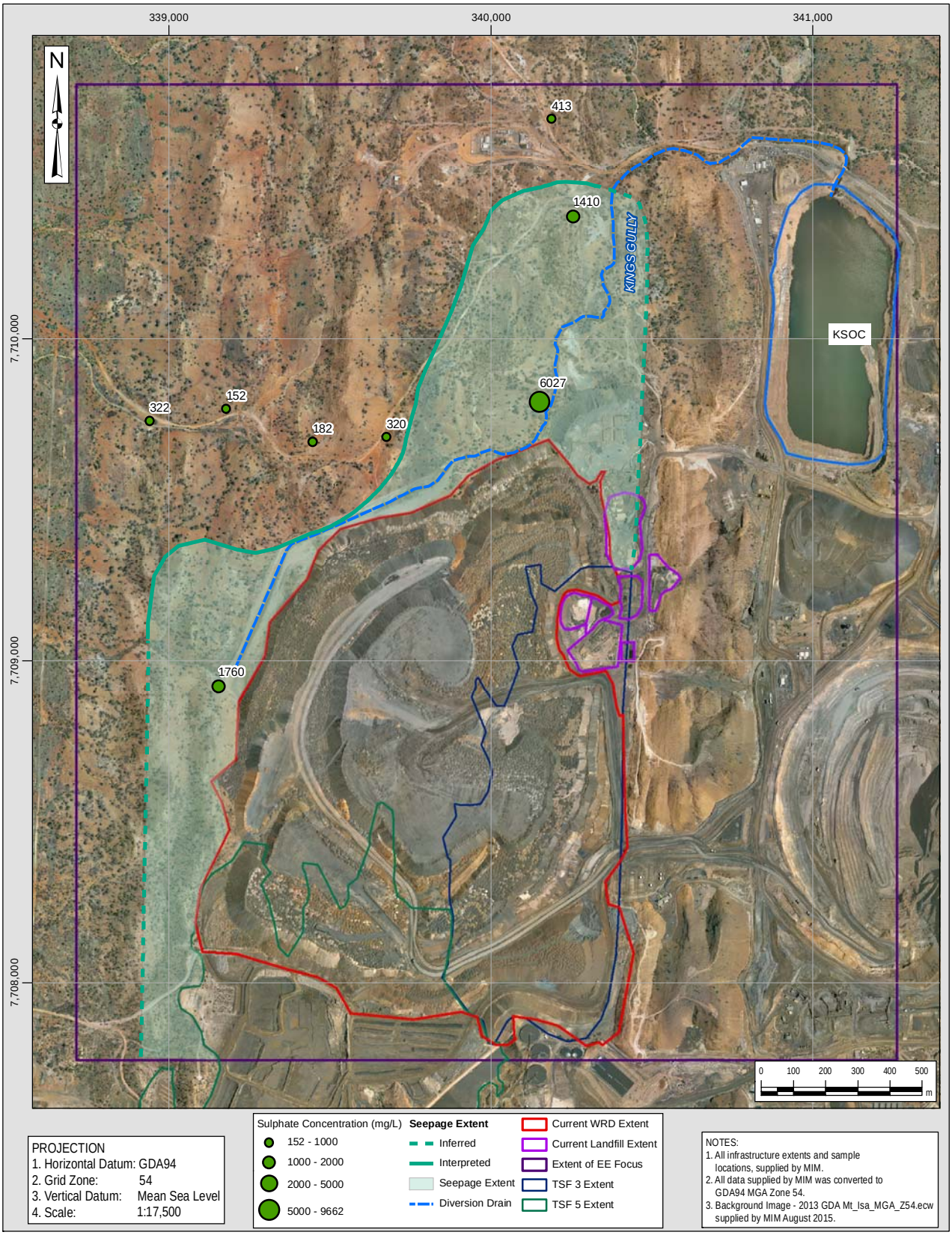

Figure 5-69: Interpreted and Inferred Extent of Seepage within the Bedrock

6 IMPACT ASSESSMENT

This section of the report addresses item 2b, of the EE Notice, which states that the investigation must:

Assess impacts on the receiving environment[10] *and all identified environmental values, the assessment must include consideration of:*

- *Water quality for surface water and groundwater's (including any shallow ephemeral aquifers);* (Sections 6.1.1 and 6.1.2)
- *Sediment quality* (Section 6.1.3)
- *Soils; and,* (Section 6.1.3)
- *Flora and fauna.* (Section 6.1.4)

The impact assessment was undertaken by Amec FW (2016) (flora and fauna, sediment quality / soils) and KCB (groundwater and surface water), based on the previously established environmental values. A summary of the identified environmental values, the identified area of impact and potential impacts are provided in the following sections.

Amec FW's Receiving Environment Assessment report is provided in Appendix IV.

6.1 Identified Environmental Values

Environmental values (EVs) have been previously established for key environmental components across ML8058. These EVs have been used to assess potential impact from the BSOC WRD landform seepage.

6.1.1 Surface Water

This section provides a discussion on the water quality criteria that have been proposed based on the understanding of the environmental values for the surface drainages from the site and the receiving environment.

Background to Environmental Values

The Leichhardt River is the main ephemeral watercourse draining the MIM lease area. During the winter months, the majority of water upstream of Lake Moondarra exists as discontinuous pools. Its channel is over 50 m wide and has developed an alluvium thickness typically of 7 m.
The Leichhardt River and tributaries are an important water source for stock, fauna and recreational use.

The portion of the Leichhardt River between the Mount Isa Mines and Lake Moondarra is a water source for stock and aquatic fauna and is also used recreationally for fishing and swimming. Lake Moondarra provides the drinking water supply for Mount Isa, as well as industrial and potable water for Mount Isa Mines. Water extracted from Lake Moondarra is treated to render it potable.

[10] The EE notice defines "receiving environment" as *all groundwater and surface water that are not in disturbed areas authorised by this environmental authority and excludes land within the surface water containment areas*.

Areas surrounding the Leichhardt River support a range of land uses, which may impact on the water quality in the Leichhardt River. These include stormwater and sewage discharges from Mount Isa municipal areas and discharges from Mount Isa Mines. Cattle grazing adjacent to Leichhardt River and recreational activities such as boating, fishing and water skiing may also impact on water quality.

An assessment of the surface water environmental values downstream of the mine sites, the reach of the Leichhardt River catchment between the Mount Isa Mines and Lake Moondarra, as well as Spring Creek downstream of the George Fisher and HHOC Mines, has been divided into three zones (Pink, Green and Blue Zones), which recognise past and present land use activities and the environmental values supported within each zone. The zones are shown on Figure 6-1.

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The water quality criteria for the operational conditions have been developed based on the environmental values for the surface water flows agreed with EHP, shown in Table 6-1 and discussed below.

Table 6-1: Summary of Environmental Values adopted for the EA

Location	Reference Zones (Figure 6-1)		
	Pink Zone	Green Zone	Blue Zone
Slightly to moderately disturbed ecosystem	✓	✓	✓
Suitability of drinking water supply at Lake Moondarra	✓	✓	-
Suitability of drinking water supply	-	-	✓
Suitability of primary contact at Green Zone and Lake Moondarra	✓	-	-
Suitability of primary contact	-	✓	✓
Suitability of secondary recreation	✓	✓	✓
Suitability of agricultural use at Green Zone and Lake Moondarra	✓	-	-
Suitability of agricultural use	-	✓	✓
Suitability of human consumption of aquatic food	✓	✓	✓
Suitability for industrial use at Lake Moondarra	✓	✓	-
Suitability for industrial use	-	-	✓
Protection of cultural and spiritual values	✓	✓	✓

For sections of the Leichhardt River in town and close to the mine discharges, as well as Hazeldene Creek and parts of Spring Creek (see Table 6-1, pink zone in Figure 6-1), the adopted environmental values were as follows:

- Slightly to moderately disturbed ecosystem
- Suitable for drinking water supply at Lake Moondarra
- Suitable for primary contact at Green Zone and Lake Moondarra
- Suitable for secondary recreation
- Suitable for agricultural use at Green Zone and Lake Moondarra
- Suitable for human consumption of aquatic food
- Suitability for industrial use at Lake Moondarra
- Protection of cultural and spiritual values.

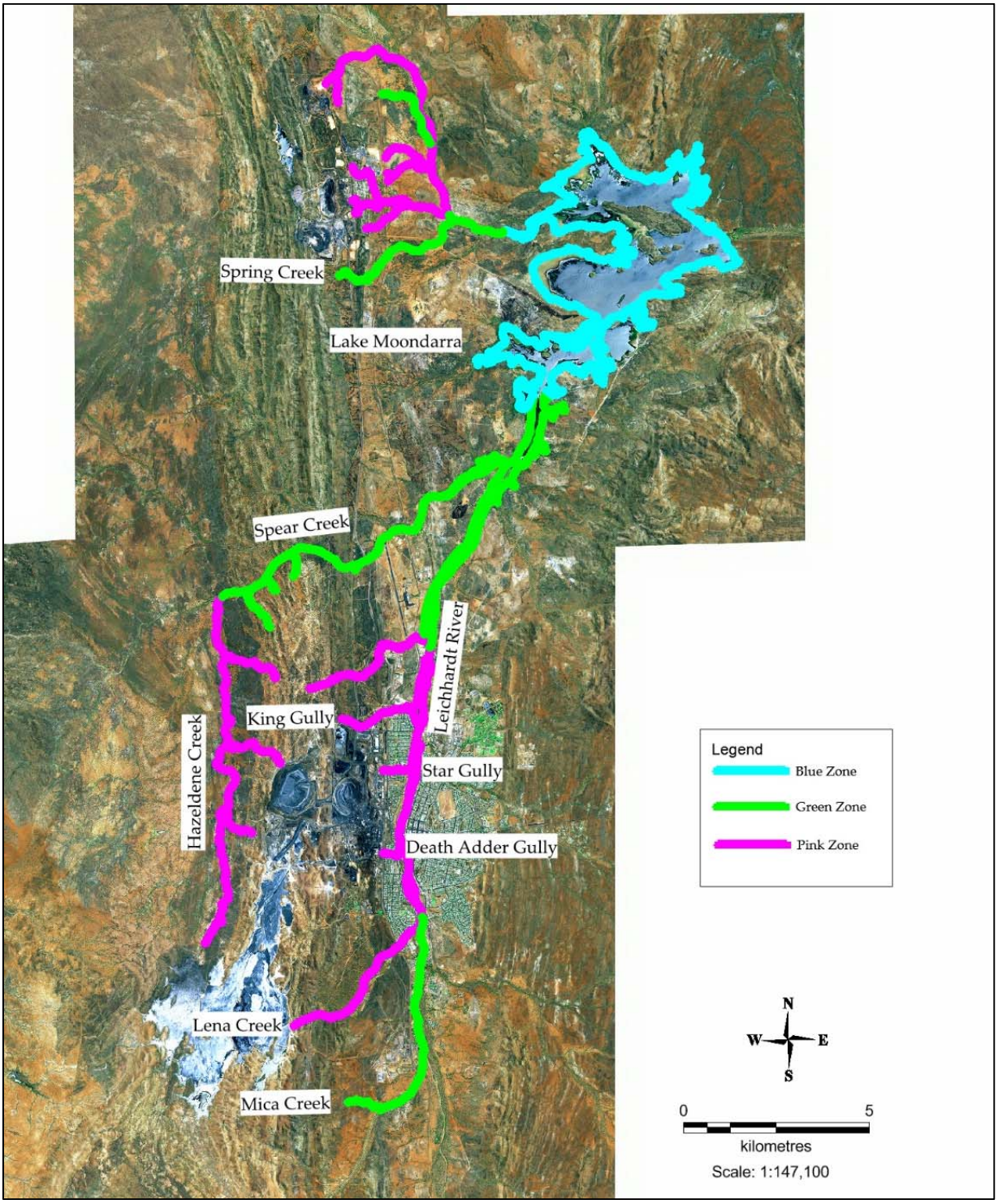

Figure 6-1: Environmental Value Zones for the Leichhardt River

For the above zones, EHP indicated that the Leichhardt River in town is not suitable for primary contact due to quality of the water and that the Mount Isa City Council (MICC) is actively discouraging the use of the water from the river. Furthermore, water from this part of the catchment is not likely to be used in the future for agricultural, industrial, or drinking water supply. However discharges into this part of the river cannot cause the river water or sediment quality to be deteriorated to the extent that these uses are impeded in other parts of the river.

The reaches of the Leichhardt River upstream and downstream of the town site, as well as Spear Creek and parts of Spring Creek, (see Table 6-1, Green Zone in Figure 6-1) the following applies:

- Slightly to moderately disturbed ecosystem
- Suitable for drinking water supply at Lake Moondarra
- Suitable for primary contact
- Suitable for secondary recreation
- Suitable for agricultural use
- Suitable for human consumption of aquatic food
- Suitable for industrial use at Lake Moondarra
- Protection of cultural and spiritual value.

These parts of the catchments are not used or likely to be used in the future for industrial or drinking water supply. However discharges into these parts of the river system cannot cause the water or sediment quality to be deteriorated to the extent where these uses are impeded in other parts of the catchment.

For Lake Moondarra (Blue Zone – see Table 6-1, Figure 6-1) the following applies:

- Slightly to moderately disturbed ecosystem
- Suitable for drinking water supply
- Suitable for primary contact
- Suitable for secondary recreation
- Suitable for agricultural use
- Suitable for human consumption of aquatic food
- Suitable for industrial use
- Protection of cultural and spiritual value.

The EA has been developed for operational conditions to be protective of these environmental values. Compared to the above environmental values, the expectation is that the receiving water quality criteria should vary according to the zones and that permissible concentrations should progressively decrease toward Lake Moondarra, consistent with the defined environmental values. However, the EA Condition H9 presents a single set of interim release limits that currently need to be met at all downstream compliance points. This investigation acknowledges the interim release limits of EA Condition H9, but also identifies that release limit concentrations for the catchments upstream should progressively contain parameter higher concentrations. A comparison between the interim release limits contained in EA Condition H9, drinking water quality criteria (NHMRC, 2011) and stock drinking water quality criteria (ANZECC, 2000) is provided in Table 6-2 for key parameters. In the absence of a groundwater trigger limit for the project site, the stock drinking water quality criteria (ANZECC, 2000) has been applied.

Table 6-2: Comparison of Various Water Quality Objectives / Criteria / Limits

Parameter	Units	EA Stock Exclusion Guidelines^	Drinking Water Guidelines~		Interim Limits for Uncontrolled Releases
			Health	Aesthetic	EA Condition H9
EC	uS/cm	5,970	-	-	1,000
SO_4	mg/L	1,000	500	250	250
Al	ug/L	5,000	-*	200	2,280
Sb	ug/L	-	3	-	3
As	ug/L	500	10	-	13
Be	ug/L	-	60	-	100
B	ug/L	-	4,000	-	370
Cd	ug/L	10	0.2	-	12.5
Cu	ug/L	1,000	2,000	-	86
Cr	ug/L	-	50	-	3
Co	ug/L	1,000	-*	-	6
Pb	ug/L	100	10	-	67
Mn	ug/L	-	500	100	1,900
Hg	ug/L	-	1	-	1
Mo	ug/L	-	50	-	24
Ni	ug/L	1,000	20	-	20
Se	ug/L	-	10	-	10
Ag	ug/L	-	100	-	100
Tl	ug/L	-	-*	-	10
U	ug/L	-	17	-	10
V	ug/L	-	-*	-	99%tile of ref site#
Zn	ug/L	20,000	-*	3000	41.6

^ANZECC 2000
~ NHMRC, 2011
* insufficient data
# Reference sites are the relevant reference sites in Schedule H Table 8 of the EA.

6.1.2 Groundwater

Groundwater EVs have been established across ML8058 (EA EPML00977513 – Amendment Application Supporting Documentation version number 1.6 (MIM, 2015a)) and apply to both alluvium and bedrock aquifers. These EVs include:

- Biological integrity – i.e. maintaining the water quality in the waterways to support existing fauna and flora;
- Industrial use; and,
- Suitability for primary industry including livestock drinking water and small-scale irrigation (gardens).

6.1.3 Sediment / Soil Quality

Specific EVs for sediment / soil quality on ML8058 have not been established, however, EVs for Land Use on ML8058 have been established and can be applied to sediment / soil quality. These EVs have been derived from the EA EPML00977513 – Amendment Application Supporting Documentation version number 1.6 (MIM, 2015a) and EA EPML00977513 – Amendment Application Supporting Documentation version number 1.2 (MIM, 2015b); and, comprise:

- Ecosystem biodiversity, health and significance;

- Integrity of land surfaces, which relates to management and prevention of contamination, stability of surfaces and final landforms, and restoration of disturbed land to appropriate land use; and,
- Cultural and spiritual values.

6.1.4 Flora and Fauna

Flora and fauna EVs on ML8058 are defined in EA EPML00977513 – Amendment Application Supporting Documentation version number 1.2 (MIM, 2015b) as the existing EVs for Land. These EVs include:

- Ecosystem biodiversity, health and significance;
- Integrity of land surfaces, which relates to management and prevention of contamination, stability of surfaces and final landforms, and restoration of disturbed land to appropriate land use; and,
- Cultural and spiritual values.

Further definition of the existing flora and fauna EVs is provided in the Receiving Environment (Flora and Fauna) Assessment report (Amec FW, 2016 – Appendix IV). A summary of the terrestrial flora and terrestrial fauna are provided in the following sections. Due to no permanent or semi-permanent pools of water being present across the study area; and, considering stream topographies and substrate characteristic results in streams drying out following rainfall events; the presence of an aquatic ecosystem within the study area is not considered.

Terrestrial Fauna

The area is predominantly disturbed and developed for mining purposes including BSOC WRD, King Gully Dam, Diversion Drain, stockpiles and access roads. The northern boundary, north-west corner, and western boundary of the Study Area are mostly undeveloped and mapped as containing remnant vegetation. REs found in the Study Area and respective extents are listed in Table 6-3 and illustrated in Figure 6-2.

Table 6-3: Regional Ecosystems in Study Area (2014 Dry Season; 2015 Wet Season)

Regional Ecosystem	Biodiversity Status
1.11.2a *Eucalyptus leucophloia* (snappy gum) low open woodland. Occurs on steep hills.	No Concern at Present
1.11.3X1b Low open woodland *Eucalyptus leucophylla* often with Corymbia terminalis. Occurs on broad low hills; gently undulating.	No Concern at Present
1.3.4 *Acacia cambagei* low open woodland to woodland on earths in valleys	Of Concern
1.3.7a Riverine wetland or fringing riverine wetland	Endangered
1.5.3 *Eucalyptus leucophloia* (snappy gum) low open woodland and woodland sometimes with shrubby understorey dominated by Acacia spp	No Concern at Present
1.5.4 *Eucalyptus leucophylla* low open woodland on red earths in valleys	No Concern at Present
1.5.4a Low open woodland of *Corymbia terminalis*, scattered shrub layer of Carissa lanceolata and tussock grass ground layer.	No Concern at Present
1.5.6 x2 Low woodland of *Acacia cambagei* with generally sparse ground layer of Triodia longiceps and/or tussock grasses. Bare patches are common	No Concern at Present

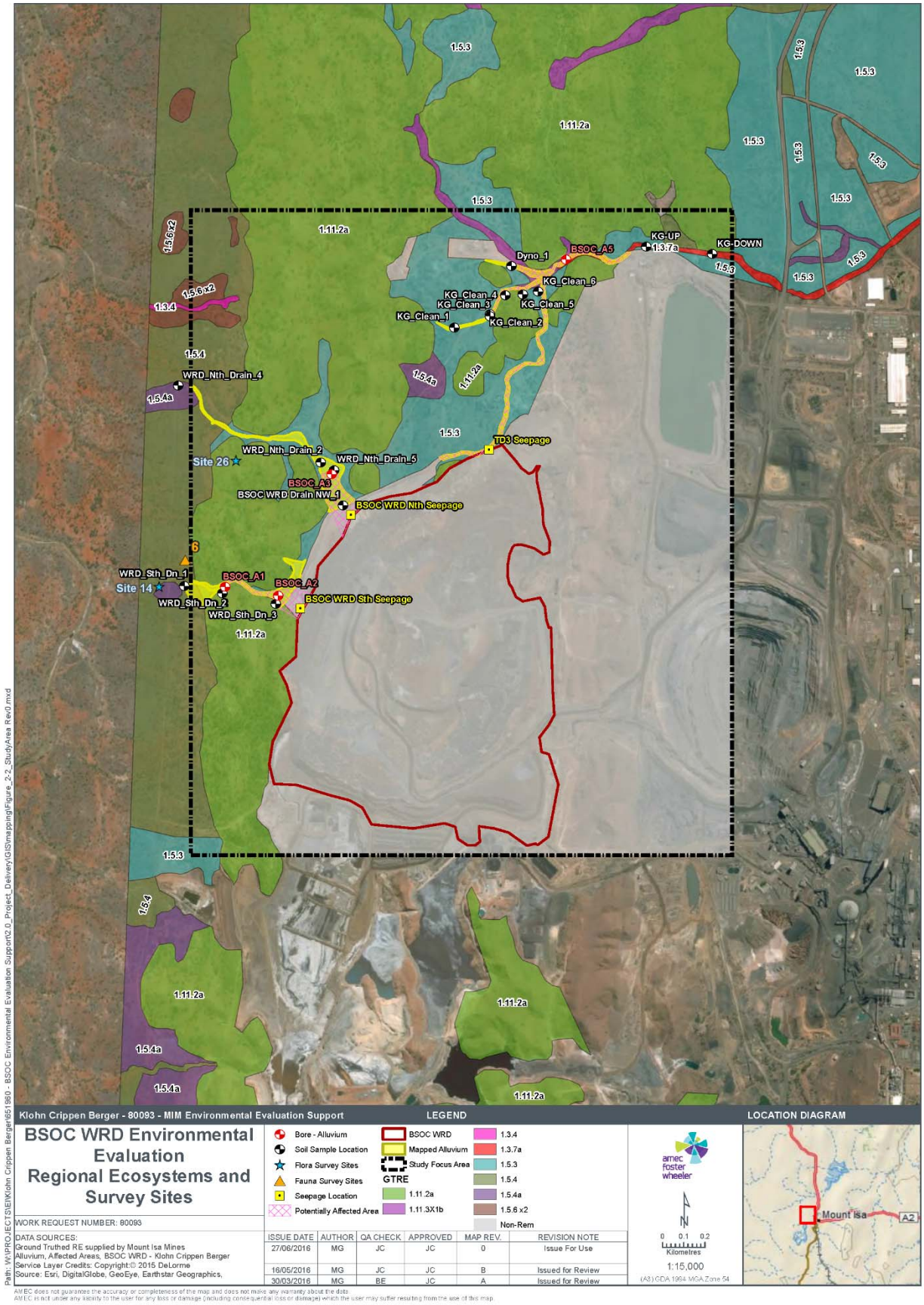

Figure 6-2: Regional Ecosystem Extents in Study Area

Terrestrial Fauna

On the western boundary of the Study Area was a fauna survey site located in RE 1.5.4 (Eucalyptus leucophylla low open woodland on red earths in valleys). Fauna surveys included Elliot (A and B) trapping, funnel trapping, pit fall trapping, cage traps, remote camera trapping, nocturnal spotlighting, active herpetile searching, scat analysis and watercourse and waterhole surveys.

The survey site (RE 1.5.4 Eucalyptus leucophylla low open woodland on red earths in valleys) was dominated by snappy gum (Eucalyptus leucophloia subsp. euroa) with whitewood (Atalaya hemiglauca). A sparse shrub layer of Chisholm's wattle (Acacia chisholmii) was also present. Ground layer was very sparse and dominated by occasional spinifex, with very occasional Ptilotus sp. also present. There were 19 avian species, 2 mammals and 2 reptiles recorded across both dry and wet season surveys. Fauna species observed included:

- Australian raven (Corvus coronoides)
- black-faced cuckoo-shrike (Coracina novaehollandiae)
- common bronzewing (Phaps chalcoptera)
- crested pigeon (Ocyphaps lophotes)
- double-barred finch (Taeniopygia bichenovii)
- grey-crowned babbler (Pomatostomus temporalis)
- little friarbird (Philemon citreogularis)
- rainbow bee-eater (Merops ornatus)
- variegated fairy-wren (Malurus lamberti)
- gecko (Gehyra robusta)
- gecko (Gehyra veriegata)
- common wallaroo (Macropus robustus)
- striped faced dunnart (Sminthopsis macroura).

Based on vegetation communities occurring in the Study Area and habitat features present, the area is likely to support limited fauna species. Areas consisting of RE1.11.2a with rocky outcrops on hills may support mammal species, including the purple-necked rock wallaby and common wallaroo. The striped-faced dunnart may utilize areas with lower slopes and alluvium with vegetation communities containing tussock grasses. Birds and reptiles are likely to utilise all areas. In the wet season, when creeks contain some water, fauna species are likely to be drawn to these areas. Microbats are unlikely to utilise the Study Area due to a lack of hollow bearing trees and flyways.

6.2 Existing and Potential Impacts

The interpreted BSOC WRD landform seepage plume extents have been correlated with the key receiving environment EVs (Section 6.1) to identify potential impacts on the EVs. A summary of the existing and potential impacts for the key EVs are provided in the following sections.

6.2.1 Surface Water

6.2.1.1 Existing Impacts to Surface Water

The occurrence of the BSOC WRD landform seepages as surface water occurs at each of the three seepage locations where the seepage discharges into the Diversion Drain, or seepage collection trench for BSOC WRD South Seepage. The occurrence of the seepage as surface water is managed by the Diversion Drain, which discharges the seepage water into KSOC pit, mitigating flow into the downstream water course (i.e. Leichhardt River, Hazeldene Creek). Therefore, existing impacts to the receiving environment surface water EVs from the BSOC WRD landform seepage is not been identified.

6.2.1.2 Potential Impacts to Surface Water

Daylighting of groundwater as surface water has been interpreted to occur during the wet season as a result of saturation of the alluvial aquifer and hydraulic connection with the surface water course. Discussion regarding the alluvium aquifer groundwater contribution to surface water is provided in Section 6.2.2, and includes discussion regarding potential impacts to the Surface Water EVs.

6.2.2 Groundwater

6.2.2.1 Seepage Migration Map

Alluvial Aquifer

The interpreted extent of BSOC WRD Landform seepage migration in the alluvial aquifer is provided in Figure 5-68 and is based on groundwater quality monitoring results (Section 5.4.3) and the analytical assessment of groundwater movement within the alluvial aquifer (Section 5.4.8). Based on Figure 5-68, the BSOC WRD landform seepage plume in the alluvium aquifer is ~300 m downstream of BSOC WRD South Seepage and ~200 m downstream of BSOC WRD North Seepage. Seepage migration in the alluvium downstream of TD3 Seepage has been identified in the groundwater quality of BSOC_A5 (~1.2 km downstream of TD3 Seepage), with observational evidence of seepage (e.g. mineral precipitation on surface, surface water pooling in alluvium during dry season) indicating seepage migration beyond BSOC_A5. Seepage migration in the alluvial aquifer of King Gully will ultimately be diverted by the King Gully first flush facility (weir), which diverts seepage in the alluvium into KSOC pit.

Sulphate has been selected as the parameter to represent the extent of the BSOC WRD landform seepage plume, with a trigger level of 1,000 mg/L (ANZECC livestock watering guidelines (ANZECC, 2000)) used to represent the extent seepage. Sulphate was selected due to the conservative nature of the parameter (limited influence of sorption/attenuation mechanisms in the aquifer), therefore, the interpreted extent of the seepage plume is considered conservative.

Bedrock Aquifer

The interpreted extent of BSOC WRD landform seepage in the bedrock aquifer is provided in Figure 5-69 and is based on groundwater quality monitoring results (Section 5.4.3) and the analytical assessment of groundwater movement within the bedrock aquifer (Section 5.4.8). Bedrock seepage is interpreted to be most prominent to the north of TD3 Seepage (~800 m) and

seepage migration to the west of BSOC WRD South Seepage (~300 m). As per the alluvial aquifer seepage assessment, sulphate was selected as the parameter to represent the seepage plume extent, therefore, the same level of conservatism is applied to the interpreted bedrock aquifer extent.

An analysis of migration rates in the bedrock aquifer was conducted to estimate the timeframe required for the development of the current seepage plume and to predict the timeframe required for the seepage plume to reach the northern extent of the study area (north of TD3 Seepage). The estimated timing for the seepage plume extent to reach the northern study boundary is from 2029 (weathered bedrock) to 2061 (bedrock).

6.2.2.2 Existing Impacts to Groundwater EVs

The interpreted seepage plume extents, based on the 1,000 mg/L SO_4 trigger limit, for the alluvium and bedrock aquifers are provided in Figure 5-68 and Figure 5-69, respectively.

The extent of seepage in the alluvium aquifer is interpreted to be 200 m and 300 m downstream of the BSOC WRD North and South Seepages. The nearest downstream receptor with EVs is Hazeldene Creek (surface water EVs (Pink Zone), based on the conservative assumption that the alluvium aquifer contributes to the Hazeldene Creek surface water system), which is located ~2 km and ~1.1 km downstream of the BSOC WRD North and South Seepages, respectively.

These seepage plume extents were interpreted based on groundwater sampling of the monitoring bore network downstream of the BSOC WRD landform (Figure 5-14) following the Phase 2 field investigation program, and subsequent one dimensional analytical modelling (Section 5.4.8). Conservative assumptions were adopted for the one dimensional analytical modelling, including:

- Constant source term concentrations (based on the SO_4 concentration from each of the seepage locations) for the duration of the BSOC WRD landform development (including development of the underlying TSFs); and
- Constant flow velocities within the underlying aquifer (based on interpreted current flow velocities) for the duration of the BSOC WRD landform development (including development of the underlying TSFs).

Therefore, the interpreted seepage plume extents for the alluvium and bedrock aquifers are considered conservative. Additionally, as the one dimensional analytical assessment and associated interpretations are based on monitoring / sampling completed as part of this investigation the interpreted seepage plume extents are considered to represent the current seepage plume extents.

Groundwater usage for industrial use, livestock watering and/or small scale irrigation is not observed within the vicinity of the interpreted seepage plume extents or within the study area. Additionally, discharge of groundwater to waterways supporting existing fauna and flora communities was not identified within the vicinity of the study area during the field investigation program. Therefore, existing impacts to the groundwater EVs as a result of BSOC WRD landform seepage has not been identified.

6.2.2.3 Potential Impacts to Groundwater EVs

Section 6.2.2.2 identified that there is no existing impact on groundwater EVs as a result of the interpreted current seepage plume extents in the alluvium and bedrock aquifers (Figure 5-68 and Figure 5-69). Further downstream migration of the sulphate plume may occur over time; and, based on the one dimensional analytical assessment (Section 5.4.8) the predicted migration time for the seepages to reach the downstream receptors are:

- BSOC WRD North Seepage alluvium aquifer seepage plume migration to Hazeldene Creek (2 km downstream of BSOC WRD North Seepage) – 154 years;
- BSOC WRD South Seepage alluvium aquifer seepage plume migration to Hazeldene Creek (1.1 km downstream of BSOC WRD South Seepage) – 106 years; and
- TD3 Seepage bedrock aquifer seepage plume migration to Spear Creek (5.3 km downstream of TD3 Seepage) – 465 years.

Although the one dimensional analytical assessment has predicted migration times for the seepage plumes to reach the downstream receptors, ranging from 106 years to 465 years, periodic monitoring / sampling of the groundwater monitoring bore network downstream of the BSOC WRD landform should be undertaken. Periodic monitoring will provide an understanding of the transient characteristics of the seepage plume. This proposed monitoring program is provided as part of the seepage adaptive management strategy detailed in Section 9.3.

Groundwater levels in the alluvium aquifer are generally below the ground surface (Table 5-1). For the alluvium aquifer downstream of the BSOC WRD North and South Seepages these groundwater levels range from 0.81 mbGL to 2.37 mbGL (note: BSOC_A4 was dry during monitoring). These measured groundwater levels are representatives of levels measured following the Phase 2 field investigation program. However, during periods of high rainfall it is anticipated that the alluvium aquifer groundwater level will rise as a result of direct rainfall infiltration and may potentially rise above the ground surface and contribute to surface water flow. It is interpreted that rainfall infiltration into the alluvium aquifer and the mixing of the alluvium groundwater with the surface water runoff, following the rise of the groundwater level above the ground surface, would result in the dilution of the seepage water quality concentrations. The potential impact to the surface water EVs as a result of alluvium aquifer groundwater contributing to the surface water runoff is considered low due to the dilution of the groundwater quality concentrations by rainfall infiltration and runoff. Additionally, the occurrence of alluvium groundwater mixing with the surface water runoff is considered sporadic and would only occur following high intensity and/or prolonged rainfall events, which are typically isolated to the wet season. Further assessment of the surface water quality from the water courses downstream of the BSOC WRD North and South Seepages is required to assess the potential impacts to the surface water EVs. This assessment has been included as part of the seepage adaptive management strategy detailed in Section 9.3.

6.2.3 Sediment / Soil Quality

6.2.3.1 Existing Impacts to Sediment / Soil EVs

Sediment / soil sampling completed as part of the Phase 1 field investigation program targeted the watercourses due to poor soil development across the study area and the majority of sediment accumulation occurring adjacent to the watercourses (alluvium). Additionally, the

sampling program targeted zones of observable seepage impact (e.g. mineral precipitation on the surface) and downstream locations for assumed background concentrations. Based on the sediment quality results, the presence of BSOC WRD landform seepage influence on the sediment extent (alluvium) is comparable to the seepage plume extent interpreted for the alluvial aquifer (Figure 5-68).

Specific EVs for sediment / soil quality have not been developed for ML8058, however, in this absence the established EVs for Land Use has been adopted. As described above the seepage plume extents identified for the alluvial aquifer is comparable to the influence of the seepage on the sediment / soil quality. Therefore, for the existing impact assessment an area limited to the identified seepage plume (~300 m downstream of BSOC WRD South Seepage and ~200 m downstream of BSOC WRD North Seepage) was applied. No observable or interpreted existing impacts to the ecosystem biodiversity, health and significance (e.g. vegetation die-back) or the integrity of the land surface for associated land use have been identified.

6.2.3.2 Potential Impacts to Sediment / Soil EVs

The existing impact assessment identified in Section 6.2.3.1 indicate that sediment / soil concentrations correlate with the seepage plume extents identified for the alluvial aquifer. Interpretation of the seepage plume extents in the alluvial aquifer are based on monitoring results collected during this investigation, which represents current conditions. One dimensional analytical assessment has predicted that the seepage plume may migrate downstream in the alluvial aquifer over time, indicating that the extent of the sediment / soil quality being influenced by the seepage may increase. However, the potential impact to the Land Use EVs as a result of the sediment / soil quality being influenced by the seepage is considered low. Further monitoring of the seepage plume and downstream EVs should be undertaken to assess potential impacts on the EVs. Details of the proposed monitoring program is provided as part of the seepage adaptive management strategy in Section 9.3.

6.2.4 Flora and Fauna

The assessment of impacts to flora and fauna from the BSOC WRD landform seepage has been based on the potential of uptake of the impacted surface water and groundwater by flora and fauna. Therefore, flora and fauna communities identified by Amec FW (2016) (Appendix IV) have been correlated with the seepage extents identified for the surface water system and the alluvial aquifer (groundwater) to undertake the impact assessment. Groundwater of the bedrock aquifer is considered to be too deep (i.e. 5 m to 12 m – groundwater intersected between 9 m and 42 m (groundwater levels are higher than intersected levels due to confined aquifer conditions)) (see Section 5.2.2.1) for vegetation to source, therefore, the interpreted seepage plume extent in the bedrock aquifer has not been included in the flora and fauna impact assessment.

Flora and fauna EVs have been previously defined in Section 6.1.4. These EVs form the basis of the impact assessment for both existing and potential impacts, a summary of which are provided in the following sections.

6.2.4.1 Existing Impacts to Flora EVs

Groundwater levels in the alluvial aquifer were observed to be 0.81 m to 2.37 m (note: BSOC_A4 was dry during monitoring) below the ground surface. It is anticipated that vegetation within the

alluvial extent downstream of the BSOC North and South Seepages may source water from the alluvial aquifer. However, the extent of where impact may occur is limited to the alluvium aquifer seepage extents downstream of BSOC WRD North and South Seepage (~200 m and ~300 m, respectively). Copper concentrations associated with alluvium aquifer seepage have been identified as contaminant of concern for the terrestrial flora, however, the variability of the root uptake process between contaminants of concern, soil characteristics and plant types makes it difficult to be confident that high levels of contaminant of concern will result in impact to vegetation.

Seepage occurs in an area with the following vegetation communities:

- RE11.3X1b Low open woodland *Eucalyptus leucophylla* often with *Corymbia terminalis*. (No Concern at Present Biodiversity Status); and
- RE1.5.3 *Eucalyptus leucophloia* (snappy gum) low open woodland and woodland sometimes with shrubby understorey dominated by Acacia spp. (No Concern at Present Biodiversity Status).

As both of these communities naturally have sparse canopy trees and cover, it is anticipated that the remnant status of vegetation within the identified alluvium aquifer seepage plume extent has not been impacted by the BSOC WRD landform seepage.

6.2.4.2 Potential Impacts to Flora EVs

One dimensional analytical assessment of the BSOC WRD landform seepage plume downstream of BSOC WRD North and South Seepages indicate that seepage plume may migrate downstream in the alluvium aquifer over time (Section 5.4.8). In addition to the potential increase in the extent of the seepage plume an increase in seepage water quality concentrations may also be observed over time across the seepage extents. Therefore, potential impact to terrestrial flora from the BSOC WRD landform seepage may occur, limited to the extent of the seepage within the alluvial aquifer.

Monitoring of vegetation condition was considered to assess impacts in the future, however compared with monitoring water quality this was considered to be a lagging indicator (as some vegetation may take several seasons to show signs of stress from contaminants) and therefore any mitigation measures proposed as a result of water quality monitoring program would be appropriate. Details of the proposed monitoring is provided as part of the seepage adaptive management strategy in Section 9.3.

6.2.4.3 Existing and Potential Impacts to Fauna

Consumption of seepage-influenced water by fauna is considered the pathway for the BSOC WRD seepage to impact fauna. Groundwater in the bedrock aquifer is not identified to discharge to the surface, and therefore, is not considered to impact fauna. In the alluvial aquifer groundwater levels may rise to the surface during periods of high rainfall events (wet season), which may be consumed by fauna. It is anticipated that the rainfall events will dilute water quality concentrations in the alluvial aquifer groundwater, however, during these periods of high rainfall events it is also anticipated that pooled rain water will be accessible to fauna for consumption. Therefore, the existing and potential impact to fauna from BSOC WRD seepage in the groundwater is not anticipated.

BSOC WRD seepages into the diversion drain occur throughout the year. Access to the diversion drain and seepage locations by livestock is restricted by the property fence located along the western boundary of the study area. Therefore, existing and potential impacts to livestock from the BSOC WRD landform seepage is not anticipated.

7 BSOC WRD SEEPAGE PREVENTION / REDUCTION

This section of the report addresses item 3, of the EE Notice:

Determine all potential options for the prevention or reduction of any further release of seepage from the BSOC WRD to the receiving environment; for all options providing:

- *A detailed description of each option; and,*
- *Cost for implementation of each option; and,*
- *A timeframe for implementation of each option.*

The interpreted seepage extent in the alluvial and bedrock aquifers is used as the basis to identify, select and develop conceptual designs for mitigation options to prevent / reduce further release of seepage. These mitigation options are summarised in the following sections.

As discussed in Section 6.2 the impact assessment shows that the potential options provided in the following sections are not currently justified. Notwithstanding, potential options are presented here for the purposes of meeting the EE Notice requirements. The adaptive management approach presented in Section 9.3 will determine whether any of these potential options are justified in future. These options could be considered at that time.

7.1 Description of Potential Seepage Mitigation Options

7.1.1 Alluvial Aquifer

BSOC WRD landform seepage in the alluvial aquifer has been identified approximately 200 m and 300 m downstream of the BSOC WRD North and South Seepages, respectively. The nearest downstream receptor with EVs is interpreted to be Hazeldene Creek, which is located approximately 2 km and 1.1 km downstream of the BSOC WRD North and South Seepages; and, the Leichhardt River (downstream of King Gully) to the east. Due to the relatively shallow thicknesses of the alluvial aquifer (~9 m at the BSOC WRD South Seepage and ~3 m at the BSOC WRD North Seepage) and consistent hydraulic parameters across the extent of the aquifer, it is proposed that the most effective approach to mitigate the seepage could be to intercept the groundwater flow. Based on this proposed approach, three seepage mitigation options have been identified:

- Seepage interception borefield;
- Seepage interception trench; and,
- Alluvial aquifer cut-off wall.

An options assessment matrix for the proposed mitigation options, based on the effectiveness, industry leading practice, long-term cost implications (Operating Expenditure (OPEX)) and applicability for the closure strategy is provided in Table 7-1.

Table 7-1: Potential Alluvial Aquifer Seepage Mitigation Options Assessment Matrix

	Effectiveness	Industry Leading Practice	OPEX
Interception Borefield	*Minor seepage migration beyond system possible*	X	X
Interception Trench	X	X	X
Cut-off Wall	X	X	*X*

* "X" denotes that category is applicable to the seepage mitigation option

7.1.2 Bedrock Aquifer

BSOC WRD seepage in the bedrock aquifer has been identified to the north of TD3 Seepage and to the west of BSOC WRD South Seepage, however, existing and potential impacts to key receiving environment EVs within the study area have not been identified. The nearest downstream receptor that could potentially be impacted by the seepage in the bedrock aquifer with EVs is interpreted to be Spear Creek, which is located approximately 4.3 km north of the study area boundary.

Seepage from the BSOC WRD landform into the weathered bedrock / bedrock aquifer, from the TD3 Seepage catchment area (i.e. upstream area of the BSOC WRD contributing to TD3 Seepage) is ~4% (0.05 to 0.16 L/s) of the total flux leaving the BSOC WRD from the TD3 Seepage catchment. Based on the Phase 2 field investigation program, and analysis of the field program results, this seepage is interpreted to be diffuse within bedrock aquifer, flowing preferential to the orientation of the bedrock bedding plane (south to north). The interpreted low seepage rates and the prolonged duration of seepage migration (i.e. approximately 465 years to reach Spear Creek) (Section 5.4.8) is a reflection of the low permeability and limited storage of the bedrock aquifer. The extent of the seepage front is interpreted to be 450 m wide, with a thickness of ~55 m (groundwater was not encountered below 60 m and standing water level at the seepage front is approximately 5 mbGL).

Mitigation of the identified seepage in the bedrock aquifer is limited by the diffuse nature of the seepage characteristics and the interpreted depth of the seepage. The proposed approach for addressing the seepage during mine operational conditions comprises the interception of the groundwater flow in the bedrock aquifer along the seepage front using groundwater bores.

An option assessment matrix for the proposed mitigation option, based on the effectiveness, industry leading practice, long-term cost implications (OPEX) and applicability for the closure strategy is provided in Table 7-2.

Table 7-2: Potential Bedrock Aquifer Seepage Mitigation Option Assessment Matrix

	Effectiveness	Industry Leading Practice	OPEX
Interception Borefield	*Seepage migration beyond system possible*	X	X

* "X" denotes that category is applicable to the seepage mitigation option

7.2 Conceptual Design for Each Option

As discussed in Section 6.2, the impact assessment shows that these potential options are not currently justified. Notwithstanding, conceptual designs for each option are presented here for the purposes of meeting the EE Notice requirements.

7.2.1 Alluvial Aquifer

The conceptual designs for the alluvial aquifer seepage mitigation options (Section 7.1.1) are provided in the following sections.

Groundwater Interception Borefield

The groundwater interception borefield for the alluvial aquifer would comprise a series of production bores installed along an alignment perpendicular to the groundwater flow direction in the alluvial aquifer downstream of both BSOC WRD South and North Seepages. Drilling for the production bores would be completed to below the alluvium profile and into the bedrock. The anticipated maximum depth of the alluvium is ~9 m at the BSOC WRD South Seepage (based on BSOC_A2) and ~3 m at the BSOC WRD North Seepage (based on BSOC_A3). Bore construction would be completed within each drill hole with the construction comprising a screened interval (to allow groundwater inflow) across the entire alluvium profile. The conceptual locations of the proposed interception borefields are provided in Figure 7-1.

Preliminary drilling and hydraulic testing at each of the proposed interception borefields would be required to be conducted prior to installation of the system to confirm the number of production bores, associated bore spacings and pump type / sizing to operate the interception system. Intercepted groundwater would be discharged into the Diversion Drain for surface water management, as per current BSOC WRD seepages.

Although the interception borefield would collect a large proportion of BSOC WRD seepage in the alluvial aquifer, it is anticipated that some seepage may migrate beyond the interception system, as the system would not be able to capture 100% of seepage. Additionally, ongoing operation and maintenance of the interception system would be required.

Groundwater Interception Trench

The groundwater interception trench for the alluvial aquifer would operate in a similar manner to the interception borefield with the exception that a trench to the base of the alluvial profile, and into the upper bedrock, would replace the production bores (Figure 7-1). Each interception trench would be required to be excavated to a minimum depth of 0.5 m into the bedrock. The interception trenches could be a minimum of 1 m wide, however, in order to maintain stability of the trench walls (assuming support structures are not used) a “cut-back” slope of a minimum 2:1 (horizontal:vertical) would be required and maintained for the duration of trench operation. This “cut-back” equates to a trench width of approximately 36 m and 12 m for the interception trenches at BSOC WRD South and North Seepages, respectively.

Once excavated, groundwater flow in the alluvial aquifer would discharge into the excavation trench. A transfer pump, with pump intake installed in the excavation trench, would be required to transfer the seepage water from the trench to the diversion channel.

Preliminary testing of the alluvial material would be required to obtain hydraulic parameters for the assessment of inflow rates into the trench (for transfer pump sizing); and, to support the detailed design of the trench (e.g. trench wall stability, on-going maintenance). Ongoing operation and maintenance of the interception system would be required.

Cut-off Wall

The alluvial aquifer cut-off walls would be conceptually located along the same alignment as the interception borefields and trenches[11] (Figure 7-1). The cut-off walls would comprise a 1 to 1.5 m wide low permeability cement/bentonite slurry that would be installed across the alluvial profile and "keyed" into the bedrock.

The locations of the cut-off walls are indicative and would be subject to site investigations to confirm the extent of the alluvials and the depth to bedrock. A cut-off wall installed across the alluvials would significantly reduce groundwater flow potential within the alluvial aquifer. As groundwater flow in the alluvials downstream of BSOC WRD South and North Seepages is generally east to west, groundwater heads would mound east (upstream) of the cut-off wall and groundwater would express as surface water in the drain. Ideally, cut-off walls would be located either upstream of the current drain alignment or immediately upstream of the drain invert. In the upstream option, intercepted groundwater would be collected and discharged to the drain under gravity. With the cut-off wall immediately north of the current drain invert for BSOC WRD North Seepage, and immediately west of the current drain invert for BSOC WRD South Seepage; intercepted groundwater would discharge directly into the drain.

Based on interpretations to date, significant lengths of the current drain intersect alluvials, for example, at BSOC WRD North Seepage (Figure 5-10). Cut-off wall hydraulic efficiency is, in part, a function of the total wall surface area, i.e., for the same aquifer head conditions, less cutoff wall surface area is better than more surface area. In situations such as BSOC WRD South Seepage, it is assumed that the cut-off wall cannot be located upstream of the drain, and an indicative location is shown downstream of the drain which limits the cut-off surface area required. Cut-off wall locations located downstream of the drain (e.g. Figure 7-1) would require capture of seepage upstream of the wall and pumping back to the drain. Intercepted water could be collected in a shallow well or caisson structure.

Preliminary testing of the alluvium material would be required to be undertaken to allow assessment of:

- Configuration and nature of the contact between the alluvium and bedrock;
- Methodology for trench excavation and slurry installation; and,
- Required cement/bentonite slurry characteristics.

Based on previous experience with cut-off wall installations using low permeability cement / bentonite slurries, it is anticipated that the cut-off wall excavation and slurry installation would be conducted concurrently, minimising the requirement to support the trench walls for prolonged periods while the cut-off wall is installed and cured. The cut-off wall would be required to be installed across the entire alluvium profile and to above the ground surface to mitigate the risk of rising groundwater levels flowing over the cut-off wall. An assessment and subsequent reconfiguration of the surface drainage at each cut-off wall location would be required to manage the rising alluvial groundwater level (upstream of the cut-off wall) to discharge into the Diversion Drain. Following installation, there would be minimal on-going operational costs for the cut-off wall (e.g. downstream monitoring for QA/QC).

[11] Proposed conceptual cut-off wall location is indicative. Field investigations/testing will be required to confirm the cut-off wall locations.

Downstream Monitoring Network

For each of the above mitigation options, a downstream alluvial aquifer monitoring network should be installed to assess the effectiveness of the mitigation measure. This network would comprise of the existing downstream alluvial monitoring bores, BSOC_A1, BSOC_A2, BSOC_A3, BSOC_A4. Monitoring of the proposed monitoring network is to be conducted to assess the effectiveness of the mitigation measure.

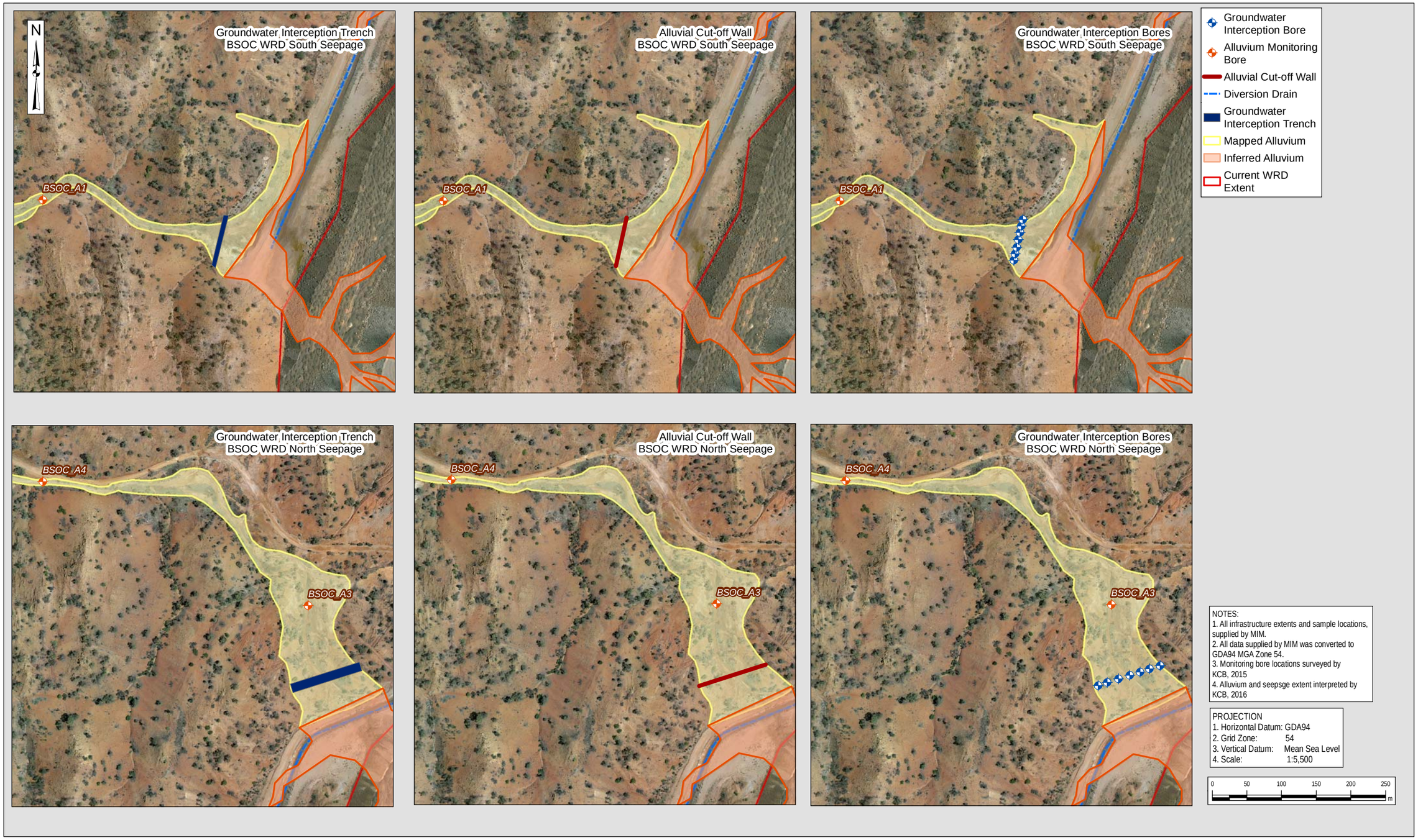

Figure 7-1: Conceptual Design for Alluvial Aquifer Seepage Prevention / Reduction

7.2.2 Bedrock Aquifer

The conceptual designs for the bedrock aquifer seepage mitigation option during mine operations (Section 7.1.2) is provided in the following section.

Groundwater Interception Borefield

The bedrock aquifer groundwater interception borefield would comprise a series of production bores installed to a minimum depth of 60 m (interpreted maximum depth of seepage) aligned perpendicular to the groundwater flow direction across the width of the interpreted seepage migration front (~450 m in length) (Figure 7-2). Production bore construction would comprise a screened interval from the bottom of the production bore to the height of the first water strike encountered during drilling. This would allow the interception of the inflow zones from the first water strike to the base of the interpreted seepage extent. Groundwater abstracted from the interception borefield would be discharged into the Diversion Drain to be managed as per the current BSOC WRD seepages.

Preliminary drilling and hydraulic testing across the bedrock seepage front would be required to confirm the characteristics of the seepage front and aquifer hydraulic parameters to support the design of the interception borefield (e.g. borefield extent, number of production bores) and associated pumping infrastructure. Ongoing operation and maintenance of the borefield would be required to mitigate seepage in the bedrock aquifer.

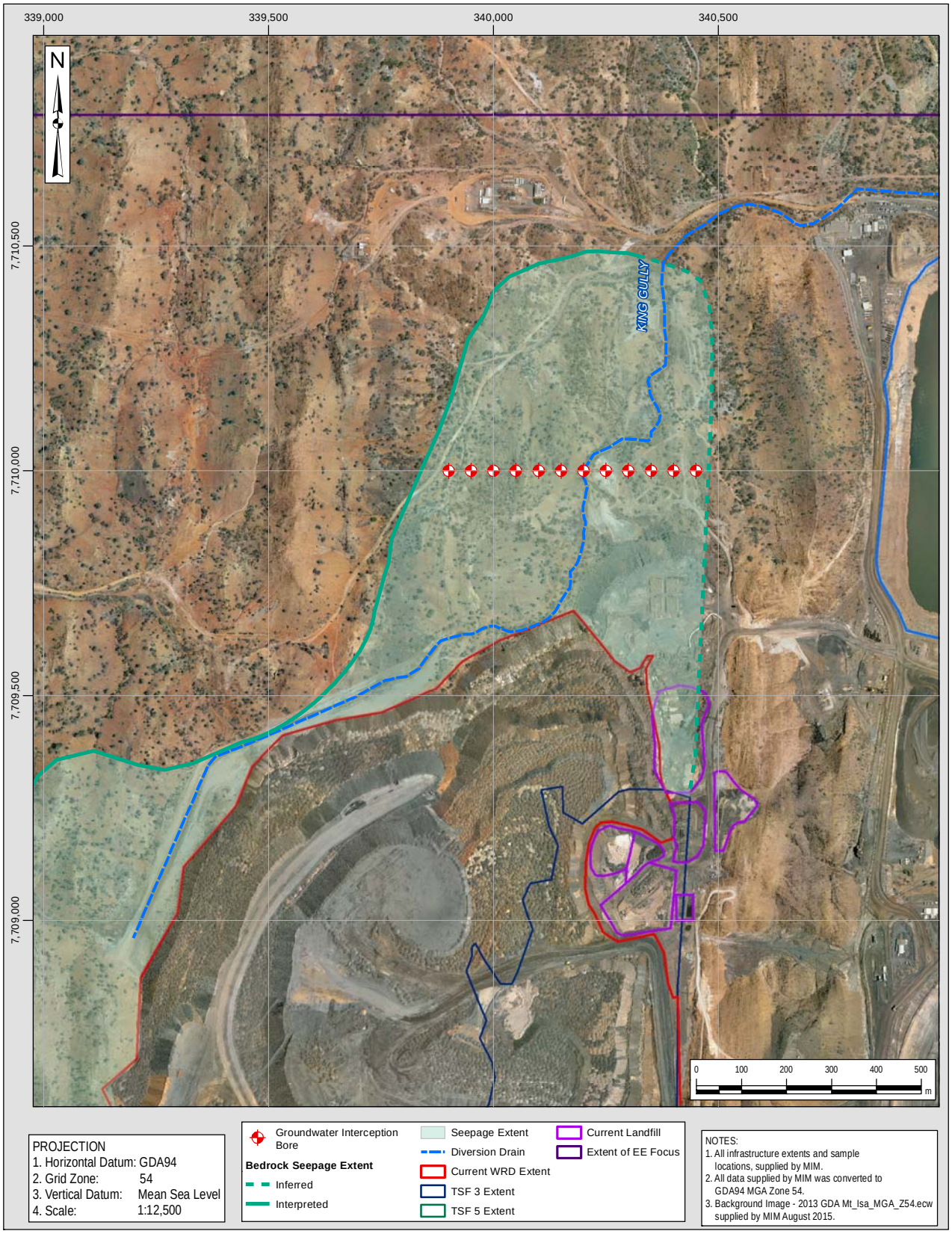

Figure 7-2: Conceptual Design for Bedrock Seepage Reduction / Prevention

7.3 Cost Estimate for Conceptual Mitigation Options

7.3.1 Cut-off Wall – Alluvial Aquifer

The preliminary estimated costs associated with the preliminary works and installation of the alluvial aquifer Cut-off Walls is provided in Table 7-3.

Table 7-3: Alluvial Aquifer Cut-off Wall Preliminary Cost Estimate

Cost Estimate Line Item	Cost
1. Field Testing	$50,000
2. Infrastructure Design	$60,000
3. Construction (Contractor & Materials)	$200,000
4. Construction Supervision	$30,000
5. Pumping Infrastructure Costs (as per MIM cost estimate)	$600,000
Total	**$940,000**
Contingency (30%)	**$282,000**
Total + Contingency	**$1,222,000**

The basis for the above preliminary cost estimate is provided as follows:

- Field testing comprises the undertaking of a geotechnical testing program, including drilling, geotechnical testing (laboratory), hydraulic testing and reporting. A duration of 2 weeks is estimated from the field testing program.
- Infrastructure design comprises the in-office detailed design of both Cut-off Wall infrastructures.
- Cut-off Wall construction costs have been developed based on KCB previous experience with Cut-off Wall installations in unconsolidated materials to a depth shallower than 10 m. The all-inclusive (contractor and materials) unitary rate for the Cut-off Wall construction is $250/m^2 of Cut-off Wall (BSOC South Seepage Cut-off Wall = 450 m^2, BSOC North Seepage Cut-off Wall = 350 m^2).

7.3.2 Interception Borefield – Alluvial Aquifer

A conceptual layout of the alluvial aquifer groundwater interception borefield is provided in Figure 7-1. Nominally, seven interception bores have been proposed for each seepage location (14 interception bores in total), however, this may vary based on the results of the initial drilling and hydraulic testing program. The following preliminary cost estimate for this mitigation option has been developed based on the nominal 14 interception bores (Table 7-4).

Table 7-4: Alluvial Aquifer Interception Borefield Preliminary Cost Estimate

Cost Estimate Line Item	Cost
1. Field Testing	$105,000
2. Infrastructure Design	$75,000
3. Installation (Contractor & Materials / Equipment)	$385,000
4. Construction Supervision	$30,000
Total	**$595,000**
Contingency (30%)	**$178,500**
Total + Contingency	**$773,500**

The basis for the above preliminary cost estimate is provided as follows:

- Field testing comprises the drilling and construction of three test interception bores at each seepage location, hydraulic testing, field supervision and reporting. A duration of 2 weeks is estimated from the field testing program.
- Infrastructure design comprises the in-office detailed design of both interception borefields.
- Borefield installation costs have been developed based on KCB experience with borefield design, drilling contractor rates, bore construction material costs and pumping / reticulation costs.
- Operating costs have not been included with this estimate due to uncertainty regarding the conceptual design (e.g. number of bores, size of pumps etc).

7.3.3 Interception Trench

A conceptual layout of the alluvial aquifer groundwater interception trench is provided in Figure 7-1. The conceptual interception trench sizings have been based on the interpreted alluvium extent and the bedrock interception depth identified during the site investigation program. These sizings include:

- BSOC WRD South Seepage – 50 m (length) x 36 m (width) x 9 m (depth)
- BSOC WRD North Seepage – 100 m (length) x 14 m (width) x 3.5 m (depth)

The width of the trench has been selected based on a cut-back ratio of 2:1 (horizontal:vertical), to maintain stability of the trench walls in the alluvium. The following preliminary cost estimate for this mitigation option has been developed based on the interception trench sizings (Table 7-5).

Table 7-5: Alluvial Aquifer Interception Trench Preliminary Cost Estimate

Cost Estimate Line Item	Cost
1. Field Testing	$45,000
2. Infrastructure Design	$75,000
3. Installation (Contractor & Materials / Equipment) – South Trench	$410,000
4. Installation (Contractor & Materials / Equipment) – North Trench	$195,000
Total	**$725,000**
Contingency (30%)	**$217,500**
Total + Contingency	**$942,500**

The basis for the above preliminary cost estimate is provided as follows:

- Field testing comprises the drilling of three drill holes across the trench alignment at each seepage location, geotechnical testing, field supervision and reporting. A duration of 1 week is estimated from the field testing program.
- Infrastructure design comprises the in-office detailed design of both interception trenches.
- Interception trench costs have been developed based on unitary rates for site preparation, excavation, pumping equipment and reticulation provided in the Australian Construction Handbook (Rawlinsons, 2015).

- Operating costs have not been included with this estimate due to uncertainty regarding the conceptual design (e.g. sizing of trenches, size of pumps etc.).

7.3.4 Interception Borefield – Bedrock Aquifer

A conceptual layout of the bedrock aquifer groundwater interception borefield is provided in Figure 7-2. Nominally, 12 interception bores have been proposed for this network, however, this may vary based on the results of the initial drilling and hydraulic testing program. The following preliminary cost estimate for this mitigation option has been developed based on the nominal 12 interception bores (Table 7-6).

Table 7-6: Bedrock Aquifer Interception Borefield Preliminary Cost Estimate

Cost Estimate Line Item	Cost
1. Field Testing	$140,000
2. Infrastructure Design	$75,000
3. Installation (Contractor & Materials / Equipment)	$495,000
4. Construction Supervision	$50,000
Total	**$760,000**
Contingency (30%)	**$228,000**
Total + Contingency	**$988,000**

The basis for the above preliminary cost estimate is provided as follows:

- Field testing comprises the drilling and construction of five test interception bores (to 60 m depth), hydraulic testing, field supervision and reporting. A duration of 3 weeks is estimated from the field testing program.
- Infrastructure design comprises the in-office detailed design of the interception borefield.
- Borefield installation costs have been developed based on KCB experience with borefield design, drilling contractor rates, bore construction material costs and pumping / reticulation costs.
- Operating costs have not been included with this estimate due to uncertainty regarding the conceptual design (e.g. number of bores, size of pumps etc).

7.4 Timeframe for Implementation of Mitigation Options

7.4.1 Cut-off Wall Option

The anticipated timeframe for the installation of the alluvial aquifer Cut-off Wall seepage mitigation option is provided in Figure 7-3, broken down into key schedule items. The anticipated timeframe indicates an implementation timeframe of 12 months for the Cut-off Walls.

Schedule Items	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
Testing Program / Detail Design												
Preparation of Scope of Work												
Invitation to Submit Tenders												
Review of Submitted Tenders												
Finalisation of Contract												
Field Program												
Detailed Design												
Cut-off Wall Installation												
Preparation of Scope of Work												
Invitation to Submit Tenders												
Review of Submitted Tenders												
Finalisation of Contract												
Materials / Equipment Procurement												
Cut-off Wall Installation												

Figure 7-3: Anticipated Alluvial Aquifer Cut-off Wall Installation Timeframe

7.4.2 Alluvial Aquifer Interception Borefields Option

The anticipated timeframe for the installation of the alluvial aquifer interception borefields is provided in Figure 7-4, broken down into key schedule items. The anticipated timeframe indicates an installation timeframe of 11 months for the interception borefields.

Schedule Items	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
Testing Program / Detail Design												
Preparation of Scope of Work												
Invitation to Submit Tenders												
Review of Submitted Tenders												
Finalisation of Contract												
Field Program												
Detailed Design												
Interception Borefields Installation												
Preparation of Scope of Work												
Invitation to Submit Tenders												
Review of Submitted Tenders												
Finalisation of Contract												
Materials / Equipment Procurement												
Interception Borefields Installation												

Figure 7-4: Anticipated Alluvial Aquifer Interception Borefields Installation Timeframe

7.4.3 Alluvial Aquifer Interception Trenches

The anticipated timeframe for the installation of the alluvial aquifer interception trenches is provided in Figure 7-5, broken down into key schedule items. The anticipated timeframe indicates an installation timeframe of 10 months for the interception trenches.

	Months											
Schedule Items	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Testing Program / Detail Design												
Preparation of Scope of Work												
Invitation to Submit Tenders												
Review of Submitted Tenders												
Finalisation of Contract												
Field Program												
Detailed Design												
Interception Trenches Installation												
Preparation of Scope of Work												
Invitation to Submit Tenders												
Review of Submitted Tenders												
Finalisation of Contract												
Materials / Equipment Procurement												
Interception Trenches Installation												

Figure 7-5: Anticipated Alluvial Aquifer Interception Trenches Installation Timeframe

7.4.4 Bedrock Aquifer Interception Borefields

The anticipated timeframe for the installation of the bedrock aquifer interception borefield is provided in Figure 7-6, broken down into key schedule items. The anticipated timeframe indicates an installation timeframe of 12 months for the interception borefields.

Schedule Items	Months											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Testing Program / Detail Design												
Preparation of Scope of Work												
Invitation to Submit Tenders												
Review of Submitted Tenders												
Finalisation of Contract												
Field Program												
Detailed Design												
Interception Borefield Installation												
Preparation of Scope of Work												
Invitation to Submit Tenders												
Review of Submitted Tenders												
Finalisation of Contract												
Materials / Equipment Procurement												
Interception Borefield Installation												

Figure 7-6: Anticipated Bedrock Aquifer Interception Borefield Installation Timeframe

8 PREFERRED IMPACT AREA REMEDIATION OPTION/S

This section of the report addresses item 4, of the EE Notice:

Identify a preferred option/s for both the remediation of identified impacts to the receiving environment, and measure to prevent or limit any future impacts. Provide justification for the nominated option/s, which includes assessment against best practice environmental management; and identify a timeframe for implementation of the nominated option/s.

8.1 Preferred Option/s Assessment Results

Impacts to the receiving environment EVs as a result of seepage from the BSOC WRD landform have been assessed for groundwater (alluvial and bedrock), surface water, sediment / soil quality and flora / fauna. Currently, no existing impacts to the receiving environment EVs have been identified and the potential for future impacts will require the implementation of an adaptive management strategy comprising ongoing monitoring, impact assessment and, if required, implementation of a preferred mitigation option/s. Therefore, the immediate implementation of a preferred impact mitigation option/s is not considered necessary.

The monitoring program to be implemented as part of the adaptive management strategy comprises:

- Surface water (within the water course downstream of BSOC WRD North and South Seepages prior to the confluence with Hazeldene Creek):
  - Installation of rising-stage samplers to allow collection of surface water samples following rainfall / surface water flow event, including “first flush” flow and longer-term flow
  - Sample collection should be event-based, with samples collected following rainfall / surface water flow event for analytical testing. New sample bottle should be replaced in the rising-stage samplers immediately following sample collection. The analytical suite for testing includes:
    - Physico-chemical parameters – pH, EC, TDS, Temp, Redox
    - Major ionic constituents – Na, Mg, K, Ca, CO_3, HCO_3, Cl, SO_4
    - N-species – total N, nitrate, nitrite, Ammonia as N
    - Metals – Al, Sb, As, Ba, Be, Bi, Bo, Cd, Cr, Co, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, Ag, Sr, Th, Ti, U, V, Zn
- Alluvial aquifer (BSOC_A1, BSOC_A2 – BSOC WRD South Seepage; BSOC_A3, BSOC_A4 – BSOC WRD North Seepage):
  - Groundwater levels – quarterly frequency (to capture seasonal variability); groundwater level data-loggers should also be installed to allow automated daily measurements of groundwater levels,
  - Groundwater quality – quarterly frequency (to capture seasonal variability):
    - Physico-chemical parameters – pH, EC, TDS, Temp, Redox
    - Major ionic constituents – Na, Mg, K, Ca, CO_3, HCO_3, Cl, SO_4

    - N-species – total N, nitrate, nitrite, Ammonia as N
    - Metals – Al, Sb, As, Ba, Be, Bi, Bo, Cd, Cr, Co, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, Ag, Sr, Th, Ti, U, V, Zn
- Bedrock aquifer (Bore 23, Bore 24, MIOP1 / S2, BSOC_B1, BSOC_B2, BSOC_B3, BSOC_B4 BSOC_B5, BSOC_B6):
  - Groundwater levels – quarterly frequency
  - Groundwater quality – quarterly frequency:
    - Physico-chemical parameters – pH, EC, TDS, Temp, Redox
    - Major ionic constituents – Na, Mg, K, Ca, CO_3, HCO_3, Cl, SO_4
    - N-species – total N, nitrate, nitrite, Ammonia as N
    - Metals – Al, Sb, As, Ba, Be, Bi, Bo, Cd, Cr, Co, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, Ag, Sr, Th, Ti, U, V, Zn
- BSOC WRD landform seepages:
  - Seepage flow rates (Weir 1, Weir 2, Weir 3) – automated monitoring (0.5 minute intervals), quarterly downloads with manual reading for flow verification
  - Seepage water quality (BSOC WRD South Seepage, BSOC WRD North Seepage, TD3 Seepage) – quarterly frequency:
    - Physico-chemical parameters – pH, EC, TDS, Temp, Redox
    - Major ionic constituents – Na, Mg, K, Ca, CO_3, HCO_3, Cl, SO_4
    - N-species – total N, nitrate, nitrite, Ammonia as N
    - Metals – Al, Sb, As, Ba, Be, Bi, Bo, Cd, Cr, Co, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, Ag, Sr, Th, Ti, U, V, Zn
- Flora:
  - The monitoring of vegetation condition was considered as a recommendation, however compared with monitoring water quality this was considered to be a lagging indicator (as some vegetation may take several seasons to show signs of stress from contaminants) and therefore any mitigation measures proposed as a result of water quality monitoring program would be appropriate.

At the completion of each quarterly monitoring round, and following the collation of the monitoring data, a review of the monitoring data set, including historical monitoring results, should be conducted. The objective of this review will be to identify potential changes to the BSOC WRD landform seepage characteristics; the seepage plume characteristics; downstream surface water quality and, potential impacts to the receiving environment (surface water quality monitoring and/or seepage plume characteristics). The review will identify whether or not implementation of a seepage mitigation option/s is required.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Seepage Mechanisms and Extent

Data compiled from previous investigations and during the field investigation program were used to conceptualise the hydrogeological system, the BSOC WRD landform and the interaction between these systems. Key components of these systems include:

- Aquifer characteristics in the hydrogeological system
  - aquifer extents
  - groundwater levels and flow gradients
  - aquifer hydraulic parameters
  - groundwater quality
- BSOC WRD landform
  - reconstructed landform, including surfaces for the original topography, the buried TSF3 and the buried TSF5
  - waste rock and tailings geochemistry
  - interpreted hydraulic parameters for the waste material (waste rock and tailings) in the BSOC WRD landform
  - seepage water quality

Conceptualisation of the hydrogeological system and the BSOC WRD landform, as well as the assessment of the waste rock and tailings geochemistry, the seepage hydrochemistry and the downstream groundwater hydrochemistry, provided the basis for the seepage analysis. The combined results of these assessments provided an understanding of the seepage characteristics – the seepage extent, proportion of seepage source contribution, interpreted timeframe of seepage development and predicted timeframe for seepage migration.

Historical groundwater monitoring (levels and water quality) has indicated groundwater mounding within the vicinity of the BSOC WRD landform. Groundwater quality records have indicated increased concentrations of selected parameters from bores within the vicinity of BSOC WRD, which are comparable to parameter concentrations from the BSOC WRD seepages. Both of these items of evidence indicate that seepage migration in the alluvial and bedrock aquifers are driven by seepage / infiltration from the BSOC WRD landform.

BSOC WRD seepage migration has been identified in the alluvial aquifer downstream of TD3 Seepage, BSOC WRD North Seepage and BSOC WRD South Seepage:

- TD3 Seepage – Downstream of TD3 Seepage the extent of the BSOC WRD seepage migration is to the discharge location at the KSOC pit. The alluvial aquifer downstream of TD3 Seepage is saturated as a result of seepage from TD3 Seepage and the collected seepage from the BSOC WRD North and South Seepages discharging into the diversion drain.

- BSOC WRD North Seepage – The extent of seepage migration in the alluvial aquifer downstream of the BSOC WRD North Seepage (alluvial extent to the north) is interpreted to be ~200 m to the north of the diversion drain. This interpretation is based on the groundwater quality results from monitoring bore BSOC_A3 (based on an interpreted seepage extent trigger of sulphate = 1,000 mg/L), and further supported by the lack of groundwater in monitoring bore BSOC_A4.
- BSOC WRD South Seepage – The extent of the seepage migration in the alluvial aquifer downstream of the BSOC WRD South Seepage (alluvial extent to the west of the seepage) is interpreted to be ~300 m to the west of the BSOC WRD South Seepage. Sulphate concentrations from alluvial aquifer monitoring bores located downstream of the BSOC WRD South Seepage (BSOC_A1 and BSOC_A2) indicate that the seepage has migrated beyond BSOC_A2 (~5,500 mg/L) and has not reached BSOC_A1 (~580 mg/L).

BSOC WRD seepage migration in the bedrock aquifer was interpreted based on the groundwater quality results from monitoring bores installed in the weathered bedrock / bedrock aquifer, including bores installed as part of the Phase 2 field investigation program targeting previously interpreted discrete geological structures. As per the alluvial aquifer, a sulphate concentration of 1,000 mg/L was adopted as an indicator of the seepage front. Weathered bedrock / bedrock aquifer water quality results indicate that the BSOC WRD seepage extent is generally localised to the BSOC WRD landform with two zones of seepage migration; to the north of TD3 Seepage, and to the west of BSOC WRD South Seepage. Bedrock aquifer seepage migration extends to the north of TD3 Seepage to ~800 m and seepage migration to the west of the BSOC WRD South Seepage to ~350 m.

The analytical results were compared to the existing groundwater quality data. Analytical contaminant transport analyses were undertaken to assess the travel time of the seepage migration front, and to predict the timing of further migration of the seepage. For conservatism sulphate was used as the contaminant parameter, while the extent of the study area was used as the receptor for the simulation. The nearest receiving environment receptor to the study area for the alluvium aquifer is Hazeldene Creek and the Leichhardt River (2 km and 1.1 km downstream of the BSOC WRD North and South Seepage, respectively); and, Spear Creek, which is located a 5.3 km to the north of TD3 Seepage. The analytical assessment is based on the assumption that seepage commenced during the development of underlying TSFs (i.e. TSF3 for TD3 Seepage; and, TSF5 for BSOC WRD North and South Seepages). The analytical assessment results indicate that the seepage migration in the bedrock aquifer to the north of TD3 Seepage has taken ~63 years to develop; and based on the current migration rate the seepage front may reach Spear Creek (~5.3km) in another 465 years.

Water quality data from impacted groundwater monitoring bores, BSOC WRD seepages and tailings seepage water (TD5 pit) were assessed to identify the source of the BSOC WRD seepages and the downstream impacted groundwater. This assessment indicates that both BSOC waste rock leachate water and tailings seepage water (both TSF3 and TSF5) are likely to be contributing to seepages from the BSOC WRD landform.

9.2 Seepage Mitigation Options Evaluation

The impact assessment shows that these potential options are not currently justified. Notwithstanding, potential options are presented here for the purposes of meeting the EE Notice requirements.

Mitigation options to prevent / reduce seepage in the alluvial and bedrock aquifers have been identified. These mitigation options, associated costs and anticipated implementation schedule are provided in the following:

- Alluvial aquifer seepage mitigation:
  - Interception borefield; $773,500; 11 months
  - Interception trench; $942,500; 10 months
  - Cut-off Wall; $1,222,000; 12 months
- Bedrock aquifer seepage mitigation:
  - Interception borefield; $988,000; 12 months

9.3 Potential Impact Mitigation

Current impacts to the receiving environment EVs as a result of the BSOC WRD landform seepage have not been identified. The potential for impacts to the receiving environment EVs in the future is uncertain and will require the implementation of an adaptive management strategy comprising the undertaking of an ongoing monitoring program, impact assessment and, if required, implementation of a preferred seepage mitigation strategy. As a result, the immediate implementation of a preferred impact mitigation option/s is not considered necessary.

10 CLOSING

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of Mount Isa Mines Limited. (Client) for the specific application to the Black Star Open Cut Waste Rock Dump Environmental Evaluation. The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this report, Klohn Crippen Berger has endeavoured to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

KLOHN CRIPPEN BERGER LTD.

Chris Strachotta
Project Manager

REFERENCES

Amec Foster Wheeler (2015) Mount Isa Mines 2014 Biodiversity Study Report Biodiversity Assessment of ML8058

Amec Foster Wheler (2016) BSOC Environmental Evaluation – Receiving Environment (Flora and Fauna) Assessment. Draft Report for Klohn Crippen Berger. 651960-ENV-RPT-001. May 2016.

Australasian Groundwater and Environmental Consultants Pty Ltd, 2002a. Report on Groundwater Monitoring Review, Mount Isa Mine. Consultant report NG136. August 2002

Australasian Groundwater and Environmental Consultants Pty Ltd, 2004. Report on Kennedy Siltstone Open Cut Groundwater Study. Consultant report NG189. July 2004.

Australian and New Zealand Environmental and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality, October 2000.

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428

Bureau of Meteorology (2016) Rainfall data for Mount Isa. http://www.bom.gov.au/. - Accessed 21 February 2016.

Butler, J.J., Jr., 1998. The Design, Performance, and Analysis of Slug Tests, Lewis Publishers, New York, 252p.

CMLR (2009) Mount Isa Mines Ground Water Review. March 2009

Crosbie, R., Morrow, D., Cresswell, R., Leaney, F., Lamontagne, S. & Lefournour, M. (2012). New insights to the chemical and isotopic composition of rainfall across Australia. Water for a Healthy Country Flagship Report series ISSN: 1835-095X.

Department of Environment and Heritage Protection (2013) Manual for Assessing Consequence Categories and Hydraulic Performance of Structures. EM635 Version 4.

Department of Environment and Heritage Protection (2014a) Notice to conduct or commission an environmental evaluation. EPML00977513. Ref 101/0008689. December 2014.

Department of Environment and Heritage Protection (2014b) Guideline: Structures Which Are Dams or Levees Constructed as Part of Environmentally Relevant Activities. EM634 Version 6.

Department of Environment and Heritage Protection (2015a) Environmental Authority – Permit number: EPML00977513. May 2015.

Department of Environment and Heritage Protection (2015b) Environmentally Relevant Activities Compliance and Enforcement – Guideline. EM1019. January 2015

Department of Environment and Heritage Protection (2015c) Environmental Evaluation – Guideline. EM1027. October 2015.

Harries JR (1990) Acid Drainage From Waste Rock Dumps at Mine Sites. May 2009.

Houslby, A.C, 1976. Routine Interpretation of the Lugeon Water-Test in Quarterly Journal of Engineering Geology Vol.9 pp 303-313.

Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, Mississippi, pp. 1-50

Hyder, Z., J.J. Butler, Jr., C.D. McElwee and W. Liu, 1994. Slug tests in partially penetrating wells, Water Resources Research, vol. 30, no. 11, pp. 2945-2957.

Forrestal, P. J., 1990. Mount Isa and Hilton Silver-Lead-Zinc Deposits, In Geology of the Mineral Deposits of Australia and Papua New Guinea (Ed .F.E Hughes), pp 927 -931.

Forsyth, B. & Edraki, M. (2010). Tailings Seepage Surface and Ground Water Quality Data Review Mount Isa Mine 2000-2009 Conducted as part of Xstrata – CMLR Tailings Seepage Project

Forsyth, B. A., 2014. Understanding the Long-term Seepage Geochemistry of Base Metal Mine Tailings in a Semiarid Subtropical Climate, Mount Isa, Australia, Unpublished PhD Thesis.

Jell PA (ed) (2012) Geology of Queensland. Geological Survey of Queensland, 175-183.

Klohn Crippen Berger Ltd (2011a). Black Rock Open Cut Groundwater Impact Assessment. Report prepared for Xstrata Mount Isa Mines. February, 2011.

Klohn Crippen Berger Ltd (2011b). BSOC South Project Feasibility Study Groundwater Impact Assessment. Report prepared for Xstrata Mount Isa Mine. Report prepared for Xstrata Mount Isa Mines. February, 2011.

Klohn Crippen Berger Ltd (2011c). Mount Isa Open Pit Groundwater Monitoring Network Assessment. Report prepared for Xstrata Mount Isa Mines. September, 2011.

Klohn Crippen Berger Ltd (2013a). Mount Isa Open Pit (MIOP) Hydrogeological Test Pumping Program and Assessment. Report prepared for Xstrata Mount Isa Mines.

Klohn Crippen Berger Ltd (2013b). MIOP Project PFS Hydrogeological Report. Report prepared for Gamut Consulting Pty Ltd.

Klohn Crippen Berger (2015) Environmental Evaluation - Black Star Open Cut Waste Rock Dump Proposal for Consulting Services. Proposal PR12D05.17.

Klohn Crippen Berger (2016) Black Star Open Cut Waste Rock Dump Environmental Evaluation: Data Gap Assessment. Final Report. January 2016.

Mount Isa Mines (2014c) Mount Isa Mines Rehabilitation Plan Revision Number 1.1. December 2014.

National Uniform Drillers Licensing Committee (NUDLC) (2012), Minimum Construction Requirements for Water Bores in Australia – Third Edition, NUDLC, South Australia.

Ogata A, Banks RB (1961) A solution of the differential equation of longitudinal dispersion in porous media. US Geological Survev Prof Pap 411-A: 1–9.

Pilgram, DH, ed. (1987). Australian Rainfall & Runoff – A Guide to Flood Estimation. Barton, ACT: Institution of Engineers Australia.

Rohde, TK and Williams DJ (2009). Early Hydrological Monitoring of Cadia's Instrumented Trial Waste Rock Dump. Conference Proceedings ICARD 2009.

Schneider AC. (2012) Plant Soil Relationshops in Constructed Covers of Mine Waste Material. pHD Thesis. University of Queensland.

State of Queensland (2016). Environmental Protection Act 1994. Current as of 27 April, 2016.

Thiem, G. 1906. The relation between the lowering piezometric surface and the rate and duration of discharge of a well using groundwater storage. Transactions, American Geophysical Union 16; 519-524.

TMR. 2010. "Road Drainage Manual: A Guide to the Planning, Design, Operation and Maintenance of Road Drainage Infrastructure."

United States Bureau of Reclamation. 1965. Earth Manual. U.S. Bureau of Reclamation, Denver, Colorado, First Edition, Revised.

URS, 2004. Black Star Open Pit Project Waste Rock Dump Design and Management Strategy. Environmental report

URS Australia Pty Ltd (2010a). Groundwater Assessment – Mount Isa Mines (Draft Report). Report prepared for Xstrata Mount Isa Mines. 2010.

URS Australia Pty Ltd (2010b). Groundwater Resources – Mt Isa Mines Transition Project (Draft for Discussion).

Worley Parsons Resources and Energy. 2014. “King Gully Dirty Water Diversion Works - As Constructed Report.” 201001-00424 – 00-EN-REP-0003. Prepared for Glencore Mount Isa Mines.

GLOSSARY OF TERMS

Aquifer: Permeable earth material such as porous sediments or fractured hard rock, saturated with groundwater. The permeability should be such that it is capable of conducting and yielding usable quantities of groundwater to a borehole(s) and / or springs. An aquifer is 'a geological formation which has structures or textures that hold water or permit appreciable water movement through them'.

Aquitard: A confining bed that retards, but does not completely stop the flow of water to or from an adjacent aquifer. Although it does not readily release water to boreholes or springs, it may function as a storage chamber for groundwater.

Chemical attenuation: The capacity of aquifer solids to remove dissolved or suspended contaminants from groundwater and retain them.

Confined aquifer: An aquifer which is overlain by a confining layer of low permeability. The groundwater is confined under pressure greater than atmospheric pressure such that if the aquifer is penetrated the water level may rise above the top of the aquifer.

Confining layer/unit: Geologic material with little permeability or hydraulic conductivity.

Contamination: The introduction into the environment of any substance by the action of man.

Darcy's Law: Darcy's Law is used to calculate the rate at which groundwater is moving in porous media. It states that the rate of flow through a porous medium is proportional to the loss of head, and inversely proportional to the length of the flow path and is defined by the following equation:

$$Q = T\ i\ w$$

where:

Q = Discharge

T = Transmissivity

i = Groundwater gradient

w = Length of groundwater unit perpendicular to flow

Dewatering: The process of removing water from an underground mine or open pit, or from the surrounding rock or non-lithified materials. The term is also commonly used for the reduction of water content in concentrates, tailings and treatment sludges.

