

**APPENDIX 11-F
WATER STORAGE FACILITY SEEPAGE
MITIGATION MODELLING**

June 14, 2013

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Dear Mr. Murphy:

KSM Project
Water Storage Facility Seepage Mitigation Modelling

We are pleased to submit our report on groundwater modelling of seepage management systems for the assessment of the Water Storage Facility (WSF). Seepage losses from the WSF are controlled and captured with the use of low hydraulic conductivity grout curtains and dam core zones, seepage interception tunnels, drain curtains and a seepage recovery pond.

Yours truly,
KLOHN CRIPPEN BERGER LTD.



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EXECUTIVE SUMMARY

General

The Water Storage Dam (WSD) lies across the Mitchell Valley to a design crest elevation of El. 716 m with a spillway elevation of 706 m. The dam crest elevation is provided to attenuate the 200 Year Wet Year runoff inflows and to contain potential avalanche waves and routing of floods. Normal seasonal high water within the pond is less than El. 650 m during operations and closure periods.

This report presents the assessment of the seepage modeling for the Water Storage Facility (WSF) and, in particular, the effectiveness of the seepage management system (SMS) to capture contact water seepage that reports to the WSF from the mine area. The SMS assessment involved 3-D numerical modelling in FEFLOW with consideration of the following SMS design elements:

- seepage interception tunnels and drain curtains;
- WSD dam and Seepage Recovery Dam foundation grout curtains; and
- asphalt dam core.

Model Update

The 3-D model was updated in 2012 with a comprehensive review of new data collected in 2012, as well as existing data collected in 2010 and 2011, and the updated geology model for the site. The main geologic features that were identified with the geology review include:

- Dominant bedding planes strike broadly north-south and dip steeply westward (70 degrees).
- A calcareous siltstone and sandstone unit approximately 80 m to 90 m thick is present in the foundation beneath the dam. The calcareous sediments are bounded to the east by altered volcanics.
- The locations of three sub-regional inferred fault alignments, labeled in KCB (2012) as “Downstream fault”, “Central Fault”, and “Upstream Fault”.
- Mapped graphitic beds, and felsic dykes as discrete, discontinuous features.
- Mapped joint dip and dip directions, with three main joint sets.
- A revised overburden isopach and lithology distribution map was developed which included data from the 2012 seismic refraction profiles and 2012 drilling data and core analysis.
- Based on the higher persistence and more frequent occurrence of bedding parallel joint sets, it is reasonable to assume that there will be preferential flow in a north-south direction. Furthermore, from a hydrogeological perspective, the bedding parallel hydraulic conductivity (K_y and K_z) is assumed to be dominant. The K_x axis is oriented approximately perpendicular to the strike of the bedding.

Groundwater Flow System and Model Design

The groundwater flow system is expected to be strongly controlled by the significant topographic relief (up to 1,600 m) across the McTagg and Mitchell Valley catchments. Groundwater flow is characterized in four major systems:

1. Local scale, unconfined to semi-confined, groundwater flow systems within shallow glacial till and fluvial/alluvial/moraine sediments that are present in the low-lying valley floors.
2. Local scale, unconfined to semi-confined, groundwater flow systems within areas of highly fractured, faulted or locally dissolved and jointed shallow bedrock at depths of <100 m.
3. Intermediate scale, confined, groundwater flow systems within fractured, faulted and jointed bedrock at depths of between 100 m and 400 m.
4. Regional scale, confined groundwater flow systems within tight fractures and faults at depths of greater than 400 m.

Sulphurets Creek is interpreted to be a groundwater divide. This is based on the likelihood of this creek being a discharge feature for deeper, regional groundwater flow. With elevated groundwater levels throughout ridgelines surrounding the WSF, the conceptual model indicates that there will be lateral hydraulic containment of pond contact water.

An equivalent porous medium (EPM) method has been adopted. The three-dimensional, finite-element model platform FEFLOW was selected to meet the objectives and requirements of this seepage modelling investigation. The model domain covers a planar area of approximately 60.8 km² and encompasses the greater parts of the McTagg Creek catchment, the Mitchell Creek catchment and the northern side of the Sulphurets Creek catchment, as well as the WSF and KSM mine area.

Seepage Management System

The following SMS elements were incorporated:

- The asphalt core of the WSF dam was represented as a vertical zone of isotropic, low K (1.0×10^{-10} m/s) along the centerline of the dam.
- The water storage dam foundation grout curtain was represented as a near-vertical zone of isotropic, low K (1.0×10^{-07} m/s) beneath the centerline of the dam.
- Seepage interception tunnels (with drain hole curtains) were represented as discrete feature elements.
- The Seepage Recovery Dam was represented as a group of seepage face boundary conditions (to represent emergent seepage and collection at surface) with a low permeability foundation grout curtain.

Base Case Model Results

Table E.1 provides a summary of the model-predicted seepage losses and gains through the base of the WSF pond for the unmitigated and mitigated design case scenarios. The vertical flux into the pond represents the influx of regional groundwater into the pond, and the flux out of the pond represents contact water from the pond seeping back into the groundwater system. Design case simulations show that fluxes into the WSF pond exceed fluxes out (which are <3 L/s). These predictions support the concept that the Lower Mitchell Valley is acting as a convergent groundwater flow zone with upward hydraulic gradients resulting in lateral hydraulic containment in the vicinity of the canyon.

Table E.1 Vertical Flow in/out of the WSF pond – Pond Operating Level 650 m

Simulation	Flux into Pond (L/s)	Flux out of Pond (L/s)
Unmitigated Pond Case	160	<1.0
Pond SMS Design Case	106	2.7

The model under unmitigated conditions predicts the WSF to act as an efficient groundwater sink. The main driver for the modest increase in seepage from the system (WSF pond) to the Seepage Recovery Dam under base case mitigated conditions is the presence of the seepage interception tunnels, which draw seepage flows within the abutment towards them.

Table E.2 provides a summary of the model-predicted lateral seepage bypassing beneath the crest of the WSF and beneath the crest of the Seepage Recovery Dam (for all model layers) for the unmitigated and mitigation design base case. Total seepage capture rates from the seepage interception tunnels and Seepage Recovery Dam are also summarized in Table E.2. The total flow passing under the crest of the WSF is two to three orders of magnitude higher than the predicted seepage losses summarized in Table E.1 above. This differential indicates that water reporting to the Seepage Recovery Dam is dominated by regional groundwater. The total modelled flux bypassing the Seepage Recovery Dam is <1.0 L/s. This small flux is due to the predicted localized depressurization caused by the seepage interception tunnels. The locally depressed hydraulic heads above the seepage interception has led to a localized reversal of groundwater gradient beneath the Seepage Recovery Dam with flux towards the tunnels. The volume of groundwater captured in the tunnels and the recovery dam appears dominated by regional groundwater rather than contact water.

Table E.2 Total Flow beneath WSD and Flow Bypassing Seepage Recovery Dam – Pond Operating Level 650 m

Simulation	Total Flux Passing under WSD (L/s)	Total Seepage Capture (L/s) in Seepage Pond	Total Flux Bypassing the Seepage Recovery Dam (L/s)
Unmitigated Pond Case	2.4	50	<1.0
Pond SMS Design Case	64.4	81	<1.0

Forward, steady-state particle tracking was undertaken to assess seepage pathways and fate of contact water throughout the base of the WSF. The purpose of the particle tracking was to identify whether the contact water that seeps from the WSF daylightings within the catchment of the Seepage Recovery Dam, is intercepted in the tunnels, or bypasses these interception features and migrates beyond the Seepage Recovery Dam. Pathlines show the predicted flow direction of a non-reactive solute travelling via advection only. The simulation predicts that seepage reports to the seepage interception tunnels and Seepage Recovery Dam catchment. There is no predicted migration of contact water beyond the Seepage Recovery Dam.

Upper Bound Sensitivity Analysis

Sensitivity analysis runs were completed for “upper bound” scenarios to characterize/quantify the significance of parameter uncertainty on calibrated model predictions. The most significant areas of sensitivity present in the calibrated models are deemed to be:

- increased recharge rate;
- effects of variations in hydraulic conductivity (K);
- effects of variations associated with transmissivity of the sub-regional faults;
- effects of variations in quality of grout curtain construction;
- effects of increased K in the calcareous siltstone and sandstone beds underlying the WSF; and
- effects of varying persistence and interconnectivity of counter-bedding Joint Sets B and C.

Table E.3 provides a summary of the model-predicted lateral seepage bypassing beneath the crest of the WSF and beneath the crest of the Seepage Recovery Dam (for all model layers) for the unmitigated and mitigation design upper bound sensitivity scenarios. Total seepage capture rates from the seepage interception tunnels and Seepage Recovery Dam are also summarized in Table E.3.

The total flow passing under the crest of the WSD is two to three orders of magnitude higher than the predicted seepage losses. This differential indicates that most of the water passing under the WSD is regional groundwater driven by deeper flow systems which are recharged in higher elevations. The total flux bypassing the Seepage Recovery Dam is between 0.1 L/s to 0.5 L/s for the suite of upper bound sensitivity runs.

Table E.3 Upper Bound Sensitivity - Total Flow beneath WSF and Bypassing Seepage Recovery Dam

Simulation	Total Flux Passing under WSF (L/s)	Total Seepage Capture (Seepage Interception Tunnels plus Seepage Recovery Dam) (L/s)	Total Flux Bypassing the Seepage Recovery Dam (L/s)
Unmitigated Pond Case	2.4	50	<1.0
Higher Recharge Rate	130.9	81	<1.0
UBS Run 1: Sub Regional Faults	96	78	<1.0
UBS Run 2: Grout Curtain	53	93	<1.0
UBS Run 3: Kx	113	69	<1.0
UBS Run 4: Calcareous Dissolution	33	104	<1.0
UBS Run 5: Stuhini x5	113	72	0.5
UBS Run 6: Stuhini /5	17	81	-

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1 INTRODUCTION

Klohn Crippen Berger Ltd (KCB) has been retained by Seabridge Gold (Seabridge) to complete a Feasibility Study Level (FS) engineering design for the mine area and Water Storage Facility (WSF) at the Kerr-Sulphurets-Mitchell (KSM) project site. A groundwater modelling assessment was undertaken in 2012 as part of engineering design of the WSF. The objectives of the groundwater modelling assessment were:

- revise the 2011 prefeasibility level (PFS) hydrogeology conceptual model for the WSF and adjacent rock embankments using FS level site investigation data;
- construct and calibrate a local-scale (catchment-based rather than regional) numerical groundwater model to baseline pre-mining conditions;
- quantify the predicted unmitigated contact water seepage fluxes discharging from the WSF pond under maximum annual average pond height conditions;
- predict the effectiveness of the FS-level seepage mitigation system (SMS) in capturing contact water seepage fluxes; and
- report the seepage fluxes bypassing the SMS in the FS-level mitigation system.

1.1 Limitations and Use of Report

This report is an instrument of service of Klohn Crippen Berger Ltd. The report has been prepared for the exclusive use of Seabridge Gold Inc. (Client) for the specific application to the KSM Project. 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.

1.2 Background and Project Context

The proposed KSM mine Water Storage Facility (WSF) is located in the lower Mitchell Valley (Figure 1). The mountainous terrain for the site is typical of northwest British Columbia. The mine site is surrounded by very steep slopes below snow-capped ridgelines. These steep slopes meet in the "U-shaped" Mitchell and McTagg valleys shaped by glacial processes (Figure 2). Lower Mitchell Valley has been eroded into a steep bedrock canyon in the surrounding the Water Storage Dam (WSD) site.

The WSF is designed to store contact water generated from the McTagg Valley and Mitchell Valley Rock Storage Facilities (RSF), prior to transfer to the mine area Water Treatment Plant (WTP). The proposed WSD lies across the Mitchell Valley to a design crest elevation of El. 716 m (Figure 2) with spillway elevation of 706 m. The dam crest elevation is provided to store the 200 Year Wet Year runoff volume and to contain potential avalanche waves. Normal seasonal high water within the pond is less than El. 650 m during operations and closure periods.

The effectiveness of the SMS to capture contact water seepage was assessed as part of the WSF pre-feasibility study (PFS) (KCB, 2011a). The 2011 PFS conceptual groundwater model for the mine area and WSF site was based on geology and hydrogeology data obtained from site investigations completed up to and including 2010. The SMS assessment involved 3D numerical modelling in FEFLOW with consideration of the following SMS design elements:

- seepage interception tunnels and drain curtains;
- foundation grout curtains at the WSD and Seepage Recovery Dam; and
- asphalt dam core.

At that stage of investigation, the primary groundwater flow paths were considered to be associated with local opening of bedding planes, dissolution and fracturing within a localized zone of low rock quality, and increased permeability along the east abutment of the dam and pond area. The seepage assessment was undertaken with the objective of predicting seepage exiting from the pond and migrating through to a Seepage Recovery Dam situated down-gradient of the WSF. The area of the model domain included the KSM mine area to minimize boundary interference effects.

Rescan is conducting regional groundwater flow and solute transport modelling to assess site-wide environmental impacts. BGC has conducted mine area pit dewatering/depressurization modelling. KCB has been engaged to assess that seepage mitigation measures meet the dam design requirements for the WSF.

2 UPDATE TO HYDROGEOLOGY CONCEPTUAL MODEL

2.1 Review Process

A review of existing KCB mine area hydrogeology datasets and reports was conducted to enable the hydrogeology conceptual model to be updated. The following data/reports were considered during conceptual groundwater model development:

- KCB Mine area 2010 site investigation report (KCB, 2010a);
- KCB 2011 updated water storage facility hydrogeology modelling report (KCB, 2011a);
- KCB 2011 site investigation report for the mine area (KCB, 2011b);
- Rescan 2009 and 2010 hydrogeology baseline report (Rescan, 2010a);
- Rescan 2010 hydrogeological modelling report (Rescan, 2010b);
- KCB 2012 internal memorandum dated November 9, 2012: Geology of the WSF (KCB, 2012a);
- KCB 2012 mine area engineering final (Rev D): Draft Hydrology memorandum, dated October 3, 2012 (KCB, 2012b);
- KCB 2010 internal memorandum: KSM mine area hydrogeological modelling (KCB, 2010c);
- KCB mine area packer test database (including preliminary 2012 SI data); and
- KCB mine area hydrogeology database (including preliminary 2012 SI data).

As part of the data review process, 2012 and pre-existing site investigation data were scrutinized to identify data outliers and identify and account for any influencing data limitations (e.g. placing a lower confidence on open hole groundwater level measurements versus fully installed piezometers). The data quality review was focused primarily on groundwater level data and packer test data from the 2012 site investigation, with a review of existing published data from previous years for the purposes of integrating the various datasets. Figure 3 shows the drill hole and monitoring well sites that were included in the FS hydrogeology data review.

2.2 Site Geology Update

The 2012 site investigation included a revised naming convention for sedimentary rocks and metamorphosed sedimentary rocks encountered at the WSF site (KCB, 2012). The main rock types in the vicinity of the WSF are part of the Triassic - Stuhini Formation and are summarized as:

- siltstone (massive) and shale (foliated);
- altered volcanic rocks;
- calc-silicate hornfels;
- calcareous siltstone and sandstone with minor calc-silicate hornfels; and
- altered felsic dykes.

A bedrock geology map (including the rock types summarized above) for the local-scale WSF site is provided in Figure 4. This map shows:

- Dominant bedding planes to strike broadly north-south and dip steeply westward (70 degrees). The strike and dip of bedding is consistent given that the site is situated on the western limb of the north plunging McTagg Anticlinorium (assumed here to be an anticline).
- A calcareous siltstone and sandstone unit approximately 80 m to 90 m thick is present in the foundation beneath the dam. The calcareous sediments are bounded to the east by altered volcanics.
- The locations of three sub-regional inferred fault alignments, labeled in KCB (2012) as “Downstream fault”, “Central Fault”, and “Upstream Fault”. These three faults were inferred from topographic lineations and trend broadly north to south, and are assumed to be sub-vertical in association with the steeply dipping bedding planes.
- Mapped graphitic beds, and felsic dykes as discrete, non-continuous features.
- Mapped joint dip and dip directions.

A revised overburden isopach and lithology distribution map is provided as Figures 5 and 6. The revised overburden distribution has been updated (in comparison to PFS investigation) to include the 2012 seismic refraction profiles and 2012 drilling data and core analysis.

KCB (2012) have summarized three main joint sets for the WSF site and immediate west and east embankments. These sets have been identified as Set A, Set B, and Set C. Set A is bedding parallel (Dip 69°, dip direction 258°), Set B is counter bedding (Dip 21°, dip direction 106°) and Set C is a high-angle, cross cutting set (Dip 78°, dip direction 349°). Joint Set A has been interpreted as continuous and highly persistent. Joint Set B has been interpreted as less persistent (1 m-10 m) and discontinuous between thinly bedded rock as opposed to widely bedded rock (KCB, 2012). Joint set C is hard to detect in outcrop, core and aerial photography due to the high dip angle of 78°. KCB (2012) noted that LiDAR imagery shows high persistence in Joint set C in an area southeast of the dam footprint.

KCB (2012) conducted geomechanical observations of core log joint apertures and joint orientation for KC12-55 through KC12-60. These geomechanical observations are also complemented by analysis of optical and acoustic televiewer data from KC10-18A, KC10-33, and KC10-33A. The core and televiewer data support the presence of the three major joint sets. Although due to resolution limitations and other effects, the aperture measurements have been deemed to be inapplicable to estimating fracture flow (KCB, 2012), the joint set orientations are deemed to be relatively reliable. As summarized in KCB (2012), between 62% to 77% of all joints recognized in core are aligned with Joint Set A (based on 1552 observations). Alternatively, only 657 observations were aligned with Joint Sets B and C (23% to 38% of total recognized occurrence). Based on the higher persistence and more frequent occurrence of bedding parallel joint sets, it is reasonable to assume that there will be preferential fracture flow in a north-south direction within joint set A. Furthermore, from a hydrogeological perspective, the bedding parallel hydraulic conductivity (K_y and K_z) is thus assessed

as being dominant, as compared to counter bedding hydraulic conductivity (K_x). The antithesis of this assumption is tested in model sensitivity analysis.

2.3 Hydraulic Conductivity Review

2.3.1 Packer Test Data Review

2010 site investigations at the WSD site consisted of the drilling of seven geotechnical/hydrogeological drill holes in the WSF area (KC10-17A and B, KC10-18,18A and 18B, KC10-33 and 33A). These holes totaled 1,038 m in drilling length. Packer testing was completed at 37 locations in these drill holes and results were assessed in the 2010 Site Investigation Report.

The 2011 and 2012 site investigations included drilling and down-hole packer testing at 48 locations in seven new drill holes at the WSD site totaling 1,130 m of drilling. KC11-39, KC12-56, KC12-57, KC12-59 and KC12-60 were drilled into the east abutment and KC12-55 and KC12-58 were drilled into the west abutment. Packer testing was typically completed at less than 20 m intervals in all seven drill holes. The 2011 and 2012 packer tests were analyzed by KCB as part of the 2011 and 2012 site investigation reports.

Between 2008 and 2012, additional holes were drilled and packer tested in the WSF area by KCB and by others for environmental monitoring and other geotechnical purposes.

After review of the overall KCB mine area packer test database, a total of 209 packer test hydraulic conductivity (K) values were selected for inclusion in the WSF groundwater conceptual model. Of those 209 values, 98 were within the abutments of the WSF dam site, and 111 were outside of the direct area of interest and were considered to be regionally representative. Each individual packer test interval and test response was interrogated in terms of the following criteria and rock characteristics:

- depth of the test interval;
- core Recovery %;
- RQD %;
- rock type (2012 lithologic descriptions as per Section 2.2 nomenclature);
- diagnostic pressure versus flow response curves;
- drilling observations of fault zones, voids, fracturing and other evidence of structural deformation (e.g. slickensides); and
- core photos.

Table 2.1 and Figure 7 present statistical summaries of packer test-derived hydraulic conductivity values for each of the major rock types.

Table 2.1 Summary of Packer Test-derived Hydraulic Conductivity Values for Local-scale and Regional-scale Rock Types

Area Tested	Rock Type Tested	Number of Packer Test K Values	Minimum (m/s)	Geomean (m/s)	Standard Deviation (m/s)	Maximum (m/s)
Local-scale WSF abutments	Altered felsic dyke	2	1.3x10 ⁻⁰⁸	9.2x10 ⁻⁰⁸	4.4x10 ⁻⁰⁷	6.3x10 ⁻⁰⁷
	Altered volcanics	6	7.0x10 ⁻⁰⁹	7.0x10 ⁻⁰⁷	5.4x10 ⁻⁰⁶	1.0x10 ⁻⁰⁵
	Calcareous siltstone and/or sandstone (shale, metasilstone)	21	1.1x10 ⁻⁰⁸	7.5x10 ⁻⁰⁷	4.9x10 ⁻⁰⁶	1.0x10 ⁻⁰⁵
	Calc-silicate hornfels	3	2.5x10 ⁻⁰⁸	4.1x10 ⁻⁰⁸	3.4x10 ⁻⁰⁸	8.6x10 ⁻⁰⁸
	Metasilstone and/or metasandstone	10	2.9x10 ⁻⁰⁹	8.6x10 ⁻⁰⁸	3.3x10 ⁻⁰⁷	1.1x10 ⁻⁰⁶
	Siltstone and/or shale (sandstone, metasilstone)	56	1.0x10 ⁻⁰⁹	1.39x10 ⁻⁰⁷	3.5x10 ⁻⁰⁶	1.0x10 ⁻⁰⁵
Broader mine area	Regional undifferentiated Stuhini Formation	31	5.3x10 ⁻¹⁰	8.7x10 ⁻⁰⁸	1.7x10 ⁻⁰⁶	6.5x10 ⁻⁰⁶
	Regional Mine Area undifferentiated geology (including Hazelton Group)	77	2.9x10 ⁻⁰⁹	1.4x10 ⁻⁰⁷	2.4x10 ⁻⁰⁶	1.2x10 ⁻⁰⁵

2.3.2 Packer Test Trend Analysis

To evaluate spatial and vertical trends in hydraulic conductivity, hypotheses were established and tested. Table 2.2 summarizes the various hypotheses that were developed to explain K distribution trends in the local-scale WSF area and across the greater mine area.

Table 2.2 Summary of the Hypotheses Tested as part of Defining the Spatial and Vertical Trends in Hydraulic Conductivity

Hypothesis	How Tested	Outcome
Rock type and lithology control distribution of K	Separation of K data into rock types and presentation as box and whisker plot	Distinct K distribution contrasts were noted between rock types (Figure 7). This justified the inclusion of different rock type units as unique hydrostratigraphic units in the model domain.
K is depth-controlled	Scatter plot analysis of average packer test depth interval (mbgl) versus K (m/s)	With the exception of calcareous siltstone and sandstone beds, higher K (>1x10 ⁻⁰⁶ m/s) was associated with samples from depths of < 80m, while lower K (<1x10 ⁻⁰⁸ m/s) was typically associated with testing depths of >80m. A plot of regional, undifferentiated Stuhini formation tests shows a distinct reduction in K at depths >100 m with very low K (<1x10 ⁻⁰⁹ m/s) assessed at depths >400 m.
K is elevation-controlled (to test if K is associated with a laterally-continuous feature such as a low-angle thrust fault). This test dampens the effect of steep terrain across the site.	Scatter plot analysis of average packer test elevation (masl) versus K (m/s)	There is a broad negative correlation between K and elevation of testing interval. There are no distinguishable trends that suggest higher K zones or lower K barriers are occurring at certain elevations.

Hypothesis	How Tested	Outcome
There is correlation between RQD and K	Scatter plot analysis of average RQD % over the packer interval versus K (m/s)	There are three main data populations that stand out: 1) A large population of shales and siltstones of the Stuhini Formation which show a range of K that is largely independent of RQD. 2) A small population of low RQD (<50%) rocks that have higher K values in the 1×10^{-05} m/s to 1×10^{-06} m/s range. 3) A small population of mainly calcareous rocks that have a higher RQD (>70%) and higher K in the 1×10^{-05} m/s to 1×10^{-06} m/s range.
There is correlation between K and proximity to Mitchell Valley canyon.	Scatter plot analysis of distance to Lower Mitchell Creek canyon (m) versus K (m/s)	The calcareous siltstone and sandstone beds beneath the centerline of the WSF make up the only rock type that showed a positive correlation between higher K and proximity to the canyon. This suggests that the mechanism (physical or and/or chemical) for altering the calcareous rocks was/is in close vicinity to the canyon. The higher K ($>5 \times 10^{-7}$ m/s) packer tests for the calcareous rocks were all within 150 m of the canyon. Every lower K (3×10^{-7} to 1×10^{-8}) packer test in the calcareous rocks occurred at distances of 100 m to 400 m from the canyon.

The following K trends/relationships were established:

- rock type influences the K distribution shown in Table 2.1 and Figure 7;
- generally, higher K occurs at shallow depths of <100 m, and K generally reduces with increasing depth;
- there are no distinguishable trends that suggest higher K zones or lower K barriers are occurring at certain elevations; and
- there is a small population of mainly calcareous rocks that have a higher RQD (>70%) and correlated higher K in the 1×10^{-06} m/s to 1×10^{-05} m/s range. These are generally situated within close proximity of the canyon.

Appendix I provides the scatter plots developed to test the hypotheses. Figure 8 presents the hydrostratigraphic conceptual framework developed with intent to capture an adequate amount of detail in the geology and structure to account for a bulk of the K trends that were observed during hypothesis testing.

When considering packer test K distributions, the following should be noted:

- As previously noted in KCB (2011b), a number of packer tests were aborted due to the formation take exceeding the rig pump capacity or available water supply of approximately 1.5 L/s. The hydraulic conductivity in these zones will be higher than the maximum value recorded in successful tests. To capture these higher permeability zones and to reduce the potential downward skew in averaged K data that exclusion of these tests may cause, an

estimate of 1×10^{-05} m/s was adopted for these tests for this investigation. This estimate was derived from judgement of likely high K values in this type of hydrogeological setting.

- Fault K values were estimated to be 6×10^{-05} m/s based on previous investigations (Rescan, 2010b).

2.3.3 Overburden Data Review

Very limited field testing has been completed for overburden K values in the immediate vicinity of the WSF. For this investigation, previous Rescan testing (2009, 2010a, 2010b) and KCB testing of similar materials at the TMF site (KCB, 2012) were adopted for the overburden materials.

2.4 Groundwater Level Review

2.4.1 Previous (PFS) Observations and Findings

The PFS hydrogeological review (KCB, 2011a) noted contrasting groundwater level conditions between the WSF east abutment and the west abutment. Deeper, unconfined groundwater levels were noted on the east abutment, while shallower, confined groundwater levels were noted on the west abutment. KCB (2011a) also noted that deeper groundwater levels in the east abutment approximately correlated with the elevation of Mitchell Creek (approximately 65m below ground surface), suggesting potential interactions between the two features. Prominent observations of surface water runoff on the west abutment were not observed on the east abutment, and this was attributed to the assumption of percolation of water through exposed fractures and open bedding on the east abutment.

2.4.2 Groundwater Level Data Review and Updated Observations

Before modeling commenced, a review of groundwater level data was undertaken:

- To amalgamate the pre-existing groundwater level datasets (for monitoring sites installed up to and including 2010 SI) with the 2011 and 2012 groundwater level datasets.
- To re-interpret trends in groundwater levels and interrogate the previous observations in the east and west abutments using additional well sites added in 2011 and 2012.
- To confirm the monitoring well locations, monitoring well construction details, and where applicable, inclined hole details and vibrating wire piezometer (vertical depth correction) details.
- To evaluate the data against basic reliability criteria including:
 - ◆ whether the site is a completed piezometer or well, or an open hole;
 - ◆ whether artesian heads have been accurately measured or field estimated;
 - ◆ whether dry holes were totally excluded;

- ◆ notification of any issues or concerns with the well based on field notes (e.g. “well casing bent at ground surface”, or “flowing water sounds heard at depth”);
- ◆ location accuracy/inaccuracy (measured by surveyor or handheld GPS); and
- ◆ specific concerns about a particular measurement (unexplained outlier) that does not conform in the context of the historical database (e.g. a reading that is 50 m higher than expected for that time of year).

A total of 38 groundwater level monitoring sites were used as model calibration targets. Most groundwater level measurements have been recorded in the months of June/July and September/October over the period of 2008 to 2012. A review of pressure transducer data was conducted for:

- Rescan sites RES-MW-07A, RES-MW-07B, RES-MW-14A, and RES-MW-15A for a period from August 2009 to November 2010; and,
- KCB sites KC10-17 and KC10-18A from September 2011 to July 2012.

These continuous groundwater level records indicated a bi-modal distribution of peak annual groundwater levels associated with May/June and September/October. These periods correspond with peak seasonal groundwater recharge events: snowmelt in April/May and rainfall in the fall. This implies that baseline groundwater level data may be biased towards peak seasonal groundwater storage. However, the typical seasonal variations in individual sites varied between 1 m to 5 m, which is a fraction of the topographic relief across the mine area which is >1,500 m. An annual average groundwater level for each site based on all data was considered appropriate for this investigation. The annual averages are provided in Appendix II.

Figure 9 shows an interpolated map of annual average observed groundwater levels across the WSF and mine areas. This map was generated using averaged data described above and a kriging algorithm within the contouring program Surfer. This map shows a NE to SW trend in groundwater flow direction across the Mitchell Valley and broadly shows a convergence in flow towards the Upper and Lower Mitchell Valley floors, reinforcing the concept that these valley floors are predominant groundwater discharge zones.

Figure 10 shows an interpolated map of depth to annual average groundwater levels across the WSF. These levels include a combination of measurements of the water table and confined hydraulic heads. This map was also generated using a kriging algorithm within Surfer and shows that inclusion of the 2011 and 2012 data invalidates the previous assumption that lower groundwater levels were restricted to the east abutment, and indicates that there may not be an extensive high permeability zone along the east abutment. Three groundwater level depressions are noted in the WSF abutments, with one zone beneath the centerline of the dam. Deeper groundwater levels within a cluster of adjacent wells on both east and west abutments are noted for KC12-55, KC10-18B, KC1017, KC10-33, KC11-39, KC12-56 and KC12-57. Higher groundwater levels were noted directly to the west of this cluster (at KC10-18A on the west abutment, and KC12-60 on the east abutment), as

well directly to the east of the cluster (at KC12-58 on the west abutment and KC12-59 on the east abutment). The cause and spatial extent of these deeper groundwater levels may be associated with structural, bedding or dissolution related features located near the canyon walls.

2.5 Site Recharge and Discharge

Based on Rescan (2010b) and KCB (2011a), the lower areas of the U-shaped Mitchell and McTagg Valleys are interpreted zones of groundwater discharge. Rescan stream gauging data at sites in the upper Mitchell Valley (MC-1) and McTagg Valley (MCT-H1) indicates that base flow maintains stream flow during dry periods (Rescan, 2010b and KCB, 2011a).

Previous groundwater modelling investigations (Rescan, 2010b and KCB, 2011a) have established spatially-variable recharge estimates controlled by elevation. The supporting recharge conceptual model suggests that infiltration of snowmelt (and rainfall) preferentially occurs in elevated areas that contain open fractures or faults at the near surface. Observations of springs and seeps at breaks of slope throughout the Lower Mitchell Valley have been interpreted to be associated with groundwater discharge zones. The recharge values for the mine area are summarized in Table 2.3.

Table 2.3 Groundwater Recharge Estimates for the KSM Mine Area based on Previous Groundwater Modelling Investigations

Recharge Zone	Recharge Rate (mm/year)	% of Annual Average precipitation (1,655 mm)	Description
1	115	7%	<400 masl (Unuk River Valley)
2	128	8%	400 masl to 900 masl (valley bottom and no glacier coverage)
3	173	10%	900 masl to 1300 masl (mid-slope and no glacier coverage)
4	218	13%	>1300 masl (uplands and no glacier coverage)
5	40	2%	Glacier and permanent snow pack coverage

3 NUMERICAL MODELLING

3.1 Model Objectives

The objectives of the groundwater modelling assessment were:

- revise the PFS hydrogeology conceptual model for the WSF and adjacent rock embankments using FS site investigation data;
- construct and calibrate a local-scale (catchment-based rather than regional) numerical groundwater model to baseline pre-mining conditions;
- quantify the unmitigated contact water seepage fluxes discharging from the WSF pond under maximum annual average pond height conditions;
- predict the effectiveness of the FS-level seepage mitigation system (SMS) in capturing contact water seepage fluxes; and
- report the seepage fluxes bypassing the SMS.

3.2 Model Domain and Hydrogeological Area of Interest

The spatial extent of the WSF groundwater model domain was developed with the following criteria:

- The boundaries were intended to be far enough out to capture the dominant hydrogeological control of the steep mountainous terrain up to the ridgelines surrounding the McTagg Valley and the Upper and Lower Mitchell Valley.
- The boundaries were also extended out to include the locations of the planned rock storage facilities and mine pits/underground workings to assess potential interaction with the WSF.
- The specific area of interest within the model is the WSF and its surrounding embankments, and therefore, the model requires greater mesh refinement in this area for simulating WSF pond seepage fluxes and pathways, as well as inclusion of detailed seepage mitigation systems (e.g. grout curtain alignments and seepage interception tunnels).

The model domain and mesh configuration is shown in Figure 12.

3.3 Conceptual Hydrogeology Model

3.3.1 Geology Framework

The geological units used in the numerical model are summarized in Figure 8, and presented in Figure 4 (bedrock geology) and Figure 5 (overburden geology). Figure 8 lays out the hydrostratigraphic units as they are encountered across the model from west to east. The regional Stuhini Formation (light purple in Figure 4) is situated to the west, north and east of the local-scale WSF geology units. The local scale Stuhini Formation is characterized in dark purple in Figure 4. Within the WSF area, there are also metasediments, calcareous siltstone and sandstone, altered

volcanics, and felsic dykes. To the far east of the model domain, the regional mine area geology including the Hazelton Group has been integrated into one unit.

Each individual hydrostratigraphic unit has decreasing material properties with depth as described in Figure 8. The geometric mean, maximum and minimum K values provided per depth interval in Figure 8 are based on statistical analyses of local (WSF) and regional scale packer test K values.

3.3.2 Local Fracture Flow System

The conceptual model for the mine area groundwater system is primarily a fracture-flow system consisting of a low permeability bulk rock matrix (consisting of low hydraulic conductivity carbonaceous and calcareous shales and siltstones) intersected by a complex and anisotropic network of secondary porosity in the form of joint sets, fracture networks and faults. The degree of persistency, the level of interconnection and the density and aperture conditions of these joints/fractures/faults dictate the local-scale variability in hydraulic conductivity and therefore preferential flow paths within the WSF abutments.

3.3.3 Local-scale Dissolution of Calcareous Rocks

Fracture and fault networks that intersect soluble calcareous rock beneath the centerline of the dam have created localized dissolution openings, as witnessed in several areas in OTV data from KC10-33 (KCB, 2012). Drilling evidence supporting the presence of dissolution features includes televiewer imagery of enlarged fracture openings caused by dissolution at intersection of joints and circulation losses while drilling through these rocks. The spatial distribution of the features appears to be associated with intersections of structural features (joints). The presence of the dissolution features are incorporated in the model with the use of higher hydraulic conductivities within the calcareous unit and with the anisotropic parameters, which incorporates higher hydraulic conductivity along the main structural feature (e.g. bedding joints).

3.3.4 Groundwater Flow Systems

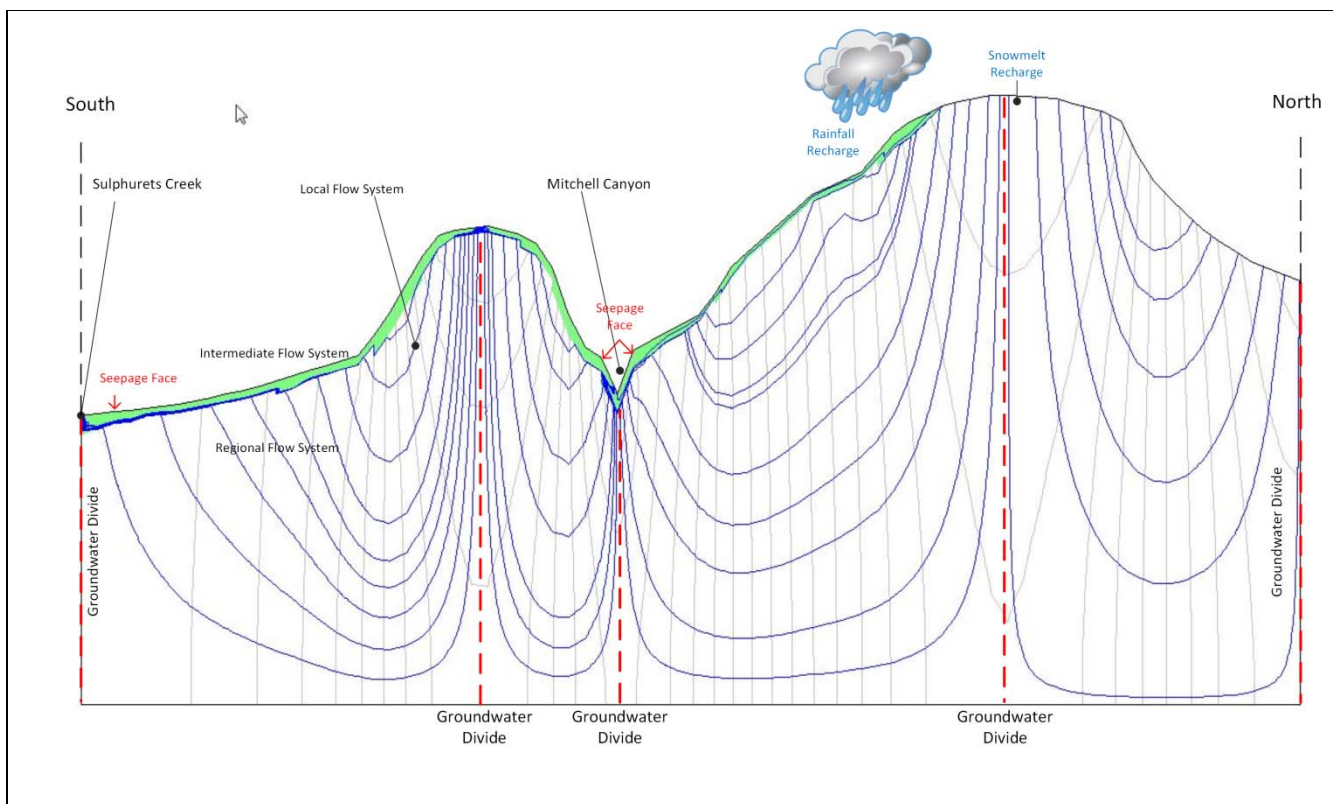
The groundwater flow system is expected to be strongly controlled by the significant relief (up to 1,600 m) across the McTagg and Mitchell Valley catchments. Groundwater flow is expected to be characterized in four major ways:

- Local scale, unconfined to semi-confined, groundwater flow systems within shallow glacial till and fluvial/alluvial/moraine sediments that are present in the low-lying valley floors.
- Local scale, unconfined to semi-confined, groundwater flow systems within areas of highly fractured, faulted or locally dissolved and jointed shallow bedrock at depths of <100 m.
- Intermediate scale, confined, groundwater flow systems within fractured, faulted and jointed bedrock at depths of between 100 m and 400 m.
- Regional scale, confined groundwater flow systems within tight fractures and faults at depths of greater than 400 m.

Groundwater flow directions are expected to be convergent from outer ridgelines which form physical (no-flow) groundwater divides, with flow inwards toward discharge areas in low-lying valley floors associated with Mitchell Creek, McTagg Creek, and Sulphurets Creek.

Figure 11 presents a scatter plot of hydraulic head versus ground surface elevation. This figure demonstrates that groundwater is a muted reflection of topography across the flow system, supporting the convergent groundwater flow conceptual model. The cluster of wells (circled) that deviate away from this straight line are the same grouping of wells with depressed groundwater levels discussed in Section 2.4.2 (last paragraph).

The schematic below provides a conceptual illustration of topographically driven flow mechanisms at site.



Schematic 1 Topographically Driven Flow Mechanism for Project Site

Sulphurets Creek is interpreted to represent a groundwater divide. This is based on the likelihood of this creek being a discharge feature for deeper, regional groundwater flow.

With elevated groundwater levels throughout ridgelines surrounding the WSF, the conceptual model indicates that there will be hydraulic containment of pond contact water on the flanks of the WSF. Due to surrounding terrain, this containment is expected to be most effective towards the north and east (higher elevations) of the site, and as well to the south of the site (moderately high elevations). As a result, any potential migration direction of seepage water from the WSF pond would thus be to the west and south-west, down-gradient of the WSD and toward the seepage pond.

3.3.5 Anisotropy

As discussed in Section 2.2, there are three main joint sets that have been identified in the abutments of the WSF. With regards to local-scale anisotropy, the following is assumed for the conceptual model:

- The predominant bedding-aligned Joint Set A is affiliated with K_y (broadly North-South) and K_z (vertical) and is expected to dominate the local groundwater flow system.
- The less predominant counter-bedding Joint Sets B and C are aligned with K_x (broadly West-East), with Joint Set C is also aligned with K_z (vertical).
- The consequence of the affiliation of the predominant joint set with K_y and K_z , is that groundwater flow will be preferentially in the north-south direction with limited cross-cutting fractures to facilitate east to west flow.

4 MODEL DESIGN

4.1 Representing Fractured Media

The KSM WSF groundwater flow system has been represented by an equivalent porous medium (EPM) method with a limited number of discrete high K embedded fault zones. This approach replaces the primary and secondary porosity and K distributions with a continuous porous medium having effective hydraulic properties (Anderson and Woessner, 1991).

One of the inadequacies of the EPM method is that although it replicates the behavior of a regional flow system well, it is less suitable to reproduce small scale variations in conditions. Given the complexity and scale of the WSF site relative to geological variations, the dominating control of the steep terrain on groundwater flow paths and the relative simplifications that have been made with regards to the hydrostratigraphy, the EPM approach is considered valid for this FS level. There is far too much geological variation across this site to justify using a discrete fracture (DF) modelling method or a dual porosity (DP) modelling method.

4.2 Model Code Selection

The model code requirements for the WSF seepage assessment included:

- numerical representation of three-dimensional flow within a mountainous setting with steep hydraulic gradients;
- ability to simulate discrete permeable features such as faults and tunnels;
- ability to simulate anisotropy;
- ability to numerically represent spatial variations in material hydraulic properties for both unconsolidated deposits and fractured/competent bedrock;
- ability to simulate flow in area surrounding WSF at a coarse level of model refinement, while concurrently simulating WSF seepage at a much finer level of model resolution;
- ability to conduct fluid flux analysis at discrete sections for seepage analysis, and to conduct particle tracking analysis to quantify source-pathway-receptor processes; and
- recognition as industry standard software.

The three-dimensional, finite-element model platform FEFLOW was selected to meet the objectives and requirements of this particular seepage modelling investigation.

4.3 Model Discretization

The model domain and mesh discretization are shown in Figure 12. The model domain covers a planar area of approximately 60.8 km² and encompasses the greater parts of the McTagg Creek catchment, the Mitchell Creek catchment and the northern side of the Sulphurets Creek catchment, as well as the WSF and KSM mine area.

The model domain boundary was chosen to capture the ridgelines on all sides of the WSF, as these natural features represent groundwater divides. It is anticipated that the steep terrain below these ridgelines will greatly influence the hydraulic gradients of the local, intermediate and regional groundwater flow systems. The model was designed in ARCGIS using all of the natural features (creeks, glaciers, overburden distribution, geology boundaries, faults etc.), and mine infrastructure features (pit limits, RSF limits, drains, tunnels, dams, grout curtain etc.) that were deemed influential in terms of the groundwater flow system, pond seepage and SMS effectiveness.

The model was discretized using six-noded 3D triangular finite elements resulting in 26,292 nodes per slice and 52,248 elements per layer. The pre-mining baseline model comprised 10 slices and 9 layers; resulting in 262,920 mesh nodes and 470,232 mesh elements for the entire model. A process of areal-based mesh refinement based on hierarchical areas of model interest was used to arrive at the final mesh configuration.

4.4 Model Layers

The model was constructed with 10 slices and 9 model layers for the pre-mining, baseline groundwater condition. The uppermost slice of the model was set as ground surface, and the base of the model was set at -700 masl.

Model slices were of variable elevation across the model domain and defined the upper and lower surfaces for each model layer. The layer thicknesses were based on the hydrostratigraphic model presented in Figure 8. Table 4.1 summarizes the assignment of model layer thicknesses and the hydrostratigraphic units represented in each layer.

Table 4.1 Summary of FEFLOW Model Layer Distribution

Model Layer	Thickness (m)	Hydrostratigraphic Units	Structural Features	Layer Setting
1	Varies	Unconsolidated deposits (overburden); surficial fractured bedrock	Sub-regional and regional faults	Phreatic
2	Varies up to 50 m	Local-scale WSF (Calcareous siltstones and sandstones; altered volcanic; shales and siltstones; metasediments) and regional undifferentiated Stuhini Formation and mine area geology (incl. Hazelton Group)		Unspecified
3	50m			Unspecified
4	50 m			Unspecified
5	50 m			Unspecified
6	100 m			Unspecified
7	100 m			Unspecified
8	100 m			Unspecified
9	Varies to a base elevation of -700 masl			Unspecified

4.5 Model Boundary Conditions

Boundary conditions are mathematical statements within the model domain and along boundaries of the domain that specify the dependent variable (head) or the derivative of the dependent variable

(flux). They constrain the inflows into and outflows from a model domain. The following boundary conditions were established in the mine area FEFLOW model:

- Constrained seepage face conditions were established in the low-lying U-shaped valleys associated with McTagg Creek, Mitchell Creek and Sulphurets Creeks (Schematic 1). The constraints on the seepage face dictate that once the water table levels intersect Slice 1 of the model, water is removed from the system and reports to the water balance as an outflow. This numerical representation of seepage faces is established to reflect the physical process of base flow contribution to surface water flow, or groundwater discharge at surface. If groundwater levels do not intersect topography at a seepage face boundary, outflow does not occur and the resulting hydraulic head represents the water table elevation.
- No flow boundary conditions were established on the outer vertical limits of the entire model domain to reflect groundwater divides, as shown in Schematic 1.
- Recharge was applied across Slice 1 according to the elevation-based precipitation model, at a rate equivalent to 7% to 13% of annual precipitation.

4.6 Sub-regional and Regional Faults

FEFLOW 2D (i.e. planar), quadrilateral, vertical, discrete feature elements were built into layers 1 to 7 of the 3D model to represent mapped and inferred sub-regional (within 500 m proximity of WSF) and regional scale faults (within model domain). The distribution of discrete feature elements included in the model domain is shown in Figure 12. The geological basis for faults was taken largely from the KCB geology memorandum, dated November 9, 2012 (KCB, 2012), and the conceptual understanding of the site described earlier.

All faults were modeled as vertical features and assigned a width (aperture) of 1.0 m with a K of 6×10^{-05} m/s. The high K values adopted for these features were not directly supported by field testing in the vicinity of the WSF, and were applied as conservative values to evaluate potential for preferential flow. Due to modelling limitations, the vertical representation used for the regional thrust faults several km to the east of the WSF used differs from their measured dips, however, the inferred, bedding-parallel, sub-regional faults in the vicinity of the WSF should be well represented, as these are expected to be sub-vertical (KCB, 2012).

5 PRE-MINE STEADY-STATE MODEL CALIBRATION

5.1 Pre-calibration Model Review

A process of iterative model adjustment was undertaken during the model development process to achieve confidence in the model performance, to confirm numerical stability, and to judge the models' ability to replicate the conceptual groundwater flow system in terms of groundwater flow patterns and regional scale head distributions. The model development process included sequential addition of complex model elements (outlined below), running of the un-calibrated model, and review of model boundaries and parameters and their influence on the predictive capacity of the model.

Model elements that were sequentially added and tested include:

- addition of terrain and base recharge;
- addition of layer geometry;
- addition of surficial geology;
- subsequent addition of deeper geology;
- addition of structural elements (faults); and
- addition of elevation-based recharge.

At the completion of the pre-calibration model review process, a more formal calibration process was undertaken.

5.2 Calibration Process and Metrics

Steady-state and pseudo-steady-state model calibration was performed by manually adjusting boundary conditions, layer settings, hydrostratigraphic zones and K values, and model recharge. The model was run in both confined, steady-state mode and phreatic, pseudo steady-state mode (long-term transient mode used to achieve steady-state flows and heads in the model). The following performance metrics were used to judge the quality of the model calibration:

- the Root Mean Squared Error and correlation coefficient (r^2) for the model-predicted versus observed hydraulic heads for 38 primary monitoring well locations;
- the systematic/unsystematic nature and magnitude of over-prediction or under-prediction of hydraulic heads at 38 calibration targets (observation points);
- the spatial distribution of model residuals (heads) plotted across the model domain;
- the predicted base flow (flux) at McTagg and Upper Mitchell Creek catchments, as compared to calculated base flow at the corresponding hydrometric stations;

- review of flownet sections throughout the model domain to confirm whether the groundwater flow system is honouring the conceptual model; and
- the water balance for the model domain.

5.3 Calibration Targets

Thirty-eight monitoring well calibration targets were used for head matching, with a further seven monitoring wells used as secondary calibration targets. The secondary calibration targets were not deemed to be reliable monitoring well sites due to a combination of factors including open hole well construction, inaccurate artesian head measurements (known to be artesian but not by how much), or dry wells. Figure 13 shows the locations of the thirty-eight calibration targets, seven secondary calibration targets, and an additional 15 seep locations provided by Rescan. The seep locations were used for verifying the model was able to simulate artesian conditions in the Upper Mitchell Valley.

Base flow estimates from two stream gauges, were used as calibration targets. Estimated base flow for stations MCT-H1 (McTagg Creek) and MC-H1 (Upper Mitchell Creek) are summarized in Table 5.1. These base flow estimates are reported as mean annual low flow estimates.

Table 5.1 Summary of Estimated Base flow for Hydrometric Stations MCT-H1 and MC-H1

Station ID	Estimated 7-day Annual Low Flow (m ³ /s)
MC-H1 (Upper Mitchell Creek)	0.14
MCT-H1 (McTagg Creek)	0.10

A trial-and-error calibration method was used with parameter values and boundary conditions adjusted incrementally to achieve a better match between calibration targets and simulated heads and flows.

5.4 Calibration Results and Statistics

Scatter plots of baseline predicted versus observed hydraulic heads are presented in Figure 14. Predicted steady-state, confined potentiometric surface plots for the calibrated model are shown on Figure 15. The statistics from the calibrated model are reported in Table 5.2. The confined steady state water balance error is less than 1%. However, when the model is run in pseudo steady state under unconfined conditions (as required for overburden and shallow fractured bedrock) the water balance errors are outside of conventional limits¹. Because of the importance of representing the water table in shallow fractured bedrock (particularly in the calcareous beds with a deeper water table) and overburden in the vicinity of the WSF, these water balance errors were acknowledged but no further effort was assigned to addressing their effect on the model. Given the complexity of the

¹ FEFLOW can report inaccurate water balance estimates in unconfined settings with steeply dipping layers (see BC modelling guidelines Chapter 5). The use of the phreatic or the variably saturated option can lead to numerical instability and/or non-convergence if the water table crosses model layers.

site geology, the uncertainty in true physical boundaries conditions, and the steep hydraulic gradients previously discussed, the overall calibration metrics indicate that the model is suitable for:

- replicating head and flux behavior at a catchment scale;
- predicting seepage fluxes from the WSF pond; and
- gauging the seepage capture effectiveness of the designed SMS.

Table 5.2 Summary of Steady-state Model Calibration

Statistical Metric	Calibration Metrics: Confined, steady-state model (units)	Calibration Metrics: Phreatic, steady-state model (units)
Number of primary head calibration targets	38	38
Number of secondary head calibration targets	7	7
Number of secondary seepage discharge targets	15	15
RMS	17.5 (%)	2.3 (%)
Correlation coefficient	0.736	0.997
Minimum Residual	-0.6 (m)	-0.3 (m)
Maximum Residual	-626.1 (m)	-65.5 (m)
Average Residual	-84.7 (m)	-9.5 (m)
water balance error	0.0001 (%)	32 (%)
Mitchell Creek base flow prediction	0.06 (m ³ /s)	0.36 (m ³ /s)
McTagg Creek base flow prediction	0.07 (m ³ /s)	0.18 (m ³ /s)

Note: Negative number indicates a model under-prediction.

5.5 Calibrated Hydraulic Parameters

Table 5.3 summarizes the calibrated hydraulic parameters for the upper seven layers of the model.

Table 5.3 Summary of Calibrated Hydraulic Parameters

Layer	Hydrostratigraphic Unit	Ky (m/s)	Kz (m/s)	Kx (m/s)
1	Glacial Till deposits	3.0x10 ⁻⁰⁷	3.0x10 ⁻⁰⁷	3.0x10 ⁻⁰⁷
1	Fluvial/alluvial/moraine deposits	1.0x10 ⁻⁰⁵	1.0x10 ⁻⁰⁵	1.0x10 ⁻⁰⁵
1	Fractured upper bedrock	2.0x10 ⁻⁰⁶	2.0x10 ⁻⁰⁶	2.0x10 ⁻⁰⁶
2-3	Regional undifferentiated Stuhini Fm (siltstones and shales)	2.9x10 ⁻⁰⁷	2.9x10 ⁻⁰⁷	2.9x10 ⁻⁰⁸
4		3.4x10 ⁻⁰⁸	3.4x10 ⁻⁰⁸	3.4x10 ⁻⁰⁹
5		1.6x10 ⁻⁰⁸	1.6x10 ⁻⁰⁸	1.6x10 ⁻⁰⁹
6		3.0x10 ⁻⁰⁹	3.0x10 ⁻⁰⁹	3.0x10 ⁻¹⁰
7		1.1x10 ⁻⁰⁹	1.1x10 ⁻⁰⁹	2.0x10 ⁻¹⁰
8-9		4.0x10 ⁻¹⁰	4.0x10 ⁻¹⁰	1.0x10 ⁻¹⁰
2-3	Regional undifferentiated mine area geology (incl. Hazelton Group)	8.1x10 ⁻⁰⁷	8.1x10 ⁻⁰⁷	8.1x10 ⁻⁰⁷
4-5		2.2x10 ⁻⁰⁷	2.2x10 ⁻⁰⁷	2.2x10 ⁻⁰⁷
6		4.3x10 ⁻⁰⁸	4.3x10 ⁻⁰⁸	4.3x10 ⁻⁰⁸
7		8.6x10 ⁻⁰⁹	8.6x10 ⁻⁰⁹	1.1x10 ⁻⁰⁹
8-9		2.9x10 ⁻⁰⁹	2.9x10 ⁻⁰⁹	6.0x10 ⁻¹⁰

Layer	Hydrostratigraphic Unit	Ky (m/s)	Kz (m/s)	Kx (m/s)
2-4	WSF Local-scale (calcareous siltstones and sandstones)	1.0×10^{-05}	1.0×10^{-05}	1.0×10^{-06}
5		1.2×10^{-07}	1.2×10^{-07}	1.2×10^{-08}
6		2.3×10^{-08}	2.3×10^{-08}	2.3×10^{-09}
7		4.6×10^{-09}	4.6×10^{-09}	9.0×10^{-10}
8-9		1.0×10^{-09}	1.0×10^{-09}	3.0×10^{-10}
2	WSF Local-scale (altered volcanics)	5.0×10^{-05}	5.0×10^{-05}	5.0×10^{-06}
3		1.3×10^{-05}	1.3×10^{-05}	1.3×10^{-06}
4		5.1×10^{-08}	5.1×10^{-08}	5.1×10^{-09}
5		2.0×10^{-08}	2.0×10^{-08}	2.0×10^{-09}
6		4.0×10^{-09}	4.0×10^{-09}	4.0×10^{-09}
7		8×10^{-10}	8.0×10^{-10}	2.0×10^{-10}
8-9		3×10^{-10}	3.0×10^{-10}	1.0×10^{-10}
2-3	WSF Local-scale (metasediments)	1.1×10^{-07}	1.1×10^{-07}	1.1×10^{-08}
4-5		5.7×10^{-08}	5.7×10^{-08}	5.7×10^{-09}
6		1.1×10^{-08}	1.1×10^{-08}	1.1×10^{-09}
7		2.3×10^{-09}	2.3×10^{-09}	5.0×10^{-10}
8-9		8.0×10^{-10}	8.0×10^{-10}	2.0×10^{-10}

For the purposes of this study and in recognition of the reduced understanding of ground conditions away from areas of field study, calibration results are considered satisfactory for the purposes of SMS performance assessment.

6 MINE DEVELOPMENT AND WSF SCENARIOS

6.1 “Pond SMS Design Case” Model Development

A “Pond SMS Design Case” to represent the operational/closure states of the WSF and the seepage interception systems was developed and assessed. In addition, an “Unmitigated Pond Case” was also developed which only included the mine area, the pond, the dam and the grout curtain. No seepage interception systems were included in the unmitigated case. Figure 16 shows the mine infrastructure and WSF layout represented in the groundwater model. In summary, the following mine area and WSF infrastructure features were simulated:

- maximum constructed Rock Storage Facilities (McTagg, Sulphurets and Mitchell);
- open pit and underground mine workings associated with the mine area;
- mine tunnels for water handling purposes (Diversion and Drainage Tunnels);
- water storage dam and asphalt core;
- WSF foundation grout curtain;
- WSF down-gradient Seepage Recovery Dam and associated foundation grout curtain; and
- seepage interception tunnels in the abutments down-gradient of the WSF.

6.1.1 Mine Area representation

The following revisions were made to the model to represent the mine area infrastructure:

- Rock storage facilities were represented in Layer 1 of the model with upper elevations equivalent to the maximum constructed height of the facilities, and lower elevations equal to pre-mine ground surface. An isotropic K of 2.0×10^{-5} m/s was applied and an elevation-based recharge (in accordance with the calibrated model) was applied to the surface of Slice 1.
- Mine workings were represented in the model as zones of depressed groundwater heads in accordance with the elevation of the final mine floors. Underground workings were represented as polygons of modified K (1.1×10^{-3} m/s). The model has not been calibrated for, or intended to be used for, dewatering predictions.
- Mine tunnels for water handling were represented as 3rd type fluid transfer boundary conditions with specified elevations at each node to represent the elevation of the pipe (assuming zero pressure within the tunnel). An additional constraint to disallow the tunnels to recharge the aquifer was applied.

6.1.2 WSF representation

The following revisions were made to the calibrated model to represent the WSF pond during the “Pond SMS Design Case” and “Unmitigated Pond Case” simulations:

- An infrastructure slice was added as the uppermost slice to the model. This was used to permit generation of the profile of the WSD and pond without needing to alter the elevations of the underlying geology layers.
- A constant-head, Dirichlet-type boundary condition with an elevation of 650 m was assigned to the newly added model slice 1 across the footprint of the pond.
- A zone of isotropic, high K (1.0×10^{-2} m/s) was applied in Layer 1 above the base of the pond (Slice 2) to represent the pond. Away from the pond, the new layer was seamlessly incorporated into the geological layer underneath.

The elevation of slice 1 was re-profiled to incorporate the dam. The dam was numerically represented as follows:

- A zone of isotropic, moderate K (2.5×10^{-5} m/s) was applied throughout the dam structure representing dam fill.
- The asphalt core was represented as a vertical zone of isotropic, low K (1.0×10^{-10} m/s) along the centerline of the dam.

6.1.3 Seepage Management Systems

The following SMS elements were incorporated into the “Pond SMS Design Case” model:

- The water storage dam foundation grout curtain was represented as a near-vertical zone of isotropic, low K (1.0×10^{-7} m/s) beneath the centerline of the dam. The curtain was inclined up-gradient at an approximate angle of 20 degrees from vertical in accord with proposed design.
- Seepage interception tunnels were represented as discrete feature elements that drain to the Seepage Recovery Dam.
- The Seepage Recovery Dam was represented as a group of seepage face boundary conditions (to represent emergent seepage and collection at surface).