Dilution: To diminish the concentration by mixing one mass with another. For example, the mixing of one flow of water with another flow to obtain a flow with an intermediate aqueous concentration. This process is used to reduce the concentration of metals or other potentially deleterious contaminants in the more concentrated flow. Dilution may take place by diffusion and dispersion. Dispersion mechanisms include turbulent flow in a river or creek, or currents and wind generated mixing in lakes.

Dissolution: The process whereby solid matter dissolves in a liquid. For example, the dissolving of limestone (calcium carbonate) in rain and groundwater. See also solubility.

Ecosystem: An interconnected and interacting system comprising living organisms – including animals, plants, fungi, and microorganisms - and their non-living environment.

Environmental: The interrelated physical, chemical, biological, social, spiritual and cultural components that affect the growth and development of living organisms.

Geochemistry: Study of the distribution and abundance of elements in *minerals, rocks, soils,* water and the atmosphere.

Geology: The study of the earth, its history and the changes that have occurred or are occurring and the rocks and non-lithified materials of which it is composed and their mode of formation and transformation.

Grain: Crystals or multi-crystal fragments within a *lithified matrix*. For example, sand grains in sandstone and quartz grains in sand sized particles.

Groundwater: The water in the aquifer.

Humidity Cell Test: A *kinetic test* procedure used primarily to measure rates of *acid generation* and *neutralization* in *sulphide* bearing *rock*. Critical test conditions include detailed pre- and post-test sample characterization, running the test for sufficient duration, aerobic weathering conditions, the use of excess drainage to fully dissolve the soluble products of primary *mineral weathering* and conducting the necessary analyses on the drainage to model *mineral* solubility. The accuracy of the subsequent prediction will depend on the test procedures, the *sample* composition, the validity of the various assumptions and the manner in which the analytical data is interpreted. Details of the test protocols are critical to the interpretation and must be included with the results. The standard methodology is to place a *sample* of *rock* (about 1 kg) into an enclosed vertical plexiglass column and expose the *sulphides* within the *rock* to 3 days each of humid and dry air. On the seventh day, the test material is flushed and resultant *leachate sample* is collected and analyzed to determine its chemical composition. Results from the chemical analyses of the leachate are used to calculate primary mineral reaction rates.

Hydraulic conductivity: Describes the ease with which water can move through pore spaces or fractures. It depends on the intrinsic permeability of the material and on the degree of saturation. Saturated hydraulic conductivity, Ksat, describes water movement through saturated media.

Hydraulic gradient: The change in hydraulic head or water level over a distance.

Hydraulic head: The height above a datum (such as sea level) of the column of water that can be supported by the hydraulic pressure at a given point in a groundwater system.

Hydrogeochemistry: The study of the chemical processes and reactions that govern the composition of water in relation to its interaction with rocks and the aquifer.

Kinetic Test: A procedure used to measure the magnitude and/or effects of dynamic processes including rates of reaction, material *alteration* and *drainage chemistry* and loadings that results from *weathering*. Unlike *static tests*, kinetic tests measure the performance of a *sample* over a prolonged period of time. Material composition and/or environmental conditions are often simplified or controlled to permit measurement of the physical, chemical, or biological characteristics, processes or relationships which are of interest. Kinetic tests have many different forms and locations, including *lysimeters*, field test pads, *leach columns* and *humidity cells.* In ML/ARD studies, the most common form of kinetic tests are laboratory procedures designed to determined the quality of water and rates of reaction resulting form the interaction of water and the mine material Tests can be divided into two categories, those designed to simulate *drainage chemistry* (e.g. *leach columns*) and those designed to measure primary reaction rates (e.g. *humidity cell test*).

Leaching: Dissolution of substances in the soil and removal by percolating water.

Leach Column: A *kinetic test* designed to simulate the *leaching* and secondary *mineral* precipitation and dissolution that determine *drainage chemistry.* In a leach column, the test material is placed in some form of tube and subjected to natural *leaching* in a field test or an artificial *leaching* regime in a laboratory study. Columns are most commonly set up in the laboratory. Laboratory studies attempt to simulate the important aspects of field *weathering* conditions. Secondary *mineral* precipitation and dissolution in the areas of *leaching* may be detected through changes in *leachate* composition. Columns may be constructed of plexiglass to allow the observation of changes in colour or other physical properties. Post-test analysis of the test materials may be used to evaluate changes in the solid phase, spatial variability and/or the *mineral* factors controlling *drainage chemistry*. The accuracy of the subsequent prediction will depend on the test procedures, the *sample* composition, the validity of the various assumptions and the manner in which the analytical data is interpreted. Details of the test protocols are critical to the interpretation and must be included with the results.

Lithology: The systematic description of sediment and rocks, in terms of composition, texture and internal structure.

Metal: A class of chemical elements generally characterized by ductility, malleability, luster and conductivity of heat and electricity including alkali, alkali earth, *base, heavy* and *precious metals*. See also *metalloid*.

Metal Leaching: The extraction of soluble *metals* by percolating solvents. *Leaching* may be natural or induced. Primary *mineral weathering* commonly accelerates *metal dissolution* and removal in *minesite drainage*.

Minor Element: Those elements that commonly occur in geologic materials at concentrations of 0.1 to 1 wt%. Usually includes manganese, phosphorous and titanium.

Model: A formalized expression of a theory, event, object, process or system used for prediction or control; an experimental design based on a casual situation that generates observed data. A model can be viewed as a selective approximation which by the elimination of incidental detail, allows some fundamental, relevant or interesting aspect of the real world to appear in a generalized form.

Particle: Separate fragments in an unconsolidated *matrix*. For example, the particle of various sizes in iwaste rock *and* till. To avoid confusion, it is recommended that use of the term *grain* be limited to crystals or multi-crystal fragments within a consolidated *matrix*. For example, sand grains in sandstone.

Particle Size: The dimension of *particles*. Commonly measured by sieving, settling velocities and image analysis. Particle sizes include the various types of coarse fragments (>2 mm), such as boulders, stones and gravel, and the different *soil-sizes* (<2 mm), *sand* (2mm – 62.5 µm), *silt* (2 µm – 62.5 µm) and *clay* (<2 µm).

Permeability: Refers to the ease with which a fluid can pass through a porous medium. In hydrogeology, permeability is often used synonymously with hydraulic conductivity, which specifically refers to the ease with which water is transmitted through a porous medium. It is defined as the volume of water discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (expressed as $m^3/m^2/d$ or m/d).

pH: The negative logarithm to the base 10 of the hydrogen ion activity [H^+] in solution.

Preferential flow: The preferential movement of water through more permeable zones in the subsurface.

Primary aquifer: An aquifer in which water moves through the original interstices of the geological formation, e.g. pores between sand grains. This type of porosity is termed primary porosity.

Rainfall Recharge: Recharge derived from rainfall; see below.

Receiving Environment - The EE notice defines "receiving environment" as *all groundwater and surface water that are not in disturbed areas authorised by this environmental authority and excludes land within the surface water containment areas*.

Recharge: The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.

Redox Conditions: A measure of the theoretical electron activity of an *environment*. A high redox potential indicates *aerobic* conditions. A low redox potential indicates oxygen poor or reducing conditions.

Rock: Naturally formed, solid mass of one or more *mineral, amorphous* inorganic matter or organic matter.

Saturated zone: That part of the geological stratum in which all the voids are filled with water under pressure greater than that of the atmosphere.

Secondary aquifer: An aquifer in which water moves through the secondary interstices, which are a result of post-depositional processes, such as joints and faults.

Sediment – Solid fragmental materials, both inorganic and organic, that have been deposited after being transported by air, water, or ice, chemically precipitated from solution or secreted by organisms.

Seepage - The EE notice defines "seepage" as *any liquid originating from the Black Star Waste Rock Dump footprint regardless of its contaminant concentration that has the potential to enter the receiving environment.*

Soil zone: The usually thin upper surface layer of the earth's crust comprising living organisms, organic matter, decomposed rock or unconsolidated sediments, water and gases with properties attributable to the interaction of its parent material, time, climate, fauna and flora.

Solubility: The quantity of solute that dissolves in a given volume and type of solvent, at a given temperature and pressure, to form a saturated solution. The degree to which compounds are soluble depends on their ability and that of the other dissolved *species*, to form ions and aqueous complexes in a particular *drainage chemistry*.

Speciation: The chemical form in which an element is present or the process whereby various states or forms of an element become differentiated into ions.

Species: A chemical entity such as an ion, atom or molecule.

Sorption: The attachment of an ion, molecule or compound to a charged surface of a particle, usually a clay or organic matter.

Storativity: The storage coefficient or storativity is a measure of the volume of water per volume of aquifer released as a result of a change in head. For confined aquifers, the storage coefficient is equal to the product of the specific storage and aquifer thickness.

Sulphate: A *mineral*, compound or ion containing the SO_4^{2-} functional group in which sulphur is in the +6 oxidation state.

Sulphide: A *mineral*, compound or ion containing the S_2^{2-} or S^{2-} functional group in which sulphur is in the -1 or -2 oxidation state. Sulphide minerals also contain *metals* (e.g., pyrite, FeS_2, galena, PbS or chalcopyrite, $CuFeS_2$) or *metalloids* (e.g. arsenopyrite, FeAsS).

Sulphide Oxidation: Exothermic *oxidation* of chemically reduced *sulphide* (S_2^{2-} or S^{2-}) to a partially or fully oxidized form, such as *sulphate* (SO_4^{2-}). One indication of *sulphide oxidation* is elevated *sulphate* concentrations in *drainage*.

Sulphide-Sulphur: Sulphur occurring in the *sulphide* oxidation state. The analysis for sulphide-sulphur is one in a series of sulphur analyses that are a part of Acid Base Accounting. Expressed as % S.

Tailings – The ground *rock* waste product from a *mill* or *process plant*, the materials remaining after the economically valuable elements are removed from the *ore*. Ti remove the valuable elements, blasted *rock* typically goes through several steps of crushing and extraction or washing. The *tailings* usually leave the *mill* as a *slurry* of *sand sized* and/or *silt sized particles* in water. *Tailings* are commonly stored in a surface *impoundment* but can also be placed sub-aqueously in natural water bodies or backfilled into *underground workings.*

Total Sulphate-Sulphur: All sulphur occurring as *sulphate*. One in a series of sulphur analyses that are a part of Acid Base Accounting. Expressed as % S.

Total Sulphur: All the sulphur in a *sample*. One in a series of analyses that are a part of Acid Base Accounting. Expressed as % S. See also *sulphide-sulphur, acid leachable sulphate0sulphur, total sulphate-sulphur, organic-sulphur, del % S*.

Trace Elements: Those elements that commonly occur in relatively small concentrations, such as boron, cadmium, and cobalt. Elements that commonly occur in geologic materials at concentrations of less than 0.1 wt% or in water at concentrations less than 1 mg/L. Includes all *precious metals* and *base metals*, with the exception of aluminum and iron. See also *major elements* and *minor elements*.

Transmissivity: Transmissivity is the rate at which water is transmitted through a unit thickness of aquifer under a unit hydraulic gradient (Driscoll, 1986). It is the product of the hydraulic conductivity and the contributing thickness of the aquifer to flow.

Unconfined aquifer: An aquifer whose upper surface (water table) is free to fluctuate.

Unsaturated zone: That part of the geological stratum above the saturated zone in which the voids contain both air and water.

Waste Rock: Rock with insufficient amounts of economically valuable elements to warrant its extraction, but which has to be removed to allow physical access to the *ore*. *Waste rock* is typically blasted into smaller *particles* to allow its removal by truck and shovel. Disposal occurs in *sub-aerial* or *subaqueous* surface *dumps* or *backfill* to *open pits* or *underground workings*. In *heap leaching*, spent *ore* is sometimes referred to as *waste rock*. In coal mining, *waste rock* may be referred to as "spoils", "gob", or "rejects", terms which can also apply to waste materials from the density separation and the *wash plant*. See also *coarse refuse, fine refuse* and *mined-rock piles.*

Waste Rock Dump: A *mined rock pile* containing *waste rock*.

Water Balance: A term used in the context of mining to describe an inventory of *drainage* inputs and outputs, water volumes and the rate of flow. The water balance should be provided for each *mine component* that is an *ML/ARD* concern and for the site as a whole, at selected periods throughout the *mine*'s history.

Water Table: The top of an unconfined aquifer, where the aquifer is fully saturated and the water pressure is equal to atmospheric pressure. Usually measured in metres below ground level or below top of casing.

Water Quality: Chemical and physical properties defined by measureable attributes of water, *sediment* and aquatic life, compared to a standard or criterion. See also *drainage chemistry* and *receiving environment objectives*.

Weathering: The processes by which *particles, rocks* and *minerals* are altered on exposure to surface temperature and pressure and atmospheric agents such as air, water, and biological activity.

Whole-Rock Elemental Analysis: *Assays* which measure the total concentration of cations in the solid phase. Common procedures include XRF and wet chemical digestion methods. Concerns include accuracy, detection limits and, for wet chemical digestions, the potential for incomplete digestion.

APPENDIX I

Environmental Evaluation Approach

Klohn Crippen Berger

July 20, 2015

Mount Isa Mines Limited
Private Mail Bag 6
Mount Isa QLD 4825

Tamara Groves
ZOPS Environmental Advisor

Dear Ms. Groves:

BSOC WRD Environmental Evaluation
Conceptual Environmental Evaluation Outline

1 INTRODUCTION

Klohn Crippen Berger Ltd (KCB) have been commissioned by Mount Isa Mines Limited (MIM) to undertake an environmental investigation to address a *Notice to conduct or commission an environmental evaluation* (EE notice) issued by the Department of Environment and Heritage Protection (EHP) on December 24, 2014. The EE notice was issued in relation to seepage from the Black Star Open Cut (BSOC) waste rock dump (WRD) *likely to have caused or be causing environmental harm*.

2 BSOC WRD ENVIRONMENTAL EVALUATION BACKGROUND

EHP conducted a compliance inspection of the MIM site in November 2013 and identified seepage from the BSOC WRD. During the pre-wet inspection in October 2014 the same seepage was identified as having continued and an additional seepage point (TD3) was identified. Following the October 2014 pre-wet inspection, EHP issued the EE notice, a copy of which is provided in Attachment A.

The EE notice directs MIM to conduct an environmental investigation into the likely environmental harm caused by, or being caused by, the BSOC WRD seepage. The requirements of this environmental investigation are provided in **Section B. Requirements** of Attachment A.

3 CONCEPTUAL ENVIRONMENTAL EVALUATION OUTLINE

The following sections summarises the conceptual environmental evaluation outline and the proposed approach to undertake the environmental investigation.

3.1 Environmental Evaluation Summary and Flow Chart

Figure 1 presents the flow chart for the undertaking of the EE investigation.

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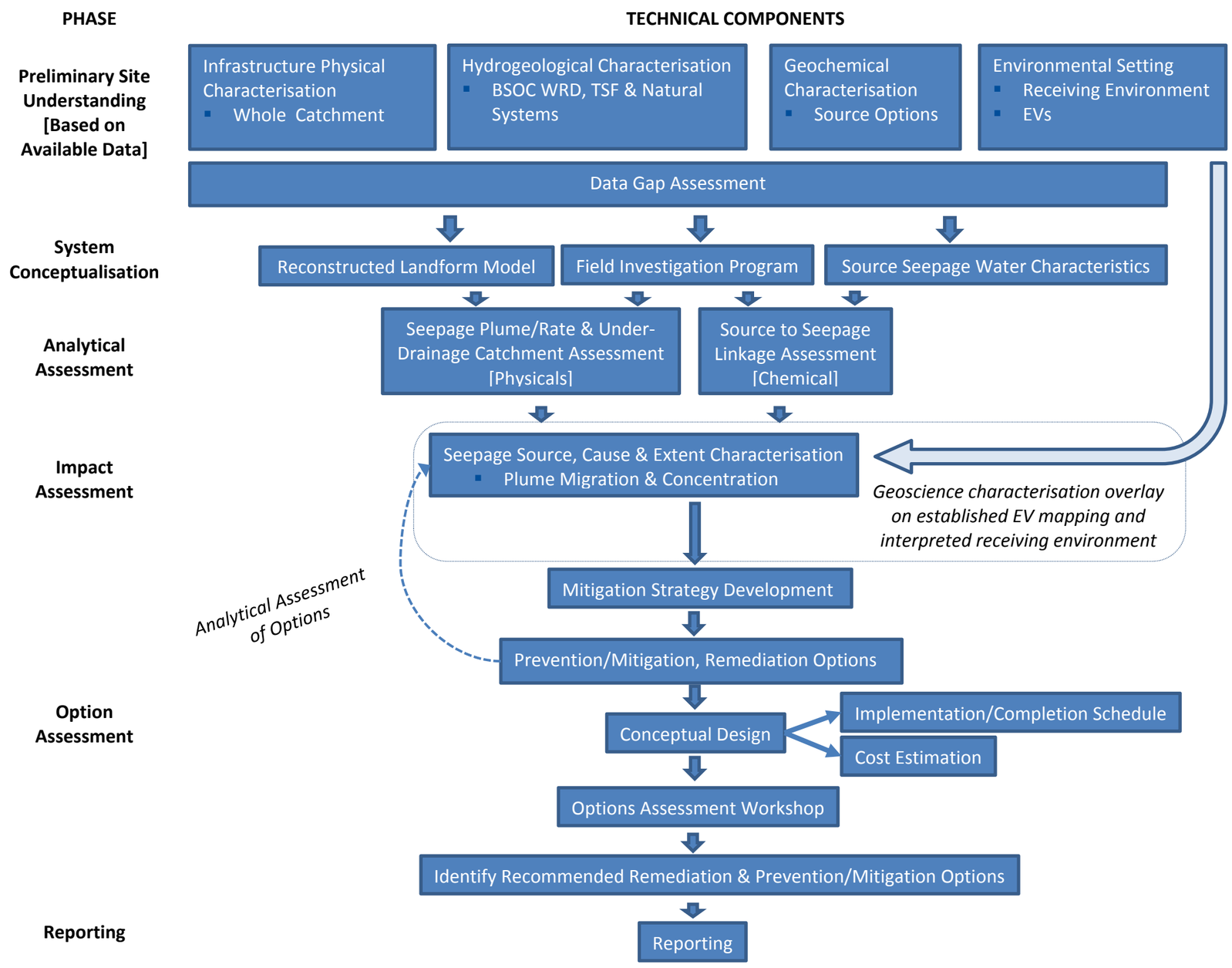

Figure 1 Environmental Evaluation Outline Flow Chart

3.2 Environmental Evaluation Tasks

3.2.1 Information/Data Review, Project Site Conceptualisation and Data Gap Assessment

A relatively large information/dataset is available on the BSOC WRD, adjacent infrastructure and associated environmental setting. The information and datasets will be collated to support the conceptualisation of the project site. Project site conceptualisation will include:

- Physical characterisation of the infrastructure
  - This physical characterisation comprises the reconstruction of the BSOC WRD landform, including the various landform surfaces (e.g. original topography, TD3 surface, BSOC WRD surface) and associated infrastructure (e.g. TD5, northern diversion drain, landfill sludge ponds).
- Conceptual hydrogeological model
  - The conceptual hydrogeological model will be developed based on the available site information and will focus on understanding the hydrogeological system, aquifer parameters, flow direction/gradients, recharge/discharge mechanism and associated groundwater quality. This conceptualisation will include both in-situ hydrogeology (groundwater flow within the natural geological – alluvium and bedrock) and within the various waste infrastructure (e.g. BSOC WRD, TD3, TD5, landfill sludge pits).
- Geochemical and waste seepage water quality characteristics
  - A review of the background water quality and geochemical characterisation data will be conducted to develop a preliminary understanding of the water quality evolution across the project site and potential linkages between the water quality, mine waste material and/or landfill sludge pits.
- Downstream environmental setting
  - The downstream environmental setting will be delineated as part of the site conceptualisation. This will be based on previous ecological assessments conducted across the project site and will highlight the environmental values of the downstream receiving environment.

Preliminary conceptualisation of the seepage source, cause and extent will be undertaken following characterisation of the above components. Based on this conceptualisation, a data gap assessment will be conducted, to guide the field investigation program to obtain data for the assessment of the seepage source, cause and extent.

3.2.2 Field Investigation Program

3.2.2.1 Phase 1 – Site Observations and Field Mapping

A site observation and field mapping program across the project site will be completed as part of a Phase 1 field mobilisation. Key activities associated with this mobilisation include:

- Seepage rate estimates and/or the collection of seepage samples from seepages and standing water from within the vicinity of the BSOC WRD, including from upstream facilities (e.g. TSF5), along the downstream toe and downstream of the diversion drain.

The collected samples will be sent to an analytical laboratory for testing, based on a parameter suite recommended by KCB. The testing suite will be developed based on the preliminary site understanding and the MIM indicator parameters.

Optional: An assessment of the necessity for WRD seepage monitoring infrastructure (e.g. weirs, data loggers) will be conducted during the field mobilisation. An inspection of each of the seepage locations will be conducted to identify the appropriate location and infrastructure to accurately monitor/record the seepage rates.

- Inspection and selection of proposed sites for drilling, monitoring infrastructure installation and testing activities to be conducted during Phase 2. This inspection will focus filling the data gaps and aspects such as site access (e.g. tracks, creek crossings), target site clearance (e.g. drilling platform clearance) and requirements for barriers and/or signage and notification in potential high traffic areas.
- Mapping of the alluvium extent downstream of BSOC WRD. This will include visual inspection of the alluvium characteristics, particularly evidence of potential seepage impacts (e.g. sulphate or metal precipitation). Additionally, detailed surface mapping of the alluvium within the vicinity of the BSOC WRD Diversion Drain (including in the diversion drain) will be undertaken to identify areas of potential seepage migration through the alluvium.
- Inspection of bedrock outcrops to the north of BSOC WRD (along the interpreted bedrock bedding planes) will be conducted to find evidence of potential bedrock seepage "daylighting" at the surface.

3.2.2.2 Phase 2 – Drilling, Monitoring Infrastructure Installation and Testing/Sampling

Activities for the Phase 2 field mobilisation are summarised in the following bullet points:

- Drilling and monitoring infrastructure installation:
  - Based on the current site understanding, KCB propose to drill 11 groundwater monitoring holes. These holes have been tentatively selected at the following locations:
    - One hole located to the north of BSOC WRD South Seepage Point to allow assessment of potential bedrock seepage migration and connectivity with TSF5.
    - Two holes downstream of the TD3 seepage targeting the bedrock aquifer. The purpose of these holes is to assess potential preferential seepage flow paths along an interpreted fault structure and a geophysical anomaly identified in the 2011 electromagnetic geophysical surface (Seepage Investigation – BSOC Waste Rock Dump (MIM, 2014)).
    - Two monitoring bore pairs (i.e. four bores), with each pair comprising a monitoring bore installation in the alluvium and the bedrock aquifers, drilled and installed downstream (to the north-northwest) of the BSOC WRD North Seepage Point to target potential seepage migration in both aquifers. EM31 geophysical survey results indicate an anomaly within this region (Seepage Investigation – BSOC Waste Rock Dump (MIM, 2014)).

    - Two monitoring bore pairs (i.e. four bores), with each pair comprising a monitoring bore installation in the alluvium and the bedrock aquifers, drilled and installed downstream of the BSOC WRD South Seepage Point (to the west) to target potential seepage migration in both aquifers. EM31 geophysical survey results indicate anomalies downstream of the site within the vicinity of the confluence with Hazeldene Creek (Seepage Investigation – BSOC Waste Rock Dump (MIM, 2014)).It is uncertain if these anomalies may be attributed to impacts from upstream of Hazeldene Creek, and these monitoring bore pairs will provide further understanding of the hydrogeology downstream of the South Seepage Point.

- Aquifer Hydraulic Testing
  - Hydraulic testing of the bedrock aquifer will be conducted during drilling by packer testing. Packer testing isolates zones within the drill hole to selectively test for hydraulic conductivity.
  - Testing of the hydraulic conductivity of the alluvial aquifer will be completed with the use of the installed monitoring bores using falling-head/rising-head / slug-testing techniques. MIM hydraulic testing equipment will be used for this program.
  - The hydraulic conductivity of the waste rock material will be tested using a 'soakaway' style test on the BSOC WRD surface. A number of locations (up to six) on the WRD surface will be selected during Phase 1 for testing. This will provide an understanding of the hydraulic conductivity across the facility.
- Sampling
  - Groundwater sampling from each of the installed monitoring bores and WRD seepage sampling will be conducted as part of the Phase 2 program. Sampling and analytical testing will be conducted by MIM personnel Environment Group personnel, consistent with current site procedures. A parameter list for the analytical testing of the collected water samples will be provided by KCB prior to the commencement of sampling. Generally, these parameters will comprise:
    - Physico-chemical parameters
    - Major ionic constituents
    - Metals
    - Nitrogen-species parameters
    - Stable isotopes
    - Organic (pending results of background review of Landfill Sludge Pit inventory)

3.2.3 Analytical Assessment

Interpreted results from the field investigation program will be used to update the preliminary conceptualisation of the project site. Based on the updated conceptualisation, analytical assessments will be conducted to assess the source, cause and extent of the WRD seepage. These analytical assessments include:

- Two-dimensional infiltration/seepage modelling, across up to nine cross-section alignments through the WRD;
- Seepage water quality assessments including geochemical comparisons and source seepage analysis (e.g. mixing models); and,
- Water balance modelling of the BSOC WRD.

These will provide a means to consolidate the physical and chemical characterisation of the WRD seepage. The results of these assessments will be collated, reviewed and interpreted to provide the source, cause and extent of the BSOC WRD seepages.

3.2.4 Impact Assessment

The seepage plume migration map will be used to assess impacts to the receiving environment and associated environmental values. The methodology to undertake the impact assessment is as follows:

- Using a risk-based approach, assess and quantify potential impacts to vegetation communities and conservation of significant flora species known to occur within the delineated impact areas. This analysis will use information from MIM's 2014/15 biodiversity assessment, along with a scientific literature review of potential pathways for plant uptake accumulation and concentration tolerance to each specific contaminant of concern.
- Using a risk-based approach, assess potential impacts to livestock and conservation of significant fauna known to occur in the area. This will use information from the 2014/15 biodiversity assessment, along with an assessment of potential vectors for transport of contaminants within the ecosystem and a scientific literature review of metabolism / ecotoxicology risk for each specific contaminant of concern.

3.2.5 Options Assessment for Prevention/Reduction of Seepage to the Receiving Environment and to Remediate Identified Impacts Areas

The results of the impact assessment will guide the development of the seepage prevention/mitigation strategy; the remediation strategy; and, the design criteria of potential prevention/mitigation and remediation options. Once these strategies have been considered, an assessment of options to address the seepage and remediate the impact will be undertaken. At this point of the investigation, all options, within the design criteria of the adopted strategies and industry-leading practice, will be raised. The range of options will likely include both passive and active systems/infrastructure.

Based on the compiled list of seepage prevention/mitigation options and remediation options, an options assessment matrix will be developed that will provide:

- a brief description of the seepage prevention/mitigation option;
- interpretation of the potential effectiveness of the option (see below);
- the passive or active nature of the options and implications for Capital Expenditure (CAPEX) and Operating Expenditure (OPEX);
- estimated implementation schedule for the option; and,

- compliance of the option against the rehabilitation objectives specified in the MIM Rehabilitation Plan (2014).

Selected seepage prevention/mitigation options will be taken forward to a conceptual design level and to assess implementation requirements. This will allow a more accurate cost estimate (CAPEX and OPEX) and construction/implementation schedule to be developed.

KCB will present results to MIM; the identified options will then be ranked and a preferred option selected will be selected.

3.2.6 Reporting

An Environmental Evaluation report will serve as the key deliverable for this investigation. This report will be provided to EHP in response to the Environmental Evaluation Notice. Key components of the report will include:

- conceptual Environmental Evaluation outline;
- a summary of the information/data reviewed;
- a description of the methodology/approach undertaken;
- analysis and interpretation of the investigation results;
- assessment of potential impacts;
- description of recommended seepage prevention/mitigation options including description of the option, cost for implementation and the schedule for implementation; and,
- description of preferred option/s for remediation of identified impacts to the receiving environment, including costs and timeframe for option/s implementation.

4 EHP CONSULTATION

EHP will be consulted at commencement of the investigation to present the proposed approach and at the completion of the investigation, with the presentation of seepage prevention/mitigation and impact remediation options.

5 DOCUMENT CLOSURE

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of Mount Isa Mines Limited (Client) for the specific application to the Black Star Open Cut Waste Rock Dump Environmental Evaluation. The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this report, Klohn Crippen Berger has endeavoured to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Chris Strachotta
Manager – Strategy & Growth, Australasia

CS:CS

ATTACHMENT A

Notice to conduct or commission an environmental evaluation (EHP, 2014)

APPENDIX II

Site Investigation Report

Klohn Crippen Berger

Mount Isa Mines

BSOC WRD Environmental Evaluation

Site Investigation Report

Final

CANADA'S BEST MANAGED COMPANIES Platinum member

ISO 9001
ISO 14001
OHSAS 18001

D09626A20

March 2016

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Appendix VIII: Phase 2 Groundwater and Seepage Sampling Results

Appendix IX: Waste Rock Dump Photographs

1 INTRODUCTION

Klohn Crippen Berger Ltd (KCB) was commissioned by Mount Isa Mines (MIM) to undertake an Environmental Evaluation investigation regarding seepage at the Black Star Open Cut (BSOC) Waste Rock Dump (WRD). MIM were issued an Environmental Evaluation notice in December 2014 by the Department of Environment and Heritage Protection (EHP), requiring an environmental investigation into the release of contaminants through surface and sub-surface flows from the BSOC WRD.

As part of the Environmental Evaluation project, site investigations were undertaken in August and December, 2015 with the aim of addressing data gaps identified as part of the preliminary site understanding and data gap assessment (KCB, 2016).

This deliverable reports two phases of site investigation as part of Task 3, identify the source, cause and extent:

- Phase 1: Site observations and field mapping, undertaken in August, 2015.
- Phase 2: Drilling, testing and sampling, undertaken in December, 2015 by KCB personnel and January, 2016 by MIM personnel.

It should also be noted that this report is a factual report and presents only the data collected and analysis of results. Interpretation of this information will be included in the Task 7 – Reporting deliverable (final report).

2 PHASE 1 SITE INVESTIGATION

2.1 Overview

The Phase 1 site investigation was completed between August 24, and August 28, 2015. The aim of the Phase 1 investigation was to undertake observations of the project site and conduct a field mapping exercise. The investigations included inspection of site infrastructure and an assessment of any potential evidence of seepage in and/or from the following locations:

- MIM Landfill and Sludge Pits;
- BSOC WRD upper surface;
- BSOC WRD toe;
- Northern extent of TSF5;
- King Gully Dam;
- King Gully Pond and downstream watercourses; and,
- BSOC WRD Diversion Drain.

Field mapping was also conducted during the Phase 1 investigations and included:

- Mapping of the alluvial extent;
- Mapping of seepage locations;
- Visual assessment of seepage extent and impact; and,
- Mapping of potential flow paths within the bedrock aquifer.

During the Phase 1 site investigation, soil and water samples were collected from selected locations across the study area, and points of interest were mapped. Photographs from the Phase 1 investigation are provided in Appendix I. Further discussion on the site investigation and results of the sampling and mapping is included in the following sections.

During the site investigation, preliminary locations for drilling and bore installations, to be conducted as part of the Phase 2 site investigation, were selected. Drilling contractor accessibility and logistics issues associated with establishing site access were also identified to allow ground preparations prior to the Phase 2 program.

2.2 Site Observations and Field Mapping

Site observations and field mapping conducted across the study area focussed on the various site infrastructure associated with the BSOC WRD seepage; downstream water courses where evidence of seepage is anticipated to be present; and, bedrock outcrops along “breaks-in-slope” (abrupt change in topography) where potential bedrock seepage is anticipated to be present.

Soil and water samples were collected during the site observation and field mapping program to support the characterisation of potential seepage and identify background (non-impacted) concentrations. A total of nine water samples and fourteen soil samples were collected during the Phase 1 site investigation. Further details of these water and soil samples are provided in Section 2.3.

The alluvium aquifer associated with the water courses downstream of the BSOC WRD has been identified as a potential pathway for WRD seepage migration. Therefore, mapping the extent of the alluvium downstream of the WRD and the morphology of the alluvium relative to the BSOC WRD Diversion Drain was a critical component to this investigation. Figure 1 presents the extent of the alluvium aquifer within the study area.

Mineral precipitation on the alluvium and bedrock surfaces were observed across the study area. The presence of precipitation may represent evidence of WRD seepage, however, natural precipitation on bedrock surfaces has previously been identified across the MIM site. As a result, soil samples were collected from the identified precipitation locations and from background locations to support the assessment of the WRD seepage extent. A summary of the soil sampling results and locations are presented in Section 2.3.2.

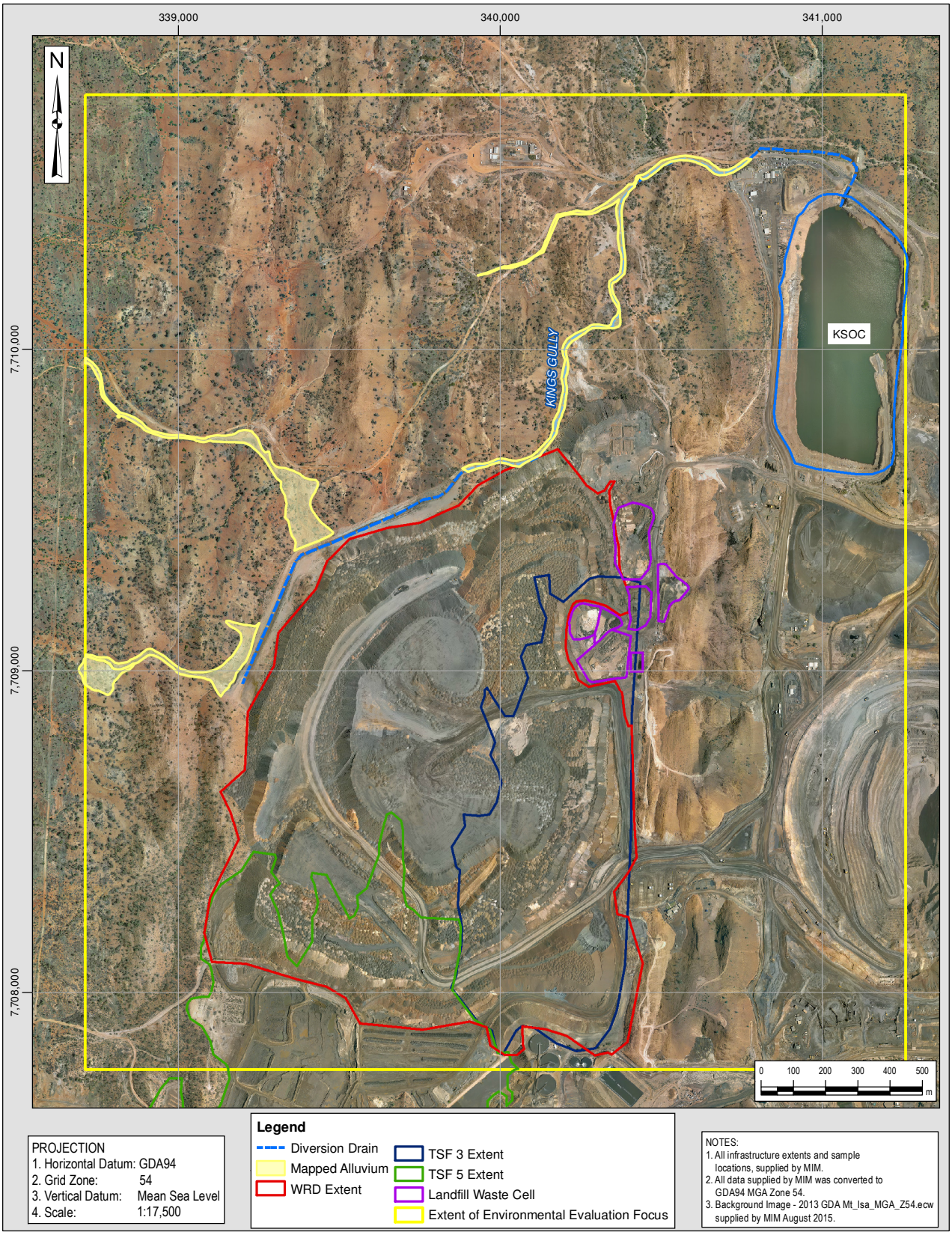

Figure 1: Location of Mapped Alluvium

2.3 Sample Collection

Water and soil samples were collected during the Phase 1 site investigation. The samples were dispatched to ALS Environmental Division in Brisbane for analysis. Certificates of analysis for the samples are presented in Appendix II, with further detail provided in the following sections.

2.3.1 Water Samples

Water samples were collected from nine locations across the study area. Sample locations are shown in Figure 2 with location details and sample names provided in Table 1.

Table 1: Water Sample Location Details

Location Description	Sample ID	Easting	Northing
		m	*m*
BSOC South Toe	WRD_Sth_2	339224	7708902
BSOC WRD South Seepage	WRD_Sth_3	339214	7708859
	WRD_Sth_4	339245	7708923
BSOC WRD North Seepage (downstream)	WRD_Nth_1	339510	7709429
TD3 Seepage (upstream)	TD3_Sth_1	339884	7709620
	TD3_Sth_2	340050	7709641
TD3 seepage	TD3_Seepage	340115	7709666
Water pooling at confluence of Kings Gully and tributary	TD3_Nth_4	340356	7710456
Downstream of Dyno. Pool in alluvium	KG_DS_1	340572	7710599

The samples were analysed for the following parameters:

- Physico-chemical parameters: pH, EC (at 25°C).
- Major and minor ionic species: calcium, magnesium, sodium, potassium, sulphate as SO_4 (turbidimetric), chloride, fluoride, bromide, and total alkalinity (as $CaCO_3$).
- Dissolved metals and metalloids: aluminium, antimony, arsenic, bismuth, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, strontium, thorium, uranium, vanadium, and zinc.
- Dissolved non-metals: ammonia [as nitrogen (N)], nitrate (as N), total nitrogen (as N), and silica.

A summary of the location details, field water quality parameters and selected ions and metals is presented in Table 2.

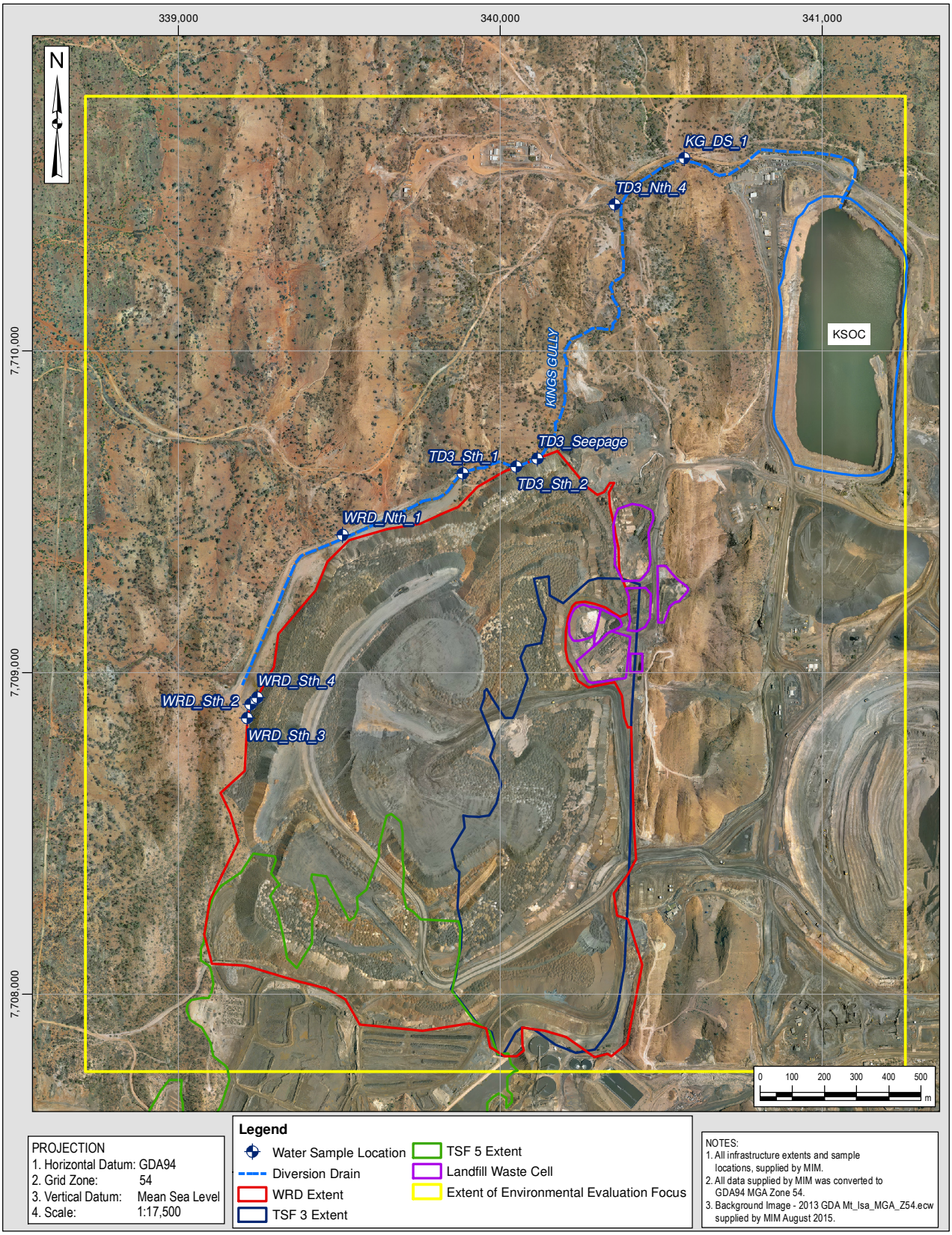

Figure 2: Phase 1 Water Sampling Locations

Table 2: Summary of Phase 1 Water Sample Results

Sample ID	Temp	pH	EC	SO_4	F	Al	As	Cd	Co	Cu	Pb	Ni	Zn
	°C	*-*	*µS/cm*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*
WRD_Sth_2	19.7	8.64	12,828	9,460	2.7	0.06	0.018	0.0026	0.002	0.158	0.03	0.002	0.245
WRD_Sth_3	28.1	8.24	7,099	3,130	5.7	0.18	0.003	0.0003	<0.001	0.018	0.008	<0.001	0.01
WRD_Sth_4	23.0	8.64	15,630	9,820	4.5	0.02	0.008	0.0018	0.002	0.048	<0.05	0.001	0.015
WRD_Nth_1	29.4	8.69	15,161	6,240	3.9	0.06	0.011	0.0017	<0.001	0.048	0.07	<0.001	0.032
TD3_Sth_1	29.5	8.80	5,535	1,130	1.8	0.02	0.003	0.0006	<0.001	0.032	0.009	<0.001	0.012
TD3_Sth_2	34.7	8.98	20,040	6,320	3.9	2.17	0.058	0.0048	0.007	0.825	0.272	0.005	0.476
TD3_Seepage	28.6	7.32	15,306	9,440	1.3	<0.05	<0.005	0.0426	0.007	0.019	<0.005	0.0045	9.57
TD3_Nth_4	19.0	8.42	24,339	16,700	2.4	<0.05	0.024	0.0035	<0.005	0.211	0.075	<0.005	0.092
KG_DS_1	23.8	9.24	8,924	900	6.2	0.05	0.054	0.0011	0.002	0.217	0.064	<0.001	0.031

Metals as total
Temperature, pH and EC measured in the field

2.3.2 Soil Samples

Details of the sample locations are provided in Table 3 and locations are shown on Figure 3. Analysis of the soil samples included the following parameters:

- Physico-chemical parameters: pH, EC (at 25°C), moisture content (dried at 103°C).
- Soluble major ionic species: calcium, magnesium, chloride, sodium, potassium, chloride, sulphate as SO_4.
- Total Metals: aluminium, boron, iron, arsenic, selenium, silver, barium, thallium, beryllium, cadmium, bismuth, cobalt, chromium, copper, thorium, manganese, strontium, molybdenum, nickel, lead, antimony, uranium, zinc, lithium, vanadium, tin.
- Nitrogen species: ammonia as N, nitrite as N, nitrate as N, total nitrogen as N, total Kjeldahl nitrogen.

A summary of the results for selected analytes are presented in Table 4, with full sample results provided in Appendix II.

Table 3: Description and Location Details of Soil Samples

Sample ID	Location Description	Easting	Northing
		m	*m*
WRD_Sth_Dn_1	Soil sample taken from alluvial tributary downstream of BSOC WRD South seepage, close to the MIM boundary	338681	7709026
WRD_Sth_Dn_2	Soil sample taken from alluvial tributary downstream of BSOC WRD South seepage	338860	7708992
WRD_Sth_Dn_3	Soil sample taken from alluvial tributary downstream of BSOC WRD South seepage, east of the diversion drain / south sump.	339110	7708943
WRD_Nth_Drain_2	Soil sample taken from alluvial tributary downstream of BSOC WRD North seepage. Precipitate was identified on the northern creek bed	339323	7709607
WRD_Nth_Drain_4	Soil sample taken from alluvial tributary downstream of BSOC WRD North seepage, close to the MIM boundary	338652	7709968
WRD_Nth_Drain_5	Soil sample taken from alluvial tributary downstream of BSOC WRD North seepage, upstream from confluence with main channel	339385	7709571
BSOC WRD Drain NW_1	Soil sample taken from northwestern side of the collection pit, adjacent to BSOC WRD North seepage	339428	7709405
KG_Clean_1	Soil sample taken from within the King Gully clean catchment. Location identified as an inferred fault / conduit	339951	7710240
KG_Clean_2	Soil sample taken from within the King Gully clean catchment. Location identified as an inferred fault / conduit	340117	7710303
KG_Clean_3	Soil sample taken from within the King Gully clean catchment, on the south side of King Gully. Location of weathered sediments in contact with coarse intrusive and alluvium	340117	7710295
KG_Clean_4	Soil sample taken from within the King Gully clean catchment, on the southern bank of alluvium with precipitate present	340190	7710393
KG_Clean_5	Soil sample taken from a notable precipitate zone, around 30m upstream of pool-confluence	340272	7710396
KG_Clean_6	Soil sample taken from within the King Gully clean catchment, sample with precipitate crust, located at confluence and pool	340345	7710410
Dyno_1	Soil sample taken from bedrock (schist, quartzite) / alluvial interface with precipitation, southeast of Dyno Nobel facility	340220	7710530

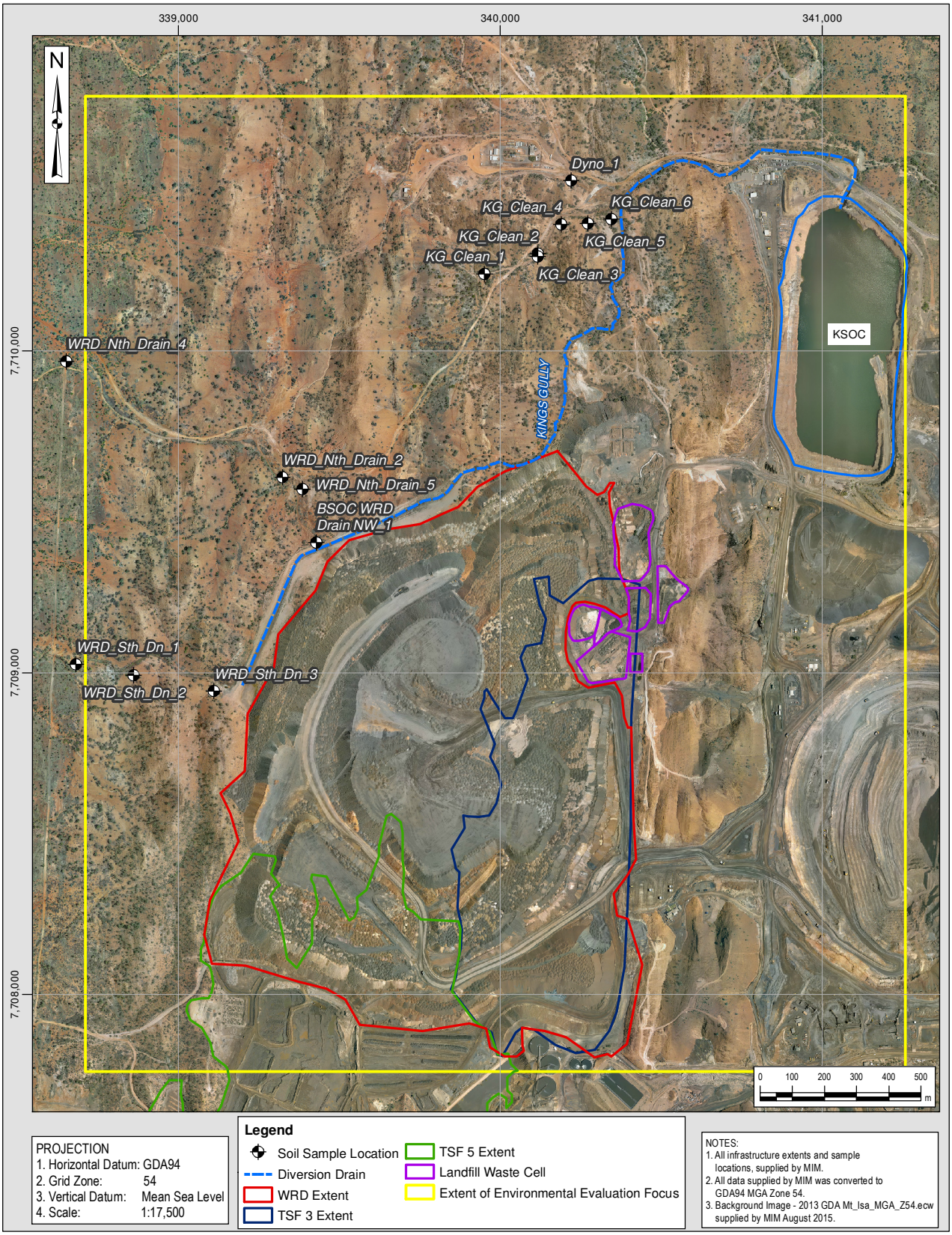

Figure 3: Phase 1 Soil Sampling Locations

Table 4: Summary of Phase 1 Soil Sample Location Details and Results

Sample ID	pH	EC	SO_4	Ca	Mg	Na	K	Cu	Pb	Zn
	-	*µS/cm*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
WRD_Sth_Dn_1	8.6	90	90	30	30	10	10	489	145	97.9
WRD_Sth_Dn_2	8.9	3,290	7,920	80	1,520	3,510	700	2,110	609	356
WRD_Sth_Dn_3	7.8	43,900	245,000	1660	33,600	63,800	7,160	400	635	813
WRD_Nth_Drain_2	9.4	14,300	55,000	700	6,840	15,200	430	222	104	103
WRD_Nth_Drain_4	8	79	120	40	60	90	20	241	102	80
WRD_Nth_Drain_5	8.5	168	270	90	30	40	10	373	138	119
BSOC WRD Drain NW_1	6.8	31,000	61,500	4,040	18,500	21,800	300	1,210	634	410
KG_Clean_1	9.3	97	190	60	30	50	10	261	82	69
KG_Clean_2	10.5	38,800	91,500	30	10	73,400	920	534	132	162
KG_Clean_3	10.2	7,430	17,600	160	190	10,300	320	443	149	144
KG_Clean_4	9.8	17,900	45,300	40	60	25,700	1,540	1,660	505	530
KG_Clean_5	9.8	6,730	17,200	580	490	7,740	130	364	142	146
KG_Clean_6	9.2	24,100	91,700	2,420	8,300	27,300	1,170	495	173	145
Dyno_1	9.9	28,800	44,000	30	10	53,600	1,530	438	137	113

2.3.3 MIM Landfill and Sludge Pits

The landfill and sludge pits were visited on August 24, 2015. Figure 4 shows the location of the landfill and sludge pits and selected photographs from this location.

Water samples were collected from both sludge pits. Certificate of analysis for these samples are presented in Appendix II, with a summary of selected parameters provided in Table 5.

Table 5: Summary of Sludge Pit Sample Results

Analyte	pH	EC	SO_4	F	Al	As	Cd	Co	Cu	Pb	Ni	Zn
Unit	pH units	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Sludge Pit 1	9.03	28,700	13,400	3.3	0.11	1.45	0.15	0.027	0.187	1.12	0.124	0.607
Sludge Pit 2	5.43	4,650	2,540	6.3	2.59	0.858	2.66	0.568	44.2	3.51	0.446	15.3

Metals as total
EC and pH – lab values

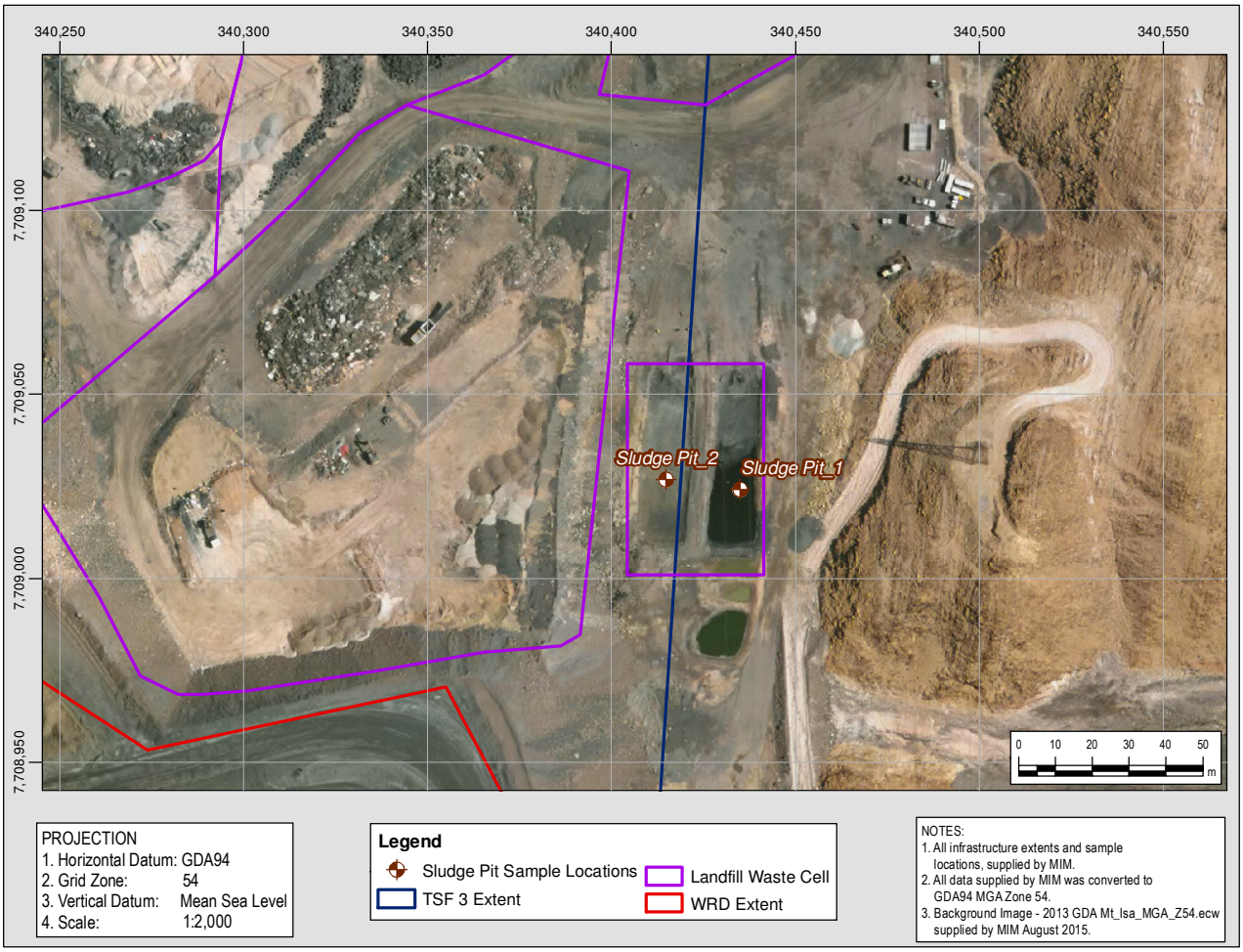

Figure 4: Landfill and Sludge Pit Locations

3 PHASE 2 SITE INVESTIGATION

3.1 Overview

The Phase 2 site investigation was completed between December 7, and December 22, 2015 by KCB Hydrogeologists. Additional components were conducted in January and February, 2016 by MIM personnel. The Phase 2 site investigation comprised the following:

- Drilling and construction of six bedrock monitoring bores;
- Packer testing of the bedrock bores, with two to three tests conducted per hole;
- Drilling and construction of five alluvial monitoring bores located within the creek beds;
- Development of the 11 new bores (conducted by MIM personnel);
- Aquifer testing of existing monitoring bores (conducted by MIM personnel);
- Groundwater sampling of the new monitoring bores (conducted by MIM personnel); and,
- Infiltration testing on the WRD.

The following sections provide details and results of each of the Phase 2 site investigation components.

3.2 Drilling Program

3.2.1 Drilling Target Selection

The drilling targets were selected based on the conceptual understanding of the site developed during the data gap assessment (KCB, 2016) and the findings from the Phase 1 site investigation as described previously. Table 6 provides details of the rationale for each of the drilling targets with their final locations shown Figure 5.

Table 6: Drilling Target Rationale

Target Aquifer	Bore ID	Rationale
Alluvium	BSOC_A1	To investigate seepage movement through the alluvial aquifer associated with BSOC WRD South Seepage and the diversion drain
	BSOC_A2	
	BSOC_A3	To investigate seepage movement through the alluvial aquifer associated with BSOC WRD North Seepage and the diversion drain
	BSOC_A4	
	BSOC_A5	To investigate seepage movement through the alluvial aquifer associated with TD3 Seepage, downstream of King Gully Dam
Bedrock	BSOC_B1	To investigate seepage movement through the bedrock aquifer associated with BSOC WRD South Seepage
	BSOC_B2	To investigate seepage movement through the bedrock aquifer associated with BSOC WRD North Seepage
	BSOC_B3	To investigate seepage movement through the bedrock aquifer associated with BSOC WRD North Seepage
	BSOC_B4	To investigate seepage movement through the bedrock aquifer associated with BSOC WRD North Seepage
	BSOC_B5	To investigate seepage movement through the bedrock aquifer associated with TD3 Seepage
	BSOC_B6	To investigate seepage movement through the bedrock aquifer and possible fault structure

Figure 5: BSOC EE Bore Drilling Locations

3.2.2 Drilling and Construction

The drilling program was completed between December 10, and December 20, 2015 by Tulla Drilling, under the supervision of a KCB Hydrogeologist. Location, drilling and construction details are presented in Table 7.

Table 7: Location and Completion Details for Monitoring Bores

Target Aquifer	Bore ID	GDA94 MGA Zone 54*		Ground Elevation* (mAHD)	Stick up (m)	Drilled Depth (mbGL)	Water Strike (mbGL)	Screened Interval (mbGL)	Screened Geology
		Easting (m)	Northing (m)						
Alluvium	BSOC_A1	338873	7709022	368	0.94	4	-	1.3 to 2.8	Alluvium, clayey gravel
	BSOC_A2	339122	7708981	375	0.70	10	7	3.6 to 9.6	Alluvium, silty gravel
	BSOC_A3	339373	7709550	378	0.94	5.5	-	0.8 to 2.8	Alluvium, clayey gravel
	BSOC_A4	338990	7709729	366	0.84	5.0	-	0.7 to 1.7	Alluvium, gravel and sand
	BSOC_A5	340475	7710561	362	0.85	5.0	-	0.5 to 1.5	Alluvium, gravel and sand
Bedrock	BSOC_B1	339153	7708920	384	0.75	29.2	9	11.0 to 29.0	Metasediments, fresh, fractured
	BSOC_B2	339177	7709783	388	1.06	26.2	9	7.8 to 25.8	Metasediments, fresh, fractured
	BSOC_B3	339446	7709681	381	0.29	35.3	20	17.2 to 35.2	Metasediments, fresh, fractured
	BSOC_B4	339676	7709695	386	1.11	36.3	20	18.3 to 36.3	Metasediments, fresh, fractured
	BSOC_B5	340255	7710381	367	1.07	35.0	14	14.3 to 32.3	Metasediments, fresh, fractured
	BSOC_B6	340189	7710685	369	0.75	72.0	42	37.0 to 55.0	Metasediments, fresh, fractured

* Bores surveyed using MIM handheld GPS.

Drilling was performed using a Verasdrill rig (TD05) using a 123mm hammer bit, with the exception of BSOC_B4, which was drilled using a poly-crystalline diamond (PCD) drill bit. Drilling cuttings were returned to the surface using air circulation, with the addition of water[1] to BSOC_B3 and BSOC_B2 to aid removal of the drill cuttings.

The final depth of the drill hole was determined based on the first water strike interval with an additional 18m of drilling to allow for installation of the slotted screen over the water inflow zones. Cuttings were collected and logged at 1m intervals. Photographs of drill cuttings are included in Appendix IV, with geological logs and detailed bore schematics provided in Appendix III.

Bores were constructed with 50 mm uPVC Class 12 threaded plain casing and 1mm aperture machine slotted casing. A gravel pack was installed adjacent to the screens and a bentonite seal placed on top. Backfill was then installed to ~6mbGL and a cement grout to surface. Protective bore monuments and a 2m x 2m plinth for each site were also constructed. All bores were

[1] Water was sourced from the Dyno Nobel facility. Water Quality was 26.8°C, 453µS/cm and 8.37pH

constructed in accordance to the 'Minimum Construction Requirements for Water Bores in Australia' (NUDLC, 2012).

3.2.3 Airlift Development

Airlift development was completed by MIM personnel on January 14 and January 15, 2016. The development procedure involved delivering compressed air into each bore via a HDPE hose, allowing air / water to be lifted and directed away from the bore. Field water quality parameters (pH, EC, temperature, DO, ORP) were recorded during the development process. Development was determined to be complete once the field water quality readings had stabilised over at least a five minute interval and the fines content had significantly reduced.

A summary of the final water quality parameters is provided in Table 8, with full development records provided in Appendix V.

Table 8: Summary of Airlift Development

Bore ID	Approximate Volume Removed (L)	Field Water Quality Parameters			Observations at Completion of Airlifting
		EC (µS/cm)	pH	Temperature (°C)	
BSOC_A1	21	3,005	9.02	27.2	-
BSOC_A2	720	10,667	8.12	28.9	Light brown, sandy colour, not many fines
BSOC_A3	42	4,745	8.76	26.7	Milky, sandy colour, no fines
BSOC_A4	4	2,918	8.60	26.5	Coffee coloured, not many fines
BSOC_A5	28	16,173	8.29	28.7	Sandy / grey colour, not many fines
BSOC_B1	1,800	4,430	8.18	29.8	Clean and clear
BSOC_B2	1,320	1,315	7.58	29.5	Clear water, no fines
BSOC_B3	300	3,469	8.44	29.4	Light grey colour, not many fines
BSOC_B4	172	1,334	8.77	30.0	Grey colour, not many fines
BSOC_B5	1,300	5,685	8.22	30.0	Light grey colour, no fines
BSOC_B6	321	6,117	9.05	29.6	Grey, brown colour, not many fines

3.2.4 Groundwater and Seepage Sampling

Following completion of airlift development, groundwater samples were collected by MIM personnel from the new monitoring bores and dispatched under chain of custody protocol to ALS for analysis. A summary of the field water quality parameters and results of the sample analysis are presented in Table 9. Samples were also collected from BSOC WRD South Seepage and TD3 Seepage. BSOC WRD North Seepage was not flowing at the time of sample collection.

Isotope sampling was also carried out on the new monitoring bores, seepage locations and selected existing monitoring bores.

The samples were collected and sent to the University of Queensland for analysis for hydrogen (^{1}H and Deuterium) and Oxygen ($^{16}O/^{18}O$), and sulphur isotope ^{34}S. At the time of this report issue, sample results were still pending and will be discussed in detail in the Task 7 report.

Table 9: Summary of Phase 2 Groundwater and Seepage Sampling Results

Sample Type	Sample ID	Date Sampled	Field Parameters*			Laboratory Results									
			Temp	pH	EC	SO_4	F	Al	As	Cd	Co	Cu	Pb	Ni	Zn
	Unit			-	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Groundwater	BSOC_A1	19/1/16	32.9	8.66	3,933	576	2.3	0.9	0.003	<0.0001	<0.001	0.005	<0.001	<0.001	<0.005
	BSOC_A2	19/1/16	29.4	7.18	12,753	5,580	6.4	2.20	0.002	<0.0001	<0.001	0.005	0.002	0.002	0.006
	BSOC_A3	21/1/16	33.7	8.23	5,830	727	3.4	25.8	0.007	<0.0001	<0.001	0.049	0.002	<0.001	<0.005
	BSOC_A4	Dry	-	-	-	-	-	-	-	-	-	-	-	-	-
	BSOC_A5	19/1/16	34.8	7.39	16,048	4,870	5.1	18.5	0.014	0.0001	0.004	0.002	0.002	0.003	0.015
	BSOC_B1	20/1/15	30.7	7.28	5,372	1,760	5.3	1.51	<0.001	<0.0001	<0.001	0.001	<0.001	<0.001	0.007
	BSOC_B2	20/1/15	30.1	6.93	1,346	152	1.8	0.35	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.006
	BSOC_B3	20/1/15	30.0	7.13	3,926	182	5.3	0.39	<0.001	<0.0001	<0.001	0.005	0.004	<0.001	0.022
	BSOC_B4	21/1/16	36.7	8.33	3,699	320	4.1	0.68	0.010	<0.0001	<0.001	<0.001	<0.001	<0.001	<0.005
	BSOC_B5	20/1/16	30.6	7.13	6,364	1,410	6.1	0.35	0.011	<0.0001	<0.001	<0.001	<0.001	<0.001	0.006
	BSOC_B6	21/1/16	35.0	8.79	6,224	413	4.7	4.15	0.012	<0.0001	<0.001	0.038	0.004	0.001	0.005
Seepage	BSOC WRD South Sump	25/1/16	32.2	8.57	18,600	11,900	3.9	0.1	0.092	<0.0001	0.002	0.067	0.004	0.002	0.008
	BSOC WRD South Seepage	25/1/16	30.8	8.31	12,000	8,030	4.6	0.12	0.005	0.0011	0.002	0.051	0.019	0.002	0.036
	TD3 Seepage	25/1/16	28.3	7.76	11,900	8,720	1.4	0.03	0.002	0.0344	0.002	0.026	0.009	0.036	7.59
	TD5 Pit	29/1/16	-	8.38	15,700	7,920	5.3	0.07	0.02	0.0011	0.046	0.034	0.039	0.013	0.126

*Seepage Samples – EC / pH laboratory values
Metal as total

3.2.5 Groundwater Levels

Groundwater levels were collected from the new bores by MIM personnel before groundwater sampling took place between January 19 and 21, 2016 and are presented in Table 10.

Table 10: BSOC EE and Existing Bores - Groundwater Levels

Bore ID	Easting	Northing	Ground Elevation (Lidar) (mAHD)	Stick-up (m)	Groundwater Levels			
					19-21 January 2016		27 January 2016	
					mbGL	mAHD (Lidar)	mbGL	mAHD (Lidar)
Bore 23	340150	7709794	368.54	0.95	-	-	1.44	367.10
Bore 24	340152	7709805	368.38	0.95	-	-	1.38	367.00
Bore 27	341033	7710520	357.07	0.72	-	-	11.06	346.01
Bore 29	341032	7710642	351.98	0.73	-	-	4.71	347.27
Bore 36	338325	7705939	377.94	0.54	-	-	4.71	373.23
Bore 37	338469	7706973	380.09	0.57	-	-	8.43	371.66
Bore 38	338467	7707626	370.86	0.56	-	-	4.51	366.35
Bore 39	338605	7709065	366.95	0.57	-	-	4.85	362.10
Bore 40	338940	7709746	368.33	0.48	-	-	5.43	362.90
Bore 4A	338035	7707765	366.75	0.17	-	-	6.14	360.61
S2 / MIOP01	340279	7710441	360.20	0.44	-	-	1.63	358.57
S3	338118	7707757	367.11	0.44	-	-	6.11	361.00
S8	338684	7709024	367.94	0.80	-	-	6.2	361.74
MIOP02	338847	7710387	367.76	0.74	-	-	11.91	355.85
MIOP03	338517	7710037	365.58	0.73	-	-	12.54	353.04
BSOC_A1	338873	7709022	371.38	0.94	0.81	370.57	0.87	370.51
BSOC_A2	339122	7708981	375.02	0.70	2.00	373.02	1.35	373.67
BSOC_A3	339373	7709550	374.23	0.94	2.37	371.86	2.41	371.82
BSOC_A4	338990	7709729	368.14	0.84	Dry	Dry	1.8	366.34
BSOC_A5	340475	7710561	356.72	0.85	0.74	355.98	0.69	356.03
BSOC_B1	339153	7708920	380.38	0.75	5.82	374.56	5.87	374.51
BSOC_B2	339177	7709783	375.77	1.06	6.62	369.15	5.59	370.18
BSOC_B3	339446	7709681	379.06	0.29	4.93	374.13	4.83	374.23
BSOC_B4	339676	7709695	385.43	1.11	11.24	374.19	11.07	374.36
BSOC_B5	340255	7710381	363.83	1.07	5.69	358.14	4.99	358.84
BSOC_B6	340189	7710685	366.31	0.75	7.18	359.13	7.13	359.18

Groundwater levels were also collected across all new and existing bores within the vicinity of the WRD on January 27, 2016 by MIM personnel. These levels are also shown in the table and presented spatially on Figure 6.

It should be noted that the ground elevation presented in the table and referenced for groundwater elevations has been extracted from the MIM Lidar (2010) surface. This elevation was selected to maintain consistency across all bores[2] and for use in future tasks for this project.

[2] Elevations on existing bore logs may contain errors or are presented using an alternative height datum.

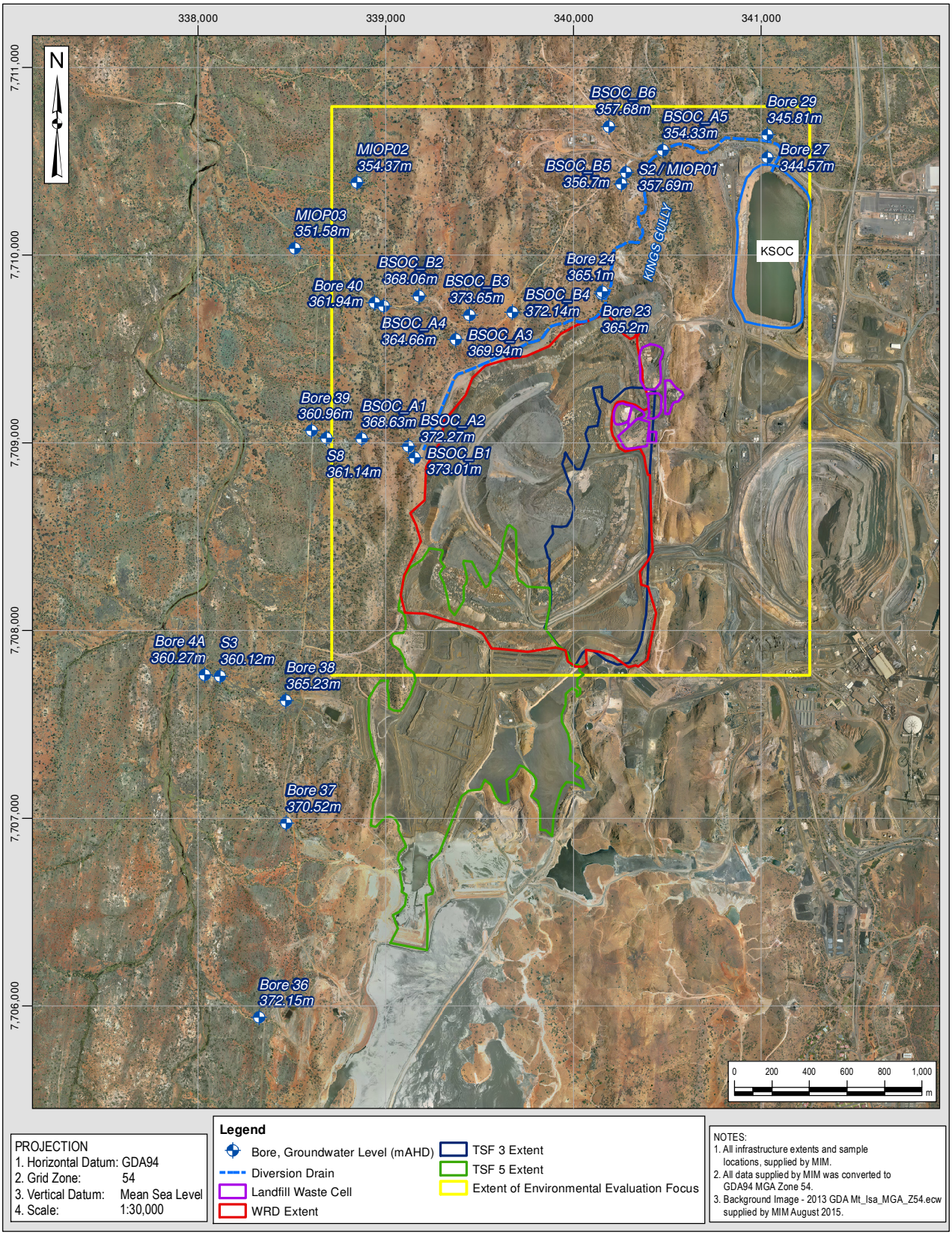

Figure 6: Groundwater Levels (January 2016)

3.3 Permeability Testing - Packer Testing

3.3.1 Overview

Borehole packers are designed to enable permeability testing in open holes and/or discrete test sections. Inflatable packers are used to seal off (isolate) the desired section of the hole prior to testing. To carry out the test, drill rods are inserted to the selected depth and packers sit beneath the drill rods. The packers are used to seal off an open section of the hole for testing and inflated using nitrogen gas. Once the packers are inflated and the selected interval isolated, hydraulic testing is undertaken by injecting water into the formation under constant pressure, with a measurement of the average stabilised flow rate (or water consumption) at the test pressure. This is repeated at a number of different pressure steps to measure the formation response at different pressures (Lugeon Tests). The resulting data are used to calculate a transmissivity of the test interval and consequently the hydraulic conductivity of the formation.

For this program a wireline straddle packer system (hired from AGE Developments Pty) was used. Drill rods of HWT size were installed in the hole, with a PQ size packer system. Water was injected into a 2 m section of the drill hole at three ascending pressure steps and two descending pressure steps.

Testing was undertaken on five of the bedrock bores, with two or three tests carried out per hole. Testing was not completed on BSOC_B6 due to problems with the packer equipment. The testing intervals were selected based on the drill cuttings and airlift yields or water inflow zones identified during drilling. A summary of the tests and results for each bores are provided in the following sections, with the full results for each hole presented in Appendix VI.

3.3.2 Data Evaluation

The following section provides some information relating to the data evaluation of packer tests:

- ***Lugeon Value Calculation and Interpretation:*** Lugeon values for each time step were calculated using the method of Houlsby (1976). Houlsby presents a method for calculating and interpreting Lugeon values based on 811 actual field tests. The method involves calculation of individual values at a range of five ascending and descending pressure steps. The magnitude of the Lugeon value defines a Lugeon pattern that can be interpreted as representing one of five flow regimes: Laminar, Turbulent, Dilation, Washout and Void Filling.
- ***Flow versus Pressure Curves*** are generated by plotting the recorded average flow for each pressure step versus pressure over time. The shape of these curves can provide information about the hydraulic system of the test interval.
- ***Hydraulic Conductivity:*** Bulk rock mass permeability has been estimated using solutions by Houslby (1976) and Thiem (1906). The Thiem method is a steady state solution which is recommended by the United States Bureau of Reclamation (USBOR) “Earth Manual” (1965). The Thiem solution requires estimation of the test radius of influence (R). The USBOR method in common use assumes that R = the length of the test interval, and uses the term ‘L’ to represent both the length of the test interval and the radius of influence. This assumption has been adopted for calculation of hydraulic conductivity using the Thiem method.

3.3.3 Testing and Results

A summary of the bore specific testing and an estimate of the average hydraulic conductivity for each testing interval are presented in Table 11. The table includes each interval tested and a description of the interval. Full results for each test are presented in Appendix VI.

Table 11: Summary of Packer Testing Intervals and Average Hydraulic Conductivity

Bore ID	Test Interval Depth (mbGL)	Interval Description	Average Hydraulic Conductivity (m/d)	
			Thiem (1906)	Houlsby (1976)
BSOC_B1	12.9 to 14.9	Water inflow zone, with yield increase observed during drilling at ~14m	0.32	0.25
	22.9 to 24.9	Fresh bedrock, with little or no fracture evidence	0.006	0.005
BSOC_B2	7.9 to 9.9	First water strike, less than 0.2 L/s. Meta-sediments, moderately weathered, strong evidence of water contact	1.58	1.23
	13.9 to 15.9	Increase in yield observed at this depth and continuous flow from airlift sustained	1.3	1.01
	20.9 to 22.9	Quartzite with potential matrix flow and an increase in yield to 1.6 L/s observed during airlifting.	0.04	0.03
BSOC_B3	19.9 to 21.9	First water strike interval	0.09	0.07
	24.4 to 26.4	Fresh bedrock with limited fracturing	0.003	0.002
BSOC_B4	18.9 to 20.9	First water strike interval	0.21	0.16
	27.2 to 29.2	Fresh bedrock with evidence of fracturing	0.001	0.001
	32.2 to 34.2	Fresh bedrock, with schist (very weak) layers. No evidence of fracturing or matrix flow	0.004	0.003
BSOC_B5	12.8 to 14.8	First water strike interval	0.12	0.08
	18.9 to 20.9	Fresh rock with no evidence of fracturing	0.004	0.003
	28.7 to 30.7	Significant water inflow zone identified during drilling at ~30m.	0.68	0.53

3.4 In-situ Permeability Testing

Hydraulic (slug) testing was completed on existing MIM monitoring bores by MIM personnel between 2 February and 25 February, 2016, to provide estimates of hydraulic conductivity. The location of the bores tested are presented in Figure 7.

A slug of known volume was either added to the monitoring bore (falling head test) or removed from the bore (rising head test), and the change in water level was measured using a pressure transducer data logger (PTDL) until the water level had recovered to at least 95% of the original level. Where high to moderate conductivity was observed, three sets of falling head / rising head tests were completed per monitoring bore to provide multiple data sets to assess for consistency in aquifer responses. If the recovery period was slow, one test was completed.

The raw data for each falling head test and rising head test was plotted as pressure head versus time. The raw data was then converted to deviation from static (or displacement) versus time. A normalised deviation plot is then created by dividing deviation from static by the maximum displacement.

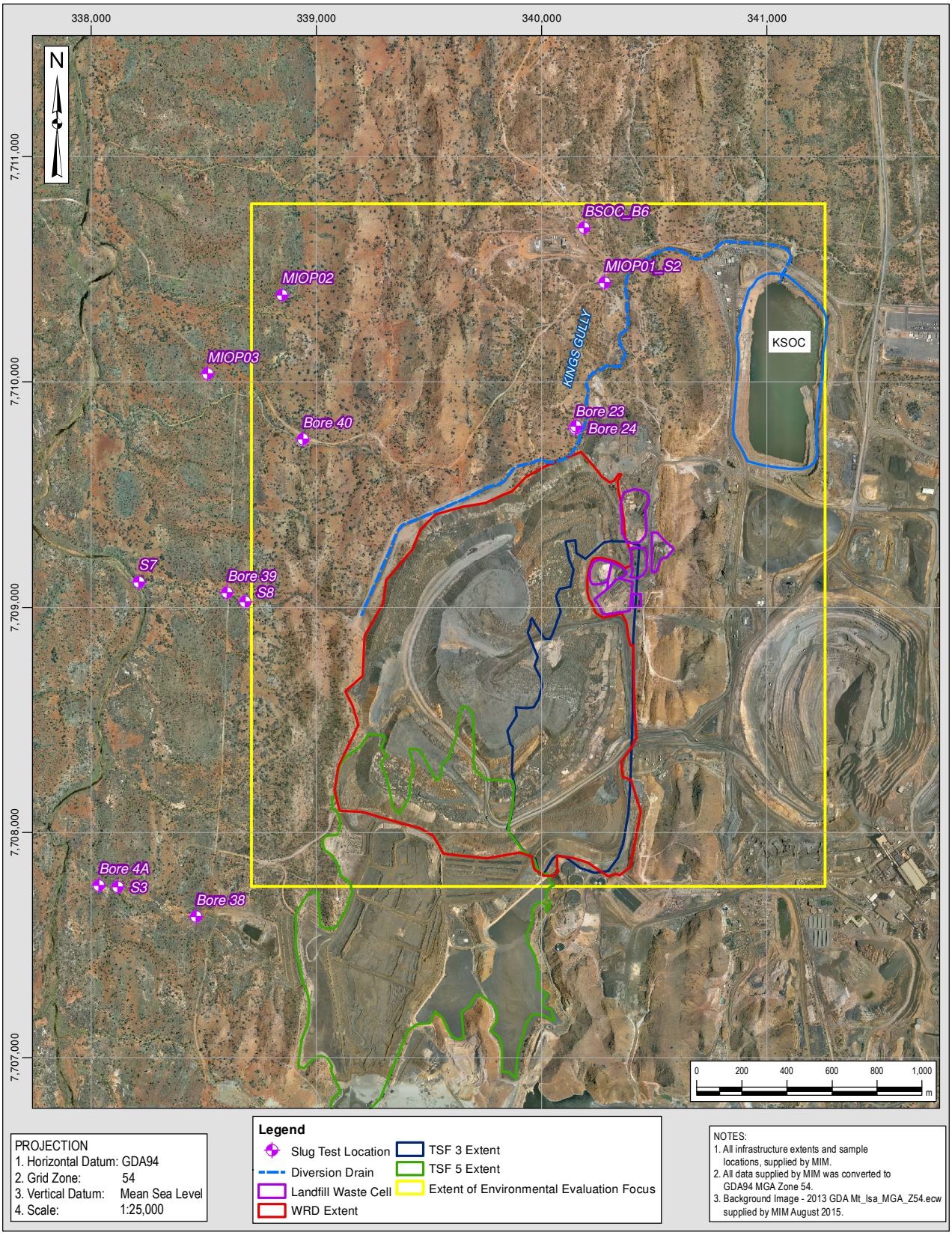

Figure 7: Location of In-situ Permeability Testing

The normalised head versus time plots were reviewed to determine if there were any issues apparent with the tests[3]. Theoretical examples of common issues to look out for in the normalised head plots include non-instantaneous introduction of the slug (which needs to be corrected), removal of the data logger during the test and a lack of coincidence in repeat tests indicating insufficient development of the well.

Hydraulic conductivity values were calculated using AQTESOLV Pro v4.5 software. Analytical solutions were selected based on underlying analytical assumptions, specific well conditions, and aquifer responses (Butler, 1998). Estimates of hydraulic conductivity are summarised in Table 12 with interpretations obtained from the AQTESOLV Pro v4.5 software included in Appendix VII.

The majority of tests were analysed using the Bouwer and Rice (1976), KGS Model (Hyder et al., 1994) methods and Hvorslev (1951). If bores are screened across the water table these required additional compensation to account for the effective screened interval using Bouwer and Rice (1976) as described in Butler (1998).

Table 12: Estimates of Hydraulic Conductivity

Bore ID	Screened Interval (mbGL)	Assumed Geology	Aquifer Model	Analysis Method	Average Hydraulic Conductivity (m/d)
BSOC_B6	37.0 to 55.0	Bedrock	Confined	KGS Model	0.0006
Bore 23	4.0 to 8.0	Weathered Bedrock	Unconfined	KGS Model	2.0
Bore 24	40.0 to 58.0	Bedrock	Confined	Hvorslev	0.07
Bore 38	29.0 to 37.0	Bedrock	Confined	Hvorslev	0.0006
Bore 39	18.5 to 24.5	Bedrock	Confined	KGS Model	2.4
Bore 40	19.0 to 25.0	Bedrock	Confined	KGS Model	2.0
Bore 4A	10.0 to 47.5	Bedrock	Confined	KGS Model	0.03
MIOP01/S2	2.5 to 5.5	Weathered Bedrock	Unconfined	Bouwer and Rice, corrected	0.04
MIOP02	10.0 to 15.0	Weathered Bedrock	Unconfined	Bouwer and Rice, corrected	0.1
S3	11.0 to 14.0	Weathered Bedrock	Confined	KGS Model	0.1
S7	8.0 to 13.0	Weathered Bedrock	Confined	Hvorslev	0.6
S8	11.0 to 14.0	Bedrock	Confined	KGS Model	0.003

[3] Tests were conducted for MIOP3 and BSOC_A5, however results were unsuitable for analysis

3.5 WRD Infiltration Testing

Infiltration testing on the WRD surface was planned to be completed using a 'soakaway' style test to estimate the rate of infiltration. A test was attempted in the centre of the WRD (see Figure 8), however, the rate of infiltration was greater than the rate of filling from the water truck (150 L/min) and the test was abandoned.