6.2 “Pond SMS Design Case” Model Results

To assess the effectiveness of the SMS, the following analysis was conducted on the predictive simulations:

- Horizontal fluid flux analysis: to calculate lateral fluxes passing beneath the crest of the WSD, and also beneath the crest of the Seepage Recovery Dam.

- Vertical fluid flux analysis: to calculate fluxes passing into and out of the WSF pond.
- Tunnel discrete feature capture rate: to calculate the rate of water reporting to the seepage interception tunnels.
- Seepage Recovery Dam capture rate: to calculate the flux of water reporting to the seepage face boundary conditions established to represent the recovery dam.

6.2.1 Seepage from the WSF Pond

Table 6.1 provides a summary of the model-predicted seepage losses and gains through the base of the WSF pond for the unmitigated and mitigated design case scenarios. The vertical flux into the pond represents the influx of regional groundwater into the pond, and the flux out of the pond represents contact water from the pond seeping into the groundwater system. Both simulations show that fluxes into the WSF pond exceed fluxes out (which are <3 L/s). These predictions support the concept that the Lower Mitchell Valley is acting as a convergent groundwater flow zone with upward hydraulic gradients resulting in lateral hydraulic containment in the vicinity of the canyon.

Table 6.1 Vertical Flow in/out of the WSF Pond – Pond Operating Level 650 m

Simulation	Flux into Pond (L/s)	Flux out of Pond (L/s)
Unmitigated Pond Case	160	<1.0
Pond SMS Design Case	106	2.7

The model under unmitigated conditions predicts the WSF to act as an efficient terminal groundwater sink. The main driver for the modest increase in seepage from the system (WSF pond) to the seepage pond under design case mitigated conditions is the presence of the seepage interception tunnels, which naturally draw a degree of the seepage flows within the abutment towards them.

6.2.2 Seepage Bypassing WSF and Seepage Recovery Dam

Table 6.2 provides a summary of the model-predicted lateral seepage bypassing beneath the crest of the WSF and beneath the crest of the Seepage Recovery Dam (for all model layers) for the unmitigated and mitigation design case scenarios (for both initial and higher recharges). Total seepage capture rates from the seepage interception tunnels and Seepage Recovery Dam are also summarized in Table 6.2. The total flow passing under the crest of the WSF is two to three orders of magnitude higher than the predicted seepage losses summarized in Table 6.1 above. This differential indicates that water reporting to the seepage collection dam is dominated by regional groundwater. The total flux bypassing the Seepage Recovery Dam is <1.0 L/s for both cases. This low flux is due to the predicted localized depressurization caused by the seepage interception tunnels. The locally depressed hydraulic heads above the seepage interception has led to a localized reversal of groundwater gradient beneath the Seepage Recovery Dam with flux towards the tunnels. The rate of capture in the tunnels and the recovery dam appears dominated by regional groundwater rather than contact water.

Table 6.2 Total Flow beneath WSF and Bypassing Seepage Recovery Dam – Pond Operating Level 650 m

Simulation	Total Flux Passing under WSF (L/s)	Total Seepage Capture (L/s)	Total Flux Bypassing the Seepage Recovery Dam (L/s)
Unmitigated Pond Case	2.4	50	<1.0
Pond SMS Design Case	64.4	81	<1.0

6.2.3 Particle Tracking

Forward, steady-state particle tracking was undertaken on the base case models to assess seepage pathways and fate of contact water throughout the base of the WSF. The purpose of the particle tracking was to identify whether the contact water that departs from the pond daylight within the catchment of the Seepage Recovery Dam, is intercepted in the tunnels, or bypasses these interception features and migrates beyond the Seepage Recovery Dam. Pathlines show the predicted flow direction of a non-reactive solute travelling via advection only. Particle tracking does not consider secondary processes which will reduce the contaminant concentration with time and distance travelled (adsorption, diffusion, dispersion).

Figure 17 shows the particle tracking analysis with residence time presented as a colour gradational scale from 2 days to <365 days. The simulation predicts that emergent seepage reports to the seepage interception tunnels and Seepage Recovery Dam catchment. There is no predicted migration of contact water beyond the Seepage Recovery Dam under the conditions modeled. The general configuration of the pathlines shows that the system is dominated by the permeable calcareous siltstone and sandstone beds prior to being forced past the grout curtain and re-emerging on the downstream side of the grout curtain. From here, the particles enter the capture zone of the seepage interception tunnel within the east embankment.

6.3 Upper Bound Sensitivity Analysis

6.3.1 General

Sensitivity analysis runs were completed for “upper bound” scenarios to characterize/quantify the effects of parameter variations on calibrated model predictions. The most significant areas of sensitivity present in the calibrated model runs are deemed to be:

- uncertainty in recharge rate;
- effects of uncertainty in K (especially those related to vertical flux gradients beneath the pond and the transmissive capacity of the bedrock groundwater flow system receiving pond seepage);
- effects of uncertainty associated with sub-regional fault transmissive capacity;
- effects of variations in quality of grout curtain construction;

- effects of potential dissolution in the calcareous siltstone and sandstone beds underlying the WSF; and
- effects of varying persistence and interconnectivity of counter-bedding Joint Sets B and C.

The “upper bound” scenarios utilized an upper bound recharge rate. The specific “upper bound” sensitivity scenarios that were developed for this seepage assessment are summarized in Table 6.3.

Table 6.3 Summary of Upper Bound Sensitivity Runs

Condition Varied	Magnitude of Change	Purpose
Recharge rate increased	Increase recharge rate in the order of 2x's	Assess potential effect of higher recharge rate.
UBS Run 1: Sub-regional faults	Increase K by a factor of 10 for all inferred sub-regional faults.	Field testing in the area of the inferred central fault did not indicate higher hydraulic conductivity. However, this scenario is to determine if highly permeable faults can influence seepage conditions and create preferential pathways away from the WSF (and the SMS).
UBS Run 2: Grout curtain	Increase grout curtain K by factor of 10	Given potential difficulties in installing grout curtain in this terrain (into vuggy calcareous beds etc), this analysis will look at the impact of a less successful grouting program with an inefficient completion over the entire wall. This simulation does not predict the fate of seepage under a condition where a “hole” in the grout curtain results from failed installation.
UBS Run 3: Kx	Increase Kx by a factor of 10 for all foundation materials	To test the significance of a situation where counter-bedding Joint Sets B and C may be more persistent and interconnected resulting in a generally higher bulk K conditions across the rock mass.
UBS Run 4: Calcareous siltstones and sandstones tending towards dissolution	Increase K of Calcareous Unit "Zone A" by a factor of 100	To test the significance of increased spatial extent of dissolution along fractures and joints in the calcareous beds. The K used is typically at the higher end for carbonate rocks.
UBS Run 5: Regional and local Stuhini Fm	Increase K by a factor of 5	. To test the influence that regional bedrock flow systems have in controlling lateral hydraulic containment of the WSF pond.
UBS Run 6: Regional and local Stuhini Fm	Decrease K by a factor of 5	To test the influence that regional bedrock flow systems have in controlling lateral hydraulic containment of the WSF pond.

Note UBS = Upper Bound Sensitivity.

6.3.2 Upper Bound Seepage from the WSF Pond

Table 6.4 provides a summary of the model-predicted seepage losses and gains through the base of the WSF for the unmitigated pond case and mitigated design “upper bound” sensitivity scenarios (for high recharge case). The vertical flux into the pond represents the influx of regional groundwater into the pond, and the flux out of the pond represents contact water from the pond seeping into the groundwater system.

All scenarios show that fluxes into the pond far exceed the minor fluxes out of the pond. Upper bound sensitivity run 1 (Higher K faults) show an order of magnitude increase in flux out of the pond, as compared to the other sensitivity scenarios. These predictions generally support the conceptual model that the Lower Mitchell Valley is a convergent groundwater flow zone with upward hydraulic gradients stimulating hydraulic containment in the vicinity of the canyon. However, the potential for

a structural conduit does present a mechanism that may create either a “leaky sink” condition or an active pathway for emergent flow if fault continuity and hydraulic conditions are unfavorable.

Table 6.4 Vertical Flow in/out of the WSF Pond – Pond Operating Level 650 m

Simulation	Flux into Pond (L/s)	Flux out of Pond (L/s)
Unmitigated Pond Case	160	<1.0
Higher Recharge Rate Case	121	2.4
UBS Run 1: Sub Regional Faults	485	35
UBS Run 2: Grout Curtain	239	2
UBS Run 3: Kx	155	2
UBS Run 4: Calcareous dissolution	137	8.0
UBS Run 5: Stuhini x5	144	4
UBS Run 6: Stuhini /5	66	1.8

6.3.3 Upper Bound Seepage Bypassing WSF and Seepage Recovery Dam

Table 6.5 provides a summary of the model-predicted lateral seepage bypassing beneath the crest of the WSF and beneath the crest of the Seepage Recovery Dam (for all model layers) for the unmitigated and mitigation design upper bound sensitivity scenarios (for high recharge case). Total seepage capture rates from the seepage interception tunnels and Seepage Recovery Dam are also summarized in Table 6.5.

The total flow passing under the crest of the WSD is two to three orders of magnitude higher than the predicted seepage losses in Table 6.4. This differential indicates that most of the water passing under the WSD is probably regional groundwater driven by deeper flow systems which are recharged in higher elevations. The total flux bypassing the Seepage Recovery Dam is 0.1 L/s to 0.5 L/s for the suite of upper bound sensitivity runs. This low flux appears generally due to the localized depressurization caused by the seepage interception tunnels which have led to a reversal of groundwater gradient beneath the Seepage Recovery Dam with flux generally towards the tunnels. The rate of capture in the tunnels and the recovery dam is probably dominated by regional groundwater rather than WSF contact water.

Table 6.5 Total Flow beneath WSF and Bypassing Seepage Recovery Dam – Pond Operating Level 650 m

Simulation	Total Flux Passing under WSF (L/s)	Total Seepage Capture (Seepage Interception Tunnels plus Seepage Recovery Dam) (L/s)	Total Flux Bypassing the Seepage Recovery Dam (L/s)
Unmitigated	2.4	50	<1.0
Higher Recharge Rate	130.9	81	<1.0
UBS Run 1: Sub Regional Faults	96	78	<1.0
UBS Run 2: Grout Curtain	53	93	<1.0
UBS Run 3: Kx	113	69	<1.0
UBS Run 4: Karstification	33	104	<1.0
UBS Run 5: Stuhini x5	113	72	0.5
UBS Run 6: Stuhini /5	17	81	-

6.3.4 Particle Tracking

Forward, steady-state particle tracking was undertaken on the upper bound sensitivity runs to assess seepage pathways and fate of contact water WSF as compared to the base case condition. Figure 17 shows the particle tracking analysis for the base and high recharge cases and Figure 18, 19 and 20 shows the outcomes of the particle tracking analysis for the 6 UBS Runs. Key notes are provided:

- UBS Run 1, Figure 18 (sub regional faults) shows that the central inferred fault that cuts across the valley has the potential to redirect flux in a southwards direction towards Sulphurets Creek. This fault is inferred, and its presence has not been verified in the field. If the fault is present, is open (i.e. extensional rather than compressional), and is not sealed or filled with gouge, then there may be potential for redirection of seepage away from the WSF.
- UBS Run 2 Figure 18 (grout curtain) does not indicate any significant excursion from predicted performance under the design case grout curtain for either of the calibrated and high recharge model. Particle tracks are predicted to be intercepted before the seepage collection dam.
- UBS Run 3 Figure 19 (Kx) indicates no change to predicted particle tracks. Increasing bulk permeability for foundation materials would be expected to observe an increased flux departing the facility (consistent with Table 6.5). However, as long as regional groundwater conditions dominate and the system retains performance as a groundwater sink, seepage from the facility is predicted to be intercepted.
- UBS Run 4 Figure 19 (dissolution) shows greater seepage reporting to the SMS elements as would be expected. This scenario indicates the SMS is capable of managing such conditions under the premise that SMS infrastructure is correctly placed.
- UBS Run 5 & 6 Figure 20 (Stuhini x5 & /5) indicate little impact to predict particle tracks with a similar amount of water reporting to SMS infrastructure in both cases (Table 6.5).

7 ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations are associated with the groundwater modelling completed for this investigation:

- The physical process of interflow is not explicitly simulated by the model.
- Recharge from the creeks is assumed to be a minor component of the water balance and has been ignored in the present model.
- The dynamic nature of the recharge cycle has not been accounted for. The snowmelt and late-season precipitation recharge events have not been separated. It is likely in reality, that the snowmelt will be a more effective recharge source than the late-season precipitation and that recharge will be generated more in the freshet cycle as melt water enters into fractures in the bedrock, than the more rapid precipitation cycle which will be strongly runoff-dominant.
- Evapotranspiration has not been explicitly modelled, but rather included as part of the effective recharge.
- The ridgelines have been assumed as no flow boundaries and that regional discharge is to McTagg, Mitchell and Sulphurets surface water features in areas of low relief. Underflow of the entire system was not considered.
- The WSF pond has been simulated as a constant head boundary of 650 m elevation (highest seasonal pond level).
- Faults, bedding planes and fracture/joint planes that are sub-vertical have been represented as vertical features due to limitations of FEFLOW.
- Geology Conditions:
 - ◆ This investigation has not considered the effects of increased (stimulated) permeability in fractures and joints. Stimulated permeability is associated with pressure dilation of fractures and joints once pressure is applied e.g. while the pond is in operation and into closure. The background fracture K 's in baseline conditions have only been considered.
 - ◆ The potential for increased K within the calcareous bedrock unit is valid. Failure to pressurize during some packer tests, instances of losing circulation during drilling, and OTV evidence of localized dissolution on some joints suggest that localized dissolution features may be present in the vicinity of the WSF calcareous bedrock unit.
 - ◆ The inferred sub-regional faults in the vicinity of the WSF have been included in the model and these faults are assumed to be conduits for groundwater flow, although their true capacity to transmit or contain groundwater is uncertain (only one test, which indicated low k , was conducted in one fault) and will need to be further tested.

8 CONCLUSIONS

The model scenarios assessed, both base case and upper bound cases, predict that the WSF is hydraulically contained within the Lower Mitchell Valley groundwater discharge zone. Analysis of pond seepage rates, lateral seepage rates, and particle tracking analysis indicate effective hydraulic containment of WSF pond seepage and capture of losses by the Seepage Recovery Pond.

The structural influence of the inferred faults was identified as an upper bound element in the sensitivity case. It is possible that extremely high permeabilities on the faults could create a localized flow-through system with the potential to increase seepage away from containment structures and into the bedrock groundwater flow system. Alternatively, faults may behave as barriers to groundwater flow where they are sealed (through burial or metamorphism), or infilled with gouge. Currently, all faults identified within the WSF have been inferred based on site investigation data and terrain interpretation. Current site investigation data does not suggest that the inferred faults have high permeability.

The influence of the potential for localized dissolution features was identified as an upper bound element in the sensitivity case. It is possible that localized features will increase the overall bulk hydraulic conductivity of the calcareous bedrock unit. Currently, all features identified appear to be localized and not spatially extensive.

The interpreted conceptual hydrogeological model simulating depressed groundwater levels beneath the centerline of the dam (identified in Section 2.4.2) should continue to be assessed as future site investigation and monitoring data are collected to further confirm that the groundwater model simulates site conditions.

The complexity and nuances of any seepage mitigation design typically require commissioning and management to rely on an observational approach to performance. Systems do not perform exactly as predicted – this is a function of the variability of hydrogeology away from control points (drill holes) and the broad nature of underlying assumptions and assertions required within the modelling domain. It is neither practical nor efficient to attempt to replicate the model determined design in a practical context without supporting construction with close observation and design modifications as needed.

9 CLOSING

This report provides a description of the hydrogeological model used to develop a 3-D FEFLOW groundwater model for the Water Storage Facility. Values for pre-mining groundwater fluxes are presented and values for base case, sensitivity case and upper bound seepage fluxes and seepage losses past the seepage management systems are presented.

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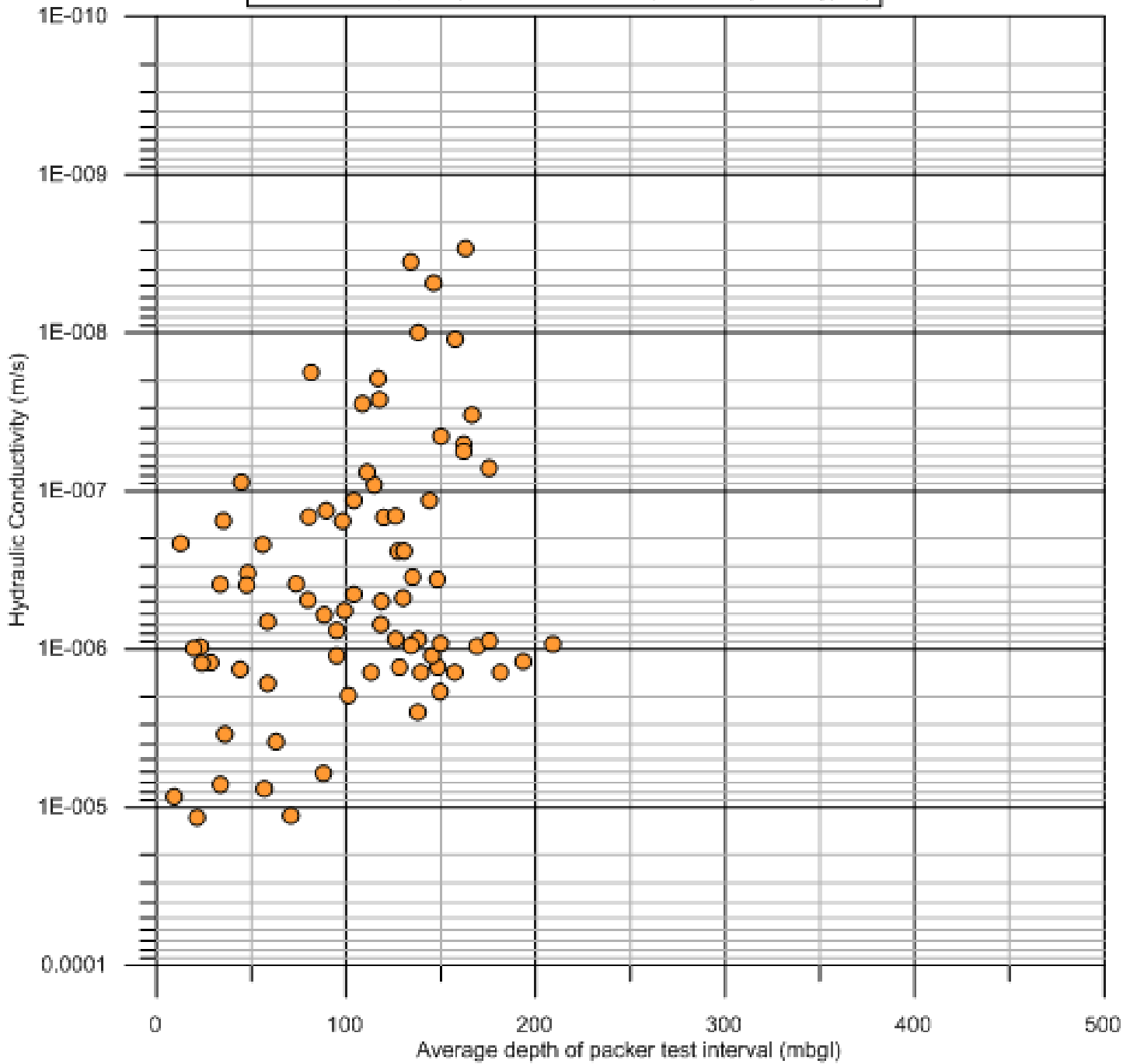
Graham Parkinson, P. Geo., P. Geoph
Project Manager



APPENDIX I

Hypotheses Scatter Plots

KSM Water Storage Facility: Regional Bedrock
Plot of K vs Depth of packer test interval (classified by rock types)

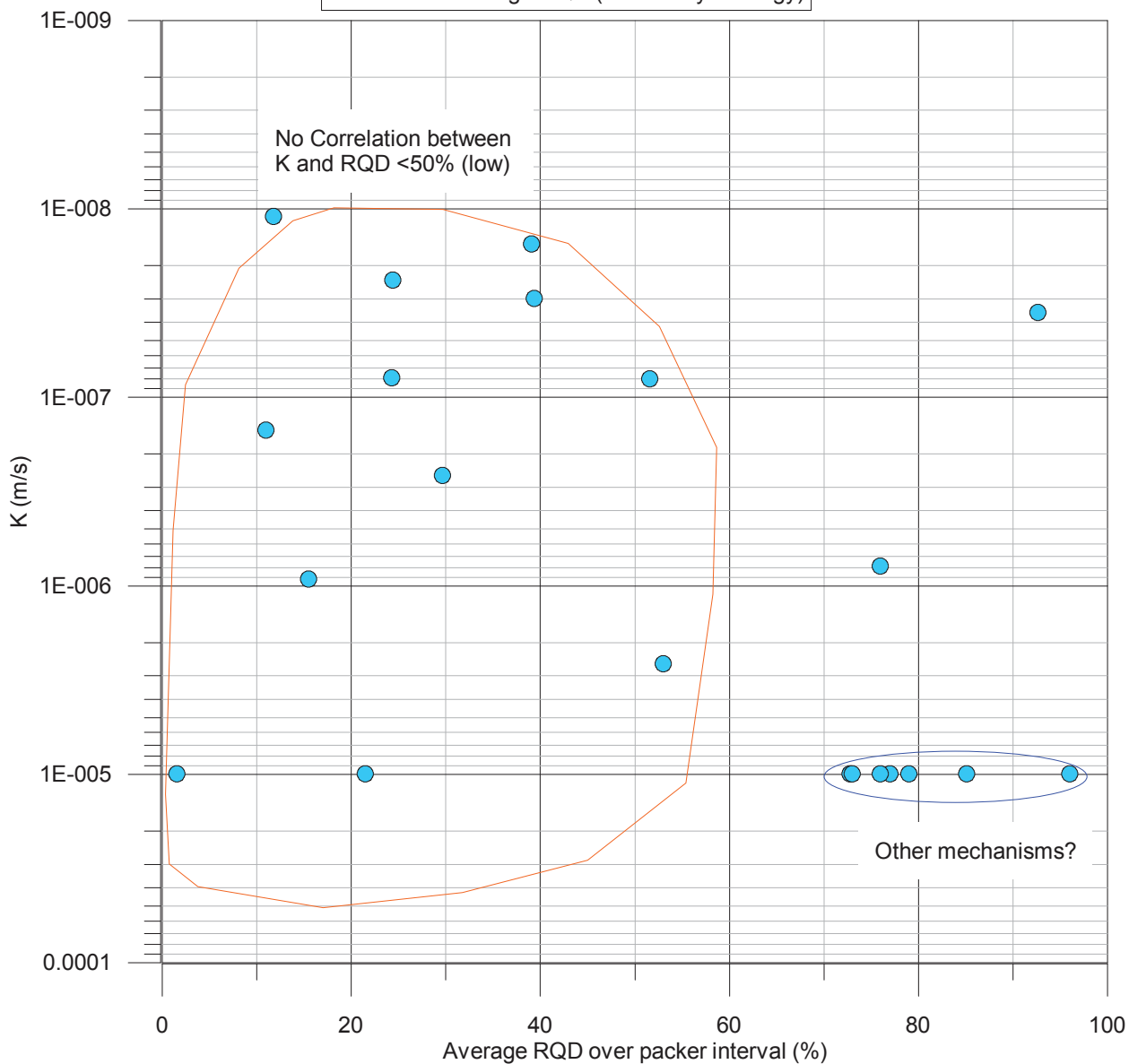


- Regional undifferentiated Stuhini Formation
- Undifferentiated Mine Area Geology

APPENDIX II

Hydraulic Conductivity Cross Plots

KSM Water Storage Facility
Plot of K vs Average RQD (classed by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasiltstone)

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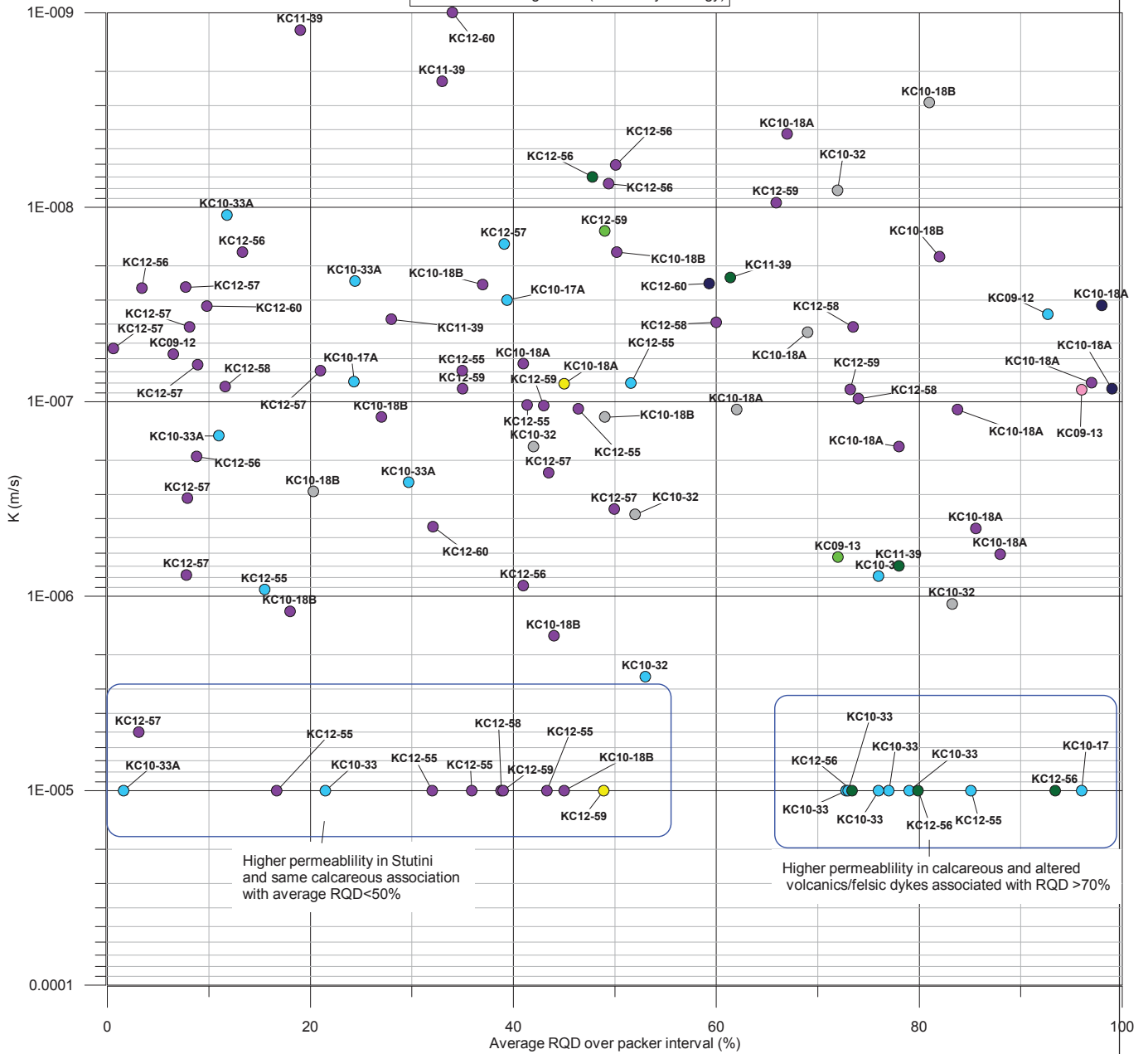
CLIENT

SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT	KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling	
TITLE	KSM Water Storage Facility (WSF) Plot K vs Average RQD	
PROJECT NO.	M09480A04	FIGURE NO.
		APPENDIX II (a)

KSM Water Storage Facility
Plot of K vs Average RQD (classed by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasiltstone)
- Calc-silicate hornfels
- Metasiltstone and/or metasandstone
- Sandstone
- Siltstone and minor Shale (graphitic)
- Siltstone and/or shale (sandstone, metasiltstone)