Observational evidence was collected across the WRD surface to assess potential areas where the rate of infiltration may vary. Figure 8 presents the location of where the information was collected, with photographs presented in Appendix IX. Some observations relating to the observational evidence include:

- The size range of waste rock at the location of the trial test pit are highly variable, with rocks observed greater than 10 cm on the surface (photograph IX-2)
- A surface test was carried out on a highly trafficked area, shown in photographs IX-3, IX-4 and IX-5. Water pooled on the surface for longer than the test pit and generally the size of the rocks in this area is no greater than 2 cm and appears compacted.
- Heavy metals rejects (HMR) is also deposited on the waste rock dump surface. The rock size in this area is relatively uniform and no greater than 3 cm, with little or no compaction observed.
- Photograph IX-7 shows a highly compacted area of the WRD, located within a trafficked section. The photograph shows the size range of waste rock as being between 1 cm and 5 cm and shows evidence of precipitation. Silt sized particles were also present as a result of erosion and compaction of the rock.
- In general, the surface of the WRD had a range of waste rock sizes, with compaction limited to areas of traffic flow.
- Information from site personnel also indicated that during / after a rain event, there was no ponding of water on the WRD surface.

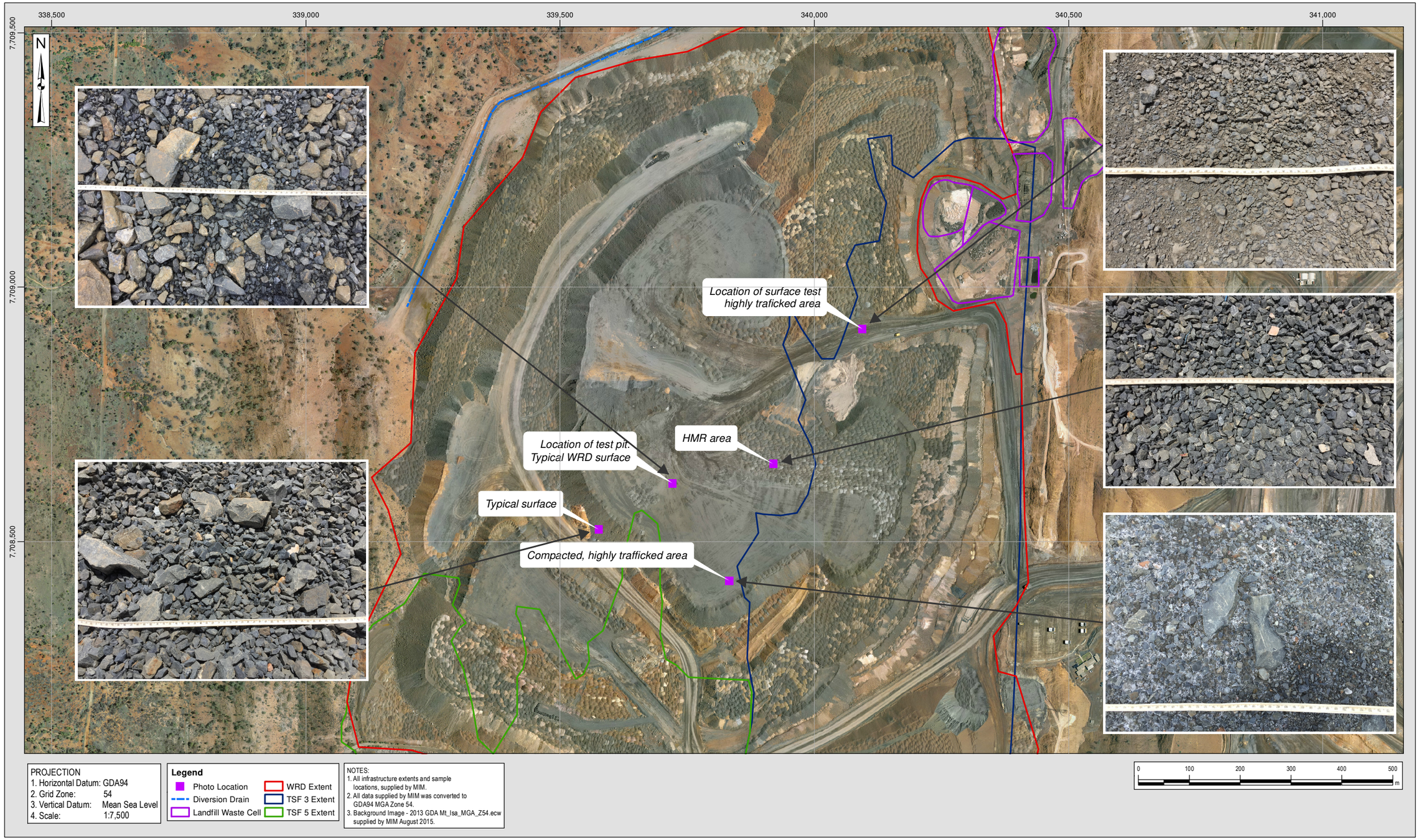

Figure 8: Location of WRD Infiltration Testing and Selected Photographs

4 CLOSING

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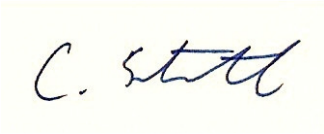
Hydrogeologist



Chris Strachotta
Project Manager

REFERENCES

Australian and New Zealand Environmental and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand, 2000. Australian and New Zealand Guidelines for Fresh and Marin Water Quality, October 2000.

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428

Butler, J.J., Jr., 1998. The Design, Performance, and Analysis of Slug Tests, Lewis Publishers, New York, 252p.

Houslby, A.C, 1976. Routine Interpretation of the Lugeon Water-Test in *Quarterly Journal of Engineering* Geology Vol.9 pp 303-313.

Hvorslev, M.J., 1951. Time Lag and Soil Permeability in Ground-Water Observations, Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, Mississippi, pp. 1-50

Hyder, Z., J.J. Butler, Jr., C.D. McElwee and W. Liu, 1994. Slug tests in partially penetrating wells, Water Resources Research, vol. 30, no. 11, pp. 2945-2957.

Klohn Crippen Berger. 2016. Black Star Open Cut Waste Rock Dump Environmental Evaluation: Data Gap Assessment. Final Report

National Uniform Drillers Licensing Committee (NUDLC) (2012), Minimum Construction Requirements for Water Bores in Australia – Third Edition, NUDLC, South Australia.

Thiem, G. 1906. The relation between the lowering piezometric surface and the rate and duration of discharge of a well using groundwater storage. *Transactions, American Geophysical Union* 16; 519-524.

United States Bureau of Reclamation. 1965. Earth Manual. U.S. Bureau of Reclamation, Denver, Colorado, First Edition, Revised.

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APPENDIX I

Phase 1 Site Investigation Photographs

Appendix I
Phase 1 Field Mapping and Site Reconnaissance Photographs

Sludge Pits and Landfill

Photograph I-1: Sludge Pit East Wall Facing West

Photograph I-2: Sludge Pit 3 Facing South

Photograph I-3: West Sludge Pit Facing North

Photograph I-4: BSOC WRD Extent South of Sludge Pit 2

Photograph I-5: Landfill North of Sludge Pits (Facing South)

Photograph I-6: Waste Cell North of Sludge Pit (Facing Southeast)

King Gully Dam

Photograph I-7: King Gully Dam, Upstream

Photograph I-8: King Gully Dam In-Take Pipe, Upstream

Photograph I-9: King Gully Dam, Upstream; BSOC WRD in background

Photograph I-10: King Gully Dam, Upstream

Photograph I-11: King Gully Dam, Upstream

Photograph I-12: King Gully Dam, Downstream; BSOC Seepage Diversion to KSOC

Photograph I-13: King Gully Dam, Downstream

Seepage – BSOC WRD South

Photograph I-14: South of BSOC WRD South Seepage, Western Edge of BSOC WRD, Facing South

Photograph I-15: South of BSOC WRD South Seepage, Western Edge of BSOC WRD, Facing North

Photograph I-16: Western Edge of BSOC WRD, Facing North; Seepage Trench at BSOC WRD South – start of diversion drain

Photograph I-17: BSOC WRD South Seepage Trench, Facing South

Photograph I-18: BSOC WRD South Seepage Trench

Photograph I-19: BSOC WRD South Seepage Trench, Facing North

Photograph I-20: BSOC WRD South Seepage Trench, WRD Toe

Photograph I-21: BSOC WRD South Seepage Trench, Facing Southwest

Photograph I-22: Diversion Drain, downstream of BSOC WRD South Seepage

Photograph I-23: Diversion Drain, downstream of BSOC WRD South Seepage

Photograph I-24: Diversion Drain, downstream of BSOC WRD South Seepage, Facing North

Photograph I-25: Diversion Drain, downstream of BSOC WRD South Seepage, Facing East

Photograph I-26: Diversion Drain, downstream of BSOC WRD South Seepage, Facing South

Seepage – BSOC WRD North

Photograph I-27: New seepage, downstream of BSOC WRD North Seepage

Photograph I-28: New seepage, downstream of BSOC WRD North Seepage

Photograph I-29: New seepage, downstream of BSOC WRD North Seepage

Photograph I-20: Bedrock Exposure in Diversion Drain Southern Wall; BSOC WRD North Seepage

Photograph I-21: Diversion Drain Downstream of BSOC WRD North Seepage, Facing West. Seepage Infiltrating into Alluvium

Seepage – TD3

Photograph I-22: Seepage in Diversion Drain, Upstream of TD3 Seepage, Facing South

Photograph I-23: Seepage and Precipitation in Diversion Drain, Upstream of TD3 Seepage, Facing East, BSOC WRD in Background

Photograph I-24: TD3 Seepage, Main Seepage Point

Downstream of BSOC WRD

Photograph I-25: Precipitation on Bedrock in Creek Downstream from King Gully Dam, North of BSOC WRD, Facing South

Photograph I-26: Ponding and Precipitation at Confluence of Creek and King Gully, Downstream from King Gully Dam, Facing West

Photograph I-27: Bedrock Outcrop in Creek Downstream from Dyno Nobel Facility, Surface Precipitation, Facing South

Photograph I-28: Bedrock Outcrop in Creek Downstream from Dyno Nobel Facility, Facing South, BSOC WRD in Background

APPENDIX II

Phase 1 Soil and Water Sampling Results

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1527223**	Page	: 1 of 4
Client	: **MOUNT ISA MINES LIMITED**	Laboratory	: Environmental Division Brisbane
Contact	: MS TAMARA GROVES	Contact	: Joy Morgan
Address	: PRIVATE MAIL BAG 6 MOUNT ISA QLD, AUSTRALIA 4825	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: tamara.groves@glencore.com.au	E-mail	: joy.morgan@alsglobal.com
Telephone	: +61 07 47443310	Telephone	: + 61 7 4796 0605
Facsimile	: ----	Facsimile	: +61-7-3243 7218
Project	: BSOC WRD EE Sampling	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: CTCMMG	Date Samples Received	: 27-Aug-2015 09:10
C-O-C number	: ----	Date Analysis Commenced	: 28-Aug-2015
Sampler	: ----	Issue Date	: 03-Sep-2015 13:26
Site	: Mount Isa Mines		
		No. of samples received	: 2
Quote number	: ----	No. of samples analysed	: 2

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

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

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	WB Water Lab Brisbane

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.

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.

- The presence of high SO4 may bias the EC low.
- TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	Sludge Pit 1 16568	Sludge Pit 2 16569	----	----	----
			Client sampling date / time	[25-Aug-2015]	[25-Aug-2015]	----	----	----
Compound	CAS Number	LOR	Unit	EB1527223-001	EB1527223-002	--------	--------	--------
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	9.03	5.43	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	28700	4650	----	----	----
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	----	10	mg/L	34500	3870	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	1990	<1	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	5340	4	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	7340	4	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	13400	2540	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	3080	399	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	70	406	----	----	----
Magnesium	7439-95-4	1	mg/L	1240	222	----	----	----
Sodium	7440-23-5	1	mg/L	7090	301	----	----	----
Potassium	7440-09-7	1	mg/L	501	56	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Arsenic	7440-38-2	0.001	mg/L	1.45	0.858	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	0.150	2.66	----	----	----
Chromium	7440-47-3	0.001	mg/L	0.004	0.002	----	----	----
Copper	7440-50-8	0.001	mg/L	0.187	44.2	----	----	----
Nickel	7440-02-0	0.001	mg/L	0.124	0.446	----	----	----
Lead	7439-92-1	0.001	mg/L	1.12	3.51	----	----	----
Zinc	7440-66-6	0.005	mg/L	0.607	15.3	----	----	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.11	2.59	----	----	----
Antimony	7440-36-0	0.001	mg/L	0.023	0.017	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.005	<0.001	----	----	----
Barium	7440-39-3	0.001	mg/L	0.163	0.016	----	----	----
Bismuth	7440-69-9	0.001	mg/L	<0.005	0.008	----	----	----
Cobalt	7440-48-4	0.001	mg/L	0.027	0.568	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	Sludge Pit 1 16568	Sludge Pit 2 16569	----	----	----
			Client sampling date / time	[25-Aug-2015]	[25-Aug-2015]	----	----	----
Compound	CAS Number	LOR	Unit	EB1527223-001	EB1527223-002	--------	--------	--------
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Manganese	7439-96-5	0.001	mg/L	**0.511**	**4.05**	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.081**	**0.001**	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.05	**0.04**	----	----	----
Silver	7440-22-4	0.001	mg/L	<0.005	<0.001	----	----	----
Strontium	7440-24-6	0.001	mg/L	**0.591**	**0.588**	----	----	----
Thallium	7440-28-0	0.001	mg/L	**0.050**	**1.50**	----	----	----
Thorium	7440-29-1	0.001	mg/L	<0.005	<0.001	----	----	----
Titanium	7440-32-6	0.01	mg/L	<0.05	<0.01	----	----	----
Uranium	7440-61-1	0.001	mg/L	**0.016**	**0.001**	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.05	<0.01	----	----	----
Boron	7440-42-8	0.05	mg/L	**1.85**	**0.27**	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.94**	**8.62**	----	----	----
EG035F: Dissolved 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	**3.3**	**6.3**	----	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.12**	**27.7**	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	<0.01	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N	14797-55-8	0.01	mg/L	<0.01	<0.01	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	<0.01	<0.01	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**7.50**	**0.83**	----	----	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**512**	**64.2**	----	----	----
^ Total Cations	----	0.01	meq/L	**427**	**53.0**	----	----	----
^ Ionic Balance	----	0.01	%	**9.17**	**9.51**	----	----	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	0.2	mg/L	**2.0**	**11.3**	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1527395**	Page	: 1 of 6
Client	: **MOUNT ISA MINES LIMITED**	Laboratory	: Environmental Division Brisbane
Contact	: MS TAMARA GROVES	Contact	: Joy Morgan
Address	: PRIVATE MAIL BAG 6 MOUNT ISA QLD, AUSTRALIA 4825	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: tamara.groves@glencore.com.au	E-mail	: joy.morgan@alsglobal.com
Telephone	: +61 07 47443310	Telephone	: + 61 7 4796 0605
Facsimile	: ----	Facsimile	: +61-7-3243 7218
Project	: Mount Isa Mines	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: CTCMMG	Date Samples Received	: 28-Aug-2015 09:10
C-O-C number	: BSOC WRD EE Sampling	Date Analysis Commenced	: 01-Sep-2015
Sampler	: ----	Issue Date	: 07-Sep-2015 15:14
Site	: Mount Isa Mines		
		No. of samples received	: 10
Quote number	: ----	No. of samples analysed	: 10

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

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Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics

General Comments

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^ = This result is computed from individual analyte detections at or above the level of reporting
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- EG005T (Total Metals): Sample EB1527395-002 (D/S BSOC Sth 2) shows poor spike recovery due to sample heterogeneity. Confirmed by visual inspection.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	D/S BSOC Sth 1	D/S BSOC Sth 2	D/S BSOC Sth 3	Nrth Seepage Trib 1	Nrth Seepage Trib 2
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527395-001	EB1527395-002	EB1527395-003	EB1527395-004	EB1527395-005
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.6	8.9	7.8	8.0	9.4
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	90	3290	43900	79	14300
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	<1.0	25.0	11.5	<1.0	1.7
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	90	7920	245000	120	55000
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	3650	23800	<10	6310
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	30	80	1660	40	700
Magnesium	7439-95-4	10	mg/kg	30	1520	33600	60	6840
Sodium	7440-23-5	10	mg/kg	10	3510	63800	90	15200
Potassium	7440-09-7	10	mg/kg	10	700	7160	20	430
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2460	9170	9000	2190	5510
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	9640	18400	17500	9100	12800
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	13.7	90.3	27.6	9.5	12.8
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	<1	1
Silver	7440-22-4	0.1	mg/kg	0.2	0.9	1.5	0.1	0.2
Barium	7440-39-3	0.1	mg/kg	14.8	53.6	32.2	12.1	30.0
Thallium	7440-28-0	0.1	mg/kg	0.4	2.0	1.8	0.3	0.3
Beryllium	7440-41-7	0.1	mg/kg	0.2	0.7	0.6	0.2	0.5
Cadmium	7440-43-9	0.1	mg/kg	1.0	3.0	3.1	0.9	1.8
Bismuth	7440-69-9	0.1	mg/kg	0.9	5.2	0.8	0.6	0.5
Cobalt	7440-48-4	0.1	mg/kg	7.9	30.1	13.6	4.6	6.8
Chromium	7440-47-3	0.1	mg/kg	6.2	15.9	12.3	5.3	9.2
Copper	7440-50-8	0.1	mg/kg	489	2110	400	241	222
Thorium	7440-29-1	0.1	mg/kg	1.4	3.0	3.0	1.5	2.4
Manganese	7439-96-5	0.1	mg/kg	80.4	337	252	59.2	112
Strontium	7440-24-6	0.1	mg/kg	4.0	16.7	34.8	1.9	29.0
Molybdenum	7439-98-7	0.1	mg/kg	0.2	0.6	1.8	0.2	0.8

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	D/S BSOC Sth 1	D/S BSOC Sth 2	D/S BSOC Sth 3	Nrth Seepage Trib 1	Nrth Seepage Trib 2
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527395-001	EB1527395-002	EB1527395-003	EB1527395-004	EB1527395-005
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Nickel	7440-02-0	0.1	mg/kg	5.1	17.8	13.8	4.5	7.8
Lead	7439-92-1	0.1	mg/kg	145	609	635	102	104
Antimony	7440-36-0	0.1	mg/kg	0.5	1.4	1.9	0.4	0.4
Uranium	7440-61-1	0.1	mg/kg	0.4	1.6	4.5	0.3	2.4
Zinc	7440-66-6	0.5	mg/kg	97.9	356	813	80.3	103
Lithium	7439-93-2	0.1	mg/kg	1.0	4.5	4.9	0.8	2.3
Vanadium	7440-62-2	1	mg/kg	30	31	18	26	47
Tin	7440-31-5	0.1	mg/kg	0.2	1.2	0.4	0.7	1.9
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	0.2
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	2.5	1.3	48.5	1.0	21.2
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	2.5	1.3	48.5	1.0	21.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	80	660	270	40	160
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	80	660	320	40	180

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Nrth Seepage Trib 3	Nrth Seepage Trib 4	King Gully Clean US 1	King Gully Clean US 2	King Gully Clean US 3
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527395-006	EB1527395-007	EB1527395-008	EB1527395-009	EB1527395-010
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.5	6.8	9.3	10.5	10.2
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	168	31000	97	38800	7430
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	<1.0	14.2	1.6	7.7	4.1
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	270	61500	190	91500	17600
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	53100	<10	30400	4080
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	90	4040	60	30	160
Magnesium	7439-95-4	10	mg/kg	30	18500	30	10	190
Sodium	7440-23-5	10	mg/kg	40	21800	50	73400	10300
Potassium	7440-09-7	10	mg/kg	10	300	10	920	320
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2870	13100	3320	6600	3200
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	10000	21400	8740	9530	6110
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	10.5	57.1	6.0	14.3	10.9
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	1	<1
Silver	7440-22-4	0.1	mg/kg	0.3	2.7	<0.1	0.5	0.2
Barium	7440-39-3	0.1	mg/kg	16.4	47.6	26.3	22.6	20.6
Thallium	7440-28-0	0.1	mg/kg	0.4	1.8	0.2	0.3	0.4
Beryllium	7440-41-7	0.1	mg/kg	0.3	1.1	0.2	0.2	0.2
Cadmium	7440-43-9	0.1	mg/kg	1.4	17.3	0.9	1.3	1.5
Bismuth	7440-69-9	0.1	mg/kg	0.6	2.8	0.3	0.6	0.5
Cobalt	7440-48-4	0.1	mg/kg	5.8	17.5	5.6	5.5	5.1
Chromium	7440-47-3	0.1	mg/kg	8.6	18.3	4.2	5.2	4.0
Copper	7440-50-8	0.1	mg/kg	373	1210	261	534	443
Thorium	7440-29-1	0.1	mg/kg	2.0	9.3	1.4	1.5	1.2
Manganese	7439-96-5	0.1	mg/kg	99.8	312	148	51.6	95.5
Strontium	7440-24-6	0.1	mg/kg	6.5	174	19.6	9.2	11.8
Molybdenum	7439-98-7	0.1	mg/kg	0.2	1.6	0.2	1.6	0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Nrth Seepage Trib 3	Nrth Seepage Trib 4	King Gully Clean US 1	King Gully Clean US 2	King Gully Clean US 3
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527395-006	EB1527395-007	EB1527395-008	EB1527395-009	EB1527395-010
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Nickel	7440-02-0	0.1	mg/kg	5.7	21.9	4.9	4.8	3.6
Lead	7439-92-1	0.1	mg/kg	138	634	82.4	132	149
Antimony	7440-36-0	0.1	mg/kg	0.5	1.5	0.3	0.4	0.5
Uranium	7440-61-1	0.1	mg/kg	0.7	1.0	0.2	4.7	0.5
Zinc	7440-66-6	0.5	mg/kg	119	410	69.4	162	144
Lithium	7439-93-2	0.1	mg/kg	1.0	4.6	1.4	2.8	1.2
Vanadium	7440-62-2	1	mg/kg	24	39	27	38	18
Tin	7440-31-5	0.1	mg/kg	5.0	0.9	1.2	0.4	0.2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	5.2	0.7
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	0.8	114	1.0	455	87.5
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	0.8	114	1.0	460	88.2
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	50	540	30	130	100
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	50	650	30	590	190

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1527395**	Page	: 1 of 6
Amendment	: **1**		
Client	: **MOUNT ISA MINES LIMITED**	Laboratory	: Environmental Division Brisbane
Contact	: MS TAMARA GROVES	Contact	: Joy Morgan
Address	: PRIVATE MAIL BAG 6 MOUNT ISA QLD, AUSTRALIA 4825	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: tamara.groves@glencore.com.au	E-mail	: joy.morgan@alsglobal.com
Telephone	: +61 07 47443310	Telephone	: + 61 7 4796 0605
Facsimile	: ----	Facsimile	: +61-7-3243 7218
Project	: Mount Isa Mines	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: CTCMMG	Date Samples Received	: 28-Aug-2015 09:10
C-O-C number	: BSOC WRD EE Sampling	Date Analysis Commenced	: 01-Sep-2015
Sampler	: ----	Issue Date	: 07-Sep-2015 16:32
Site	: Mount Isa Mines		
		No. of samples received	: 10
Quote number	: ----	No. of samples analysed	: 10

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Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics

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.

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.

- This report has been amended as a result of a request to change sample identification numbers (IDs) received by ALS from Jessica Naylor on 7/9/15. All analysis results are as per the previous report.
- EG005T (Total Metals): Sample EB1527395-002 (D/S BSOC Sth 2) shows poor spike recovery due to sample heterogeneity. Confirmed by visual inspection.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	D/S BSOC Sth 1 16580	D/S BSOC Sth 2 16581	D/S BSOC Sth 3 16582	Nrth Seepage Trib 1 16583	Nrth Seepage Trib 2 16584
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527395-001	EB1527395-002	EB1527395-003	EB1527395-004	EB1527395-005
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.6	8.9	7.8	8.0	9.4
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	90	3290	43900	79	14300
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	<1.0	25.0	11.5	<1.0	1.7
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	90	7920	245000	120	55000
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	3650	23800	<10	6310
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	30	80	1660	40	700
Magnesium	7439-95-4	10	mg/kg	30	1520	33600	60	6840
Sodium	7440-23-5	10	mg/kg	10	3510	63800	90	15200
Potassium	7440-09-7	10	mg/kg	10	700	7160	20	430
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2460	9170	9000	2190	5510
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	9640	18400	17500	9100	12800
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	13.7	90.3	27.6	9.5	12.8
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	<1	1
Silver	7440-22-4	0.1	mg/kg	0.2	0.9	1.5	0.1	0.2
Barium	7440-39-3	0.1	mg/kg	14.8	53.6	32.2	12.1	30.0
Thallium	7440-28-0	0.1	mg/kg	0.4	2.0	1.8	0.3	0.3
Beryllium	7440-41-7	0.1	mg/kg	0.2	0.7	0.6	0.2	0.5
Cadmium	7440-43-9	0.1	mg/kg	1.0	3.0	3.1	0.9	1.8
Bismuth	7440-69-9	0.1	mg/kg	0.9	5.2	0.8	0.6	0.5
Cobalt	7440-48-4	0.1	mg/kg	7.9	30.1	13.6	4.6	6.8
Chromium	7440-47-3	0.1	mg/kg	6.2	15.9	12.3	5.3	9.2
Copper	7440-50-8	0.1	mg/kg	489	2110	400	241	222
Thorium	7440-29-1	0.1	mg/kg	1.4	3.0	3.0	1.5	2.4
Manganese	7439-96-5	0.1	mg/kg	80.4	337	252	59.2	112
Strontium	7440-24-6	0.1	mg/kg	4.0	16.7	34.8	1.9	29.0
Molybdenum	7439-98-7	0.1	mg/kg	0.2	0.6	1.8	0.2	0.8

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	D/S BSOC Sth 1 16580	D/S BSOC Sth 2 16581	D/S BSOC Sth 3 16582	Nrth Seepage Trib 1 16583	Nrth Seepage Trib 2 16584
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527395-001	EB1527395-002	EB1527395-003	EB1527395-004	EB1527395-005
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Nickel	7440-02-0	0.1	mg/kg	5.1	17.8	13.8	4.5	7.8
Lead	7439-92-1	0.1	mg/kg	145	609	635	102	104
Antimony	7440-36-0	0.1	mg/kg	0.5	1.4	1.9	0.4	0.4
Uranium	7440-61-1	0.1	mg/kg	0.4	1.6	4.5	0.3	2.4
Zinc	7440-66-6	0.5	mg/kg	97.9	356	813	80.3	103
Lithium	7439-93-2	0.1	mg/kg	1.0	4.5	4.9	0.8	2.3
Vanadium	7440-62-2	1	mg/kg	30	31	18	26	47
Tin	7440-31-5	0.1	mg/kg	0.2	1.2	0.4	0.7	1.9
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	0.2
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	2.5	1.3	48.5	1.0	21.2
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	2.5	1.3	48.5	1.0	21.4
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	80	660	270	40	160
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	80	660	320	40	180

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Nrth Seepage Trib 3 16585	Nrth Seepage Trib 4 16586	King Gully Clean US 1 16587	King Gully Clean US 2 16588	King Gully Clean US 3 16589
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527395-006	EB1527395-007	EB1527395-008	EB1527395-009	EB1527395-010
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	8.5	6.8	9.3	10.5	10.2
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	168	31000	97	38800	7430
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	<1.0	14.2	1.6	7.7	4.1
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	270	61500	190	91500	17600
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	53100	<10	30400	4080
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	90	4040	60	30	160
Magnesium	7439-95-4	10	mg/kg	30	18500	30	10	190
Sodium	7440-23-5	10	mg/kg	40	21800	50	73400	10300
Potassium	7440-09-7	10	mg/kg	10	300	10	920	320
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	2870	13100	3320	6600	3200
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	10000	21400	8740	9530	6110
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	10.5	57.1	6.0	14.3	10.9
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	1	<1
Silver	7440-22-4	0.1	mg/kg	0.3	2.7	<0.1	0.5	0.2
Barium	7440-39-3	0.1	mg/kg	16.4	47.6	26.3	22.6	20.6
Thallium	7440-28-0	0.1	mg/kg	0.4	1.8	0.2	0.3	0.4
Beryllium	7440-41-7	0.1	mg/kg	0.3	1.1	0.2	0.2	0.2
Cadmium	7440-43-9	0.1	mg/kg	1.4	17.3	0.9	1.3	1.5
Bismuth	7440-69-9	0.1	mg/kg	0.6	2.8	0.3	0.6	0.5
Cobalt	7440-48-4	0.1	mg/kg	5.8	17.5	5.6	5.5	5.1
Chromium	7440-47-3	0.1	mg/kg	8.6	18.3	4.2	5.2	4.0
Copper	7440-50-8	0.1	mg/kg	373	1210	261	534	443
Thorium	7440-29-1	0.1	mg/kg	2.0	9.3	1.4	1.5	1.2
Manganese	7439-96-5	0.1	mg/kg	99.8	312	148	51.6	95.5
Strontium	7440-24-6	0.1	mg/kg	6.5	174	19.6	9.2	11.8
Molybdenum	7439-98-7	0.1	mg/kg	0.2	1.6	0.2	1.6	0.5

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	Nrth Seepage Trib 3 16585	Nrth Seepage Trib 4 16586	King Gully Clean US 1 16587	King Gully Clean US 2 16588	King Gully Clean US 3 16589
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527395-006	EB1527395-007	EB1527395-008	EB1527395-009	EB1527395-010
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Nickel	7440-02-0	0.1	mg/kg	5.7	21.9	4.9	4.8	3.6
Lead	7439-92-1	0.1	mg/kg	138	634	82.4	132	149
Antimony	7440-36-0	0.1	mg/kg	0.5	1.5	0.3	0.4	0.5
Uranium	7440-61-1	0.1	mg/kg	0.7	1.0	0.2	4.7	0.5
Zinc	7440-66-6	0.5	mg/kg	119	410	69.4	162	144
Lithium	7439-93-2	0.1	mg/kg	1.0	4.6	1.4	2.8	1.2
Vanadium	7440-62-2	1	mg/kg	24	39	27	38	18
Tin	7440-31-5	0.1	mg/kg	5.0	0.9	1.2	0.4	0.2
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	<20
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	<0.1	<0.1	<0.1	5.2	0.7
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	0.8	114	1.0	455	87.5
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	0.8	114	1.0	460	88.2
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	50	540	30	130	100
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	50	650	30	590	190

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1527396**	Page	: 1 of 8
Client	: **MOUNT ISA MINES LIMITED**	Laboratory	: Environmental Division Brisbane
Contact	: MS TAMARA GROVES	Contact	: Joy Morgan
Address	: PRIVATE MAIL BAG 6 MOUNT ISA QLD, AUSTRALIA 4825	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: tamara.groves@glencore.com.au	E-mail	: joy.morgan@alsglobal.com
Telephone	: +61 07 47443310	Telephone	: + 61 7 4796 0605
Facsimile	: ----	Facsimile	: +61-7-3243 7218
Project	: BSOC WRD EE Sampling	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: CTCMMG	Date Samples Received	: 28-Aug-2015 09:10
C-O-C number	: BSOC WRD EE Sampling	Date Analysis Commenced	: 31-Aug-2015
Sampler	: ----	Issue Date	: 07-Sep-2015 17:55
Site	: Mount Isa Mines		
		No. of samples received	: 9
Quote number	: ----	No. of samples analysed	: 9

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
Ryan Story	2IC Organic Instrument Chemist	Brisbane Organics

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.

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.

- EG020-F and EG020-T (Dissolved Metals and Total Metals by ICP-MS): Limit of reporting raised for some samples due to matrix interference.
- **It is recognised that EG020-T (Total Metals by ICP-MS) is less than EG020-F (Dissolved Metals by ICP-MS) for some samples. However, the difference is within experimental variation of the methods.**
- **EG020-F (Dissolved Metals by ICP-MS) were found to be higher than EG020-T (Total Metals by ICP-MS) for some samples. This was confirmed by re-digestion and re-analysis.**
- EK067G (Total Phosphorus as P): Samples were diluted due to matrix interference. LOR adjusted accordingly.
- The presence of high SO4 may bias the EC low.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC Sth Toe 16571	Sth Seep Sth 16572	Sth Seep Nth 16573	Nth Seep D/S 1 16574	TD3 U/S 1 16575
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527396-001	EB1527396-002	EB1527396-003	EB1527396-004	EB1527396-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	8.34	8.15	8.41	8.49	8.55
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	11600	5400	13100	11500	4120
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	----	10	mg/L	13300	4670	14500	10700	3090
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	16	<1	38	59	59
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	390	415	428	497	374
Total Alkalinity as CaCO3	----	1	mg/L	406	415	466	556	433
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	9460	3130	9820	6240	1130
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	633	244	699	752	566
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	332	56	320	90	62
Magnesium	7439-95-4	1	mg/L	1460	538	1340	712	288
Sodium	7440-23-5	1	mg/L	1270	595	1650	2130	439
Potassium	7440-09-7	1	mg/L	137	110	172	170	70
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Antimony	7440-36-0	0.001	mg/L	0.006	<0.001	<0.001	0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.015	0.002	0.010	0.010	0.003
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	0.016	0.018	0.017	0.027	0.084
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	0.0024	0.0004	0.0016	0.0016	0.0004
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	0.126	0.012	1.02	0.030	0.022
Cobalt	7440-48-4	0.001	mg/L	0.002	<0.001	0.002	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	0.002	<0.001	0.002	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	0.021	0.005	0.014	0.013	0.004
Zinc	7440-66-6	0.005	mg/L	0.206	<0.005	0.012	0.009	0.012
Manganese	7439-96-5	0.001	mg/L	0.003	0.053	0.016	0.380	0.008

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC Sth Toe 16571	Sth Seep Sth 16572	Sth Seep Nth 16573	Nth Seep D/S 1 16574	TD3 U/S 1 16575
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527396-001	EB1527396-002	EB1527396-003	EB1527396-004	EB1527396-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Molybdenum	7439-98-7	0.001	mg/L	**0.012**	<0.001	**0.007**	**0.005**	**0.002**
Selenium	7782-49-2	0.01	mg/L	**0.01**	**0.02**	**0.04**	<0.01	<0.01
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L	**2.12**	**0.916**	**2.66**	**1.73**	**0.720**
Thallium	7440-28-0	0.001	mg/L	**0.004**	<0.001	<0.001	<0.001	<0.001
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	7440-61-1	0.001	mg/L	**0.037**	**0.032**	**0.092**	**0.096**	**0.015**
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	**0.03**	**0.16**
Boron	7440-42-8	0.05	mg/L	**0.11**	<0.05	<0.05	**0.23**	**0.10**
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.06**	**0.18**	**0.02**	**0.06**	**0.02**
Antimony	7440-36-0	0.001	mg/L	**0.006**	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	**0.018**	**0.003**	**0.008**	**0.011**	**0.003**
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	**0.021**	**0.022**	**0.019**	**0.037**	**0.082**
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	**0.0026**	**0.0003**	**0.0018**	**0.0017**	**0.0006**
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	**0.158**	**0.018**	**0.048**	**0.048**	**0.032**
Cobalt	7440-48-4	0.001	mg/L	**0.002**	<0.001	**0.002**	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	**0.002**	<0.001	**0.001**	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	**0.038**	**0.008**	**0.012**	**0.070**	**0.009**
Zinc	7440-66-6	0.005	mg/L	**0.245**	**0.010**	**0.015**	**0.032**	**0.015**
Manganese	7439-96-5	0.001	mg/L	**0.009**	**0.050**	**0.019**	**0.045**	**0.007**
Molybdenum	7439-98-7	0.001	mg/L	**0.014**	<0.001	**0.008**	**0.004**	**0.003**
Selenium	7782-49-2	0.01	mg/L	**0.01**	**0.03**	**0.04**	<0.01	<0.01
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L	**2.36**	**0.997**	**2.91**	**1.97**	**0.710**
Thallium	7440-28-0	0.001	mg/L	**0.004**	<0.001	<0.001	<0.001	<0.001
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	7440-61-1	0.001	mg/L	**0.044**	**0.038**	**0.110**	**0.105**	**0.018**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC Sth Toe 16571	Sth Seep Sth 16572	Sth Seep Nth 16573	Nth Seep D/S 1 16574	TD3 U/S 1 16575
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]	[26-Aug-2015]
Compound	CAS Number	LOR	Unit	EB1527396-001	EB1527396-002	EB1527396-003	EB1527396-004	EB1527396-005
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	<0.01	0.04	0.18
Boron	7440-42-8	0.05	mg/L	0.15	0.10	0.15	0.30	0.23
Iron	7439-89-6	0.05	mg/L	0.14	0.15	<0.05	0.16	<0.05
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	0.0015	<0.0001
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	2.7	5.7	4.5	3.9	1.8
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	0.12	0.05	0.17	0.01	0.04
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	0.03	0.76	3.25	0.31	0.30
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N	14797-55-8	0.01	mg/L	28.1	48.8	38.6	21.2	12.6
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	28.1	49.6	41.9	21.5	12.9
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	0.19	0.17	0.18	0.10	0.09
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	223	80.3	233	162	48.1
^ Total Cations	----	0.01	meq/L	195	75.8	202	160	47.7
^ Ionic Balance	----	0.01	%	6.58	2.96	7.15	0.70	0.50
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	<1	<1	<1	1	<1

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TD3 U/S 2 16576	TD3 16577	KG Dam D/S 1 16578	KG Dam D/S 1-A 16579	----
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	----
Compound	CAS Number	LOR	Unit	EB1527396-006	EB1527396-007	EB1527396-008	EB1527396-009	--------
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	8.68	7.26	8.23	8.23	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	11800	11700	22800	22800	----
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	----	10	mg/L	11000	14500	28600	28700	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	161	<1	<1	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	475	104	519	520	----
Total Alkalinity as CaCO3	----	1	mg/L	636	104	519	520	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	6320	9440	16700	17900	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	1150	823	1910	1970	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	132	498	643	565	----
Magnesium	7439-95-4	1	mg/L	890	1790	3070	2960	----
Sodium	7440-23-5	1	mg/L	2050	818	3070	2960	----
Potassium	7440-09-7	1	mg/L	123	118	374	365	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	0.10	<0.05	<0.05	----
Antimony	7440-36-0	0.001	mg/L	0.004	<0.005	<0.005	<0.005	----
Arsenic	7440-38-2	0.001	mg/L	0.040	<0.005	0.020	0.020	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.005	<0.005	<0.005	----
Barium	7440-39-3	0.001	mg/L	0.021	0.014	0.044	0.044	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.005	<0.005	<0.005	----
Cadmium	7440-43-9	0.0001	mg/L	0.0012	0.0403	0.0032	0.0032	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.005	<0.005	<0.005	----
Copper	7440-50-8	0.001	mg/L	0.139	0.021	0.211	0.202	----
Cobalt	7440-48-4	0.001	mg/L	0.002	0.006	<0.005	<0.005	----
Nickel	7440-02-0	0.001	mg/L	0.001	0.043	0.006	<0.005	----
Lead	7439-92-1	0.001	mg/L	0.010	<0.005	0.040	0.038	----
Zinc	7440-66-6	0.005	mg/L	0.012	10.4	0.068	0.054	----
Manganese	7439-96-5	0.001	mg/L	0.108	0.584	0.029	0.029	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TD3 U/S 2 16576	TD3 16577	KG Dam D/S 1 16578	KG Dam D/S 1-A 16579	----
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	----
Compound	CAS Number	LOR	Unit	EB1527396-006	EB1527396-007	EB1527396-008	EB1527396-009	--------
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Molybdenum	7439-98-7	0.001	mg/L	**0.007**	<0.005	<0.005	<0.005	----
Selenium	7782-49-2	0.01	mg/L	**0.01**	<0.05	<0.05	<0.05	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.005	<0.005	<0.005	----
Strontium	7440-24-6	0.001	mg/L	**1.27**	**2.04**	**5.43**	**5.12**	----
Thallium	7440-28-0	0.001	mg/L	<0.001	**0.347**	<0.005	<0.005	----
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.005	<0.005	<0.005	----
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.05	<0.05	<0.05	----
Uranium	7440-61-1	0.001	mg/L	**0.059**	<0.005	**0.048**	**0.046**	----
Vanadium	7440-62-2	0.01	mg/L	**0.02**	<0.05	<0.05	<0.05	----
Boron	7440-42-8	0.05	mg/L	**0.15**	**0.36**	**0.20**	**0.30**	----
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**2.17**	<0.05	<0.05	<0.05	----
Antimony	7440-36-0	0.001	mg/L	**0.005**	<0.005	<0.005	<0.005	----
Arsenic	7440-38-2	0.001	mg/L	**0.058**	<0.005	**0.023**	**0.024**	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.005	<0.005	<0.005	----
Barium	7440-39-3	0.001	mg/L	**0.080**	**0.018**	**0.056**	**0.054**	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.005	<0.005	<0.005	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0048**	**0.0426**	**0.0035**	**0.0033**	----
Chromium	7440-47-3	0.001	mg/L	**0.003**	<0.005	<0.005	<0.005	----
Copper	7440-50-8	0.001	mg/L	**0.825**	**0.019**	**0.211**	**0.213**	----
Cobalt	7440-48-4	0.001	mg/L	**0.007**	**0.007**	<0.005	<0.005	----
Nickel	7440-02-0	0.001	mg/L	**0.005**	**0.045**	<0.005	<0.005	----
Lead	7439-92-1	0.001	mg/L	**0.272**	<0.005	**0.075**	**0.064**	----
Zinc	7440-66-6	0.005	mg/L	**0.476**	**9.57**	**0.092**	**0.072**	----
Manganese	7439-96-5	0.001	mg/L	**0.229**	**0.585**	**0.033**	**0.032**	----
Molybdenum	7439-98-7	0.001	mg/L	**0.007**	<0.005	**0.006**	<0.005	----
Selenium	7782-49-2	0.01	mg/L	**0.02**	<0.05	<0.05	<0.05	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.005	<0.005	<0.005	----
Strontium	7440-24-6	0.001	mg/L	**1.88**	**2.19**	**6.11**	**6.06**	----
Thallium	7440-28-0	0.001	mg/L	**0.001**	**0.351**	<0.005	<0.005	----
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.005	<0.005	<0.005	----
Titanium	7440-32-6	0.01	mg/L	**0.09**	<0.05	<0.05	<0.05	----
Uranium	7440-61-1	0.001	mg/L	**0.068**	<0.005	**0.050**	**0.049**	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TD3 U/S 2 16576	TD3 16577	KG Dam D/S 1 16578	KG Dam D/S 1-A 16579	----
			Client sampling date / time	[26-Aug-2015]	[26-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	----
Compound	CAS Number	LOR	Unit	EB1527396-006	EB1527396-007	EB1527396-008	EB1527396-009	--------
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Vanadium	7440-62-2	0.01	mg/L	**0.03**	<0.05	<0.05	<0.05	----
Boron	7440-42-8	0.05	mg/L	**0.24**	<0.25	**0.32**	**0.28**	----
Iron	7439-89-6	0.05	mg/L	**3.53**	<0.25	<0.25	<0.25	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**3.9**	**1.3**	**2.4**	**2.4**	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.16**	**0.02**	**0.01**	<0.01	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	**0.82**	<0.01	<0.01	<0.01	----
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N	14797-55-8	0.01	mg/L	**6.42**	**4.58**	<0.01	<0.01	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**7.24**	**4.58**	<0.01	<0.01	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.16**	**0.16**	<0.05	<0.05	----
EN055: Ionic Balance								
^ Total Anions	----	0.01	meq/L	**177**	**222**	**412**	**439**	----
^ Total Cations	----	0.01	meq/L	**172**	**211**	**428**	**410**	----
^ Ionic Balance	----	0.01	%	**1.34**	**2.58**	**1.87**	**3.41**	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	**9**	<1	**4**	**3**	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1527714**	Page	: 1 of 5
Client	: **MOUNT ISA MINES LIMITED**	Laboratory	: Environmental Division Brisbane
Contact	: MS TAMARA GROVES	Contact	: Joy Morgan
Address	: PRIVATE MAIL BAG 6 MOUNT ISA QLD, AUSTRALIA 4825	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: tamara.groves@glencore.com.au	E-mail	: joy.morgan@alsglobal.com
Telephone	: +61 07 47443310	Telephone	: + 61 7 4796 0605
Facsimile	: ----	Facsimile	: +61-7-3243 7218
Project	: BSOC WRD EE Sampling	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: CTCMMG	Date Samples Received	: 02-Sep-2015 09:30
C-O-C number	: BSOC WRD EE Sampling	Date Analysis Commenced	: 02-Sep-2015
Sampler	: ----	Issue Date	: 10-Sep-2015 07:12
Site	: Mount Isa Mines		
		No. of samples received	: 1
Quote number	: ----	No. of samples analysed	: 1

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics
Ryan Story	2IC Organic Instrument Chemist	Brisbane Organics

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.

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.

- **It is recognised that EG020-T (Total Metals by ICP-MS) is less than EG020-F (Dissolved Metals by ICP-MS) for some samples. However, the difference is within experimental variation of the methods.**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KG D/S 1 16640	----	----	----	----
			Client sampling date / time	27-Aug-2015 15:10	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1527714-001	--------	--------	--------	--------
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	8.89	----	----	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	7590	----	----	----	----
EA015: Total Dissolved Solids								
^ Total Dissolved Solids @180°C	----	10	mg/L	4690	----	----	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	280	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	723	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L	1000	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	900	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	1490	----	----	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	22	----	----	----	----
Magnesium	7439-95-4	1	mg/L	190	----	----	----	----
Sodium	7440-23-5	1	mg/L	1190	----	----	----	----
Potassium	7440-09-7	1	mg/L	152	----	----	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	0.005	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	0.052	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Barium	7440-39-3	0.001	mg/L	0.033	----	----	----	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	0.0008	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	0.115	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	0.001	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	0.040	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	0.016	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	0.126	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KG D/S 1 16640	----	----	----	----
			Client sampling date / time	27-Aug-2015 15:10	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1527714-001	--------	--------	--------	--------
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Molybdenum	7439-98-7	0.001	mg/L	**0.010**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	----	----	----	----
Strontium	7440-24-6	0.001	mg/L	**0.240**	----	----	----	----
Thallium	7440-28-0	0.001	mg/L	**0.002**	----	----	----	----
Thorium	7440-29-1	0.001	mg/L	<0.001	----	----	----	----
Titanium	7440-32-6	0.01	mg/L	<0.01	----	----	----	----
Uranium	7440-61-1	0.001	mg/L	**0.032**	----	----	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Boron	7440-42-8	0.05	mg/L	**0.33**	----	----	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	----	----	----	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.05**	----	----	----	----
Antimony	7440-36-0	0.001	mg/L	**0.005**	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.054**	----	----	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	----	----	----	----
Barium	7440-39-3	0.001	mg/L	**0.039**	----	----	----	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0011**	----	----	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	----	----	----	----
Copper	7440-50-8	0.001	mg/L	**0.217**	----	----	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.002**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L	<0.001	----	----	----	----
Lead	7439-92-1	0.001	mg/L	**0.064**	----	----	----	----
Zinc	7440-66-6	0.005	mg/L	**0.031**	----	----	----	----
Manganese	7439-96-5	0.001	mg/L	**0.129**	----	----	----	----
Molybdenum	7439-98-7	0.001	mg/L	**0.012**	----	----	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	----	----	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	----	----	----	----
Strontium	7440-24-6	0.001	mg/L	**0.250**	----	----	----	----
Thallium	7440-28-0	0.001	mg/L	**0.002**	----	----	----	----
Thorium	7440-29-1	0.001	mg/L	<0.001	----	----	----	----
Titanium	7440-32-6	0.01	mg/L	<0.01	----	----	----	----
Uranium	7440-61-1	0.001	mg/L	**0.034**	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KG D/S 1 16640	----	----	----	----
			Client sampling date / time	27-Aug-2015 15:10	----	----	----	----
Compound	CAS Number	LOR	Unit	EB1527714-001	--------	--------	--------	--------
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Vanadium	7440-62-2	0.01	mg/L	<0.01	----	----	----	----
Boron	7440-42-8	0.05	mg/L	**0.25**	----	----	----	----
Iron	7439-89-6	0.05	mg/L	**0.13**	----	----	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	----	----	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**6.2**	----	----	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.09**	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	**0.01**	----	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N	14797-55-8	0.01	mg/L	**0.03**	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.04**	----	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.10**	----	----	----	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	**26**	----	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1527718**	Page	: 1 of 4
Client	: **MOUNT ISA MINES LIMITED**	Laboratory	: Environmental Division Brisbane
Contact	: MS TAMARA GROVES	Contact	: Joy Morgan
Address	: PRIVATE MAIL BAG 6 MOUNT ISA QLD, AUSTRALIA 4825	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: tamara.groves@glencore.com.au	E-mail	: joy.morgan@alsglobal.com
Telephone	: +61 07 47443310	Telephone	: + 61 7 4796 0605
Facsimile	: ----	Facsimile	: +61-7-3243 7218
Project	: BSOC WRD EE Sampling	QC Level	: NEPM 2013 Schedule B(3) and ALS QCS3 requirement
Order number	: CTCMMG	Date Samples Received	: 02-Sep-2015 09:30
C-O-C number	: BSOC WRD EE Sampling	Date Analysis Commenced	: 03-Sep-2015
Sampler	: ----	Issue Date	: 14-Sep-2015 14:01
Site	: Mount Isa Mines		
		No. of samples received	: 4
Quote number	: ----	No. of samples analysed	: 4

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

WORLD RECOGNISED ACCREDITATION

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics

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.

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.

- **EK061 (Total Kjeldahl Nitrogen); Sample EB1527666 019 shows poor spike recovery due to sample heterogeneity. This was confirmed by visual inspection.**
- EK061G (Total Kjeldahl Nitrogen): The Total Kjeldahl Nitrogen may bias low for sample EB1527718-003 (DYNO D/S 1) due to presence of high NOx content.
- EK061G (Total Kjeldhal Nitrogen as N): Sample EB1527718-003 (DYNO D/S 1) shows poor duplicate results due to sample heterogeneity. Confirmed by re-extraction and re-analysis.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	King Gully Clean US 4 16637	King Gully Clean US 5 16638	DYNO D/S 1 16639	KG Clean US 6 16641	----
			Client sampling date / time	[27-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	----
Compound	CAS Number	LOR	Unit	EB1527718-001	EB1527718-002	EB1527718-003	EB1527718-004	--------
				Result	Result	Result	Result	Result
EA002 : pH (Soils)								
pH Value	----	0.1	pH Unit	9.8	9.8	9.9	9.2	----
EA010: Conductivity								
Electrical Conductivity @ 25°C	----	1	µS/cm	17900	6730	28800	24100	----
EA055: Moisture Content								
^ Moisture Content (dried @ 103°C)	----	1	%	1.7	<1.0	5.9	2.4	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	45300	17200	44000	91700	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	7890	1360	21200	9530	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	40	580	30	2420	----
Magnesium	7439-95-4	10	mg/kg	60	490	10	8300	----
Sodium	7440-23-5	10	mg/kg	25700	7740	53600	27300	----
Potassium	7440-09-7	10	mg/kg	1540	130	1530	1170	----
EG005T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	7200	3560	13300	3380	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	----
Iron	7439-89-6	50	mg/kg	15100	15700	11400	28700	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	54.2	9.2	12.8	11.2	----
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	<1	----
Silver	7440-22-4	0.1	mg/kg	1.4	0.1	0.2	0.2	----
Barium	7440-39-3	0.1	mg/kg	46.2	20.6	43.0	19.6	----
Thallium	7440-28-0	0.1	mg/kg	1.5	0.4	0.3	0.4	----
Beryllium	7440-41-7	0.1	mg/kg	0.3	0.2	0.4	0.2	----
Cadmium	7440-43-9	0.1	mg/kg	3.9	1.7	1.1	1.5	----
Bismuth	7440-69-9	0.1	mg/kg	2.9	0.6	0.5	0.7	----
Cobalt	7440-48-4	0.1	mg/kg	15.8	7.6	5.8	8.1	----
Chromium	7440-47-3	0.1	mg/kg	8.6	6.2	8.8	8.3	----
Copper	7440-50-8	0.1	mg/kg	1660	364	438	495	----
Thorium	7440-29-1	0.1	mg/kg	2.4	1.6	2.0	1.6	----
Manganese	7439-96-5	0.1	mg/kg	139	104	85.9	95.7	----
Strontium	7440-24-6	0.1	mg/kg	11.9	17.9	10.6	23.3	----
Molybdenum	7439-98-7	0.1	mg/kg	1.8	0.4	2.1	0.5	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	King Gully Clean US 4 16637	King Gully Clean US 5 16638	DYNO D/S 1 16639	KG Clean US 6 16641	----
			Client sampling date / time	[27-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	[27-Aug-2015]	----
Compound	CAS Number	LOR	Unit	EB1527718-001	EB1527718-002	EB1527718-003	EB1527718-004	--------
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Nickel	7440-02-0	0.1	mg/kg	9.6	5.6	7.6	7.1	----
Lead	7439-92-1	0.1	mg/kg	505	142	137	173	----
Antimony	7440-36-0	0.1	mg/kg	2.0	0.5	0.4	0.7	----
Uranium	7440-61-1	0.1	mg/kg	0.7	0.6	1.2	0.9	----
Zinc	7440-66-6	0.5	mg/kg	530	146	113	145	----
Lithium	7439-93-2	0.1	mg/kg	2.9	1.2	3.8	1.2	----
Vanadium	7440-62-2	1	mg/kg	29	43	33	79	----
Tin	7440-31-5	0.1	mg/kg	0.7	0.2	0.4	0.6	----
EK055: Ammonia as N								
Ammonia as N	7664-41-7	20	mg/kg	<20	<20	<20	<20	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	2.8	0.1	10.5	0.1	----
EK058G: Nitrate as N by Discrete Analyser								
^ Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	43.3	2.7	7980	11.5	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	46.1	2.8	7990	11.6	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	20	mg/kg	140	60	830	80	----
EK062: Total Nitrogen as N (TKN + NOx)								
^ Total Nitrogen as N	----	20	mg/kg	190	60	8820	90	----

APPENDIX III

BSOC EE Bores - Geological Logs

BORE LOG: BSOC_A1

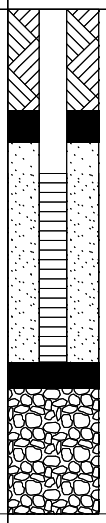
Klohn Crippen Berger

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Hammer
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 4
BOREHOLE SIZE (mm) 203
STATIC WATER LEVEL (mbGL) 0.61 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 20/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 338873mE, 7709022mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 368.00
STICK UP (m) 0.94
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture (1.3 to 2.8m)

COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH	WATER STRIKE	STATIC WATER LEVEL (mbGL)	WELL DIAGRAM
			GRAVEL & SAND medium grained sand, fine gravel; well graded; loose; angular; brown / red; moist; quartz	1.00		▼	Casing, uPVC, Blank, 50mm, Cemented Bentonite Seal
1			**CLAYEY GRAVEL** fine gravel; minor silt; well graded; loose; angular; brown / grey; moist; quartz				
2	366						Gravel Pack, 1-5mm washed silica Screen, uPVC, 1mm aperture, slotted Bentonite Seal
3				3.00			
			METASEDIMENTS slate, siltstone; dark grey / grey; slightly weathered; weak rock; quartz, iron / oxidation staining; dry				Backfill
4	364		Borehole terminated at 4.0 m	4.00			
5							
6	362						
7							
8	360						
9							
10	358						
11							



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▼ Static Water Level

Klohn Crippen Berger

BORE LOG: BSOC_A2

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Hammer
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 11
BOREHOLE SIZE (mm) 203
STATIC WATER LEVEL (mbGL) 1.97 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 20/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 339122mE, 7708981mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 375.00
STICK UP (m) 0.7
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture (3.6 to 9.6m)

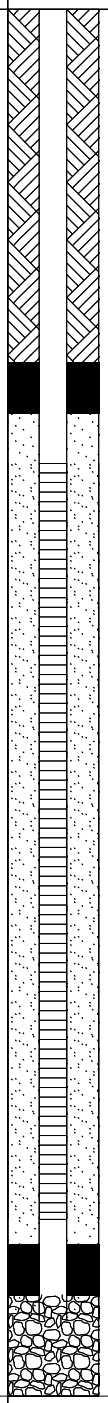
COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	LITHOLOGIC DESCRIPTION	CONTACT DEPTH
		SANDY GRAVEL coarse gravel, fine to medium grained sand; well graded; loose; angular; brown / red / pink; moist; quartz, weathered, iron / oxidation staining	1.00
1	374	**CLAYEY SAND & SILT** fine to medium grained sand; some gravel; well graded; loose; angular; brown / red; moist; quartz, calcite, weathered, iron / oxidation staining	2.00
2		**CLAYEY SILT & GRAVEL** coarse gravel; well graded; loose; angular; light brown / cream; moist; quartz, calcite	3.00
3	372	**GRAVEL & SILT** coarse gravel; trace sand; well graded; loose; angular; brown / grey / white; moist; quartz	4.00
4		**GRAVEL & SILT** coarse gravel; ; well graded; loose; angular; yellow / cream / grey; moist; quartz, calcite	5.00
5	370	**SILTY GRAVEL** coarse gravel; trace sand; well graded; loose; angular; white / grey / brown / green; wet; quartz, chlorite; WQ at 6.3m 8.09pH, 8694uS/cm	
6			
7	368		
8			
9	366		
10			10.00
		METASEDIMENTS slate, siltstone; grey / brown fresh rock; medium strong rock; iron / oxidation staining, quartz, calcite; wet	11.00
11	364	Borehole terminated at 11.0 m	

WATER STRIKE

STATIC WATER LEVEL (mbGL)

WELL DIAGRAM



Static Water Level

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Klohn Crippen Berger

BORE LOG: BSOC_A3

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Hammer
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 5.5
BOREHOLE SIZE (mm) 203
STATIC WATER LEVEL (mbGL) 0.8 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 20/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 339373mE, 7709550mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 378.00
STICK UP (m) 0.94
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture (0.8 to 20.8m)

COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH	WATER STRIKE	STATIC WATER LEVEL (mbGL)	WELL DIAGRAM
1			**GRAVEL & SAND** medium grained sand, coarse gravel; some cobbles; well graded; loose; angular; brown / red; moist; quartz, weathered siltstone, schist	1.00		▼	Casing, uPVC, Blank, 50mm, Cemented Bentonite Seal
2	376		**CLAYEY GRAVEL** fine gravel; some cobbles, some fine grained sand; well graded; loose; angular; light brown / grey; moist; quartzite (pink), metasediments, quartz	3.00			Gravel Pack, 1-5mm washed silica Screen, uPVC, 1mm aperture, slotted Bentonite Seal
3			**METASEDIMENTS** slate, siltstone; grey / brown / pink; moderately weathered; medium strong rock; quartz, chlorite alteration; dry				
4	374						Backfill
5				5.50			
6	372		Borehole terminated at 5.5 m				
7							
8	370						
9							
10	368						
11							

▼ Static Water Level

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Klohn Crippen Berger

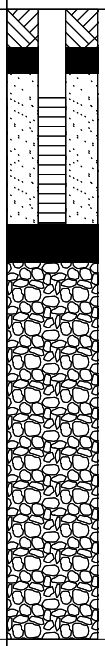
BORE LOG: BSOC_A4

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Hammer
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 5
BOREHOLE SIZE (mm) 203
STATIC WATER LEVEL (mbGL) 1.19 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 20/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 338990mE, 7709729mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 366.00
STICK UP (m) 0.84
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture (0.7 to 1.7m)

COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH	WATER STRIKE	STATIC WATER LEVEL (mbGL)	WELL DIAGRAM
1			**GRAVEL & SAND** fine to medium grained sand, coarse gravel; some cobbles and boulders; well graded; loose; angular; brown / red; moist; quartz, weathered siltstone, schist; seepage into hole observed after drilling at 0.7mbGL			▼	Casing, uPVC, Blank, 50mm, Cemented Bentonite Seal; Gravel Pack, 1-5mm washed silica; Screen, uPVC, 1mm aperture, slotted; Bentonite Seal; Backfill
2	364			2.00			
			METASEDIMENTS slate; black / dark grey; fresh rock; verystrong rock; quartz; dry				
3							
4	362						
5				5.00			
			Borehole terminated at 5.0 m				
6	360						
7							
8	358						
9							
10	356						
11							



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▼ Static Water Level

Klohn Crippen Berger

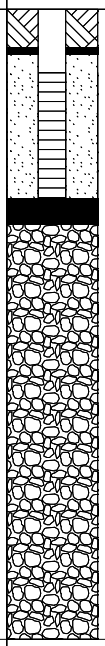
BORE LOG: BSOC_A5

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Hammer
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 5
BOREHOLE SIZE (mm) 203
STATIC WATER LEVEL (mbGL) 0.43 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 20/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 340475mE, 7710561mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 362.00
STICK UP (m) 0.85
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture (0.5 to 1.5m)

COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH	WATER STRIKE	STATIC WATER LEVEL (mbGL)	WELL DIAGRAM
1			**GRAVEL & SAND** medium gravel, fine grained sand; some silt; well graded; loose; angular; brown / red; moist; quartz				Casing, uPVC, Blank, 50mm, Cemented Bentonite Seal; Gravel Pack, 1-5mm washed silica; Screen, uPVC, 1mm aperture, slotted; Bentonite Seal; Backfill
2	360		**METASEDIMENTS** schist; grey; moderately weathered; weak rock; minor quartz, chlorite, iron / oxidation staining; dry	2.00			
3							
4	358		**METASEDIMENTS** slate, schist; grey; fresh; medium strong rock; minor quartz; dry	4.00			
5			Borehole terminated at 5.0 m	5.00			
6	356						
7							
8	354						
9							
10	352						
11							



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▼ Static Water Level

Klohn Crippen Berger

BORE LOG: BSOC_B1

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Hammer
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 29.2
BOREHOLE SIZE (mm) 123
STATIC WATER LEVEL (mbGL) 6.26 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 20/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 339153mE, 7708920mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 384.00
STICK UP (m) 0.75
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture (11.0 to 29.0m)

COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH	WATER STRIKE	STATIC WATER LEVEL (mbGL)	WELL DIAGRAM
1			**TOPSOIL** weathered metasediments; brown / grey; residual soil / highly weathered; extremely weak rock; dry	1.00			
2	382		**METASEDIMENTS** slate, siltstone; brown / grey / white; moderately weathered; weak rock; calcite, quartz; dry	3.00			
3			**METASEDIMENTS** slate, siltstone; grey; silt sized; slightly weathered; medium strong rock; foliated, iron / oxidation staining; dry	4.00			Casing, uPVC, Blank, 50mm, Cemented
4	380						
5			**METASEDIMENTS** slate, quartzite; light grey / dark grey / green; fresh rock; strong rock; quartz, chlorite alteration, minor mica, minor foliations; dry				
6	378					▼	
7			**METASEDIMENTS** slate; dark grey; fresh rock; very strong rock; iron / oxidation staining, folliated; damp; WQ from airlift at 9m 9.05pH, 5704uS/cm	7.00			
8	376						Bentonite Seal
9				9.00			
10	374		**METASEDIMENTS** quartz, siltstone, slate; green / grey / brown / clear; fresh rock; very strong rock; quartz (translucent / transparent), chlorite alteration, minor mica, minor foliations; damp	10.00			
11							
12	372		**METASEDIMENTS** slate, siltstone; orange / brown / green / grey; silt sized; fresh rock; very strong rock; iron / oxidation staining, chlorite alteration, minor quartz; increase in yield from 11m, continuous water flow ~0.3 L/s at 15m; WQ at 15m 8.67pH, 4765uS/cm				
13							
14	370						
15				15.00			
16	368		**METASEDIMENTS** slate, schist; dark grey / light grey / green; silt sized; fresh rock; very strong rock to very weak rock; foliated, iron / oxidation staining (increases at 17m), minor chlorite alteration, minor quartz; continuous water flow				
17							
18	366						
19				19.00			
20	364		**SCHIST** dark grey / black / green; fresh rock; very weak rock; minor quartz and chlorite, minor iron / oxidation staining; wet, continuous water flow	20.00			Gravel Pack, 1-5mm washed silica
21			**METASEDIMENTS** siltstone, sandstone; grey; silt sized, fine grained sand; fresh rock; very weak rock; quartz, minor mica and chlorite; wet, continuous water flow; WQ at 21m 8.60pH, 4741uS/cm	22.00			Screen, uPVC, 1mm aperture, slotted
22	362						
23			**METASEDIMENTS** slate, schist, quartzite; grey / light grey / green; fresh rock; very strong to very weak rock; quartz (translucent), minor chlorite, iron / oxidation staining; wet, continuous water flow; WQ at 27m 8.5pH, 4660uS/cm				
24	360						
25							
26	358						
27							
28	356						
29				29.20			uPVC end cap
30	354		Borehole terminated at 29.2 m				
31							
32	352						
33							
34	350						
35							
36	348						
37							
38	346						
39							

KLOHN_ESDAT_GINT.GLB Log HYDRO LOG 2012 50M GINT LOGS.GPJ <<DrawingFile>> 09/02/2016 14:41

▼ Static Water Level

Klohn Crippen Berger

BORE LOG: BSOC_B2

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Hammer
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 26.2
BOREHOLE SIZE (mm) 123
STATIC WATER LEVEL (mbGL) 6.27 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 18/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 339177mE, 7709783mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 388.00
STICK UP (m) 1.06
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture (8.8 to 25.8m)

COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH	WATER STRIKE	STATIC WATER LEVEL (mbGL)	WELL DIAGRAM
1			**TOPSOIL** weathered metasediments; red / brown; residual soil / highly weathered; extremely weak rock; dry	2.00			Casing, uPVC, Blank, 50mm, Cemented
2	386		**METASEDIMENTS** quartzite, slate; grey / brown / pink; moderately weathered; medium strong rock; quartz; dry	4.00			
3							
4	384		**QUARTZITE** grey / pink; slightly weathered; very strong rock; translucent quartz, with minor chlorite alteration between 7-8m; dry	8.00			
5							
6	382					▼	Bentonite Seal
7							
8	380		**METASEDIMENTS** siltstone; light grey; silt sized grains; slightly weathered; very strong rock; quartz (translucent), iron / oxidation staining; damp, no continuous flow; WQ at 9m 10.36pH, 1966uS/cm	10.00			
9							
10	378		**QUARTZITE** grey / brown / green; fresh rock; very strong rock; quartz, minor chlorite ateration, iron / oxidation staining; damp, no continuous flow	15.00			
11							
12	376						
13							
14	374						
15			**METASEDIMENTS** sandstone, quartzite; white / light grey / dark grey; fine grained sand; fresh rock; very strong rock; quartz (translucent and transparent), iron / oxidation staining; wet, continuous water flow ~0.2L/s; WQ at 15m 9.70pH, 1567uS/cm	16.00			Gravel Pack, 1-5mm washed silica
16	372			17.00			
17			**METASEDIMENTS** sandstone, quartzite; white / grey / brown / green; fine to medium grained sand; fresh rock; very strong rock; quartz, iron / oxidation staining, chlorite alteration; wet, continuous water flow	18.00			Screen, uPVC, 1mm aperture, slotted
18	370						
19			**METASEDIMENTS** slate; black; fresh rock; very strong rock; minor foliations, minor iron / oxidation staining; wet, continuous water flow				
20	368						
21							
22	366		**METASEDIMENTS** sandstone, schist; light grey / black / green; ; fresh rock; very strong to very weak rock; quartz, minor chlorite, iron / oxidation staining (increases at 21-22m); wet, continuous water flow; WQ at 21m 8.95pH, 1418uS/cm	22.00			
23							
24	364		**QUARTZITE** minor schist; white / translucent / dark grey / green; ; fresh rock; very strong to very weak rock; quartz, minor chlorite, minor iron / oxidation staining; wet, continuous water flow ~1.6L/s; WQ at 26.2m 8.60pH, 1372uS/cm	26.20			uPVC end cap
25							
26	362						
27			Borehole terminated at 26.2 m				
28	360						
29							
30	358						
31							
32	356						
33							
34	354						
35							
36	352						
37							
38	350						
39							

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▼ Static Water Level

BORE LOG: BSOC_B3

Klohn Crippen Berger

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Hammer
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 35.3
BOREHOLE SIZE (mm) 123
STATIC WATER LEVEL (mbGL) 5.37 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 16/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 339446mE, 7709681mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 381.00
STICK UP (m) 0.29
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture (17.2 to 35.2m)

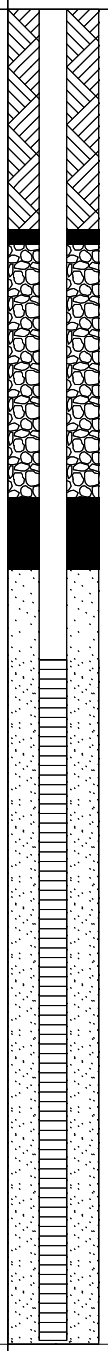
COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	LITHOLOGIC DESCRIPTION	CONTACT DEPTH
1	380	**TOPSOIL** weathered metasediments; red / brown; residual soil / highly weathered; extremely weak; dry	2.00
3	378	**METASEDIMENTS** slate ; grey / brown; slightly weathered; medium strong rock; minor quartz, minor foliations; dry	4.00
5	376	**METASEDIMENTS** slate, schist, minor siltstone; grey / black / brown; slightly weathered; medium strong rock; minor quartz, strongly folliated, iron / oxidation staining; dry	9.00
9	372	**METASEDIMENTS** siltstone; grey; silt sized; fresh rock; medium strong rock; quartz, iron / oxidation staining; dry	10.00
11	370	**METASEDIMENTS** slate, siltstone; grey; silt sized; fresh rock; strong rock; quartz (translucent, transparent), pink quartz at 11m, iron / oxidation staining; dry	13.00
13	368	**METASEDIMENTS** siltstone; light grey / dark grey; silt sized; fresh rock; strong rock; pink quartz, minor chlorite, folliated, iron / oxidation staining increasing with depth, visible grains reducing; damp, no continuous flow	18.00
19	362	**METASEDIMENTS** slate; dark grey; fresh rock; very strong rock; minor iron / oxidation staining, minor foliations; damp, no continuous flow	20.00
21	360	**METASEDIMENTS** siltstone; light grey / dark grey; silt sized; fresh rock; medium strong rock; iron /oxidation staining; damp, no continuous flow; WQ at 21m (rod change) 9.37pH, 5821uS/cm	23.00
25	356	**METASEDIMENTS** siltstone; grey; silt sized; fresh rock; medium strong rock; minor quartz, minor foliations, minor iron / oxidation staining; damp, no continuous flow; driller added water at 28m to aid with cutting removal (very silty)	29.00
31	350	**METASEDIMENTS** slate and schist; grey / dark grey / green / brown; fresh rock; very strong rock; quartz (translucent, transparent), minor mica, minor chlorite, folliated, iron / oxidation staining (increases at 29 and 33m); final WQ 8.56pH, 4880uS/cm	35.30
37	344	Borehole terminated at 35.3 m	

WATER STRIKE

STATIC WATER LEVEL (mbGL)

WELL DIAGRAM



Static Water Level

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BORE LOG: BSOC_B4

Klohn Crippen Berger

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Rotary
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 36.3
BOREHOLE SIZE (mm) 123
STATIC WATER LEVEL (mbGL) 11.65 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 13/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 339676mE, 7709695mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 386.00
STICK UP (m) 1.11
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture 18.0 to 36.0m)

COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH	WATER STRIKE	STATIC WATER LEVEL (mbGL)	WELL DIAGRAM
1, 2, 3, 4, 5, 6, 7, 8	384, 382, 380, 378		**METASEDIMENTS** siltstone; grey / dark grey; silt sized; slightly weathered; weak rock; quartz, minor calcite; dry	8.00			Casing, uPVC, Blank, 50mm, Cemented
9, 10, 11	376		**METASEDIMENTS** siltstone; grey / dark grey; silt sized; slightly weathered; medium strong rock; minor quartz, minor calcite, iron / oxidation staining; dry	11.00			Backfill
12, 13, 14	374, 372		**METASEDIMENTS** slate, minor schist; dark grey / black; fresh rock; weak rock; foliated, iron / oxidation staining; dry	14.00		▼	
15, 16, 17	370		**QUARTZITE** light green; fresh rock; very strong rock; translucent, some pink quartz, chlorite alteration; dry	17.50			Bentonite Seal
18, 19, 20	368, 366		**METASEDIMENTS** schist; green / black; fresh rock; very weak rock; foliated, mica; dry	20.00			
21, 22, 23, 24, 25, 26, 27, 28, 29, 30	364, 362, 360, 358, 356		**METASEDIMENTS** slate, siltstone; dark grey / black; fresh rock; strong rock; minor quartz, iron / oxidation staining (reducing towards 30m); damp, no continuous water flow; WQ at 20m 8.35pH, 2384uS/cm	30.00			Gravel Pack, 1-5mm washed silica Screen, uPVC, 1mm aperture, slotted
31			**METASEDIMENTS** schist and quatzite; green / grey; fresh rock; very strong rock to very weak rock; quatz both translucent and transparent, calcite; damp, no continuous water flow	31.00			
32, 33, 34	354, 352		**QUARTZITE** green / grey; fresh rock; very strong rock; transparent quartz, minor folliations; damp, no continuous water flow	34.00			
35, 36	350		**METASEDIMENTS** slate, minor schist; green / grey; fresh rock; very strong rock to very weak; transluncent quartz, difficult drilling between 34-35m; damp, no continuous water flow	36.30			uPVC end cap
37, 38, 39	348		Borehole terminated at 36.3 m				

▼ Static Water Level

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Klohn Crippen Berger

BORE LOG: BSOC_B5

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Hammer
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 35.3
BOREHOLE SIZE (mm) 123
STATIC WATER LEVEL (mbGL) 5.5 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 15/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 340255mE, 7710381mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 367.00
STICK UP (m) 1.07
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture (14.3 to 32.3m)

COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH	WATER STRIKE	STATIC WATER LEVEL (mbGL)	WELL DIAGRAM
1	366		**TOPSOIL** weathered metasediments; brown / grey; residual soil / highly weathered; extremely weak; dry	1.00			Casing, uPVC, Blank, 50mm, Cemented
2			**METASEDIMENTS** slate, schist; grey; highly weathered; weak rock; iron / oxidation staining; dry	3.00			
3	364		**METASEDIMENTS** slate, schist; grey; slightly weathered; medium strong rock; iron / oxidation staining; dry				
4							
5	362					▼	
6							
7	360			7.00			
8			**METASEDIMENTS** slate, schist; grey / dark grey / green; slightly weathered; weak rock; transparent quartz, mica, chlorite alteration, minor iron / oxidation staining, foliated; dry	8.00			Backfill
9	358		**METASEDIMENTS** slate, minor schist; grey / dark grey / green; slightly weathered; medium strong rock; quartz, chlorite alteration, increased iron / oxidation staining, minor foliation; dry				
10							
11	356						Bentonite Seal
12				12.00			
13	354		**METASEDIMENTS** slate, minor schist; grey; slightly weathered; medium strong rock; quartz, iron / oxidation staining; dry	13.00			
14				14.00			
15	352		**METASEDIMENTS** slate, quartzite; grey / brown; fresh rock; strong rock; translucent quartz, minor foliation, iron / oxidation staining; wet, no continuous water flow; WQ at 14m 8.12pH, 7071uS/cm	15.00			
16							
17	350		**METASEDIMENTS** slate, quartzite; grey / black / green; fresh rock; strong rock; quartz, chlorite alteration, significant iron / oxidation staining, minor foliation; wet, no continuous water flow				
18							
19	348		**METASEDIMENTS** quartzite, minor slate; grey / green; fresh rock; strong rock; quartz, minor mica, chlorite alteration, minor iron / oxidation staining; wet, no continuous water flow	20.00			
20							
21	346		**METASEDIMENTS** quartzite, minor slate; grey / pink; fresh rock; strong rock; pink quartz, minor mica, iron / oxidation staining; wet, no continuous water flow				
22							
23	344			23.00			Screen, uPVC, 1mm aperture, slotted
24			**METASEDIMENTS** slate; grey / black; fresh rock; strong rock; translucent quartz, iron / oxidation staining (increase at 29-30m); wet, continuous water flow from 30m ~0.8L/s; WQ at 30m 8.37pH, 8048uS/cm				Gravel Pack, 1-5mm washed silica
25	342						
26							
27	340						
28							
29	338						
30							
31	336			31.00			
32			**METASEDIMENTS** slate, minor schist; black /grey; fresh rock; very strong rock; minor iron / oxidation staining; wet, continuous water flow ~0.8L/s; final WQ 8.55pH, 7725uS/cm				
33	334						
34							Casing, uPVC, Blank, 50mm, uPVC end cap
35	332			35.30			
36			Borehole terminated at 35.3 m				
37	330						
38							
39	328						

▼ Static Water Level

KLOHN_ESDAT_GINT.GLB Log HYDRO LOG 2012 50M GINT LOGS.GPJ <<DrawingFile>> 09/02/2016 14:41

Klohn Crippen Berger

BORE LOG: BSOC_B6

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
DRILLING METHOD Air Hammer
SAMPLING METHOD Drill Cuttings
LOGGED BY CK
TOTAL DEPTH (mbGL) 72
BOREHOLE SIZE (mm) 123
STATIC WATER LEVEL (mbGL) 8.01 (21/12/2015)

CLIENT Mount Isa Mines Limited
COMPLETION DATE 19/12/2015
DRILL CONTRACTOR Tulla Drilling
COORDINATES 340189mE, 7710685mN (GDA94, MGA Zone 54)
SURFACE ELEVATION (m) 369.00
STICK UP (m) 0.75
BLANK Class 12 uPVC 50mm
SCREEN Slotted, 1mm aperture (37.0 to 55.0m)

COMMENTS SWL measured prior to development. Location and elevation surveyed by handheld GPS

DEPTH (mbGL)	ELEVATION (mAHD)	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH	WATER STRIKE	STATIC WATER LEVEL (mbGL)	WELL DIAGRAM
1	368		**METASEDIMENTS** schist, siltstone; orange / brown / grey / red; silt sized grains; extremely weathered; extremely to very weak rock; dry	1.00			Casing, uPVC, Blank, 50mm, Cemented
2, 3	366		**METASEDIMENTS** schist, slate; grey / brown; slightly weathered; extremely to very weak rock; dry	3.00			
4, 5	364		**METASEDIMENTS** schist, siltstone; grey / green; silt sized grains; slightly weathered; very weak rock; minor iron / oxidation staining, foliated; dry	5.00			
6, 7, 8, 9, 10, 11, 12, 13, 14, 15	362, 360, 358, 356, 354		**METASEDIMENTS** quartzite, schist; green / grey; fresh rock; medium strong rock to very weak rock; quartz (translucent and transparent), chlorite alteration; dry	15.00		▼	
16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31	352, 350, 348, 346, 344, 342, 340, 338		**NO RECOVERY** limited cutting return due to drill rod configuration; mostly grey dust; dry at the end of each rod change	31.00			Backfill
32, 33, 34	336		**METASEDIMENTS** siltstone; dark grey; fresh rock; very strong rock; quartz, minor chlorite; dry	34.00			Bentonite Seal
35, 36, 37	334, 332		**METASEDIMENTS** siltstone, slate; grey / dark grey; fresh rock; very strong rock; quartz, minor chlorite; dry	37.00			
38, 39	330		**METASEDIMENTS** slate, schist, siltstone; grey / dark grey; fresh rock; very strong rock; quartz, minor calcite, iron / oxidation staining from 42m; damp, no continuous water flow; WQ from 72m 8.72pH, 4944uS/cm				

KLOHN_ESDAT_GINT.GLB Log HYDRO LOG 2012 50M GINT LOGS.GPJ <<DrawingFile>> 09/02/2016 14:41

▼ Static Water Level

BORE LOG: BSOC_B6

Klohn Crippen Berger

PROJECT NUMBER D09626A20
PROJECT NAME BSOC WRD Environmental Evaluation
LOCATION Mount Isa
CLIENT Mount Isa Mines Limited
COMPLETION DATE 19/12/2015

- Continued from Previous Page -

DEPTH (mbGL)	ELEVATION (mAHD)	GRAPHIC LOG	LITHOLOGIC DESCRIPTION	CONTACT DEPTH	WATER STRIKE	STATIC WATER LEVEL (mbGL)	WELL DIAGRAM
41	328		**METASEDIMENTS** slate, schist, siltstone; grey / dark grey; fresh rock; very strong rock; quartz, minor calcite, iron / oxidation staining from 42m; damp, no continuous water flow; WQ from 72m 8.72pH, 4944uS/cm				Gravel Pack, 1-5mm washed silica Screen, uPVC, 1mm aperture, slotted
42							
43	326						
44							
45	324						
46							
47	322						
48							
49	320						
50							
51	318						
52							
53	316						
54							
55	314						Bentonite Seal
56							
57	312						
58							
59	310						
60							
61	308						
62							
63	306						
64							Backfill
65	304						
66							
67	302						
68							
69	300						
70							
71	298						
72				72.00			
73	296		Borehole terminated at 72.0 m				
74							
75	294						
76							
77	292						
78							
79	290						
80							
81	288						
82							
83	286						

KLOHN_ESDAT_GINT.GLB Log HYDRO LOG 2012 50M GINT LOGS.GPJ <<DrawingFile>> 09/02/2016 14:41

Static Water Level

APPENDIX IV

BSOC EE Bores – Drill Cutting Photographs

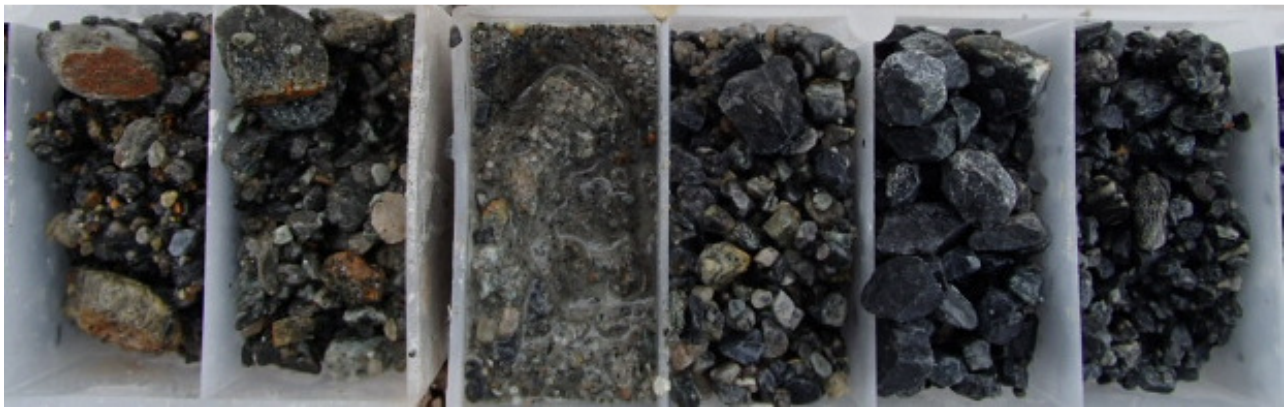
Appendix IV
Phase 2 Site Investigation - Drill Cutting Photographs

BSOC_B1

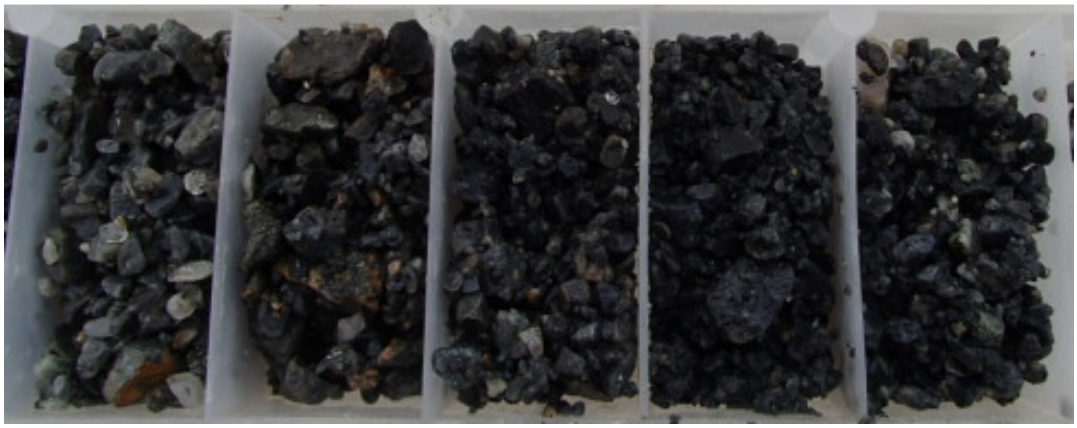
Photograph IV-1: BSOC_B1 Drill Cuttings, 0-6m

Photograph IV-2: BSOC_B1 Drill Cuttings, 6-12m

Photograph II-3: BSOC_B1 Drill Cuttings, 12-18m



Photograph II-4: BSOC_B1 Drill Cuttings, 18-24m



Photograph II-5: BSOC_B1 Drill Cuttings, 24-29m; End of Hole.

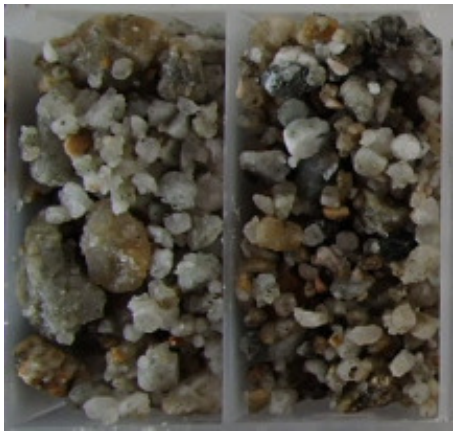
BSOC_B2

Photograph II-6: BSOC_B2 Drill Cuttings, 0-6m

Photograph II-7: BSOC_B2 Drill Cuttings, 6-12m

Photograph II-8: BSOC_B2 Drill Cuttings, 12-18m

Photograph II-9: BSOC_B2 Drill Cuttings, 18-24m



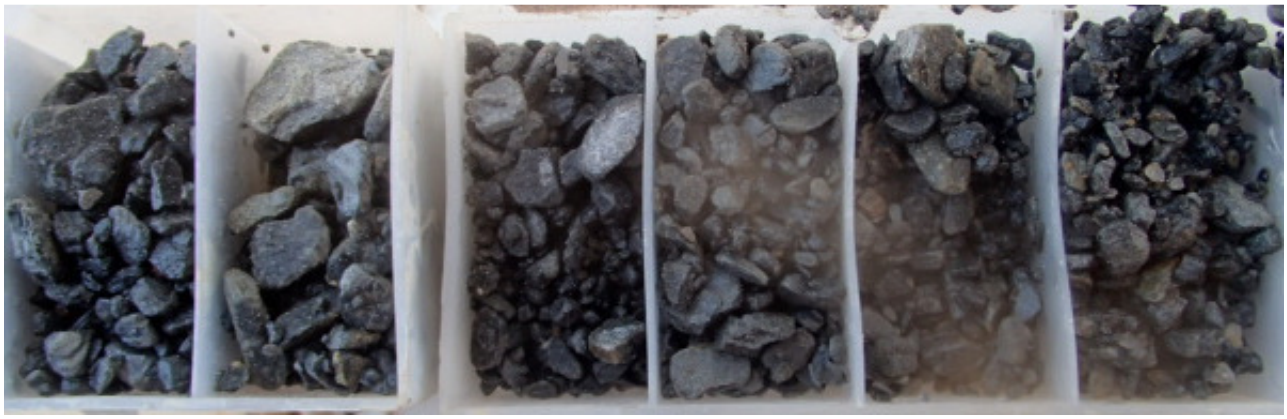
Photograph II-10: BSOC_B2 Drill Cuttings, 24-26m; End of hole.

BSOC_B3

Photograph II-11: BSOC_B3 Drill Cuttings, 0-6m

Photograph II-12: BSOC_B3 Drill Cuttings, 6-12m

Photograph II-13: BSOC_B3 Drill Cuttings, 12-18m



Photograph II-14: BSOC_B3 Drill Cuttings, 18-24m

Photograph II-15: BSOC_B3 Drill Cuttings, 24-30m

Photograph II-16: BSOC_B3 Drill Cuttings, 30-35m; End of Hole

BSOC_B4

Photograph II-17: BSOC_B4 Drill Cuttings, 0-6m

Photograph II-18: BSOC_B4 Drill Cuttings, 6-12m

Photograph II-19: BSOC_B4 Drill Cuttings, 12-18m

Photograph II-20: BSOC_B4 Drill Cuttings, 18-24m

Photograph II-21: BSOC_B4 Drill Cuttings, 24-30m

Photograph II-22: BSOC_B4 Drill Cuttings, 30-36m; End of Hole.

BSOC_B5

Photograph II-23: BSOC_B5 Drill Cuttings, 0-6m

Photograph II-24: BSOC_B5 Drill Cuttings, 6-12m

Photograph II-25: BSOC_B5 Drill Cuttings, 12-18m

Photograph II-26: BSOC_B5 Drill Cuttings, 18-24m

Photograph II-27: BSOC_B5 Drill Cuttings, 24-30m

Photograph II-28: BSOC_B5 Drill Cuttings, 30-35m; End of Hole.

BSOC_B6

Photograph II-29: BSOC_B6 Drill Cuttings, 0-6m

Photograph II-30: BSOC_B6 Drill Cuttings, 6-12m

Photograph II-31: BSOC_B6 Drill Cuttings, 12-18m

Photograph II-32: BSOC_B6 Drill Cuttings, 18-24m

Photograph II-33: BSOC_B6 Drill Cuttings, 24-30m

Photograph II-34: BSOC_B6 Drill Cuttings, 30-36m

Photograph II-35: BSOC_B6 Drill Cuttings, 36-42m

Photograph II-36: BSOC_B6 Drill Cuttings, 42-48m

Photograph II-37: BSOC_B6 Drill Cuttings, 48-54m

Photograph II-38: BSOC_B6 Drill Cuttings, 54-60m

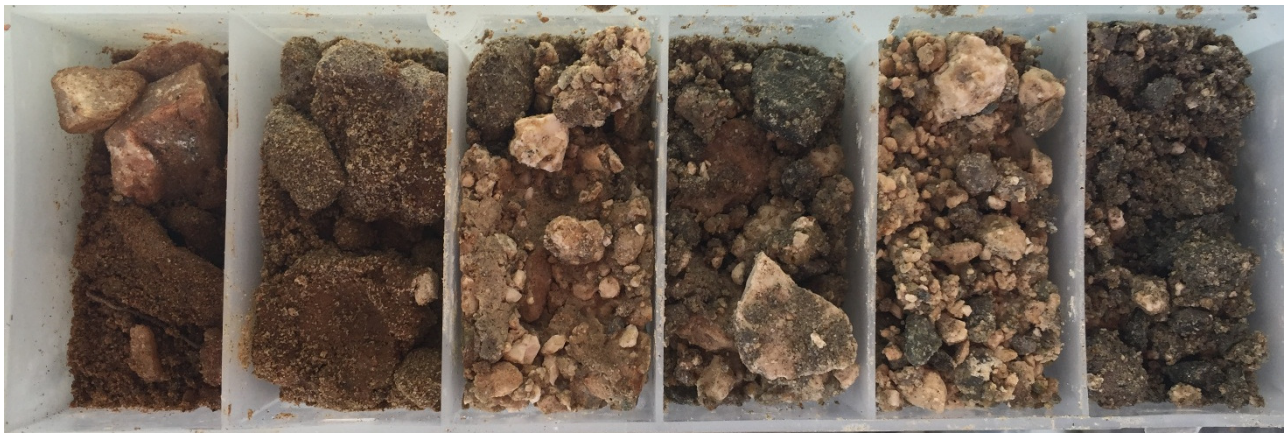
Photograph II-39: BSOC_B6 Drill Cuttings, 60-66m

Photograph II-40: BSOC_B6 Drill Cuttings, 66-72m; End of hole.

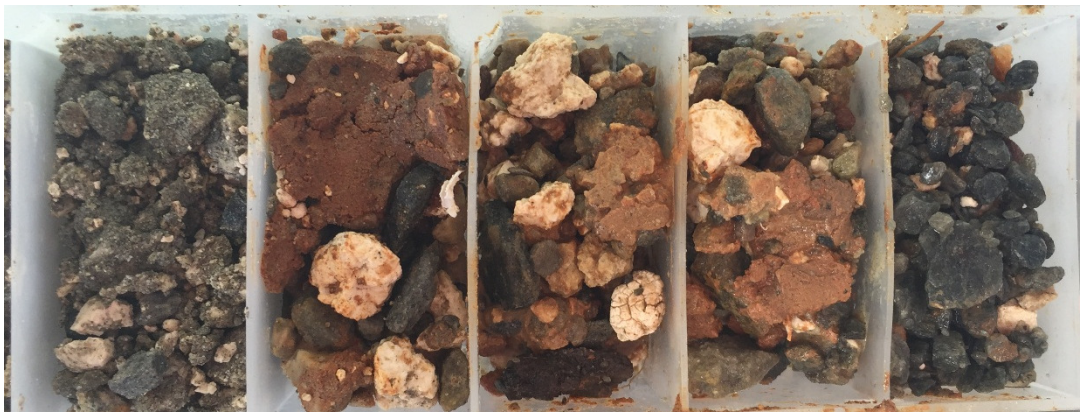
BSOC_A1

Photograph II-41: BSOC_A1 Drill Cuttings, 0-4; End of hole.

BSOC_A2



Photograph II-42: BSOC_A2 Drill Cuttings, 0-6

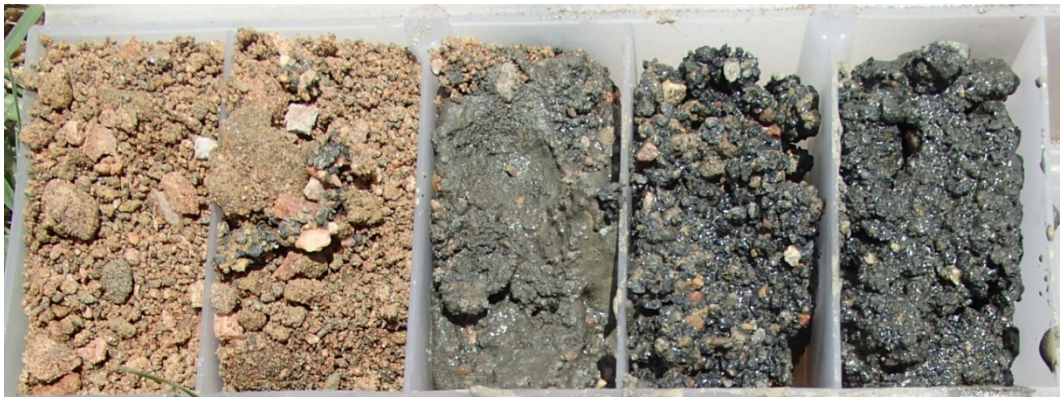


Photograph II-43: BSOC_A2 Drill Cuttings, 6-11; End of hole.

BSOC_A3

Photograph II-44: BSOC_A3 Drill Cuttings, 0-5; End of hole.

BSOC_A4



Photograph II-45: BSOC_A4 Drill Cuttings, 0-5; End of hole.

BSOC_A5

Photograph II-46: BSOC_A5 Drill Cuttings, 0-5; End of hole.

APPENDIX V

BSOC EE Bores – Development Records

Appendix V
Bore Development Records

Table V-1: BSOC_A1 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
14/1/16	11:13								
	11:14	0.008	31.7	9.68	2,650	-440.1	4.9	70	stagnant, earthy smell, turbid, brown
	11:18		31.5	9.51	2,694	-453.1	3.8	54	same as above, stopped to recharge
	11:28								started again
	11:33		31.6	9.45	2,661	-439.3	4.9	65	slight turbid colour, odour
	11:43								started again
	11:49		28.7	9.31	2,797	-469.7	6.1	81	less turbid brown colour, slight odour
	13:13		28.9	9.08	3,024	-529.3	4.9	67	
	13:19		27.2	9.02	3005	-494.5	5.3	72	

Table V-2: BSOC_A2 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
14/1/16	12:10		30.1	7.69	10,052	-472.9	5.5	78	dark caramel, stagnant smell, sandy fines
	12:15	0.3	29.0	8.07	10,404	-474.9	5.6	78	as above
	12:20	0.5	29.2	8.08	10,718	-484	5.8	82	as above
	12:25	0.3	29.1	8.09	10,021	-471.3	5.9	83	less creamy colour, same fines
	12:30	0.257	29.1	8.1	10,790	-482.2	5.8	82	as above
	12:35	0.267	29.1	8.09	10,728	-491.2	5.7	79	light caramel colour, some fines
	12:40	0.235	28.9	8.09	10,699	-491.1	6.1	84	as above
	12:45	0.235	29.0	8.09	10,703	-499.7	5.7	80	light sandy brown colour, not many fines
	12:50	0.235	28.9	8.11	10,663	-487.6	5.9	83	as above
	12:55	0.235	28.9	8.12	10,667	-472.8	5.9	81	as above

Table V-3: BSOC_A3 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
14/1/16	16:20								Development commences
	16:22	0.083	32.0	8.37	4,830	-640.4	5.1	73	milky sand colour, no odour, silty
	16:27	0.029	31.1	8.5	4,792	-603.4	5.1	73	some fines, as above
	16:32		27.7	8.73	4,660	-599.8	5	67	as above
15/1/16	10:20	0.005	30.4	8.66	4,891	45.5	5.1	72	very few fines, milky sandy colour
	10:25	0.006	28.4	8.72	4,749	41.2	5.4	75	as above
	10:30	0.005	27.0	8.75	4,734	34	41	54	as above
	10:38	0.005	26.7	8.76	4,945	33.9	45	59	no fines

Table V-4: BSOC_A4 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
14/1/16	14:31								
	14:36	0.01	30.5	8.34	2,286	-525.2	5.5	76	wet sand, odour
	14:46		28.0	8.52	2,579	-540.6	4.5	60	dark grey / brown milky colour
15/1/16	10:04		26.5	8.60	2,918	46.6	46	61	coffee colour, no odour, not many fines

Table V-5: BSOC_A5 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
15/1/16	8:25		31.2	7.90	18,372	-14.7	4.7	69	foamy on surface from aeration, light grey colour
	8:32	0.006	24.9	8.29	16,832	38.4	5.5	73	sandy, odour, grey fines
	11:50		31.6	8.01	16,248	-491.7	5.2	78	as above, some fines
	11:53		30.5	8.17	16,059	-490.1	5.3	77	as above, less fines
	11:58		28.7	8.29	16,173	-499.6	5.3	76	as above, not many fines

Table V-6: BSOC_B1 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
14/1/16	9:50		31.3	7.78	5,647	79.0	4.3	62	creamy brown colour, lots of fines
	10:00	0.5	30.3	7.86	5,558	86.6	6.2	87	as above
	10:05		30.1	8.04	5,000	80.0	5.9	80	as above
	10:10		29.8	8.10	4,857	76.0	5.8	82	less creamy colour, lots of fines
	10:15		29.8	8.08	4,691	73.4	6.0	84	slight brown, turbid
	10:20		29.5	8.09	4,610	71.0	6.0	83	as above
	10:25		29.8	8.13	4,529	-295.8	6.0	82	clean and clear
	10:30		29.7	8.12	4,470	-385.4	6.2	80	clean and clear
	10:35	0.5	29.8	8.12	4,458	-384	5.7	80	clean and clear
	10:40		29.6	8.14	4,430	-400.7	5.7	80	clean and clear
	10:45		29.7	8.17	4,414	-405.9	6.1	88	clean and clear
	10:50	0.5	29.8	8.18	4,430	-401.2	5.6	78	clean and clear

Table V-7: BSOC_B2 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
14/1/16	15:01		30.8	7.28	1321	-586.7	4.9	69	clear water and very few fines
	15:06	1	29.6	7.54	1295	-532	5.3	73	as above
	15:11		29.5	7.62	1306	-551.8	4.9	56	as above
	15:16		29.5	7.58	1313	-561	4.6	63	as above
	15:21	1	29.5	7.58	1315	-566.3	5	68	as above

Table V-8: BSOC_B3 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
14/1/16	15:36	0.2	30.5	7.38	2,056	-562.7	3.1	43	light grey, with grey foam, strong odour
	15:41	0.2	29.9	8.29	2,845	-553.9	5	69	grey colour, fines
	15:46		29.7	8.39	3,034	-550.3	5.7	78	as above
	15:51		29.9	8.42	3,294	-557.7	4.9	69	as above
	15:56		29.6	8.41	3,384	-582.7	5.2	73	as above, very fine silt
	16:01	0.2	29.5	8.42	3,464	-553.7	5.4	74	slightly clearer, less fines
	16:06		29.4	8.44	3,469	-571.6	4.8	66	as above

Table V-9: BSOC_B4 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
14/1/16	16:50	0.08	31.7	7.45	758	-573.5	3.8	55	grey colour, stagnant odour (strong)
	16:55	0.14	30.1	8.14	902	-572.6	4.8	67	dark grey colour, fines, odour
	17:00	0.04	30.4	8.38	891	-570.2	5.1	70	dark grey colour, fines, odour
	17:05	0.01	30.7	8.49	911	-575.4	5	70	dark grey colour, fines, odour
	17:10	0.02	30.6	8.59	948	-579.6	5.4	83	dark grey colour, fines, odour
15/1/16	10:51	0.02	31.2	7.31	1,359	26.2	2.4	34	wet cement colour, same odour
	10:54		30.6	7.76	1,298	2.1	4.4	62	slight odour, light grey colour, no fines
	10:56		30.6	7.97	1,332	-5.4	6.1	86	as above
	10:58		30.2	8.16	1,283	2.5	6	84	darker grey colour, minimal fines
	11:05		30	8.35	1,255	24.8	5.9	82	as above, no fines, grey colour
	11:14		30.4	8.63	1,274	27	4.4	62	as above, lighter colour, less fines
	11:25	0.02	30.4	8.78	1,319	-458.6	4.3	60	clearer, barely any fines
	11:31	0.02	30	8.77	1,334	-476.1	5.8	80	as above

Table V-10: BSOC_B5 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
15/1/16	8:45		30.3	7.58	4277	-121.6	3.3	45	strong stagnant odour, not many fines, light grey colour
	8:50		30.1	8.10	5761	-107.3	5.6	78	grey-brown colour
	8:55	0.1	30.1	8.11	5805	-109.9	5.8	81	as above
	9:00	0.1	30.0	8.16	5728	-105.7	6.0	83	as above
	9:05		29.9	8.18	5679	-97.8	5.1	70	dry grey cement colour
	9:10		29.9	8.19	5644	-85.0	5.8	81	lighter colour, little fines
	9:15	0.1	29.9	8.21	5656	-74.1	5.3	74	as above, less fines
	9:20	0.1	30.0	8.22	5685	-70.5	6.3	88	as above, barely any fines

Table X-11: BSOC_B6 Development Record

Date	Time	Yield	Water Quality						Comments
			Temp	pH	EC	ORP	DO	DO	
			°C		µS/cm	mV	mg/L	%	
15/1/16	6:35	0.08	29.7	7.72	5,096	-171.3	2.1	29	very stagnant odour, grey colour, foam, few fines
	6:40	0.06							moved pipe down, dark grey colour
	6:45		29.1	8.09	5,434	-93.8	5.5	76	dark grey colour, fines, odour
	6:50	0.03	27.3	8.78	5,216	-3.3	5.7	76	as above
	6:55		27.4	8.84	5,472	10.7	6.3	84	as above
	7:00	0.03	27.2	8.89	5,789	12.8	5	67	as above, lighter grey colour
	7:05		27.2	8.9	5,839	25.1	5.2	69	as above, less odour
	7:10		27	8.95	5,976	29.9	5.8	77	foamy from aeration, not many fines
	7:15		27	8.91	6,086	36.8	5.3	71	very foamy, same colour, more fines
	7:20	0.03	27.1	8.9	6,140	41.4	5.6	75	as above
	7:38		26.9	8.94	5,949	-0.8	5.5	73	as above
	7:50	0.06	26.8	8.87	6,138	34.1	5.6	75	as above
	8:00		26.8	8.96	6,465	39.5	5.9	78	less foamy, same colour, little odour
	12:45	0.05	31.2	7.77	5,164	-519.6	4.1	58	foamy, aerated on top, light grey, very little fines
	12:50		30.8	8.24	5,182	-529.8	4.4	62	as above
	12:55	0.05	30.1	8.25	6,346	-528.9	5.4	73	as above
	13:00		30.5	8.36	6,561	-525.6	5.3	74	as above
	13:05		29.9	8.50	6,535	-533.6	5.1	72	as above, some fines
	13:10		30.3	8.62	6,482	-528.5	4.8	69	as above, less fines
	13:15		30.1	8.85	6,430	-535.1	5.2	72	as above
	16:15	0.05	32.1	8.49	5,265	-575.6	5.7	74	very foamy, grey brown colour, no odour, some fines
	16:21	0.07	30.4	8.57	5,855	-567.8	5.1	73	as above
	16:25		30.2	8.80	5,931	-563.2	5.1	72	as above, fewer fines
	16:33		30.1	8.95	6,036	-573.6	5.7	80	as above, fewer fines
	16:37		29.6	9.05	6,117	-571.1	4.8	66	as above, barely any fines

APPENDIX VI

BSOC EE Bores – Packer Testing Records and Results

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

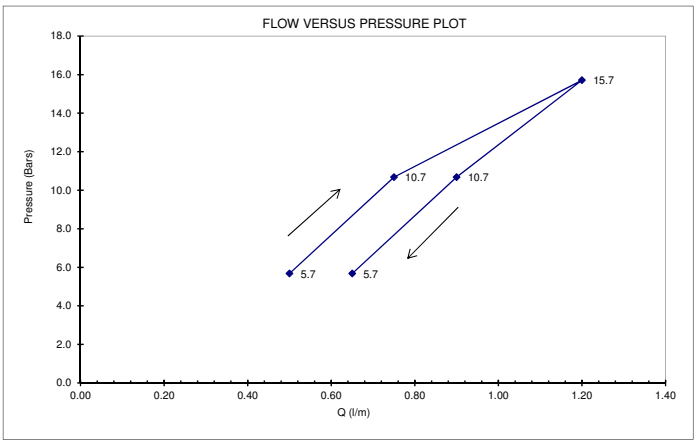
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B1

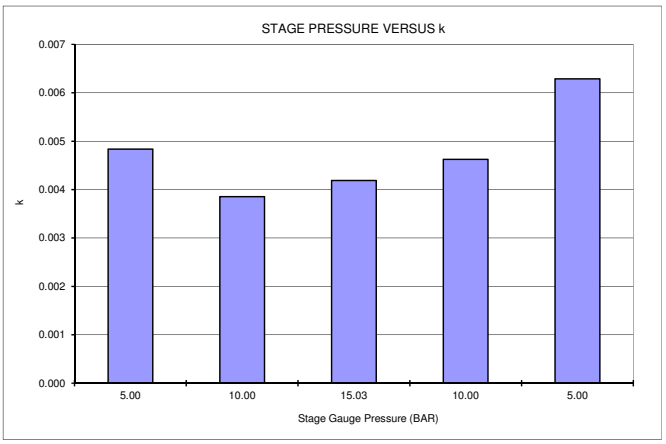
AREA: Close to BSOC WRD South Seep **TEST NO:** 1

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.3 m **TOP OF TEST INTERVAL:** 22.90 m (DOWN HOLE)

DATE: 19-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 24.90 m (DOWN HOLE)

GAUGE P	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW	T
(BAR)	Flowmeter	litres	6202.5	6203.5	6204.5	6205.5	6206.5	6207.5			litres/min	m2/d
	Take	litres		1.0	1.0	1.0	1.0	1.0			LEAKAGE 2.5L	
5.00	Average Take	l/m		1.0	1.0	1.0	1.0	1.0			0.50	0.01
GAUGE P	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW	
(BAR)	Flowmeter	litres	6210.0	6211.8	6213.5	6215.3	6217.0	6218.8			litres/min	
	Take	litres		1.8	1.8	1.8	1.8	1.8			LEAKAGE 5L	
10.00	Average Take	l/m		1.8	1.8	1.8	1.8	1.8			0.75	0.01
GAUGE P	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW	
(BAR)	Flowmeter	litres	6223.5	6226.0	6228.5	6231.0	6234.0	6237.0			litres/min	
	Take	litres		2.5	2.5	2.5	3.0	3.0			LEAKAGE 7.5L	
15.03	Average Take	l/m		2.5	2.5	2.5	3.0	3.0			1.20	0.01
GAUGE P	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW	
(BAR)	Flowmeter	litres	6238.5	6240.3	6242.0	6244.8	6245.8	6248.0			litres/min	
	Take	litres		1.8	1.8	2.8	1.0	2.3			LEAKAGE 5L	
10.00	Average Take	l/m		1.8	1.8	2.8	1.0	2.3			0.90	0.01
GAUGE P	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW	
(BAR)	Flowmeter	litres	6249.5	6250.5	6251.5	6252.8	6254.0	6255.3			litres/min	
	Take	litres		1.0	1.0	1.3	1.3	1.3			LEAKAGE 2.5L	
5.00	Average Take	l/m		1.0	1.0	1.3	1.3	1.3			0.65	0.01





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 0.006

MIN k= 0.004

AVG k= 0.0048

INTERPRETATION laminar, with possible scour of fissures

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. All 5 Lugeons are about equal and hence laminar flow. Use the average of the five lugeons (to the nearest whole number)

DRILLING / TEST RESULTS COMMENTS:

Interval chosen as fresh bedrock with limited water inflow or fractures
Leakage experienced during the test and has been accounted for in the average flow rates. Measured at well head during each interval
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

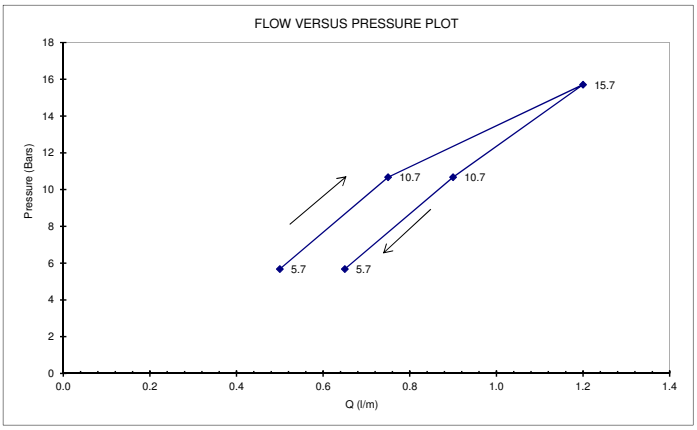
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B1

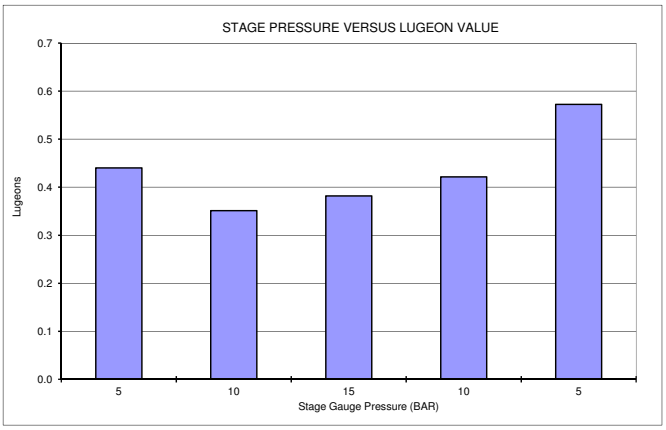
AREA: Close to BSOC WRD South Seep **TEST NO:** 1

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.3 m **TOP OF TEST INTERVAL:** 22.90 m (DOWN HOLE)

DATE: 19-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 24.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			litres/min	
	Flowmeter	litres	6202.5	6203.5	6204.5	6205.5	6206.5	6207.5				
	Take	litres		1.0	1.0	1.0	1.0	1.0			LEAKAGE 2.5L	
5.00	Average Take	l/m		1.0	1.0	1.0	1.0	1.0			0.50	0.44
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	LUGEON
	Flowmeter	litres	6210.0	6211.8	6213.5	6215.3	6217.0	6218.8				
	Take	litres		1.8	1.8	1.8	1.8	1.8			LEAKAGE 5L	
10.00	Average Take	l/m		1.8	1.8	1.8	1.8	1.8			0.75	0.35
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	LUGEON
	Flowmeter	litres	6223.5	6226.0	6228.5	6231.0	6234.0	6237.0				
	Take	litres		2.5	2.5	2.5	3.0	3.0			LEAKAGE 7.5L	
15.03	Average Take	l/m		2.5	2.5	2.5	3.0	3.0			1.20	0.38
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	LUGEON
	Flowmeter	litres	6238.5	6240.3	6242.0	6244.8	6245.8	6248.0				
	Take	litres		1.8	1.8	2.8	1.0	2.3			LEAKAGE 5L	
10.00	Average Take	l/m		1.8	1.8	2.8	1.0	2.3			0.90	0.42
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	LUGEON
	Flowmeter	litres	6249.5	6250.5	6251.5	6252.8	6254.0	6255.3				
	Take	litres		1.0	1.0	1.3	1.3	1.3			LEAKAGE 2.5L	
5.00	Average Take	l/m		1.0	1.0	1.3	1.3	1.3			0.65	0.57





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	0.572	MAX k=	0.005
MIN Lu=	0.351	MIN k=	0.003
AVG Lu=	0.433	AVG k=	0.004

INTERPRETATION Laminar, with possible scour of fissures

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification.
All 5 Lugeons are about equal and hence laminar flow. Use the average of the five lugeons (to the nearest whole number)

DRILLING / TEST RESULTS COMMENTS:
Interval chosen as fresh bedrock with limited water inflow or fractures
Leakage experienced during the test and has been accounted for in the average flow rates. Measured at well head during each interval
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

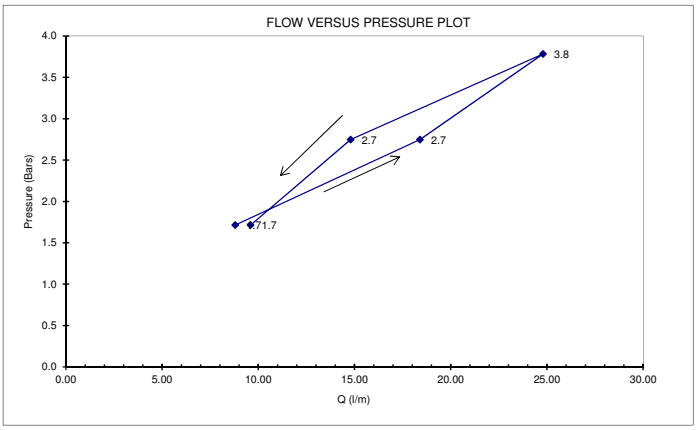
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B1

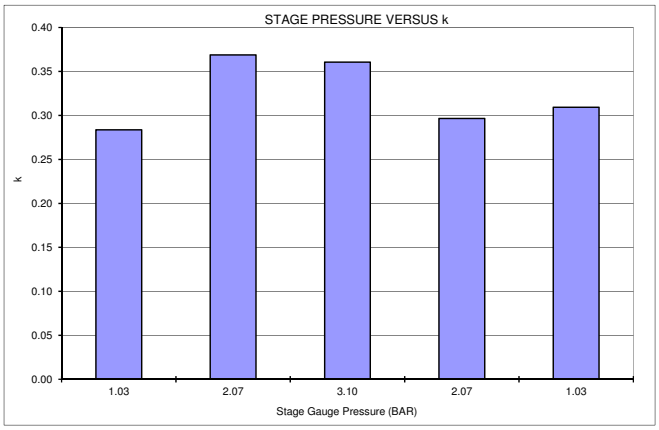
AREA: Close to BSOC WRD South Seep **TEST NO:** 2

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.3 m **TOP OF TEST INTERVAL:** 12.90 m (DOWN HOLE)

DATE: 19-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 14.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	T m2/d
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	6393.0	6401.5	6411.0	6420.0	6429.0	6437.0				
	Take	litres		8.5	9.5	9.0	9.0	8.0				
1.03	Average Take	l/m		8.5	9.5	9.0	9.0	8.0			8.80	0.57
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	6482.0	6497.0	6516.0	6537.0	6555.0	6574.0				
	Take	litres		15.0	19.0	21.0	18.0	19.0				
2.07	Average Take	l/m		15.0	19.0	21.0	18.0	19.0			18.40	0.74
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	6593.0	6619.0	6644.0	6669.0	6692.0	6717.0				
	Take	litres		26.0	25.0	25.0	23.0	25.0				
3.10	Average Take	l/m		26.0	25.0	25.0	23.0	25.0			24.80	0.72
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	6742.0	6756.0	6771.0	6787.0	6801.0	6816.0				
	Take	litres		14.0	15.0	16.0	14.0	15.0				
2.07	Average Take	l/m		14.0	15.0	16.0	14.0	15.0			14.80	0.59
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	6827.0	6837.0	6846.5	6856.0	6865.5	6875.0				
	Take	litres		10.0	9.5	9.5	9.5	9.5				
1.03	Average Take	l/m		10.0	9.5	9.5	9.5	9.5			9.60	0.62





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 0.369

MIN k= 0.284

AVG k= 0.3237

INTERPRETATION laminar flow

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification.
All 5 Lugeons are about equal and hence laminar flow. Use the average of the five lugeons (to the nearest whole number)

DRILLING / TEST RESULTS COMMENTS:
Interval chosen due to significant increase in airlift yeild during drilling.
No leakage observed.
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

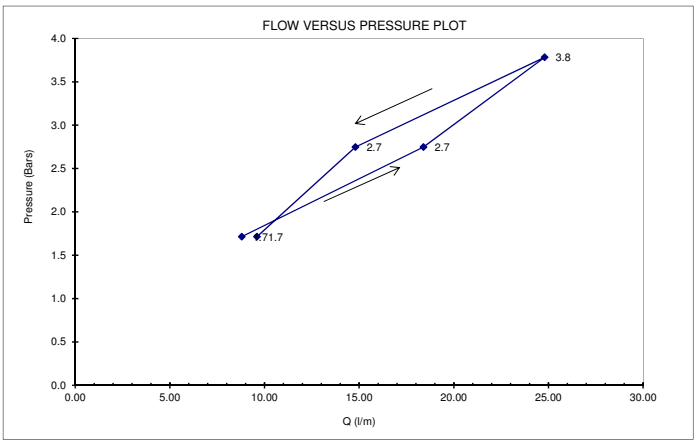
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B1

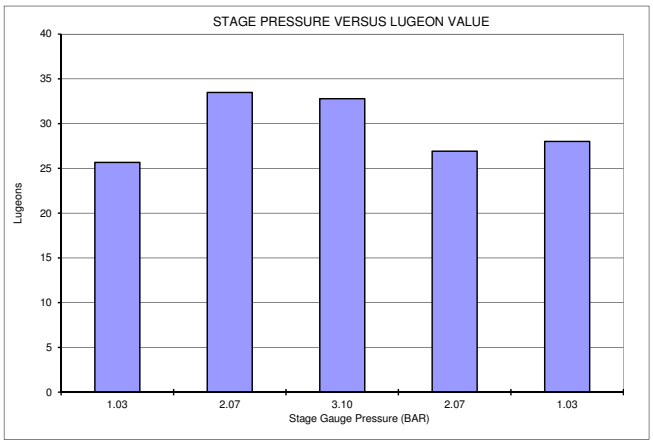
AREA: Close to BSOC WRD South Seep **TEST NO:** 2

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.3 m **TOP OF TEST INTERVAL:** 12.90 m (DOWN HOLE)

DATE: 19-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 14.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	6393.0	6401.5	6411.0	6420.0	6429.0	6437.0				
	Take	litres		8.5	9.5	9.0	9.0	8.0				
1.03	Average Take	l/m		8.5	9.5	9.0	9.0	8.0			8.80	25.67
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	6482.0	6497.0	6516.0	6537.0	6555.0	6574.0				
	Take	litres		15.0	19.0	21.0	18.0	19.0				
2.07	Average Take	l/m		15.0	19.0	21.0	18.0	19.0			18.40	33.47
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	6593.0	6619.0	6644.0	6669.0	6692.0	6717.0				
	Take	litres		26.0	25.0	25.0	23.0	25.0				
3.10	Average Take	l/m		26.0	25.0	25.0	23.0	25.0			24.80	32.78
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	6742.0	6756.0	6771.0	6787.0	6801.0	6816.0				
	Take	litres		14.0	15.0	16.0	14.0	15.0				
2.07	Average Take	l/m		14.0	15.0	16.0	14.0	15.0			14.80	26.92
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	6827.0	6837.0	6846.5	6856.0	6865.5	6875.0				
	Take	litres		10.0	9.5	9.5	9.5	9.5				
1.03	Average Take	l/m		10.0	9.5	9.5	9.5	9.5			9.60	28.00





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS

MAX Lu= 33.474

MIN Lu= 25.668

AVG Lu= 29.370

APPROXIMATE PERMEABILITY, m/d

MAX k= 0.289

MIN k= 0.222

AVG k= 0.254

INTERPRETATION Laminar flow

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification.
All 5 Lugeons are about equal and hence laminar flow. Use the average of the five lugeons (to the nearest whole number)

DRILLING / TEST RESULTS COMMENTS:

Interval chosen as water inflow zone with yield increasing during drilling at 14m
No leakage
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

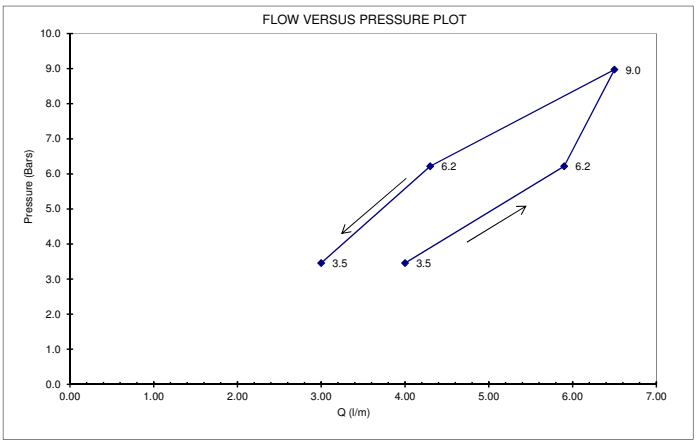
PROJECT: BSOC WRD EE **PROJECT NO:** D09626A20 **DRILLHOLE:** BSOC_B2

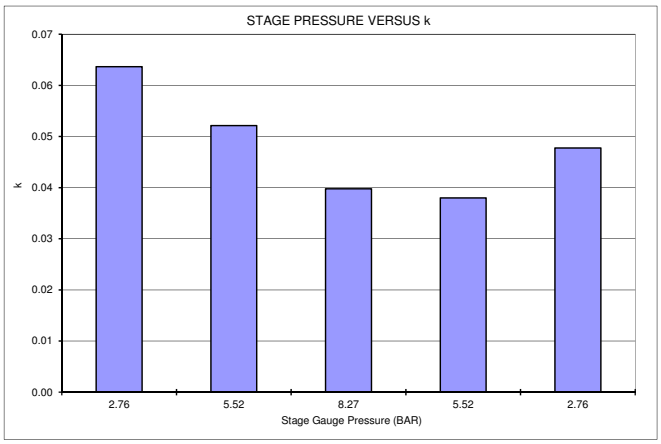
AREA: NE of BSOC WRD North Seep **TEST NO:** 1

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.5 m **TOP OF TEST INTERVAL:** 20.90 m (DOWN HOLE)

DATE: 16-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 22.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	T m2/d
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3997.0	4001.0	4005.5	4009.0	4013.5	4017.0				
	Take	litres		4.0	4.5	3.5	4.5	3.5				
2.76	Average Take	l/m		4.0	4.5	3.5	4.5	3.5			4.00	0.13
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4025.0	4031.0	4037.5	4043.0	4049.0	4054.5				
	Take	litres		6.0	6.5	5.5	6.0	5.5				
5.52	Average Take	l/m		6.0	6.5	5.5	6.0	5.5			5.90	0.10
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4074.0	4080.0	4086.0	4093.0	4100.0	4106.5				
	Take	litres		6.0	6.0	7.0	7.0	6.5				
8.27	Average Take	l/m		6.0	6.0	7.0	7.0	6.5			6.50	0.08
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4113.0	4117.0	4121.0	4125.5	4130.0	4134.5				
	Take	litres		4.0	4.0	4.5	4.5	4.5				
5.52	Average Take	l/m		4.0	4.0	4.5	4.5	4.5			4.30	0.08
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4137.5	4140.5	4143.5	4146.5	4149.5	4152.5				
	Take	litres		3.0	3.0	3.0	3.0	3.0				
2.76	Average Take	l/m		3.0	3.0	3.0	3.0	3.0			3.00	0.10





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 0.06

MIN k= 0.04

AVG k= 0.04

INTERPRETATION Turbulent flow or uplift of ground

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	YES
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. Lowest Lugeon value occurring at highest pressure hence turbulent flow. Use the lugeon value for the highest pressure.

DRILLING / TEST RESULTS COMMENTS:

Interval chosen as possible matrix flow and an increase in yield to 1.6 L/s observed during airlifting.
No leakage observed.
Flow meter in litres.

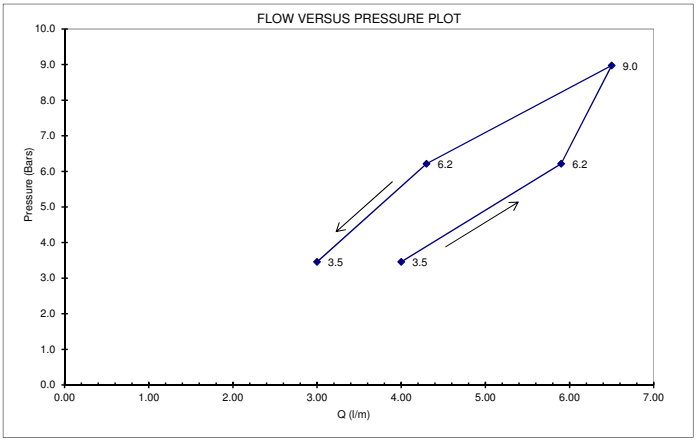
TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

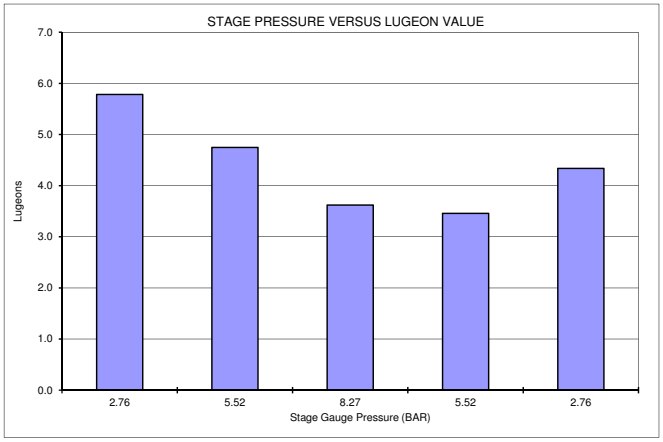
SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

PROJECT:	BSOC WRD EE	PROJECT NO:	D09620A20	DRILLHOLE:	BSOC_B2
AREA:	NE of BSOC WRD North Seep			TEST NO:	1
DIP:	90 ° (FROM HORIZONTAL)	DEPTH GROUNDWATER:	6.5 m	TOP OF TEST INTERVAL:	20.90 m (DOWN HOLE)
DATE:	16-Dec-15	GAUGE HEIGHT ABOVE GROUND:	0.5 m	BOTTOM OF TEST INTERVAL:	22.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3997.0	4001.0	4005.5	4009.0	4013.5	4017.0				
	Take	litres		4.0	4.5	3.5	4.5	3.5				
2.76	Average Take	l/m		4.0	4.5	3.5	4.5	3.5			4.00	5.78
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4025.0	4031.0	4037.5	4043.0	4049.0	4054.5				
	Take	litres		6.0	6.5	5.5	6.0	5.5				
5.52	Average Take	l/m		6.0	6.5	5.5	6.0	5.5			5.90	4.75
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4074.0	4080.0	4086.0	4093.0	4100.0	4106.5				
	Take	litres		6.0	6.0	7.0	7.0	6.5				
8.27	Average Take	l/m		6.0	6.0	7.0	7.0	6.5			6.50	3.62
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4113.0	4117.0	4121.0	4125.5	4130.0	4134.5				
	Take	litres		4.0	4.0	4.5	4.5	4.5				
5.52	Average Take	l/m		4.0	4.0	4.5	4.5	4.5			4.30	3.46
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4137.5	4140.5	4143.5	4146.5	4149.5	4152.5				
	Take	litres		3.0	3.0	3.0	3.0	3.0				
2.76	Average Take	l/m		3.0	3.0	3.0	3.0	3.0			3.00	4.34





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	5.784	MAX k=	0.05
MIN Lu=	3.459	MIN k=	0.03
AVG Lu=	3.622	AVG k=	0.03

INTERPRETATION Turbulent flow or uplift of ground

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	YES
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. Lowest Lugeon value occurring at highest pressure hence turbulent flow. Use the lugeon value for the highest pressure.

DRILLING / TEST RESULTS COMMENTS:

Interval chosen as possible matrix flow and an increase in yield to 1.6 L/s observed during airlifting.
No leakage observed.
Flow meter in litres.

TEST BY: Claire Kent

REVIEWED BY: Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

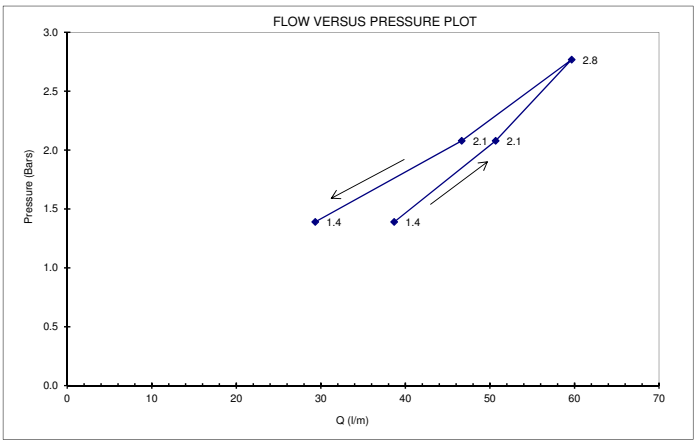
PROJECT: BSOC WRD EE **PROJECT NO:** D09626A20 **DRILLHOLE:** BSOC_B2

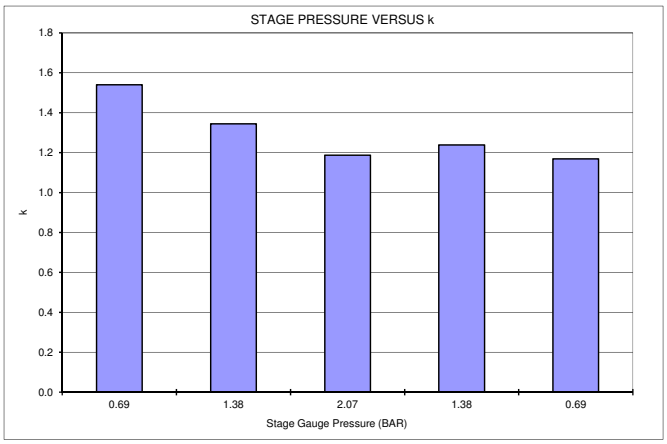
AREA: NE of BSOC WRD North Seep **TEST NO:** 2

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.5 m **TOP OF TEST INTERVAL:** 13.90 m (DOWN HOLE)

DATE: 16-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 15.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	T m2/d
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4463.0	4509.0	4544.0	4579.0						
	Take	litres		46.0	35.0	35.0						
0.69	Average Take	l/m		46.0	35.0	35.0					38.67	3.08
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4619.0	4669.0	4720.0	4771.0						
	Take	litres		50.0	51.0	51.0						
1.38	Average Take	l/m		50.0	51.0	51.0					50.67	2.69
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4800.0	4860.0	4920.0	4979.0						
	Take	litres		60.0	60.0	59.0						
2.07	Average Take	l/m		60.0	60.0	59.0					59.67	2.37
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5000.0	5048.0	5094.0	5140.0						
	Take	litres		48.0	46.0	46.0						
1.38	Average Take	l/m		48.0	46.0	46.0					46.67	2.48
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5175.0	5204.0	5234.0	5263.0						
	Take	litres		29.0	30.0	29.0						
0.69	Average Take	l/m		29.0	30.0	29.0					29.33	2.34





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 1.540

MIN k= 1.169

AVG k= 1.2958

INTERPRETATION laminar

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification.
All 5 Lugeons are about equal and hence laminar flow. Use the average of the five lugeons (to the nearest whole number)

DRILLING / TEST RESULTS COMMENTS:

No leakage
Test location - water inflow zone, test only run for three minutes due to volume of water being consumed and limited water on site.
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

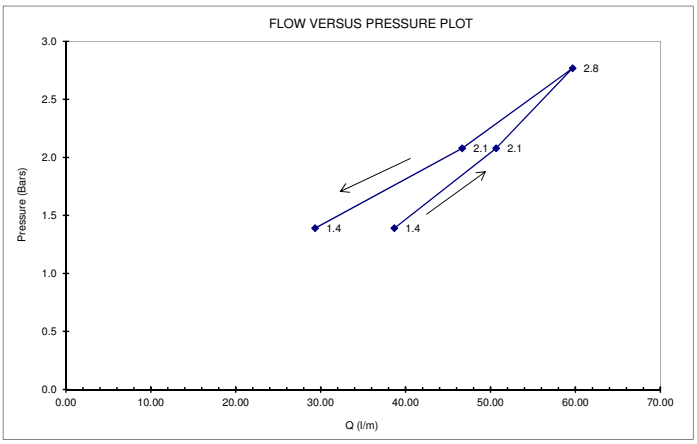
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B2

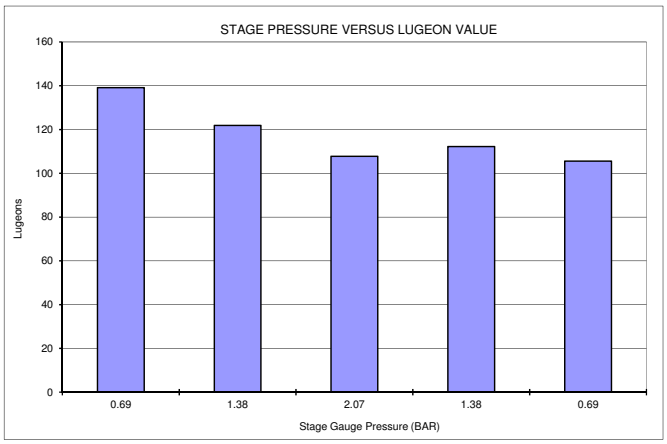
AREA: NE of BSOC WRD North Seep **TEST NO:** 2

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.5 m **TOP OF TEST INTERVAL:** 13.90 m (DOWN HOLE)

DATE: 17-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 15.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4463.0	4509.0	4544.0	4579.0						
	Take	litres		46.0	35.0	35.0						
0.69	Average Take	l/m		46.0	35.0	35.0					38.67	139.14
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4619.0	4669.0	4720.0	4771.0						
	Take	litres		50.0	51.0	51.0						
1.38	Average Take	l/m		50.0	51.0	51.0					50.67	121.86
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	4800.0	4860.0	4920.0	4979.0						
	Take	litres		60.0	60.0	59.0						
2.07	Average Take	l/m		60.0	60.0	59.0					59.67	107.76
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5000.0	5048.0	5094.0	5140.0						
	Take	litres		48.0	46.0	46.0						
1.38	Average Take	l/m		48.0	46.0	46.0					46.67	112.24
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5175.0	5204.0	5234.0	5263.0						
	Take	litres		29.0	30.0	29.0						
0.69	Average Take	l/m		29.0	30.0	29.0					29.33	105.56





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	139.141	MAX k=	1.202
MIN Lu=	105.555	MIN k=	0.912
AVG Lu=	117.310	AVG k=	1.014

INTERPRETATION laminar flow

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. All 5 Lugeons are about equal and hence laminar flow. Use the average of the five lugeons (to the nearest whole number)

DRILLING / TEST RESULTS COMMENTS:

No leakage
Test location - water inflow zone, test only run for three minutes due to volume of water being consumed and limited water on site.
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

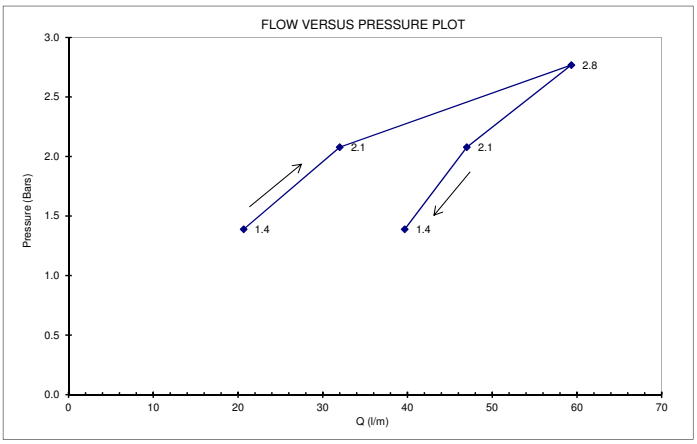
PROJECT: BSOC WRD EE **PROJECT NO:** D09626A20 **DRILLHOLE:** BSOC_B2

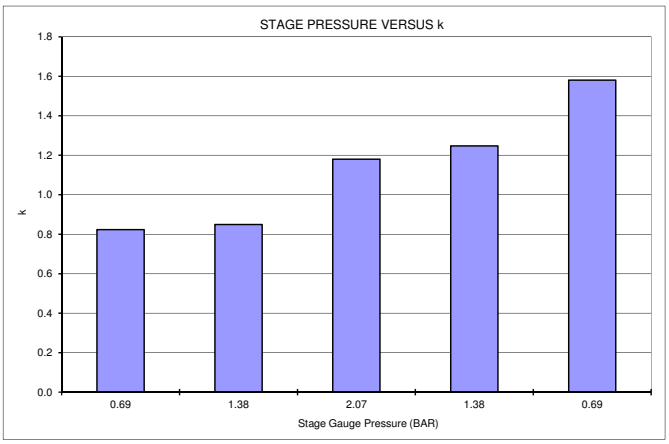
AREA: NE of BSOC WRD North Seep **TEST NO:** 3

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.5 m **TOP OF TEST INTERVAL:** 7.90 m (DOWN HOLE)

DATE: 16-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 9.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	T m2/d
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5404.0	5426.0	5448.0	5466.0						
	Take	litres		22.0	22.0	18.0						
0.69	Average Take	l/m		22.0	22.0	18.0					20.67	1.65
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5487.0	5518.0	5546.0	5583.0						
	Take	litres		31.0	28.0	37.0						
1.38	Average Take	l/m		31.0	28.0	37.0					32.00	1.70
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5622.0	5680.0	5740.0	5800.0						
	Take	litres		58.0	60.0	60.0						
2.07	Average Take	l/m		58.0	60.0	60.0					59.33	2.36
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5828.0	5869.0	5916.0	5969.0						
	Take	litres		41.0	47.0	53.0						
1.38	Average Take	l/m		41.0	47.0	53.0					47.00	2.49
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5993.0	6033.0	6072.0	6112.0						
	Take	litres		40.0	39.0	40.0						
0.69	Average Take	l/m		40.0	39.0	40.0					39.67	3.16





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 1.580

MIN k= 0.823

AVG k= 1.5803

INTERPRETATION washout, possible scour of fissures

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	YES
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. Lugeons increasing as test proceeds, hence the test is causing changes to the foundation. Use the highest lugeon value unless special reasons require otherwise.

DRILLING / TEST RESULTS COMMENTS:

No leakage.
Test location - first water strike, test only run for three minutes due to volume of water being consumed and limited water on site.
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

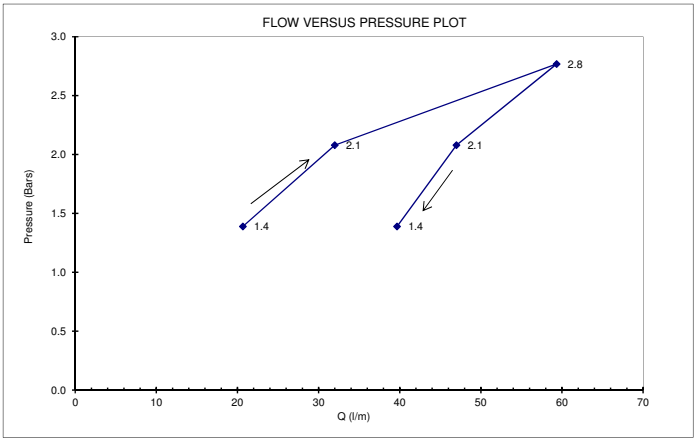
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B2

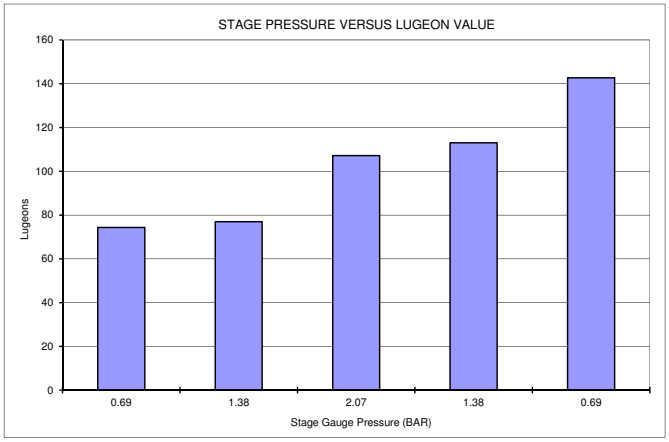
AREA: NE of BSOC WRD North Seep **TEST NO:** 3

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.5 m **TOP OF TEST INTERVAL:** 7.90 m (DOWN HOLE)

DATE: 17-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 9.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5404.0	5426.0	5448.0	5466.0						
	Take	litres		22.0	22.0	18.0						
0.69	Average Take	l/m		22.0	22.0	18.0					20.67	74.37
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5487.0	5518.0	5546.0	5583.0						
	Take	litres		31.0	28.0	37.0						
1.38	Average Take	l/m		31.0	28.0	37.0					32.00	76.96
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5622.0	5680.0	5740.0	5800.0						
	Take	litres		58.0	60.0	60.0						
2.07	Average Take	l/m		58.0	60.0	60.0					59.33	107.16
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5828.0	5869.0	5916.0	5969.0						
	Take	litres		41.0	47.0	53.0						
1.38	Average Take	l/m		41.0	47.0	53.0					47.00	113.04
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	5993.0	6033.0	6072.0	6112.0						
	Take	litres		40.0	39.0	40.0						
0.69	Average Take	l/m		40.0	39.0	40.0					39.67	142.74





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	142.740	MAX k=	1.233
MIN Lu=	74.369	MIN k=	0.643
AVG Lu=	142.740	AVG k=	1.233

INTERPRETATION washout, possible scour of fissures

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	YES
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. Lugeons increasing as test proceeds, hence the test is causing changes to the foundation. Use the highest lugeon value unless special reasons require otherwise.

DRILLING / TEST RESULTS COMMENTS:

No leakage.
Test location - first water strike, test only run for three minutes due to volume of water being consumed and limited water on site.
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

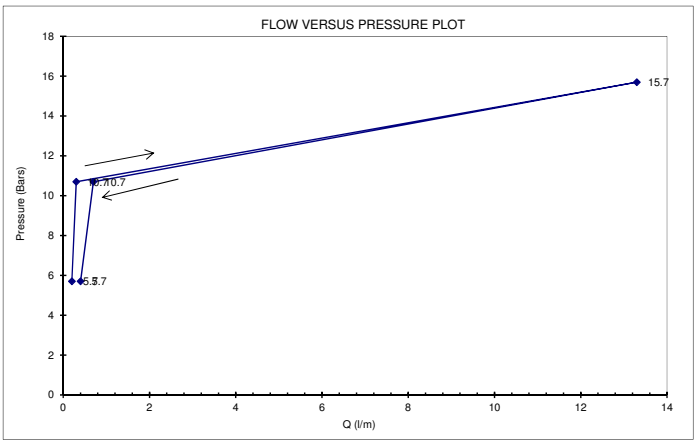
PROJECT: BSOC WRD EE **PROJECT NO:** D09626A20 **DRILLHOLE:** BSOC_B3

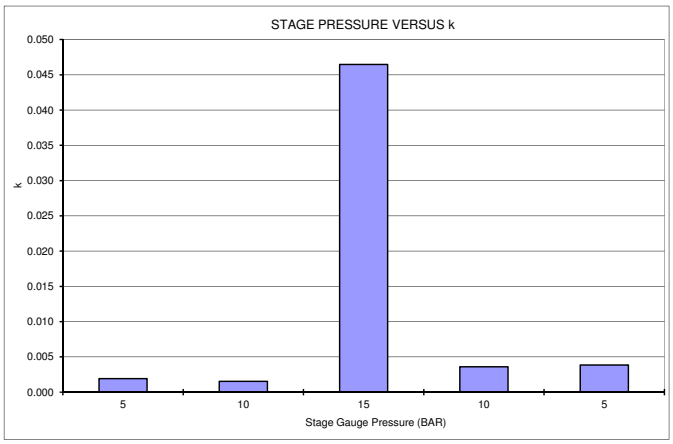
AREA: North of BSOC WRD North Seep **TEST NO:** 1

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.5 m **TOP OF TEST INTERVAL:** 24.40 m (DOWN HOLE)

DATE: 16-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 26.40 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW	T
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			litres/min	m2/d
	Flowmeter	litres	3489.0	3490.0	3490.8	3491.8	3492.5	3493.5			Leakage 3.5L	
	Take	litres		1.0	0.8	1.0	0.8	1.0				
5.00	Average Take	l/m		1.0	0.8	1.0	0.8	1.0			0.20	0.00
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	
	Flowmeter	litres	3495.0	3496.5	3498.3	3499.8	3501.5	3503.0			Leakage 6.5L	
	Take	litres		1.5	1.8	1.5	1.8	1.5				
10.00	Average Take	l/m		1.5	1.8	1.5	1.8	1.5			0.30	0.00
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	
	Flowmeter	litres	3524.0	3542.0	3558.0	3578.0	3593.0	3603.0			Leakage 12.5L	
	Take	litres		18.0	16.0	20.0	15.0	10.0				
15.00	Average Take	l/m		18.0	16.0	20.0	15.0	10.0			13.30	0.09
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	
	Flowmeter	litres	3612.0	3614.5	3616.0	3618.0	3620.0	3622.0			Leakage 6.5L	
	Take	litres		2.5	1.5	2.0	2.0	2.0				
10.00	Average Take	l/m		2.5	1.5	2.0	2.0	2.0			0.70	0.01
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	
	Flowmeter	litres	3623.5	3624.8	3625.8	3627.0	3628.0	3629.0			Leakage 3.5L	
	Take	litres		1.3	1.0	1.3	1.0	1.0				
5.00	Average Take	l/m		1.3	1.0	1.3	1.0	1.0			0.40	0.01





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 0.046

MIN k= 0.002

AVG k= 0.003

INTERPRETATION Possible scour of fissure or movement of packer at high pressure.

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	NO
3	DILATION	YES
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. Highest Lugeon occurred at highest pressure, hence dilation. Average Lugeon value from lowest pressures was used to calculate **average** permeability.

DRILLING / TEST RESULTS COMMENTS:

Interval chosen as fresh bedrock with limited fracturing.
Leakage accounted for in average flow rate.
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

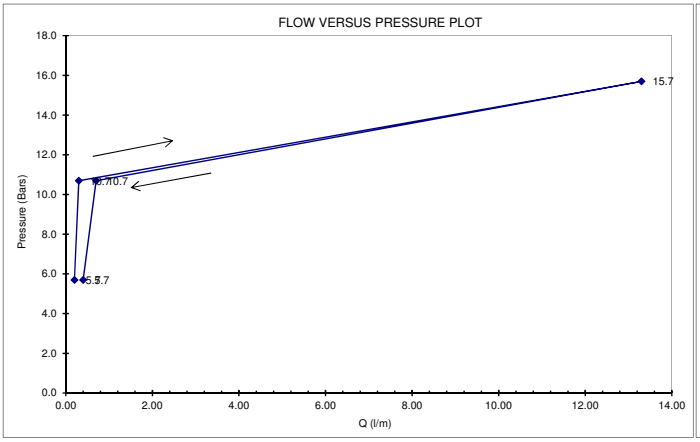
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B3

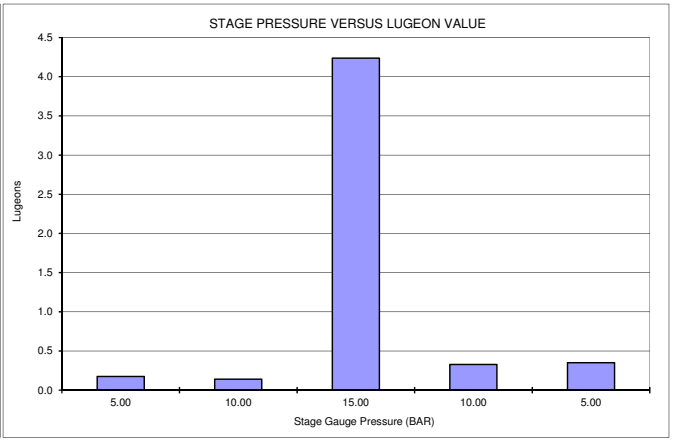
AREA: North of BSOC WRD North Seep **TEST NO:** 1

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.5 m **TOP OF TEST INTERVAL:** 24.40 m (DOWN HOLE)

DATE: 16-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 26.40 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			litres/min	
	Flowmeter	litres	3489.0	3490.0	3490.8	3491.8	3492.5	3493.5			Leakage 3.5L	
	Take	litres		1.0	0.8	1.0	0.8	1.0				
5.00	Average Take	l/m		1.0	0.8	1.0	0.8	1.0			0.20	0.18
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	LUGEON
	Flowmeter	litres	3495.0	3496.5	3498.3	3499.8	3501.5	3503.0			Leakage 6.5L	
	Take	litres		1.5	1.8	1.5	1.8	1.5				
10.00	Average Take	l/m		1.5	1.8	1.5	1.8	1.5			0.30	0.14
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	LUGEON
	Flowmeter	litres	3524.0	3542.0	3558.0	3578.0	3593.0	3603.0			Leakage 12.5L	
	Take	litres		18.0	16.0	20.0	15.0	10.0				
15.00	Average Take	l/m		18.0	16.0	20.0	15.0	10.0			13.30	4.24
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	LUGEON
	Flowmeter	litres	3612.0	3614.5	3616.0	3618.0	3620.0	3622.0			Leakage 6.5L	
	Take	litres		2.5	1.5	2.0	2.0	2.0				
10.00	Average Take	l/m		2.5	1.5	2.0	2.0	2.0			0.70	0.33
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	LUGEON
	Flowmeter	litres	3623.5	3624.8	3625.8	3627.0	3628.0	3629.0			Leakage 3.5L	
	Take	litres		1.3	1.0	1.3	1.0	1.0				
5.00	Average Take	l/m		1.3	1.0	1.3	1.0	1.0			0.40	0.35





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M}{28} f$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	4.237	MAX k=	0.037
MIN Lu=	0.140	MIN k=	0.001
AVG Lu=	0.248	AVG k=	0.002

INTERPRETATION Possible scour of fissure or movement of packer at high pressure.

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	NO
3	DILATION	YES
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification.
Highest Lugeon occurred at highest pressure, hence dilation.
Average Lugeon value from lowest pressures was used to calculate **average** permeability.

DRILLING / TEST RESULTS COMMENTS:
Interval chosen as fresh bedrock with limited fracturing.
Leakage accounted for in average flow rate.
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

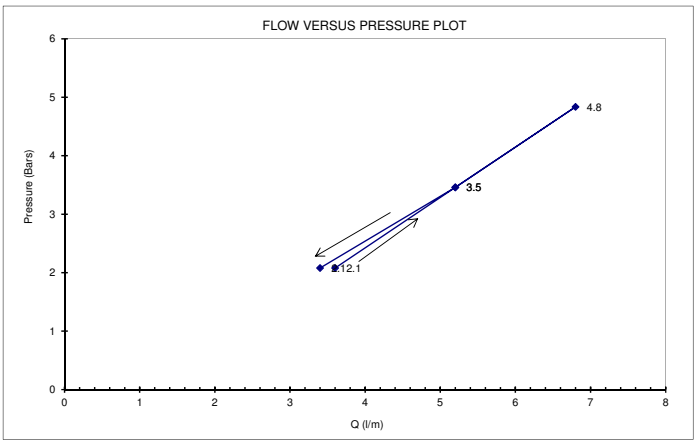
PROJECT: BSOC WRD EE **PROJECT NO:** D09626A20 **DRILLHOLE:** BSOC_B3

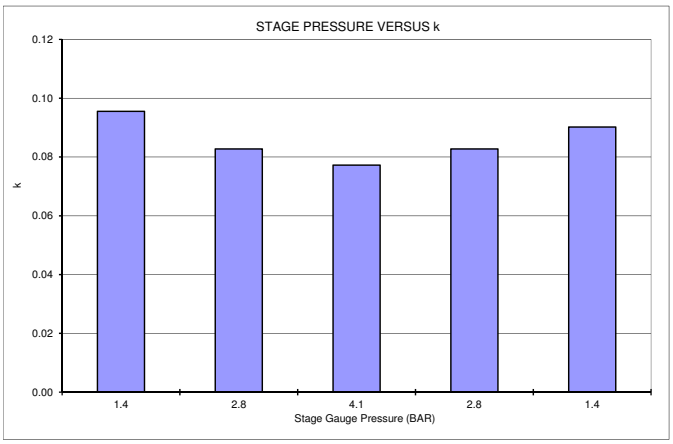
AREA: North of BSOC WRD North Seep **TEST NO:** 2

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.5 m **TOP OF TEST INTERVAL:** 19.90 m (DOWN HOLE)

DATE: 16-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 21.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	T m2/d
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3694.0	3696.0	3701.0	3705.0	3708.5	3712.0				
	Take	litres		2.0	5.0	4.0	3.5	3.5				
1.38	Average Take	l/m		2.0	5.0	4.0	3.5	3.5			3.60	0.19
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3722.0	3728.0	3733.0	3738.0	3744.0	3748.0				
	Take	litres		6.0	5.0	5.0	6.0	4.0				
2.76	Average Take	l/m		6.0	5.0	5.0	6.0	4.0			5.20	0.17
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3766.0	3772.0	3780.0	3787.0	3794.0	3800.0				
	Take	litres		6.0	8.0	7.0	7.0	6.0				
4.14	Average Take	l/m		6.0	8.0	7.0	7.0	6.0			6.80	0.15
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3804.0	3809.0	3813.0	3819.0	3825.0	3830.0				
	Take	litres		5.0	4.0	6.0	6.0	5.0				
2.76	Average Take	l/m		5.0	4.0	6.0	6.0	5.0			5.20	0.17
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3831.5	3834.5	3838.0	3841.5	3844.5	3848.5				
	Take	litres		3.0	3.5	3.5	3.0	4.0				
1.38	Average Take	l/m		3.0	3.5	3.5	3.0	4.0			3.40	0.18





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 0.096

MIN k= 0.077

AVG k= 0.0857

INTERPRETATION laminar flow

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification.
All 5 Lugeons are about equal and hence laminar flow. Use the average of the five lugeons (to the nearest whole number)

DRILLING / TEST RESULTS COMMENTS:
No leakage.
Test location - water strike interval.
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

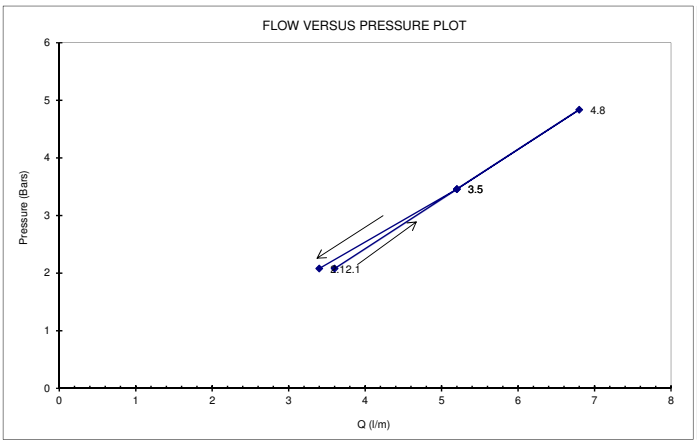
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B2

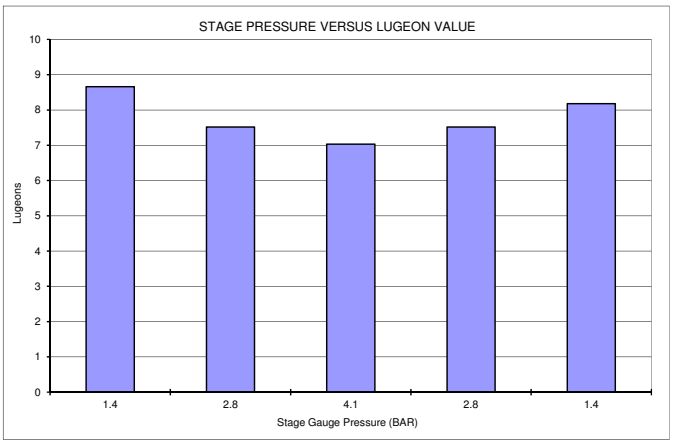
AREA: North of BSOC WRD North Seep **TEST NO:** 2

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 6.5 m **TOP OF TEST INTERVAL:** 19.90 m (DOWN HOLE)

DATE: 16-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 21.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3694.0	3696.0	3701.0	3705.0	3708.5	3712.0				
	Take	litres		2.0	5.0	4.0	3.5	3.5				
1.38	Average Take	l/m		2.0	5.0	4.0	3.5	3.5			3.60	8.66
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3722.0	3728.0	3733.0	3738.0	3744.0	3748.0				
	Take	litres		6.0	5.0	5.0	6.0	4.0				
2.76	Average Take	l/m		6.0	5.0	5.0	6.0	4.0			5.20	7.52
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3766.0	3772.0	3780.0	3787.0	3794.0	3800.0				
	Take	litres		6.0	8.0	7.0	7.0	6.0				
4.14	Average Take	l/m		6.0	8.0	7.0	7.0	6.0			6.80	7.03
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3804.0	3809.0	3813.0	3819.0	3825.0	3830.0				
	Take	litres		5.0	4.0	6.0	6.0	5.0				
2.76	Average Take	l/m		5.0	4.0	6.0	6.0	5.0			5.20	7.52
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3831.5	3834.5	3838.0	3841.5	3844.5	3848.5				
	Take	litres		3.0	3.5	3.5	3.0	4.0				
1.38	Average Take	l/m		3.0	3.5	3.5	3.0	4.0			3.40	8.18





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	8.658	MAX k=	0.075
MIN Lu=	7.029	MIN k=	0.061
AVG Lu=	7.781	AVG k=	0.067

INTERPRETATION laminar flow

INTERPRETATION TYPE OF FLOW:		
1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification.
All 5 Lugeons are about equal and hence laminar flow. Use the average of the five lugeons (to the nearest whole number)

DRILLING / TEST RESULTS COMMENTS:
No leakage.
Test location - water strike interval.
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

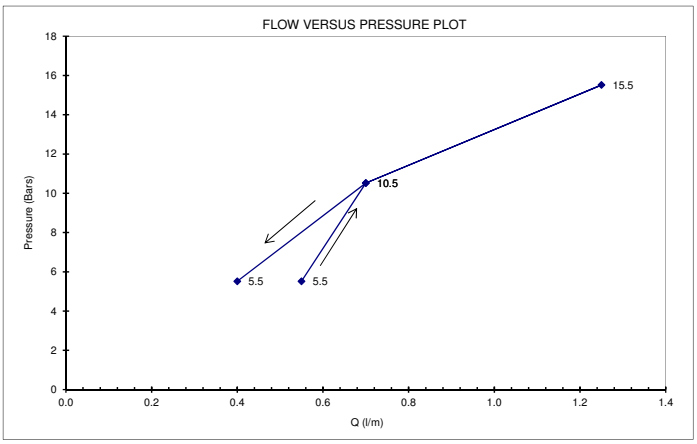
PROJECT: BSOC WRD EE **PROJECT NO:** D09626A20 **DRILLHOLE:** BSOC_B4

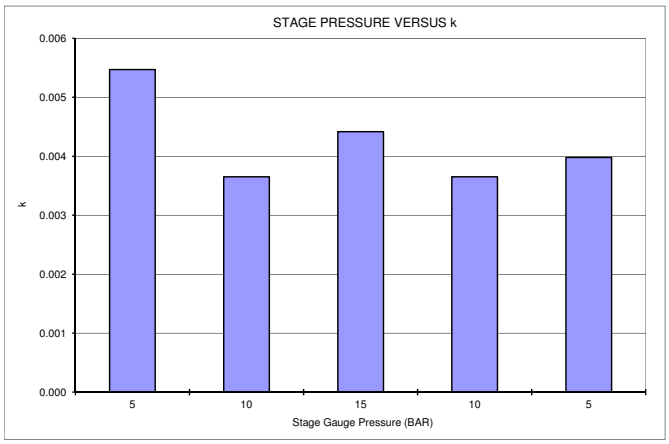
AREA: NE of BSOC WRD North Seep **TEST NO:** 1

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 4.2 m **TOP OF TEST INTERVAL:** 32.20 m (DOWN HOLE)

DATE: 12-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 1.0 m **BOTTOM OF TEST INTERVAL:** 34.20 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	T m2/d
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	294.0	294.5	295.3	295.8	296.3	296.8				
	Take	litres		0.5	0.8	0.5	0.5	0.5				
5.00	Average Take	l/m		0.5	0.8	0.5	0.5	0.5			0.55	0.011
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	
	Flowmeter	litres	301.3	302.0	302.8	303.3	304.0	304.8				
	Take	litres		0.8	0.8	0.5	0.8	0.8				
10.00	Average Take	l/m		0.8	0.8	0.5	0.8	0.8			0.70	0.007
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	
	Flowmeter	litres	306.8	307.5	308.5	310.3	311.8	313.0				
	Take	litres		0.8	1.0	1.8	1.4	1.3				
15.00	Average Take	l/m		0.8	1.0	1.8	1.4	1.3			1.25	0.009
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	
	Flowmeter	litres	313.5	314.3	315.0	315.8	316.5	317.0				
	Take	litres		0.8	0.8	0.8	0.8	0.5				
10.00	Average Take	l/m		0.8	0.8	0.8	0.8	0.5			0.70	0.007
GAUGE P (BAR)	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			AVERAGE FLOW litres/min	
	Flowmeter	litres	317.3	317.5	318.0	318.3	318.8	319.3				
	Take	litres		0.3	0.5	0.3	0.5	0.5				
5.00	Average Take	l/m		0.3	0.5	0.3	0.5	0.5			0.40	0.008





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 0.005

MIN k= 0.004

AVG k= 0.0042

INTERPRETATION Laminar flow

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification.
All five lugeons are about equal, therefore average of lugeons used to calculate average permeability.

DRILLING / TEST RESULTS COMMENTS:
Interval represents fresh stong rock with no fracturing.
No leakage.
Flow meter in litres.

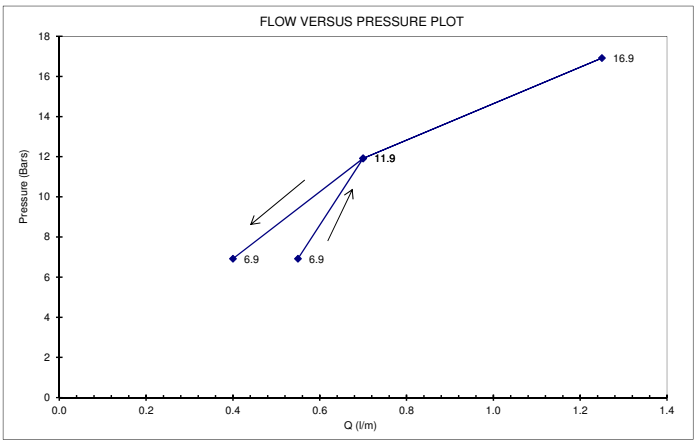
TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

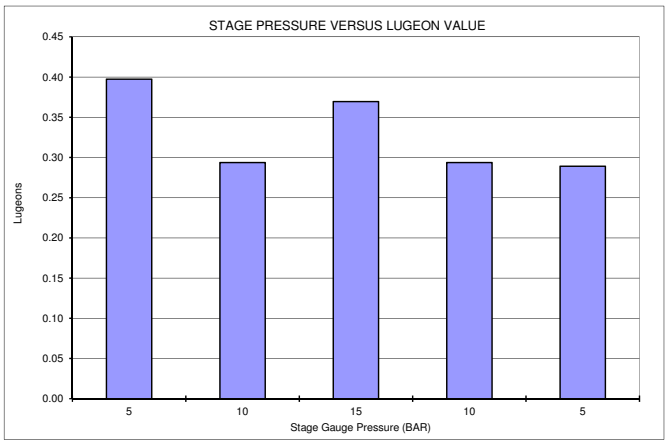
SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

PROJECT:	BSOC WRD EE	PROJECT NO:	D09620A20	DRILLHOLE:	BSOC_B4
AREA:	NE of BSOC WRD North Seep			TEST NO:	1
DIP:	90 ° (FROM HORIZONTAL)	DEPTH GROUNDWATER:	18.7 m	TOP OF TEST INTERVAL:	32.20 m (DOWN HOLE)
DATE:	12-Dec-15	GAUGE HEIGHT ABOVE GROUND:	0.5 m	BOTTOM OF TEST INTERVAL:	34.20 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	294.0	294.5	295.3	295.8	296.3	296.8				
	Take	litres		0.5	0.8	0.5	0.5	0.5				
5.00	Average Take	l/m		0.5	0.8	0.5	0.5	0.5			0.55	0.40
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	301.3	302.0	302.8	303.3	304.0	304.8				
	Take	litres		0.8	0.8	0.5	0.8	0.8				
10.00	Average Take	l/m		0.8	0.8	0.5	0.8	0.8			0.70	0.29
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	306.8	307.5	308.5	310.3	311.8	313.0				
	Take	litres		0.8	1.0	1.8	1.4	1.3				
15.00	Average Take	l/m		0.8	1.0	1.8	1.4	1.3			1.25	0.37
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	313.5	314.3	315.0	315.8	316.5	317.0				
	Take	litres		0.8	0.8	0.8	0.8	0.5				
10.00	Average Take	l/m		0.8	0.8	0.8	0.8	0.5			0.70	0.29
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	317.3	317.5	318.0	318.3	318.8	319.3				
	Take	litres		0.3	0.5	0.3	0.5	0.5				
5.00	Average Take	l/m		0.3	0.5	0.3	0.5	0.5			0.40	0.29





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	0.397	MAX k=	0.003
MIN Lu=	0.289	MIN k=	0.002
AVG Lu=	0.329	AVG k=	0.003

INTERPRETATION

Laminar flow

INTERPRETATION TYPE OF FLOW:		
1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification.
All five lugeons are about equal, therefore average of lugeons used to calculate average permeability.

DRILLING / TEST RESULTS COMMENTS:

Interval represents fresh stong rock with no fracturing.
No leakage.
Flow meter in litres.

TEST BY:	Claire Kent	REVIEWED BY:	Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

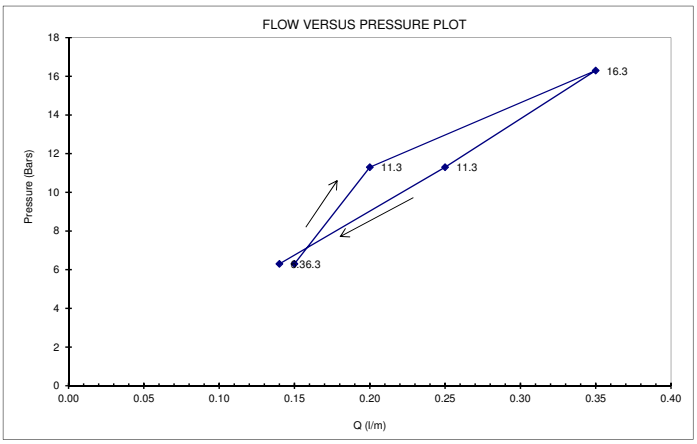
PROJECT: BSOC WRD EE **PROJECT NO:** D09626A20 **DRILLHOLE:** BSOC_B4

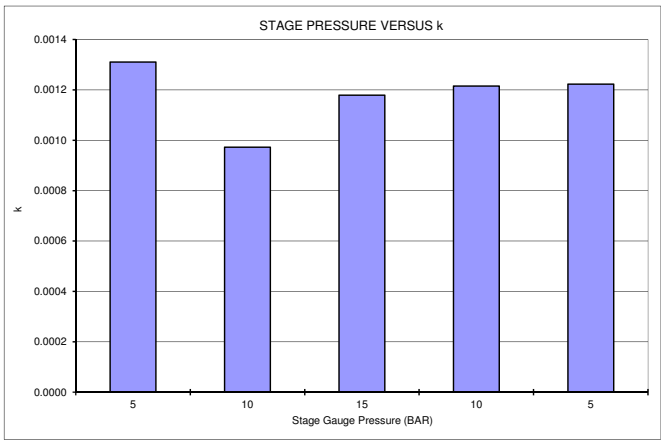
AREA: NE of BSOC WRD North Seep **TEST NO:** 2

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 12.5 m **TOP OF TEST INTERVAL:** 27.20 m (DOWN HOLE)

DATE: 13-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 29.20 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW	T
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			litres/min	m2/d
	Flowmeter	litres	478.3	479.0	479.8	480.5	481.3	482.0				
	Take	litres		0.8	0.8	0.8	0.8	0.8			LEAKAGE 3L	
5.00	Average Take	l/m		0.8	0.8	0.8	0.8	0.8			0.15	0.003
GAUGE P (BAR)											AVERAGE FLOW	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			litres/min	
	Flowmeter	litres	486.5	487.8	489.0	490.5	492.0	493.5				
	Take	litres		1.3	1.3	1.5	1.5	1.5			LEAKAGE 6L	
10.00	Average Take	l/m		1.3	1.3	1.5	1.5	1.5			0.20	0.002
GAUGE P (BAR)											AVERAGE FLOW	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			litres/min	
	Flowmeter	litres	500.8	502.8	504.8	507.0	509.5	511.5				
	Take	litres		2.0	2.0	2.3	2.5	2.0			LEAKAGE 9L	
15.00	Average Take	l/m		2.0	2.0	2.3	2.5	2.0			0.35	0.002
GAUGE P (BAR)											AVERAGE FLOW	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			litres/min	
	Flowmeter	litres	519.0	520.8	522.5	524.0	525.8	527.3				
	Take	litres		1.8	1.8	1.5	1.8	1.5			LEAKAGE 7L	
10.00	Average Take	l/m		1.8	1.8	1.5	1.8	1.5			0.25	0.002
GAUGE P (BAR)											AVERAGE FLOW	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0			litres/min	
	Flowmeter	litres	531.8	532.8	534.0	535.0	536.3	537.3				
	Take	litres		1.0	1.3	1.0	1.3	1.0			LEAKAGE 4.8L	
5.00	Average Take	l/m		1.0	1.3	1.0	1.3	1.0			0.14	0.002





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 0.001

MIN k= 0.001

AVG k= 0.0012

INTERPRETATION Laminar flow

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification.
All 5 Lugeons are about equal and hence laminar flow. Uses the average of the five lugeons as average permeability.