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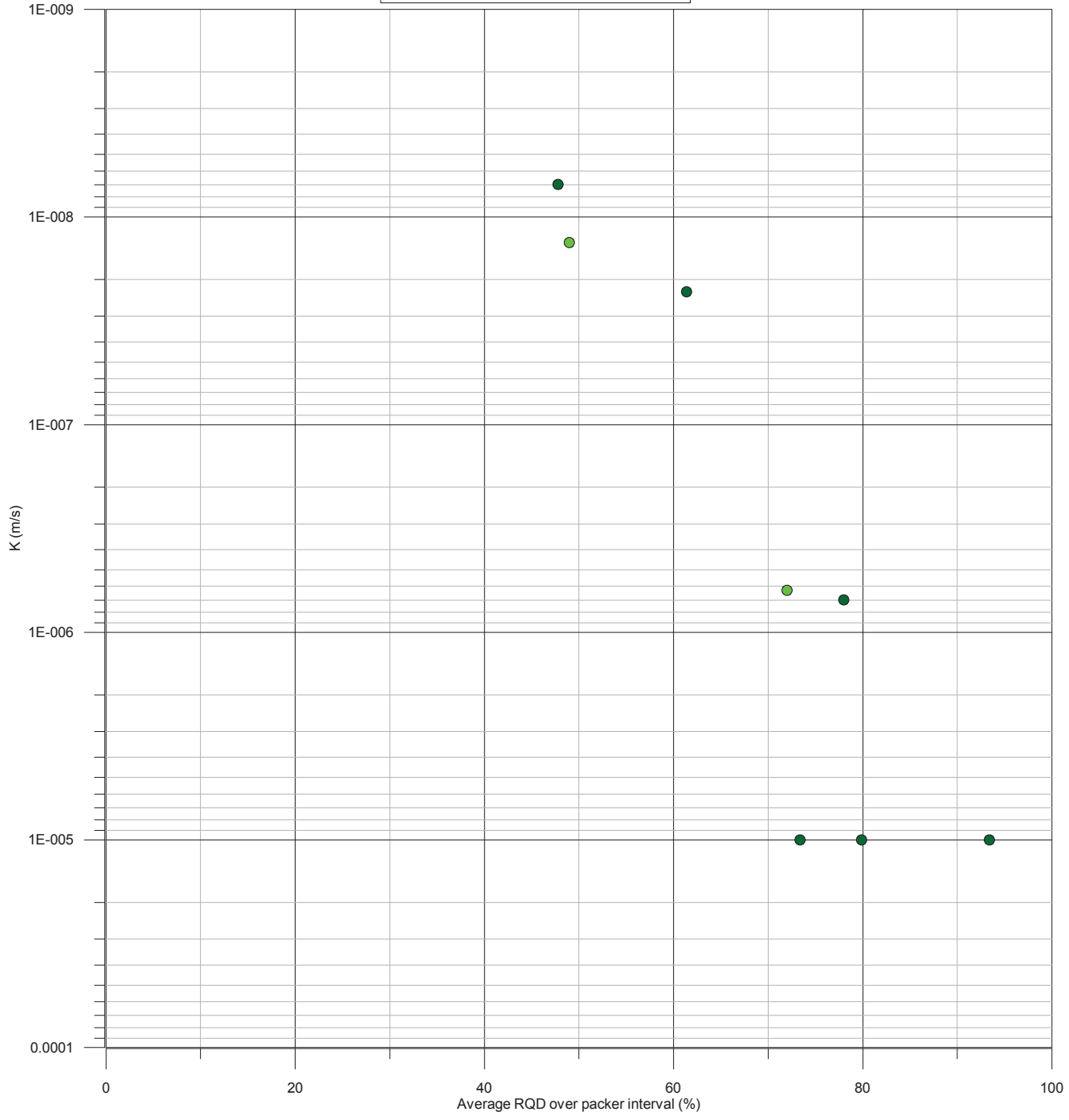
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Average RQD	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (b)

KSM Water Storage Facility
Plot of K vs Average RQD (classed by lithology)



- Altered felsic dyke
- Altered volcanics

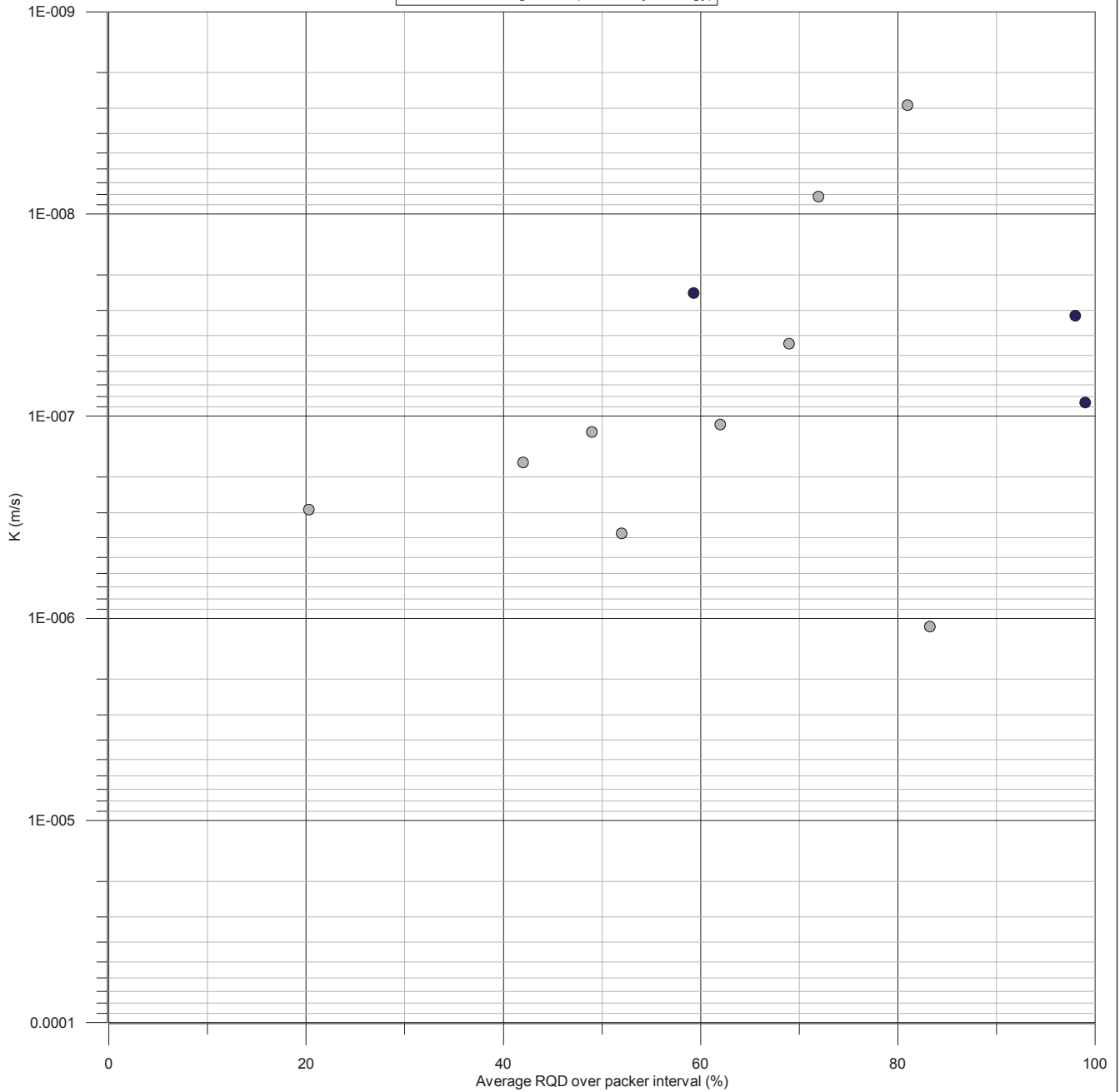
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF)	
	Plot K vs Average RQD	
PROJECT NO.	M09480A04	FIGURE NO.
		APPENDIX II (c)

KSM Water Storage Facility
Plot of K vs Average RQD (classified by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasiltstone)
- Calc-silicate hornfels
- Metasiltstone and/or metasandstone

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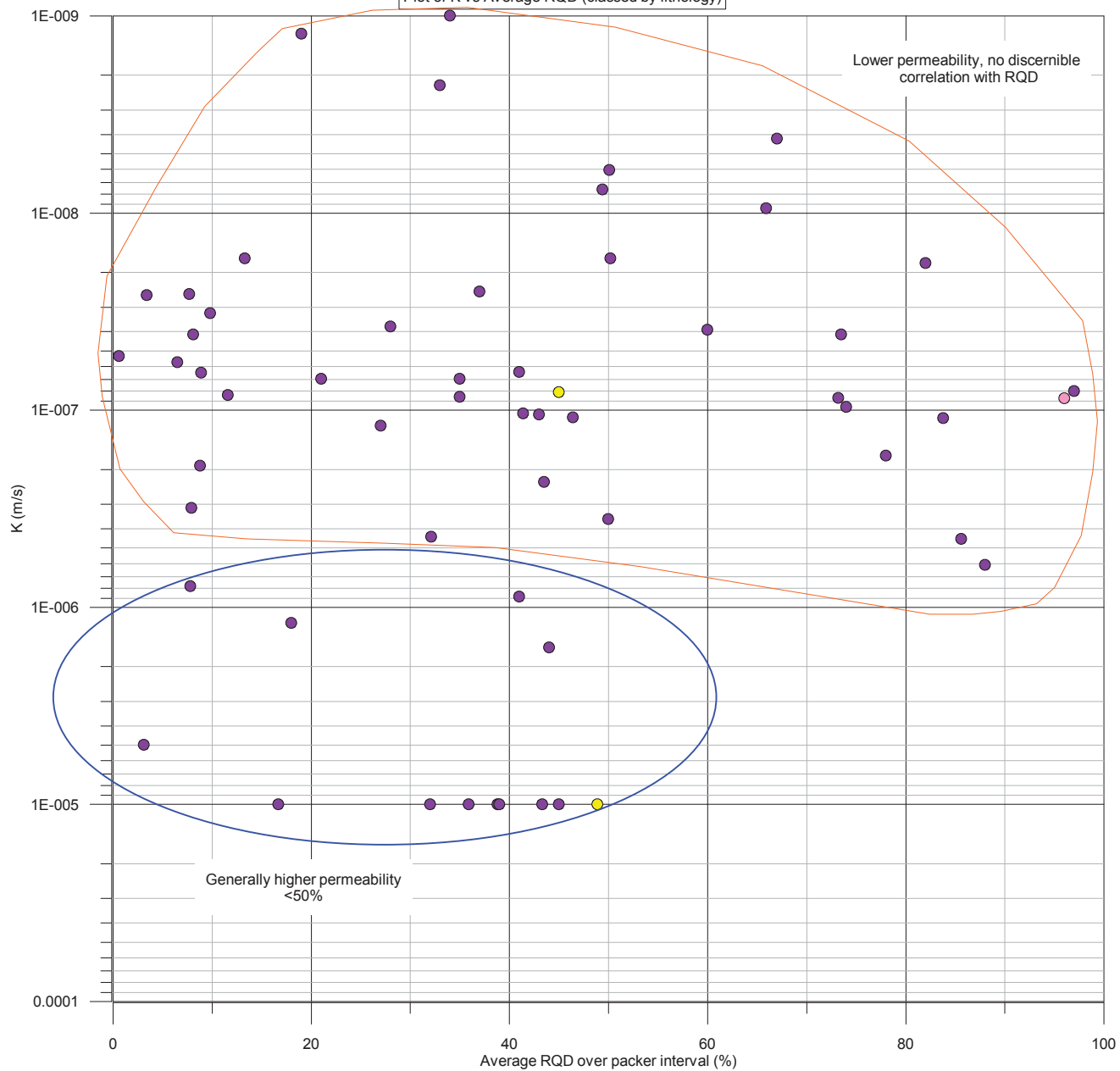
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PROJECT	KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling	
TITLE	KSM Water Storage Facility (WSF) Plot K vs Average RQD	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (d)

KSM Water Storage Facility
Plot of K vs Average RQD (classed by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasiltstone)
- Calc-silicate hornfels
- Metasiltstone and/or metasandstone
- Sandstone
- Siltstone and minor Shale (graphitic)
- Siltstone and/or shale (sandstone, metasiltstone)

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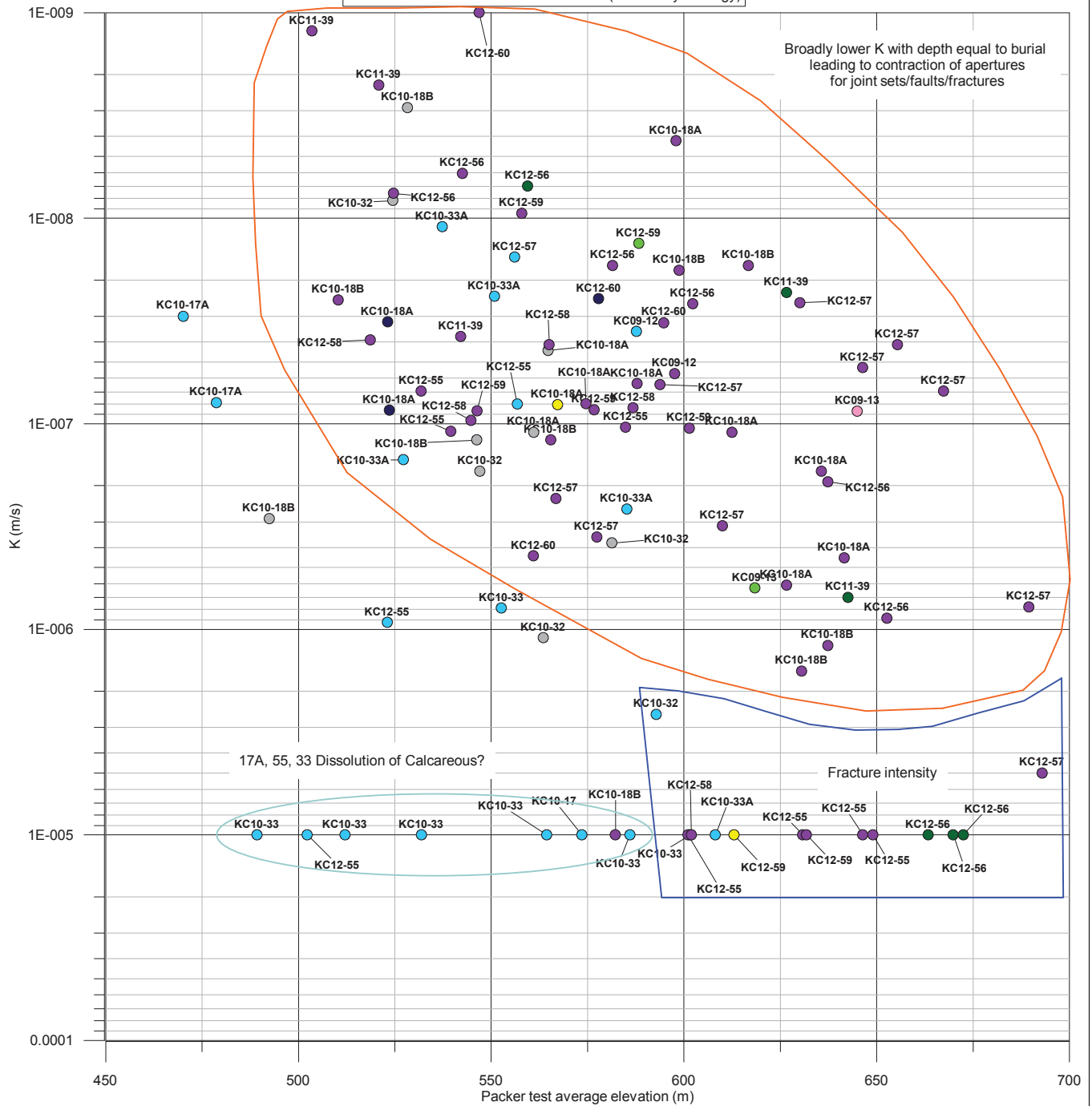
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SEABRIDGE GOLD



PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Average RQD	
PROJECT NO.	M09480A04	FIGURE NO.
		APPENDIX II (e)

KSM Water Storage Facility
Plot of K vs Packer test elevation interval (classed by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasilstone)
- Calc-silicate hornfels
- Metasilstone and/or metasandstone
- Sandstone
- Siltstone and minor Shale (graphitic)
- Siltstone and/or shale (sandstone, metasilstone)

TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED DECEMBER 2012

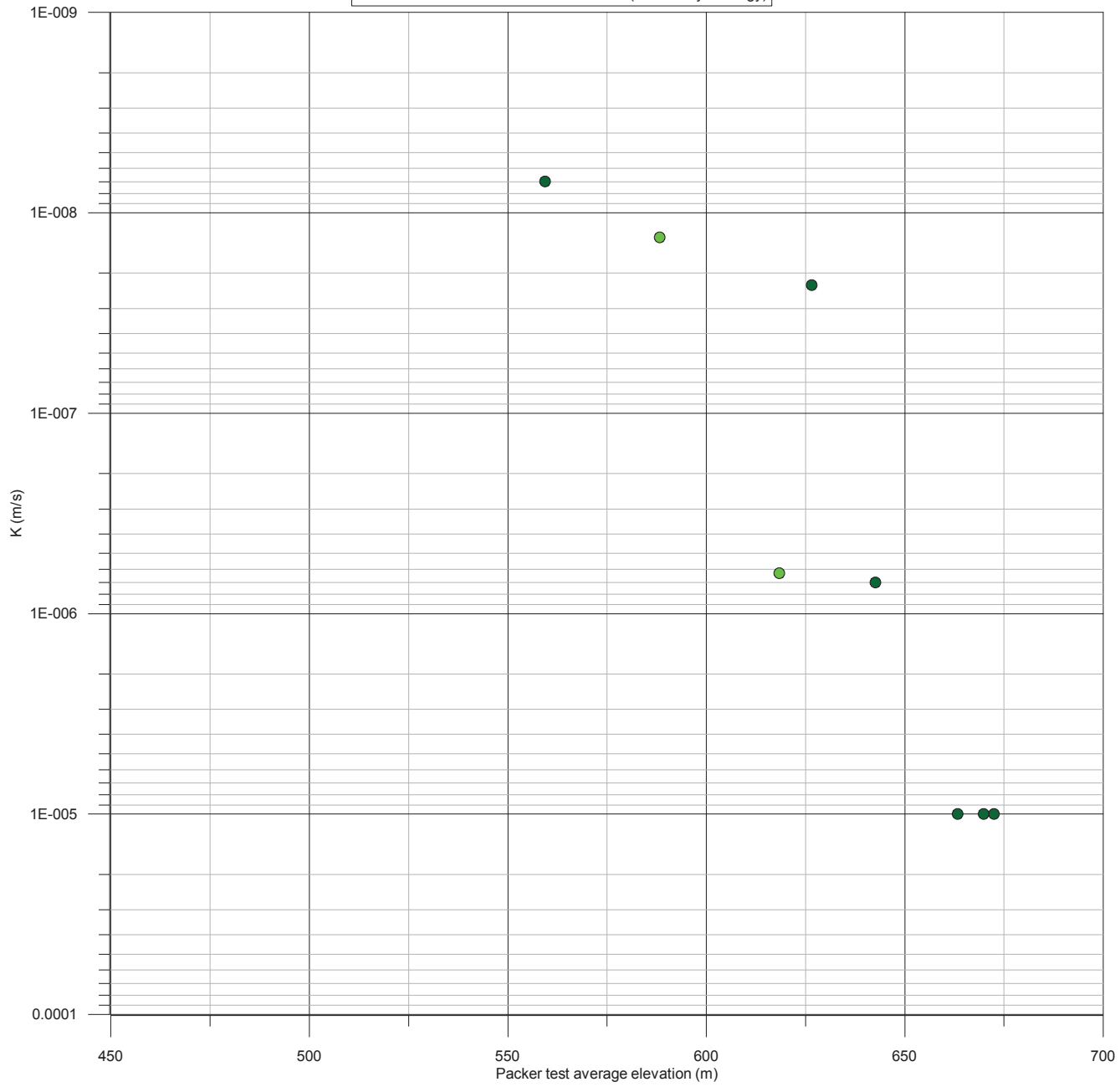
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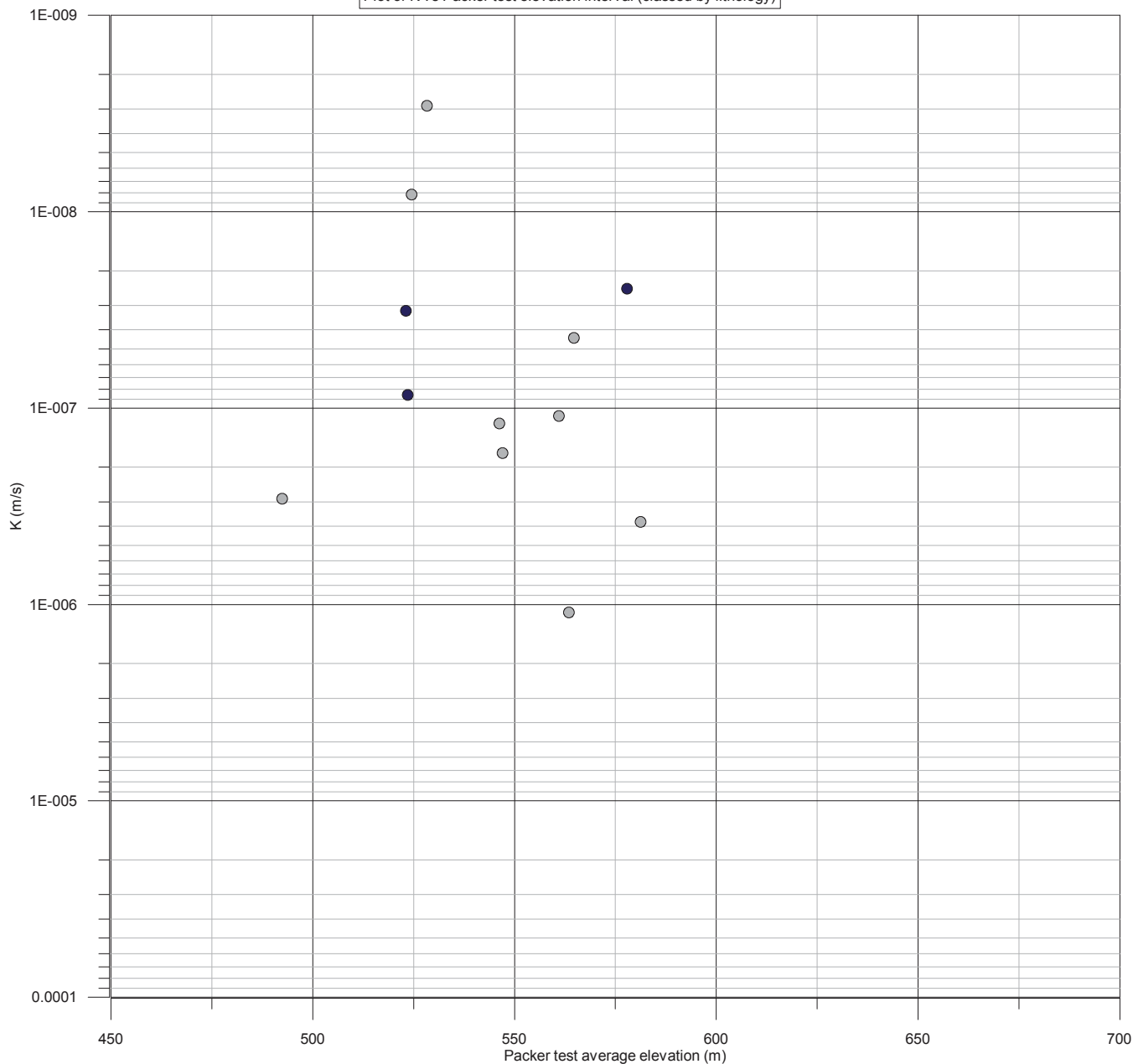
PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Elevation	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (f)

KSM Water Storage Facility
 Plot of K vs Packer test elevation interval (classed by lithology)



- Altered felsic dyke
- Altered volcanics

KSM Water Storage Facility
 Plot of K vs Packer test elevation interval (classed by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasilstone)
- Calc-silicate hornfels
- Metasilstone and/or metasandstone
- Sandstone
- Siltstone and minor Shale (graphitic)
- Siltstone and/or shale (sandstone, metasilstone)

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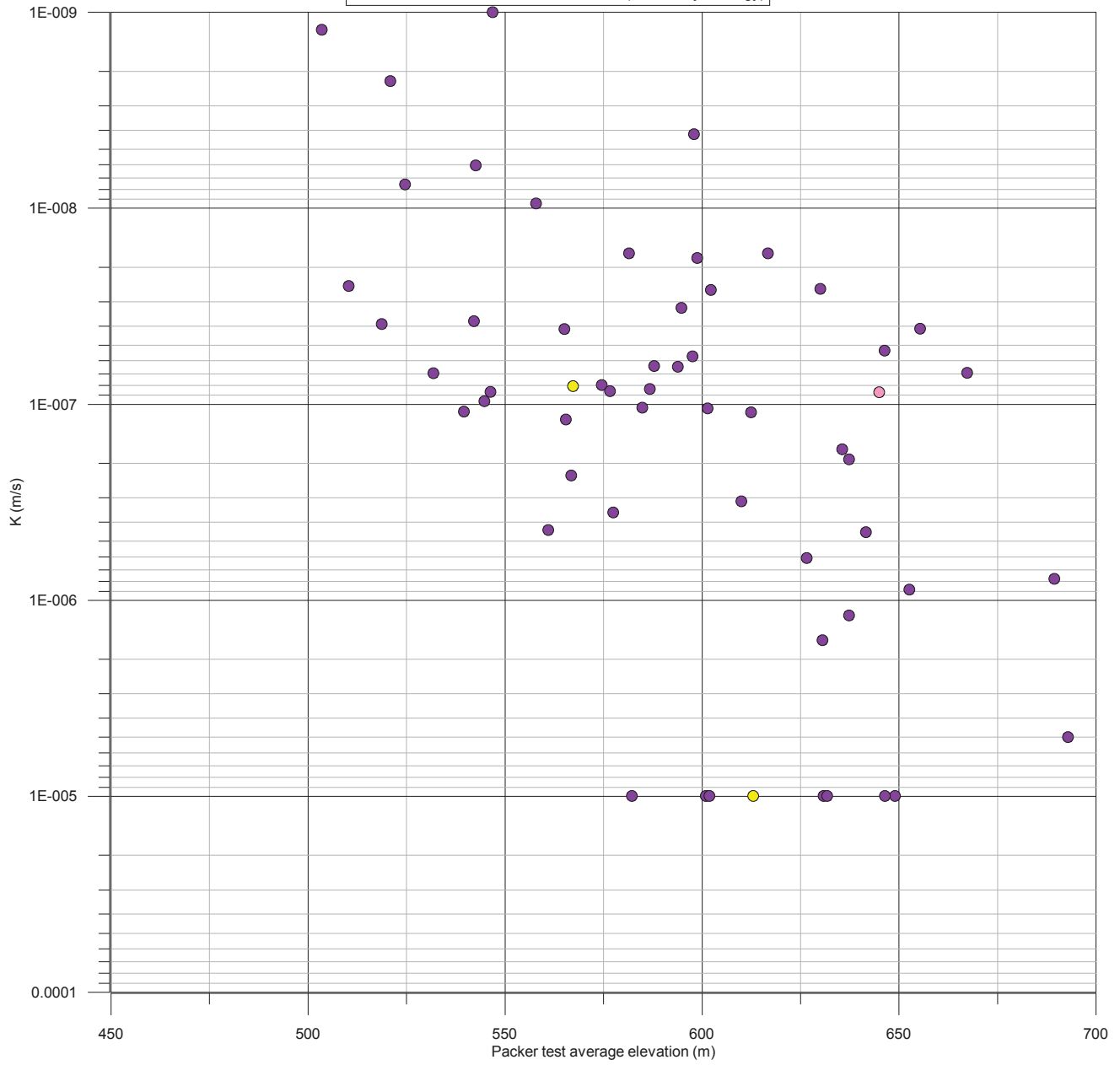
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Elevation	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (h)

KSM Water Storage Facility
Plot of K vs Packer test elevation interval (classed by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasiltstone)
- Calc-silicate hornfels
- Metasiltstone and/or metasandstone
- Sandstone
- Siltstone and minor Shale (graphitic)
- Siltstone and/or shale (sandstone, metasiltstone)

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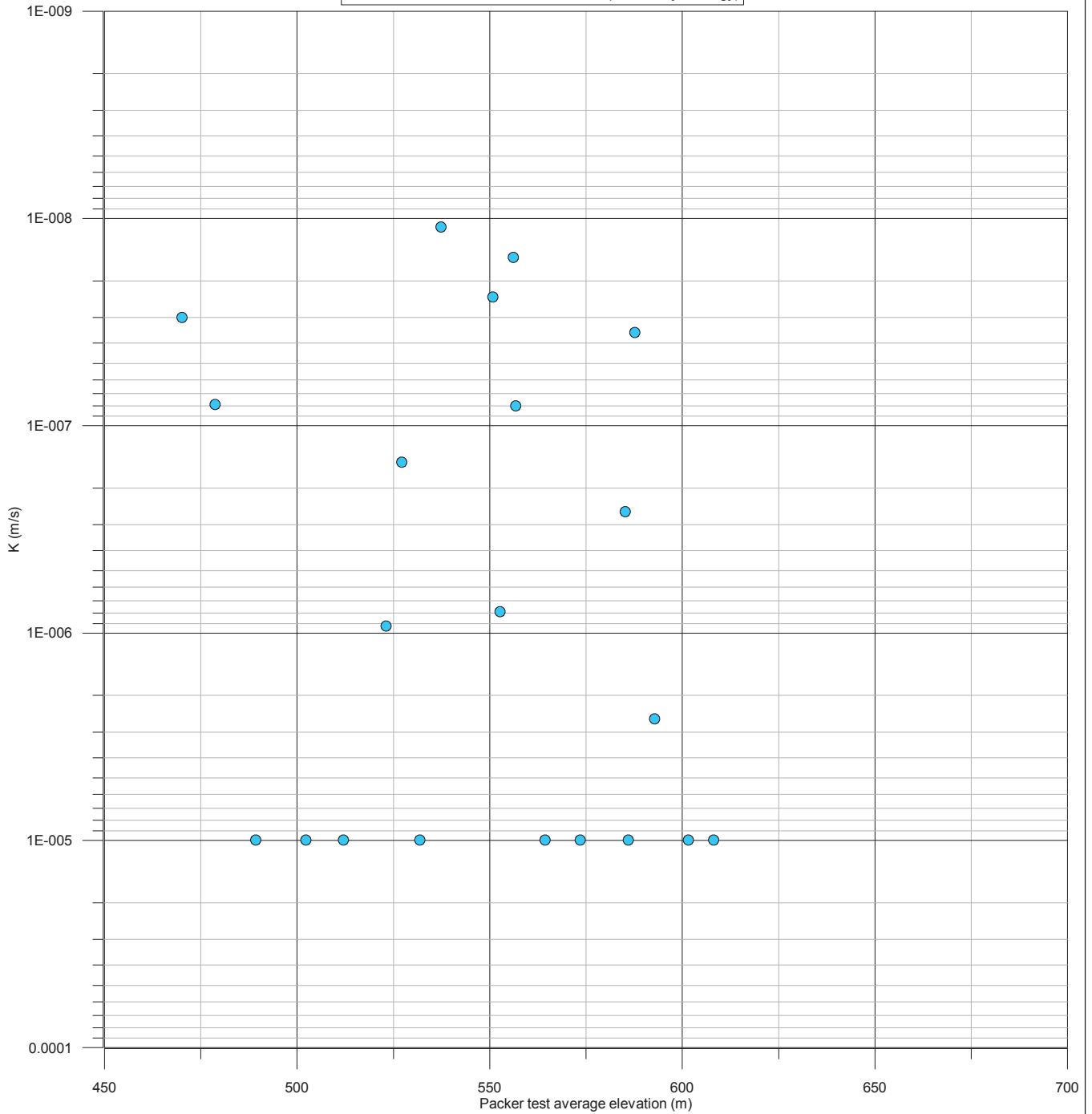
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Elevation	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (i)

KSM Water Storage Facility
 Plot of K vs Packer test elevation interval (classed by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasiltstone)

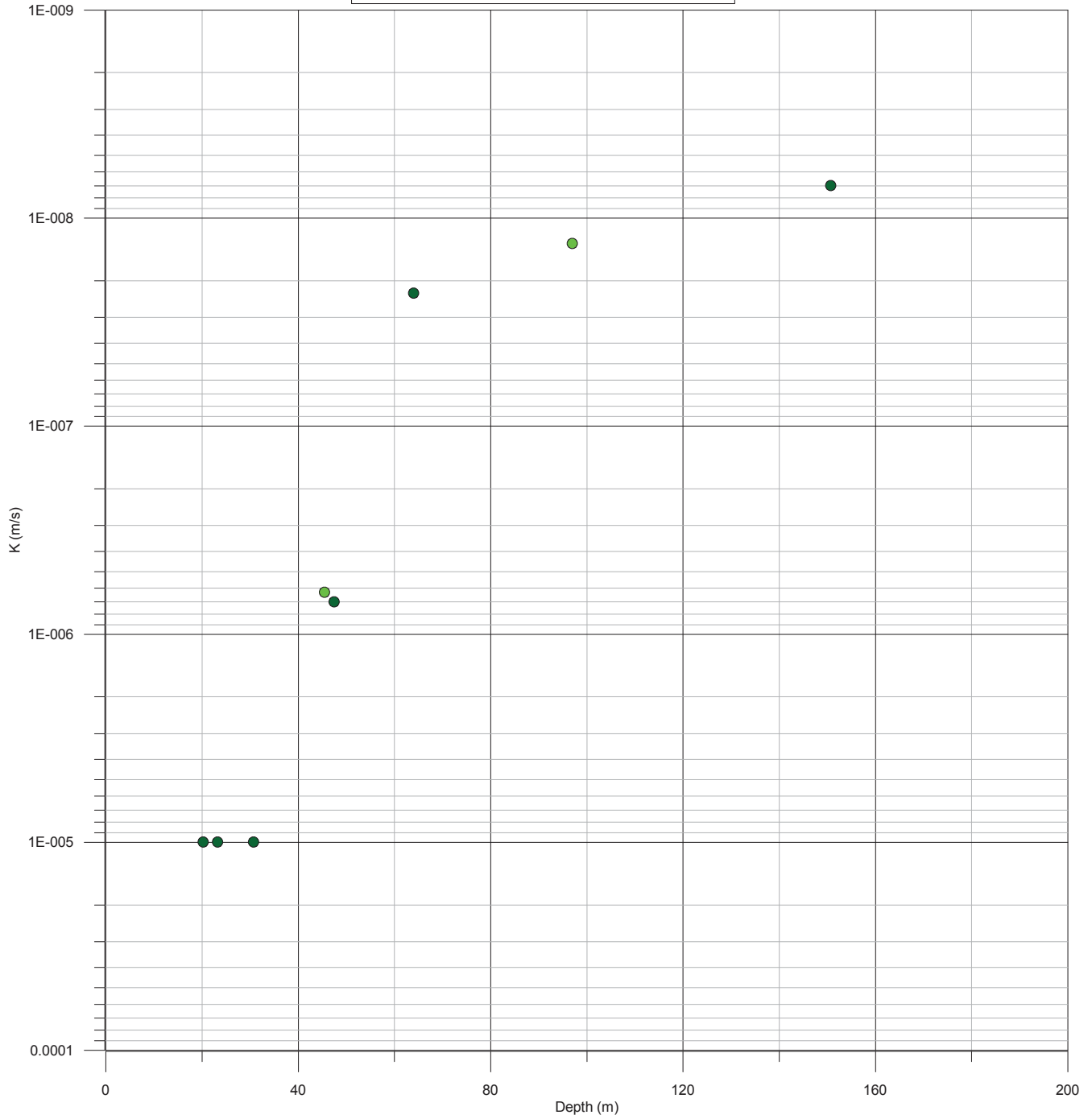
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Elevation	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (j)

KSM Water Storage Facility
Plot of K vs Packer test depth interval (classed by lithology)



- Class Scatter Plot 1
- Class Scatter Plot 2

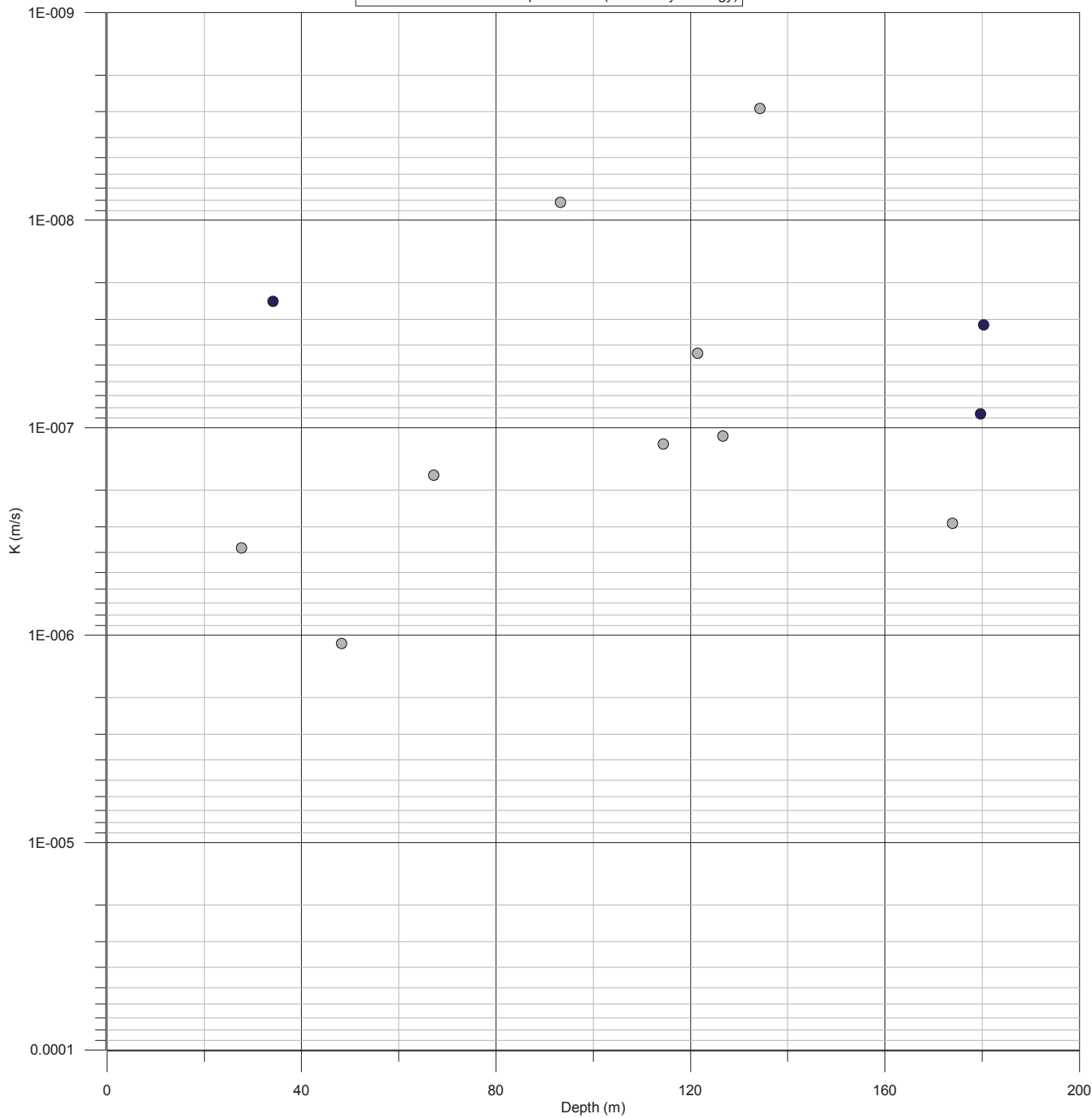
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Depth	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (k)

KSM Water Storage Facility
 Plot of K vs Packer test depth interval (classed by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone/sandstone
- Calc-silicate hornfels
- Metasediments

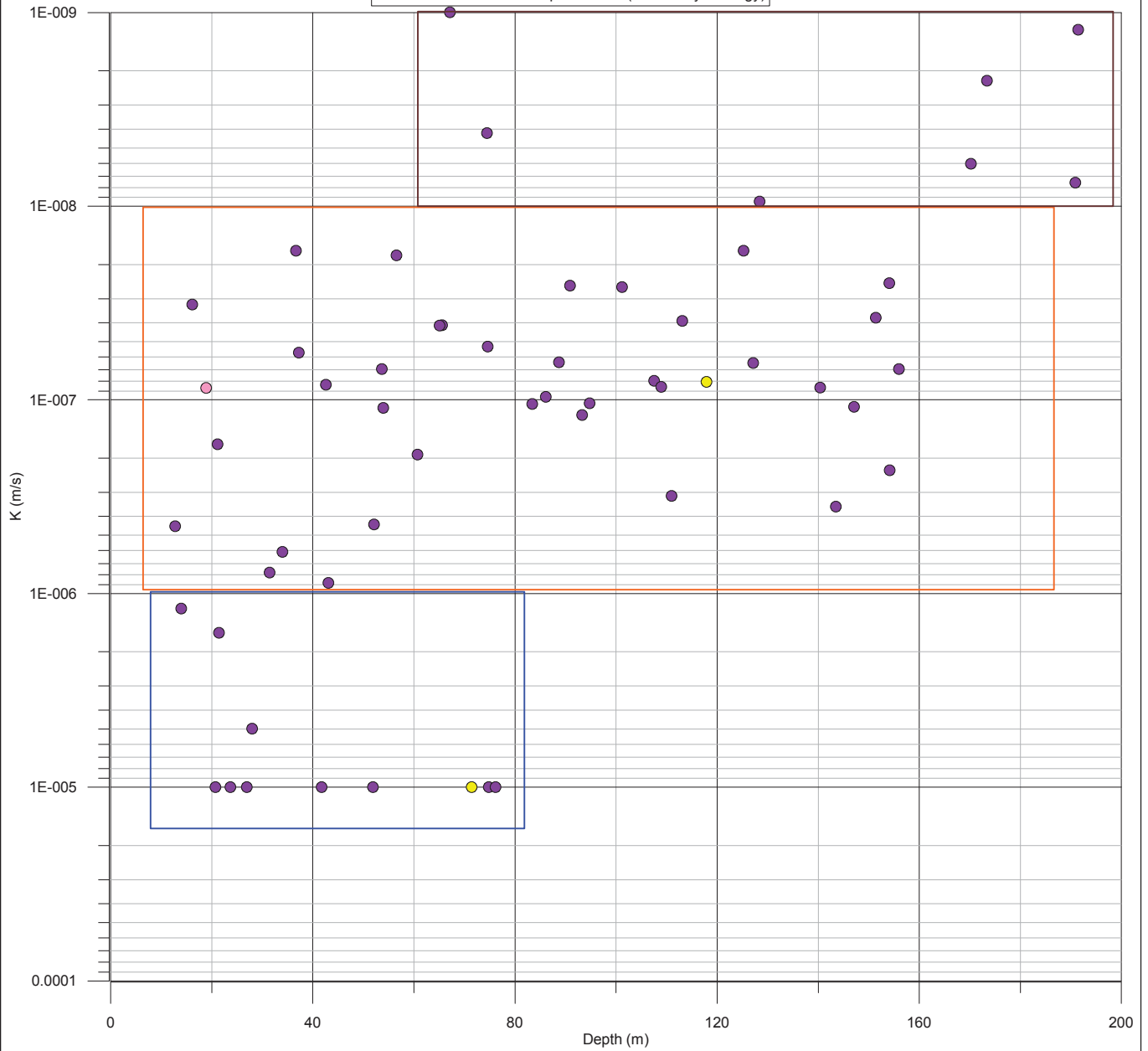
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Depth	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (I)

KSM Water Storage Facility
 Plot of K vs Packer test depth interval (classed by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone/sandstone
- Calc-silicate hornfels
- Metasediments
- Sandstone
- Siltstone/shale (graphitic)
- Siltstone/shale

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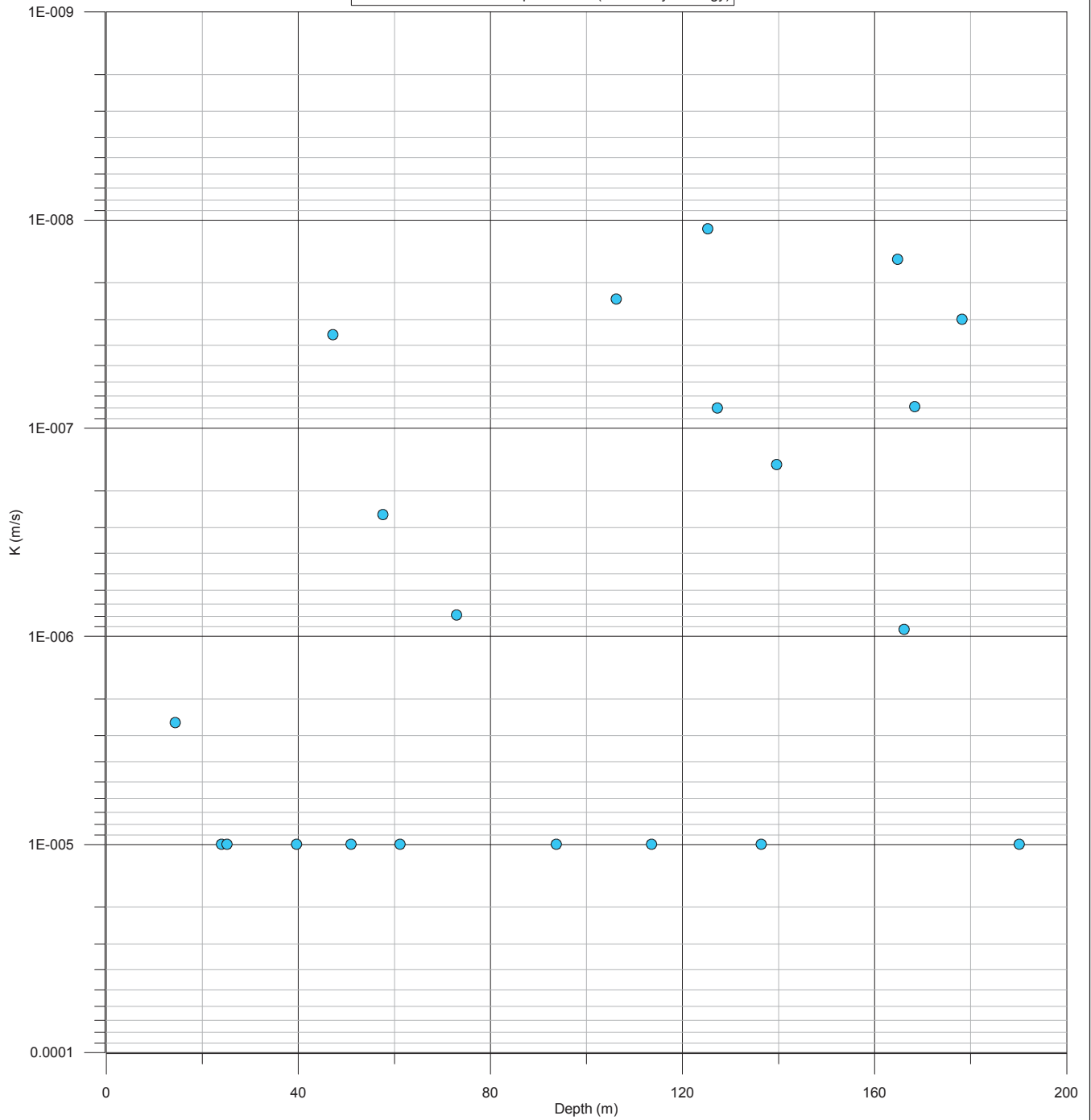
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Depth	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (m)

KSM Water Storage Facility
Plot of K vs Packer test depth interval (classed by lithology)



- Class Scatter Plot 1
- Class Scatter Plot 1
- Class Scatter Plot 1

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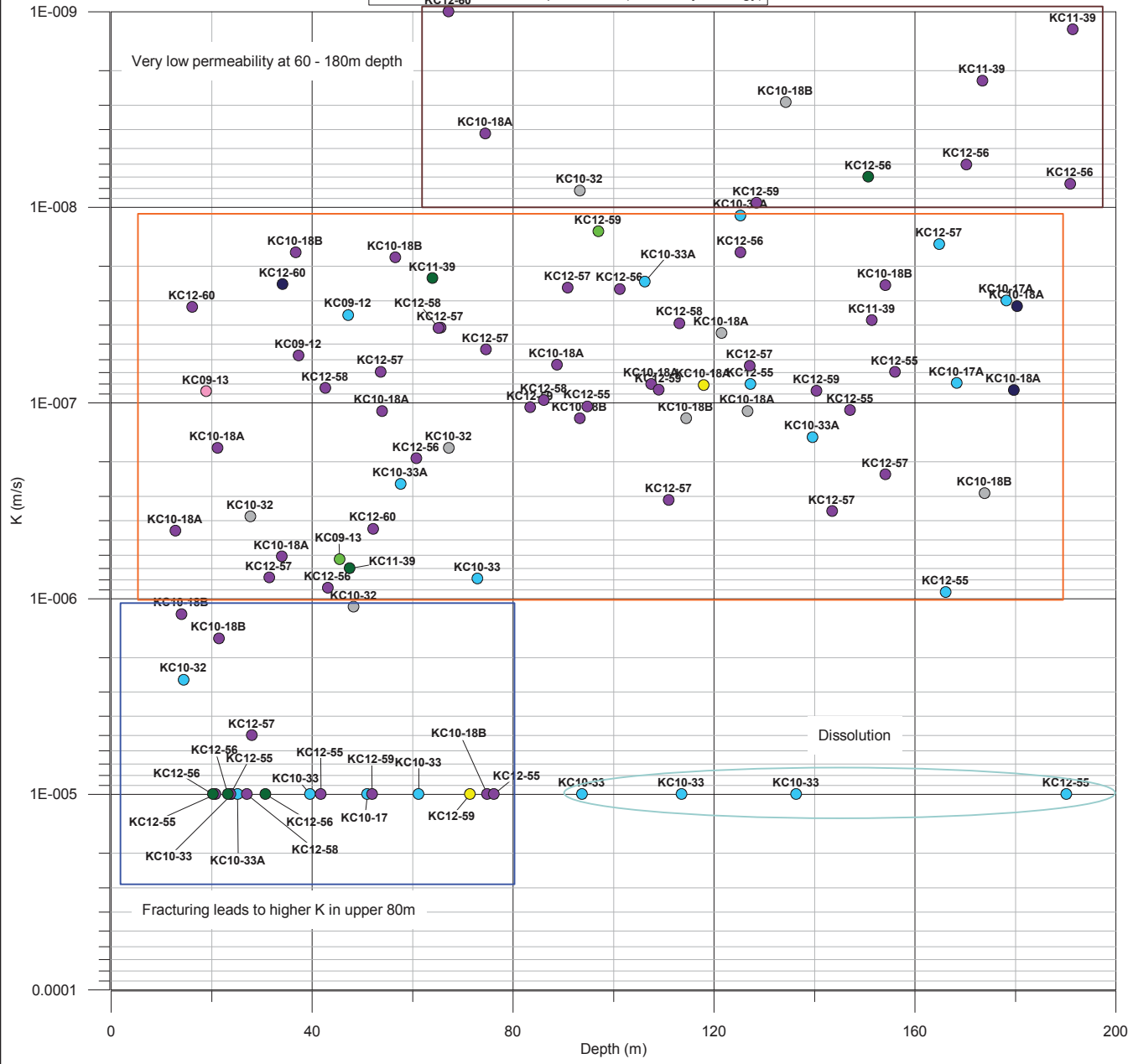
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Depth	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (n)

KSM Water Storage Facility
Plot of K vs Packer test depth interval (classified by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone/sandstone
- Calc-silicate hornfels
- Metasediments
- Sandstone
- Siltstone/shale (graphitic)
- Siltstone/shale

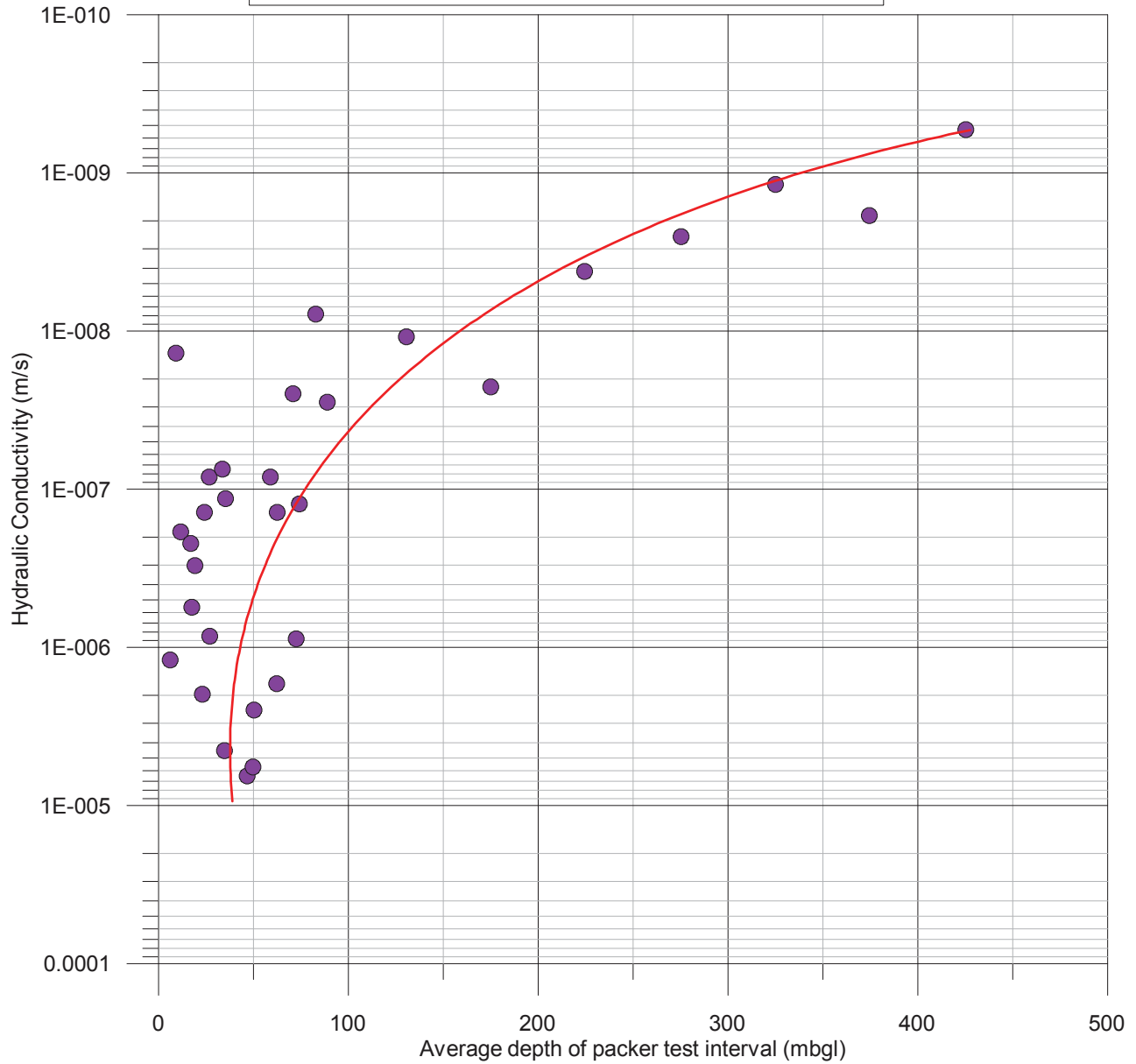
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Plot K vs Depth	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (o)

KSM Water Storage Facility: Regional Bedrock
 Plot of K vs Depth of packer test interval (classed by rock types)



● Regional undifferentiated Stuhini Formation

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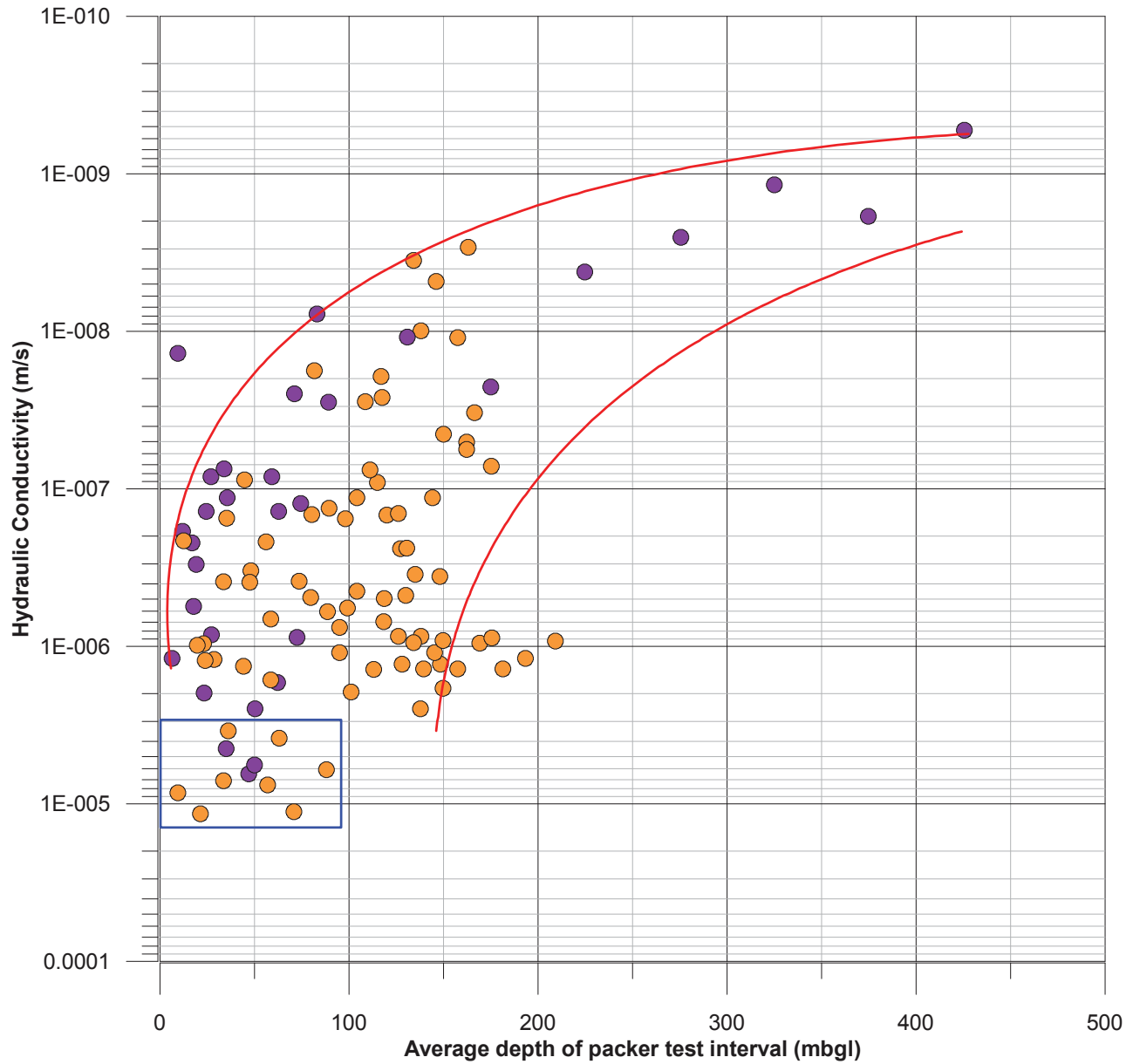
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Klohn Crippen Berger

PROJECT	KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling	
TITLE	KSM Water Storage Facility (WSF) Plot K vs Depth	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (p)



Regional undifferentiated Stuhini Formation
 Undifferentiated Mine Area Geology

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PROJECT

KSM 2012 FS Project
Water Storage Facility Seepage Mitigation Modelling

TITLE

KSM Water Storage Facility (WSF)
Plot K vs Depth

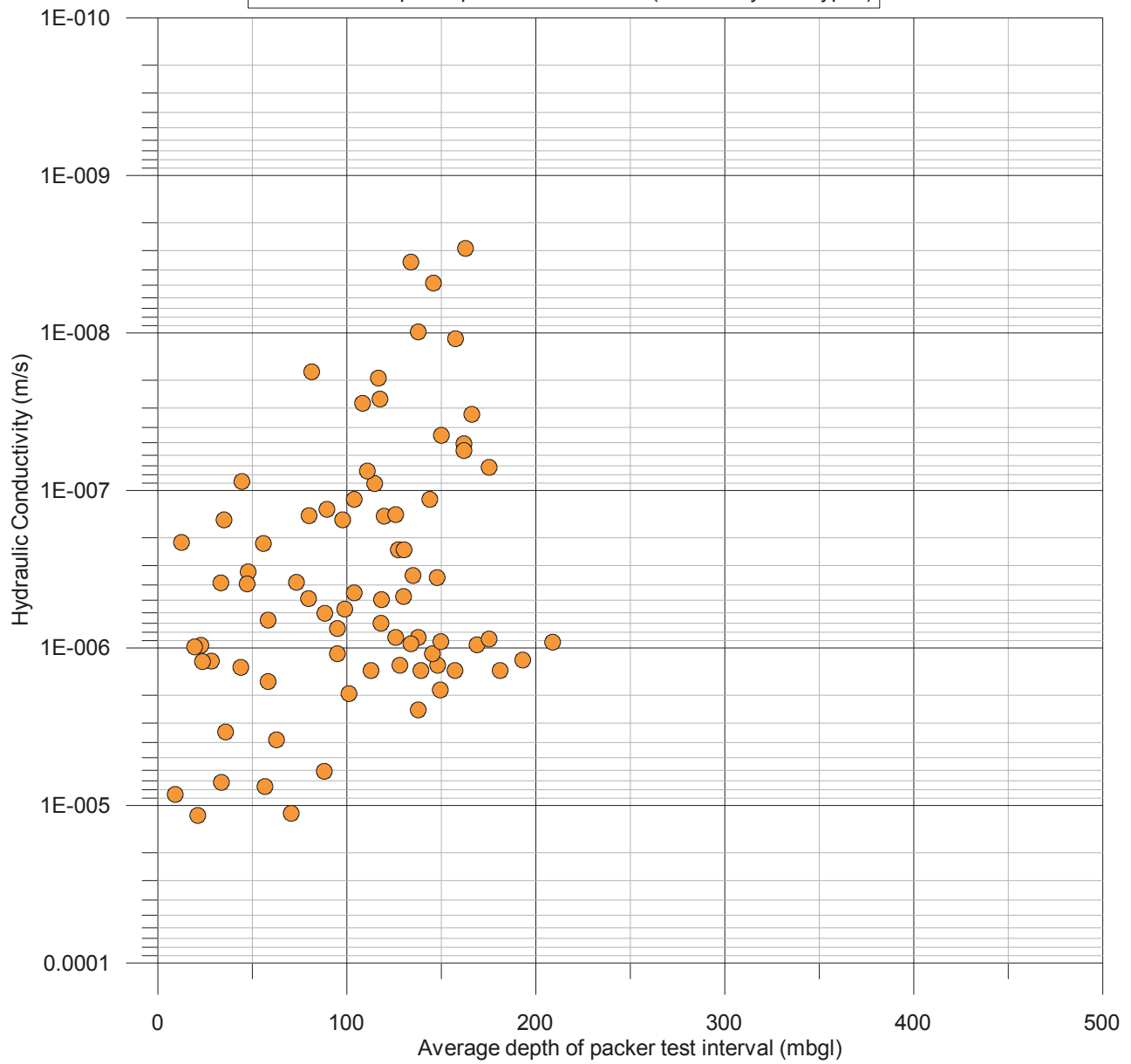
PROJECT NO.