DRILLING / TEST RESULTS COMMENTS:

Section targeting fracture zone.
Leakage measured at well head and accounted for in average flow rate.

Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

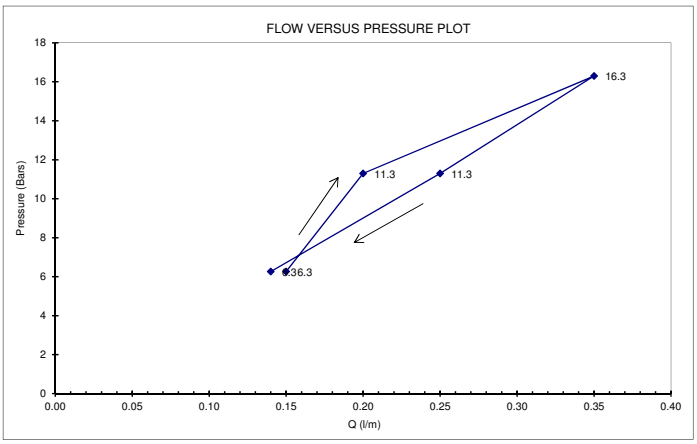
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B4

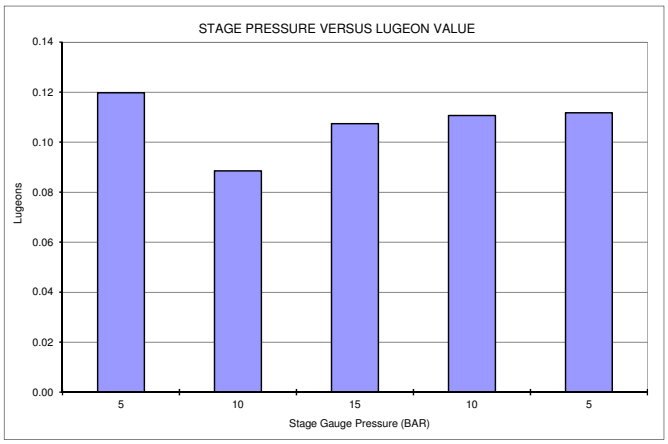
AREA: NE of BSOC WRD North Seep **TEST NO:** 2

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 12.5 m **TOP OF TEST INTERVAL:** 27.20 m (DOWN HOLE)

DATE: 13-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 29.20 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	478.3	479.0	479.8	480.5	481.3	482.0				
	Take	litres		0.8	0.8	0.8	0.8	0.8			LEAKAGE 3L	
4.96	Average Take	l/m		0.2	0.2	0.2	0.2	0.2			0.15	0.12
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	486.5	487.8	489.0	490.5	492.0	493.5				
	Take	litres		1.3	1.3	1.5	1.5	1.5			LEAKAGE 6L	
10.00	Average Take	l/m		1.3	1.3	1.5	1.5	1.5			0.20	0.09
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	500.8	502.8	504.8	507.0	509.5	511.5				
	Take	litres		2.0	2.0	2.3	2.5	2.0			LEAKAGE 9L	
15.00	Average Take	l/m		2.0	2.0	2.3	2.5	2.0			0.35	0.11
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	519.0	520.8	522.5	524.0	525.8	527.3				
	Take	litres		1.8	1.8	1.5	1.8	1.5			LEAKAGE 7L	
10.00	Average Take	l/m		1.8	1.8	1.5	1.8	1.5			0.25	0.11
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	531.8	532.8	534.0	535.0	536.3	537.3				
	Take	litres		1.0	1.3	1.0	1.3	1.0			LEAKAGE 4.8L	
4.96	Average Take	l/m		1.0	1.3	1.0	1.3	1.0			0.14	0.11





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	0.120	MAX k=	0.001
MIN Lu=	0.089	MIN k=	0.001
AVG Lu=	0.108	AVG k=	0.001

INTERPRETATION Laminar flow

INTERPRETATION TYPE OF FLOW:		
1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. All 5 Lugeons are about equal and hence laminar flow. Uses the average of the five lugeons as average permeability.

DRILLING / TEST RESULTS COMMENTS:

Section targeting fracture zone.
Leakage measured at well head and accounted for in average flow rate.

Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

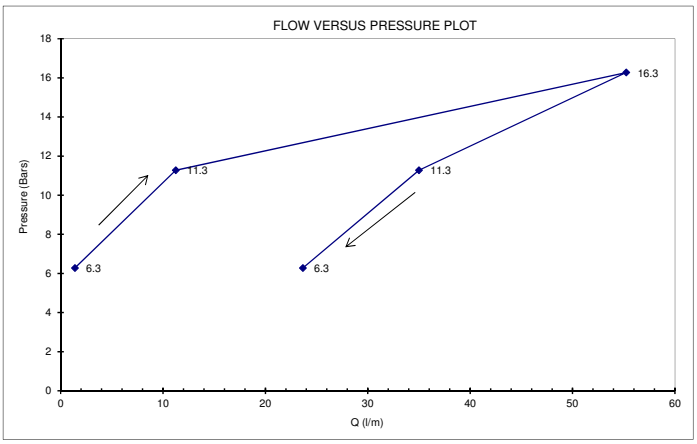
PROJECT: BSOC WRD EE **PROJECT NO:** D09626A20 **DRILLHOLE:** BSOC_B4

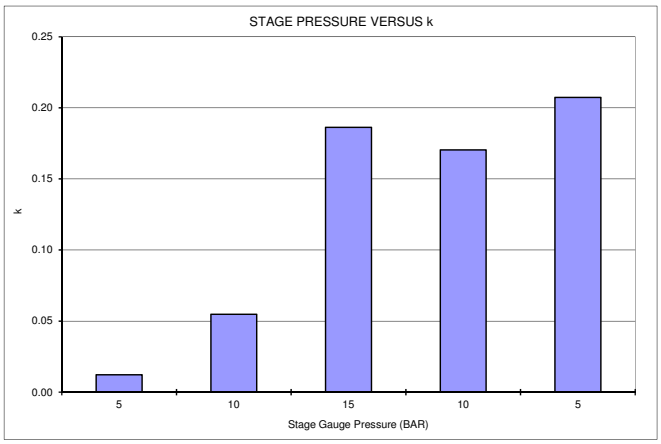
AREA: NE of BSOC WRD North Seep **TEST NO:** 3

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 12.3 m **TOP OF TEST INTERVAL:** 18.90 m (DOWN HOLE)

DATE: 13-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 20.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	T m2/d
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	592.3	593.8	595.3	596.8	598.0	599.3				
	Take	litres		1.5	1.5	1.5	1.3	1.3				
5.00	Average Take	l/m		1.5	1.5	1.5	1.3	1.3			1.40	0.02
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	606.8	614.5	623.8	635.3	649.0	663.0				
	Take	litres		7.8	9.3	11.5	13.8	14.0				
10.00	Average Take	l/m		7.8	9.3	11.5	13.8	14.0			11.25	0.11
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	686.0	728.0	785.0	846.0	907.0					
	Take	litres		42.0	57.0	61.0	61.0					
15.00	Average Take	l/m		42.0	57.0	61.0	61.0				55.25	0.37
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	932.0	967.0	1003.0	1037.0						
	Take	litres		35.0	36.0	34.0						
10.00	Average Take	l/m		35.0	36.0	34.0					35.00	0.34
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	1051.0	1073.0	1096.0	1122.0						
	Take	litres		22.0	23.0	26.0						
5.00	Average Take	l/m		22.0	23.0	26.0					23.67	0.41





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 0.207

MIN k= 0.012

AVG k= 0.2074

INTERPRETATION Possible scour of fissure or movement of packer at high pressure.

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	YES
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. Lugeons increasing as test proceeds, hence the test is causing changes to the foundation. Use the highest lugeon value as average permeability.

DRILLING / TEST RESULTS COMMENTS:

Section targeting first water strike zone, fractures identified in drill chips.
Three minute steps at end, due to water shortage at rig.
Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

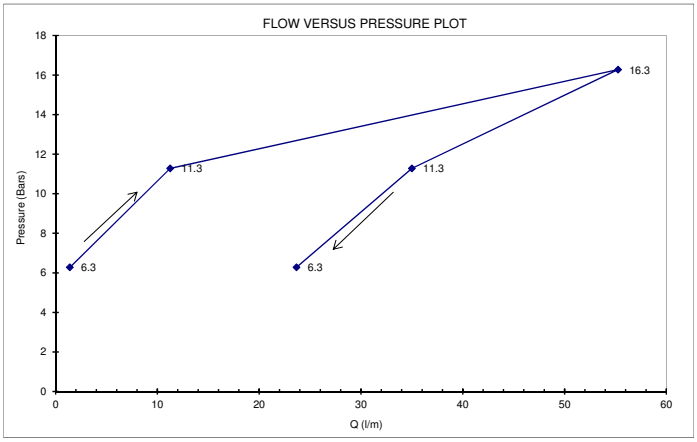
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B4

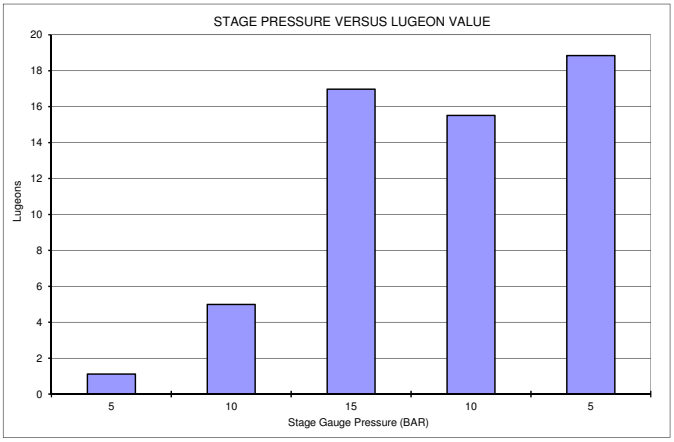
AREA: NE of BSOC WRD North Seep **TEST NO:** 3

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 12.3 m **TOP OF TEST INTERVAL:** 18.90 m (DOWN HOLE)

DATE: 13-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 20.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	592.3	593.8	595.3	596.8	598.0	599.3				
	Take	litres		1.5	1.5	1.5	1.3	1.3				
5.00	Average Take	l/m		1.5	1.5	1.5	1.3	1.3			1.40	1.11
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	606.8	614.5	623.8	635.3	649.0	663.0				
	Take	litres		7.8	9.3	11.5	13.8	14.0				
10.00	Average Take	l/m		7.8	9.3	11.5	13.8	14.0			11.25	4.99
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	686.0	728.0	785.0	846.0	907.0					
	Take	litres		42.0	57.0	61.0	61.0					
15.00	Average Take	l/m		42.0	57.0	61.0	61.0				55.25	16.97
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	932.0	967.0	1003.0	1037.0						
	Take	litres		35.0	36.0	34.0						
10.00	Average Take	l/m		35.0	36.0	34.0					35.00	15.52
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	1051.0	1073.0	1096.0	1122.0						
	Take	litres		22.0	23.0	26.0						
5.00	Average Take	l/m		22.0	23.0	26.0					23.67	18.85





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	18.847	MAX k=	0.163
MIN Lu=	1.115	MIN k=	0.010
AVG Lu=	18.847	AVG k=	0.163

INTERPRETATION Possible scour of fissure or movement of packer at high pressure.

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	YES
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. Lugeons increasing as test proceeds, hence the test is causing changes to the foundation. Use the highest lugeon value as average permeability.

DRILLING / TEST RESULTS COMMENTS:
Section targeting first water strike zone, fractures identified in drill chips.
Three minute steps at end, due to water shortage at rig.
Flow meter in litres.

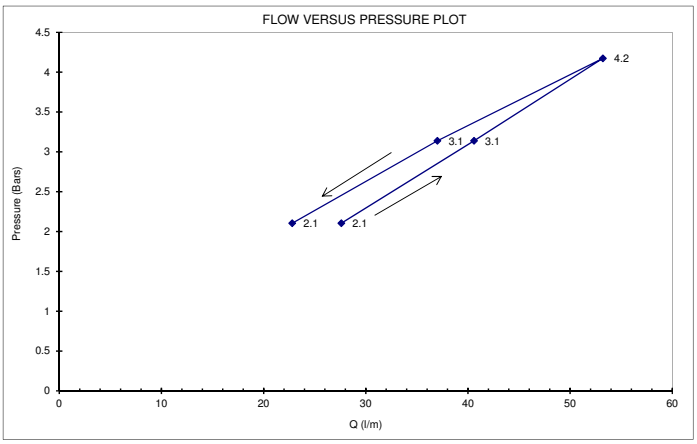
TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

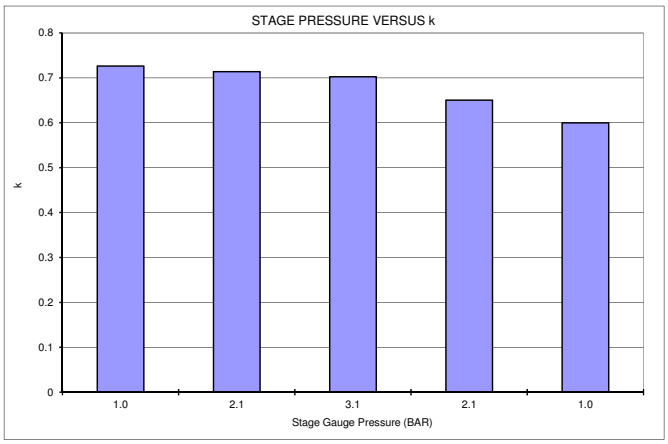
SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

PROJECT:	BSOC WRD EE	PROJECT NO:	D09626A20	DRILLHOLE:	BSOC_B5
AREA:	North of TD3 Seep			TEST NO:	1
DIP:	90 ° (FROM HORIZONTAL)	DEPTH GROUNDWATER:	10.2 m	TOP OF TEST INTERVAL:	28.70 m (DOWN HOLE)
DATE:	14-Dec-15	GAUGE HEIGHT ABOVE GROUND:	0.5 m	BOTTOM OF TEST INTERVAL:	30.70 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	T m2/d
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	1333.0	1366.0	1395.0	1421.0	1445.0	1471.0				
	Take	litres		33.0	29.0	26.0	24.0	26.0				
1.03	Average Take	l/m		33.0	29.0	26.0	24.0	26.0			27.60	1.45
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	1589.0	1629.0	1669.0	1711.0	1751.0	1792.0				
	Take	litres		40.0	40.0	42.0	40.0	41.0				
2.07	Average Take	l/m		40.0	40.0	42.0	40.0	41.0			40.60	1.43
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	1917.0	1965.0	2020.0	2074.0	2129.0	2183.0				
	Take	litres		48.0	55.0	54.0	55.0	54.0				
3.10	Average Take	l/m		48.0	55.0	54.0	55.0	54.0			53.20	1.40
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2263.0	2301.0	2337.0	2378.0	2412.0	2448.0				
	Take	litres		38.0	36.0	41.0	34.0	36.0				
2.07	Average Take	l/m		38.0	36.0	41.0	34.0	36.0			37.00	1.30
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2465.0	2486.0	2508.0	2531.0	2555.0	2579.0				
	Take	litres		21.0	22.0	23.0	24.0	24.0				
1.03	Average Take	l/m		21.0	22.0	23.0	24.0	24.0			22.80	1.20





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k=	0.726
MIN k=	0.600
AVG k=	0.6785

INTERPRETATION Laminar flow

INTERPRETATION TYPE OF FLOW:		
1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. All 5 Lugeons are about equal and hence laminar flow. Average of five lugeon values used to calculate **average** permeability.

DRILLING / TEST RESULTS COMMENTS:

Interval chosen due to significant increase in airlift yeild during drilling.

Flow meter in litres.

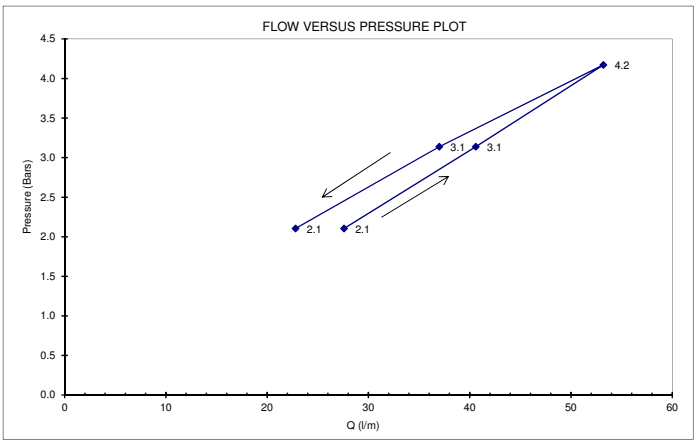
TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

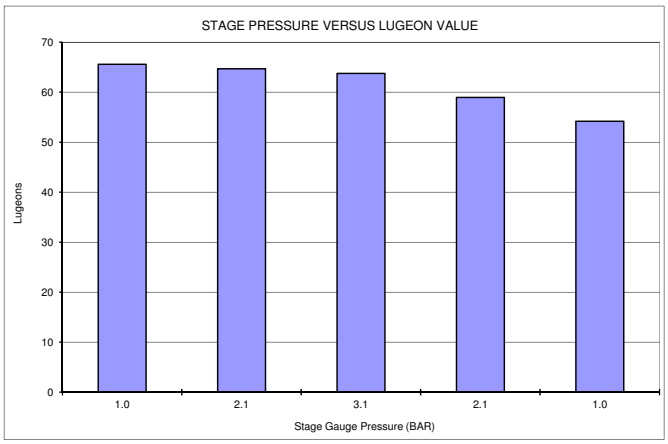
SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

PROJECT:	BSOC WRD EE	PROJECT NO:	D09620A20	DRILLHOLE:	BSOC_B5
AREA:	North of TD3 Seep			TEST NO:	1
DIP:	90 ° (FROM HORIZONTAL)	DEPTH GROUNDWATER:	10.2 m	TOP OF TEST INTERVAL:	28.70 m (DOWN HOLE)
DATE:	14-Dec-15	GAUGE HEIGHT ABOVE GROUND:	0.5 m	BOTTOM OF TEST INTERVAL:	30.70 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	1333.0	1366.0	1395.0	1421.0	1445.0	1471.0				
	Take	litres		33.0	29.0	26.0	24.0	26.0				
1.03	Average Take	l/m		33.0	29.0	26.0	24.0	26.0			27.60	65.58
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	1589.0	1629.0	1669.0	1711.0	1751.0	1792.0				
	Take	litres		40.0	40.0	42.0	40.0	41.0				
2.07	Average Take	l/m		40.0	40.0	42.0	40.0	41.0			40.60	64.68
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	1917.0	1965.0	2020.0	2074.0	2129.0	2183.0				
	Take	litres		48.0	55.0	54.0	55.0	54.0				
3.10	Average Take	l/m		48.0	55.0	54.0	55.0	54.0			53.20	63.75
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2263.0	2301.0	2337.0	2378.0	2412.0	2448.0				
	Take	litres		38.0	36.0	41.0	34.0	36.0				
2.07	Average Take	l/m		38.0	36.0	41.0	34.0	36.0			37.00	58.95
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2465.0	2486.0	2508.0	2531.0	2555.0	2579.0				
	Take	litres		21.0	22.0	23.0	24.0	24.0				
1.03	Average Take	l/m		21.0	22.0	23.0	24.0	24.0			22.80	54.18





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	65.583	MAX k=	0.567
MIN Lu=	54.177	MIN k=	0.468
AVG Lu=	61.427	AVG k=	0.531

INTERPRETATION Laminar flow

INTERPRETATION TYPE OF FLOW:		
1	LAMINAR	YES
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. All 5 Lugeons are about equal and hence laminar flow. Average of five lugeon values used to calculate average permeability.

DRILLING / TEST RESULTS COMMENTS:

Interval chosen due to significant increase in airlift yeild during drilling.

Flow meter in litres.

TEST BY: Claire Kent

REVIEWED BY: Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

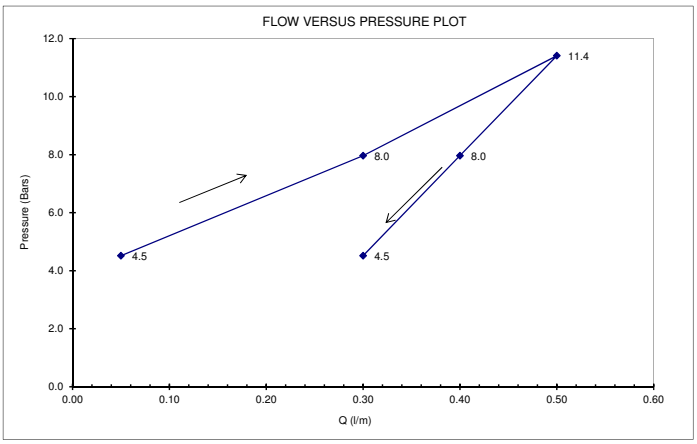
PROJECT: BSOC WRD EE **PROJECT NO:** D09626A20 **DRILLHOLE:** BSOC_B5

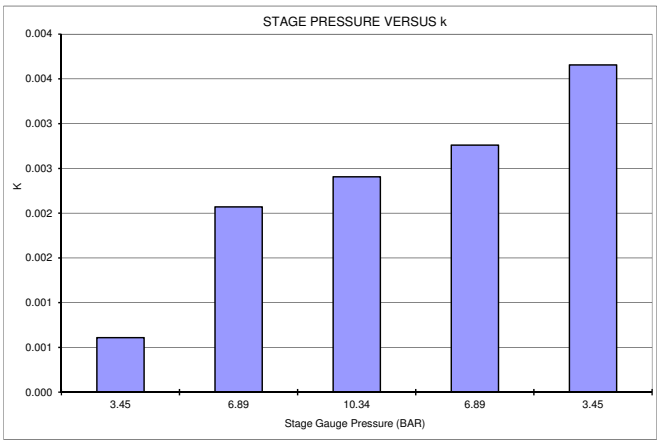
AREA: North of TD3 Seepage **TEST NO:** 2

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 10.2 m **TOP OF TEST INTERVAL:** 18.90 m (DOWN HOLE)

DATE: 14-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 20.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	T
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2664.0	2664.5	2664.8	2665.3	2665.8	2666.3				
	Take	litres		0.5	0.3	0.5	0.5	0.5				
3.45	Average Take	l/m	Leakage 2L	0.5	0.3	0.5	0.5	0.5			0.05	0.0012
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2666.8	2667.8	2668.8	2669.3	2670.3	2671.3				
	Take	litres		1.0	1.0	0.5	1.0	1.0				
6.89	Average Take	l/m	Leakage 3L	1.0	1.0	0.5	1.0	1.0			0.30	0.0041
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2681.0	2683.0	2685.5	2686.5	2688.0	2689.5				
	Take	litres		2.0	2.5	1.0	1.5	1.5				
10.34	Average Take	l/m	Leakage 6L	2.0	2.5	1.0	1.5	1.5			0.50	0.0048
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2693.0	2694.5	2695.8	2697.0	2698.0	2699.0				
	Take	litres		1.5	1.3	1.3	1.0	1.0				
6.89	Average Take	l/m	Leakage 4L	1.5	1.3	1.3	1.0	1.0			0.40	0.01
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2702.0	2702.5	2703.8	2704.5	2705.3	2706.0				
	Take	litres		0.5	1.3	0.8	0.8	0.8				
3.45	Average Take	l/m	Leakage 2.5L	0.5	1.3	0.8	0.8	0.8			0.30	0.01





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= 0.004

MIN k= n/a

AVG k= 0.004

INTERPRETATION

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	YES
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. Lugeons increasing as test proceeds, hence the test is causing changes to the foundation. Uses the highest lugeon value to calculate average permeability

DRILLING / TEST RESULTS COMMENTS:

Section targeting fracture zone. Leakage measured at well head and accounted for in average flow rate.

Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

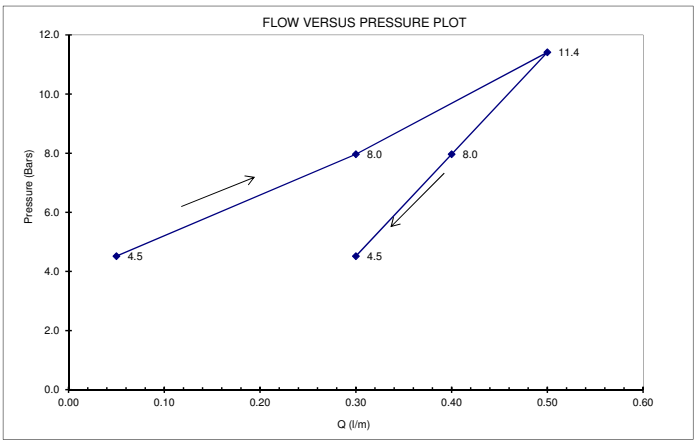
PROJECT: BSOC WRD EE **PROJECT NO:** D09620A20 **DRILLHOLE:** BSOC_B5

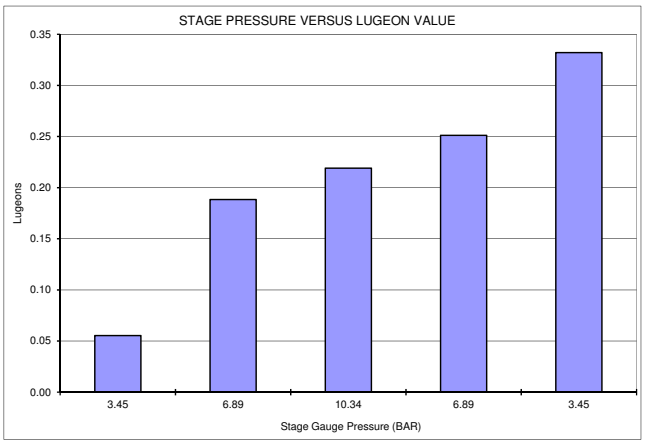
AREA: North of TD3 Seepage **TEST NO:** 2

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 10.2 m **TOP OF TEST INTERVAL:** 18.90 m (DOWN HOLE)

DATE: 14-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 20.90 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2664.0	2664.5	2664.8	2665.3	2665.8	2666.3				
	Take	litres		0.5	0.3	0.5	0.5	0.5				
3.45	Average Take	l/m	Leakage 2L	0.5	0.3	0.5	0.5	0.5			0.05	0.06
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2666.8	2667.8	2668.8	2669.3	2670.3	2671.3				
	Take	litres		1.0	1.0	0.5	1.0	1.0				
6.89	Average Take	l/m	Leakage 2L	1.0	1.0	0.5	1.0	1.0			0.30	0.19
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2681.0	2683.0	2685.5	2686.5	2688.0	2689.5				
	Take	litres		2.0	2.5	1.0	1.5	1.5				
10.34	Average Take	l/m	Leakage 6L	2.0	2.5	1.0	1.5	1.5			0.50	0.22
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2693.0	2694.5	2695.8	2697.0	2698.0	2699.0				
	Take	litres		1.5	1.3	1.3	1.0	1.0				
6.89	Average Take	l/m	Leakage 4L	1.5	1.3	1.3	1.0	1.0			0.40	0.25
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2702.0	2702.5	2703.8	2704.5	2705.3	2706.0				
	Take	litres		0.5	1.3	0.8	0.8	0.8				
3.45	Average Take	l/m	Leakage 2.5L	0.5	1.3	0.8	0.8	0.8			0.30	0.33





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	0.332	MAX k=	0.003
MIN Lu=	0.055	MIN k=	n/a
AVG Lu=	0.332	AVG k=	0.003

INTERPRETATION

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	YES
5	VOID FILLING	NO

Note: Permeability calculation dependent upon flow classification. Lugeons increasing as test proceeds, hence the test is causing changes to the foundation. Uses the highest lugeon value to calculate average permeability

DRILLING / TEST RESULTS COMMENTS:

Section targeting fracture zone. Leakage measured at well head and accounted for in average flow rate.

Flow meter in litres.

TEST BY: Claire Kent **REVIEWED BY:** Chris Strachotta

SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

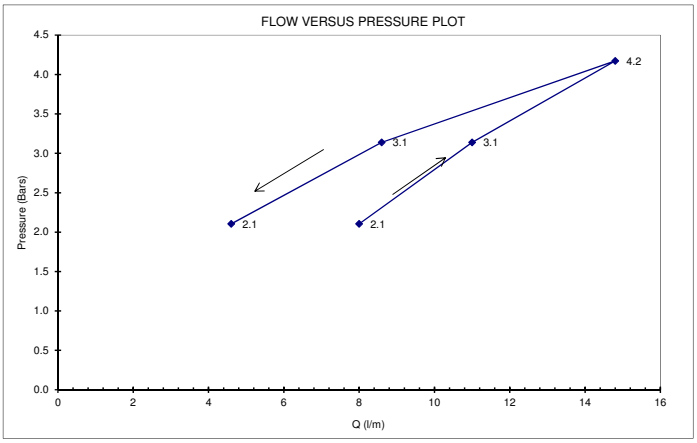
PROJECT: BSOC WRD EE **PROJECT NO:** D09626A20 **DRILLHOLE:** BSOC_B5

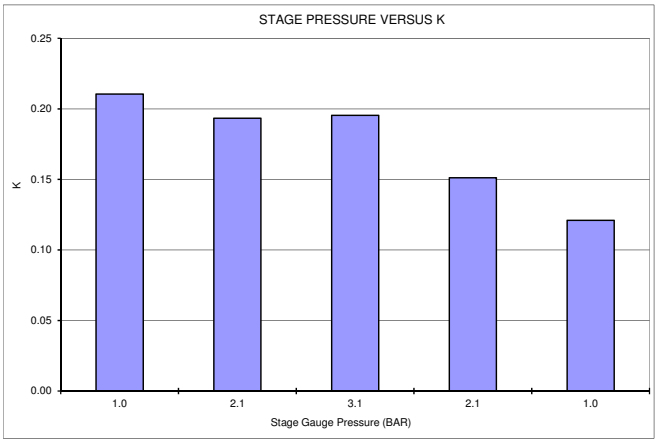
AREA: North of TD3 Seepage **TEST NO:** 1

DIP: 90 ° (FROM HORIZONTAL) **DEPTH GROUNDWATER:** 10.2 m **TOP OF TEST INTERVAL:** 12.80 m (DOWN HOLE)

DATE: 14-Dec-15 **GAUGE HEIGHT ABOVE GROUND:** 0.5 m **BOTTOM OF TEST INTERVAL:** 14.80 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	T
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2821.0	2830.0	2838.0	2845.5	2854.0	2861.0				
	Take	litres		9.0	8.0	7.5	8.5	7.0				
1.03	Average Take	l/m		9.0	8.0	7.5	8.5	7.0			8.00	0.42
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2886.0	2898.0	2908.0	2921.0	2932.0	2941.0				
	Take	litres		12.0	10.0	13.0	11.0	9.0				
2.07	Average Take	l/m		12.0	10.0	13.0	11.0	9.0			11.00	0.39
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2963.0	2978.0	2993.0	3008.0	3023.0	3037.0				
	Take	litres		15.0	15.0	15.0	15.0	14.0				
3.10	Average Take	l/m		15.0	15.0	15.0	15.0	14.0			14.80	0.39
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3045.0	3053.0	3061.0	3070.0	3079.0	3088.0				
	Take	litres		8.0	8.0	9.0	9.0	9.0				
2.07	Average Take	l/m		8.0	8.0	9.0	9.0	9.0			8.60	0.30
GAUGE P (BAR)											AVERAGE FLOW litres/min	
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3095.0	3099.0	3104.0	3108.0	3113.0	3118.0				
	Take	litres		4.0	5.0	4.0	5.0	5.0				
1.03	Average Take	l/m		4.0	5.0	4.0	5.0	5.0			4.60	0.24





Lugeon Value formula: **Thiem Equation**

APPROXIMATE PERMEABILITY, m/d

MAX k= n/a

MIN k= 0.121

AVG k= 0.1210

INTERPRETATION

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	YES

Note: Permeability calculation dependent upon flow classification. Lugeons decreasing as test proceeds hence the test is gradually filling extensive voids. Average Lugeon value from final pressure was used to calculate **average** permeability.

DRILLING / TEST RESULTS COMMENTS:

Interval chosen due to first water strike

Flow meter in litres.

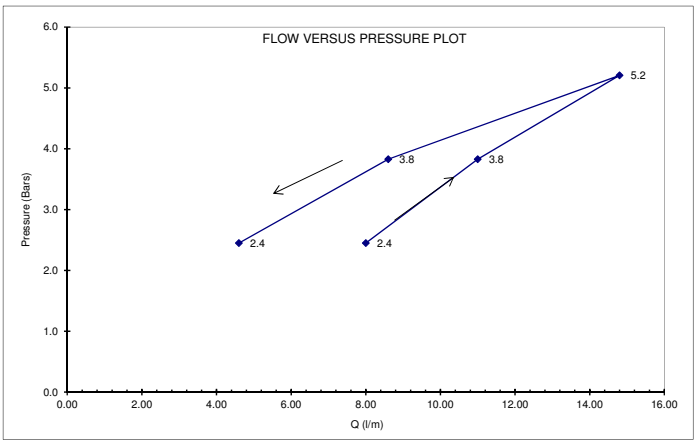
TEST BY: Claire Kent **REVIEWED BY:** Chris Strachota

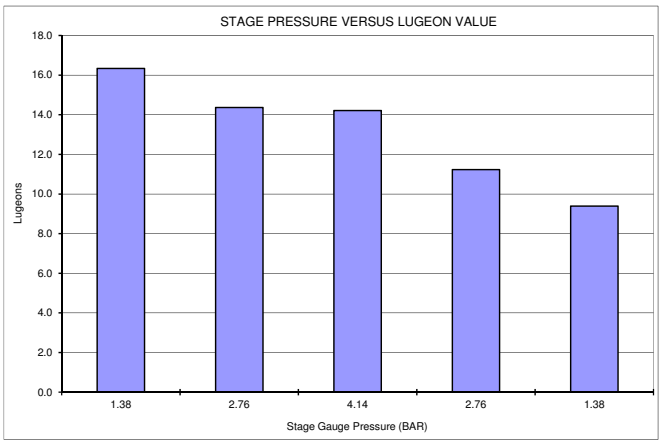
SHEET	1 OF 1

LUGEON TEST FIELD DATA SHEET

PROJECT:	BSOC WRD EE	PROJECT NO:	D09620A20	DRILLHOLE:	BSOC_B5
AREA:	North of TD3 Seepage			TEST NO:	3
DIP:	90 ° (FROM HORIZONTAL)	DEPTH GROUNDWATER:	10.2 m	TOP OF TEST INTERVAL:	12.80 m (DOWN HOLE)
DATE:	15-Dec-15	GAUGE HEIGHT ABOVE GROUND:	0.5 m	BOTTOM OF TEST INTERVAL:	14.80 m (DOWN HOLE)

GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2821.0	2830.0	2838.0	2845.5	2854.0	2861.0				
	Take	litres		9.0	8.0	7.5	8.5	7.0				
1.38	Average Take	l/m		9.0	8.0	7.5	8.5	7.0			8.00	16.33
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2886.0	2898.0	2908.0	2921.0	2932.0	2941.0				
	Take	litres		12.0	10.0	13.0	11.0	9.0				
2.76	Average Take	l/m		12.0	10.0	13.0	11.0	9.0			11.00	14.37
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	2963.0	2978.0	2993.0	3008.0	3023.0	3037.0				
	Take	litres		15.0	15.0	15.0	15.0	14.0				
4.14	Average Take	l/m		15.0	15.0	15.0	15.0	14.0			14.80	14.21
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3045.0	3053.0	3061.0	3070.0	3079.0	3088.0				
	Take	litres		8.0	8.0	9.0	9.0	9.0				
2.76	Average Take	l/m		8.0	8.0	9.0	9.0	9.0			8.60	11.23
GAUGE P (BAR)											AVERAGE FLOW litres/min	LUGEON
	Time	min	0.0	1.0	2.0	3.0	4.0	5.0				
	Flowmeter	litres	3095.0	3099.0	3104.0	3108.0	3113.0	3118.0				
	Take	litres		4.0	5.0	4.0	5.0	5.0				
1.38	Average Take	l/m		4.0	5.0	4.0	5.0	5.0			4.60	9.39





Lugeon Value formula:

$$Lu = \frac{Q}{L} * \frac{10}{(0.1 * H * \sin(a) * SG + P_{gauge})} * \frac{M_f}{28}$$

LUGEONS		APPROXIMATE PERMEABILITY, m/d	
MAX Lu=	16.334	MAX k=	n/a
MIN Lu=	9.392	MIN k=	0.081
AVG Lu=	9.392	AVG k=	0.081

INTERPRETATION

INTERPRETATION TYPE OF FLOW:

1	LAMINAR	NO
2	TURBULENT	NO
3	DILATION	NO
4	WASH-OUT	NO
5	VOID FILLING	YES

Note: Permeability calculation dependent upon flow classification. Lugeons decreasing as test proceeds hence the test is gradually filling extensive voids. Average Lugeon value from final pressure was used to calculate average permeability.

DRILLING / TEST RESULTS COMMENTS:

Interval chosen due to first water strike

Flow meter in litres.

TEST BY: Claire Kent

REVIEWED BY: Chris Strachotta

APPENDIX VII

Slug Testing Results and Analysis (Existing Bores)

Appendix VII
Slug Test Results and Analysis

BSOC_B6

Table VII-1: BSOC_B6 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head	15/2/16	6.97	KGS Model	0.0005
Rising Head	16/2/16	6.96	KGS Model	0.0007

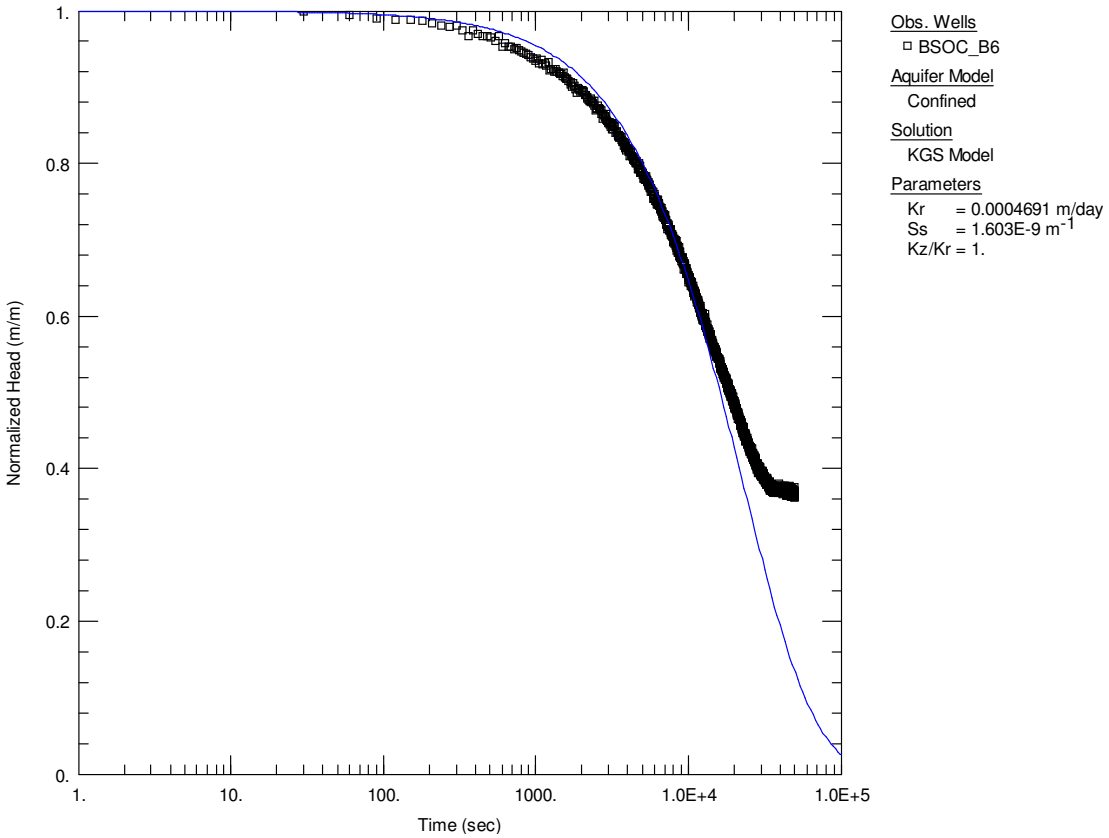


Figure VII-1: BSOC_B6 Falling Head Test 1

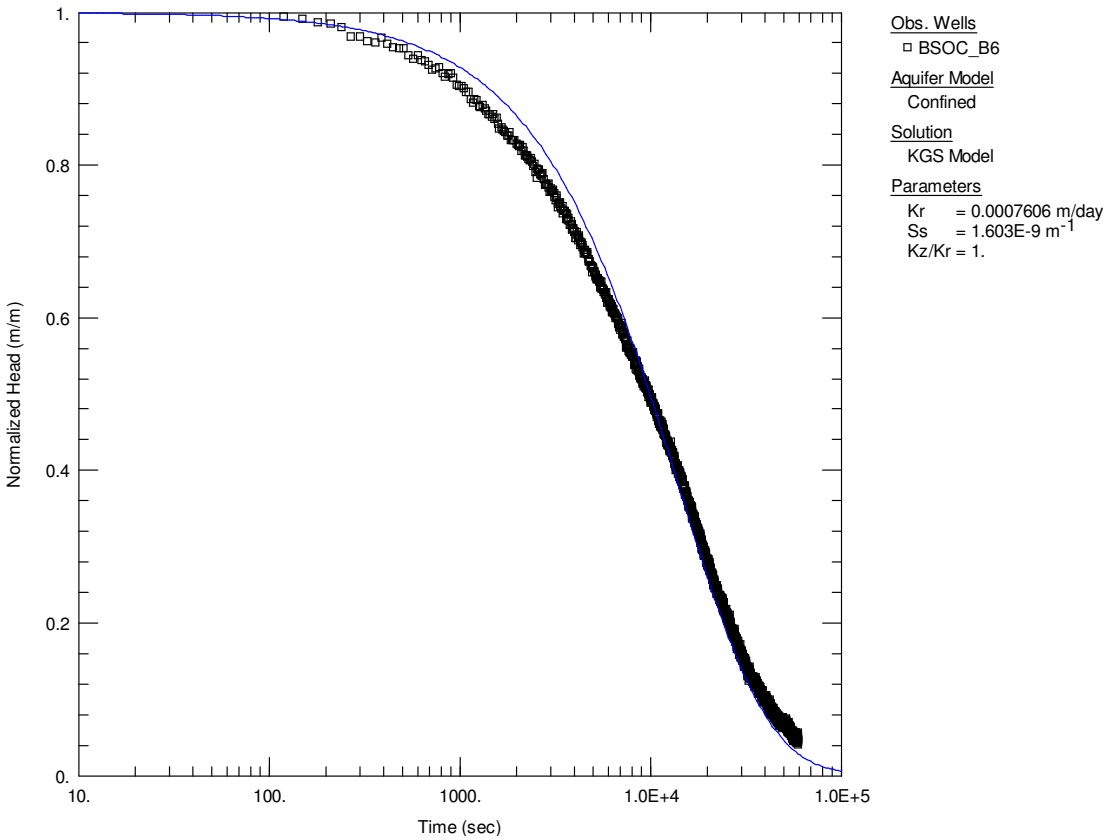


Figure VII-2: BSOC_B6 Rising Head Test 1

Bore 23

Table VII-2: Bore 23 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head	5/02/16	1.46	KGS Model	2.26
Falling Head	5/02/16	1.46	KGS Model	1.14
Falling Head	5/02/16	1.46	KGS Model	1.47
Rising Head	5/02/16	1.46	KGS Model	1.56
Rising Head	5/02/16	1.46	KGS Model	2.83
Rising Head	5/02/16	1.46	KGS Model	2.48

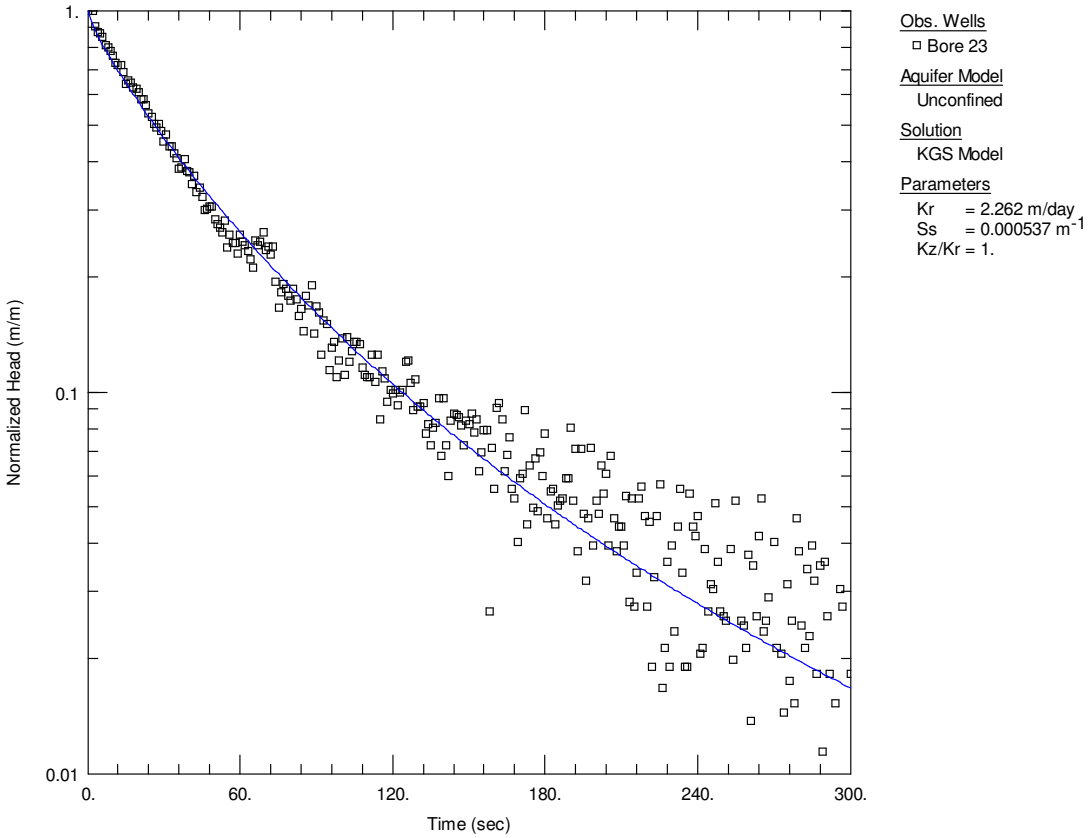


Figure VII-3: Bore 23 Falling Head Test 1

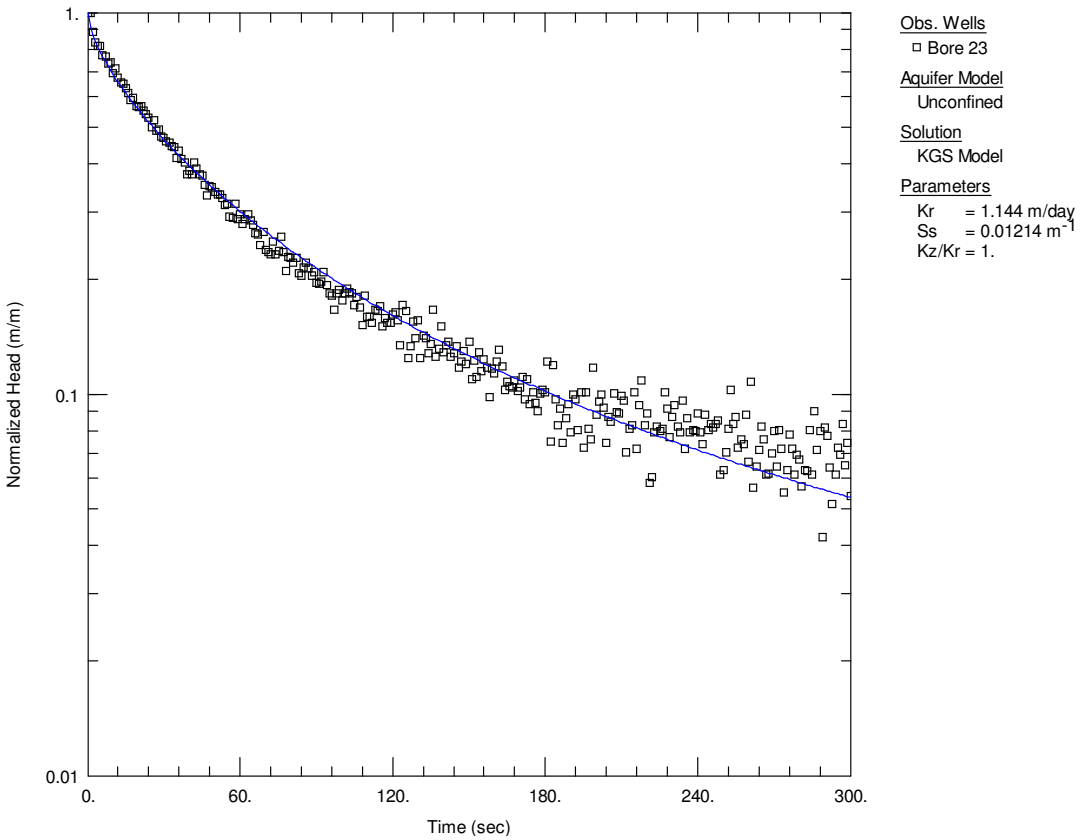


Figure VII-4: Bore 23 Falling Head Test 2

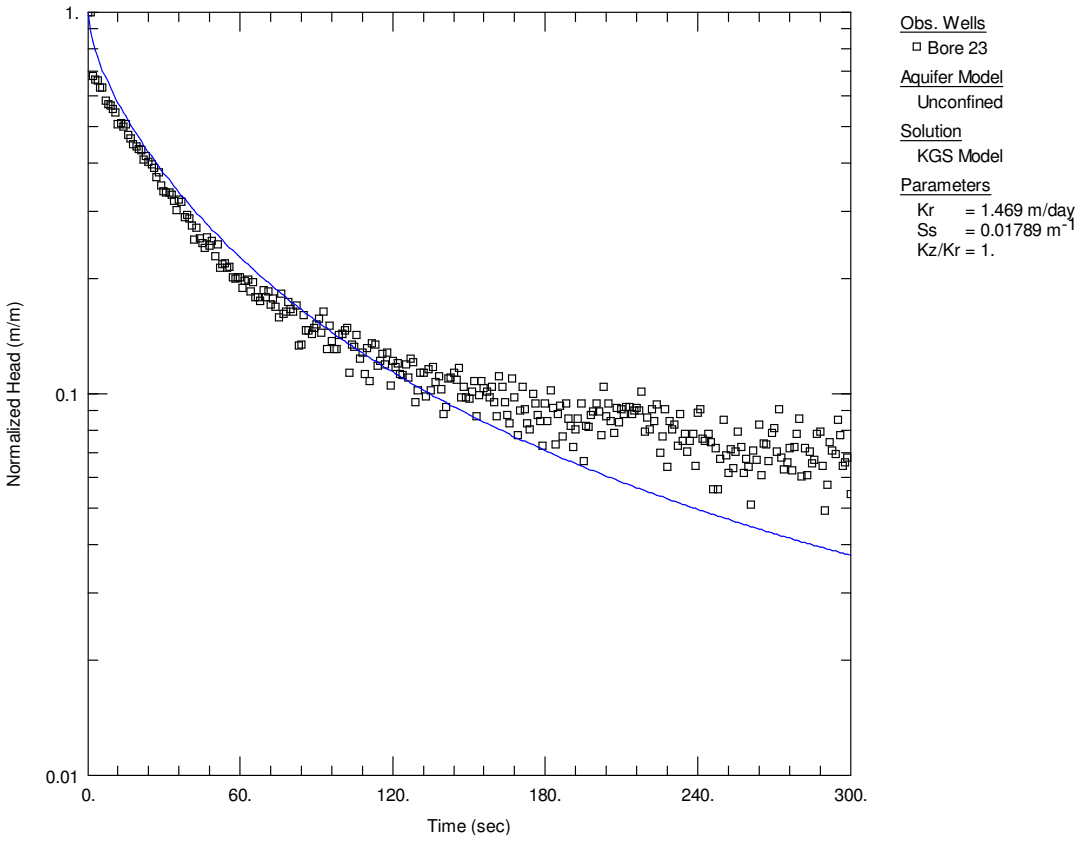


Figure VII-5: Bore 23 Falling Head Test 3

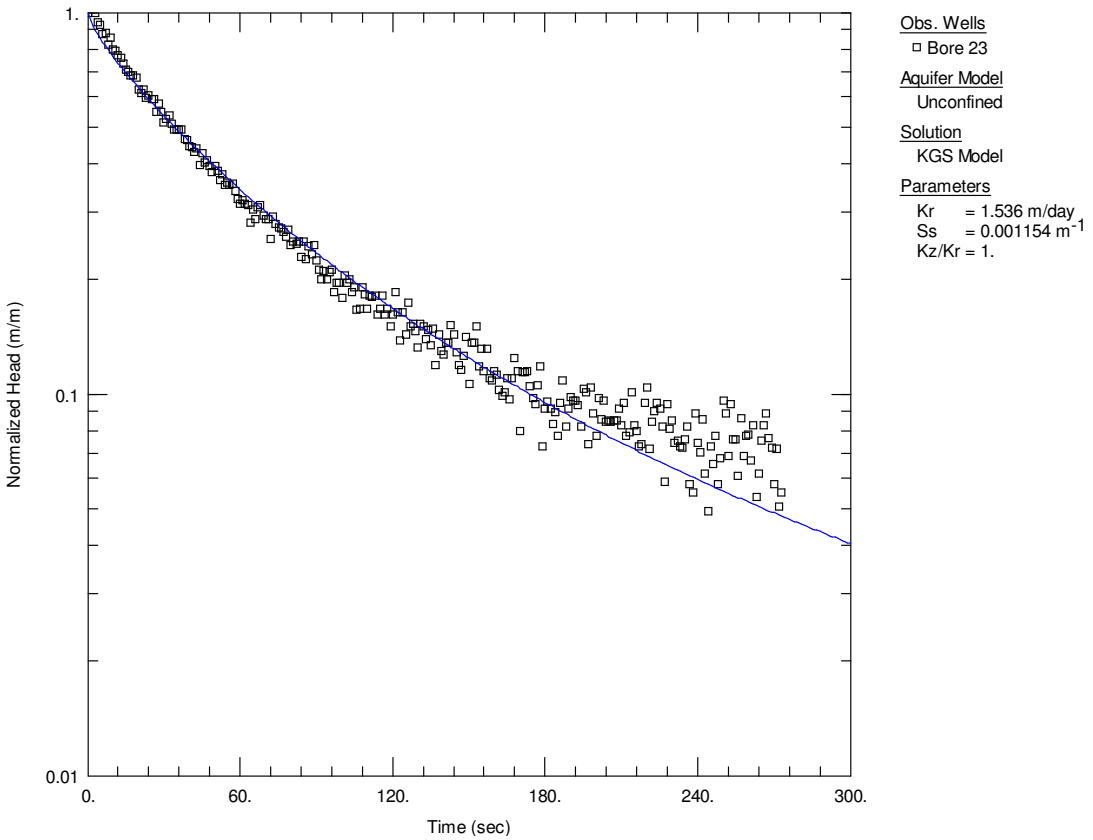


Figure VII-6: Bore 23 Rising Head Test 1

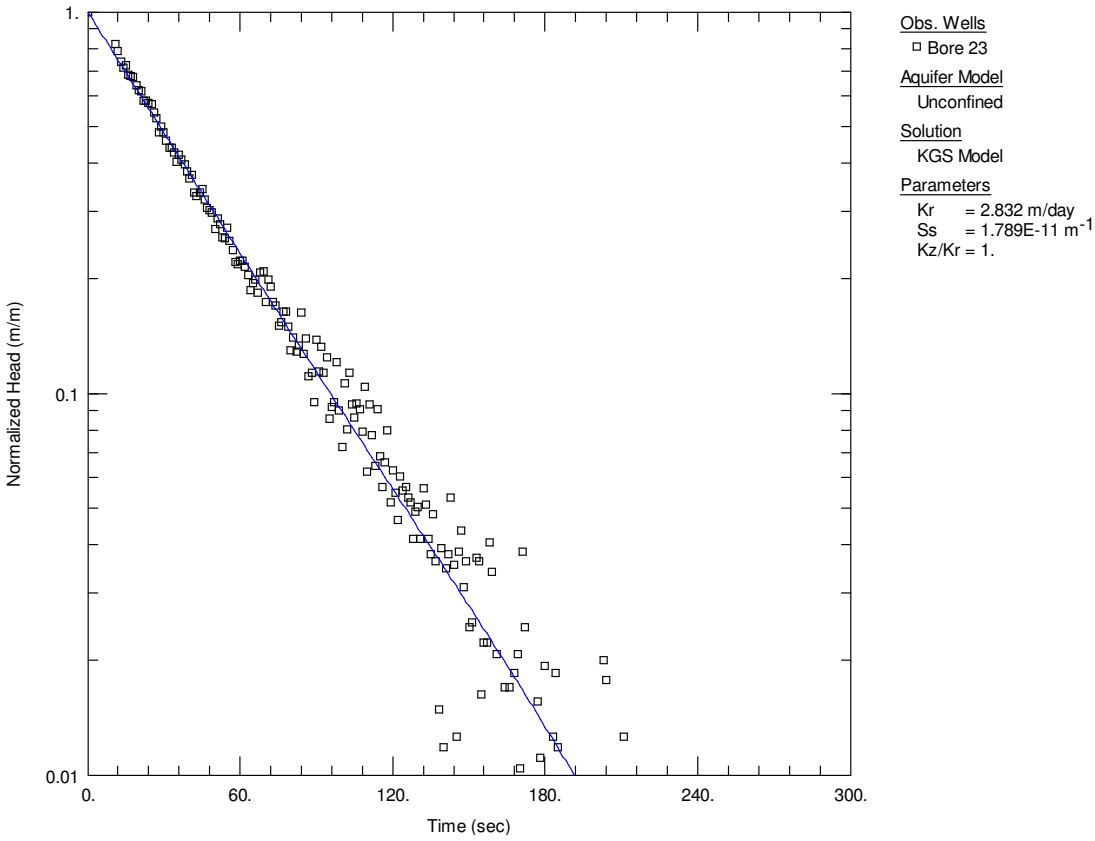


Figure VII-7: Bore 23 Rising Head Test 2

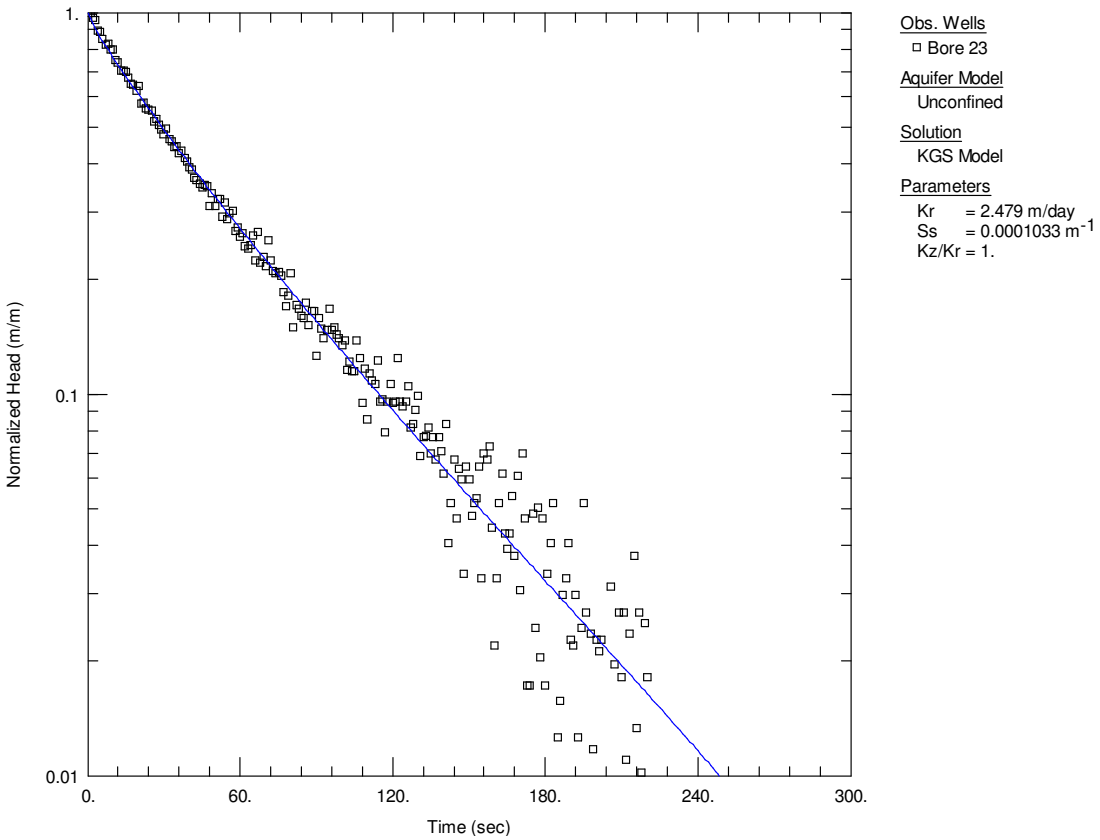


Figure VII-8: Bore 23 Rising Head Test 3

Bore 24

Table VII-3: Bore 24 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head	4/2/16	1.39	Hvorslev	0.09
Falling Head	10/2/16	1.39	Hvorslev	0.08
Falling Head	10/2/16	1.39	Hvorslev	0.05
Rising Head	4/2/16	1.39	Hvorslev	0.08
Rising Head	10/2/16	1.39	Hvorslev	0.05
Rising Head	11/2/16	1.39	Hvorslev	0.08

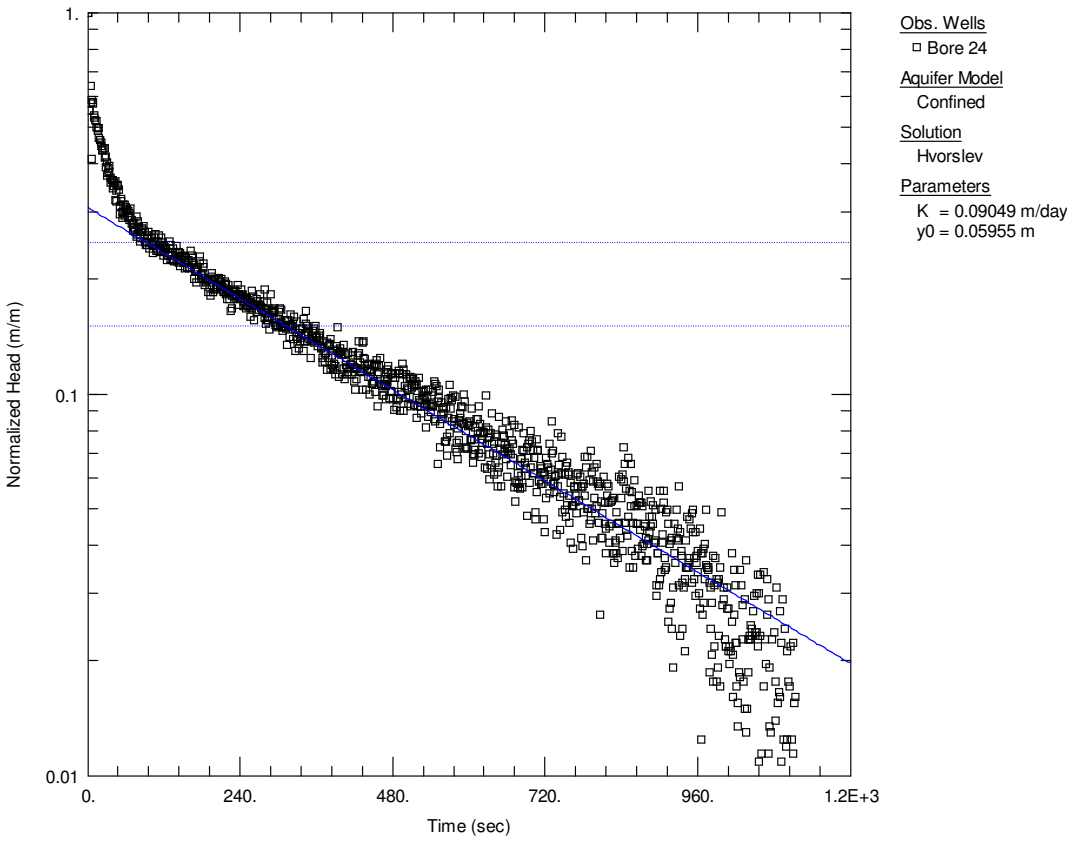


Figure VII-9: Bore 24 Falling Head Test 1

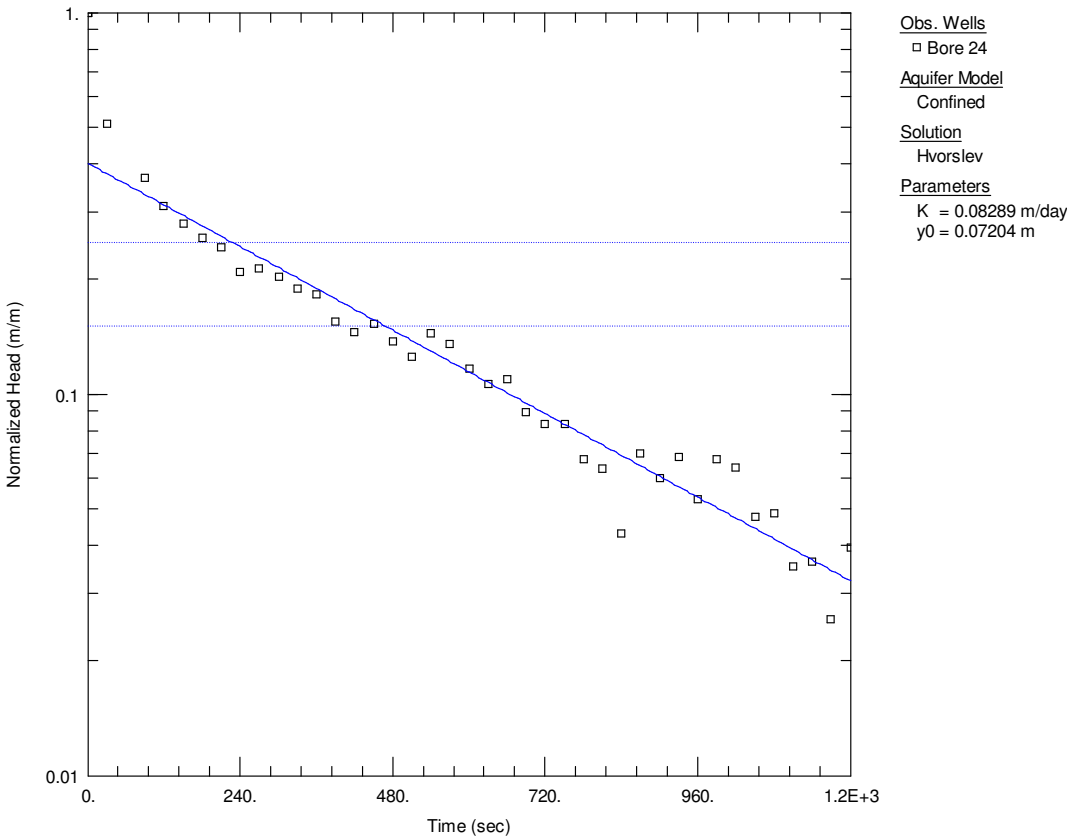


Figure VII-10: Bore 24 Falling Head Test 2

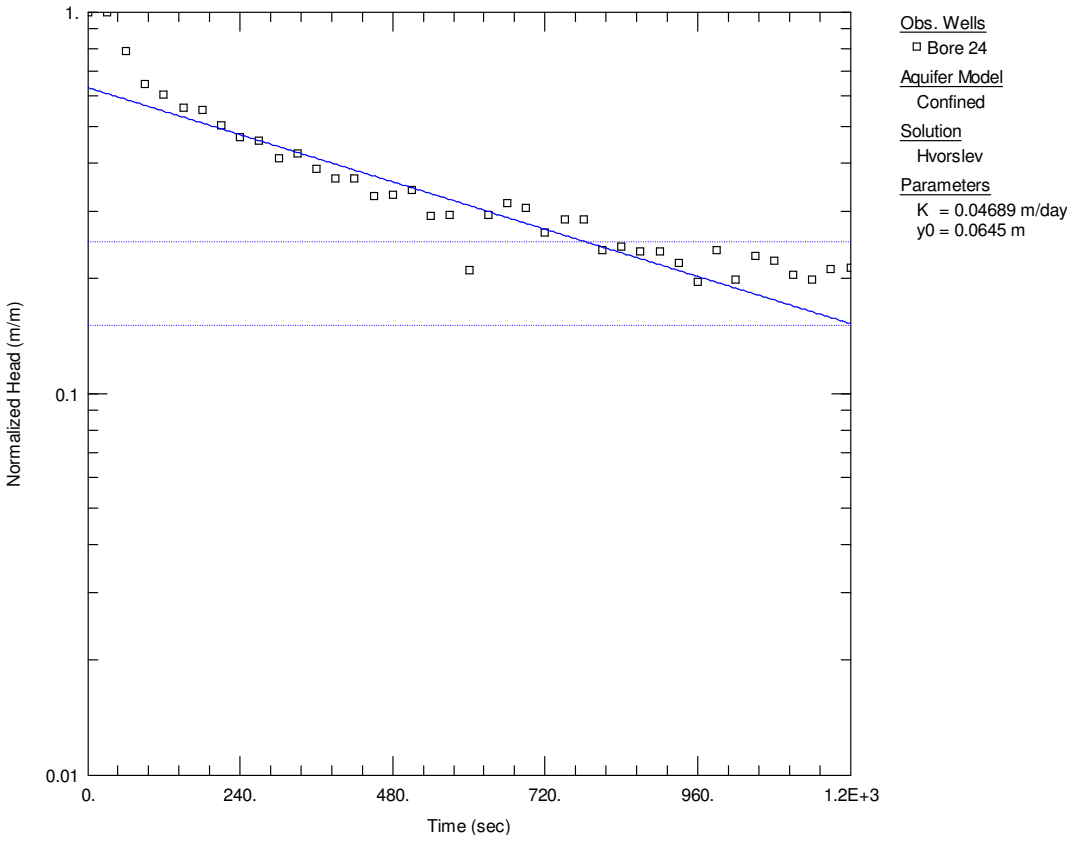


Figure VII-11: Bore 24 Falling Head Test 3

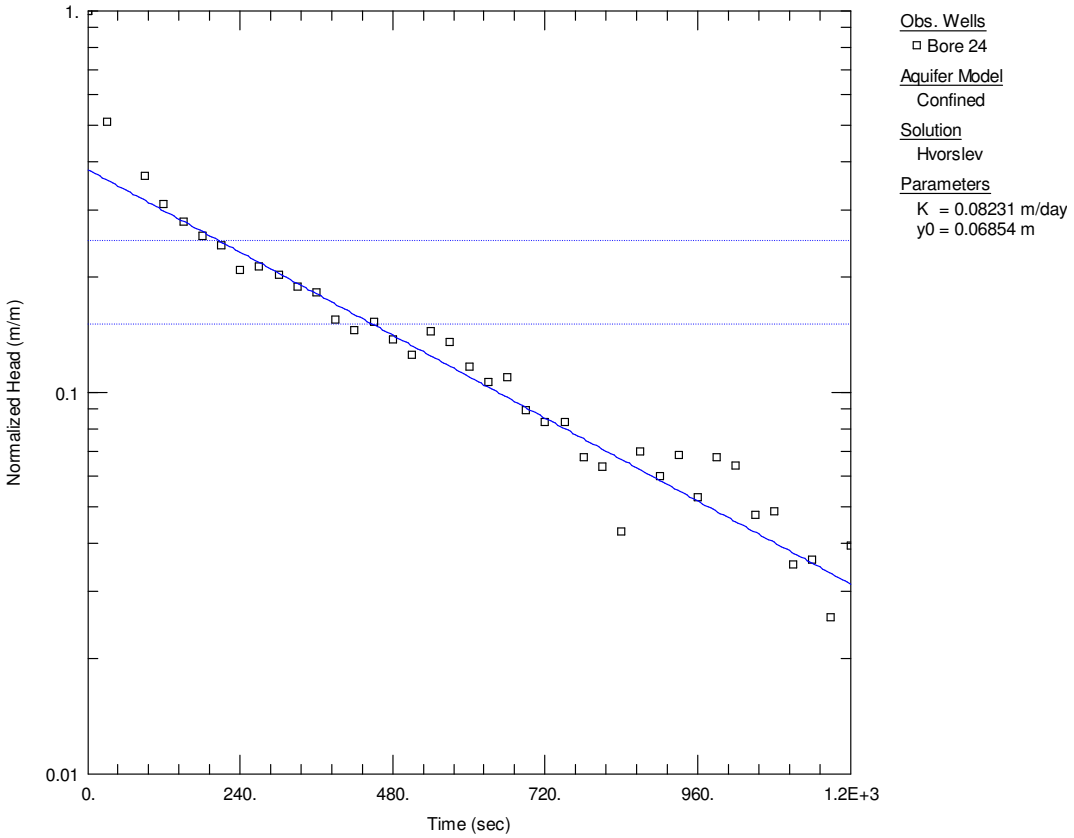


Figure VII-12: Bore 24 Rising Head Test 1

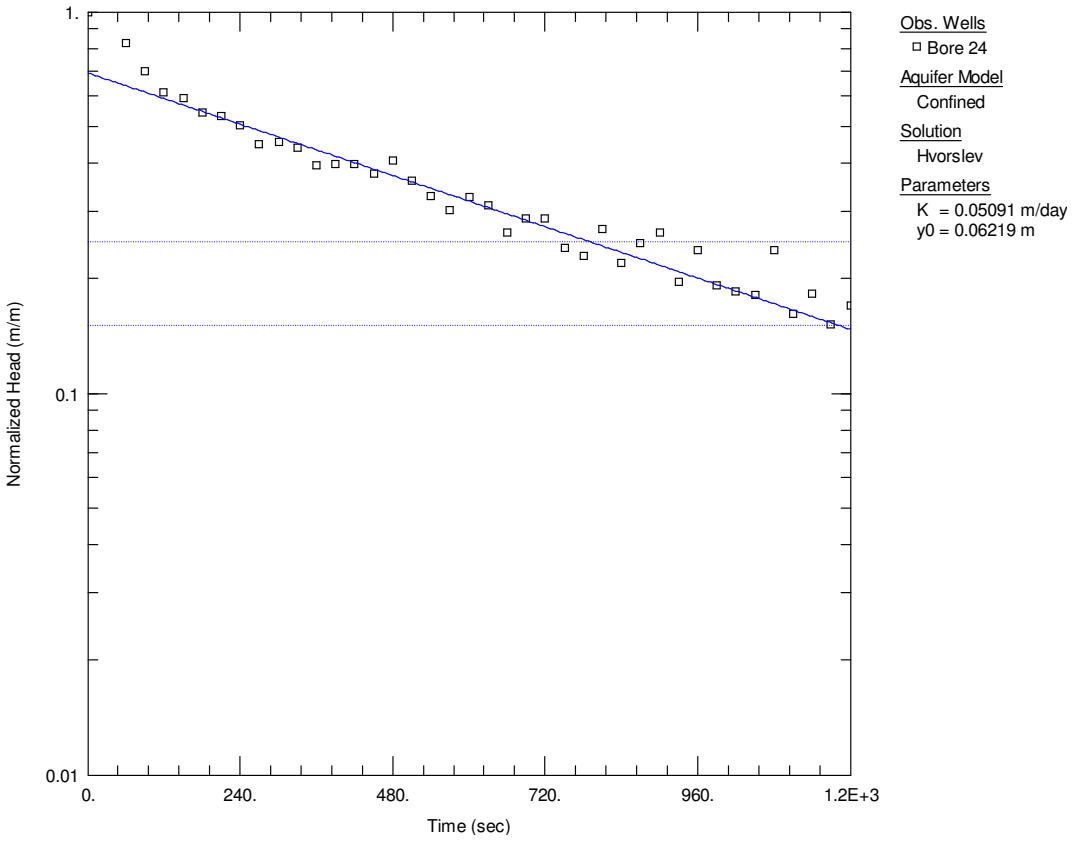


Figure VII-13: Bore 24 Rising Head Test 2

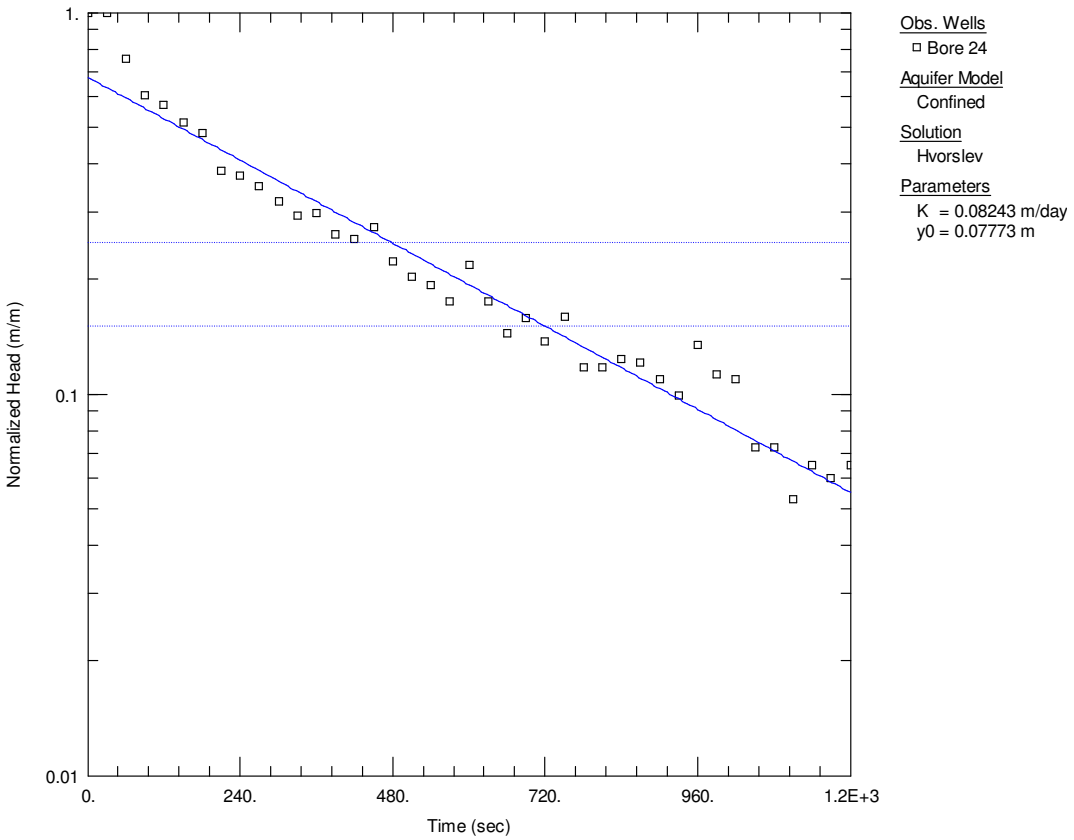


Figure VII-14: Bore 24 Rising Head Test 3

Bore 38

Table VII-4: Bore 38 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head	21/2/16	4.47	Hvorslev	0.0009
Rising Head	23/2/16	4.44	Hvorslev	0.0002

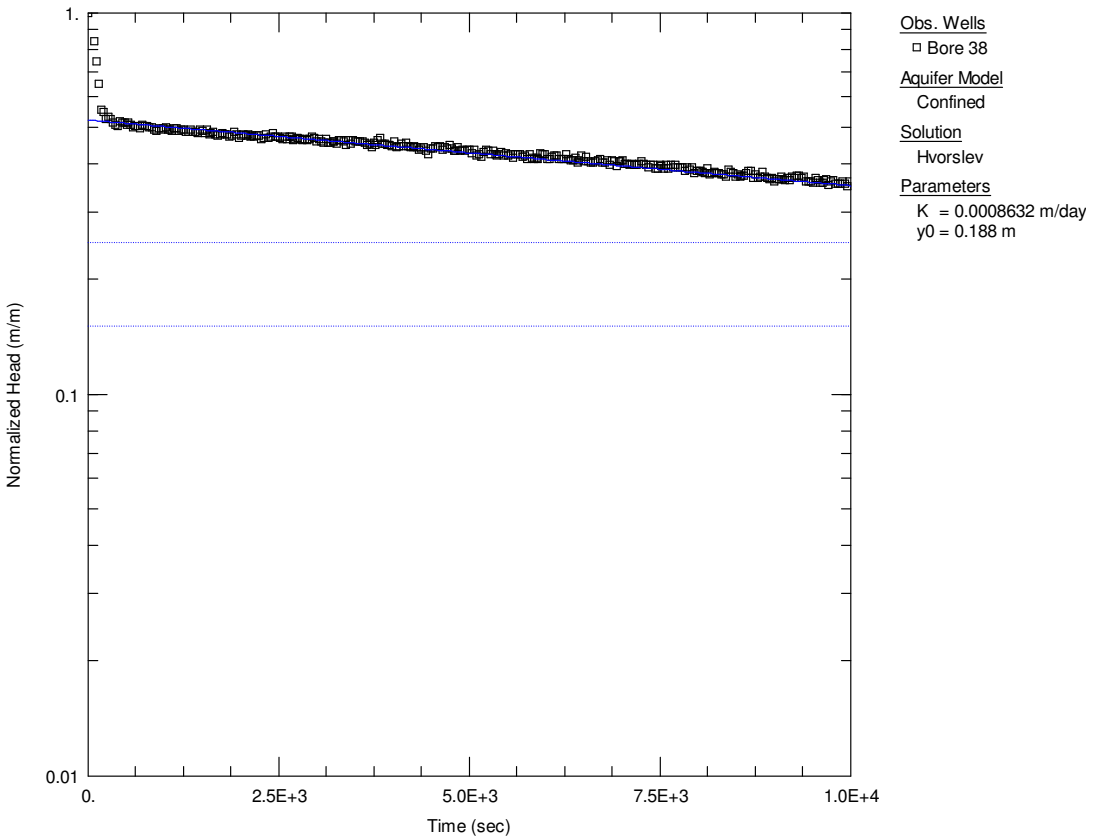


Figure VII-15: Bore 38 Falling Head Test 1

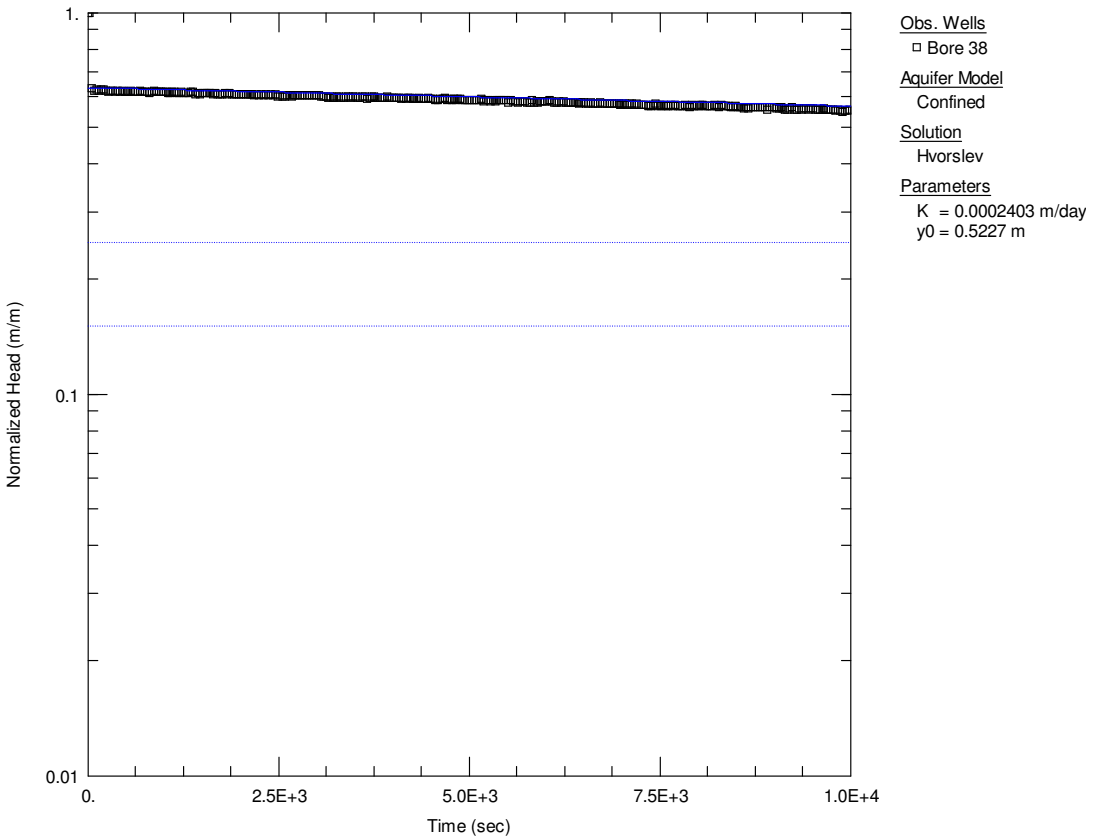


Figure VII-16: Bore 38 Rising Head Test 1

Bore 39

Table VII-5: Bore 39 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head Test	22/2/16	5.05	KGS Model	3.2
Falling Head Test	22/2/16	5.05	KGS Model	2.9
Falling Head Test	22/2/16	5.05	KGS Model	3.1
Rising Head Test	22/2/16	5.05	KGS Model	1.6
Rising Head Test	22/2/16	5.05	KGS Model	1.2
Rising Head Test	22/2/16	5.05	KGS Model	2.2