M09480A04

FIGURE NO.

APPENDIX II (q)

KSM Water Storage Facility: Regional Bedrock
 Plot of K vs Depth of packer test interval (classed by rock types)



- Regional undifferentiated Stuhini Formation
- Undifferentiated Mine Area Geology

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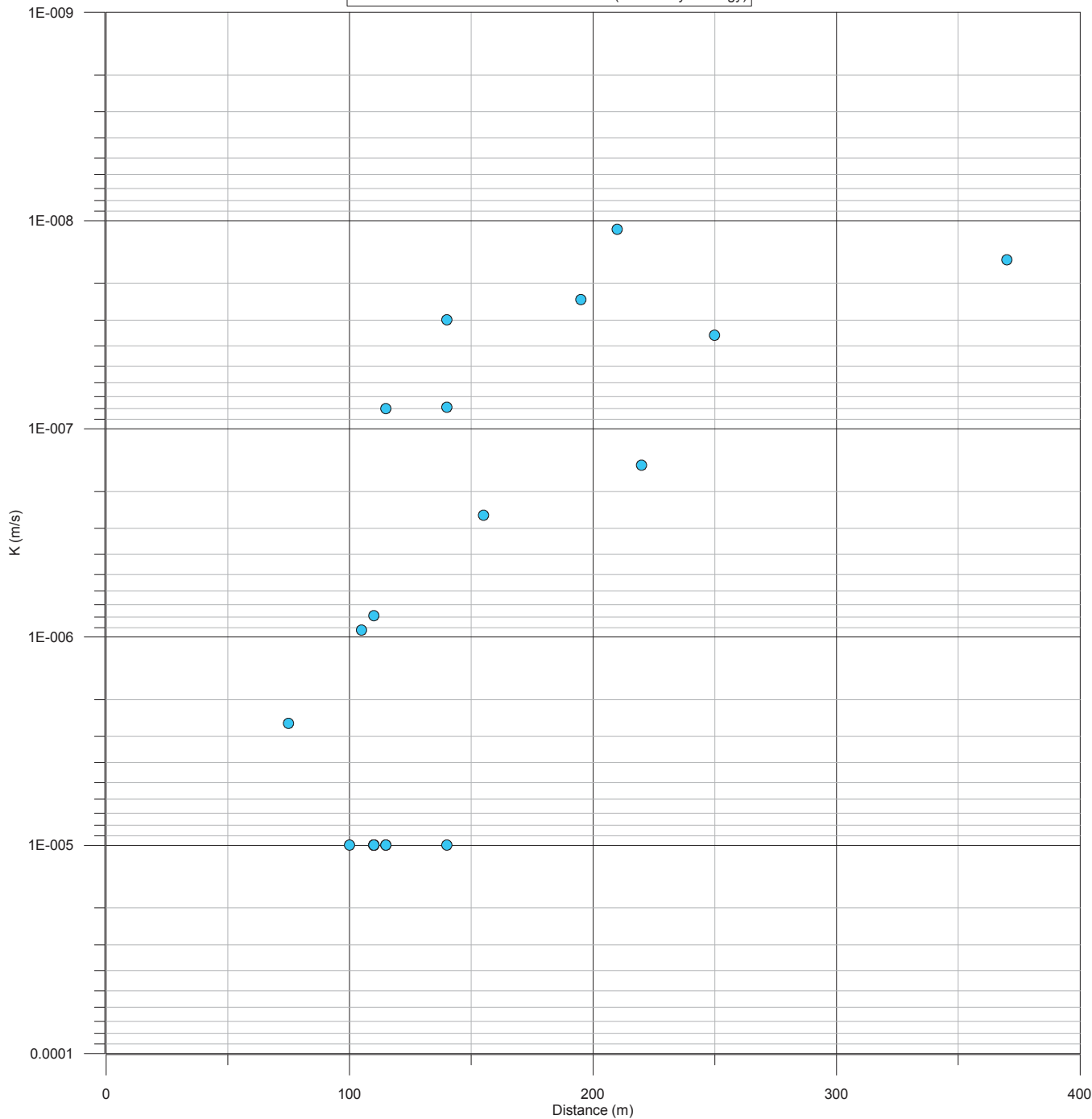
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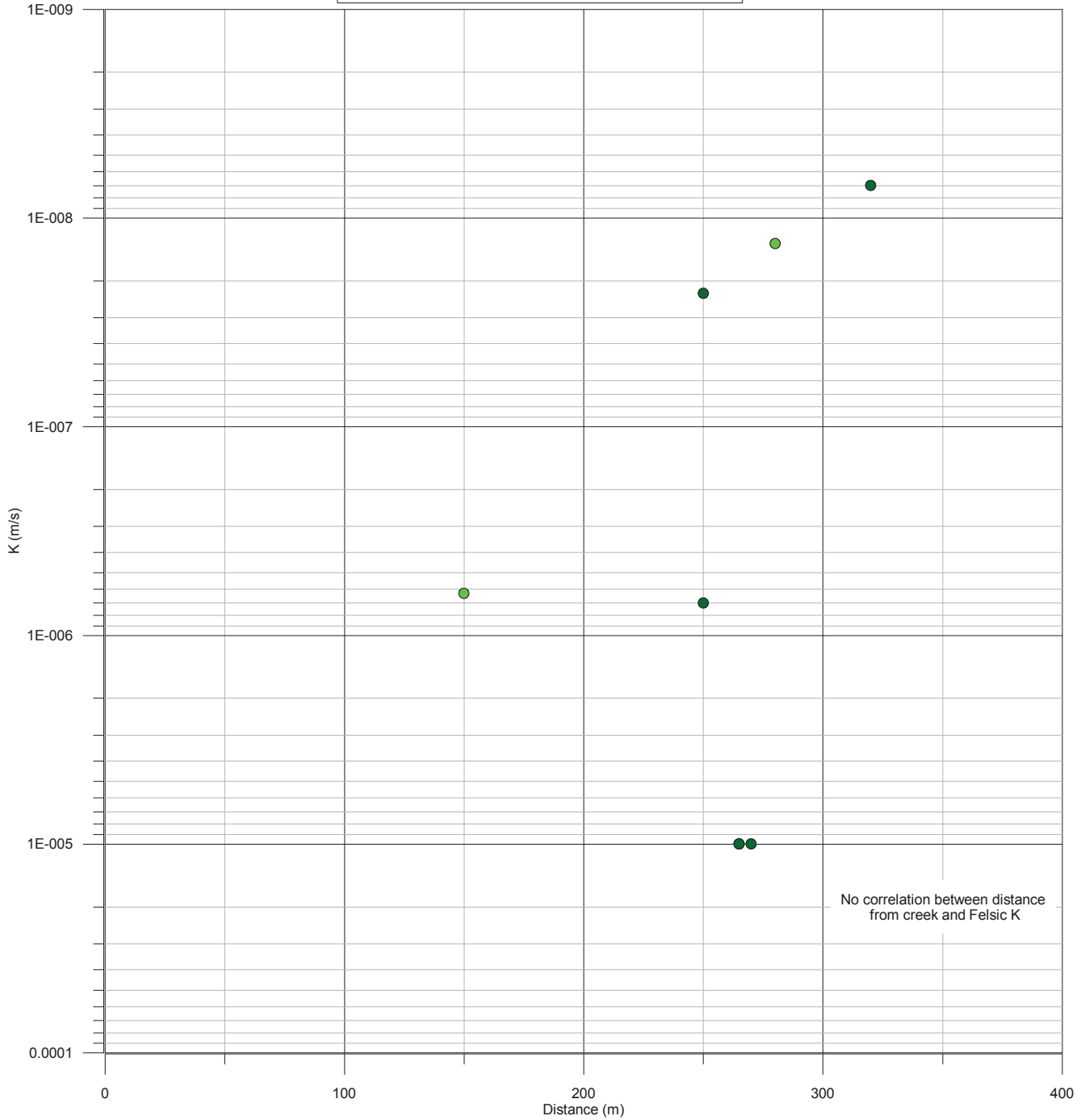
PROJECT KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling	
TITLE KSM Water Storage Facility (WSF) Plot K vs Depth	
PROJECT NO. M09480A04	FIGURE NO. APPENDIX II (r)

KSM Water Storage Facility
 Plot of K vs Distance from Mitchell Creek (classed by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasiltstone)

KSM Water Storage Facility
 Plot of K vs Distance from Mitchell Creek (classed by lithology)



- Altered felsic dyke
- Altered volcanics

No correlation between distance from creek and Felsic K

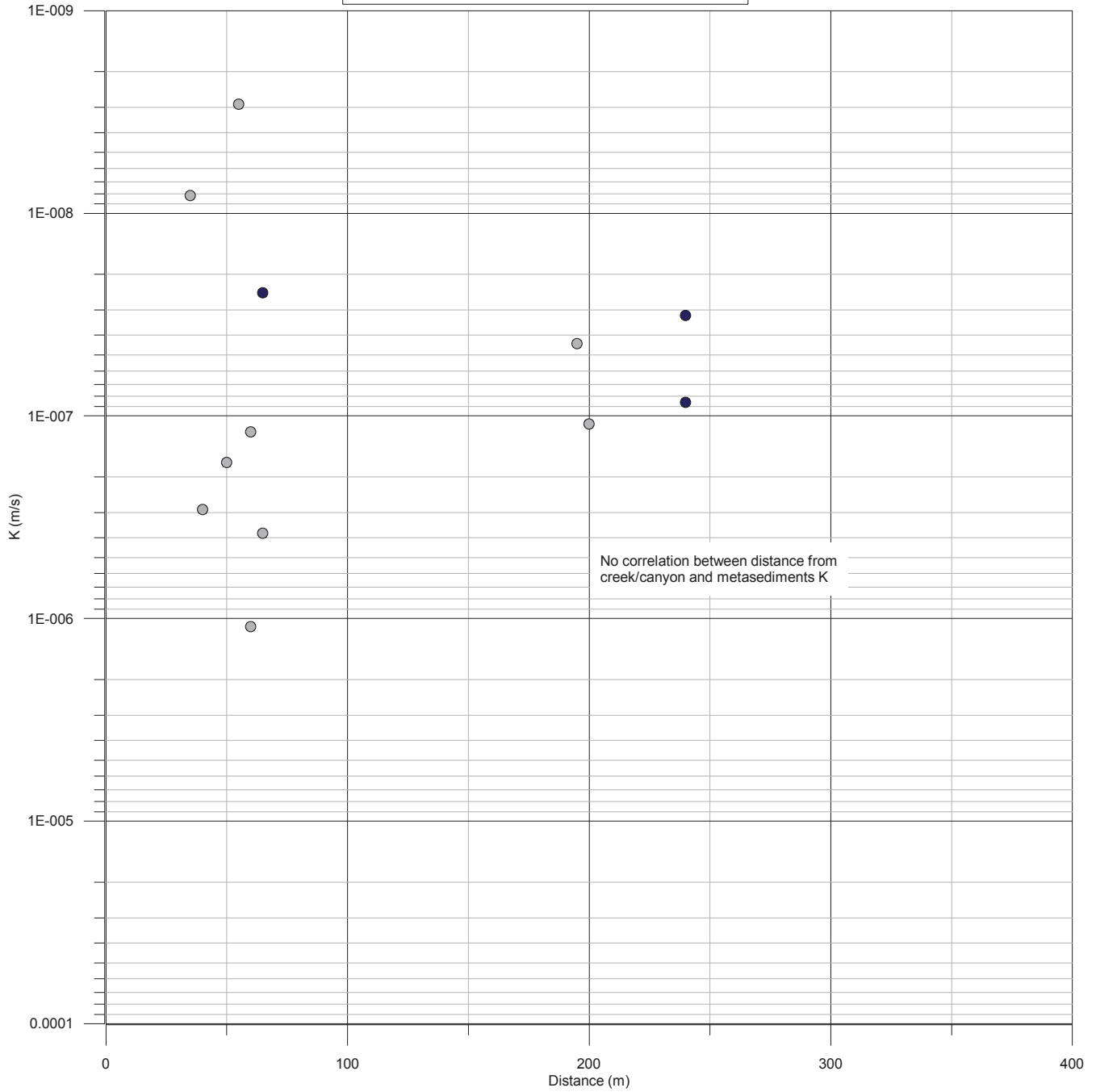
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Mitchell Canyon v K	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (u)

KSM Water Storage Facility
Plot of K vs Distance from Mitchell Creek (classed by lithology)



No correlation between distance from creek/canyon and metasediments K

- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasiltstone)
- Calc-silicate hornfels
- Metasiltstone and/or metasandstone

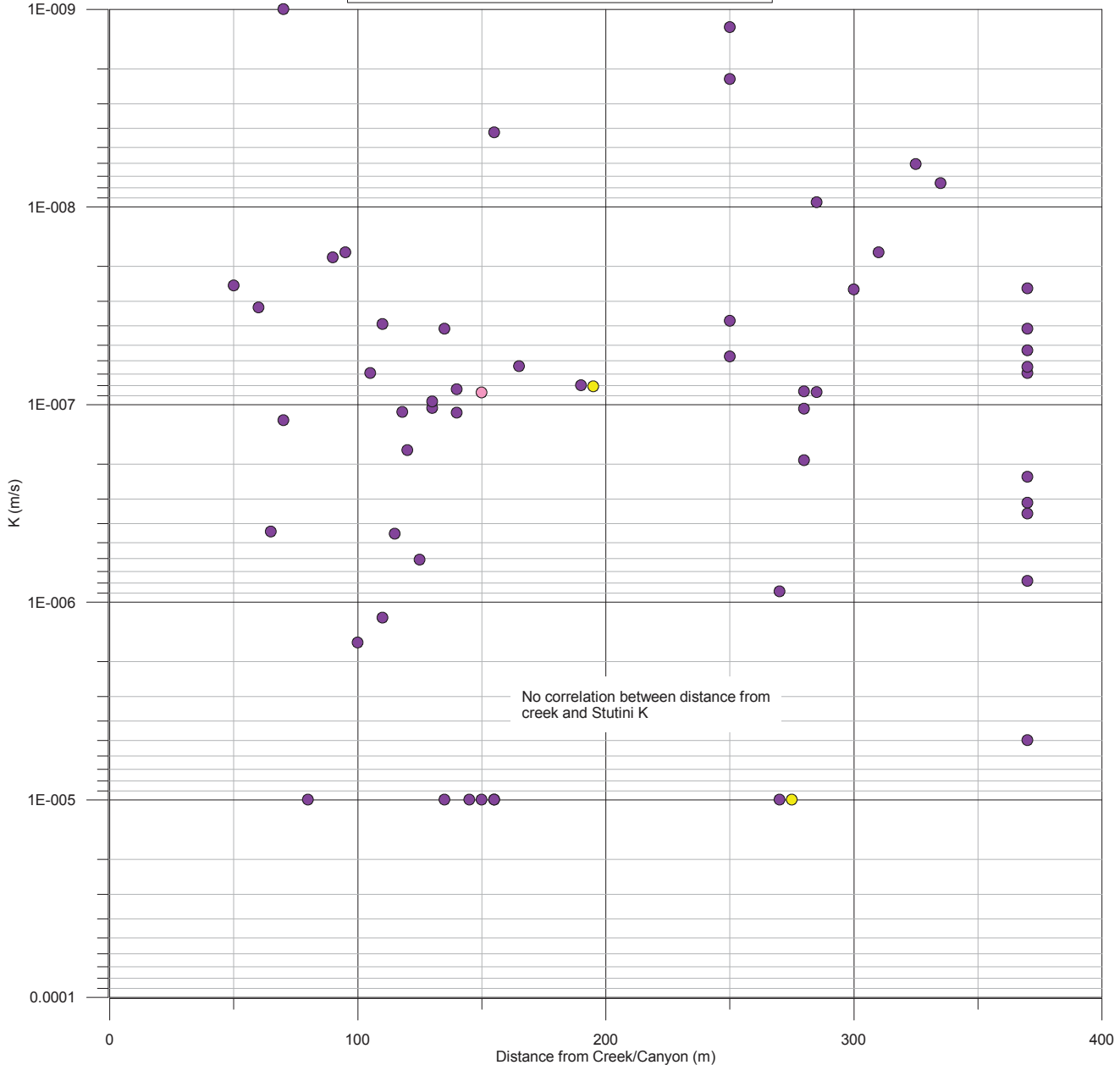
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PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Mitchell Canyon v K	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (v)

KSM Water Storage Facility
Plot of K vs Distance from Mitchell Creek (classified by lithology)



- Altered felsic dyke
- Altered volcanics
- Calcareous siltstone and/or sandstone (shale, metasiltstone)
- Calc-silicate hornfels
- Metasiltstone and/or metasandstone
- Sandstone
- Siltstone and minor Shale (graphitic)
- Siltstone and/or shale (sandstone, metasiltstone)

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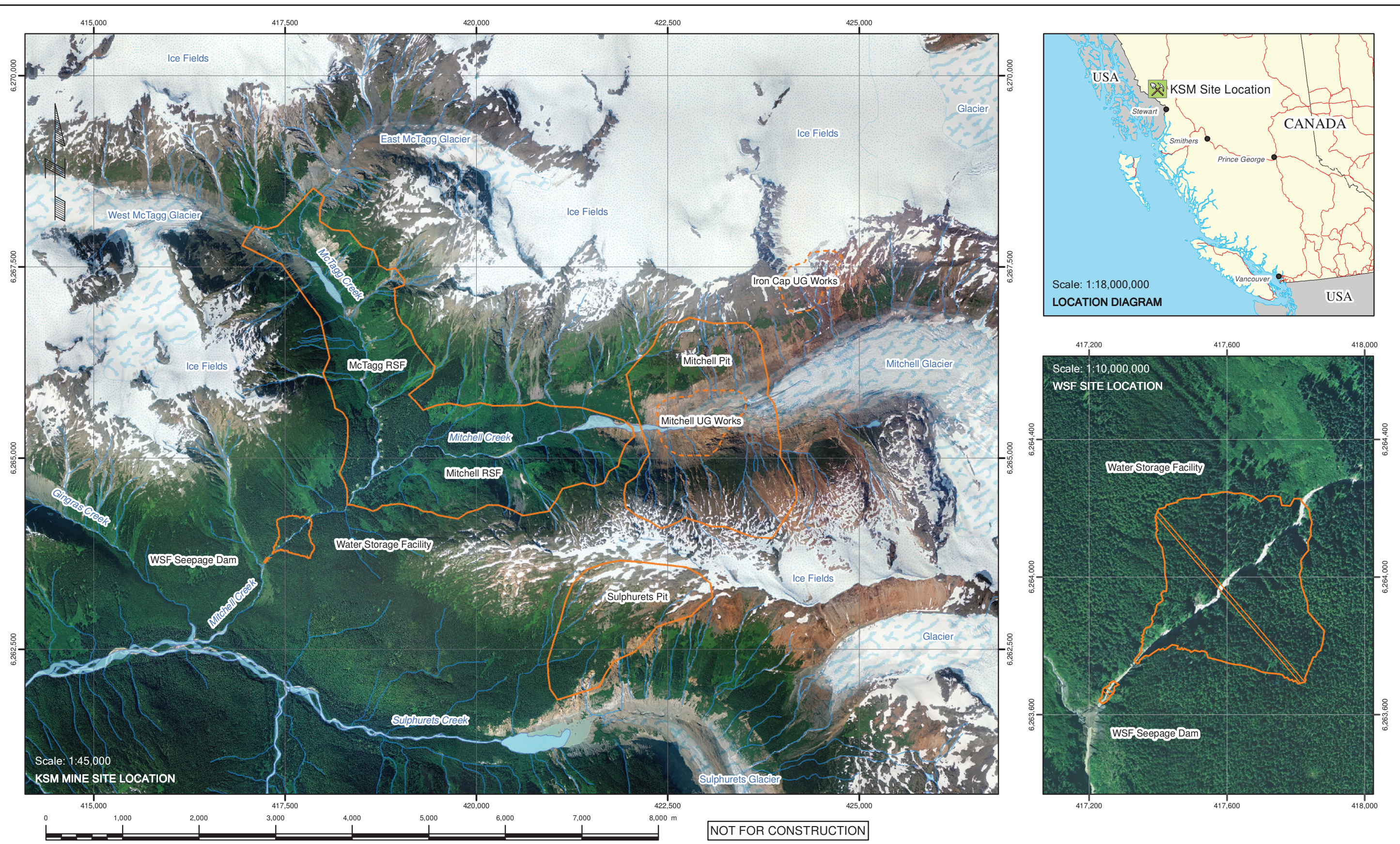


PROJECT	KSM 2012 FS Project	
TITLE	Water Storage Facility Seepage Mitigation Modelling	
	KSM Water Storage Facility (WSF) Mitchell Canyon v K	
PROJECT NO.	M09480A04	FIGURE NO. APPENDIX II (w)

FIGURES

- Figure 1 KSM Water Storage Facility (WSF) Site Map
- Figure 2 KSM Water Storage Facility (WSF) Terrain Map
- Figure 3 KSM Water Storage Facility (WSF) Drill Hole and Monitoring Sites
- Figure 4 KSM Water Storage Facility (WSF) Geology Map
- Figure 5 KSM Water Storage Facility (WSF) Overburden
- Figure 6 KSM Water Storage Facility (WSF) Ice Thickness, Glacier and Overburden Thickness
- Figure 7 KSM Water Storage Facility (WSF) Box & Whisker Plot of K Distributions
- Figure 8 KSM Water Storage Facility (WSF) Hydrostratigraphic Framework
- Figure 9 KSM Water Storage Facility (WSF) Annual Averaged Groundwater Elevations
- Figure 10 KSM Water Storage Facility (WSF) Depth to Annual Averaged Groundwater Elevations
- Figure 11 KSM Water Storage Facility (WSF) Scatter Plot of Hydraulic Head versus Ground Elevation
- Figure 12 KSM Water Storage Facility (WSF) Groundwater Model Discretisation and Location of Sub-Regional and Regional Faults represented as Discrete Features
- Figure 13 KSM Water Storage Facility (WSF) Calibration Target Locations
- Figure 14 KSM Water Storage Facility (WSF) Scatter Plot of Baseline Predicted versus Observed Hydraulic Heads
- Figure 15 KSM Water Storage Facility (WSF) Predicted Baseline, Steady-State, Confined Potentiometric Surface – Calibrated Model
- Figure 16 KSM Water Storage Facility (WSF) Infrastructure Map
- Figure 17 KSM Water Storage Facility (WSF) Particle Tracking Results
- Figure 18 KSM Water Storage Facility (WSF) Particle Tracking Results for UBS Runs 1 & 2
- Figure 19 KSM Water Storage Facility (WSF) Particle Tracking Results for UBS Runs 3 & 4
- Figure 20 KSM Water Storage Facility (WSF) Particle Tracking Results for UBS Runs 5 & 6

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Legend

	Glacier		Water Body		Infrastructure Boundary
	Icefield		Water Course		

- Notes:**
1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. SPOT 5 Imagery (n.d.)

DRAWING NO.	NO.	DATE	ISSUE / REVISION	DRAWN	CHK'D	DESIGN	APP'D
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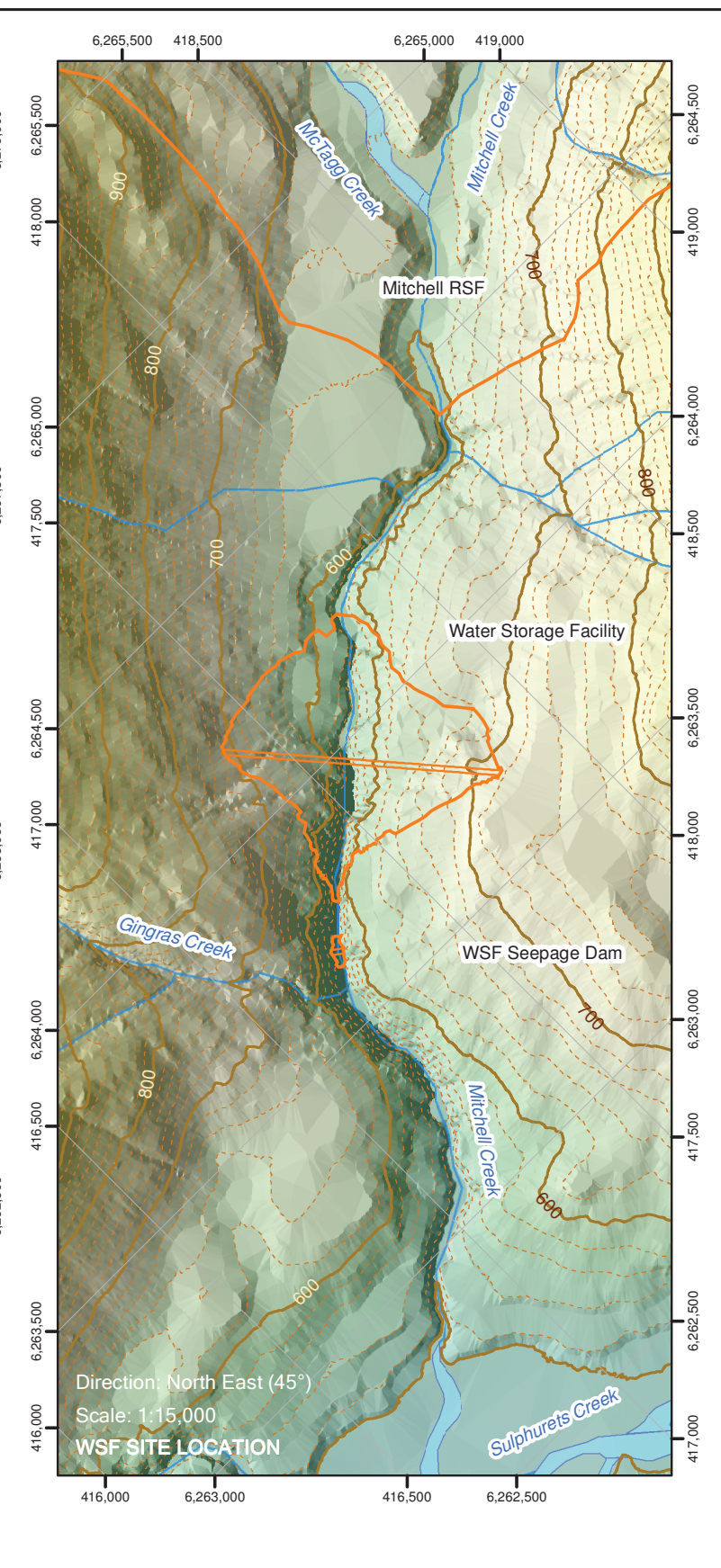
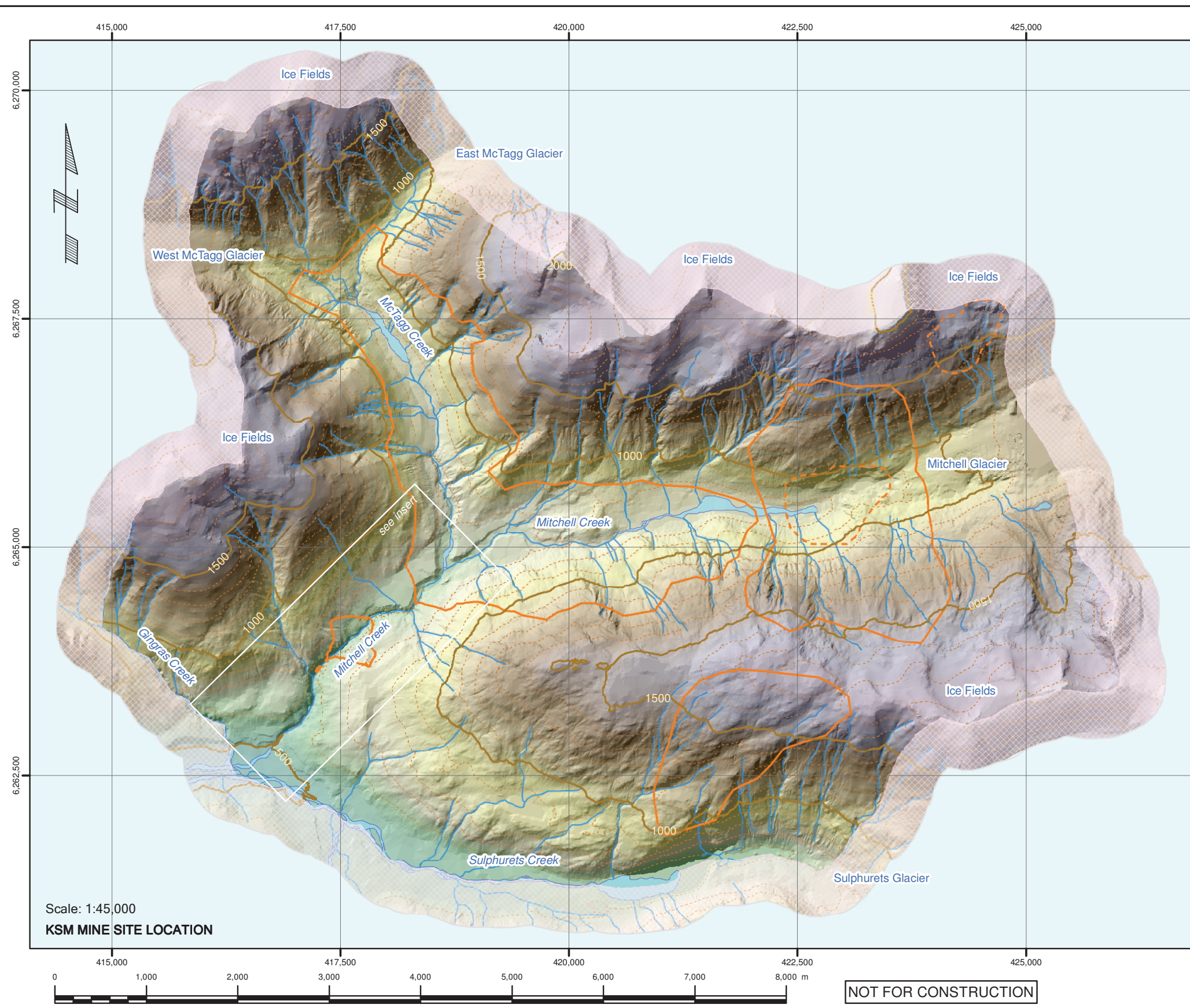
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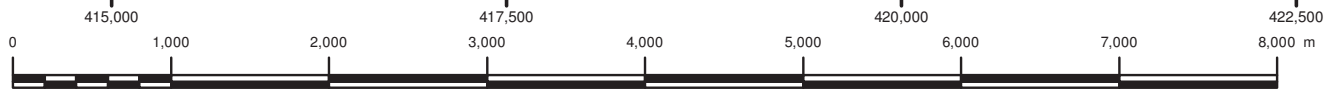
PROJECT KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE KSM WATER STORAGE FACILITY (WSF) SITE MAP			
DATE JUNE 2013	PROJECT No. M09480A04	DWG No. 01	REV. B

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Scale: 1:45,000
KSM MINE SITE LOCATION

Direction: North East (45°)
Scale: 1:15,000
WSF SITE LOCATION



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Legend

- Glacier
- Water Body
- Contour Index Interval 500m
- UG Infrastructure Footprint
- Icefield
- Water Course
- Contour Index Interval 100m
- Infrastructure Footprint

- Notes:
1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. SPOT 5 Imagery (n.d.)