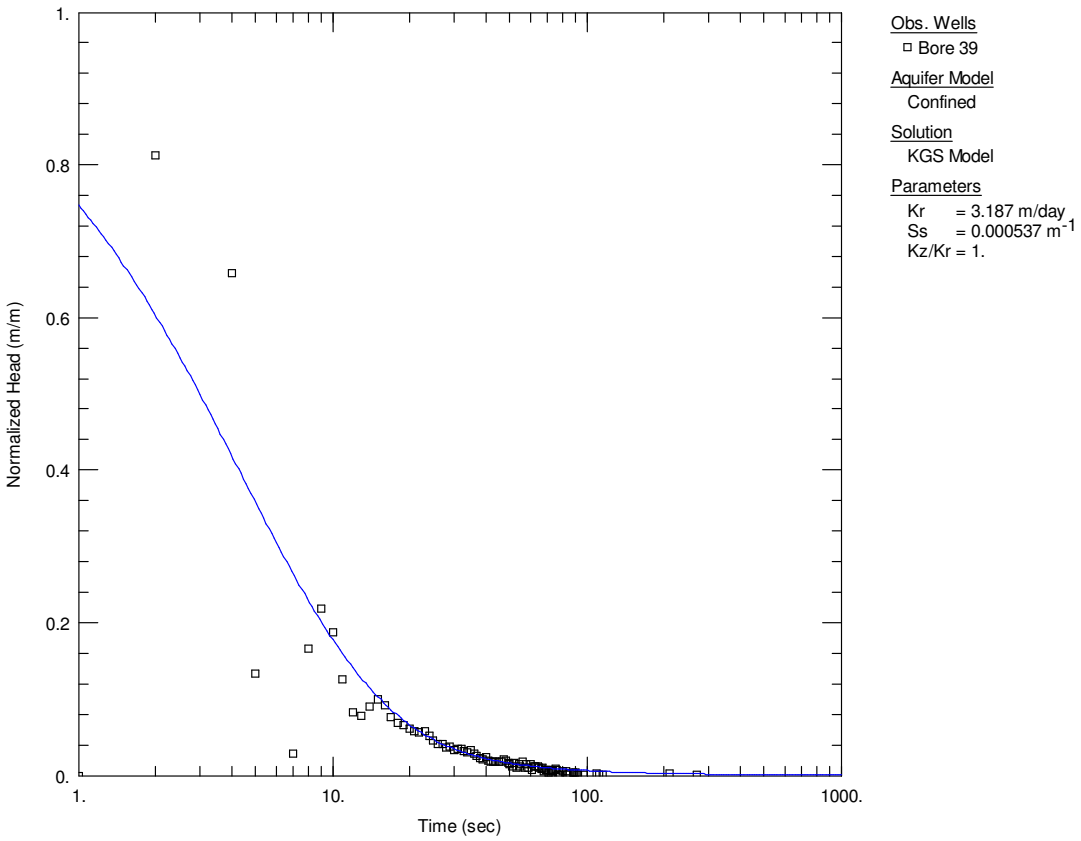


Figure VII-17: Bore 39 Falling Head Test 1

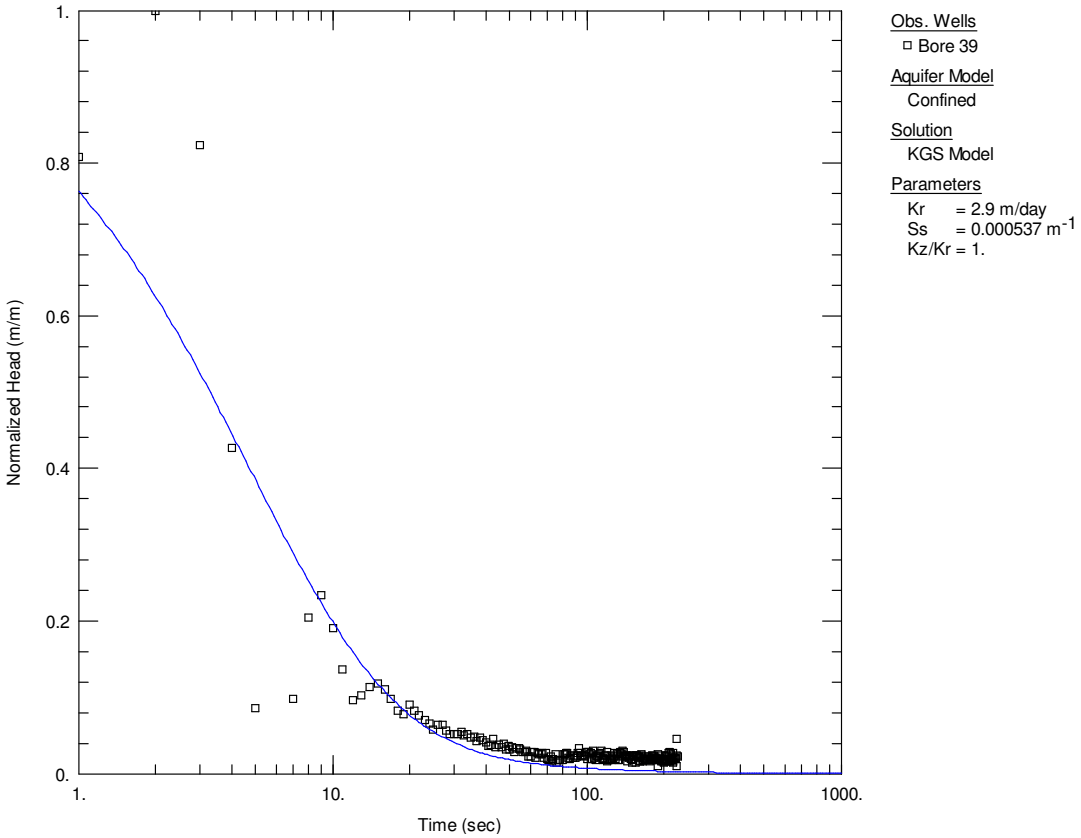


Figure VII-18: Bore 39 Falling Head Test 2

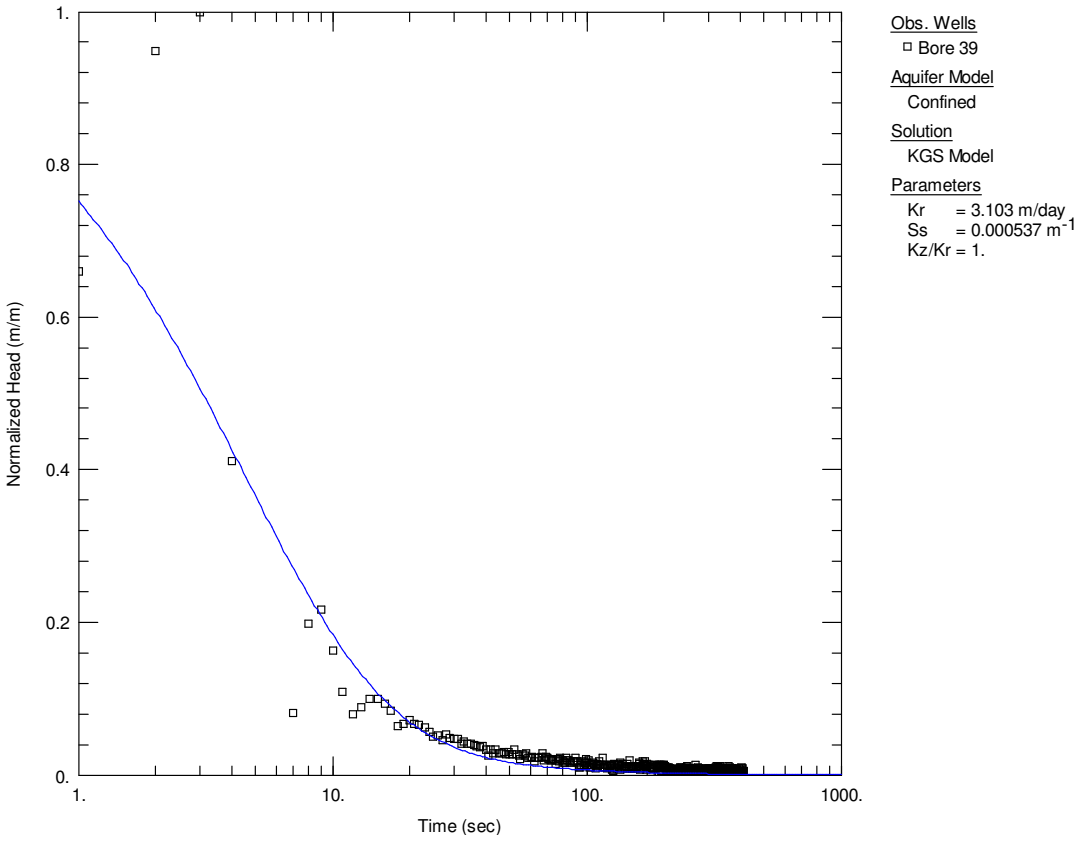


Figure VII-19: Bore 39 Falling Head Test 3

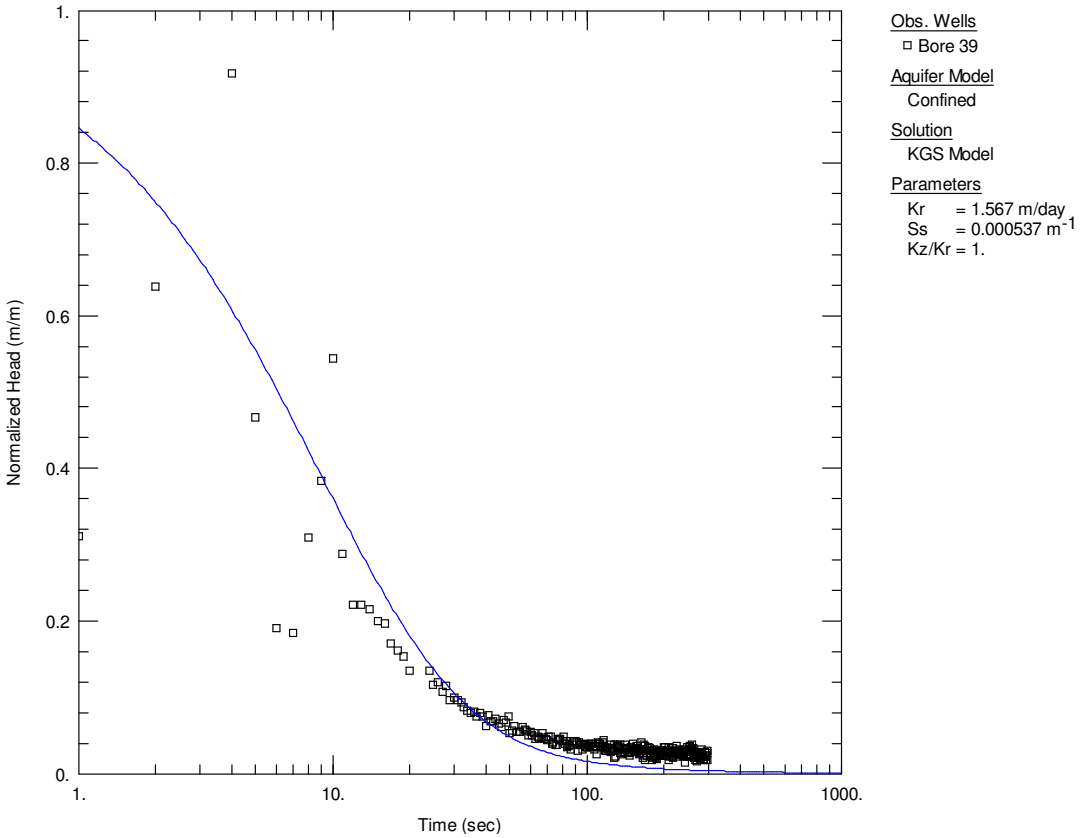


Figure VII-20: Bore 39 Rising Head Test 1

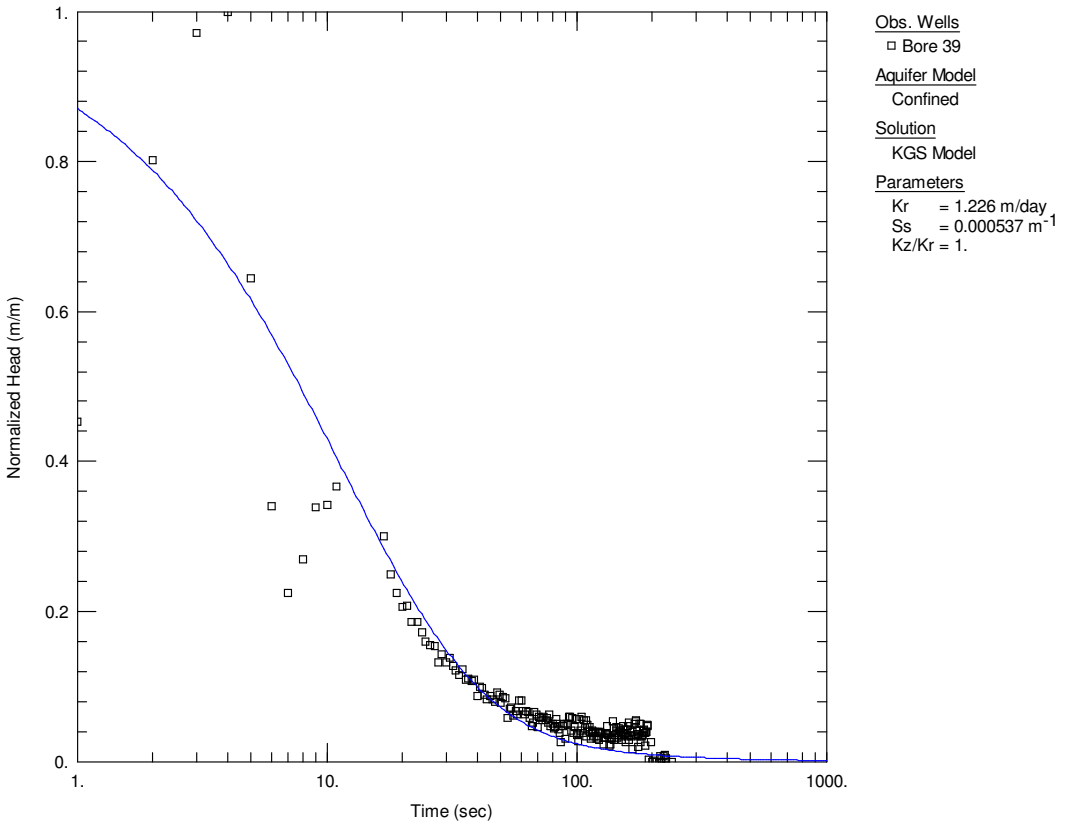


Figure VII-21: Bore 39 Rising Head Test 2

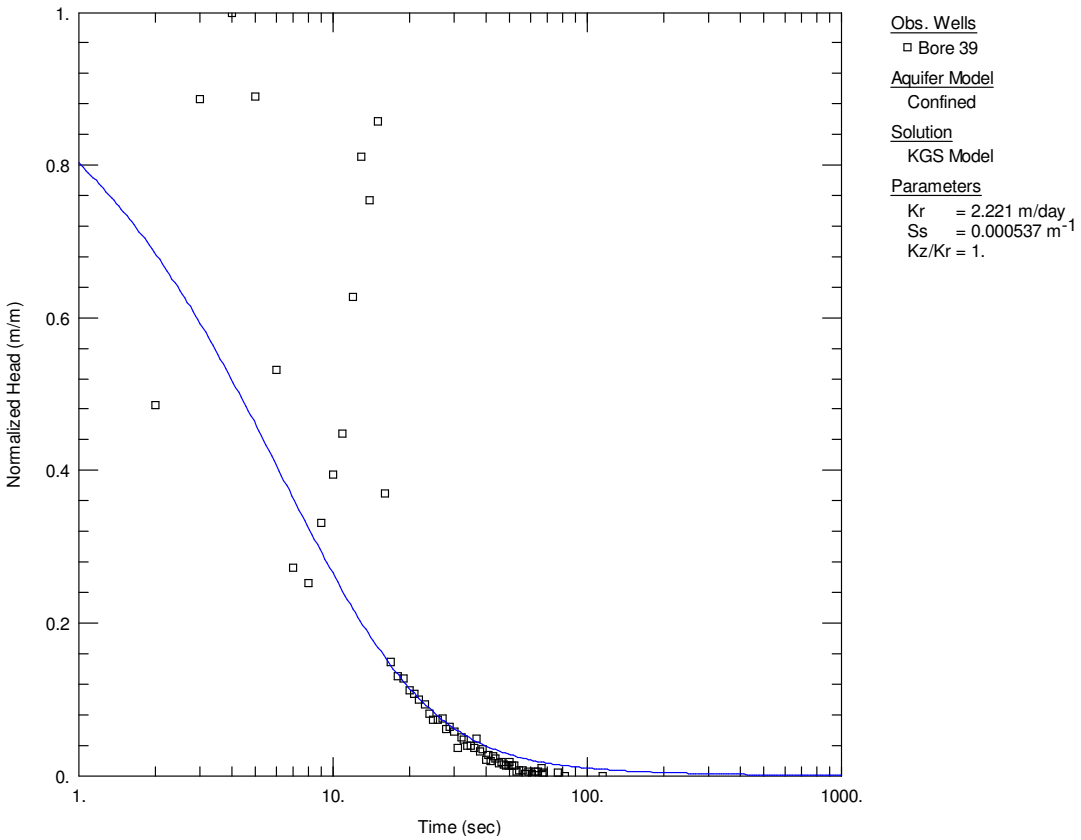


Figure VII-22: Bore 39 Rising Head Test 3

Bore 40

Table VII-6: Bore 40 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Rising Head	9/12/15	5.93	KGS Model	1.2
Rising Head	9/12/15	5.93	KGS Model	2.5
Rising Head	22/12/15	6.00	KGS Model	2.4

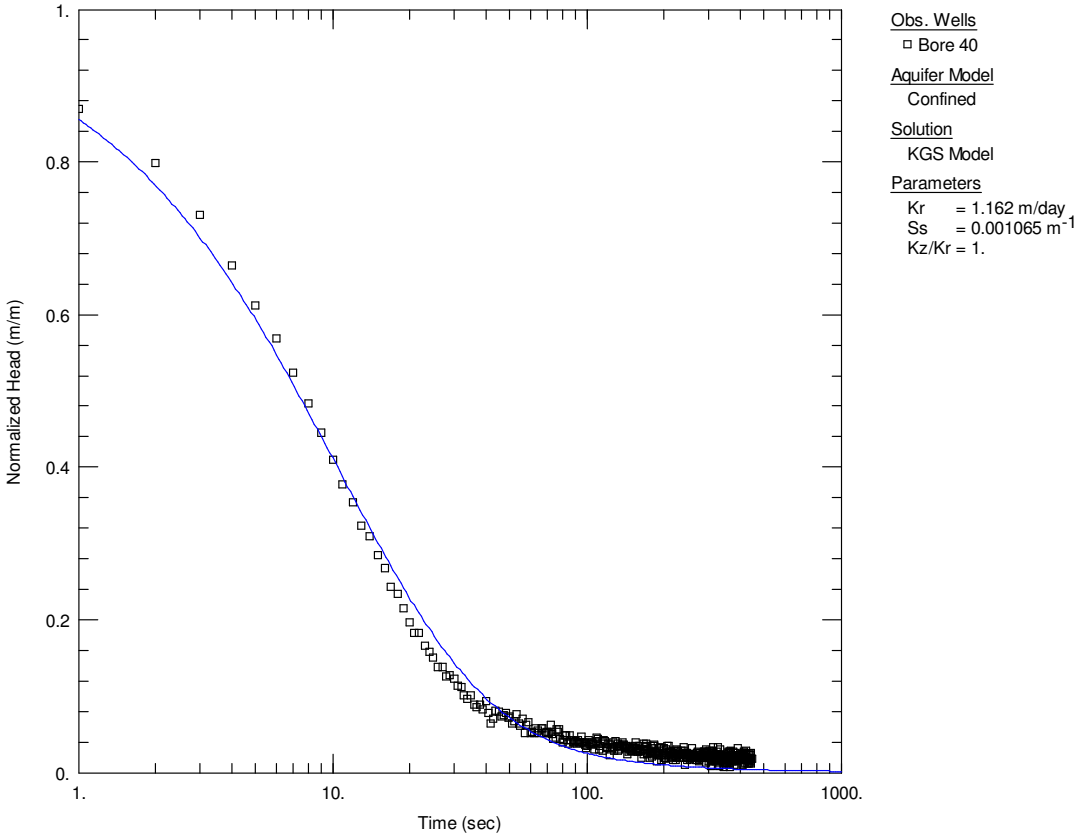


Figure VII-23: Bore 40 Rising Head Test 1

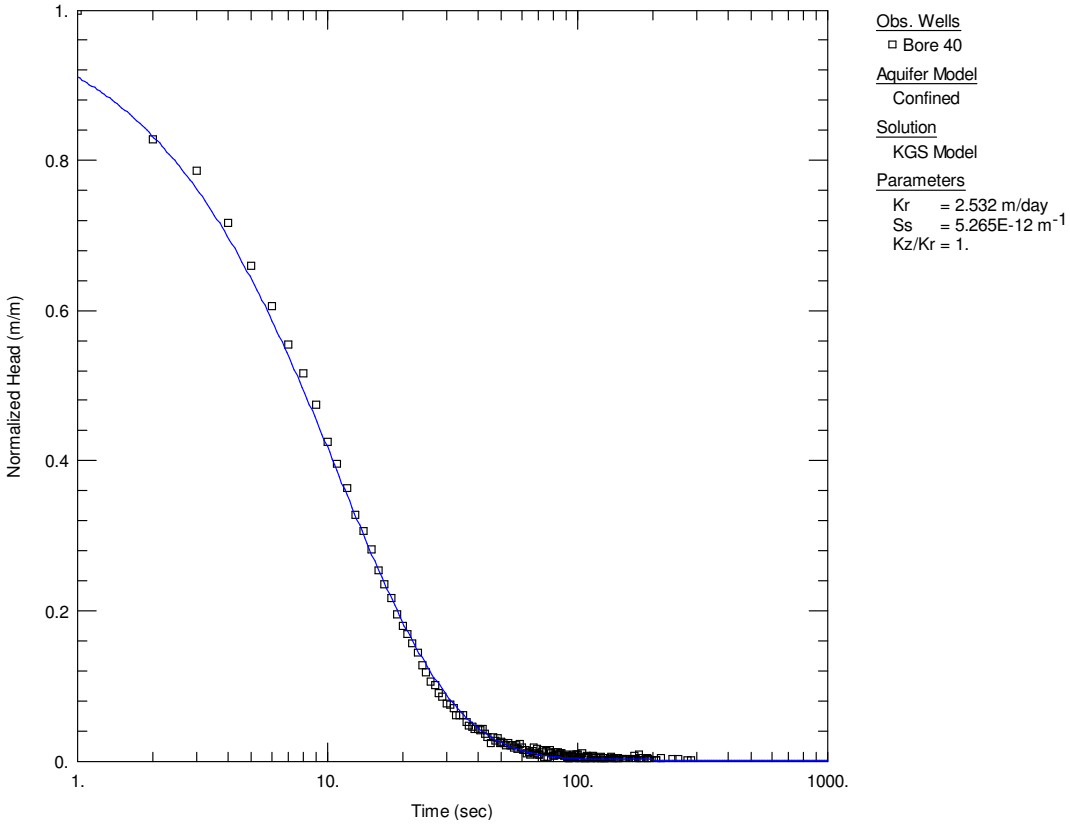


Figure VII-24: Bore 40 Rising Head Test 2

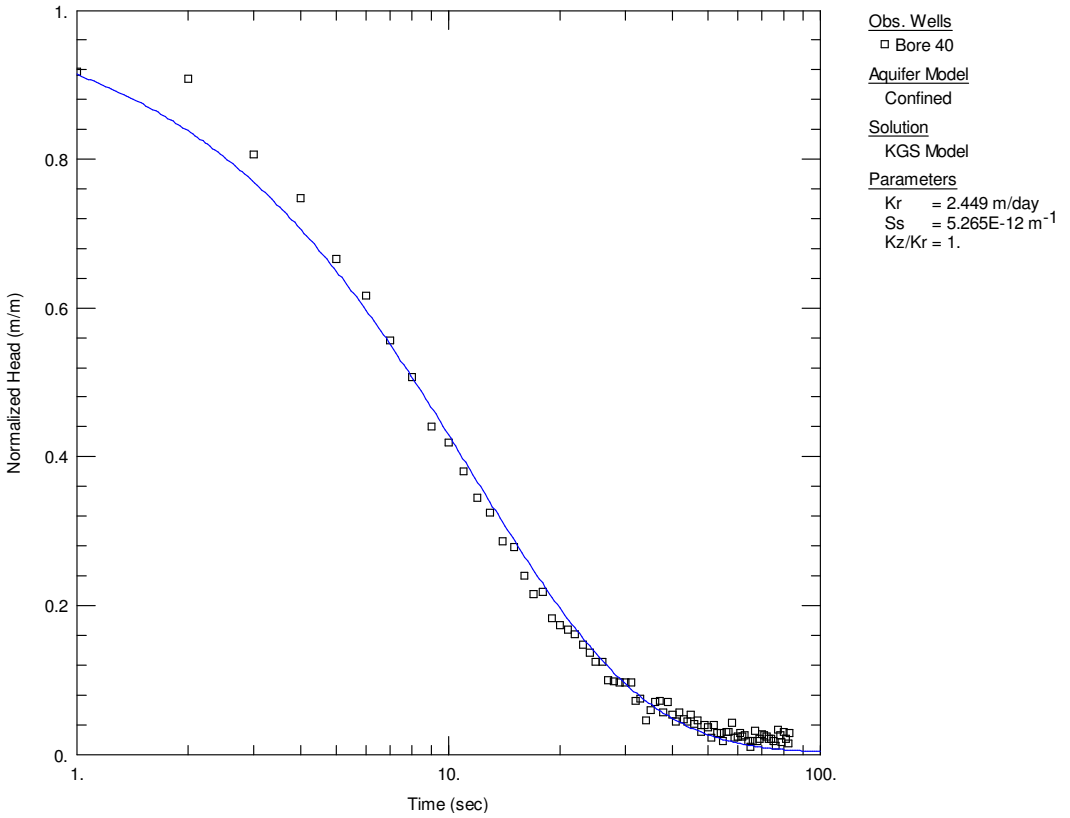


Figure VII-25: Bore 40 Rising Head Test 3

Bore 4A

Table VII-7: Bore 4A Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head Test	22/2/16	5.90	KGS Model	0.02
Falling Head Test	23/2/16	5.92	KGS Model	0.1
Rising Head Test	22/6/16	5.90	KGS Model	0.02
Rising Head Test	23/2/16	5.92	KGS Model	0.03
Rising Head Test	23/2/16	5.92	KGS Model	0.03

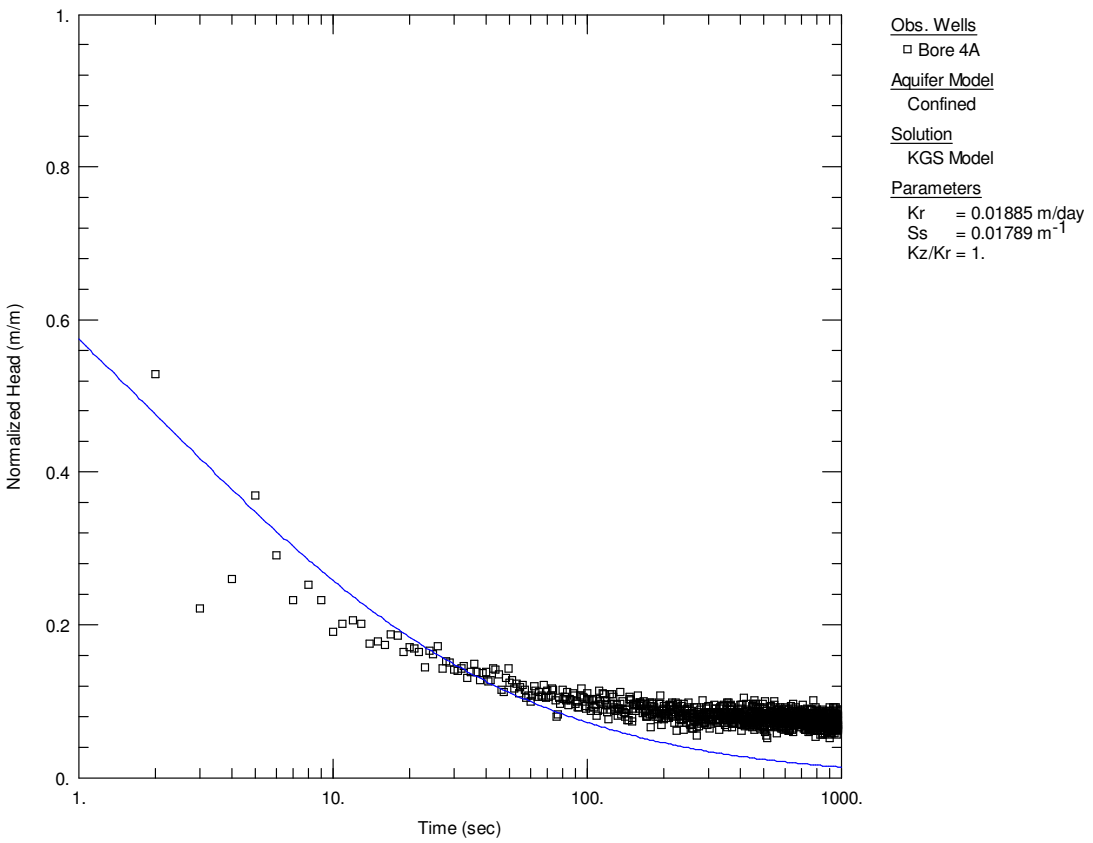


Figure VII-26: Bore 4A Falling Head Test 1

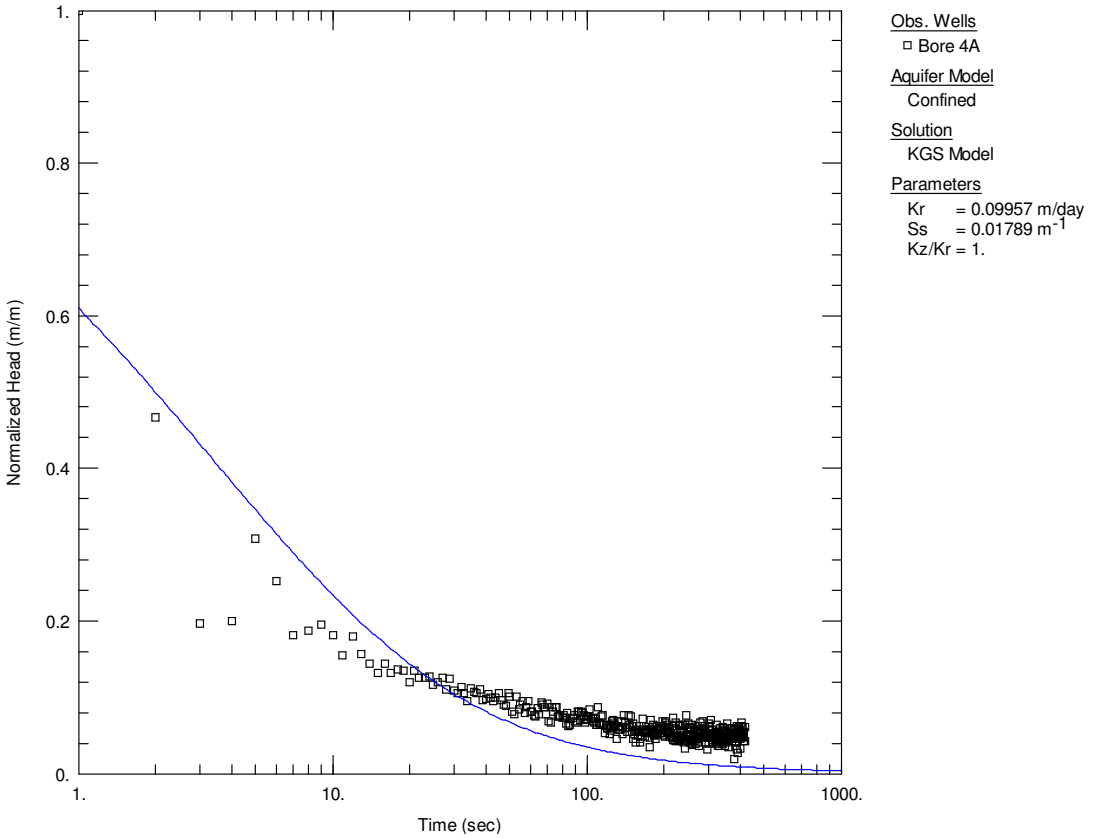


Figure VII-27: Bore 4A Falling Head Test 2

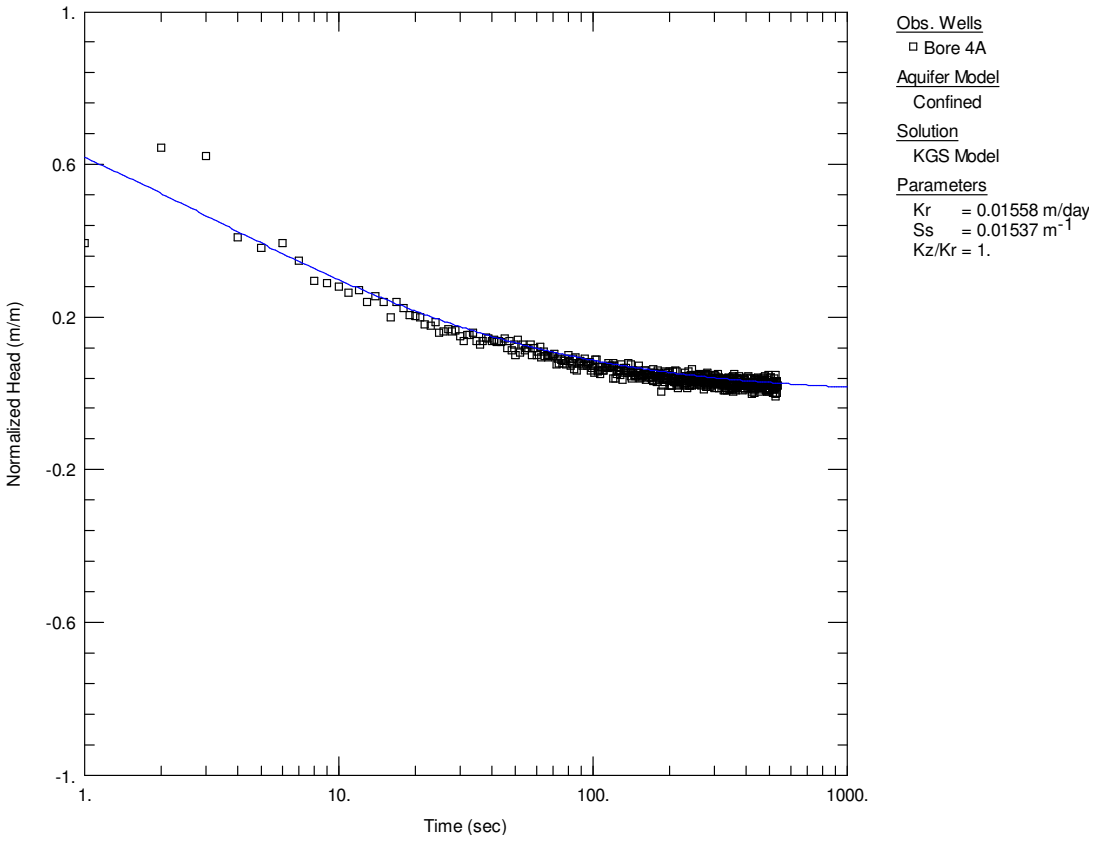


Figure VII-28: Bore 4A Rising Head Test 1

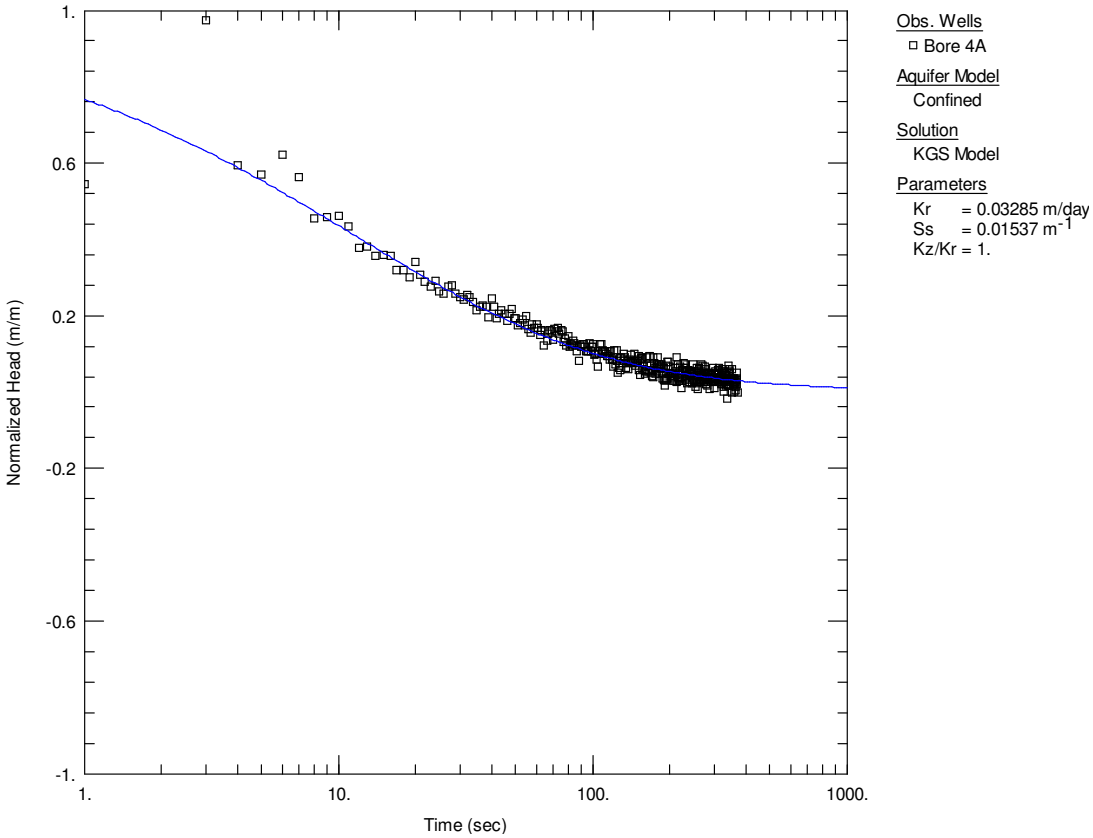


Figure VII-29: Bore 4A Rising Head Test 2

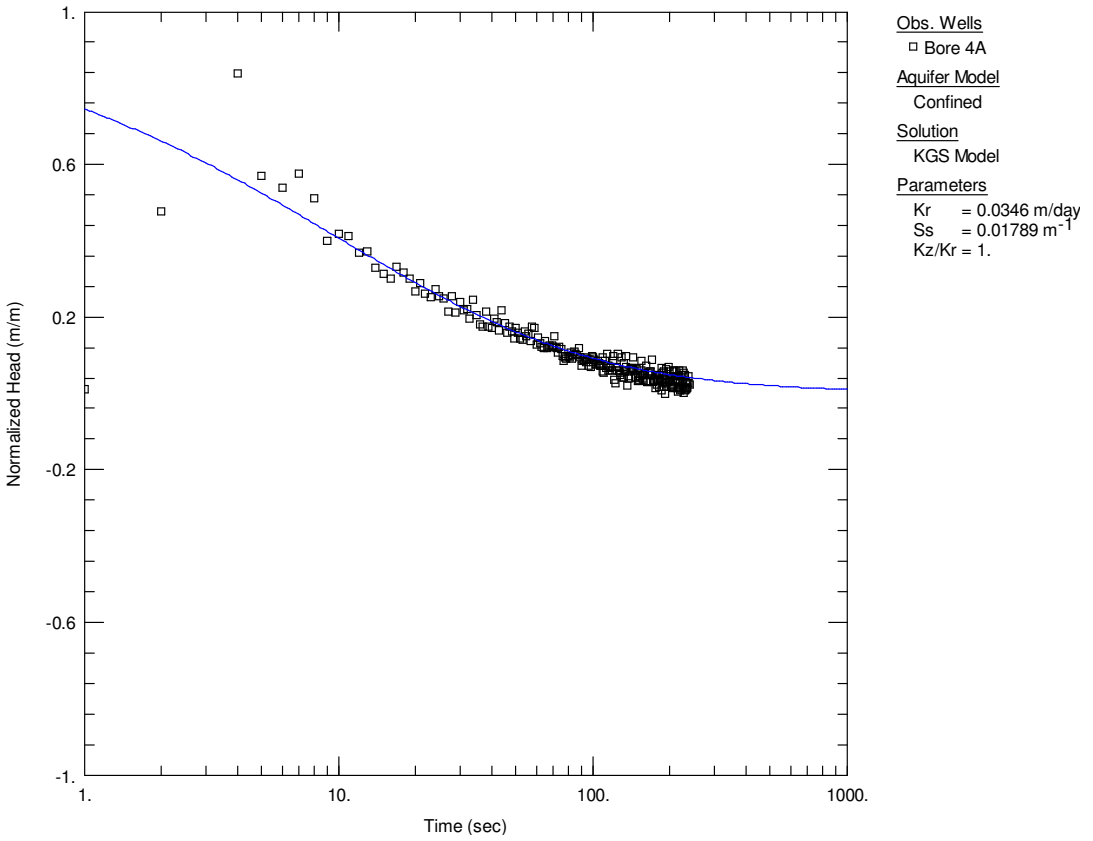


Figure VII-30: Bore 4A Rising Head Test 3

MIOP 01 / S2

Table VII-8: MIOP 01 / S2 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head	4/02/16	1.61	Bouwer and Rice - Corrected[1]	0.03
Falling Head	4/02/16	1.62	Bouwer and Rice - Corrected	0.04
Falling Head	8/02/16	1.61	Bouwer and Rice - Corrected	0.03
Rising Head	8/02/16	1.59	Bouwer and Rice - Corrected	0.06
Rising Head	8/02/16	1.60	Bouwer and Rice - Corrected	0.03
Rising Head	8/02/16	1.61	Bouwer and Rice - Corrected	0.04

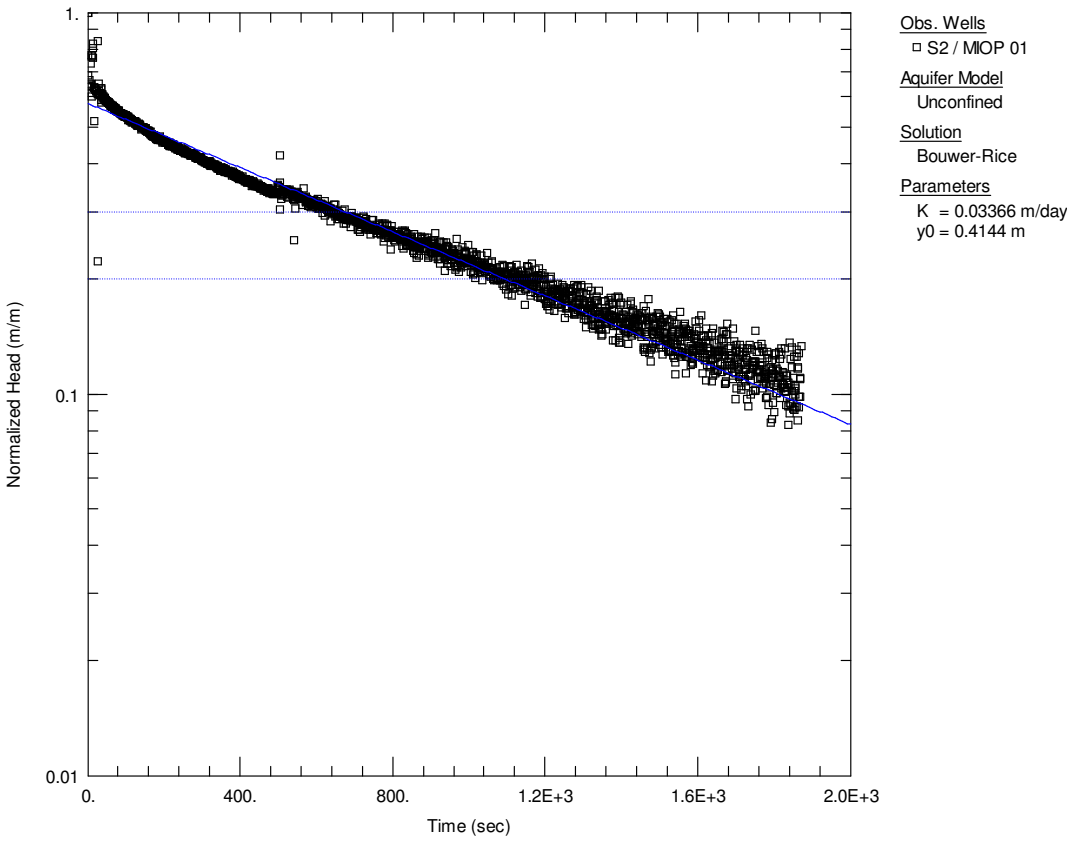


Figure VII-31: MIOP01 / S2 Falling Head Test 1

[1] Bouwer and Rice, corrected for screened across the water table

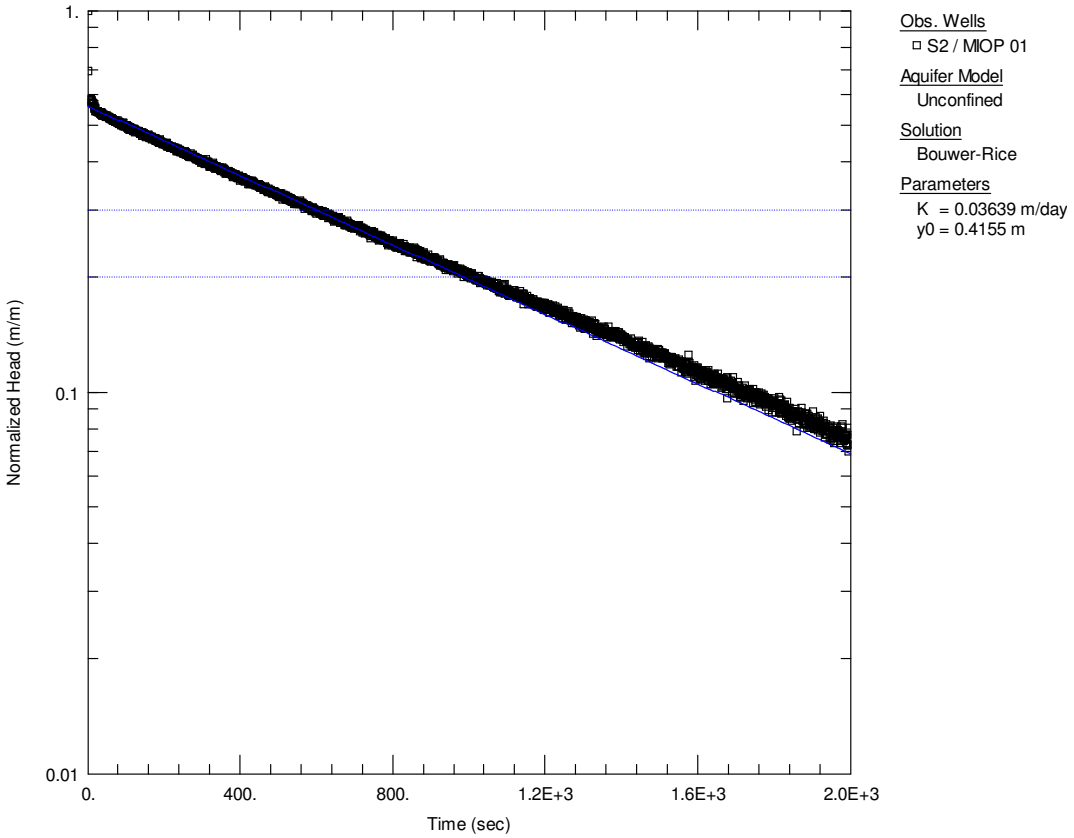


Figure VII-32: MIOP01 / S2 Falling Head Test 2

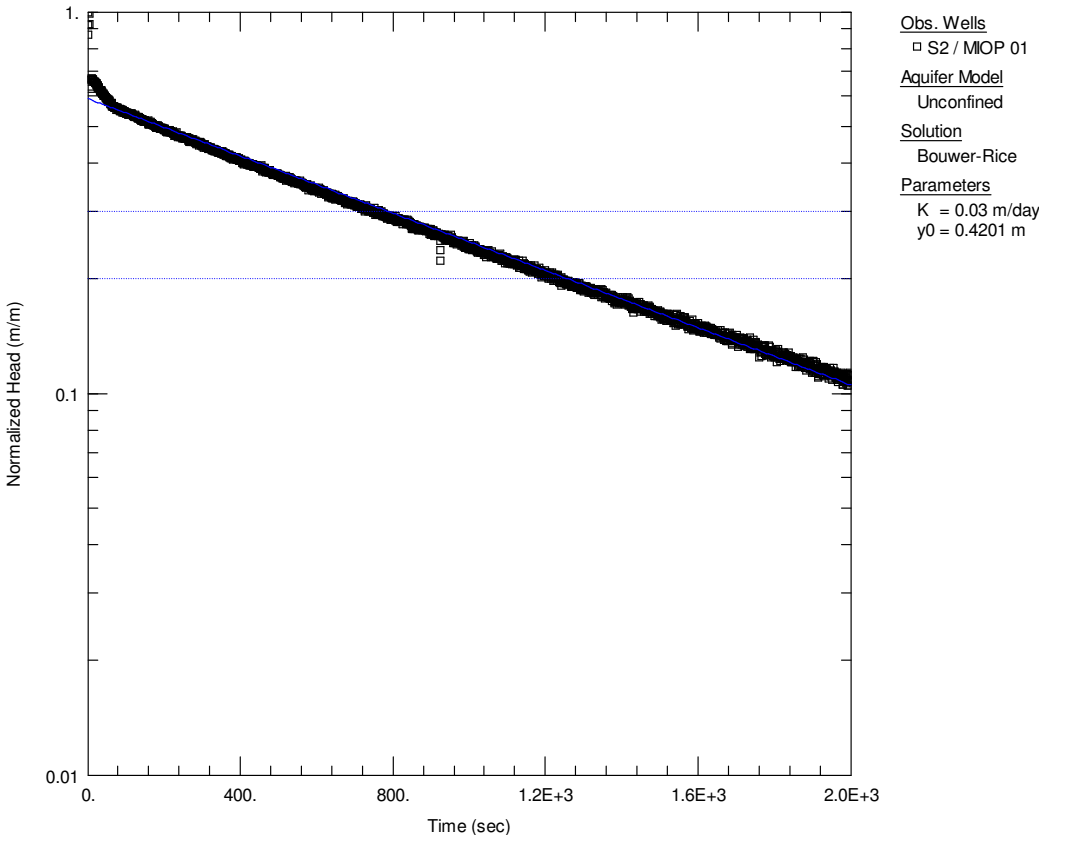


Figure VII-33: MIOP01 / S2 Falling Head Test 3

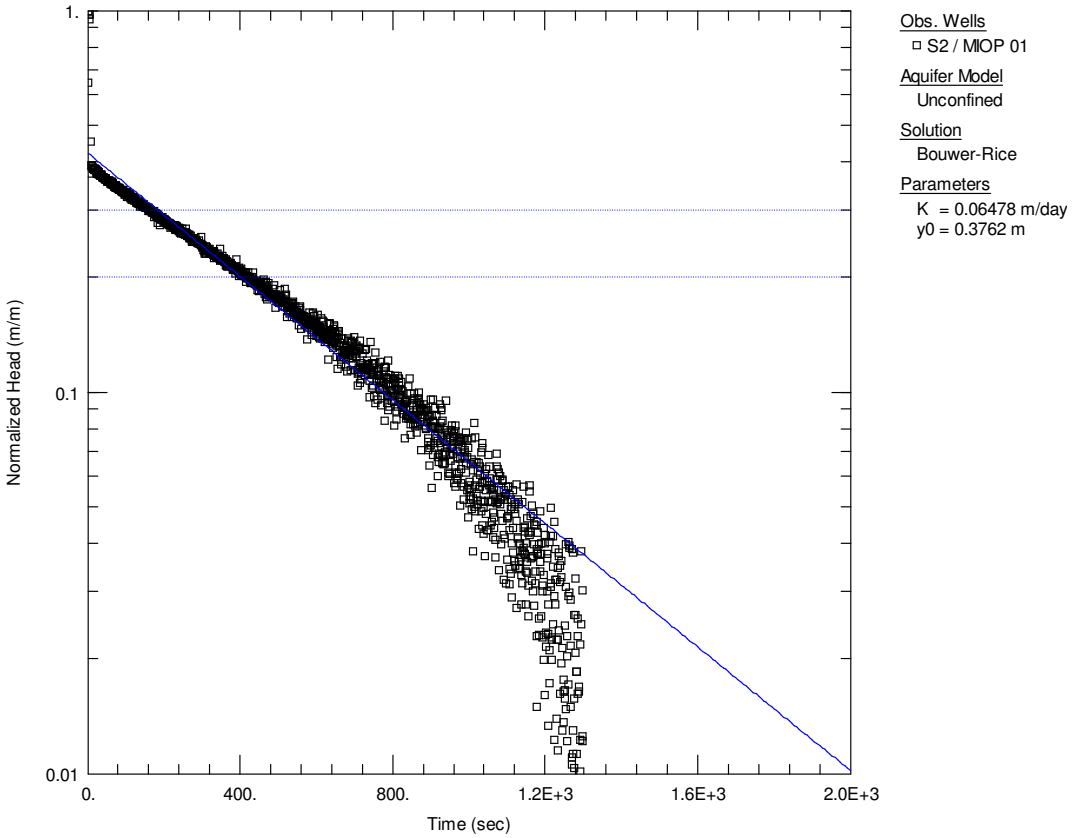


Figure VII-34: MIOP01 / S2 Rising Head Test 1

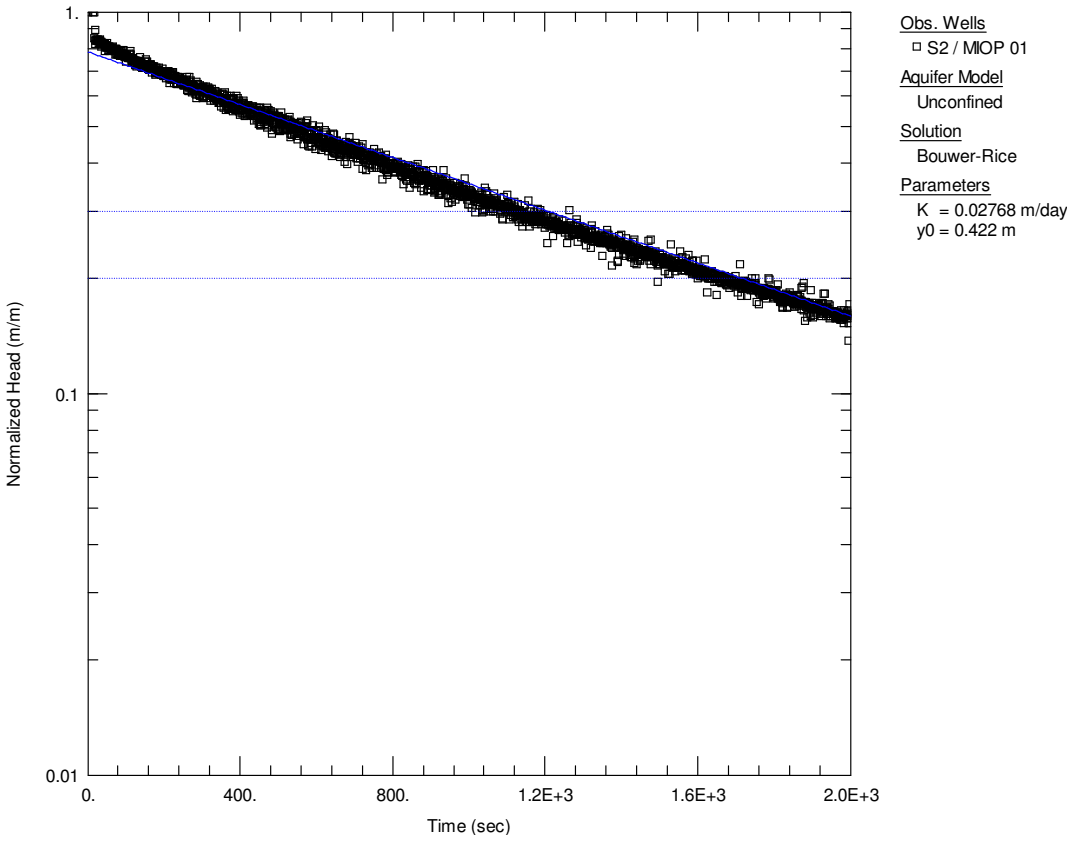


Figure VII-35: MIOP01 / S2 Rising Head Test 2

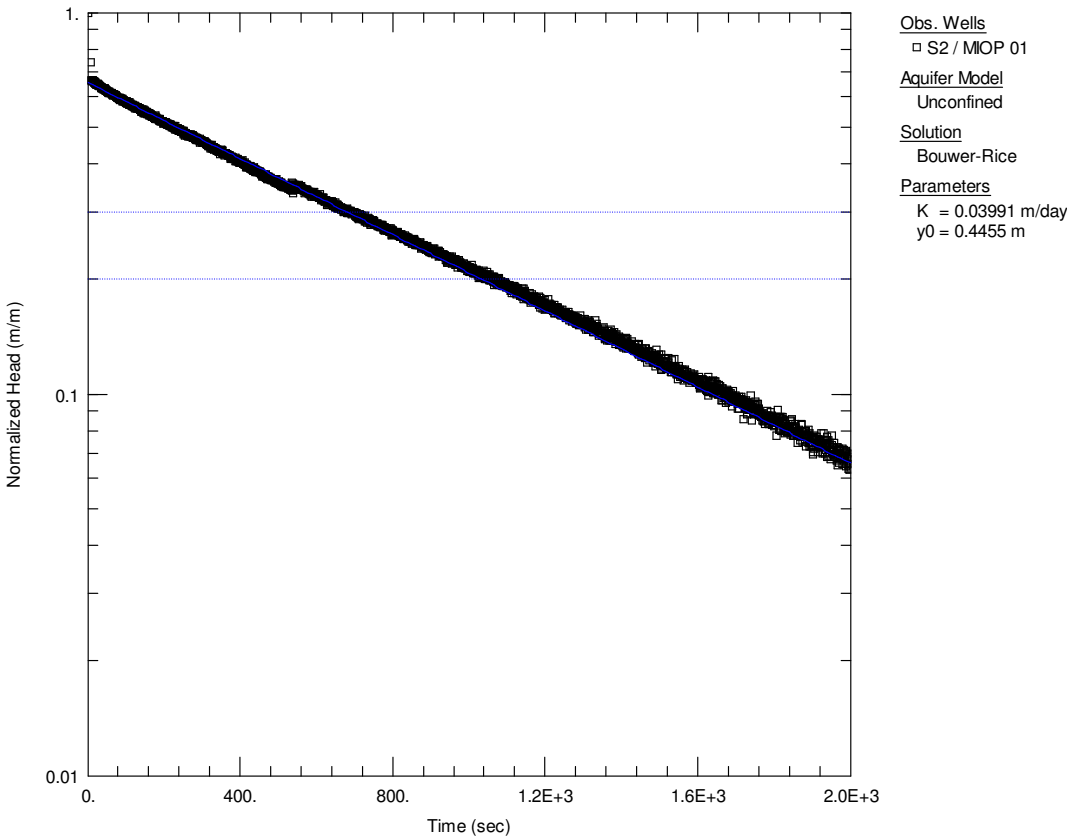


Figure VII-36: MIOP01 / S2 Rising Head Test 3

MIOP 02

Table VII-9: MIOP 02 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head	5/02/16	11.91	Bouwer and Rice, corrected	0.15
Falling Head	5/02/16	11.90	Bouwer and Rice, corrected	0.21
Falling Head	8/02/16	11.92	Bouwer and Rice, corrected	0.18
Rising Head	8/02/16	11.91	Bouwer and Rice, corrected	0.04
Rising Head	8/02/16	11.92	Bouwer and Rice, corrected	0.12
Rising Head	8/02/16	11.91	Bouwer and Rice, corrected	0.11

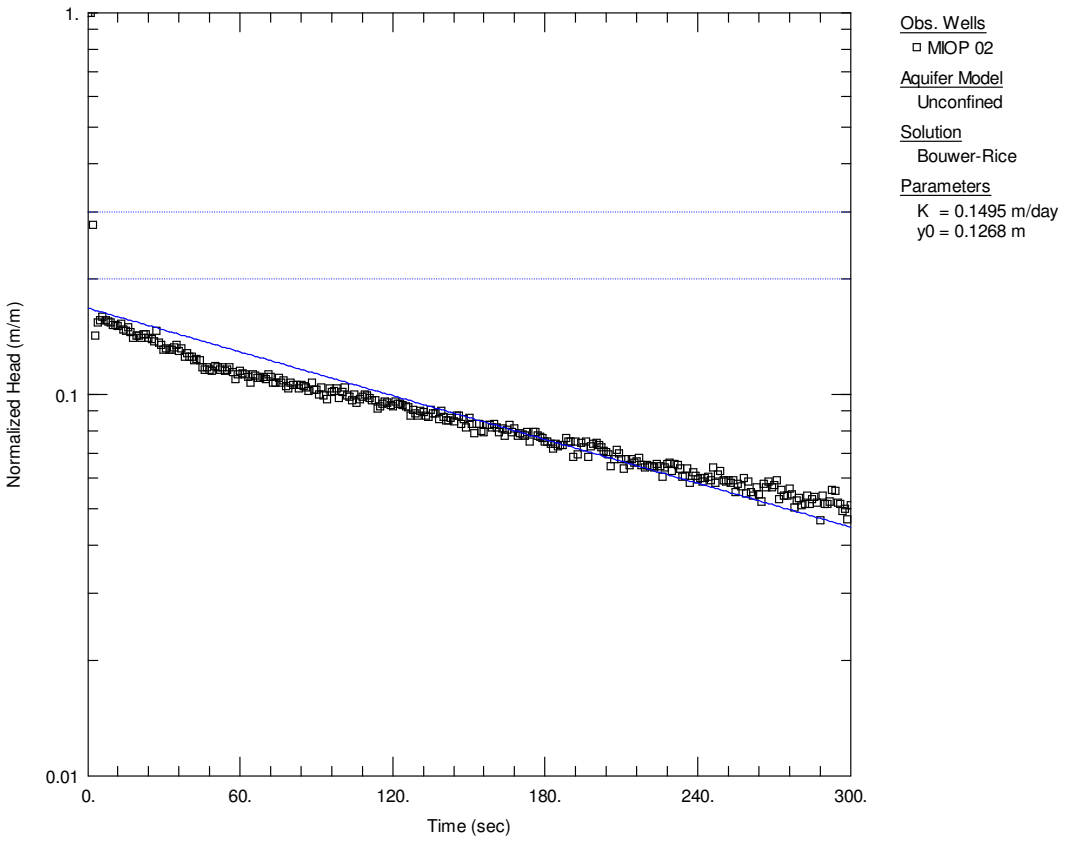


Figure VII-37: MIOP02 Falling Head Test 1

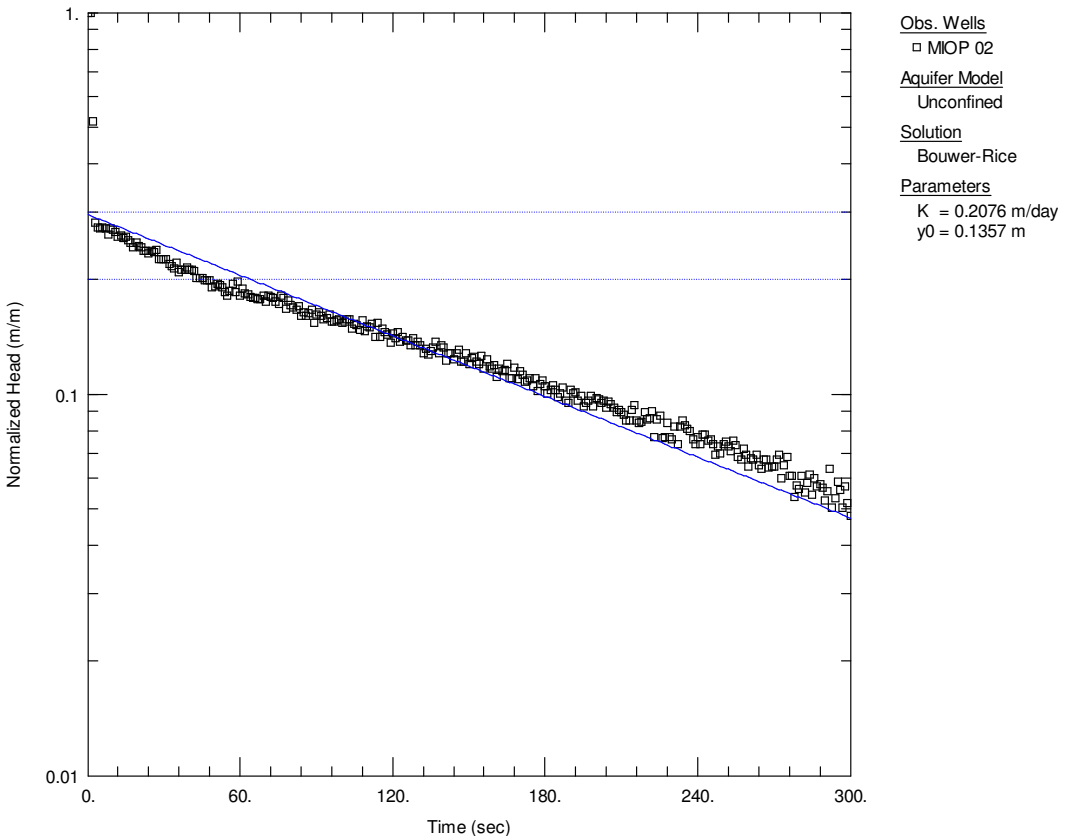


Figure VII-38: MIOP02 Falling Head Test 2

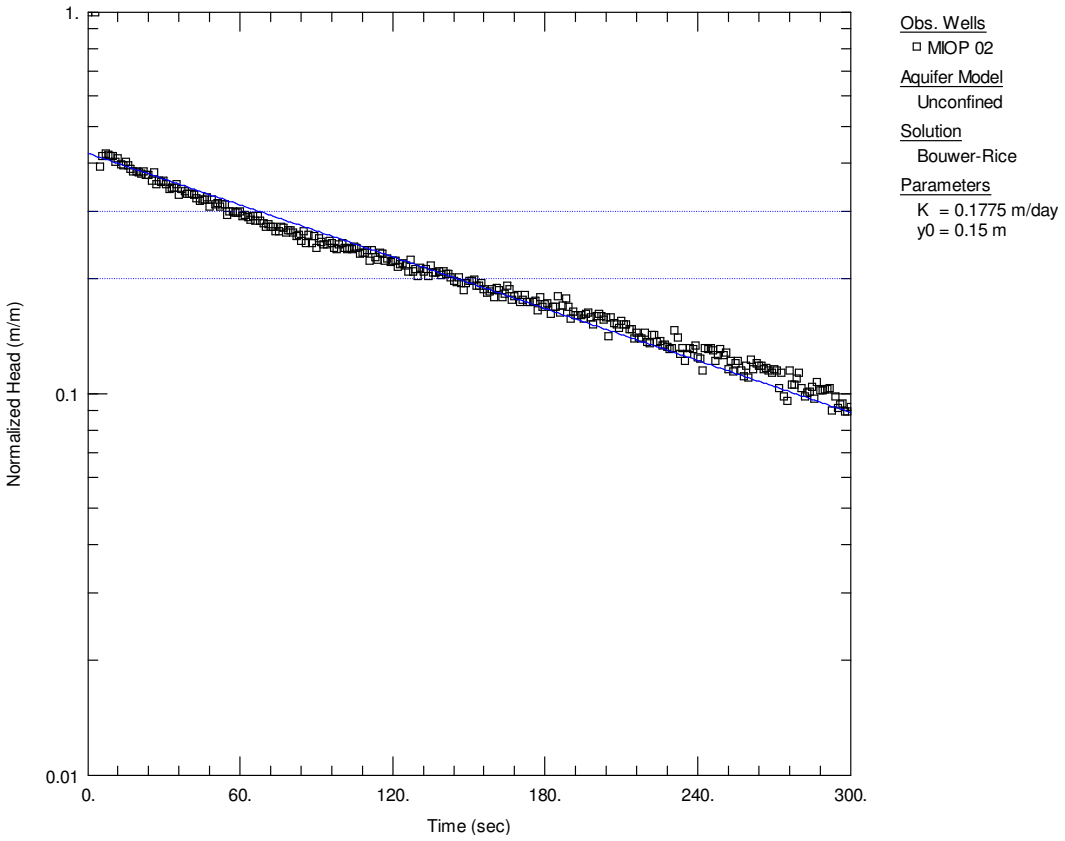


Figure VII-39: MIOP02 Falling Head Test 3

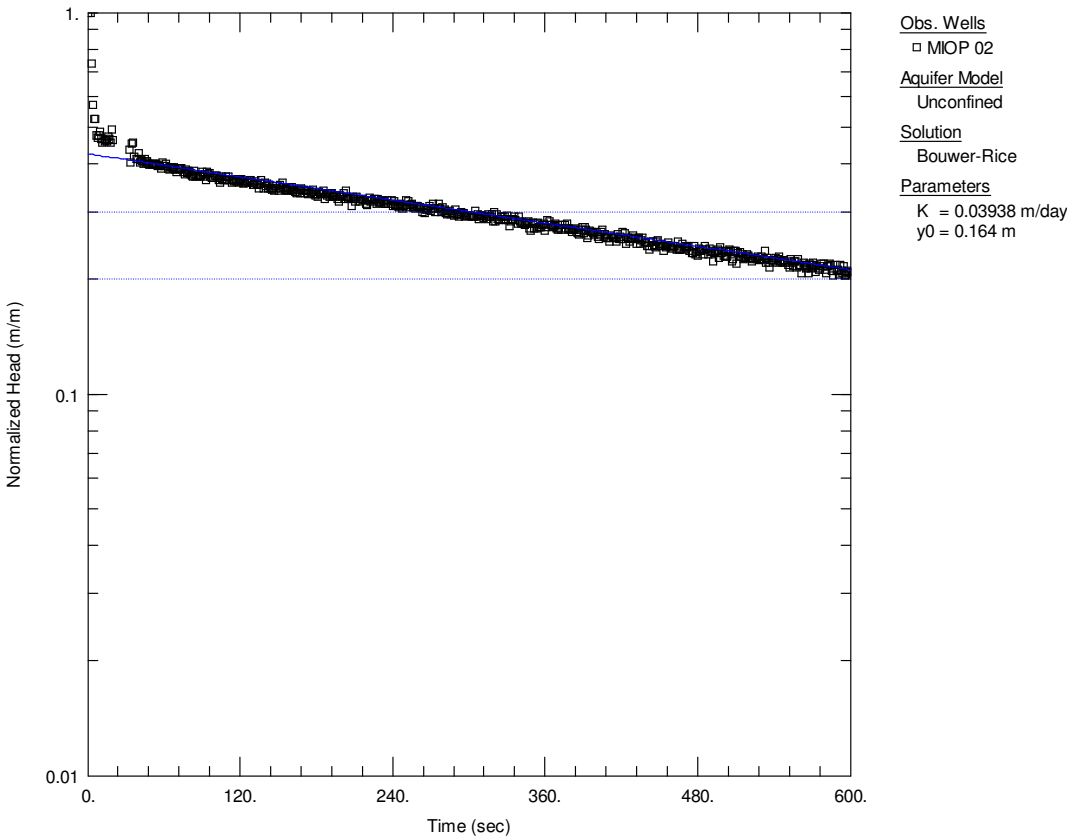


Figure VII-40: MIOP02 Rising Head Test 1

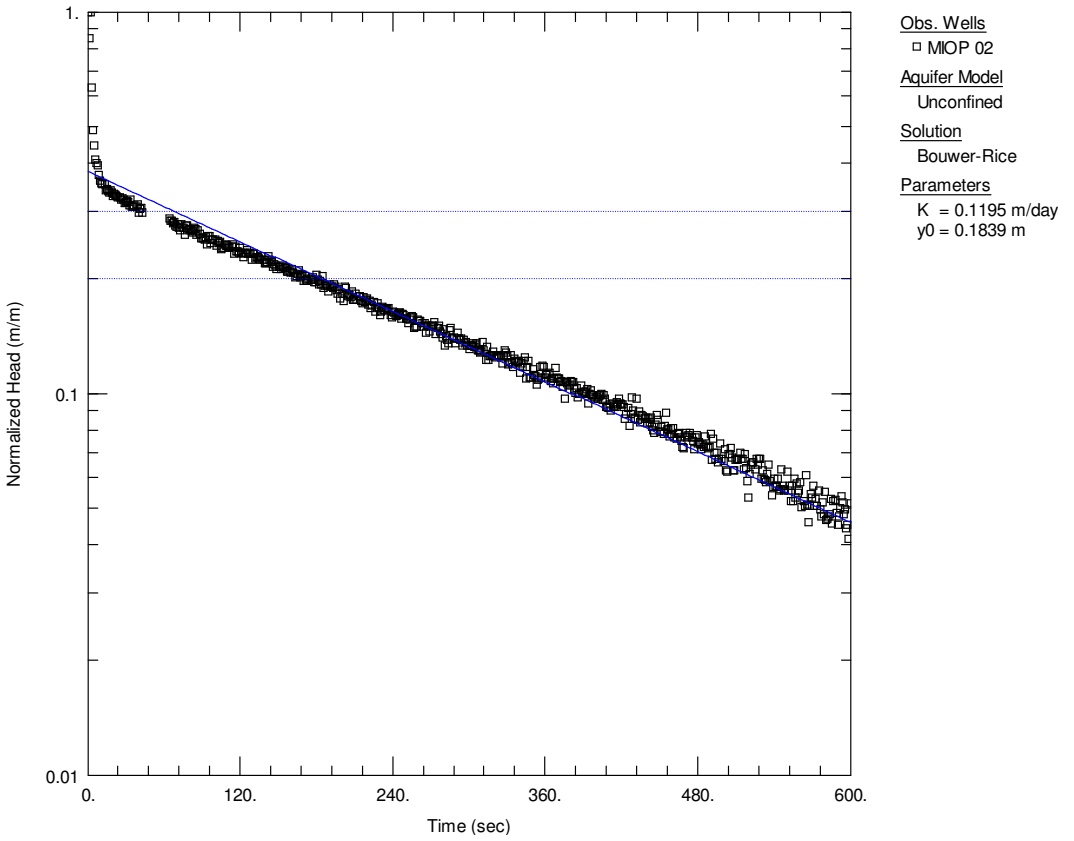


Figure VII-41: MIOP02 Rising Head Test 2

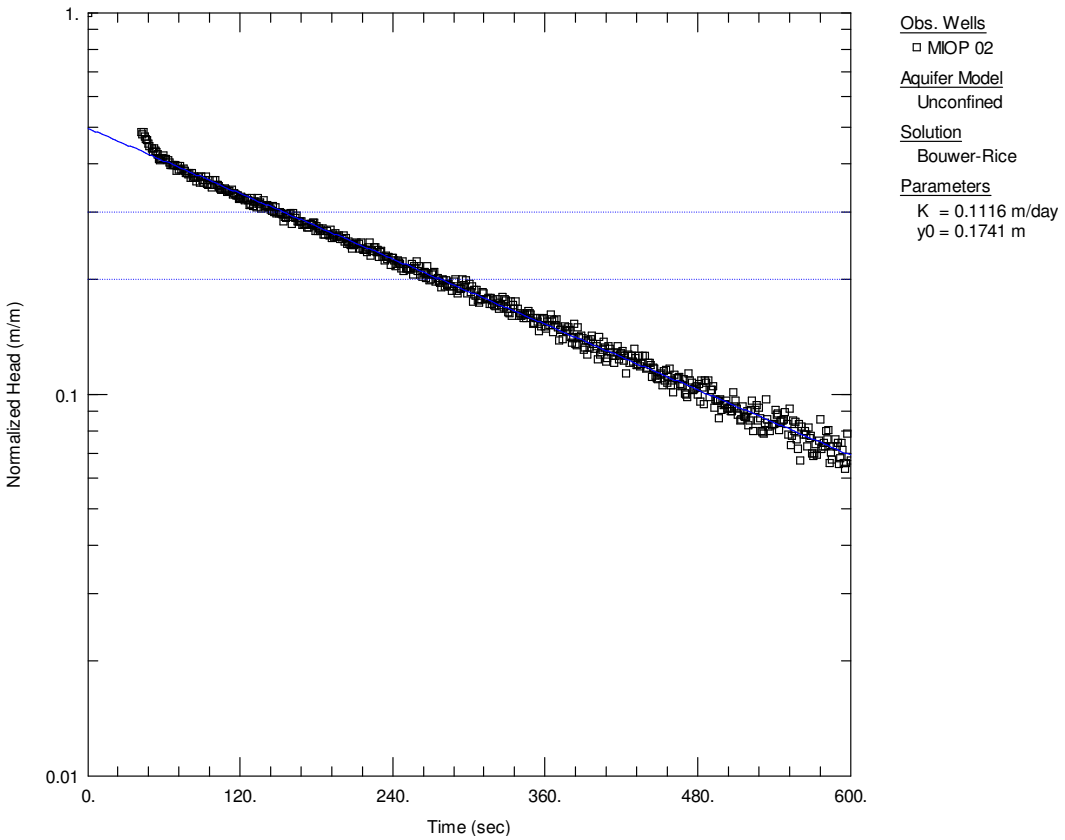


Figure VII-42: MIOP02 Rising Head Test 3

S3

Table VII-10: S3 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head	21/02/16	5.60	KGS Model	0.18
Falling Head	21/02/16	5.60	KGS Model	0.18
Falling Head	21/02/16	5.60	KGS Model	0.46
Rising Head	21/02/16	5.59	KGS Model	0.41
Rising Head	21/02/16	5.59	KGS Model	0.57
Rising Head	21/02/16	5.59	KGS Model	0.59