Scale: 1:45,000

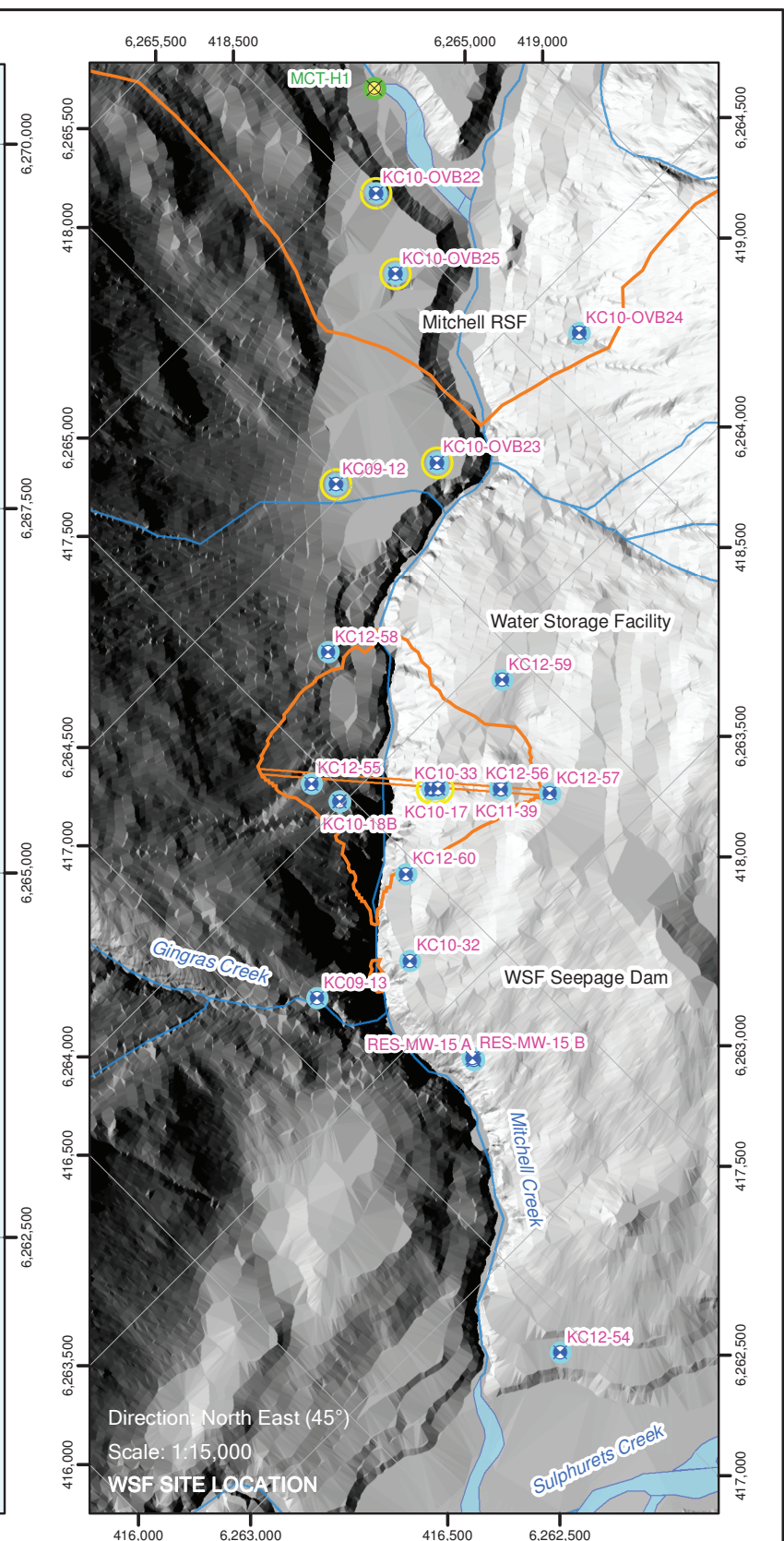
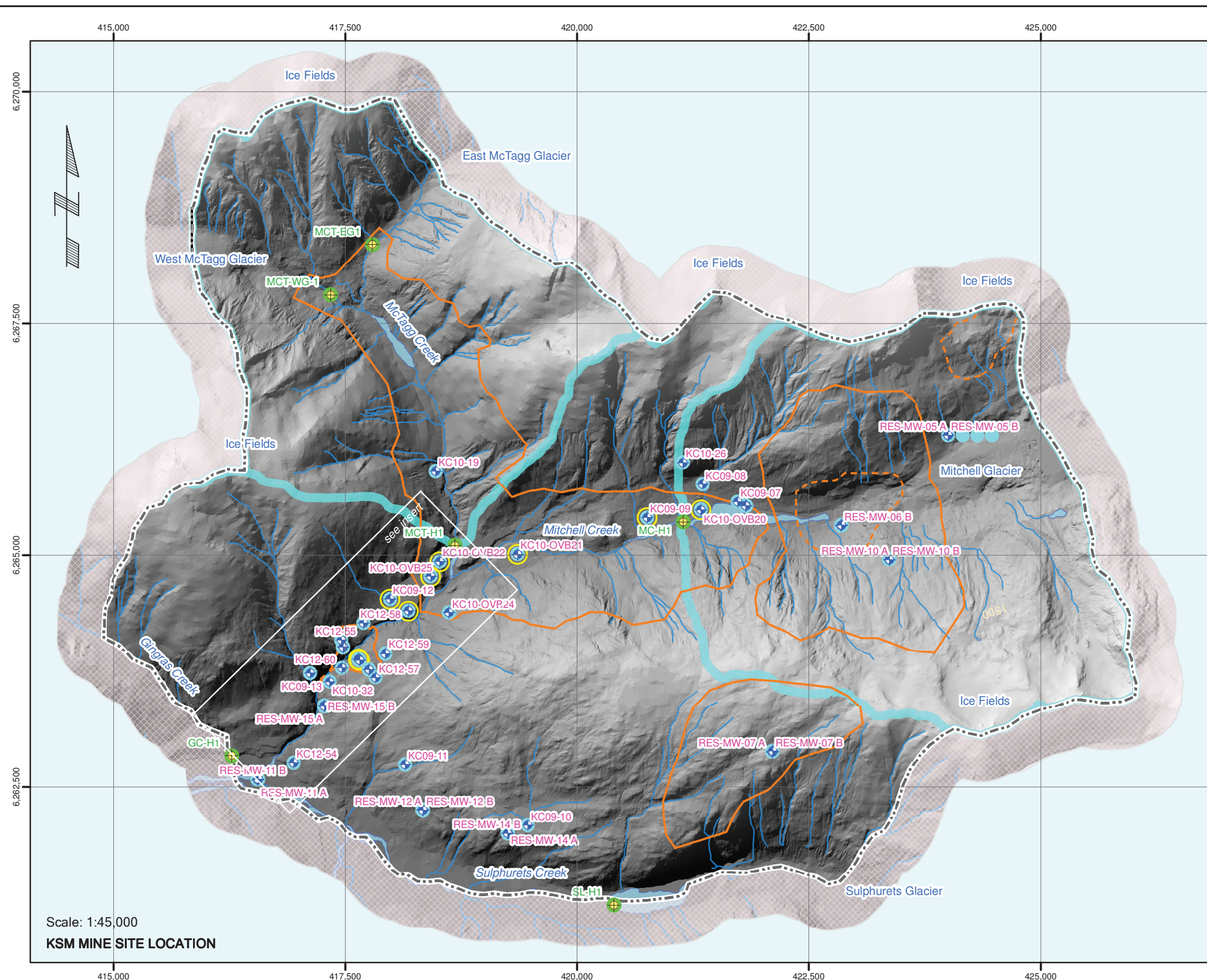
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PROJECT KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE KSM WATER STORAGE FACILITY (WSF) TERRAIN MAP			
DATE JUNE 2013	PROJECT No. M09480A04	DWG No. 02	REV. B

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Legend

- [Symbol] Glacier
- [Symbol] Water Body
- [Symbol] Hydrometric Sites
- [Symbol] Sand and Gravel
- [Symbol] Mitchell Water Catchments
- [Symbol] UG Infrastructure Footprint
- [Symbol] Icefield
- [Symbol] Water Course
- [Symbol] Drill Holes
- [Symbol] Basal Till
- [Symbol] Model Boundary
- [Symbol] Infrastructure Footprint

Notes:
 1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. LIDAR Composite DEM (n.d.)

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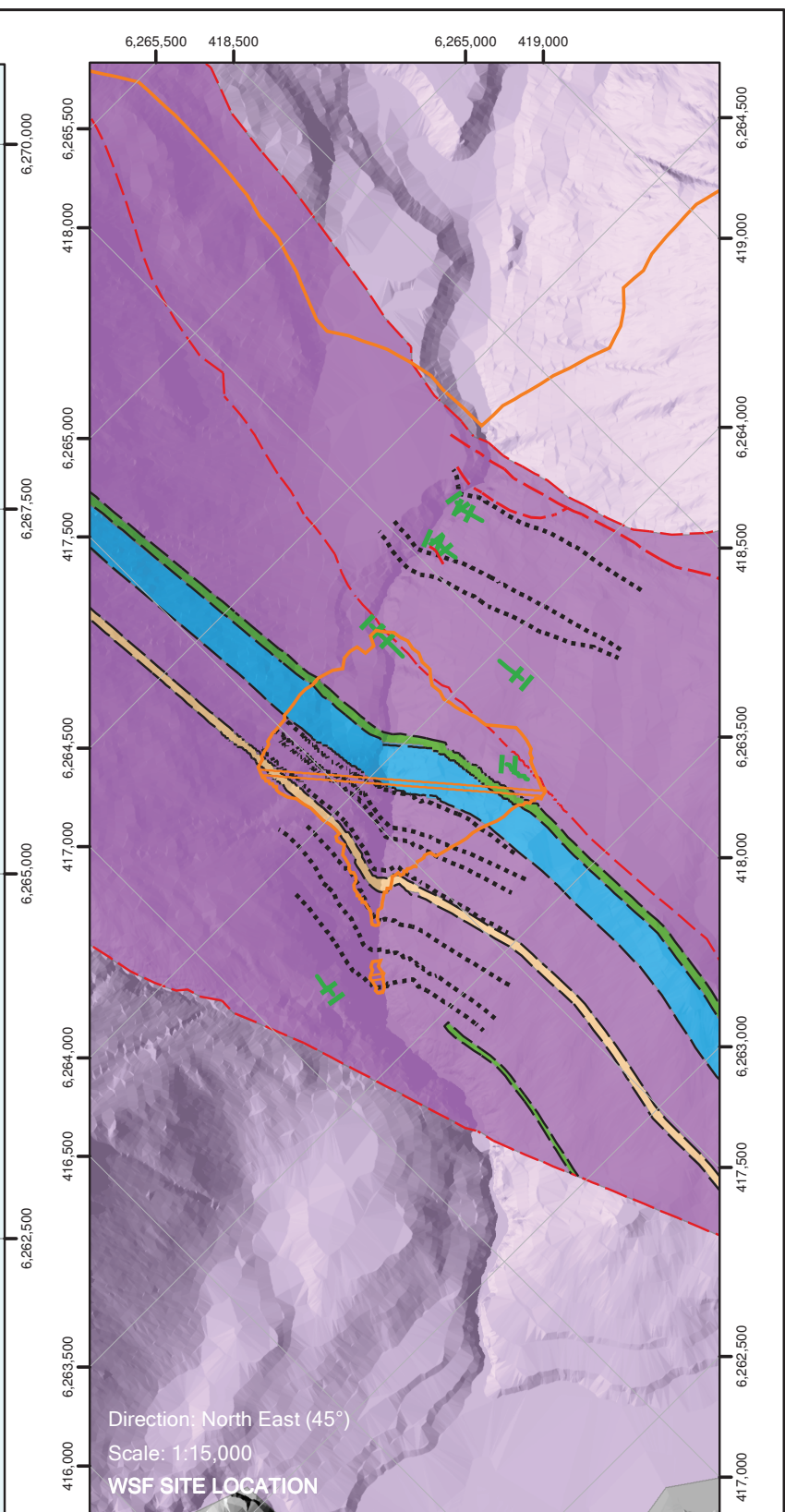
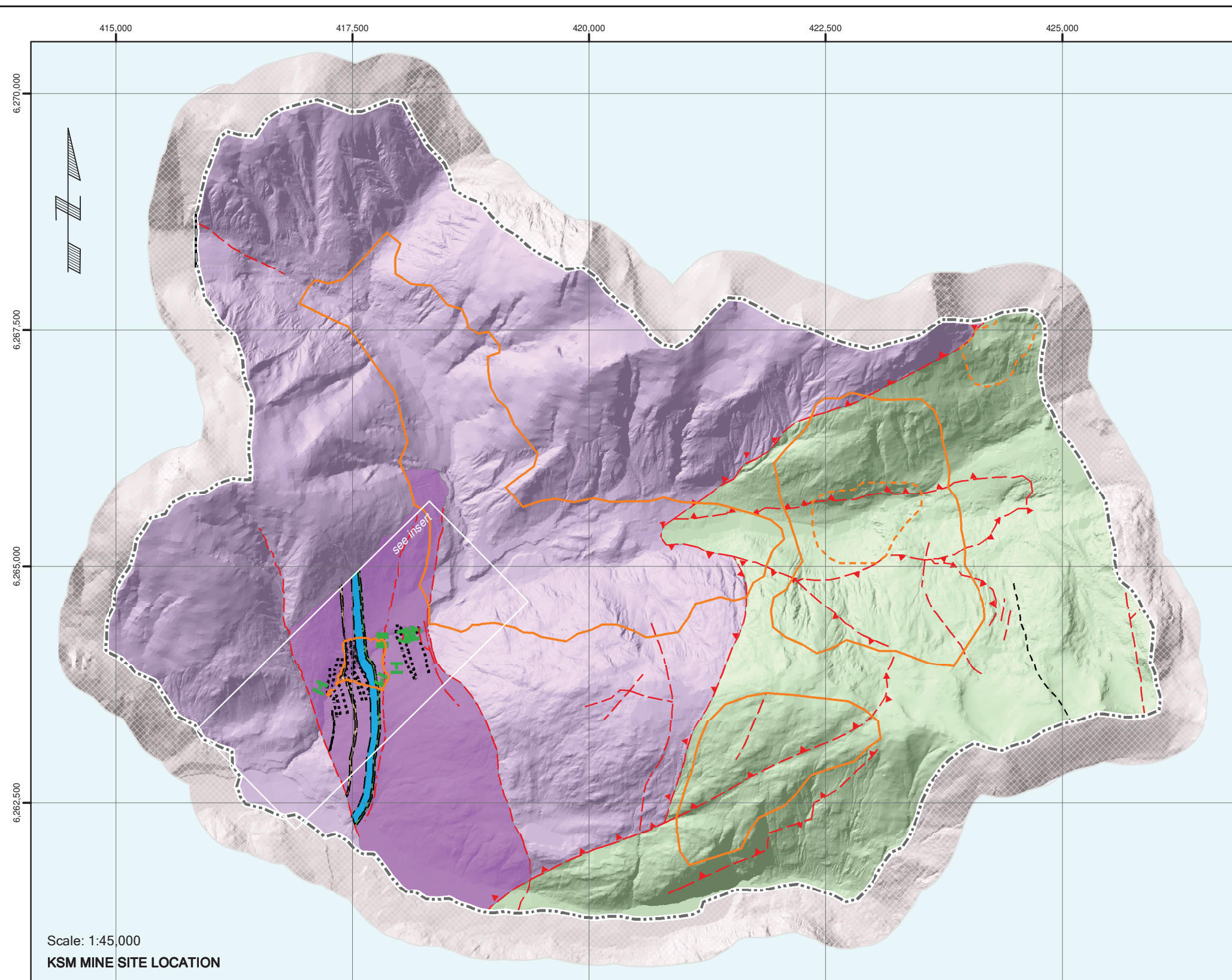
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SEABRIDGE GOLD

Klohn Crippen Berger

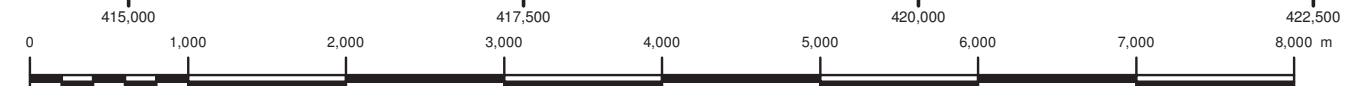
PROJECT KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE KSM WATER STORAGE FACILITY (WSF) DRILLHOLE AND MONITORING SITES			
DATE JUNE 2013	PROJECT No. M09480A04	DWG No. 03	REV. B

Z:\MINE\M09480A04 - KSM 2012 FS\Drawings\Figures\KSM Figures\updated 20130604\12_04_Geology.mxd



Scale: 1:45,000
KSM MINE SITE LOCATION

Direction: North East (45°)
Scale: 1:15,000
WSF SITE LOCATION



NOT FOR CONSTRUCTION

Legend	
--- Model Boundary	--- Contact between rock units
--- UG Infrastructure Footprint	--- Graphitic Bed
--- Infrastructure Footprint	--- Anticline
--- Regional Undifferentiated Stuhini	--- Dextral Strike Slip
--- Undifferentiated Hazelton Volcanics	--- Dyke
--- Fault	--- Porous Moraine Boundary
--- Sinistral Strike Slip	--- Thrust Fault
--- Syncline	--- Altered Volcanic Rocks
--- Fault	--- Calc-Silicate Hornfels
--- Fault	--- Calcareous Siltstone and Sandstone and Minor Calc-Silicate Hornfels
--- Fault	--- Siltstone and Shale with Lesser Calcareous Siltstone and Sandstone and Hornfels

Notes:
1. UTM Zone 9N, NAD83
2. Topographic Data from BC TRIM (n.d.)
3. LIDAR Composite DEM (n.d.)

NO.	DATE	ISSUE / REVISION	DRAWN	CHK'D	DESIGN	APP'D
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A	DECEMBER 2012	DRAFT - ISSUED FOR CLIENT REVIEW	SJ	TE	SJ	CD

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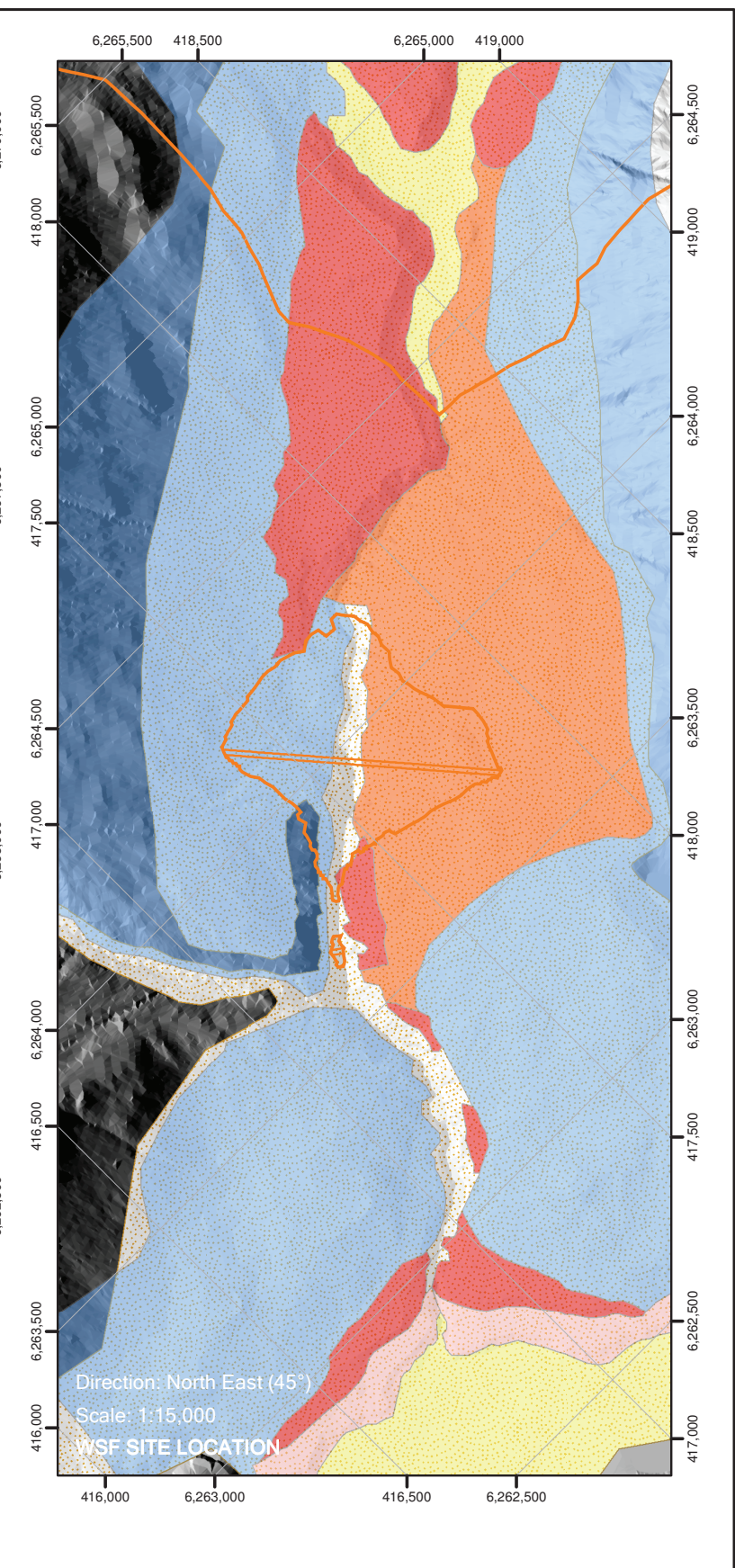
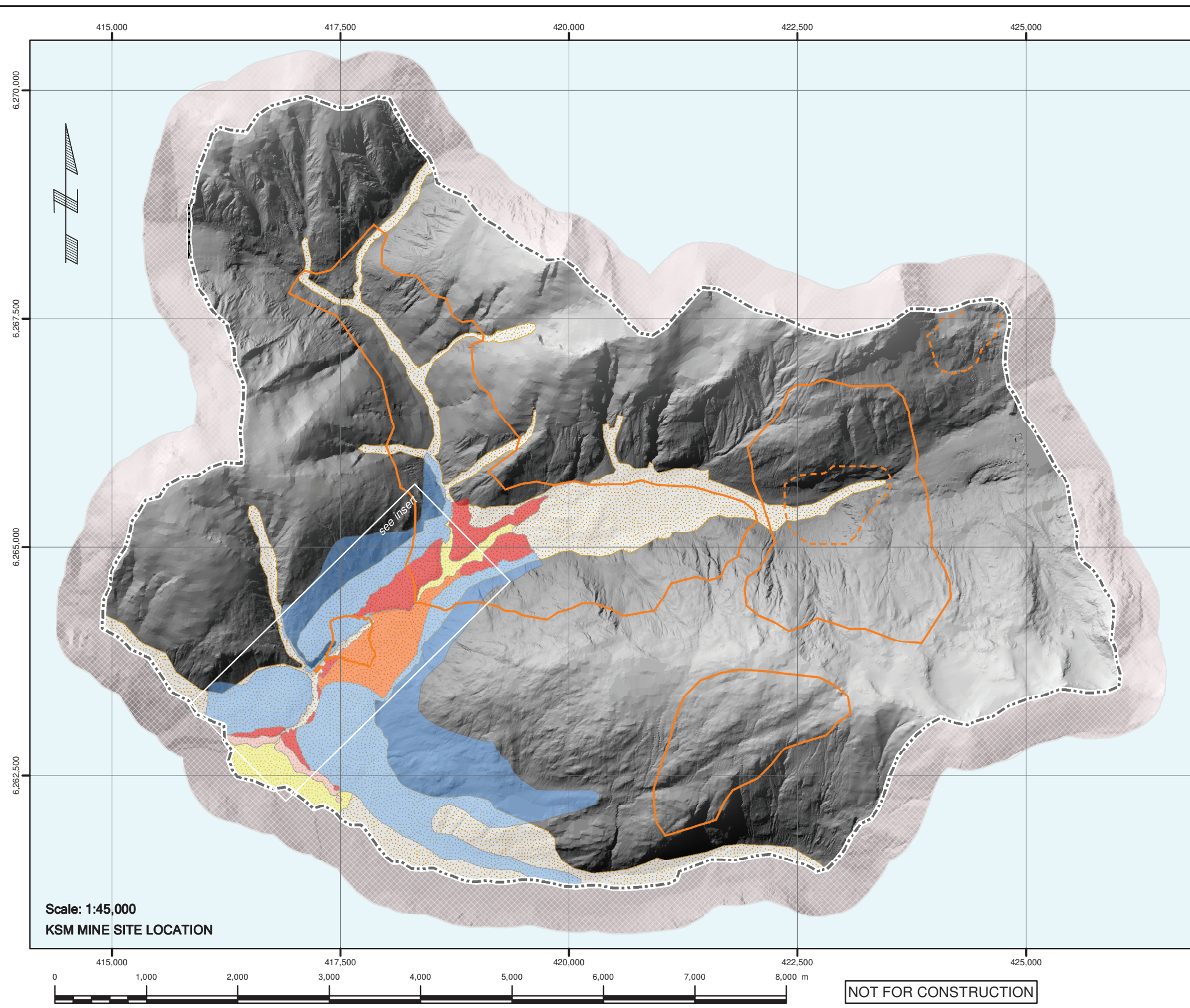
CLIENT

SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT			
KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE			
KSM WATER STORAGE FACILITY (WSF) GEOLOGY MAP			
DATE	PROJECT No.	DWG No.	REV.
JUNE 2013	M09480A04	04	B

Z:\MINE\M09480A04 - KSM 2012 FS Project\Drawings\Figures\KSM Figures\updated 20130604\12_05_Overburden.mxd