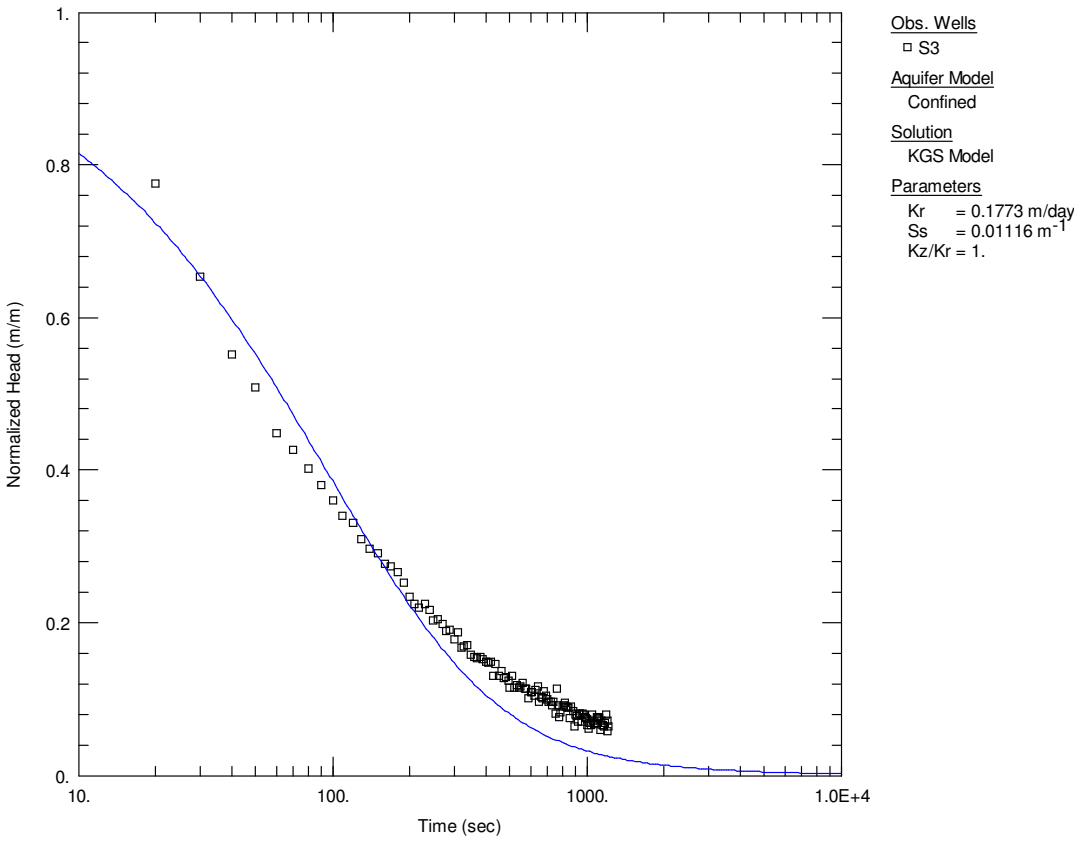


Figure VII-43: S3 Falling Head Test 1

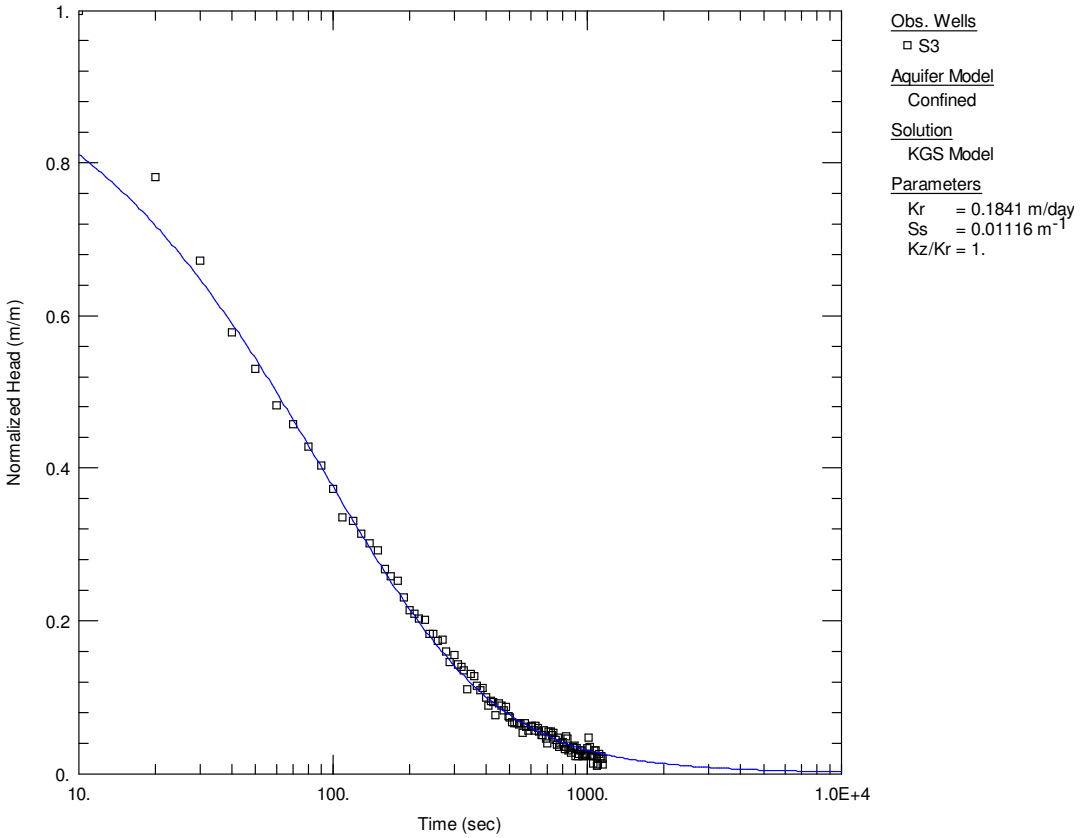


Figure VII-44: S3 Falling Head Test 2

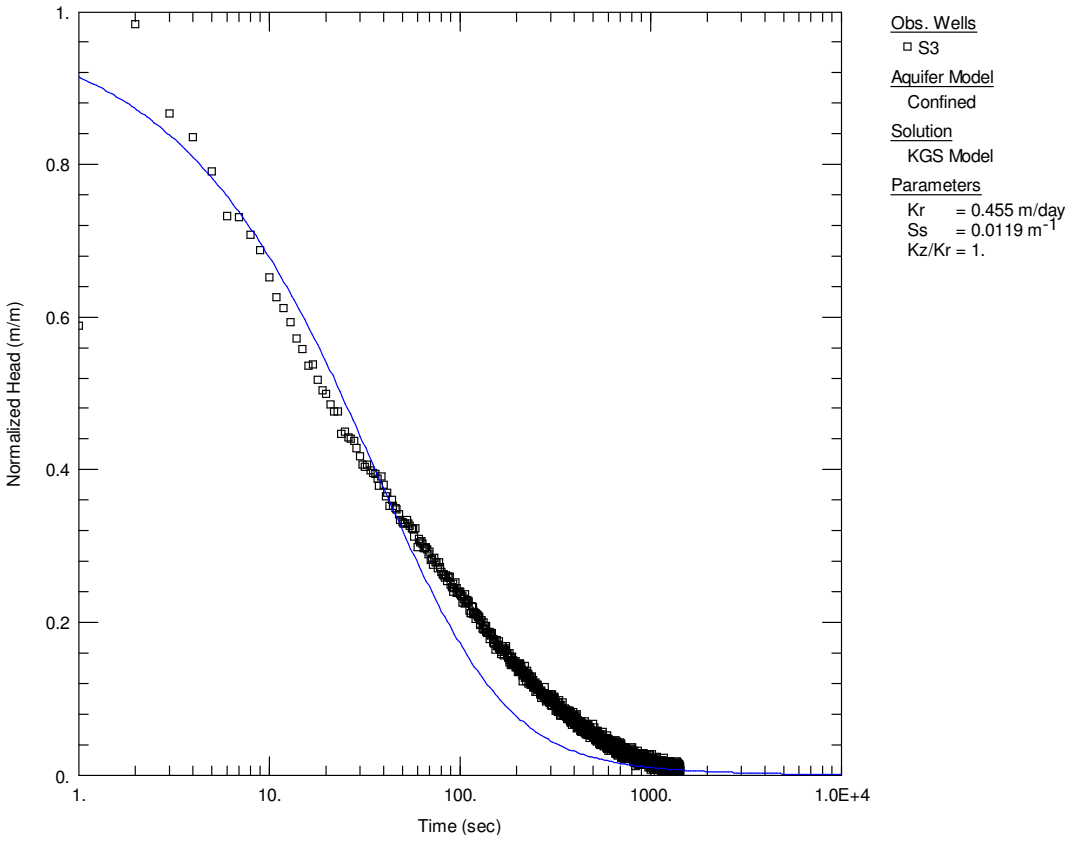


Figure VII-45: S3 Falling Head Test 3

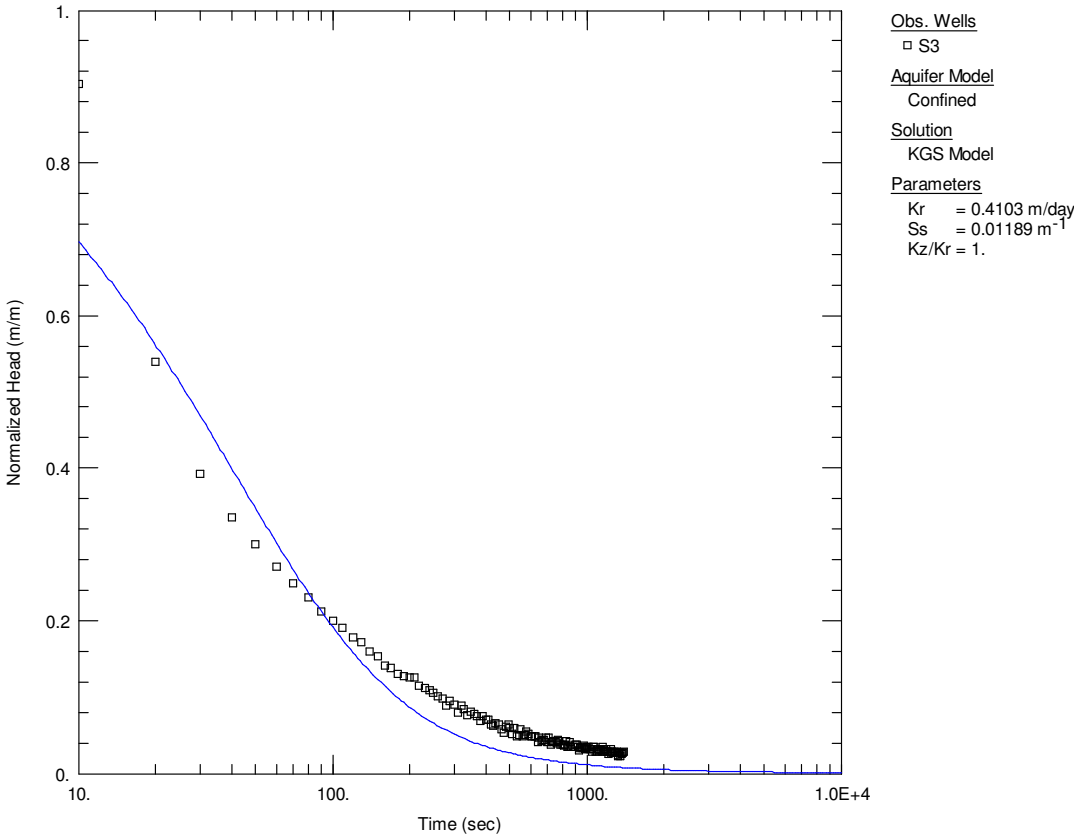


Figure VII-46: S3 Rising Head Test 1

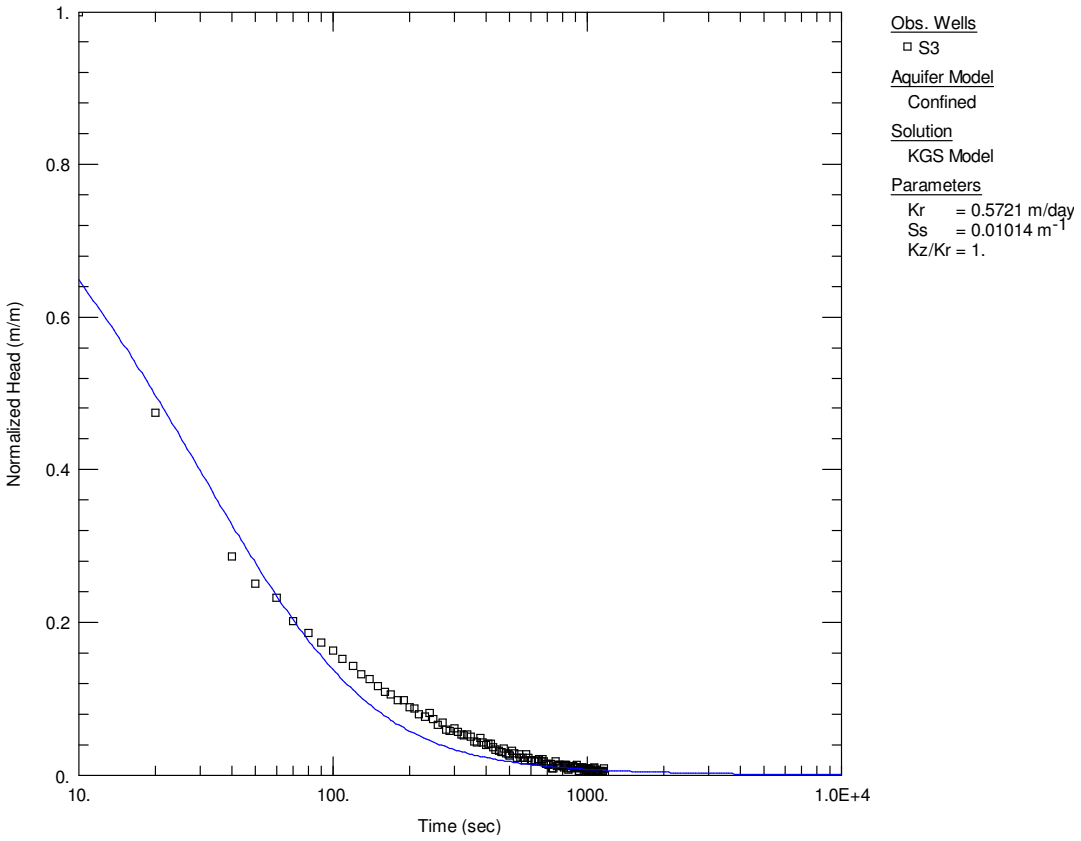


Figure VII-47: S3 Rising Head Test 2

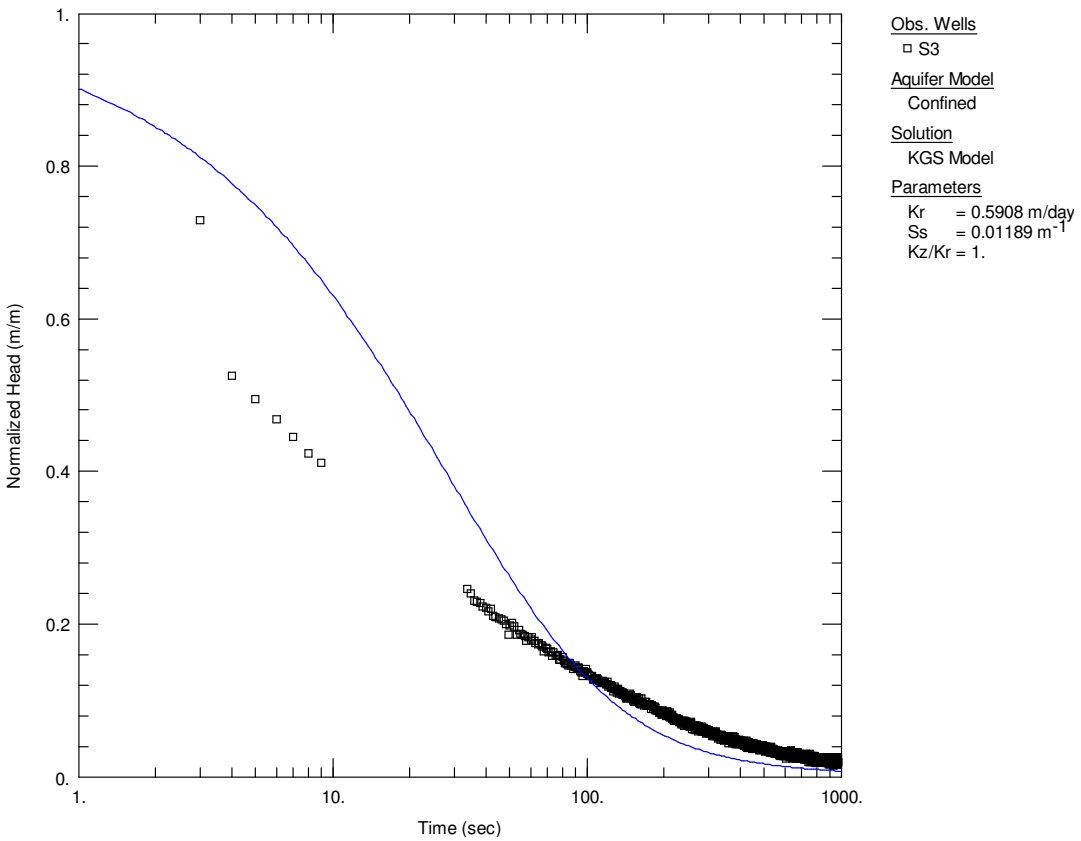


Figure VII-48: S3 Rising Head Test 3

S7

Table VII-11: S7 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head	23/2/16	3.99	Hvorslev	0.70
Falling Head	23/2/16	3.99	Hvorslev	0.70
Falling Head	23/2/16	3.99	Hvorslev	0.58
Rising Head	23/2/16	3.99	Hvorslev	0.48
Rising Head	23/2/16	3.99	Hvorslev	0.62
Rising Head	23/2/16	3.99	Hvorslev	0.38

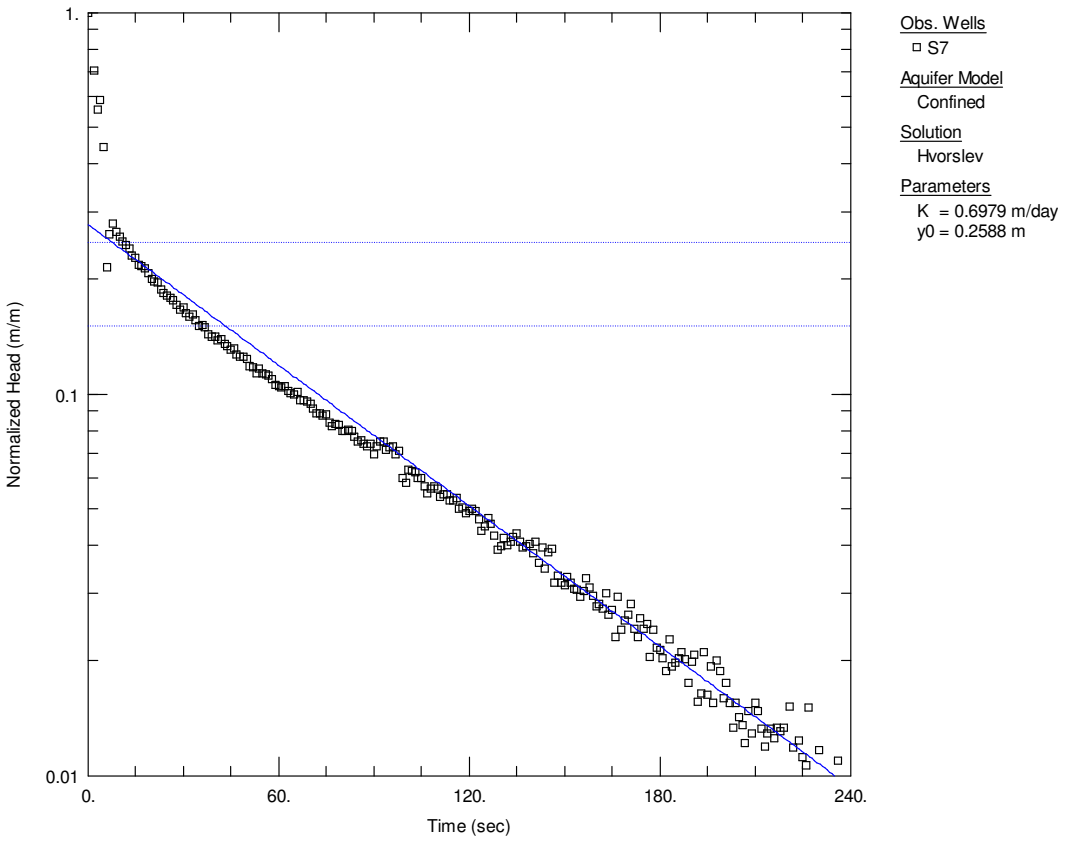


Figure VII-49: S7 Falling Head Test 1

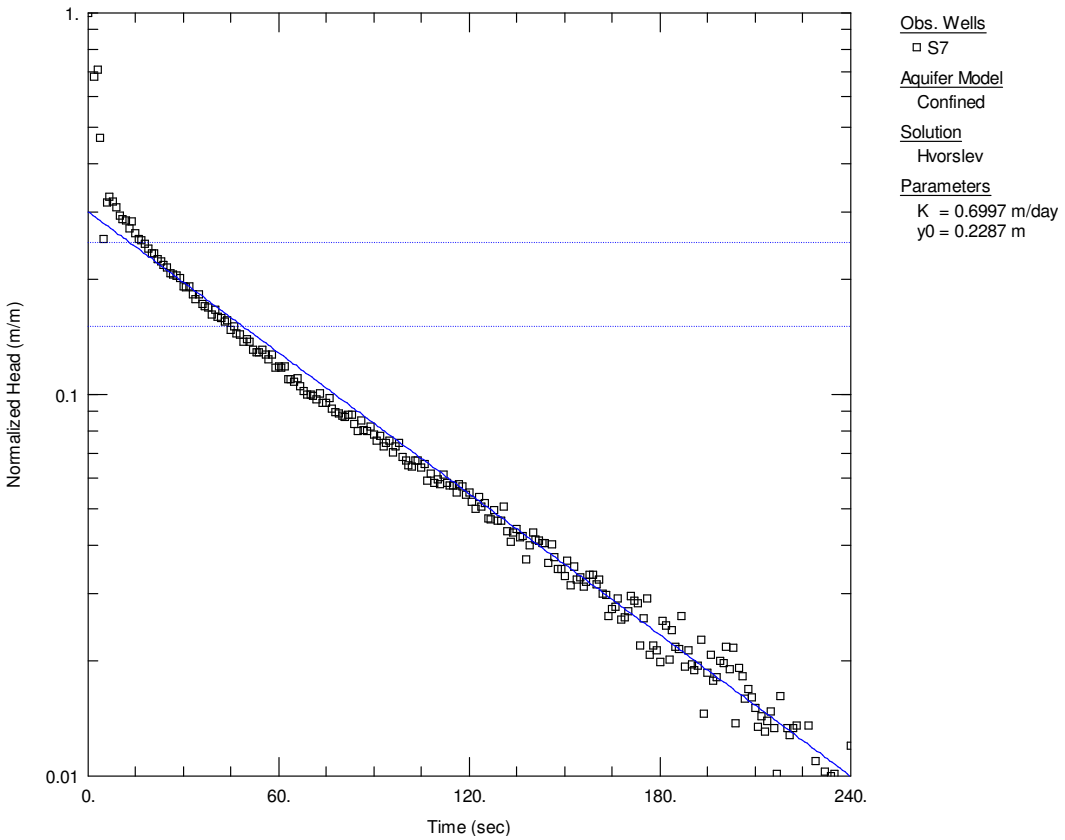


Figure VII-50: S7 Falling Head Test 2

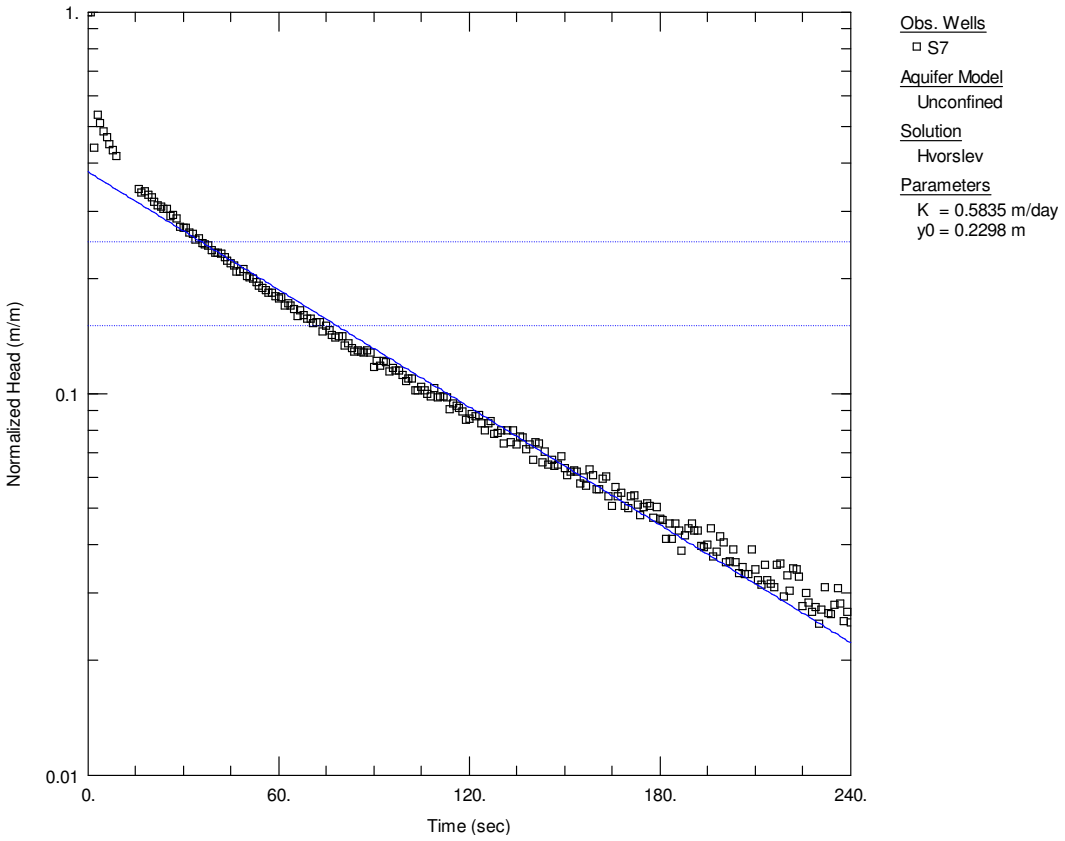


Figure VII-51: S7 Falling Head Test 3

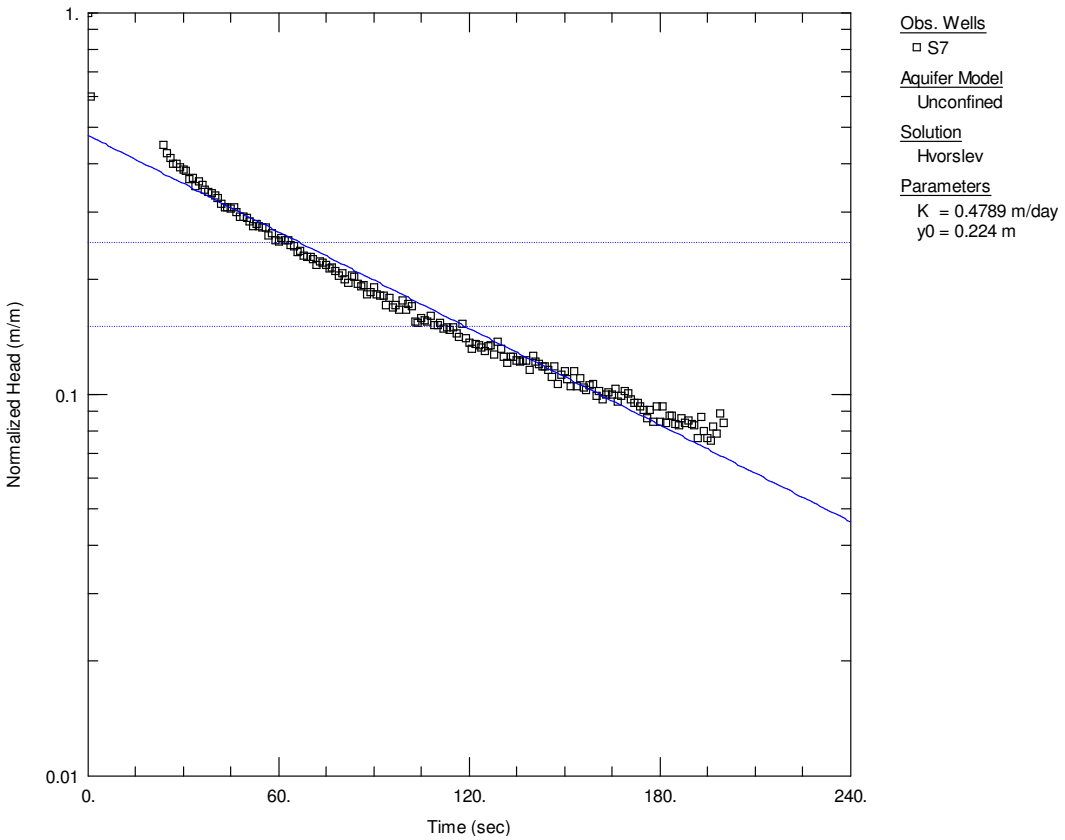


Figure VII-52: S7 Rising Head Test 1

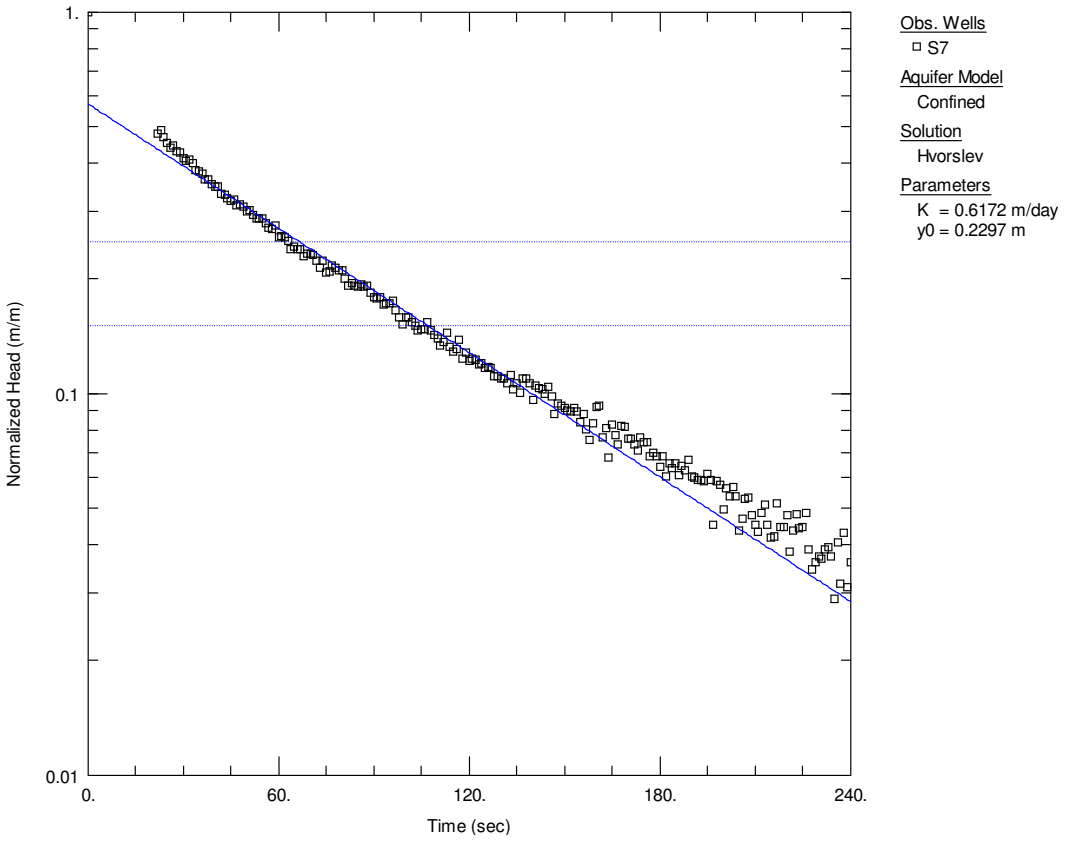


Figure VII-53: S7 Rising Head Test 2

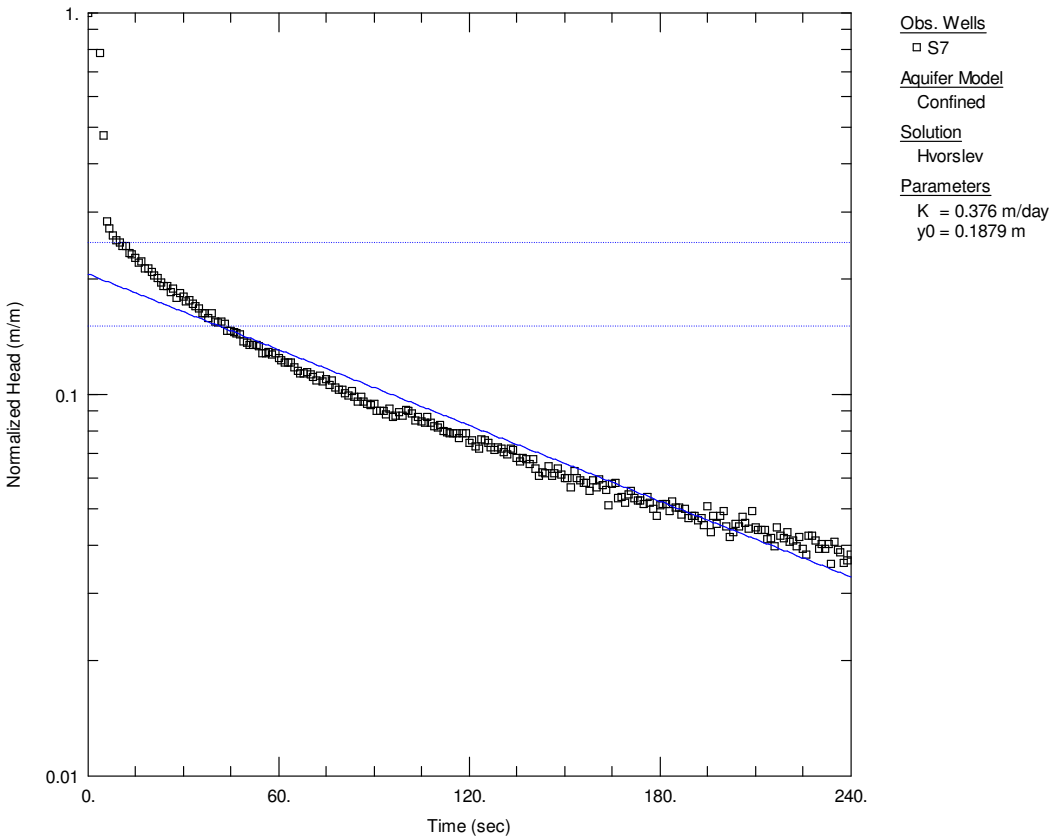


Figure VII-54: S7 Rising Head Test 3

S8

Table VII-12: S8 Testing Summary

Test Type	Test Date	Initial SWL (mbGL)	Analysis Method	Hydraulic Conductivity (m/d)
Falling Head	8/2/16	5.70	KGS Model	0.004
Falling Head	10/2/16	5.72	KGS Model	0.003
Rising Head	10/2/16	5.71	KGS Model	0.003

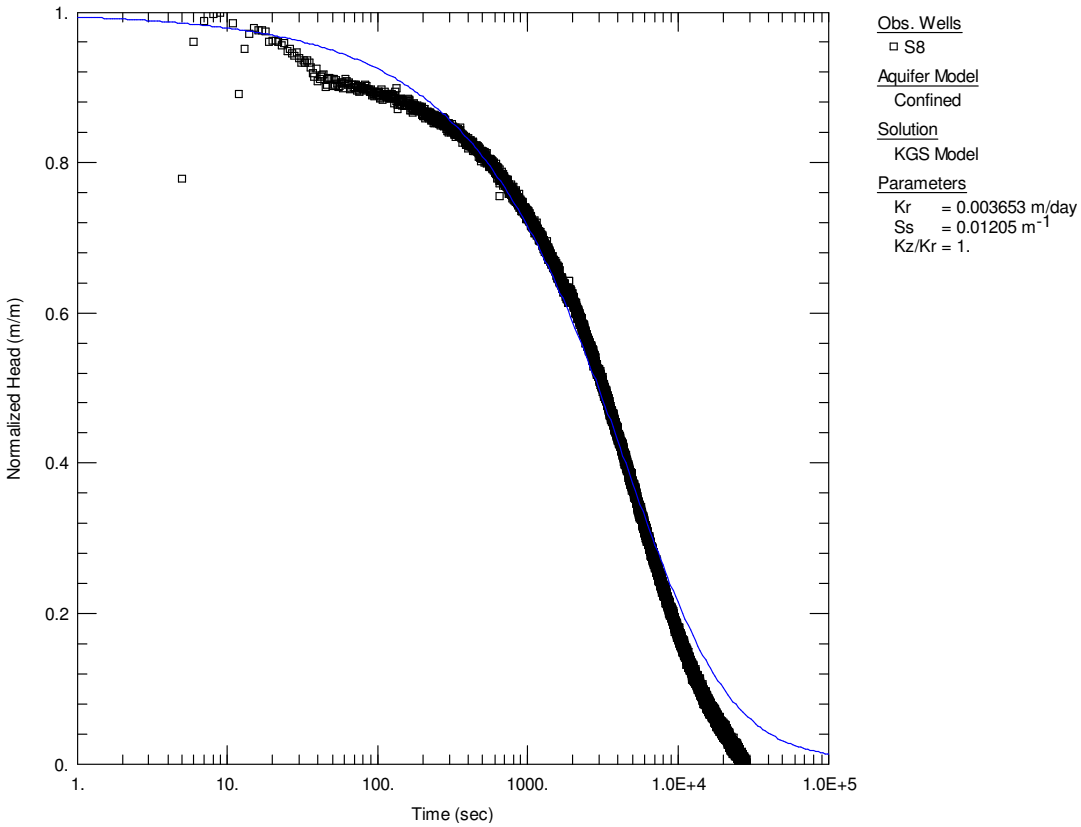


Figure VII-55: S8 Falling Head Test 1

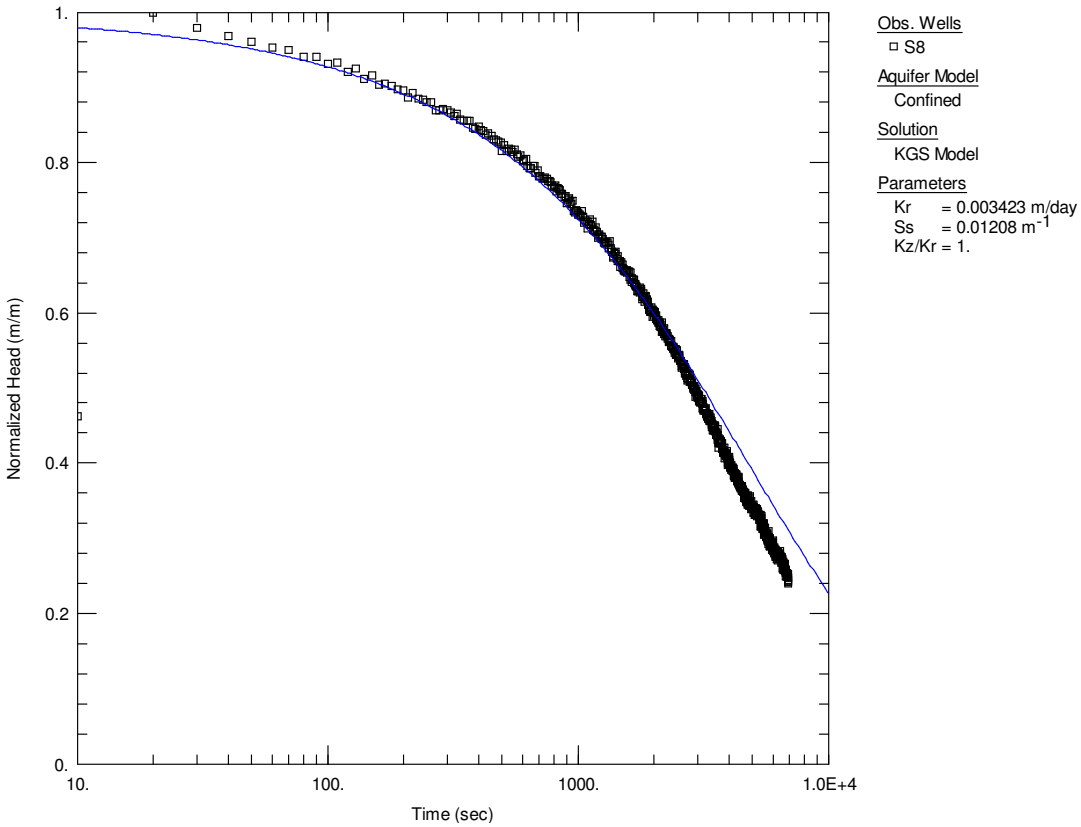


Figure VII-56: S8 Falling Head Test 2

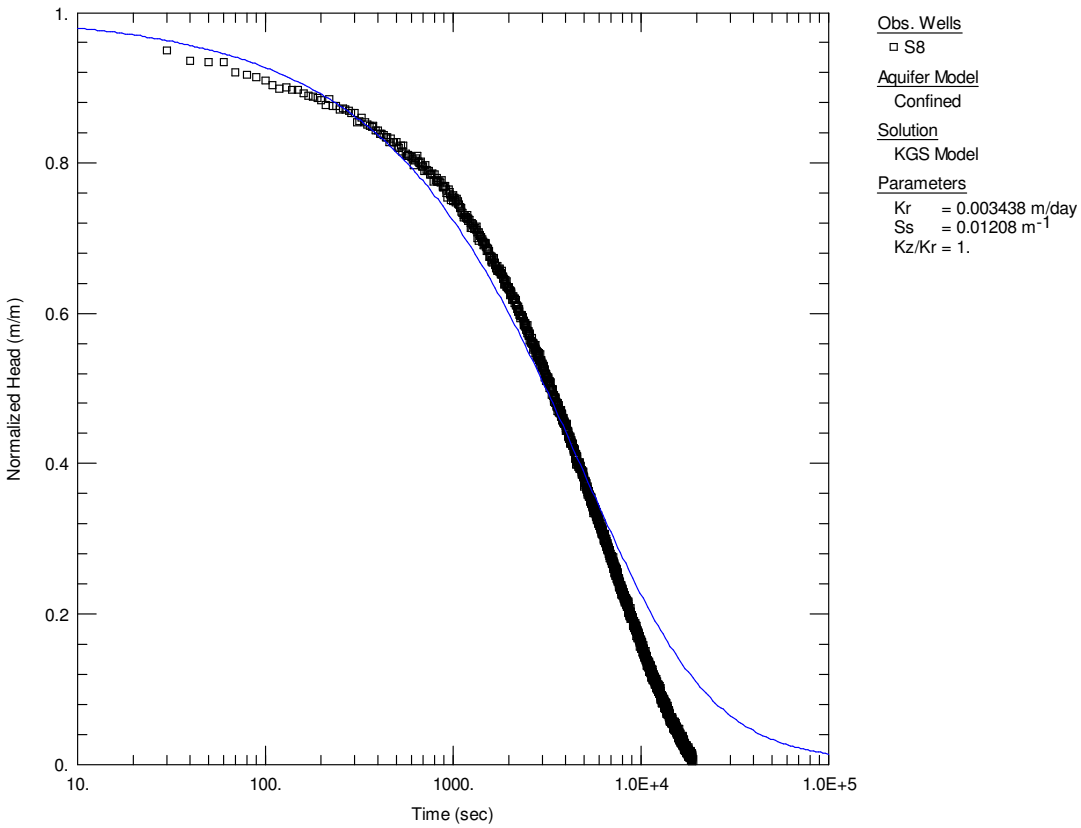


Figure VII-57: S8 Rising Head Test 1

APPENDIX VIII

Phase 2 Groundwater and Seepage Sampling Results

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1602053**	Page	: 1 of 15
Client	: **MOUNT ISA MINES LIMITED**	Laboratory	: Environmental Division Brisbane
Contact	: MS TAMARA GROVES	Contact	: Joy Morgan
Address	: PRIVATE MAIL BAG 6 MOUNT ISA QLD, AUSTRALIA 4825	Address	: 2 Byth Street Stafford QLD Australia 4053
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Project	: BSOC WRD EE	QC Level	: NEPM 2013 B3 & ALS QC Standard
Order number	: CTDGMG	Date Samples Received	: 28-Jan-2016 09:30
C-O-C number	: ----	Date Analysis Commenced	: 28-Jan-2016
Sampler	: ----	Issue Date	: 03-Feb-2016 17:55
Site	: Mount Isa Mines		
		No. of samples received	: 10
Quote number	: ----	No. of samples analysed	: 10

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD Brisbane Organics, Stafford, QLD
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD Brisbane Organics, Stafford, QLD WB Water Lab Brisbane, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Matt Frost	Senior Organic Chemist	Brisbane Organics, Stafford, QLD

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.

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.

- It is recognised that EG020T (Total Metals) is less than EG020F (Dissolved Metals) for some samples. However, the difference is within experimental variation of the methods.
- EG020-F (Dissolved Metals by ICP-MS) were found to be higher than EG020-T (Total Metals by ICP-MS) for sample EB1602053 - 009 (BSOC A3 17189) & 010 (BSOC B4 17194). This was confirmed by re-digestion and re-analysis.
- The presence of high SO4 may bias the EC low.
- TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC A2 17188	BSOC A5 17190	BSOC B3 17193	BSOC B2 17192	BSOC B1 17191
			Client sampling date / time	19-Jan-2016 10:20	19-Jan-2016 11:50	20-Jan-2016 09:45	20-Jan-2016 10:20	20-Jan-2016 11:00
Compound	CAS Number	LOR	Unit	EB1602053-001	EB1602053-002	EB1602053-003	EB1602053-004	EB1602053-005
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	8.20	8.28	8.29	8.15	8.30
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	11500	13300	3370	1170	4520
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	9460	10200	1800	683	3180
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	2310	1470	418	331	936
ED009: Anions								
Bromide	24959-67-9	0.01	mg/L	4.40	6.70	2.01	0.260	0.940
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	3
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	647	551	611	378	458
Total Alkalinity as CaCO3	----	1	mg/L	647	551	611	378	462
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	5580	4870	182	152	1760
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	758	1590	637	52	204
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	71	126	19	37	27
Magnesium	7439-95-4	1	mg/L	519	280	90	58	211
Sodium	7440-23-5	1	mg/L	1920	2540	553	122	649
Potassium	7440-09-7	1	mg/L	258	255	31	11	102
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	0.01	<0.01	<0.01
Antimony	7440-36-0	0.001	mg/L	<0.001	0.002	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.002	0.014	<0.001	<0.001	<0.001
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	0.027	0.051	0.117	0.050	0.038
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	0.003
Copper	7440-50-8	0.001	mg/L	0.005	0.002	0.005	<0.001	0.001

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC A2 17188	BSOC A5 17190	BSOC B3 17193	BSOC B2 17192	BSOC B1 17191
			Client sampling date / time	19-Jan-2016 10:20	19-Jan-2016 11:50	20-Jan-2016 09:45	20-Jan-2016 10:20	20-Jan-2016 11:00
Compound	CAS Number	LOR	Unit	EB1602053-001	EB1602053-002	EB1602053-003	EB1602053-004	EB1602053-005
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Cobalt	7440-48-4	0.001	mg/L	<0.001	**0.004**	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	**0.002**	**0.003**	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	**0.002**	**0.002**	**0.004**	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L	**0.006**	**0.015**	**0.022**	**0.006**	**0.007**
Manganese	7439-96-5	0.001	mg/L	**0.174**	**0.587**	**0.015**	**0.010**	**0.006**
Molybdenum	7439-98-7	0.001	mg/L	**0.004**	**0.058**	**0.002**	**0.002**	**0.002**
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L	**1.73**	**1.76**	**0.291**	**0.183**	**0.509**
Thallium	7440-28-0	0.001	mg/L	<0.001	**0.002**	<0.001	<0.001	<0.001
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	7440-61-1	0.001	mg/L	**0.084**	**0.062**	**0.035**	**0.003**	**0.027**
Vanadium	7440-62-2	0.01	mg/L	**0.10**	<0.01	<0.01	**0.07**	**0.02**
Boron	7440-42-8	0.05	mg/L	**0.70**	**0.51**	**0.19**	**0.08**	**0.18**
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**2.20**	**18.6**	**0.39**	**0.35**	**1.51**
Antimony	7440-36-0	0.001	mg/L	<0.001	**0.001**	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	**0.002**	**0.019**	**0.001**	<0.001	**0.001**
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	**0.036**	**0.148**	**0.124**	**0.054**	**0.044**
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	**0.0001**	**0.0007**	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	**0.002**	**0.018**	**0.003**	<0.001	**0.006**
Copper	7440-50-8	0.001	mg/L	**0.013**	**0.115**	**0.007**	**0.002**	**0.003**
Cobalt	7440-48-4	0.001	mg/L	**0.002**	**0.010**	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	**0.003**	**0.011**	**0.001**	<0.001	**0.002**
Lead	7439-92-1	0.001	mg/L	**0.005**	**0.045**	**0.004**	**0.002**	**0.002**
Zinc	7440-66-6	0.005	mg/L	**0.009**	**0.090**	**0.032**	**0.008**	**0.012**
Manganese	7439-96-5	0.001	mg/L	**0.164**	**0.676**	**0.022**	**0.012**	**0.017**
Molybdenum	7439-98-7	0.001	mg/L	**0.004**	**0.056**	**0.002**	**0.003**	**0.003**
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC A2 17188	BSOC A5 17190	BSOC B3 17193	BSOC B2 17192	BSOC B1 17191
			Client sampling date / time	19-Jan-2016 10:20	19-Jan-2016 11:50	20-Jan-2016 09:45	20-Jan-2016 10:20	20-Jan-2016 11:00
Compound	CAS Number	LOR	Unit	EB1602053-001	EB1602053-002	EB1602053-003	EB1602053-004	EB1602053-005
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Strontium	7440-24-6	0.001	mg/L	1.81	1.85	0.280	0.180	0.523
Thallium	7440-28-0	0.001	mg/L	<0.001	0.002	<0.001	<0.001	<0.001
Thorium	7440-29-1	0.001	mg/L	<0.001	0.013	<0.001	<0.001	0.002
Titanium	7440-32-6	0.01	mg/L	0.08	0.55	0.02	0.02	0.02
Uranium	7440-61-1	0.001	mg/L	0.086	0.066	0.035	0.003	0.030
Vanadium	7440-62-2	0.01	mg/L	0.10	0.04	<0.01	0.06	0.03
Boron	7440-42-8	0.05	mg/L	0.53	0.48	0.22	0.06	0.18
Iron	7439-89-6	0.05	mg/L	2.35	12.9	0.78	0.34	1.80
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
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	6.4	5.1	5.3	1.8	5.3
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	0.04	0.02	0.24	0.09	0.04
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	0.62	<0.01	6.04	7.05	8.24
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	0.04	0.16	0.07	0.06	0.08
EK085M: Sulfide as S2-								
Sulfide as S2-	18496-25-8	0.1	mg/L	----	----	----	----	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	10	85	2	2	<1
EP074A: Monocyclic Aromatic Hydrocarbons								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
Styrene	100-42-5	5	µg/L	<5	<5	<5	<5	<5
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
Isopropylbenzene	98-82-8	5	µg/L	<5	<5	<5	<5	<5
n-Propylbenzene	103-65-1	5	µg/L	<5	<5	<5	<5	<5

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC A2 17188	BSOC A5 17190	BSOC B3 17193	BSOC B2 17192	BSOC B1 17191
			Client sampling date / time	19-Jan-2016 10:20	19-Jan-2016 11:50	20-Jan-2016 09:45	20-Jan-2016 10:20	20-Jan-2016 11:00
Compound	CAS Number	LOR	Unit	EB1602053-001	EB1602053-002	EB1602053-003	EB1602053-004	EB1602053-005
				Result	Result	Result	Result	Result
EP074A: Monocyclic Aromatic Hydrocarbons - Continued								
1.3.5-Trimethylbenzene	108-67-8	5	µg/L	<5	<5	<5	<5	<5
sec-Butylbenzene	135-98-8	5	µg/L	<5	<5	<5	<5	<5
1.2.4-Trimethylbenzene	95-63-6	5	µg/L	<5	<5	<5	<5	<5
tert-Butylbenzene	98-06-6	5	µg/L	<5	<5	<5	<5	<5
p-Isopropyltoluene	99-87-6	5	µg/L	<5	<5	<5	<5	<5
n-Butylbenzene	104-51-8	5	µg/L	<5	<5	<5	<5	<5
EP074B: Oxygenated Compounds								
Vinyl Acetate	108-05-4	50	µg/L	<50	<50	<50	<50	<50
2-Butanone (MEK)	78-93-3	50	µg/L	<50	<50	<50	<50	<50
4-Methyl-2-pentanone (MIBK)	108-10-1	50	µg/L	<50	<50	<50	<50	<50
2-Hexanone (MBK)	591-78-6	50	µg/L	<50	<50	<50	<50	<50
EP074C: Sulfonated Compounds								
Carbon disulfide	75-15-0	5	µg/L	<5	<5	<5	<5	<5
EP074D: Fumigants								
2.2-Dichloropropane	594-20-7	5	µg/L	<5	<5	<5	<5	<5
1.2-Dichloropropane	78-87-5	5	µg/L	<5	<5	<5	<5	<5
cis-1.3-Dichloropropylene	10061-01-5	5	µg/L	<5	<5	<5	<5	<5
trans-1.3-Dichloropropylene	10061-02-6	5	µg/L	<5	<5	<5	<5	<5
1.2-Dibromoethane (EDB)	106-93-4	5	µg/L	<5	<5	<5	<5	<5
EP074E: Halogenated Aliphatic Compounds								
Dichlorodifluoromethane	75-71-8	50	µg/L	<50	<50	<50	<50	<50
Chloromethane	74-87-3	50	µg/L	<50	<50	<50	<50	<50
Vinyl chloride	75-01-4	50	µg/L	<50	<50	<50	<50	<50
Bromomethane	74-83-9	50	µg/L	<50	<50	<50	<50	<50
Chloroethane	75-00-3	50	µg/L	<50	<50	<50	<50	<50
Trichlorofluoromethane	75-69-4	50	µg/L	<50	<50	<50	<50	<50
1.1-Dichloroethene	75-35-4	5	µg/L	<5	<5	<5	<5	<5
Iodomethane	74-88-4	5	µg/L	<5	<5	<5	<5	<5
trans-1.2-Dichloroethene	156-60-5	5	µg/L	<5	<5	<5	<5	<5
1.1-Dichloroethane	75-34-3	5	µg/L	<5	<5	<5	<5	<5
cis-1.2-Dichloroethene	156-59-2	5	µg/L	<5	<5	<5	<5	<5
1.1.1-Trichloroethane	71-55-6	5	µg/L	<5	<5	<5	<5	<5
1.1-Dichloropropylene	563-58-6	5	µg/L	<5	<5	<5	<5	<5
Carbon Tetrachloride	56-23-5	5	µg/L	<5	<5	<5	<5	<5

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC A2 17188	BSOC A5 17190	BSOC B3 17193	BSOC B2 17192	BSOC B1 17191
			Client sampling date / time	19-Jan-2016 10:20	19-Jan-2016 11:50	20-Jan-2016 09:45	20-Jan-2016 10:20	20-Jan-2016 11:00
Compound	CAS Number	LOR	Unit	EB1602053-001	EB1602053-002	EB1602053-003	EB1602053-004	EB1602053-005
				Result	Result	Result	Result	Result
EP074E: Halogenated Aliphatic Compounds - Continued								
1.2-Dichloroethane	107-06-2	5	µg/L	<5	<5	<5	<5	<5
Trichloroethene	79-01-6	5	µg/L	<5	<5	<5	<5	<5
Dibromomethane	74-95-3	5	µg/L	<5	<5	<5	<5	<5
1.1.2-Trichloroethane	79-00-5	5	µg/L	<5	<5	<5	<5	<5
1.3-Dichloropropane	142-28-9	5	µg/L	<5	<5	<5	<5	<5
Tetrachloroethene	127-18-4	5	µg/L	<5	<5	<5	<5	<5
1.1.1.2-Tetrachloroethane	630-20-6	5	µg/L	<5	<5	<5	<5	<5
trans-1.4-Dichloro-2-butene	110-57-6	5	µg/L	<5	<5	<5	<5	<5
cis-1.4-Dichloro-2-butene	1476-11-5	5	µg/L	<5	<5	<5	<5	<5
1.1.2.2-Tetrachloroethane	79-34-5	5	µg/L	<5	<5	<5	<5	<5
1.2.3-Trichloropropane	96-18-4	5	µg/L	<5	<5	<5	<5	<5
Pentachloroethane	76-01-7	5	µg/L	<5	<5	<5	<5	<5
1.2-Dibromo-3-chloropropane	96-12-8	5	µg/L	<5	<5	<5	<5	<5
Hexachlorobutadiene	87-68-3	5	µg/L	<5	<5	<5	<5	<5
EP074F: Halogenated Aromatic Compounds								
Chlorobenzene	108-90-7	5	µg/L	<5	<5	<5	<5	<5
Bromobenzene	108-86-1	5	µg/L	<5	<5	<5	<5	<5
2-Chlorotoluene	95-49-8	5	µg/L	<5	<5	<5	<5	<5
4-Chlorotoluene	106-43-4	5	µg/L	<5	<5	<5	<5	<5
1.3-Dichlorobenzene	541-73-1	5	µg/L	<5	<5	<5	<5	<5
1.4-Dichlorobenzene	106-46-7	5	µg/L	<5	<5	<5	<5	<5
1.2-Dichlorobenzene	95-50-1	5	µg/L	<5	<5	<5	<5	<5
1.2.4-Trichlorobenzene	120-82-1	5	µg/L	<5	<5	<5	<5	<5
1.2.3-Trichlorobenzene	87-61-6	5	µg/L	<5	<5	<5	<5	<5
EP074G: Trihalomethanes								
Chloroform	67-66-3	5	µg/L	<5	<5	<5	<5	<5
Bromodichloromethane	75-27-4	5	µg/L	<5	<5	<5	<5	<5
Dibromochloromethane	124-48-1	5	µg/L	<5	<5	<5	<5	<5
Bromoform	75-25-2	5	µg/L	<5	<5	<5	<5	<5
EP074H: Naphthalene								
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	**70**	<50	<50	<50

Analytical Results

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			Client sampling date / time	19-Jan-2016 10:20	19-Jan-2016 11:50	20-Jan-2016 09:45	20-Jan-2016 10:20	20-Jan-2016 11:00
Compound	CAS Number	LOR	Unit	EB1602053-001	EB1602053-002	EB1602053-003	EB1602053-004	EB1602053-005
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons - Continued								
C15 - C28 Fraction	----	100	µg/L	<100	**920**	<100	<100	<100
C29 - C36 Fraction	----	50	µg/L	<50	**250**	<50	<50	<50
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	**1240**	<50	<50	<50
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	**150**	<100	<100	<100
>C16 - C34 Fraction	----	100	µg/L	<100	**1030**	<100	<100	<100
>C34 - C40 Fraction	----	100	µg/L	<100	**120**	<100	<100	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	**1300**	<100	<100	<100
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	**150**	<100	<100	<100
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP074S: VOC Surrogates								
1.2-Dichloroethane-D4	17060-07-0	5	%	**104**	**106**	**108**	**106**	**108**
Toluene-D8	2037-26-5	5	%	**103**	**105**	**102**	**104**	**101**
4-Bromofluorobenzene	460-00-4	5	%	**102**	**100**	**97.2**	**101**	**98.6**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**106**	**108**	**110**	**108**	**110**
Toluene-D8	2037-26-5	2	%	**98.3**	**100**	**97.8**	**99.2**	**96.8**
4-Bromofluorobenzene	460-00-4	2	%	**102**	**102**	**98.7**	**100**	**99.5**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC B5 17195	BSOC B6 17196	BSOC A1 17187	BSOC A3 17189	BSOC B4 17194
			Client sampling date / time	20-Jan-2016 11:35	21-Jan-2016 13:50	21-Jan-2016 14:15	21-Jan-2016 14:30	21-Jan-2016 15:00
Compound	CAS Number	LOR	Unit	EB1602053-006	EB1602053-007	EB1602053-008	EB1602053-009	EB1602053-010
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	8.33	8.72	8.68	8.61	8.81
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	5590	6150	3420	5170	4500
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	3640	3580	2120	3540	2590
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	558	276	261	45	481
ED009: Anions								
Bromide	24959-67-9	0.01	mg/L	2.54	5.62	1.45	3.04	3.65
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	17	160	85	61	165
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	779	928	555	604	708
Total Alkalinity as CaCO3	----	1	mg/L	796	1090	640	665	873
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	1410	413	576	727	320
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	570	1140	397	799	746
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	19	20	14	5	26
Magnesium	7439-95-4	1	mg/L	124	55	55	8	101
Sodium	7440-23-5	1	mg/L	1040	1170	557	1090	138
Potassium	7440-09-7	1	mg/L	96	103	97	14	21
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.01	0.01	0.04	<0.01
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.011	0.012	0.003	0.007	0.010
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Barium	7440-39-3	0.001	mg/L	0.073	0.086	0.068	0.080	0.074
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	0.002	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L	<0.001	0.038	0.005	0.049	<0.001

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC B5 17195	BSOC B6 17196	BSOC A1 17187	BSOC A3 17189	BSOC B4 17194
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Compound	CAS Number	LOR	Unit	EB1602053-006	EB1602053-007	EB1602053-008	EB1602053-009	EB1602053-010
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Cobalt	7440-48-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L	<0.001	0.004	<0.001	0.002	<0.001
Zinc	7440-66-6	0.005	mg/L	0.006	0.005	<0.005	<0.005	<0.005
Manganese	7439-96-5	0.001	mg/L	0.115	0.336	0.216	0.094	0.496
Molybdenum	7439-98-7	0.001	mg/L	0.004	0.011	0.009	0.032	0.008
Selenium	7782-49-2	0.01	mg/L	0.01	<0.01	<0.01	<0.01	<0.01
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Strontium	7440-24-6	0.001	mg/L	0.278	0.361	0.147	0.071	0.298
Thallium	7440-28-0	0.001	mg/L	<0.001	0.006	<0.001	<0.001	0.002
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Uranium	7440-61-1	0.001	mg/L	0.036	0.048	0.010	0.086	0.004
Vanadium	7440-62-2	0.01	mg/L	0.11	<0.01	0.03	0.05	<0.01
Boron	7440-42-8	0.05	mg/L	0.26	0.23	0.12	0.30	<0.05
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.35	4.15	0.90	25.8	0.68
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	<0.001	0.001	<0.001
Arsenic	7440-38-2	0.001	mg/L	0.012	0.015	0.005	0.022	0.052
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	0.004	<0.001
Barium	7440-39-3	0.001	mg/L	0.077	0.118	0.088	0.375	0.068
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	0.002	<0.001
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	0.0002	0.0002	0.0013	0.0009
Chromium	7440-47-3	0.001	mg/L	<0.001	0.004	0.005	0.039	<0.001
Copper	7440-50-8	0.001	mg/L	0.001	0.032	0.033	0.542	0.017
Cobalt	7440-48-4	0.001	mg/L	<0.001	0.001	0.003	0.028	<0.001
Nickel	7440-02-0	0.001	mg/L	<0.001	0.003	0.003	0.042	0.002
Lead	7439-92-1	0.001	mg/L	<0.001	0.024	0.013	0.170	0.063
Zinc	7440-66-6	0.005	mg/L	0.008	0.031	0.019	0.267	0.086
Manganese	7439-96-5	0.001	mg/L	0.112	0.413	0.321	0.797	0.332
Molybdenum	7439-98-7	0.001	mg/L	0.005	0.012	0.011	0.024	0.010
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC B5 17195	BSOC B6 17196	BSOC A1 17187	BSOC A3 17189	BSOC B4 17194
			Client sampling date / time	20-Jan-2016 11:35	21-Jan-2016 13:50	21-Jan-2016 14:15	21-Jan-2016 14:30	21-Jan-2016 15:00
Compound	CAS Number	LOR	Unit	EB1602053-006	EB1602053-007	EB1602053-008	EB1602053-009	EB1602053-010
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Strontium	7440-24-6	0.001	mg/L	0.274	0.394	0.163	0.278	0.262
Thallium	7440-28-0	0.001	mg/L	<0.001	0.006	<0.001	<0.001	0.004
Thorium	7440-29-1	0.001	mg/L	<0.001	0.004	<0.001	0.033	<0.001
Titanium	7440-32-6	0.01	mg/L	<0.01	0.02	0.10	0.23	<0.01
Uranium	7440-61-1	0.001	mg/L	0.037	0.052	0.011	0.099	0.024
Vanadium	7440-62-2	0.01	mg/L	0.10	0.01	0.04	0.13	0.01
Boron	7440-42-8	0.05	mg/L	0.20	0.26	0.16	0.29	0.15
Iron	7439-89-6	0.05	mg/L	0.18	2.70	1.78	26.6	4.44
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	0.0001	0.0002
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	6.1	4.7	2.3	3.4	4.1
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	0.09	0.02	0.02	0.19	0.45
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	1.13	0.12	<0.01	0.05	0.02
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	0.16	0.21	0.02	0.47	0.18
EK085M: Sulfide as S2-								
Sulfide as S2-	18496-25-8	0.1	mg/L	----	<0.1	<0.1	<0.1	<0.1
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	4	20	46	5	16
EP074A: Monocyclic Aromatic Hydrocarbons								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
Styrene	100-42-5	5	µg/L	<5	<5	<5	<5	<5
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
Isopropylbenzene	98-82-8	5	µg/L	<5	<5	<5	<5	<5
n-Propylbenzene	103-65-1	5	µg/L	<5	<5	<5	<5	<5

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC B5 17195	BSOC B6 17196	BSOC A1 17187	BSOC A3 17189	BSOC B4 17194
			Client sampling date / time	20-Jan-2016 11:35	21-Jan-2016 13:50	21-Jan-2016 14:15	21-Jan-2016 14:30	21-Jan-2016 15:00
Compound	CAS Number	LOR	Unit	EB1602053-006	EB1602053-007	EB1602053-008	EB1602053-009	EB1602053-010
				Result	Result	Result	Result	Result
EP074A: Monocyclic Aromatic Hydrocarbons - Continued								
1.3.5-Trimethylbenzene	108-67-8	5	µg/L	<5	<5	<5	<5	<5
sec-Butylbenzene	135-98-8	5	µg/L	<5	<5	<5	<5	<5
1.2.4-Trimethylbenzene	95-63-6	5	µg/L	<5	<5	<5	<5	<5
tert-Butylbenzene	98-06-6	5	µg/L	<5	<5	<5	<5	<5
p-Isopropyltoluene	99-87-6	5	µg/L	<5	<5	<5	<5	<5
n-Butylbenzene	104-51-8	5	µg/L	<5	<5	<5	<5	<5
EP074B: Oxygenated Compounds								
Vinyl Acetate	108-05-4	50	µg/L	<50	<50	<50	<50	<50
2-Butanone (MEK)	78-93-3	50	µg/L	<50	<50	<50	<50	<50
4-Methyl-2-pentanone (MIBK)	108-10-1	50	µg/L	<50	<50	<50	<50	<50
2-Hexanone (MBK)	591-78-6	50	µg/L	<50	<50	<50	<50	<50
EP074C: Sulfonated Compounds								
Carbon disulfide	75-15-0	5	µg/L	<5	<5	<5	<5	<5
EP074D: Fumigants								
2.2-Dichloropropane	594-20-7	5	µg/L	<5	<5	<5	<5	<5
1.2-Dichloropropane	78-87-5	5	µg/L	<5	<5	<5	<5	<5
cis-1.3-Dichloropropylene	10061-01-5	5	µg/L	<5	<5	<5	<5	<5
trans-1.3-Dichloropropylene	10061-02-6	5	µg/L	<5	<5	<5	<5	<5
1.2-Dibromoethane (EDB)	106-93-4	5	µg/L	<5	<5	<5	<5	<5
EP074E: Halogenated Aliphatic Compounds								
Dichlorodifluoromethane	75-71-8	50	µg/L	<50	<50	<50	<50	<50
Chloromethane	74-87-3	50	µg/L	<50	<50	<50	<50	<50
Vinyl chloride	75-01-4	50	µg/L	<50	<50	<50	<50	<50
Bromomethane	74-83-9	50	µg/L	<50	<50	<50	<50	<50
Chloroethane	75-00-3	50	µg/L	<50	<50	<50	<50	<50
Trichlorofluoromethane	75-69-4	50	µg/L	<50	<50	<50	<50	<50
1.1-Dichloroethene	75-35-4	5	µg/L	<5	<5	<5	<5	<5
Iodomethane	74-88-4	5	µg/L	<5	<5	<5	<5	<5
trans-1.2-Dichloroethene	156-60-5	5	µg/L	<5	<5	<5	<5	<5
1.1-Dichloroethane	75-34-3	5	µg/L	<5	<5	<5	<5	<5
cis-1.2-Dichloroethene	156-59-2	5	µg/L	<5	<5	<5	<5	<5
1.1.1-Trichloroethane	71-55-6	5	µg/L	<5	<5	<5	<5	<5
1.1-Dichloropropylene	563-58-6	5	µg/L	<5	<5	<5	<5	<5
Carbon Tetrachloride	56-23-5	5	µg/L	<5	<5	<5	<5	<5

Analytical Results

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Compound	CAS Number	LOR	Unit	EB1602053-006	EB1602053-007	EB1602053-008	EB1602053-009	EB1602053-010
				Result	Result	Result	Result	Result
EP074E: Halogenated Aliphatic Compounds - Continued								
1.2-Dichloroethane	107-06-2	5	µg/L	<5	<5	<5	<5	<5
Trichloroethene	79-01-6	5	µg/L	<5	<5	<5	<5	<5
Dibromomethane	74-95-3	5	µg/L	<5	<5	<5	<5	<5
1.1.2-Trichloroethane	79-00-5	5	µg/L	<5	<5	<5	<5	<5
1.3-Dichloropropane	142-28-9	5	µg/L	<5	<5	<5	<5	<5
Tetrachloroethene	127-18-4	5	µg/L	<5	<5	<5	<5	<5
1.1.1.2-Tetrachloroethane	630-20-6	5	µg/L	<5	<5	<5	<5	<5
trans-1.4-Dichloro-2-butene	110-57-6	5	µg/L	<5	<5	<5	<5	<5
cis-1.4-Dichloro-2-butene	1476-11-5	5	µg/L	<5	<5	<5	<5	<5
1.1.2.2-Tetrachloroethane	79-34-5	5	µg/L	<5	<5	<5	<5	<5
1.2.3-Trichloropropane	96-18-4	5	µg/L	<5	<5	<5	<5	<5
Pentachloroethane	76-01-7	5	µg/L	<5	<5	<5	<5	<5
1.2-Dibromo-3-chloropropane	96-12-8	5	µg/L	<5	<5	<5	<5	<5
Hexachlorobutadiene	87-68-3	5	µg/L	<5	<5	<5	<5	<5
EP074F: Halogenated Aromatic Compounds								
Chlorobenzene	108-90-7	5	µg/L	<5	<5	<5	<5	<5
Bromobenzene	108-86-1	5	µg/L	<5	<5	<5	<5	<5
2-Chlorotoluene	95-49-8	5	µg/L	<5	<5	<5	<5	<5
4-Chlorotoluene	106-43-4	5	µg/L	<5	<5	<5	<5	<5
1.3-Dichlorobenzene	541-73-1	5	µg/L	<5	<5	<5	<5	<5
1.4-Dichlorobenzene	106-46-7	5	µg/L	<5	<5	<5	<5	<5
1.2-Dichlorobenzene	95-50-1	5	µg/L	<5	<5	<5	<5	<5
1.2.4-Trichlorobenzene	120-82-1	5	µg/L	<5	<5	<5	<5	<5
1.2.3-Trichlorobenzene	87-61-6	5	µg/L	<5	<5	<5	<5	<5
EP074G: Trihalomethanes								
Chloroform	67-66-3	5	µg/L	<5	<5	<5	<5	<5
Bromodichloromethane	75-27-4	5	µg/L	<5	<5	<5	<5	<5
Dibromochloromethane	124-48-1	5	µg/L	<5	<5	<5	<5	<5
Bromoform	75-25-2	5	µg/L	<5	<5	<5	<5	<5
EP074H: Naphthalene								
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	<20	<20
C10 - C14 Fraction	----	50	µg/L	<50	<50	**60**	**100**	**60**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	BSOC B5 17195	BSOC B6 17196	BSOC A1 17187	BSOC A3 17189	BSOC B4 17194
			Client sampling date / time	20-Jan-2016 11:35	21-Jan-2016 13:50	21-Jan-2016 14:15	21-Jan-2016 14:30	21-Jan-2016 15:00
Compound	CAS Number	LOR	Unit	EB1602053-006	EB1602053-007	EB1602053-008	EB1602053-009	EB1602053-010
				Result	Result	Result	Result	Result
EP080/071: Total Petroleum Hydrocarbons - Continued								
C15 - C28 Fraction	----	100	µg/L	<100	**160**	**590**	**1150**	**290**
C29 - C36 Fraction	----	50	µg/L	<50	<50	**70**	**1680**	**120**
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	**160**	**720**	**2930**	**470**
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	<20	<20
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	<20	<20
>C10 - C16 Fraction	----	100	µg/L	<100	<100	**120**	**220**	**110**
>C16 - C34 Fraction	----	100	µg/L	<100	**160**	**590**	**2330**	**330**
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	**740**	<100
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	**160**	**710**	**3290**	**440**
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	**120**	**220**	**110**
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	<1	<1
Toluene	108-88-3	2	µg/L	<2	<2	<2	<2	<2
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	<2	<2
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	<2	<2
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	<2	<2
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	<2	<2
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	<1	<1
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	<5	<5
EP074S: VOC Surrogates								
1.2-Dichloroethane-D4	17060-07-0	5	%	**108**	**110**	**106**	**105**	**103**
Toluene-D8	2037-26-5	5	%	**100**	**103**	**100**	**98.7**	**101**
4-Bromofluorobenzene	460-00-4	5	%	**98.6**	**100**	**97.9**	**97.5**	**96.1**
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	**109**	**112**	**107**	**107**	**105**
Toluene-D8	2037-26-5	2	%	**95.8**	**98.6**	**96.1**	**94.4**	**97.1**
4-Bromofluorobenzene	460-00-4	2	%	**99.3**	**101**	**96.7**	**99.5**	**99.0**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1602199**	Page	: 1 of 10
Client	: **MOUNT ISA MINES LIMITED**	Laboratory	: Environmental Division Brisbane
Contact	: MS TAMARA GROVES	Contact	: Joy Morgan
Address	: PRIVATE MAIL BAG 6 MOUNT ISA QLD, AUSTRALIA 4825	Address	: 2 Byth Street Stafford QLD Australia 4053
E-mail	: tamara.groves@glencore.com.au	E-mail	: Joy.Morgan@alsglobal.com
Telephone	: +61 07 47443310	Telephone	: +61-7-3243 7222
Facsimile	: ----	Facsimile	: +61-7-3243 7218
Project	:	QC Level	: NEPM 2013 B3 & ALS QC Standard
Order number	: CTDQMG	Date Samples Received	: 28-Jan-2016 09:30
C-O-C number	: BSOC WRD Seepage	Date Analysis Commenced	: 01-Feb-2016
Sampler	: ----	Issue Date	: 08-Feb-2016 08:23
Site	: Mount Isa Mnes		
		No. of samples received	: 3
Quote number	: ----	No. of samples analysed	: 3

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

NATA Accredited Laboratory 825

Accredited for compliance with ISO/IEC 17025.

Signatories

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

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD Brisbane Organics, Stafford, QLD WB Water Lab Brisbane, Stafford, QLD
Matt Frost	Senior Organic Chemist	Brisbane Organics, Stafford, QLD

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.

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.

- EK026SF (Total Cyanide): Sample BSOC WRD South Seepage was diluted due to matrix interference. The LOR has been adjusted accordingly.
- EK026SF (Total Cyanide): All samples was passed through a 0.45µm filter prior to analysis due to suspended particulate matter as per ISO 14403.
- It is recognised that EG020-T (Total Metals by ICP-MS) is less than EG020-F (Dissolved Metals by ICP-MS) for some samples. However, the difference is within experimental variation of the methods.
- EG020-F (Dissolved Metals by ICP-MS) were found to be higher than EG020-T (Total Metals by ICP-MS) for sample EB1602199 - 002 (BSOC WRD South Seepage). This was confirmed by re-digestion and re-analysis.
- EK067G (Total Phosphorus as P): Sample EB1602199-001 (TD3 Seepage) was diluted due to matrix interference. LOR adjusted accordingly.
- The presence of high SO4 may bias the EC low.
- TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TD3 Seepage 17211	BSOC WRD South Seepage 17212	BSOC WRD South Sump 17213	----	----
			Client sampling date / time	25-Jan-2016 10:30	25-Jan-2016 11:10	25-Jan-2016 11:30	----	----
Compound	CAS Number	LOR	Unit	EB1602199-001	EB1602199-002	EB1602199-003	--------	--------
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	7.76	8.31	8.57	----	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	11900	12000	18600	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	14200	12300	19500	----	----
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	7630	5460	6800	----	----
ED009: Anions								
Bromide	24959-67-9	0.01	mg/L	0.940	0.380	1.50	----	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	2	138	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	140	476	528	----	----
Total Alkalinity as CaCO3	----	1	mg/L	140	478	666	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	8720	8030	11900	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	858	646	979	----	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	465	240	218	----	----
Magnesium	7439-95-4	1	mg/L	1740	1180	1590	----	----
Sodium	7440-23-5	1	mg/L	842	1490	2820	----	----
Potassium	7440-09-7	1	mg/L	114	164	387	----	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	0.02	<0.01	<0.01	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	0.005	----	----
Arsenic	7440-38-2	0.001	mg/L	0.002	0.004	0.086	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Barium	7440-39-3	0.001	mg/L	0.017	0.020	0.051	----	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Cadmium	7440-43-9	0.0001	mg/L	0.0329	0.0010	<0.0001	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TD3 Seepage 17211	BSOC WRD South Seepage 17212	BSOC WRD South Sump 17213	----	----
			Client sampling date / time	25-Jan-2016 10:30	25-Jan-2016 11:10	25-Jan-2016 11:30	----	----
Compound	CAS Number	LOR	Unit	EB1602199-001	EB1602199-002	EB1602199-003	--------	--------
				Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued								
Copper	7440-50-8	0.001	mg/L	**0.018**	**0.130**	**0.051**	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.002**	**0.002**	**0.002**	----	----
Nickel	7440-02-0	0.001	mg/L	**0.033**	**0.002**	**0.001**	----	----
Lead	7439-92-1	0.001	mg/L	**0.006**	**0.006**	**0.003**	----	----
Zinc	7440-66-6	0.005	mg/L	**7.39**	**0.018**	<0.005	----	----
Manganese	7439-96-5	0.001	mg/L	**0.175**	**0.057**	**0.130**	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	**0.005**	**0.018**	----	----
Selenium	7782-49-2	0.01	mg/L	<0.01	**0.02**	**0.01**	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Strontium	7440-24-6	0.001	mg/L	**1.89**	**2.07**	**3.47**	----	----
Thallium	7440-28-0	0.001	mg/L	**0.295**	<0.001	<0.001	----	----
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Uranium	7440-61-1	0.001	mg/L	**0.003**	**0.097**	**0.131**	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	**0.01**	----	----
Boron	7440-42-8	0.05	mg/L	**0.20**	**0.12**	**0.46**	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	<0.05	<0.05	----	----
EG020T: Total Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	**0.03**	**0.12**	**0.10**	----	----
Antimony	7440-36-0	0.001	mg/L	<0.001	<0.001	**0.005**	----	----
Arsenic	7440-38-2	0.001	mg/L	**0.002**	**0.005**	**0.092**	----	----
Beryllium	7440-41-7	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Barium	7440-39-3	0.001	mg/L	**0.017**	**0.032**	**0.051**	----	----
Bismuth	7440-69-9	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Cadmium	7440-43-9	0.0001	mg/L	**0.0344**	**0.0011**	<0.0001	----	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Copper	7440-50-8	0.001	mg/L	**0.026**	**0.051**	**0.067**	----	----
Cobalt	7440-48-4	0.001	mg/L	**0.002**	**0.002**	**0.002**	----	----
Nickel	7440-02-0	0.001	mg/L	**0.036**	**0.002**	**0.002**	----	----
Lead	7439-92-1	0.001	mg/L	**0.009**	**0.019**	**0.004**	----	----
Zinc	7440-66-6	0.005	mg/L	**7.59**	**0.036**	**0.008**	----	----
Manganese	7439-96-5	0.001	mg/L	**0.174**	**0.117**	**0.140**	----	----
Molybdenum	7439-98-7	0.001	mg/L	<0.001	**0.006**	**0.022**	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TD3 Seepage 17211	BSOC WRD South Seepage 17212	BSOC WRD South Sump 17213	----	----
			Client sampling date / time	25-Jan-2016 10:30	25-Jan-2016 11:10	25-Jan-2016 11:30	----	----
Compound	CAS Number	LOR	Unit	EB1602199-001	EB1602199-002	EB1602199-003	--------	--------
				Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS - Continued								
Selenium	7782-49-2	0.01	mg/L	<0.01	**0.02**	**0.01**	----	----
Silver	7440-22-4	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Strontium	7440-24-6	0.001	mg/L	**1.92**	**2.12**	**3.39**	----	----
Thallium	7440-28-0	0.001	mg/L	**0.315**	<0.001	<0.001	----	----
Thorium	7440-29-1	0.001	mg/L	<0.001	<0.001	<0.001	----	----
Titanium	7440-32-6	0.01	mg/L	<0.01	<0.01	<0.01	----	----
Uranium	7440-61-1	0.001	mg/L	**0.003**	**0.100**	**0.140**	----	----
Vanadium	7440-62-2	0.01	mg/L	<0.01	<0.01	**0.01**	----	----
Boron	7440-42-8	0.05	mg/L	**0.22**	**0.16**	**0.55**	----	----
Iron	7439-89-6	0.05	mg/L	<0.05	**0.20**	**0.08**	----	----
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	----	----
EK025SF: Free CN by Segmented Flow Analyser								
Free Cyanide	----	0.004	mg/L	<0.004	<0.004	<0.004	----	----
EK026SF: Total CN by Segmented Flow Analyser								
Total Cyanide	57-12-5	0.004	mg/L	<0.004	<0.010	<0.004	----	----
EK028SF: Weak Acid Dissociable CN by Segmented Flow Analyser								
Weak Acid Dissociable Cyanide	----	0.004	mg/L	<0.004	<0.004	<0.004	----	----
EK040P: Fluoride by PC Titrator								
Fluoride	16984-48-8	0.1	mg/L	**1.4**	**4.6**	**3.9**	----	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.12**	**0.06**	**0.13**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**4.28**	**22.9**	<0.01	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.05	<0.01	**0.05**	----	----
EK085M: Sulfide as S2-								
Sulfide as S2-	18496-25-8	0.1	mg/L	<0.1	<0.1	<0.1	----	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**208**	**195**	**289**	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TD3 Seepage 17211	BSOC WRD South Seepage 17212	BSOC WRD South Sump 17213	----	----
			Client sampling date / time	25-Jan-2016 10:30	25-Jan-2016 11:10	25-Jan-2016 11:30	----	----
Compound	CAS Number	LOR	Unit	EB1602199-001	EB1602199-002	EB1602199-003	--------	--------
				Result	Result	Result	Result	Result
EN055: Ionic Balance - Continued								
Total Cations	----	0.01	meq/L	206	178	274	----	----
Ionic Balance	----	0.01	%	0.64	4.55	2.58	----	----
EP005: Total Organic Carbon (TOC)								
Total Organic Carbon	----	1	mg/L	3	8	30	----	----
EP074A: Monocyclic Aromatic Hydrocarbons								
Benzene	71-43-2	1	µg/L	<1	<1	<1	----	----
Toluene	108-88-3	2	µg/L	<2	<2	<2	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	----	----
Styrene	100-42-5	5	µg/L	<5	<5	<5	----	----
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	----	----
Isopropylbenzene	98-82-8	5	µg/L	<5	<5	<5	----	----
n-Propylbenzene	103-65-1	5	µg/L	<5	<5	<5	----	----
1.3.5-Trimethylbenzene	108-67-8	5	µg/L	<5	<5	<5	----	----
sec-Butylbenzene	135-98-8	5	µg/L	<5	<5	<5	----	----
1.2.4-Trimethylbenzene	95-63-6	5	µg/L	<5	<5	<5	----	----
tert-Butylbenzene	98-06-6	5	µg/L	<5	<5	<5	----	----
p-Isopropyltoluene	99-87-6	5	µg/L	<5	<5	<5	----	----
n-Butylbenzene	104-51-8	5	µg/L	<5	<5	<5	----	----
EP074B: Oxygenated Compounds								
Vinyl Acetate	108-05-4	50	µg/L	<50	<50	<50	----	----
2-Butanone (MEK)	78-93-3	50	µg/L	<50	<50	<50	----	----
4-Methyl-2-pentanone (MIBK)	108-10-1	50	µg/L	<50	<50	<50	----	----
2-Hexanone (MBK)	591-78-6	50	µg/L	<50	<50	<50	----	----
EP074C: Sulfonated Compounds								
Carbon disulfide	75-15-0	5	µg/L	<5	<5	<5	----	----
EP074D: Fumigants								
2.2-Dichloropropane	594-20-7	5	µg/L	<5	<5	<5	----	----
1.2-Dichloropropane	78-87-5	5	µg/L	<5	<5	<5	----	----
cis-1.3-Dichloropropylene	10061-01-5	5	µg/L	<5	<5	<5	----	----
trans-1.3-Dichloropropylene	10061-02-6	5	µg/L	<5	<5	<5	----	----
1.2-Dibromoethane (EDB)	106-93-4	5	µg/L	<5	<5	<5	----	----
EP074E: Halogenated Aliphatic Compounds								

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TD3 Seepage 17211	BSOC WRD South Seepage 17212	BSOC WRD South Sump 17213	----	----
			Client sampling date / time	25-Jan-2016 10:30	25-Jan-2016 11:10	25-Jan-2016 11:30	----	----
Compound	CAS Number	LOR	Unit	EB1602199-001	EB1602199-002	EB1602199-003	--------	--------
				Result	Result	Result	Result	Result
EP074E: Halogenated Aliphatic Compounds - Continued								
Dichlorodifluoromethane	75-71-8	50	µg/L	<50	<50	<50	----	----
Chloromethane	74-87-3	50	µg/L	<50	<50	<50	----	----
Vinyl chloride	75-01-4	50	µg/L	<50	<50	<50	----	----
Bromomethane	74-83-9	50	µg/L	<50	<50	<50	----	----
Chloroethane	75-00-3	50	µg/L	<50	<50	<50	----	----
Trichlorofluoromethane	75-69-4	50	µg/L	<50	<50	<50	----	----
1.1-Dichloroethene	75-35-4	5	µg/L	<5	<5	<5	----	----
Iodomethane	74-88-4	5	µg/L	<5	<5	<5	----	----
trans-1.2-Dichloroethene	156-60-5	5	µg/L	<5	<5	<5	----	----
1.1-Dichloroethane	75-34-3	5	µg/L	<5	<5	<5	----	----
cis-1.2-Dichloroethene	156-59-2	5	µg/L	<5	<5	<5	----	----
1.1.1-Trichloroethane	71-55-6	5	µg/L	<5	<5	<5	----	----
1.1-Dichloropropylene	563-58-6	5	µg/L	<5	<5	<5	----	----
Carbon Tetrachloride	56-23-5	5	µg/L	<5	<5	<5	----	----
1.2-Dichloroethane	107-06-2	5	µg/L	<5	<5	<5	----	----
Trichloroethene	79-01-6	5	µg/L	<5	<5	<5	----	----
Dibromomethane	74-95-3	5	µg/L	<5	<5	<5	----	----
1.1.2-Trichloroethane	79-00-5	5	µg/L	<5	<5	<5	----	----
1.3-Dichloropropane	142-28-9	5	µg/L	<5	<5	<5	----	----
Tetrachloroethene	127-18-4	5	µg/L	<5	<5	<5	----	----
1.1.1.2-Tetrachloroethane	630-20-6	5	µg/L	<5	<5	<5	----	----
trans-1.4-Dichloro-2-butene	110-57-6	5	µg/L	<5	<5	<5	----	----
cis-1.4-Dichloro-2-butene	1476-11-5	5	µg/L	<5	<5	<5	----	----
1.1.2.2-Tetrachloroethane	79-34-5	5	µg/L	<5	<5	<5	----	----
1.2.3-Trichloropropane	96-18-4	5	µg/L	<5	<5	<5	----	----
Pentachloroethane	76-01-7	5	µg/L	<5	<5	<5	----	----
1.2-Dibromo-3-chloropropane	96-12-8	5	µg/L	<5	<5	<5	----	----
Hexachlorobutadiene	87-68-3	5	µg/L	<5	<5	<5	----	----
EP074F: Halogenated Aromatic Compounds								
Chlorobenzene	108-90-7	5	µg/L	<5	<5	<5	----	----
Bromobenzene	108-86-1	5	µg/L	<5	<5	<5	----	----
2-Chlorotoluene	95-49-8	5	µg/L	<5	<5	<5	----	----
4-Chlorotoluene	106-43-4	5	µg/L	<5	<5	<5	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TD3 Seepage 17211	BSOC WRD South Seepage 17212	BSOC WRD South Sump 17213	----	----
			Client sampling date / time	25-Jan-2016 10:30	25-Jan-2016 11:10	25-Jan-2016 11:30	----	----
Compound	CAS Number	LOR	Unit	EB1602199-001	EB1602199-002	EB1602199-003	--------	--------
				Result	Result	Result	Result	Result
EP074F: Halogenated Aromatic Compounds - Continued								
1.3-Dichlorobenzene	541-73-1	5	µg/L	<5	<5	<5	----	----
1.4-Dichlorobenzene	106-46-7	5	µg/L	<5	<5	<5	----	----
1.2-Dichlorobenzene	95-50-1	5	µg/L	<5	<5	<5	----	----
1.2.4-Trichlorobenzene	120-82-1	5	µg/L	<5	<5	<5	----	----
1.2.3-Trichlorobenzene	87-61-6	5	µg/L	<5	<5	<5	----	----
EP074G: Trihalomethanes								
Chloroform	67-66-3	5	µg/L	<5	<5	<5	----	----
Bromodichloromethane	75-27-4	5	µg/L	<5	<5	<5	----	----
Dibromochloromethane	124-48-1	5	µg/L	<5	<5	<5	----	----
Bromoform	75-25-2	5	µg/L	<5	<5	<5	----	----
EP074H: Naphthalene								
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	----	----
EP080/071: Total Petroleum Hydrocarbons								
C6 - C9 Fraction	----	20	µg/L	<20	<20	<20	----	----
C10 - C14 Fraction	----	50	µg/L	<50	<50	<50	----	----
C15 - C28 Fraction	----	100	µg/L	<100	<100	<100	----	----
C29 - C36 Fraction	----	50	µg/L	<50	<50	<50	----	----
^ C10 - C36 Fraction (sum)	----	50	µg/L	<50	<50	<50	----	----
EP080/071: Total Recoverable Hydrocarbons - NEPM 2013 Fractions								
C6 - C10 Fraction	C6_C10	20	µg/L	<20	<20	<20	----	----
^ C6 - C10 Fraction minus BTEX (F1)	C6_C10-BTEX	20	µg/L	<20	<20	<20	----	----
>C10 - C16 Fraction	----	100	µg/L	<100	<100	<100	----	----
>C16 - C34 Fraction	----	100	µg/L	<100	<100	<100	----	----
>C34 - C40 Fraction	----	100	µg/L	<100	<100	<100	----	----
^ >C10 - C40 Fraction (sum)	----	100	µg/L	<100	<100	<100	----	----
^ >C10 - C16 Fraction minus Naphthalene (F2)	----	100	µg/L	<100	<100	<100	----	----
EP080: BTEXN								
Benzene	71-43-2	1	µg/L	<1	<1	<1	----	----
Toluene	108-88-3	2	µg/L	<2	<2	<2	----	----
Ethylbenzene	100-41-4	2	µg/L	<2	<2	<2	----	----
meta- & para-Xylene	108-38-3 106-42-3	2	µg/L	<2	<2	<2	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	TD3 Seepage 17211	BSOC WRD South Seepage 17212	BSOC WRD South Sump 17213	----	----
			Client sampling date / time	25-Jan-2016 10:30	25-Jan-2016 11:10	25-Jan-2016 11:30	----	----
Compound	CAS Number	LOR	Unit	EB1602199-001	EB1602199-002	EB1602199-003	--------	--------
				Result	Result	Result	Result	Result
EP080: BTEXN - Continued								
ortho-Xylene	95-47-6	2	µg/L	<2	<2	<2	----	----
^ Total Xylenes	1330-20-7	2	µg/L	<2	<2	<2	----	----
^ Sum of BTEX	----	1	µg/L	<1	<1	<1	----	----
Naphthalene	91-20-3	5	µg/L	<5	<5	<5	----	----
EP074S: VOC Surrogates								
1.2-Dichloroethane-D4	17060-07-0	5	%	101	102	104	----	----
Toluene-D8	2037-26-5	5	%	98.4	100	100	----	----
4-Bromofluorobenzene	460-00-4	5	%	97.5	99.1	99.8	----	----
EP080S: TPH(V)/BTEX Surrogates								
1.2-Dichloroethane-D4	17060-07-0	2	%	102	103	106	----	----
Toluene-D8	2037-26-5	2	%	94.1	96.1	95.7	----	----
4-Bromofluorobenzene	460-00-4	2	%	99.3	99.6	102	----	----

APPENDIX IX

Waste Rock Dump Photographs

Appendix IX
Waste Rock Dump Surface Photographs

Photograph IX-1: Test Pit 1

Photograph IX-2: Typical Surface (at Test Pit 1)

Photograph IX-3: Surface Test at Highly Trafficked Area

Photograph IX-4: Surface Test at Highly Trafficked Area

Photograph IX-5: Surface at Highly Trafficked Area

Photograph IX-6: HMR

Photograph IX-7: Compacted / Highly Trafficked Area

Photograph IX-8: Typical Surface

APPENDIX III

Seepage Weir Design Report

Klohn Crippen Berger

November 3, 2015

Mount Isa Mines Limited
Private Mail Bag 6
Mount Isa QLD 4825

Tamara Groves
ZOPS Environmental Advisor

Dear Ms. Groves:

BSOC WRD Environmental Evaluation Investigation
Seepage Monitoring – Design and Specification

1 INTRODUCTION

Klohn Crippen Berger Ltd (KCB) was commissioned by Mount Isa Mines Limited (MIM) to undertake an environmental investigation regarding seepage at the Black Star Open Cut (BSOC) waste rock dump (WRD). MIM were issued an Environmental Evaluation notice in December 2014 by the Department of Environment and Heritage Protection (EHP), requiring an environmental investigation into the release of contaminants through surface and sub surface flows from the BSOC WRD.

As part of the environmental investigation, KCB recommended the installation of flow gauges to gain an understanding of the emergent seepage volumes and flow patterns. Note that these seepage measuring locations will only ever capture a portion of the actual seepage as they do not account for seepage via sub-surface drainage (e.g. groundwater flow).

The purpose of this report is to document the concept design and construction requirements for flow gauging weirs and pump flow meters to estimate seepage volumes from BSOC WRD.

1.1 Background

Three seepage points are identified along the northern extent of the BSOC WRD as shown on Drawing A20-A3001: the South Seepage Point (BSOC WRD S); the North Seepage Point (BSOC WRD N); and, the TD3 Seepage Point. A diversion drain (BSOC WRD Diversion Drain) was constructed at the toe of BSOC WRD to collect runoff and seepage. The diversion drain flows into a natural gully (King Gully) that flows to King Gully Dam. King Gully Dam was constructed in 2014 as part of the clean and dirty water separation project, while the BSOC WRD Diversion Drain was installed in 2011. The King Gully Dam was intended to collect the contact waters from the Diversion Drain before discharging through a pipeline to the Kennedy Siltstone Open Cut (KSOC).

In November 2013 and October 2014 the administering authority (Department of Environment and Heritage Protection (EHP)) raised concerns that the three seepage locations of BSOC WRD have caused or could be causing environmental harm. On December 24, 2014, EHP issued MIM

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with a *Notice to Conduct or Commission an Environmental Evaluation*. The investigations required for the Environmental Evaluation are:

1. identify the source, cause and extent of all seepage water being released or likely to be released from the BSOC WRD to the receiving environment;
2. assess impacts on the receiving environment and all environmental values;
3. propose options to prevent/reduce further seepage from BSOC WRD;
4. assess remediation measures for areas identified as currently impacted; and,
5. compile a report for EHP on the completed investigation.

KCB were awarded the contract to undertake this scope of works by MIM in July 2015.

1.2 Scope of Work

The scope of works being undertaken by KCB for the Environmental Evaluation requires that an understanding of the seepage flows, volumes and temporal patterns is attained. To achieve this, a series of flow gauging measures are proposed to estimate the contribution of seepage to the BSOC WRD diversion drain flows.

The scope of works includes:

- A site visit and walkover of the diversion drain, and seepage points;
- Estimation of catchment flows contributing to the proposed weirs;
- Design of flow measurement weirs;
- Management methods to monitor seepage volumes and flows at the Southern Seepage Point; and,
- Design drawings and construction details, provided as typical details to be field fit on site.

1.3 Design Basis

The design basis for the seepage monitoring weirs is outlined in Table 1-1 below.

Table 1-1 Seepage Monitoring Weirs Design Basis

Item	Design Criteria	Reference
Design Intent	To estimate the seepage volumes and flow rates, from the BSOC WRD at each of three discharge points.	(KCB 2015)
Design Life	Intended as semi-permanent structures, to gauge flows for a duration of 5 – 10 years with ongoing maintenance during this time	
Hydrology		
Rainfall	IFD for the Mount Isa Region	BOM, 1987 ARR based IFD generated at www.bom.gov.au
Runoff estimation method	Rational method Bransby-Williams Time of concentration	(Pilgram 1987; TMR 2010)
Runoff Coefficient estimate	Table 5.9.1 – Runoff coefficient estimation in rural areas	(TMR 2010)

Item	Design Criteria	Reference
Weir		
Flow Gauging Range	Able to monitor low flows (seepage) and higher, wet season flows. *Assume: maximum gauging of 5 year ARI (Average Recurrence Interval) flows*	KCB Assumption
Location	Defined channel with sufficient longitudinal grade in the channel to provide some vertical drop between the weir and the downstream channel section. Bedrock channel base, avoid alluvium materials.	
Construction Materials	Concrete and steel plate	

2 SITE OBSERVATIONS

2.1 Site Visit

KCB Senior Civil Engineer, Mr. Matthew Ind, undertook a one day site visit on August 27, 2015 to inspect the seepage points and provide feedback on recommended flow measurement methods. The weather on the day of the site visit was clear and dry; however, 0.2 mm of rainfall had been recorded at nearby gauges in the 24 hours to 9 am on the August 27. No other rainfall had been recorded in the preceding two months.

Seepage is reported at three locations associated with the BSOC WRD, as discussed below and shown on Drawing A20-A3001.

2.2 Southern Seepage Point (BSOC WRD South)

A seepage collection trench has been constructed at the southern seepage point. Seepage is periodically pumped from the trench towards the adjacent BSOC WRD Diversion Drain. The pipeline discharges approximately 30 m away from the collection trench in the catchment of the diversion drain. The point of discharge is located on a zone of alluvium associated with the original (pre-mining) surface water drainage system, which flows toward the west to Hazeldene Creek.

Figure 2-1 shows the seepage collection trench; pump and pipeline; pipeline discharge location; and, the adjacent BSOC WRD diversion drain, looking north. As shown in the photos, the pipeline discharge is noticeably upstream of the excavated diversion drain, with gravity flow of the discharge along a shallow earthen channel to the commencement of the Diversion Drain. A portion of the pumped discharge would infiltrate into the underlying alluvium in this location and where alluvium is present within the diversion drain.

The collection trench, pump and pipeline are currently not gauged and the frequency and volume of pumped seepage are not recorded.

Figure 2-1 Southern Seepage Pit (looking north)

2.3 Northern Seepage Point (BSOC WRD North)

No visible seepage was observed at the BSOC WRD North seepage point during the site inspection; however, indicators of seepage, such as staining and precipitates were evident (Figure 2-2a). The BSOC WRD Diversion Drain downstream of BSOC WRD North contained water and very minimal flow (Figure 2-2b). This was observed to be coming from seepage within the diversion channel, along the base of the channel, downstream from the BSOC WRD North seepage point.

Figure 2-2 Northern Seepage Point a) Toe of BSOC WRD b) Adjacent diversion channel (looking east-northeast)

2.4 TD3 Seepage Point

The TD3 seepage point had visible seepage emerging from the toe of the BSOC WRD, which flows towards the King Gully Dam. As seen in Figure 2-3a, the seepage at the toe was flowing during the site inspection. The seepage flows into the diversion drain, which is a wide, shallow channel at this point. The flow continues to the King Gully Dam where seepage is collected and piped to KSOC pit.

Figure 2-3 TSF3 Seepage Point a) Toe of BSOC WRD b) Adjacent King Gully (looking east-northeast)

2.5 BSOC WRD Diversion Drain

The BSOC WRD Diversion Drain diverts runoff and collected seepage from the BSOC WRD to the King Gully Dam, to reduce potentially contaminated runoff entering to the receiving environment. The Diversion Drain is unlined and constructed within bedrock for parts of the alignment, with the majority being loose alluvial soil (Figure 2-4).

Figure 2-4 BSOC WRD Diversion Drain, BSOC WRD North seepage looking north

3 DIVERSION DRAIN FLOW MONITORING

3.1 Seepage Locations

The three seepage locations all contribute seepage to the BSOC WRD Diversion Drain. To gain an understanding of the seepage flow rates at each location, it is proposed to install a series of weirs across the diversion drain. The diversion drain has been excavated in rock and soil, with zones of high permeability alluvium observed during the site inspection.

Three weirs are proposed in areas of bedrock, between seepage points along the diversion drain. The three proposed weirs are:

- BSOC WRD Weir 1 – immediately downstream of the TD3 seepage point to estimate total seepage from the BSOC WRD, and provide inputs to calculate the seepage at the TD3 seepage point.
- BSOC WRD Weir 2 – downstream of the BSOC WRD North seepage point, to provide inputs to calculate the seepage at the BSOC WRD N seepage point.
- BSOC WRD Weir 3 – upstream of the BSOC WRD North seepage point, to estimate the flow prior to the BSOC WRD North seepage point inflows. Whilst the BSOC WRD South seepage point inflows will be understood through separate monitoring of the pumping regime, BSOC WRD Weir 3 will include surface water flows from the catchment.

The proposed weirs are basic concrete structures with a steel weir plate to measure the low flows, primarily from seepage, with the higher flows estimated based on the channel cross section.

The conceptual design details and construction recommendations are outlined below. Typical layout is shown on Drawing A20-A3001 and typical construction details are shown on Drawings A20-A3002 and A20-A3003.

3.2 Weir Catchment and Flow Analysis

To gain an understanding of the likely flow depths for different rainfall events, the peak discharges at each proposed weir location was calculated. The design event adopted by KCB is approximately the 5 year average recurrence interval (ARI) peak discharge, which corresponds to approximately a 20% chance of this flow being exceeded in any one year.

The peak discharges were estimated using the rational method and Intensity-Frequency-Duration (IFD) for the site acquired from the Bureau of Meteorology (as shown in Attachment 1). The estimated peak discharges for each weir, up to the 5 year ARI are shown in Table 3-1.

Table 3-1 Catchment Characteristics and Peak Discharge

Weir	Catchment Area	1 yr ARI	2 yr ARI	5 yr ARI
	km^2	m^3/s	m^3/s	m^3/s
BSOC WRD Weir 1	0.801	3.30	4.28	5.61
BSOC WRD Weir 2	0.543	2.75	3.56	4.65
BSOC WRD Weir 3	0.390	2.35	3.04	3.96

Notes: ARI = average recurrence interval

The expected flow depths for events up to the 5 year ARI are shown in Table 3-2. The estimated flow depths are shown for the channel prior to weir installation and are an indication of the likely downstream water level during the relevant storm events.

For the weirs to operate as designed, the downstream water level needs to be significantly lower than the weir invert to allow the flow to pass over the weir freely. Where the downstream water level is near or above the weir invert, the water level logger recordings will be incorrect for a stage-discharge weir relationship (effectively, 'drowned out'). As shown in Table 3-2, this will occur at reasonably low flow depths (or discharges) due to the relatively flat grade of the channel. (Note that flow can still be estimated when the weir is drowned out from calculating a channel stage-discharge relationship using the channel hydraulics and surveyed geometry).

Table 3-2 Channel Flow Depth (m)

Weir	Flow depth – in channel, no weir (m)		
	1 yr ARI	2 yr ARI	5 yr ARI
BSOC WRD Weir 1	0.52	0.58	0.7
BSOC WRD Weir 2	0.89	0.91	1.07
BSOC WRD Weir 3	0.67	0.71	0.83

3.3 Typical Weir Details

The proposed weirs have been designed with a 90 degree v-notch weir and a large overflow section. The v-notch weir has been sized to pass low flows up to 135 L/s, with flows above this flowing over the crest of the structure. The v notch weir will be drowned out during higher flows and is designed to estimate lower flows and consisting primarily of seepage during drier periods. Higher flows will be estimated from a channel stage-discharge relationship. The typical design details and locations are shown on Drawings A20-A3001 to A20-A3003.

An automated water-level monitoring device (Attachment 2) will be installed in slotted PVC pipe approximately 2 m upstream of the weir. The monitoring device will provide a continuous record of flow depths over the weir (and hence flows). A stage-discharge relationship for the v-notch weir has been determined converting the flow depths over the weir into flow rates.

The weir staged-discharge tables are included in Attachment 3, based on the configuration shown on Drawing A20-A3003 and outlined above. The stage-discharge will need to be updated following construction, and receipt of the channel cross section survey, for each weir individually.

3.4 Construction and Installation Specifications

The design and specification of the flow monitoring weirs has been undertaken using data available to KCB. The flow monitoring weirs will require field fitting of the design and confirmation of the preferred location. The installation and site selection should be supervised by a suitably qualified engineer, familiar with the installation and construction of flow monitoring weirs and associated infrastructure.

The details provided on Drawings A20-A3002 and A20-A3003 are typical and intended to be adjusted as required to suit the installation location following discussions with the designer.

The installation of the weir should follow the following guidelines at a minimum:

- The concrete weirs should be constructed down to bedrock to limit seepage occurring underneath the measuring weir.
- To reduce excavation, the weirs should be located where bedrock is evident. (Also, the BSOC WRD diversion drain intercepts several creek channels comprising alluvium deposits, which are areas of potential infiltration losses through the base of the channel. These areas should be avoided as the water ponded behind the weirs will increase infiltration losses at these areas. Water will pond for approximately 70 m upstream of each weir, due to the relatively flat grade of the channel (e.g. approximately 0.35 m fall over 70 m length from 0.5% channel grade).
- The height of the weir (between base of the channel and the invert of the metal plate) should be at least 0.35 m.
- The upstream channel should be straight (perpendicular to the weir) for at least 20 m if practical.
- The channel (upstream and downstream) should have some change in elevation. Where possible, the weir should be installed just prior to a significant change in elevation of the base of the channel.
- The upstream edges of the weir plate should be sharp, machined or filed and free of burrs or scratches where possible.
- The connection between the weir plate and the concrete weir structure should be water tight and sealed with a suitable sealing agent. The weir plate should be perpendicular to the flow.
- The water level logger should be placed approximately 2 m upstream of the weir in a suitable location, secured at the base of the channel and calibrated to the weir invert level. The cabling should extend to the crest of the diversion embankment and be secured in place. MIM should ensure the water level logger is set up, functioning and the recording at between 1 and 30 second intervals during installation.

Further construction information and typical details are shown on Drawings A20-A3002 and A20-A3003

4 BSOC WRD SOUTH SEEPAGE MEASUREMENT

The BSOC WRD South seepage currently contributes to an excavated seepage collection trench at the toe of the BSOC WRD. The seepage is pumped at irregular intervals, for unrecorded durations towards the adjacent BSOC WRD Diversion Drain. It is understood the discharge is released upstream from the formed diversion in an area underlain with alluvium; however, the area drains towards the Diversion Drain.

To gain an understanding of the seepage volumes in this area, the implementation of several operational controls should be undertaken as follows:

- Extend pipeline to discharge onto competent ground within the defined channel as shown on Drawing A20-A3001

- Install a flow meter on the seepage transfer pipeline
  - The installation of a flow gauge and meter are recommended on the seepage transfer pipeline. The gauge will need to be capable of measuring the range of discharges regularly pumped from the pit, and include a flow meter to display and log flow rates at regular interval. Information for a recommended transducer and flow meter are included in Attachment 4.
- Undertake detailed survey of collection trench and calculate staged storage relationship
  - The detailed survey will be used to calculate a stage-storage relationship for the seepage collection trench, this will provide a means to estimate the seepage stored and pumped from the trench in conjunction with the data from the flow meter.
- Install a water level logger in the trench
  - A water level logger (as specified in Section 7, and included in Attachment 3) should be installed in the deepest point of the seepage pit to monitor the water level.

5 BILL OF QUANTITIES

A bill of quantities for the recommended design is included in Table 5-1 below and included in Attachment 5. As the designs require field fitting, a contingency allowance of 20% has been made and material requirements may change during construction.

Site mobilisation, erosion control, survey and other construction set up requirements have not been included in the bill of quantities. It has been assumed all specified materials will be available.

The bill of quantities estimate is based on information available to date and is only our opinion of probable quantities and materials for planning purposes. Actual requirements will depend on many factors which can change with time, including site conditions at the time of construction.

Table 5-1 Bill of Quantities Summary

Item Description	Quantity	Unit
Excavate, weathered rock and loose overburden - waste	16.6	m^3
Excavate, weathered rock and stockpile for backfill	25.7	m^3
Concrete, pre-mixed N32/20	7.3	m^3
Y20 reinforcing bars	52.0	m
SL81 mesh	48.5	m^2
Weir plate	3.0	unit
Water level logger (Insitu level troll 400 or 500 model), including minimum 10 m cable: (include solar panel and transmission unit if remote access required)	4.0	unit
Pipeline Flow meter (AQUIP TM Series Water Meter; TM200; pulse model - *to be confirmed based on pipe size*); calibrated (Including solar panel, flow meter logger and transmission system where required)	1.0	unit
PVC Pipe, 40 mm diameter; slotted (or perforations drilled)	53.2	m
Concrete; bucket mixed, unreinforced	2.3	m^3
Star picket with caps	8.0	unit
Riprap, D50 = 200 mm, D10 = 100 mm	11.9	m^3
Geofabric (Bidim A19) - 200 mm overlap	51.9	m^2
BSOC WRD S Seepage Collection System pipeline extension	50.0	m

6 CONSEQUENCE CATEGORY ASSESSMENT

Dams or levees that are constructed as part of an activity under an environmentally relevant activity (ERA) are subject to the *Environmental Protection Act 1994* (Qld) and the associated guidelines, *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (EM635) ('*the Manual*') and *Guideline - Structures which are dams or levees constructed as part of environmentally relevant activities* (EM634) ('*the Guideline*') (Queensland Department of Environment and Heritage Protection 2013; Queensland Department of Environment and Heritage Protection 2014).

The Manual defines dams as 'a land-based structure or a void that contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and associated works'. Therefore, in accordance with the Manual, the proposed flow monitoring weirs are classified as dams and require assessment of their consequence category prior to construction. Any dam or levee that is classified in the Significant or High consequence category is subsequently designated as a 'Regulated' dam and is subject to increased design, construction and operational regulation.

The consequence category is established through assessing the potential impacts that may occur through a failure to contain seepage or overtopping of the structure, according to the criteria in the Manual (refer to Attachment 6 – Consequence Category Assessment Criteria (Queensland Department of Environment and Heritage Protection 2013)

The proposed weirs are designed to temporarily detain the flow in the diversion channel to build up a pond – up to 0.7 m deep – and force the flow to pass through the weir plate allowing measurement of the water level to estimate the flow. The weirs are not intended to be permanent structures or impound water permanently. All flows through the weirs will ultimately be captured at the King Gully Dam, and diverted into KSOC Pit via the King Gully Weir.

A summary of the consequence category assessment of the structures is shown in Table 6-1.The weirs have been assessed as Low consequence structures according to the EHP guidelines, and would therefore not be regulated structures (as defined by the Manual).

Table 6-1 Flow Monitoring Weir Consequence Category Assessment

Category	Characteristics	Consequence Category
Harm to humans – Loss of Life	▪ No permanent population downstream of weirs ▪ Weekly to monthly monitoring of the weirs, people not likely to be in the area routinely. ▪ No expected loss of life (either with 1 weir failure or all weirs failing)	Low
Harm to humans – Water Quality	▪ Weirs are not intended to store inflows. All inflows will pass over weirs and be captured at the downstream King Gully Weir. ▪ Overtopping and seepage losses would affect less than 10 people.	Low

Category	Characteristics	Consequence Category
General Environmental Harm	▪ Surface water runoff from the BSOC waste rock dump and surrounding catchment will be temporarily detained by the weirs. ▪ All flows passing through the weirs will contribute to the King Gully weir and KSOC pit. ▪ Contaminants are likely to be released to areas other than King Gully weir and KSOC pit, with the exception of seepage which will be monitored.	Low
General economic loss or property damage	▪ All downstream infrastructure is owned by the mine. ▪ Final outflow area would be KSOC pit, for any debris or flows. ▪ Value of the weirs and associated infrastructure is expected to be less than $1 Million.	Low

7 FUTURE WORKS, SEEPAGE ESTIMATION AND MONITORING

7.1 As Constructed Survey and Updated Stage-Discharge Tables

An as-constructed survey and inspection will be required to calibrate the stage-discharge tables to the channel cross section. As the weirs will require field fitting, the invert and downstream extents may differ from design and will require updating to confirm the discharge and to estimate where the weir is no longer functioning as a weir (drowned out) as well as updating the channel section details.

The stage-discharge tables will be updated based on the as-constructed survey. A basic hydraulic model can be set up to estimate the flows based on the as-constructed cross-section and longitudinal grade, providing a stage-discharge table.

7.2 Seepage Estimation

The influence of rainfall runoff will be observed in the monitoring records for each of the weirs. Detailed rainfall records will need to be correlated against the seepage monitoring records as part of post-processing to estimate seepage rates at each location. This will require analysis of the hydrograph (flow vs time) at each location, and separation of the base flow to estimate the seepage inflows at each location. Some estimation of losses to infiltration (into the base of the diversion) and evaporation may be required.

Infiltration through the base of the upstream weir impoundments may change over time. The calculated flows should be analysed with consideration of other downstream / downslope investigations and monitoring. Possible changes to infiltration rates through the base of the BSOC WRD Diversion Drain, may change over time.

The BSOC WRD South seepage collection trench will require calculation of the stage-storage relationship; and, post-processing of the pump, flowmeter and water level logger data. Checks of the estimated seepage collected and transferred will be undertaken against the results of the data recorded in the pump operations manual.

7.3 Monitoring and Maintenance

Ongoing monitoring and maintenance of the weirs will be required to maintain the channel cross-section used to generate the provided staged-discharge curves.

The following should be inspected and maintained monthly as a minimum, and after all significant rainfall events. It is understood monthly water quality sampling is undertaken by the environment team, the monitoring of these structures should be incorporated into this and the planned maintenance manual.

- The weir should be kept free of debris and sediment build up on the upstream and downstream sides;
- The downstream riprap should be checked for movement of rocks and erosion around or beneath;
- During low flows, the downstream and upstream extents of the concrete structure should be checked for erosion and piping. The abutments of the weir should be checked regularly to ensure higher flows are not bypassing the weir. Where erosion is occurring, the area should be repaired as soon as possible;
- Movement or settlement of the weir should be checked periodically and staged-discharge curves updated. Installation of survey monuments at the weirs may assist with this process;
- The metal weir plate should remain secure against the concrete structure;
- The approach channel to the weir should be regularly monitored for erosion and siltation; and,
- The water level loggers should be checked for damage or vandalism, the data downloaded and calibrated where required.

8 CONCLUSIONS

The construction and installation of flow gauging weirs and pumped flow monitoring has been recommended as part of the environmental evaluation into the BSOC WRD seepage and related impacts. The weirs and flow monitoring is intended to gain an understanding of the seepage flows and patterns, as well as the surface water inflows.

The seepage measuring locations will only capture the combined surface water and seepage flows at the point of the weirs. This will provide an estimate only of the actual seepage from the BSOC WRD and will not account for surface water and seepage losses through the base of the WRD, infiltration at locations between the seepage points of the WRD and the flow monitoring locations or evaporation.

The conceptual design will require field fitting of the weir based on foundation and cross section characteristics. The typical details provided for weir construction will need to be adjusted to fit the selected locations. Changes may include the layout, configuration and formwork of the weir and the weir plate.

This letter report and drawings document the typical design requirements and construction information. KCB recommend all construction is overseen by a suitably qualified engineer who is experienced in the construction and installation of flow monitoring weirs. Ongoing consultation with the designers should be maintained during construction. As-built records including survey and photograph s should be provided to KCB as soon as practicable following construction.

9 CLOSING

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of *Mount Isa Mines Limited* (Client) for the specific application to the *BSOC WRD Environmental Evaluation.* The report's contents may not be relied upon by any other party without the express written permission of Klohn Crippen Berger. In this report, Klohn Crippen Berger has endeavoured to comply with generally-accepted professional practice common to the local area. Klohn Crippen Berger makes no warranty, express or implied.

Yours truly,

KLOHN CRIPPEN BERGER LTD.

Kate Brand RPEQ
Senior Civil Engineer

Chris Strachotta
Project Manager

Attachments

Attachment 1	IFD for Mount Isa region
Attachment 2	Water level logger product sheet
Attachment 3	Stage-discharge table, V Notch weir 90 deg
Attachment 4	Pipe flow meter product sheet
Attachment 5	Bill of Quantities
Attachment 6	Consequence Category Assessment Criteria
Drawings	A20-A3001 to A20-A3003

References

KCB. 2015. "Environmental Evaluation - Black Star Pen Cut Waste Rock Dump Proposal for Consulting Services." Proposal PR12D05.17.

Pilgram, DH, ed. 1987. *Australian Rainfall & Runoff – A Guide to Flood Estimation*. Barton, ACT: Institution of Engineers Australia.

Queensland Department of Environment and Heritage Protection. 2013. "Manual for Assessing Consequence Categories and Hydraulic Performance of Structures." EM635 Version 4.

Queensland Department of Environment and Heritage Protection. 2014. "Guideline: Structures Which Are Dams or Levees Constructed as Part of Environmentally Relevant Activities." EM634 Version 6.

TMR. 2010. "Road Drainage Manual: A Guide to the Planning, Design, Operation and Maintenance of Road Drainage Infrastructure."

Worley Parsons Resources and Energy. 2014. "Kings Gully Dirty Water Diversion Works - As Constructed Report." 201001-00424 – 00-EN-REP-0003. Prepared for Glencore Mount Isa Mines.

Attachment 1 – Intensity Frequency Duration, Mount Isa Mine

Location: 20.700S 139.450E NEAR.. MIM Issued: 17/9/2015

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	75.0	97.2	128	145	169	200	223
6Mins	70.0	90.8	119	136	158	187	209
10Mins	58.8	76.3	100	114	133	157	175
20Mins	45.9	59.3	77.5	88.1	102	120	134
30Mins	38.4	49.7	64.7	73.6	85.1	100	112
1Hr	26.3	34.1	44.7	51.0	59.1	69.9	78.1
2Hrs	16.4	21.5	28.8	33.2	38.8	46.4	52.2
3Hrs	12.1	15.9	21.7	25.3	29.9	36.0	40.8
6Hrs	7.03	9.37	13.3	15.7	18.8	23.1	26.4
12Hrs	4.18	5.62	8.14	9.78	11.9	14.7	17.0
24Hrs	2.60	3.50	5.08	6.12	7.43	9.24	10.7
48Hrs	1.62	2.17	3.12	3.74	4.52	5.58	6.44
72Hrs	1.16	1.55	2.24	2.69	3.26	4.03	4.65

(Raw data: 35.2, 5.62, 1.56, 71.06, 14.83, 4.03, skew=0.00, F2=3.72, F50=14.59)

© Australian Government, Bureau of Meteorology

http://www.bom.gov.au/water/designRainfalls/ifd-arr87/index.shtml

Attachment 2 – Water Level Logger Product Sheet

Attachment 3 – Stage-Discharge Table, V Notch Weir - 90 deg

H	Q	Q
m	m3/s	L/s
0.01	0.00	0.0
0.02	0.00	0.1
0.03	0.00	0.2
0.04	0.00	0.5
0.05	0.00	0.8
0.06	0.00	1.3
0.07	0.00	1.8
0.08	0.00	2.6
0.09	0.00	3.4
0.10	0.00	4.4
0.11	0.01	5.6
0.12	0.01	7.0
0.13	0.01	8.5
0.14	0.01	10.2
0.15	0.01	12.2
0.16	0.01	14.3
0.17	0.02	16.6
0.18	0.02	19.1
0.19	0.02	21.8
0.20	0.02	24.8
0.21	0.03	28.0
0.22	0.03	31.4
0.23	0.04	35.1
0.24	0.04	39.0
0.25	0.04	43.1
0.26	0.05	47.5
0.27	0.05	52.2
0.28	0.06	57.1
0.29	0.06	62.3
0.30	0.07	67.8
0.31	0.07	73.5
0.32	0.08	79.6
0.33	0.09	85.9
0.34	0.09	92.5
0.35	0.10	99.4
0.36	0.11	106.5
0.37	0.11	114.0
0.38	0.12	121.8
0.39	0.13	129.9
0.40	0.14	138.4

Attachment 4 – Pump Flow Meter Product Sheet

Attachment 5 – Bill of Quantities

ITEM No.	Item Description	Quantity	Unit
1.0	**Flow Monitoring Weir #1 - Downstream of TSF3 Seepage location**		
1.1	**Excavate, weathered rock and loose overburden**		
1.11	Rip, excavate and waste overburden. Assume 0.15 m depth across footprint.	7.6	m3
1.12	Rip and excavate to reduced level and stockpile for backfill; assume rippable rock. Assume 0.30 m depth across footprint.	15.1	m3
1.2	**Concrete Structure**		
1.21	Concrete, pre-mixed N32/20	4.2	m3
1.22	Y20 reinforcing bars, placed and secured at 0.3 m spacing	24.0	m
1.23	SL81 mesh, placed and supported as required.	26.0	m2
1.3	**Weir plate**		
1.31	0.2 mm thickness stainless steel plate; 0.6 m x 1.2 m; sharp edged, 90 deg V notch weir slot as specificed; supplied with suitable fasteners to secure to concrete structure.	1.0	unit
1.4	**Water Level Logger**		
1.41	Water level logger (Insitu level troll 400 or 500 model; or similar), including minimum 10 m cable: (include solar panel and transmission unit if remote access required)	1.0	unit
1.42	PVC Pipe, 40 mm diameter; slotted (or perforations drilled)	14.4	m
1.43	Concrete; bucket mixed, unreinforced	0.6	m3
1.44	Star picket with caps	2.0	unit
1.5	**Erosion Protection and backfill**		
1.51	Riprap, D50 = 200 mm, D10 = 100 mm	7.0	m3
1.52	Backfill with stockpiled material, pending soil testing (refer Dwg A20-A3002)	15.1	m2
1.53	Geofabric (Bidim A19) - 200 mm overlap	30.6	m2
2.0	**Flow Monitoring Weir #2 - Downstream of Northern seepage location**		
2.1	**Excavate, weathered rock and loose overburden**		
2.11	Rip, excavate and waste overburden. Assume 0.15 m depth across footprint.	2.3	m3
2.12	Rip and excavate to reduced level and stockpile for backfill; assume rippable rock. Assume 0.30 m depth across footprint.	4.5	m3
2.2	**Concrete Structure**		
2.21	Concrete, pre-mixed N32/20	1.3	m3
2.22	Y20 reinforcing bars, placed and secured at 0.3 m spacing	12.0	m
2.23	SL81 mesh, placed and supported as required.	9.5	m2
2.3	**Weir plate**		
2.31	0.2 mm thickness stainless steel plate; 0.6 m x 1.2 m; sharp edged, 90 deg V notch weir slot as specificed; supplied with suitable fasteners to secure to concrete structure.	1.0	unit
2.4	**Water Level Logger**		
2.41	Water level logger (Insitu level troll 400 or 500 model), including minimum 10 m cable: (include solar panel and transmission unit if remote access required)	1.0	unit
2.42	PVC Pipe, 40 mm diameter; slotted (or perforations drilled)	14.4	m
2.43	Concrete; bucket mixed, unreinforced	0.6	m3
2.44	Star picket with caps	2.0	unit
2.5	**Erosion Protection**		

ITEM No.	Item Description	Quantity	Unit
2.51	Riprap, D50 = 200 mm, D10 = 100 mm	2.1	m3
2.52	Backfill with stockpiled material, pending soil testing (refer Dwg A20-A3002)	4.5	m2
2.53	Geofabric (Bidim A19) - 200 mm overlap	9.2	m2
3.0	**Flow Monitoring Weir #3 - Downstream of southern seepage location**		
3.1	**Excavate, weathered rock and loose overburden**		
3.11	Rip, excavate and waste overburden. Assume 0.15 m depth across footprint.	6.7	m3
	Rip and excavate to reduced level and stockpile for backfill; assume rippable rock. Assume 0.30 m depth across footprint.	6.0	m3
3.2	**Concrete Structure**		
3.21	Concrete, pre-mixed N32/20	1.8	m3
3.22	Y20 reinforcing bars, placed and secured at 0.3 m spacing	16.0	m
3.23	SL81 mesh, placed and supported as required.	13.1	m2
3.3	**Weir plate**		
3.31	0.2 mm thickness stainless steel plate; 0.6 m x 1.2 m; sharp edged, 90 deg V notch weir slot as specificed; supplied with suitable fasteners to secure to concrete structure.	1.0	unit
3.4	**Water Level Logger**		
3.41	Water level logger (Insitu level troll 400 or 500 model), including minimum 10 m cable: (include solar panel and transmission unit if remote access required)	1.0	unit
3.42	PVC Pipe, 40 mm diameter; slotted (or perforations drilled)	14.4	m
3.43	Concrete; bucket mixed, unreinforced	0.6	m3
3.44	Star picket with caps	2.0	unit
3.5	**Erosion Protection**		
3.51	Riprap, D50 = 200 mm, D10 = 100 mm	2.8	m3
3.52	Backfill with stockpiled material, pending soil testing (refer Dwg A20-A3002)	6.0	m2
3.53	Geofabric (Bidim A19) - 200 mm overlap	12.2	m2
4.0	**BSOC WRD S Seepage Collection System**		
4.1	**Pipeline**		
4.11	Extend existing pipeline with pipeline of the same diameter and strength rating.	50.0	m
4.12	Pipeline Flow meter (AQUIP TM Series Water Meter; TM200; pulse model - *to be confirmed based on pipe size*); calibrated (Including solar panel, flow meter logger and transmission system where required)	1.0	unit
4.2	**Water Level Logger**		
4.21	Water level logger (Insitu level troll 400 or 500 model), including minimum 10 m cable: (include solar panel and transmission unit if remote access required)	1.0	unit
4.22	PVC Pipe, 40 mm diameter; slotted (or perforations drilled)	10.0	m
4.23	Concrete; bucket mixed, unreinforced	0.5	m3
4.24	Star picket with caps	2.0	unit
Summary			
	Excavate, weathered rock and loose overburden - waste	16.6	m3
	Excavate, weathered rock and stockpile for backfill	25.7	m3
	Concrete, pre-mixed N32/20	7.3	m3
	Y20 reinforcing bars	52.0	m
	SL81 mesh	48.5	m2

ITEM No.	Item Description	Quantity	Unit
	Weir plate	3.0	unit
	Water level logger (Insitu level troll 400 or 500 model), including minimum 10 m cable: (include solar panel and transmission unit if remote access required)	4.0	unit
	Pipeline Flow meter (AQUIP TM Series Water Meter; TM200; pulse model - *to be confirmed based on pipe size*); calibrated (Including solar panel, flow meter logger and transmission system where required)	1.0	unit
	PVC Pipe, 40 mm diameter; slotted (or perforations drilled)	53.2	m
	Concrete; bucket mixed, unreinforced	2.3	m3
	Star picket with caps	8.0	unit
	Riprap, D50 = 200 mm, D10 = 100 mm	11.9	m3
	Geofabric (Bidim A19) - 200 mm overlap	51.9	m2
	BSOC WRD S Seepage Collection System pipeline extension	50.0	m

Attachment 6 – Consequence Category Assessment Criteria (Queensland Department of Environment and Heritage Protection 2013)

Environmental Harm	High	Significant	Low
Harm to humans	People are routinely present in the failure path. Loss of life > 10 people is expected.	People are routinely present in the failure path. Loss of life 1 - 10 people is expected.	People are not routinely in the failure path. Loss of life (people) is not expected.
	Contamination of waters (surface and/or groundwater) used for human consumption could result in the health of 20 or more people being affected	Contamination of waters (surface and/or groundwater) used for human consumption could result in the health of 10 - 20 or more people being affected	Contamination of waters (surface and/or groundwater) used for human consumption could result in the health of less than 10 people being affected
General Environmental Harm	Location such that: a) Contaminants may be released to areas of MNES, MSES or HEV waters that are not already authorised to be disturbed to at least the same extent under other conditions of this authority subject to any applicable offset commitment (Significant Values); and b) Adverse effects10 on Significant Values are likely; and c) The adverse effects are likely to cause at least one of the following: i) Loss or damage or remedial costs greater than $50,000,000; or ii) Remediation of damage is likely to take 3 years or more; or iii) permanent alteration to existing ecosystems; or iv) The area of damage (including downstream effects) is likely to be at least 5 km^2.	Location such that contaminants may be released so that adverse effects either: a) Would be likely to be caused to Significant Values but those adverse effects would not be likely to meet the thresholds for the High consequence category and instead would be likely to cause at least one of the following: i) Loss or damage or remedial costs greater than $10,000,000 but less than $50,000,000; or ii) Remediation of damage is likely to take more than 6 months but less than 3 years; or iii) Significant alteration to existing ecosystems; or iv) The area of damage (including downstream effects) is likely to be at least 1 km^2 but less than 5 km^2. <u>or</u> b) Would be likely to be caused to environmental values classed as slightly or moderately disturbed waters, wetland of general ecological significance, riverine areas, springs or lakes and associated flora and fauna (Moderate Values), and the	Location such that either: a) Contaminants are unlikely to be released to areas of Significant Values or Moderate Values; or b) Contaminants are likely to be released to those areas, but would be unlikely to meet any of the minimum thresholds specified for the Significant Consequence Category for adverse effects.

Environmental Harm	High	Significant	Low
		adverse effects are likely to cause at least one of the following: i) Loss or damage or remedial costs greater than $20,000,000; or ii) Remediation of damage is likely to take more than 1 year; or iii) Significant alteration to existing ecosystems; or iv) The area of damage (including downstream effects) is likely to be at least 2 km^2	
General economic loss or property damage	Location such that harm to third party assets in the failure path would be expected to require $10 million or greater in rehabilitation, compensation, repair or rectification costs.	Location such that harm to third party assets in the failure path would be expected to require $1 million and greater but less than $10 million in rehabilitation, compensation, repair or rectification costs.	Location such that harm to third party assets in the failure path would be expected to require less than $1 million in rehabilitation, compensation, repair or rectification costs.

Note: This table has been abbreviated for reporting, please refer to the "Manual for Assessing Consequence Categories and Hydraulic Performance of Structures" Table 1 (Queensland Department of Environment and Heritage Protection 2013) for the complete table including notes.

APPENDIX IV

Receiving Environment (Flora and Fauna) Assessment

Klohn Crippen Berger

BSOC Environmental Evaluation – Receiving Environment (Flora and Fauna) Assessment

Document Release Date	28 July 2016
Document Number	651960-ENV-RPT-001

Revision	Date	Description	Prepared	Reviewed	Approved		
					Study Manager	Sign-off	Client
A	15/04/2016	Issued for Review	D. Evans	B. Ezzy	J. Claridge	J. Claridge	C. Strachotta
B	17/05/2016	Issued for Review	H. Savage	B. Ezzy	J. Claridge	J. Claridge	C. Strachotta
0	27/06/2016	Issued for use	H. Savage	J. Claridge	J. Claridge	J. Claridge	C. Strachotta
1	28/07/2016	Issued for use	J. Claridge	J. Claridge	J. Claridge	J. Claridge	C. Strachotta

Item	Page	Section	Comments

** Use after Rev. 0*

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1 Introduction

1.1 Purpose and scope

This report has been prepared in response to the Department of Environment and Heritage Protection's (EHP's) notice to conduct or commission an environmental evaluation (EE) (ref 101/0009689) and specifically addresses Part B, 2 a and b (iv) of the EE:

> *be in accordance with ANZECC (2000) methodology*
>
> *assess impacts on the receiving environment and identified environmental values, the assessment must include consideration of …. flora and fauna.*

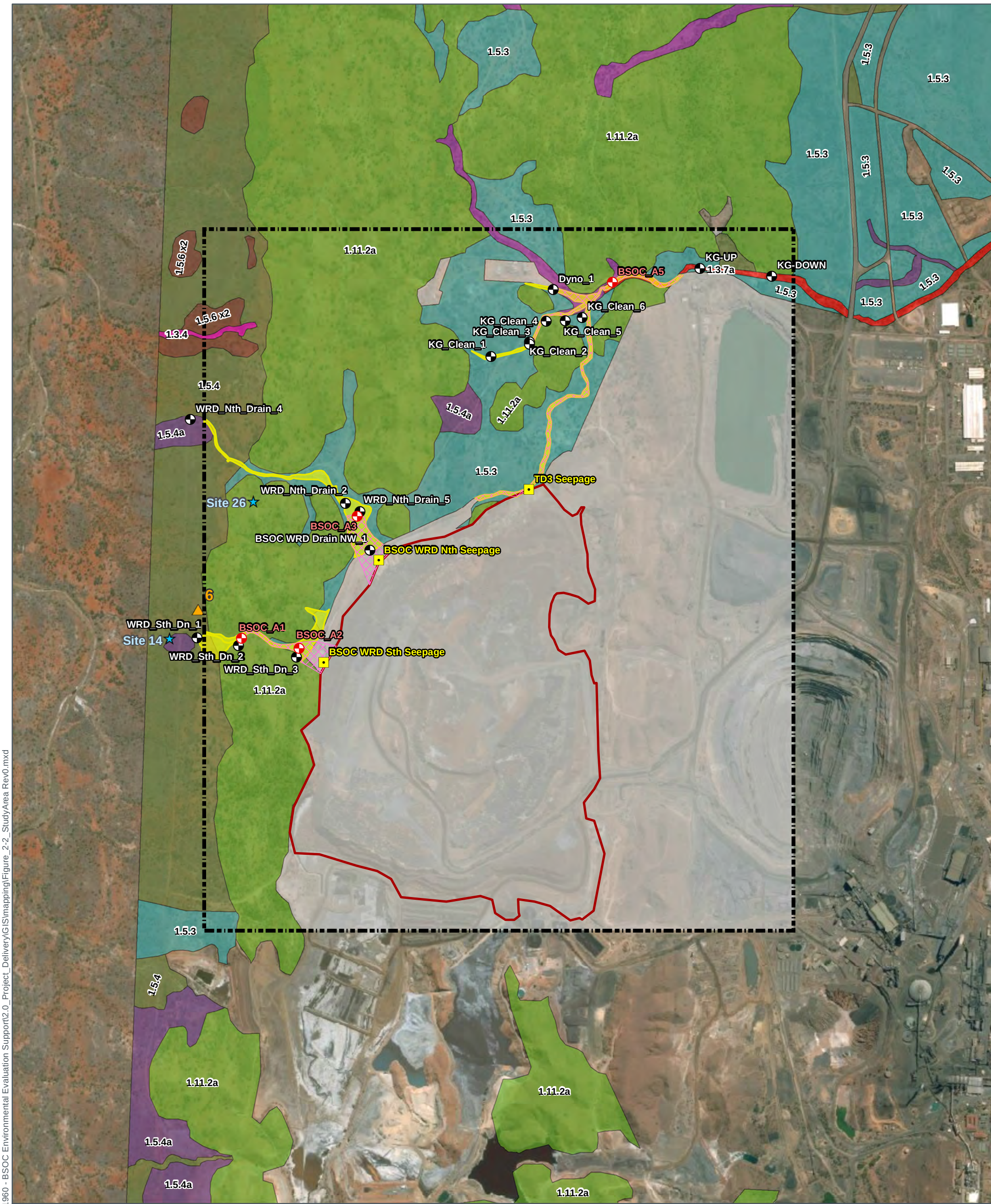
This assessment has been prepared in accordance with the requirements of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000).

1.2 Background

This assessment relates to observed seepage from the Black Star Open Cut Waste Rock Dump (BSOC WRD) within Mining Lease 8058 (ML8058). All soil and water chemistry data referenced in this assessment has been provided by Klohn Crippen Berger from field studies undertaken in 2015 and analysis provided in March 2016. Soil and water sample sites referred to in this report are presented on **Figure 1-1**. Information about the flora and fauna values of the area are derived from ecology field surveys and studies undertaken by Amec Foster Wheeler in 2014/2015 for the Mount Isa Mines 2014 Biodiversity Assessment of ML8058.

The Study Area for the purposes of this assessment is an area of approximately 772 ha surrounding the BSOC WRD as shown in **Figure 1-1**. The Study Area of this investigation was presented to EHP at the Environmental Evaluation Outline Meeting on July 22, 2015, and was based on a geographic extent beyond the anticipated current BSOC WRD landform seepage impacts. It is acknowledged that downstream surface water receptors, Hazeldene Creek and Spear Creek, are located beyond the extent of the Study Area, and as a result have been taken into account for the assessment of potential impacts.

The EE notice defines "receiving environment" as *all groundwater and surface water that are not in disturbed areas authorised by Mount Isa Mines' (MIM) Environmental Authority EPML00977513 (EA) and excludes land within the surface water containment areas*.



Klohn Crippen Berger - 80093 - MIM Environmental Evaluation Support

BSOC WRD Environmental Evaluation Regional Ecosystems and Survey Sites

WORK REQUEST NUMBER: 80093

DATA SOURCES:
Ground Truthed RE supplied by Mount Isa Mines
Alluvium, Affected Areas, BSOC WRD - Klohn Crippen Berger
Service Layer Credits: Copyright:© 2015 DeLorme
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics,

LEGEND

- Bore - Alluvium
- Soil Sample Location
- Flora Survey Sites
- Fauna Survey Sites
- Seepage Location
- Potentially Affected Area
- BSOC WRD
- Mapped Alluvium
- Study Focus Area

GTRE

- 1.11.2a
- 1.11.3X1b
- 1.3.4
- 1.3.7a
- 1.5.3
- 1.5.4
- 1.5.4a
- 1.5.6 x2
- Non-Rem

ISSUE DATE	AUTHOR	QA CHECK	APPROVED	MAP REV.	REVISION NOTE
27/06/2016	MG	JC	JC	0	Issue For Use
16/05/2016	MG	JC	JC	B	Issued for Review
30/03/2016	MG	BE	JC	A	Issued for Review

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Kilometres

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(A3) GDA 1994 MGA Zone 54

LOCATION DIAGRAM

Path: W:\PROJECTS\EI\Klohn Crippen Berger\651960 - BSOC Environmental Evaluation Support\2.0_Project_Delivery\GIS\mapping\Figure_2-2_StudyArea Rev0.mxd

AMEC does not guarantee the accuracy or completeness of the map and does not make any warranty about the data.
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2 Existing flora and fauna values

2.1 Study Area context

The existing environmental values associated with land relevant to ML8058 are described in MIM (2011). MIM (2011) provides a summary of the significant environmental values to be protected, including ecosystem biodiversity, health and significance. Land within ML8058 has been subjected to a range of disturbances over more than 90 years of mining operations. Within the mining areas, ecosystems have been largely removed, though the bulk of ML8058 remains relatively undisturbed (MIM, 2011).

The region is subject to two distinct seasons – the wet season from November to March and dry season from April to October. The highly seasonal nature of the environment impacts biodiversity and environmental cues within the ML, particularly post wet season when rainfall results in higher botanical recruitment and increased fauna species and populations recorded during biodiversity surveys (Amec Foster Wheeler 2015).

The ML is characterised by rugged, rocky hills and poor shallow soils. The vegetation reflects the complex geology, infertile soil and semi-arid climate. Low open woodland with Eucalyptus, Corymbia and Acacia species predominates, with a ground layer of Triodia species (spinifex). The ML is located partially within a sub-catchment of the Leichhardt River catchment. Streams are mostly dry, with the size and duration of water flows dependent on the highly variable wet season. The only permanent water bodies in the region exist in man-made structures, such as Lake Moondarra, Lake Julius, Lake Mary Kathleen and Rifle Creek Dam. The ML is surrounded by (and overlays) neighbouring pastoral leases, which are used for rangeland grazing. Conditions are unsuitable for improved pasture, so clearing of native vegetation has generally been limited to areas required for mining and supporting infrastructure.

In 2009, MIM commissioned a biodiversity study which included ground-truthing of regional ecosystems (REs) and preparing RE mapping at a scale of 1:20,000 across the ML. During biodiversity surveys conducted in the dry season of 2014 and wet season of 2015 (referred to as the 2014 Biodiversity Study) by Amec Foster Wheeler, it was found that overall native vegetation communities across the ML were in moderate to good condition, meeting remnant status, and close to benchmark values.

2.2 Terrestrial flora

In general, ML8058 is dominated by Snappy gum with a spinifex ground layer, a characteristic northwest Queensland landscape. Interspersed amongst the Snappy gum (*Eucalyptus racemosa*) hills and flats are a variety of ecosystems, such as Silver ironbark (*E. melanophloia*), mallee shrublands, Corymbia capricornia ridges, *Corymbia aspera* rock outcrops, Normanton box (*E. normantonen*) and Gidgee patches, all of which are dissected by narrow lines of River red gum along creeks.

The Study Area is located in the central part of the ML and west of the Mount Isa township. The area is predominantly cleared and developed for mining purposes, including BSOC WRD, King Gully Dam, diversion drains, stockpiles and access roads. The northern boundary, north-west corner, and western boundary of the Study Area are mostly undeveloped and mapped as containing remnant vegetation. REs found in the Study Area and respective extents are listed in **Table 2-1** and illustrated in **Figure 1-1**.

Table 2-1 Regional Ecosystems in Study Area and Surrounds

Regional Ecosystem	Biodiversity Status
1.11.2a *Eucalyptus leucophloia* (snappy gum) low open woodland. Occurs on steep hills.	No Concern at Present
1.11.3X1b Low open woodland *Eucalyptus leucophylla* often with Corymbia terminalis. Occurs on broad low hills; gently undulating.	No Concern at Present
1.3.4 *Acacia cambagei* low open woodland to woodland on earths in valleys	Of Concern
1.3.7a Riverine wetland or fringing riverine wetland	Endangered
1.5.3 *Eucalyptus leucophloia* (snappy gum) low open woodland and woodland sometimes with shrubby understorey dominated by Acacia spp	No Concern at Present
1.5.4 *Eucalyptus leucophylla* low open woodland on red earths in valleys	No Concern at Present

Regional Ecosystem	Biodiversity Status
1.5.4a Low open woodland of *Corymbia terminalis*, scattered shrub layer of Carissa lanceolata and tussock grass ground layer.	No Concern at Present
1.5.6 x2 Low woodland of *Acacia cambagei* with generally sparse ground layer of Triodia longiceps and/or tussock grasses. Bare patches are common	No Concern at Present

Source: Amec Foster Wheeler 2015

Vegetation surveys conducted in late 2014 and early 2015 assessed REs within and in proximity to the Study Area, noting canopy trees were sparse and there was a general absence of shrubs and groundcover. One BioCondition survey site (Site 26) is located within the Study Area as shown on **Figure 1-1** and **2-1**. The survey site was located in RE1.11.2a Snappy gum on hills. No regeneration of native flora was observed and the ground was mostly devoid of any native grasses or shrubs. Habitat features were assessed as being limited with the main habitat features consisting of rocky outcrops on land zone 11, stone shale and minimal litter cover and woody debris.

Figure 2-1 Flora Survey Site 26

Source: Amec Foster Wheeler 2015

2.3 Terrestrial fauna

On the western boundary of the Study Area was a terrestrial fauna survey site (Site 6) located in RE 1.5.4, as shown on **Figures 2-1** and **2-2**.

Figure 2-2 Fauna Survey Site 6

Source: Amec Foster Wheeler 2015

Fauna surveys included Elliot (A and B) trapping, funnel trapping, pit fall trapping, cage traps, remote camera trapping, nocturnal spotlighting, active herpetile searching, scat analysis and watercourse and waterhole surveys. The survey site was dominated by snappy gum (*Eucalyptus leucophloia subsp. euroa*) with whitewood (*Atalaya hemiglauca*). A sparse shrub layer of Chisholm's wattle (*Acacia chisholmii*) was also present. The ground layer was very sparse and dominated by occasional spinifex, with very occasional Ptilotus sp. also present. There were 19 avian species, 2 mammals and 2 reptiles recorded across both dry and wet season surveys at this survey site. Fauna species observed included:

- Australian raven (*Corvus coronoides*)
- black-faced cuckoo-shrike (*Coracina novaehollandiae*)
- common bronzewing (*Phaps chalcoptera*)
- crested pigeon (*Ocyphaps lophotes*)
- double-barred finch (*Taeniopygia bichenovii*)
- grey-crowned babbler (*Pomatostomus temporalis*)
- little friarbird (*Philemon citreogularis*)
- rainbow bee-eater (*Merops ornatus*)
- variegated fairy-wren (*Malurus lamberti*)
- gecko (*Gehyra robusta*)
- gecko (*Gehyra veriegata)*
- common wallaroo (*Macropus robustus*)
- striped faced dunnart (*Sminthopsis macroura*).

Based on vegetation communities occurring in the Study Area and surrounds and habitat features present, the area is likely to support limited fauna species. Areas consisting of RE1.11.2a with rocky outcrops on hills may support mammal species, including the purple-necked rock wallaby and common wallaroo. The striped faced dunnart may also utilise areas in lower slopes and alluvium where vegetation communities contain tussock grasses. Birds and reptiles are likely to utilise all areas. In the wet season when creeks contain some water, fauna species are likely to be drawn to these areas. Microbats are unlikely to utilise the Study Area due to a lack of hollow bearing trees and flyways.

2.4 Aquatic flora and fauna

The surface water environmental values downstream of the mine sites, the reach of the Leichhardt River catchment between Mount Isa Mines and Lake Moondarra, as well as Spring Creek downstream of the George Fisher and HHOC Mines, have been divided into three zones (Pink, Green and Blue Zones) which recognise past and present land use activities and the environmental values supported within each zone.

The water quality criteria for the operational conditions have been developed based on the environmental values for the surface water flows agreed with EHP.

For sections of the Leichhardt River in town and close to mine discharges, as well as Hazeldene Creek and parts of Spring Creek (Pink Zone in Figure 3-3) the adopted environmental values were as follows:

- Slightly to moderately disturbed ecosystem
- Suitable for drinking water supply at Lake Moondarra
- Suitable for primary contact at Green Zone and Lake Moondarra
- Suitable for secondary recreation
- Suitable for agricultural use at Green Zone and Lake Moondarra
- Suitable for human consumption of aquatic food
- Suitability for industrial use at Lake Moondarra
- Protection of cultural and spiritual values.

Within the Study Area and surrounds there are limited aquatic flora and fauna values. Streams within the Study Area and surrounds are characterised by incised channels with clay, gravel and rock banks, and sandy alluvial beds. During the dry season there is almost a complete absence of riparian flora and there are no permanent pools of water.

During the wet season there may be intermittent “flashy” overland flows during high rainfall events, however, given stream topographies and substrate characteristics, any water present within the streams quickly dries out.

3 Relevant guidelines

Based on the biotic values identified in **Section 2**, the most relevant guideline values proposed for this assessment are those outlined in **Table 3-1**.

Table 3-1 Guideline Chemical Values

Contaminant Transfer Medium	Receptor Type	Guideline Values	Justification
Water	Terrestrial fauna and flora	ANZECC 2000 livestock use	Beef cattle are one of the main mammal groups present in the area. Guideline values are well established for cattle. Other native fauna could be more sensitive to contamination but would likely travel to other non-impacted sites to feed / drink. There are no well established guidelines for water quality for native flora.
Sediment / soil	Terrestrial flora & fauna	ANZECC 2000 provisional sediment quality low trigger and high guideline values	Consideration of adsorption of soluble contaminants / deposition of particulate-bound contaminants leading to storage in alluvial sediments. Possible release at a later date triggered by prevailing water characteristics (e.g. acidic first-flush).

4 Risk assessment

The impact of contaminants from the BSOC WRD seepage is assessed in this section by evaluating the substances within the seepage potentially posing a risk to flora and fauna receptors, the degree of contamination (concentration), and the chemical behaviour of these substances to the receiving environment.

4.1 Spatial variation and extent

The extent of seepage as it occurs in the alluvium has been mapped in **Figure 1-1** based on sulfate levels of >1,000 mg/L (as provided by KCB). In addition to mapped contamination within the alluvium, contamination may occur within deeper groundwater. However, as this water is well below the root zone of vegetation, there are no potential vectors for impacts to the receiving environment. As a result, further assessment of potential impacts from deeper groundwater to flora and fauna is not considered in this report.

4.2 Potential vectors for movement of contaminants within the biotic environment

A conceptual understanding of the different pathways and sinks for seepage contamination are shown in **Figure 4-1**. This assessment has evaluated the criteria that affect exposure of the contamination contained within the seepage to down-gradient ecological receptors. Where relevant, each of the potential vectors for movement of contaminants within the biotic environment are considered.

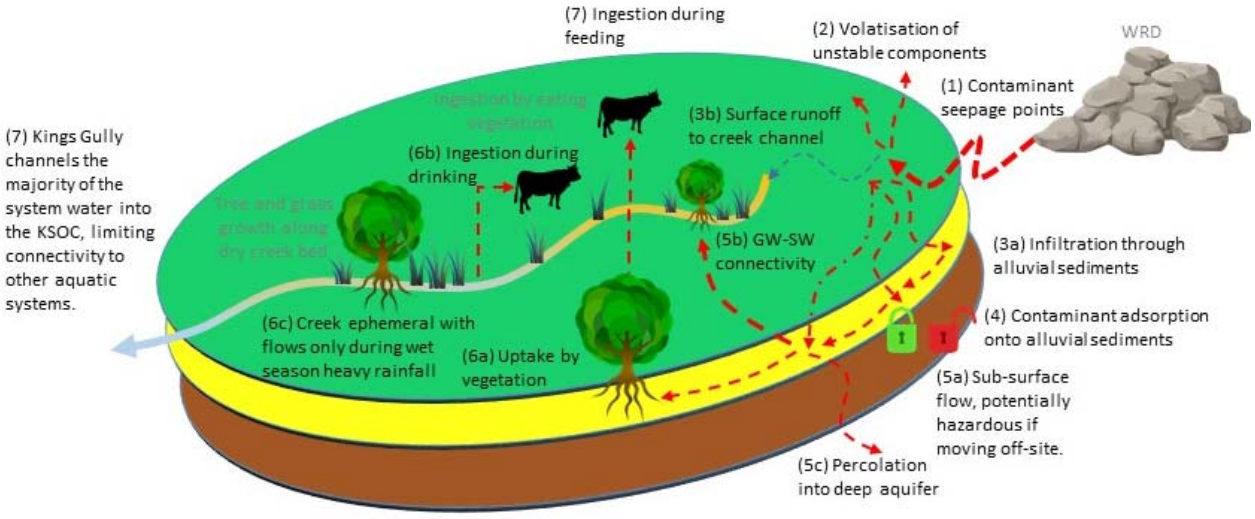

Figure 4-1 Conceptual schematic of BSOC WRD seepage ecological pathways

4.3 Screening-level risk assessment

For both groundwater and sediment, the measured environmental filtered concentration for each contaminant (in data provided by Klohn Crippen Berger from field work undertaken in 2015) was divided by the guideline values to calculate the Hazard Quotient (HQ). If the HQ was <1, that contaminant was considered to be of 'low risk' and was not considered further. If the HQ was >1, the contaminant was identified as a 'contaminant of potential ecological concern' (CPEC) (ANZECC 2000).Chemicals were reviewed against guideline values, as shown in **Tables 4-1 to 4-2**.

Table 4-1 Potential impacts to terrestrial fauna and flora - Comparison of water concentrations to ANZECC 2000 livestock (beef cattle) guideline values

		Sth Seepage*		Nth Seepage*		TD3_Seepage*		Groundwater Samples			
Major ions	**Guideline Values**	**Filtered (Range)**	**Total (Range)**	**Filtered (Range)**	**Total (Range)**	**Filtered (Range)**	**Total (Range)**	**BSOC A1**	**BSOC A2***	**BSOC A3**	**BSOC A5***
Calcium (mg/L)	**1,000**	164-493	NA	260-599	NA	185-540	Na	14	71	5	126
Fluoride (mg/L)	**2**	NA	1.5-8.6		0.4-2.8		0.8-4.1	2.3	6.4	3.4	5.1
Magnesium (mg/L)	**2,000**	691-3,730		359-5,530		1,040-2,350		55	519	8	280
Nitrate (lower) (mg NO_3/L)	**400**		0.25-113.0		0.13-82.1		0.01-54.8	ND	ND	ND	ND
Nitrate (upper) (mg NO_3/L)	**1,500**		0.25-113.1		0.13-82.2		0.01-54.9	ND	ND	ND	ND
Nitrite (mg NO_2/L)	**30**		0.01-2.54		0.01-6.11		0.01-0.17	ND	ND	ND	ND
Sulfate (lower) (mg/L)	**1,000**	4,020-9,510		1,540-22,700		6,510-10,500		576	5,580	727	4,870
Sulfate (upper) (mg/L)	**2,000**	4,020-9,510		1,540-22,700		6,510-10,500		576	5,580	727	4,870
TDS (lower) (mg/L)	**4,000**		6,400-24,100		4,300-35,600		11,800-17,500	2,120	9,460	3,540	10,200
TDS (upper) (mg/L)	**10,000**		6,400-24,100		4,300-35,600		11,800-17,500	2,120	9,460	3,540	10,200
Metals (all mg/L)	**Guideline Values**	**Sth Seepage**		**Nth Seepage**		**TD3_Seepage**					
		Filtered (Range)	**Total (Range)**	**Filtered (Range)**	**Total (Range)**	**Filtered (Range)**	**Total (Range)**	**Filtered**	**Filtered**	**Filtered**	**Filtered**
Aluminium	**5**	0.01-0.05	0.01-0.36	0.01-0.05	0.01-29.5	0.01-8.34	0.03-29	0.01	0.01	0.04	0.01
Arsenic (lower)	**0.5**	0.002-0.024	0.002-0.031	0.001-0.012	0.002-0.018	0.001-0.17	0.001-0.016	0.003	0.002	0.007	0.014
Arsenic (upper)	**5**	0.002-0.024	0.002-0.031	0.001-0.013	0.002-0.019	0.001-0.17	0.001-0.016	0.003	0.002	0.007	0.014
Boron	**5**	0.05-0.32	0.05-0.17	0.05-0.16	0.05-0.16	0.14-0.41	0.19-0.26	0.12	0.7	0.3	0.51
Cadmium	**0.01**	0.0003-0.155	0.0006-0.157	0.0017-0.149	0.0017-0.927	0.0016-0.381	0.0344-0.511	0.0001	0.0001	0.0001	0.0001
Chromium	**1**	0.001-0.009	0.001-0.005	0.001-0.01	0.001-0.01	0.001-0.005	0.001-0.005	0.002	0.001	0.001	0.001
Cobalt	**1**	0.001-0.519	0.001-0.531	0.001-0.391	0.002-1.8	0.001-0.644	0.002-0.986	0.001	0.001	0.001	0.004
Copper	**1**	0.008-3.53	0.019-3.97	0.065-2.97	0.08-5.66	0.009-5.25	0.019-7.69	0.005	0.005	0.049	0.002
Lead	**0.1**	0.003-0.161	0.005-0.284	0.008-0.148	0.011-0.371	0.001-0.196	0.005-0.5	0.001	0.002	0.002	0.002
Mercury	**0.002**	0.0001 (no range)	0.0001 (no range)	0.0001 (no range)	0.0001 (no range)	0.0001 (no range)	0.0001 (no range)	0.0001	0.0001	0.0001	0.0001
Molybdenum	**0.15**	0.002-0.016	0.004-0.111	0.002-0.01	0.002-0.11	0.001-0.011	0.001-0.005	0.009	0.004	0.032	0.058
Nickel	**1**	0.001-0.241	0.001-0.248	0.001-0.218	0.001-0.447	0.001-0.191	0.036-0.27	0.001	0.002	0.001	0.003
Selenium	**0.02**	0.01-0.21	0.01-0.15	0.01-0.1	0.01-0.1	0.01-0.09	0.01-0.05	0.01	0.01	0.01	0.01
Uranium	**0.2**	0.044-0.097	0.027-0.1	0.004-0.007	0.003-0.037	0.001-0.005	0.001-0.012	0.01	0.084	0.086	0.062
Zinc	**20**	0.011-40.2	0.005-41.0	0.154-33.8	0.221-257.0	0.014-149.0	7.59-200.0	0.005	0.006	0.005	0.015

Data below / within guideline value
Data exceeds guideline value
*** These sites do not occur within the receiving environment as defined in the EE**

Table 4-2 Potential impacts to terrestrial flora / fauna - Comparison of sediment / soil concentrations to ANZECC 2000 sediment quality guideline values

	Guideline values															
Contaminant	**ISQG-Low**	**ISQG-High**	**WRD South 1**	**WRD South 2**	**WRD South 3***	**BSOC WRD NW 1***	**WRD North 2**	**WRD North 4**	**WRD North 5**	**Kings Gully Dyno 1***	**Kings Gully Clean 1***	**Kings Gully Clean 2***	**Kings Gully Clean 3***	**Kings Gully Clean 4***	**Kings Gully Clean 5***	**Kings Gully Clean 6***
METALS (mg/kg dry wt)																
Antimony	2	25	0.5	1.4	1.9	1.5	0.4	0.4	0.5	0.4	0.3	0.4	0.5	2.0	0.5	0.7
Cadmium	1.5	10	1.0	3	3.1	17.3	1.8	0.9	1.4	1.1	0.9	1.3	1.5	3.9	1.7	1.5
Chromium	80	370	6.2	15.9	12.3	18.3	9.2	5.3	8.6	8.8	4.2	5.2	4	8.6	6.2	8.3
Copper	65	270	489	2110	400	1210	222	241	373	438	261	534	443	1660	364	495
Lead	50	220	145	609	635	634	104	102	138	137	82.4	132	149	505	142	173
Mercury	0.2	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	21	52	5.1	17.8	13.8	21.9	7.8	4.5	5.7	7.6	4.9	4.8	3.6	9.6	5.6	7.1
Silver	1	3.7	0.2	0.9	1.5	2.7	0.2	0.1	0.3	0.2	0.1	0.5	0.2	1.4	0.1	0.2
Zinc	200	410	97.9	356	813	410	103	80.3	119	113	69.4	162	144	530	146	145
METALLOIDS (mg/kg dry wt)																
Arsenic	20	70	13.7	90.3	27.6	57.1	12.8	9.5	10.5	12.8	6.0	14.3	10.9	54.2	9.2	11.2

Exceeds both low & high thresholds
Exceeds low threshold
Below both low and high thresholds
*** These sites do not occur within the receiving environment as defined in the EE**

The following chemicals exceeded relevant environmental guidelines and were shortlisted as a CPEC:

- Water impacts to flora – root zone salinity, sodium adsorption ratio, aluminium, cadmium, cobalt, copper, selenium and zinc;
- Water impacts to fauna – fluoride, sulphate, total dissolved solids (TDS), aluminium, cadmium, cobalt, copper, lead, selenium and zinc;
- Sediment impacts to flora and fauna – copper, lead, cadmium and zinc.

It follows that those chemicals compared against guideline values that were within the typical expected range will not be considered further in this investigation.

Note that no consistent guideline values exist for the phytotoxicity of heavy metals. The phytoavailability of metals can be influenced by the nature of the metal, numerous soil characteristics, and the vegetation in question (Naidu *et al*., 2003). While there are potential guides, such as the ANZECC long- and short-term trigger values for irrigation water levels, these are designed to protect crops during irrigation, and are of limited use for the remnant vegetation on the site.

4.4 Chemical properties of contaminants of potential ecological concern

Information on CPEC concentration trends and chemical behaviour was used to generate a semi-quantitative risk score. The risk scoring methodology developed for this assessment was based on the 'biological effects assessment' presented in ANZECC 2000 which separates contaminants into either low or high risk categories to determine if remedial actions are required.

The following list of five criteria were used to rank relative risks for ecological receptors:

- Concentration trends (spatial and temporal);
- Environmental stability / persistence;
- Dissolution / adsorption potential;
- Bioaccumulation potential; and
- Known toxicity issues.

Each criteria was assessed with a numerical risk score (0, 0.5 or 1 and corresponding cell colour of green, orange or red), with scores for each criteria added together to reach a final risk score for each contaminant. Results of this assessment are presented in **Table 4-3**. The final risk score for each contaminant ranged from 0 to 5, with 0 representing the lowest risk and 5 the highest. Contaminants with a risk score of 2 or less were considered to fall into a low risk category, with no further action required. Contaminants with scores of 3 or above were considered further, with the following contaminants retained as a CPEC:

- Water impacts to flora and fauna –copper; and
- Sediment impacts to flora, fauna and aquatic ecosystems –copper.

The risk scores will be considered in further detail in terms of risk posed to the site-specific areas in the following sections.

Table 4-3 CPEC semi-quantitative risk matrix

CPEC	Receptor	Concentration trends (spatial & temporal)	Stability	Dissolution / adsorption potential	Bioaccumulation potential	Known toxicity issues	Risk score
Aluminium	Terrestrial flora & fauna	Significantly below guideline values at sites A1 and A3.	Aluminium can interact and be stabilised in biological environments by complexing with both low molecular mass chelants and high molecular mass peptides (Mujika *et al*., 2014)	Not applicable	Generally, aluminium is not bioaccumulated to a significant extent (ATSDR, 2011). Certain plants can accumulate high concentrations of aluminium in leaf tissue and eucalypts are sometimes used to treat heavy metals at rehabilitated mine sites. Aluminium does not appear to accumulate to any significant degree in cow's milk or beef tissue and is, therefore, not expected to undergo biomagnification in terrestrial food chains.	Toxicity is increased at low (<5.5) and high (>9) pH. Uptake and toxicity reduced with high water hardness. pH at site A3 is 8.61 and hardness is > guideline value (45 compared to 40 mg CaCO3/L, respectively). pH range at site A5 is 7.39-8.28 and hardness is > guideline value (1470 mg CaCO3/L). Stock can tolerate many metal elements in drinking water if they are not ingesting them in quantity in the diet, because accumulation in the body depends on the amount ingested from both food and water sources.	1.0
Cadmium	Terrestrial flora & fauna	Significantly below guideline values at sites A1 and A3.	Low solubility at neutral or alkaline pH values and highly soluble under acidic conditions.	Concentrations of particulate-bound cadmium exceed low trigger guideline values at WRD North 2.	Bio-accumulation generally increases with increasing water temperature; a reduction in pH leads to greater cadmium uptake in bacteria and algae. Tissue concentrations of cadmium decrease as	The toxicity of cadmium in water is dependent upon inumerous water characteristics. Hardness-adjusted cadmium trigger values are still significantly lower than tested concentrations.	2.0

CPEC	Receptor	Concentration trends (spatial & temporal)	Stability	Dissolution / adsorption potential	Bioaccumulation potential	Known toxicity issues	Risk score
					water hardness increases.	Cadmium is also a health and biomagnification risk if ingested by stock, howver this can be mitigated if copper and sulfate levels are also elevated.	
Copper	Terrestrial flora & fauna	Significantly below guideline values at sites A1 and A3.	Generally more soluble in acidic waters, and precipitates as copper hydroxides (Cu(OH)) at pH values above 6.5. Divalent 2 copper salts are mostly very soluble in water. Copper (II) carbonate, hydroxide and sulphide are insoluble in water, while copper sulphate and nitrate are soluble. Cupric chloride is highly soluble, while cuprous chloride is almost insoluble in water (ANZECC, 2000).	Concentrations of particulate-bound copper significantly exceed low trigger values at all sites within the receiving environment.	Copper is an essential element for growth and is readily bioaccumulated.	The toxicity of copper is dependent on local water quality conditions. Copper toxicity decreases with an increase in water hardness, increase in dissolved oxygen & when present in combination with other metals.	3.0
Fluoride	Terrestrial fauna	Measured concentrations are above guideline values at sites A1 and A3.	Very pronounced electron affinity of the means it interacts with almost every element in the periodic table. It is thought to be one of the main ions that allows for the solubilisation of beryllium, scandium, niobium, tantalum and tin in natural waters. Fluoride reacts readily with calcium	Not applicable	Fluoride is readily absorbed in the free fluoride ion form if ingested. Absorption of fluoride complexes depends on their lipid solubility, the ease with which dissociation from complexes occurs in acidic medium and on the ion size and charge. No	Excessive amounts of fluoride result in tooth damage in young growing animals and bone lesions that cause crippling in older animals, especially in cattle (ANZECC, 2000). Lameness and decreased feed and water intake (foraging, mastication and drinking become painful),	2.0

CPEC	Receptor	Concentration trends (spatial & temporal)	Stability	Dissolution / adsorption potential	Bioaccumulation potential	Known toxicity issues	Risk score
			to form the relatively insoluble calcium fluoride. Where phosphate is present, an even more insoluble apatite or hydroxy apatite forms. Fluoride also reacts very readily with aluminium, a property which is made use of in the removal of fluoride from water.		bioaccumulation data exists and it is generally accepted that milk and meat are free from significant accumulations of fluoride and hence are safe to consumers.	which result in a decline in growth and health. Fluorosis is less severe when drinking water is hard.	
Lead	Terrestrial flora & fauna	Significantly below guideline values at sites A1 and A3.	Most of the lead entering aquatic ecosystems is associated with suspended sediments, while lead in the dissolved phase is usually complexed by organic ligands.	Soluble lead is removed from solution by association with sediments and suspended particulates of inorganic and organic material, such as hydrous oxides and clays and humic acids, respectively. Adsorption is the primary factor responsible for low lead concentrations in the aquatic environment. In the presence of clay suspensions at pH 5 - 7, lead is precipitated and adsorbed, mostly as relatively insoluble hydroxides. Below pH 5 - 6 the formation of stable cationic species may prevent the formation of hydroxides. Lead concentrations in	Lead uptake by fauna organisms is dependent on the action of calcium; therefore, hardness is an important factor determining the toxicity of lead.	Decreasing pH increases the bioavailability of divalent lead, which is accumulated by aquatic biota. At a constant pH, solubility decreases with increasing alkalinity. pH and alkalinity at all sites are high. Hardness-adjusted lead trigger values are higher than tested concentrations at sites A1, A2 and A5. Site A3, adjacent to WRD North seepage has soft water and is therefore still above the guideline value.	1.5

CPEC	Receptor	Concentration trends (spatial & temporal)	Stability	Dissolution / adsorption potential	Bioaccumulation potential	Known toxicity issues	Risk score
				sediments from sites within the receiving environment were above the low guideline levels.			
Sulfate	Fauna	Significantly below guideline values at sites A1 and A3.	Dependant on water chemistry conditions	Not applicable	None	Sulphur is principally absorbed in the small intestines and inorganic sulphates are poorly absorbed. Sulphate has an adverse effect on the palatability of water below the concentration that causes acute toxic effects. Sulphate often causes diarrhoea in stock that are unadapted to sulphate waters.	0.5
TDS	Fauna	Significantly below guideline values at sites A1 and A3.	Dependant on water chemistry conditions	Not applicable	None	Saline water may detrimentally affect animal health and thus performance by rendering the water unpalatable. Symptoms of diarrhoea and dehydration due to initial exposure to saline waters are common.	1.0
Zinc	Terrestrial flora & fauna	Significantly below guideline values at sites A1 and A3.	The proportion of other forms such as inorganic compounds like ZnCO; stable organic complexes like Zn- 3 cysteinate; or	Not applicable	Zinc is an essential element for growth and is readily bioaccumulated.	Adsorption of zinc by hydrous metal oxides, clay minerals and organic materials is an important process in aquatic	2.0

CPEC	Receptor	Concentration trends (spatial & temporal)	Stability	Dissolution / adsorption potential	Bioaccumulation potential	Known toxicity issues	Risk score
			colloids like Zn -clay or Zn - humic acid, depends on the chemistry of the 2+ 2+ water. The greatest dissolved zinc concentrations will occur in water with low pH, low alkalinity and high ionic strength. Chemical speciation of zinc is affected primarily by pH and alkalinity.			ecosystems since it affects the bio-availability and toxicity of zinc.	

5 Receiving environment impacts

The risk assessment and review of contaminants of concern identified some existing and potential impacts to terrestrial flora and fauna receptors within the receiving environment. As shown on **Figure 1-1**, the current spatial extent of the impact of contaminants of concern is limited. Impacts from each of the CPECs are discussed in the following sections.

5.1 Aquatic ecosystems

As stated in section 2.4, the nature of the site means potential impacts on the aquatic ecosystem is difficult to quantify. The "flashy" temporal nature of the creeks, limited hydrological linkages to natural environments, and the dilution effects of flow events large enough to cause any such linkage, result in none of the CPECs being expected to have significant impacts on aquatic ecosystems. The only consistent water flow is the diversion drain channelling water to the KSOC, where the poor water quality is unlikely to host aquatic life that would be adversely affected by contaminated water. This area is not considered part of the receiving environment as per the definition of receiving environment provided in the EE.

5.2 Terrestrial flora

The risk assessment has identified one CPEC within the receiving environment; copper.

Seepage occurs in an area with the following vegetation communities:

- RE11.3X1b Low open woodland *Eucalyptus leucophylla* often with *Corymbia terminalis*. (No Concern at Present Biodiversity Status); and
- RE1.5.3 *Eucalyptus leucophloia* (snappy gum) low open woodland and woodland sometimes with shrubby understorey dominated by Acacia spp. (No Concern at Present Biodiversity Status).

As both of these communities naturally have sparse canopy trees and cover, it is unlikely that any direct effects on vegetation will impact the remnant status of the regional ecosystems, which are currently at a "No Concern" status. The most likely vegetation to be impacted (if any) are the shallow-rooted, grasses and shrubs. This type of vegetation would be most susceptible to higher ECs (including selenium salts) likely to occur in surface soil layers. Areas of very high salinity may have some impact on canopy trees (it is estimated that only two canopy trees occur directly adjacent to the alluvium) in the medium term where these trees are reliant on alluvial groundwater with elevated sulfates. Where this occurs trees would likely show signs of stress over time, primarily in leaf margins, with symptoms of necrotic spots, leaf bronzing and possible defoliation (The State of Queensland, Department of Natural Resources, 1997). Notwithstanding these potential impacts, it is unlikely that the remnant status of the vegetation would be impacted.

Copper can be taken up by plants, however, the variability of this process between copper, soil characteristics and plant types makes it difficult to be confident that high levels of copper will result in damage to vegetation. Potential impacts to flora generally only occur at high concentrations, and generally impacts are more likely to be associated with salt loading and associated stresses (The State of Queensland, Department of Natural Resources, 1997).

5.3 Terrestrial fauna

The risk assessment has identified one CPEC within the receiving environment; copper.

Potential vectors for fauna exposure include direct uptake from surface water or ingestion of plants that have taken up metals. It is considered unlikely that fauna would ingest contaminants directly from soils and sediments themselves. As previously outlined in **Section 2.4**, the Study Area and associated receiving environment do not contain any pools of permanent or semi-permanent standing water. Any water present within creeks is most likely to occur following rainfall events, and in these conditions suitable alternative water sources are likely to be available, while diffusion is likely to reduce the potential for uptake of high levels of contaminants.

Fauna may ingest plants that have accumulated metals, however, given the total area of potential impact, it is considered unlikely that sufficient volumes of plant material could be consumed to have toxic impacts.

6 Discussion and conclusion

One potential contaminant of concern for terrestrial ecosystems within the receiving environment was identified; copper.

Although there may be some mortality of shallow-rooted, annual flora within riparian areas where there are elevated salts, it is not anticipated that the remnant status of vegetation has, or will be impacted.

Due to the limited vectors for ingestion by fauna, and the relatively small area of impact within the broader landscape, it is not anticipated that fauna have, or will be significantly impacted.

The following action is recommended:

- Implement an adaptive management strategy comprising of ongoing monitoring of surface water and groundwater quality, impact assessment and implementation of mitigation measures, if required.

Note that monitoring of vegetation condition was considered as a recommendation, however compared with monitoring water quality this was considered to be a lagging indicator (as some vegetation may take several seasons to show signs of stress from contaminants) and therefore any mitigation measures proposed as a result of water quality monitoring program would be appropriate.

7 References

Agency for Toxic Substances and Disease Registry [ATSDR] (2011) Potential for human exposure. Toxic Substances Portal. Available online at: http://www.atsdr.cdc.gov/substances/index.asp

Amec Foster Wheeler (2015) Mount Isa Mines 2014 Biodiversity Study Report Biodiversity Assessment of ML8058

ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. October 2000.

Avenant-Oldewage A and Marx HM (2000) Bioaccumulation of chromium, copper and iron in the organs and tissues of *Clarias gariepinus* in the Olifants River, Kruger National Park. Water SA Vol. **26** No. 4 October 2000.

Mount Isa Mines (2011) EM Plan

Mujika, Jon I Elixabete Rezabal,b Jose M Mercero,a Fernando Ruipérez,c Dominique Costa,d Jesus M Ugalde,a and Xabier Lopeza et al. Aluminium in Biological Environments: A Computational Approach. Computational and Structural Biotechnology Journal 9 (2014): e201403002. PMC. Web. 14 Apr. 2016.

Naidu R, Oliver D, McConnell S (2003) Heavy Metal Phytotoxicity in Soils. Proceedings of the Fifth National Workshop on the Assessment of Site Contamination. NEPC 235-241.

Oberholster PJ, Myburgh JG, Ashton PJ, Coetzee JJ, Botha AM (2012) Bioaccumulation of aluminium and iron in the food chain of Lake Loskop, South Africa. Ecotoxicol Environ Saf. 2012 Jan;**75**(1):134-41. doi: 10.1016/j.ecoenv.2011.08.018. Epub 2011 Sep 15.

Taylor MP, Hudson-Edwards KA, Mackay AK, Kuypers TL (2007) Identifying and Managing Contaminants in Drinking Water Systems: The Leichhardt River Catchment, Mount Isa, Queensland: UNESCO-IHP Symposium, Paris, 12-14 September 2007.