NOT FOR CONSTRUCTION

Legend

- Model Boundary
- Mixed Moraine Deposits and Colluvium
- Alluvium
- Secondary Terrace Deposits
- UG Infrastructure Footprint
- Till Deposits
- Terrace Deposits
- Overburden Boundary
- Infrastructure Footprint

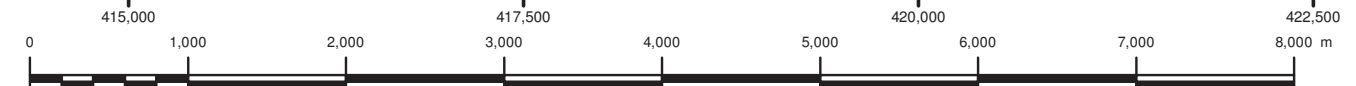
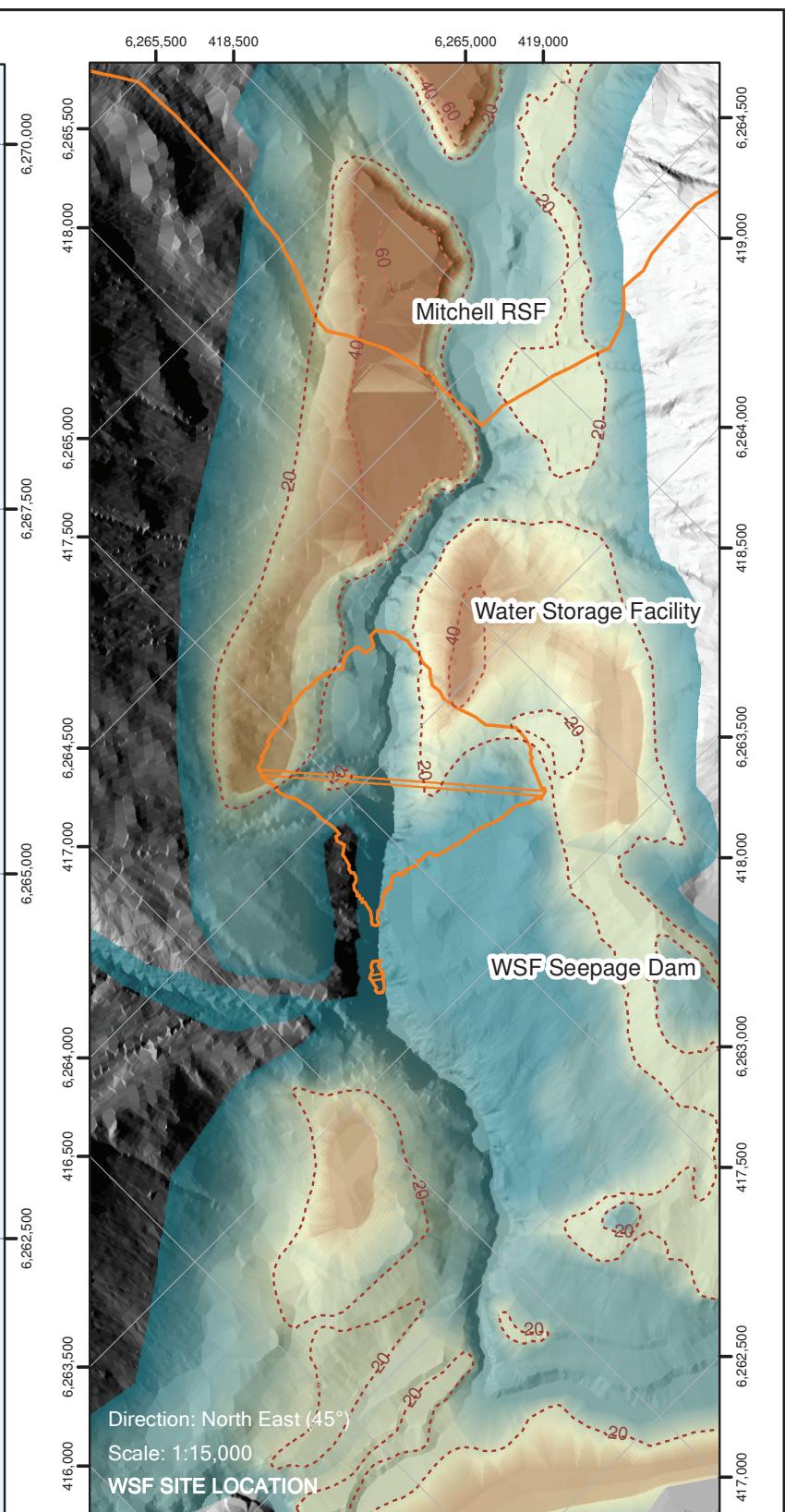
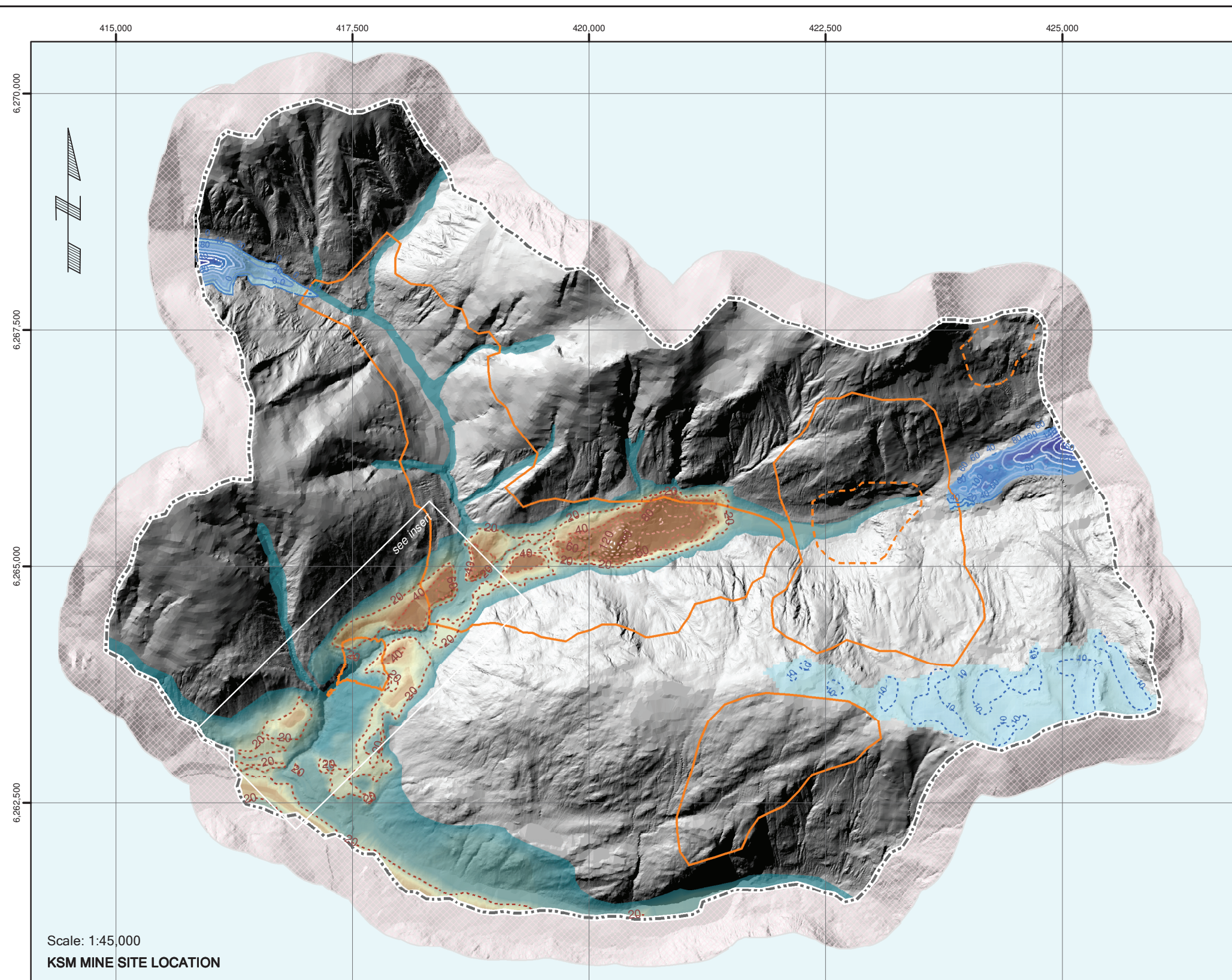
Notes:

1. UTM Zone 9N, NAD83
2. Topographic Data from BC TRIM (n.d.)
3. LiDAR Composite DEM (n.d.)

NO.	DATE	ISSUE / REVISION	DRAWN	CHK'D	DESIGN	APP'D
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		<p>TITLE</p> <p style="text-align: center;">KSM WATER STORAGE FACILITY (WSF) OVERBURDEN MAP</p>								
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 25%;">DRAWING NO.</td> <td style="width: 25%;">PROJECT No.</td> <td style="width: 25%;">DWG No.</td> <td style="width: 25%;">REV.</td> </tr> <tr> <td></td> <td style="text-align: center;">M09480A04</td> <td style="text-align: center;">05</td> <td style="text-align: center;">B</td> </tr> </table>		DRAWING NO.	PROJECT No.	DWG No.	REV.		M09480A04	05	B	<p>DATE</p> <p style="text-align: center;">JUNE 2013</p>
DRAWING NO.	PROJECT No.	DWG No.	REV.							
	M09480A04	05	B							

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Legend

Overburden Isopach (m)	Ice/Glacial Isopach (m)	Ice/Glacial Isopach	Overburden Isopach	Model Boundary
- - - 20	10 - 40	High : 210	High : 140	- - -
- - - 21 - 40	41 - 70	Low : 0	Low : 5	- - - UG Infrastructure Footprint
- - - 41 - 60	71 - 110			Infrastructure Footprint
- - - 61 - 80	111 - 160			
- - - 81 - 100	161 - 210			
- - - 101 - 120				
- - - 121 - 140				

Scale: 1:45,000

Notes:
1. UTM Zone 9N, NAD83
2. Topographic Data from BC TRIM (n.d.)
3. LiDAR Composite DEM (n.d.)

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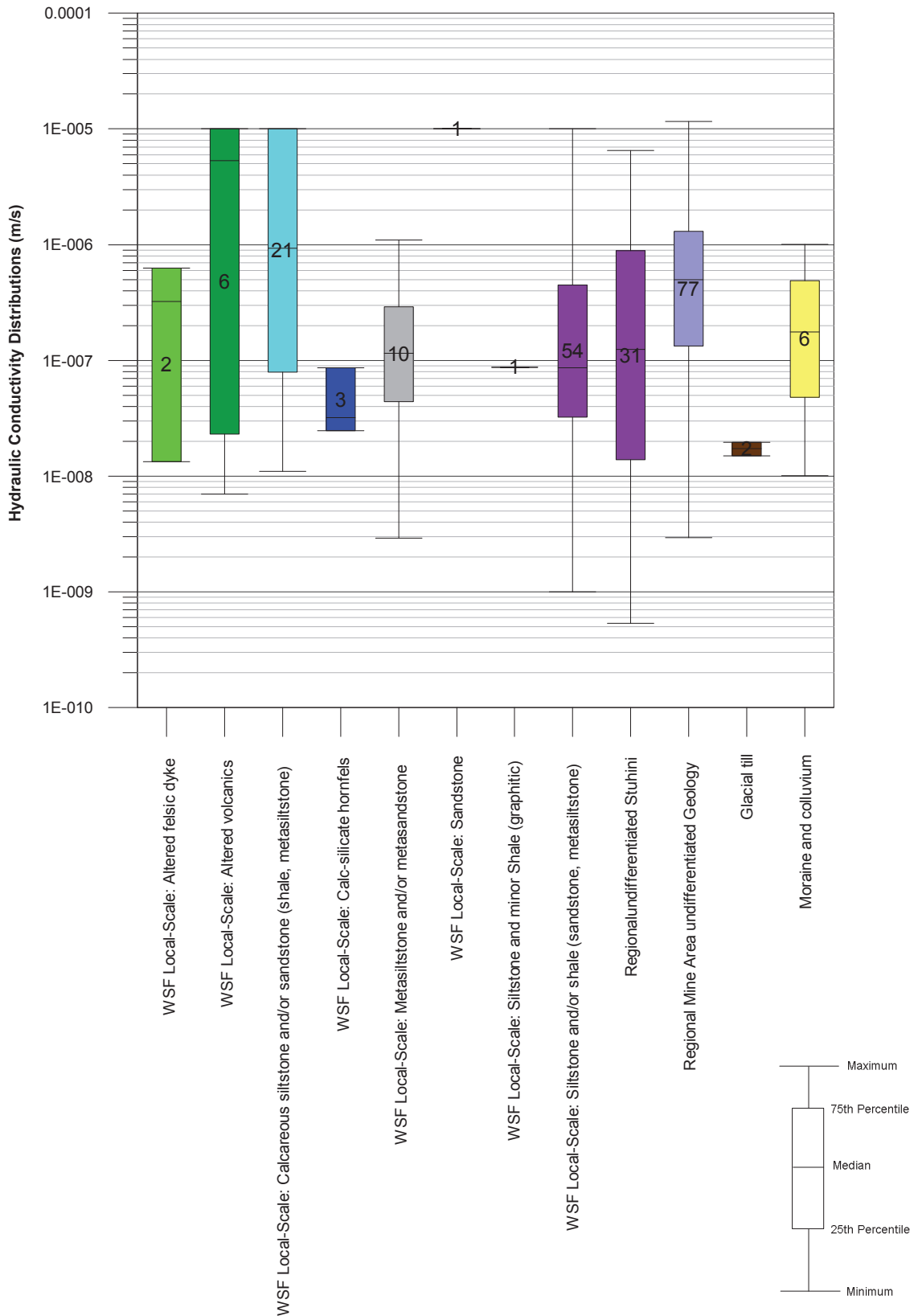
CLIENT

SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT	KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling		
TITLE	KSM WATER STORAGE FACILITY (WSF) ICE THICKNESS, GLACIER AND OVERBURDEN THICKNESS MAP		
DATE	PROJECT No.	DWG No.	REV.
JUNE 2013	M09480A04	06	B

Box and Whisker of K Distributions



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CLIENT

SEABRIDGE GOLD

PROJECT
KSM 2012 FS Project
 Water Storage Facility Seepage Mitigation Modelling

TITLE
KSM Water Storage Facility (WSF)
 Box and Whisker of K Distributions

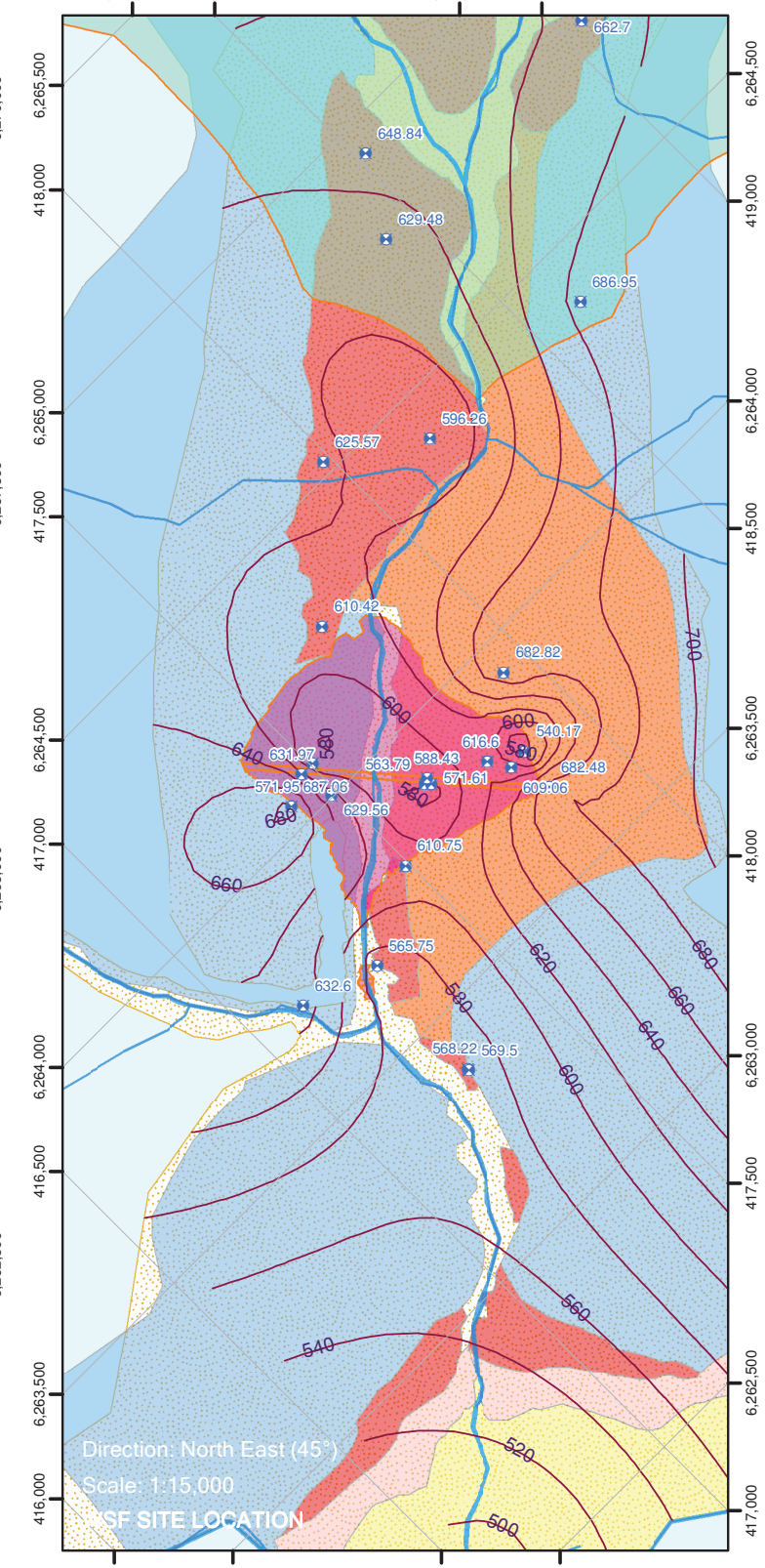
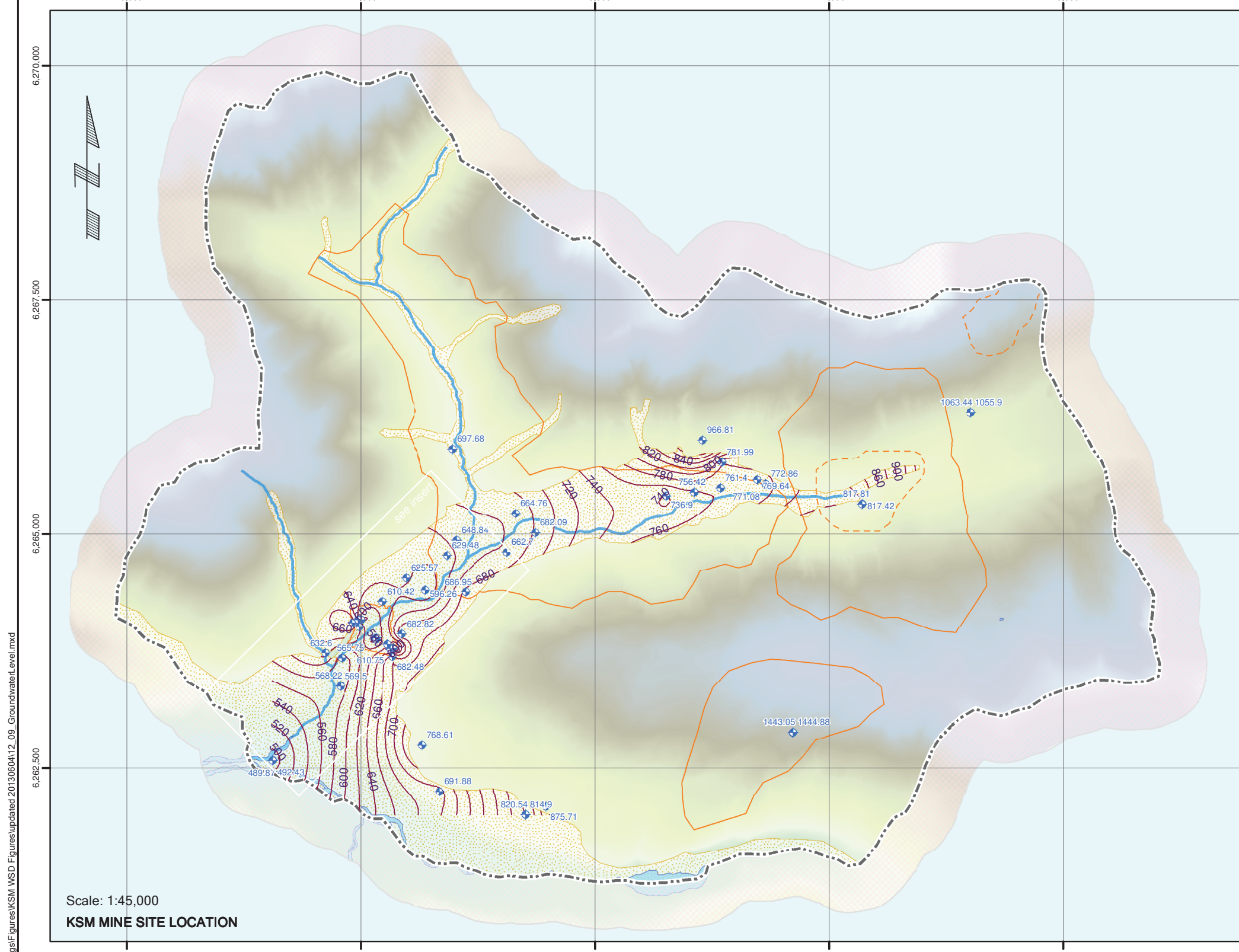
PROJECT NO. **M09480A04**

FIGURE NO. **FIGURE 07**

Scale		Down-gradient Regional	Sub-regional	Dam-site	Dam-site	Dam-site	Dam-site	Dam-site	Sub-regional	Dam-site	Dam-site	Sub-regional	Up-gradient Regional	Up-gradient Regional
HSU (Hydrostratigraphic Unit)		Regional Stuhini	Downstream fault	WSF Stuhini (Siltstone/shale)	WSF metasediments	Calcareous siltstone and sandstone ZONE A: within 150m of creek	Calcareous siltstone and sandstone ZONE B: greater than 150m from creek	Altered volcanics	Central Fault (or volcanic ridge)	WSF Stuhini (Siltstone/shale)	felsic dykes	Upstream Fault	Regional Stuhini	Regional Mine Area Geology (Hazelton Group)
Layer and Depth	1	10	DVB: see separate parameter table [incl Dam/RSF]											
	2	40	Min 7.8e-9 Max 6.5e-6 Geomean 2.87e-7	Min 1E-9 Max 1 E-5 Geomean 2.85 E-7	Min 8.2E-9 Max 1.1 E-6 Geomean 1.08E-7	Lower Bound 1e-5	Min 1.10E-8 Max 2.50E-7 Geomean 4.22E-8	Lower Bound 1E-5	Min 2.3E-8 Max 7E-7 Geomean 1.27E-7	Min 1E-9 Max 1 E-5 Geomean 2.85 E-7	Min 1.33E-8 Max 6.30E-7 Geomean 9.14E-8	Min 7.8e-9 Max 6.5e-6 Geomean 2.87e-7	Min 1.78E-8 Max 1.16E-5 Geomean 8.06E-7	
	3	50												
	60													
	70													
	80													
	90													
	100													
	4	110	Min 1.09e-8 Max 2.26E-8 Geomean 1.57e-8	Min 1.23 E-9 Max 3.57 E-7 3.43 E-8	Min 2.9E-9 Max 2.9E-7 Geomean 5.68 E-8	Min 3.00E-8 Max 9.26E-7 Geomean 1.15E-7	Single value 6.99E-9	Min 1.23 E-9 Max 3.57 E-7 3.43 E-8	Min 1.09e-8 Max 2.26E-8 Geomean 1.57e-8	Min 2.93E-9 Max 2.5 E-6 Geomean 2.16E-7				
	5	120												
	130													
	140													
	150													
	160													
	170													
	180													
	190													
	200													
	6	210	Min 2.54 e-9 Max 4.2 e-9 Geomean 3.27E-9	Refer to Regional Stuhini 200-300m	Refer to Regional Stuhini 200-300m	Refer to Regional Stuhini 200-300m	Refer to Regional Stuhini 200-300m	Refer to Regional Stuhini 200-300m	Min 2.54 e-9 Max 4.2 e-9 Geomean 3.27E-9	Previous KCB calibration: 1.6E-8				
	220													
	230													
	240													
	250													
	260													
	270													
	280													
	290													
300														
7	310	Min 1.18e-9 Max 5.33 e-10 Geomean 1.05E-9	Refer to Regional Stuhini 300-400m	Refer to Regional Stuhini 300-400m	Previous KCB calibration: 2.6E-8	Previous KCB calibration: 2.6E-8	Refer to Regional Stuhini 300-400m	Min 1.18e-9 Max 5.33 e-10 Geomean 1.05E-9	Previous KCB calibration: 7.5E-9					
320														
330														
340														
350														
360														
370														
380														
390														
400														
8	400-500	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated		
9	To elevation -700 masl	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated	Extrapolated		

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		<p>TITLE</p> <p>KSM Water Storage Facility (WSF) Hydrostratigraphic Model</p>
		<p>PROJECT NO: M09480A04</p> <p>FIGURE NO: FIGURE 08</p>



Scale: 1:45,000
KSM MINE SITE LOCATION

Direction: North East (45°)
Scale: 1:15,000
SF SITE LOCATION



NOT FOR CONSTRUCTION

- Legend**
- Model Boundary
 - UG Infrastructure Footprint
 - Infrastructure Footprint
 - ◆ Drill Site
 - Groundwater Contour 20m interval
 - Primary Drainage
 - Mixed Moraine Deposits and Colluvium
 - Till Deposits
 - Alluvium
 - Terrace Deposits
 - Secondary Terrace Deposits
 - Overburden Boundary

- Notes:**
1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. LIDAR Composite DEM (n.d.)

Scale: 1:45,000

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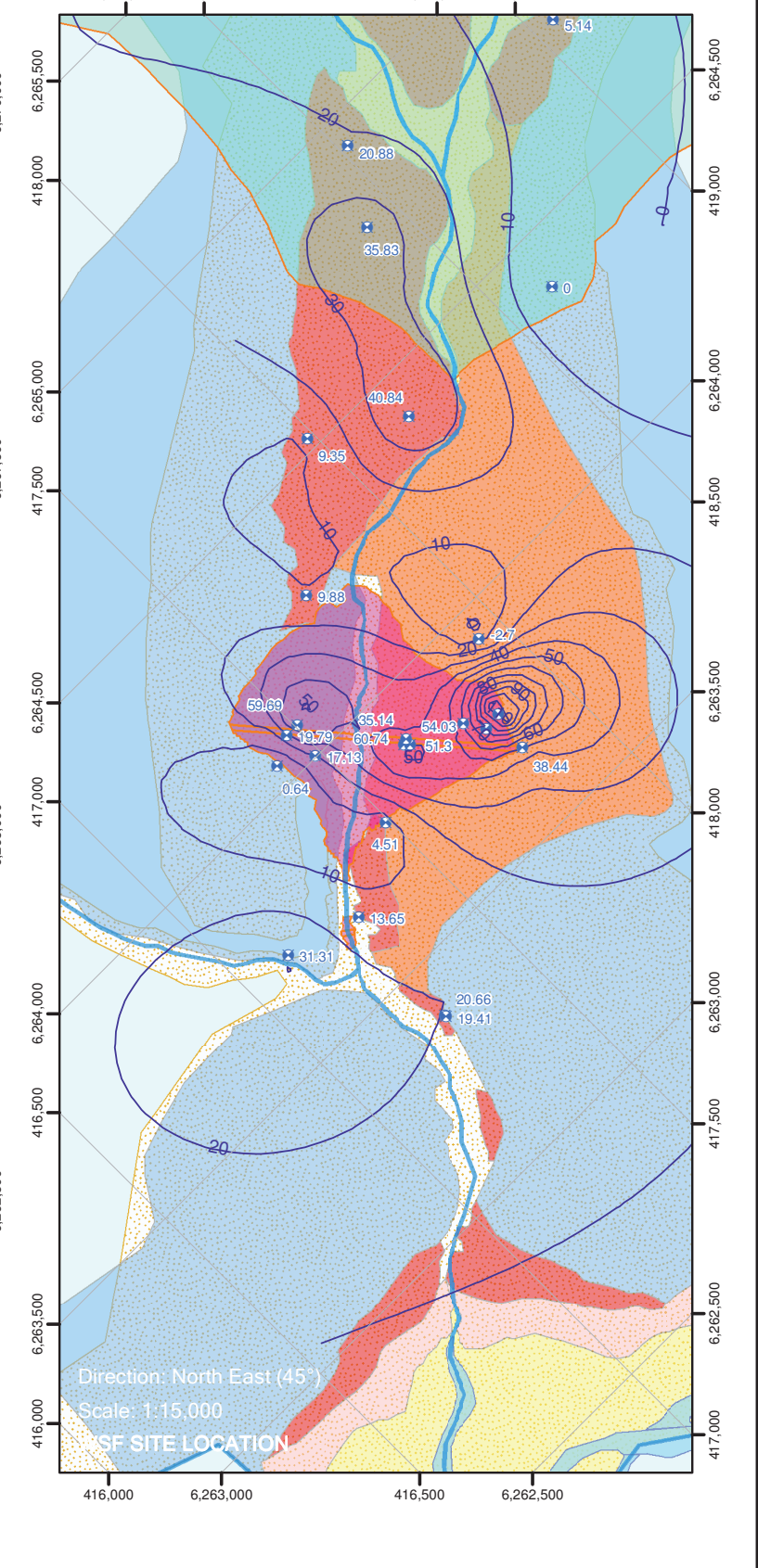
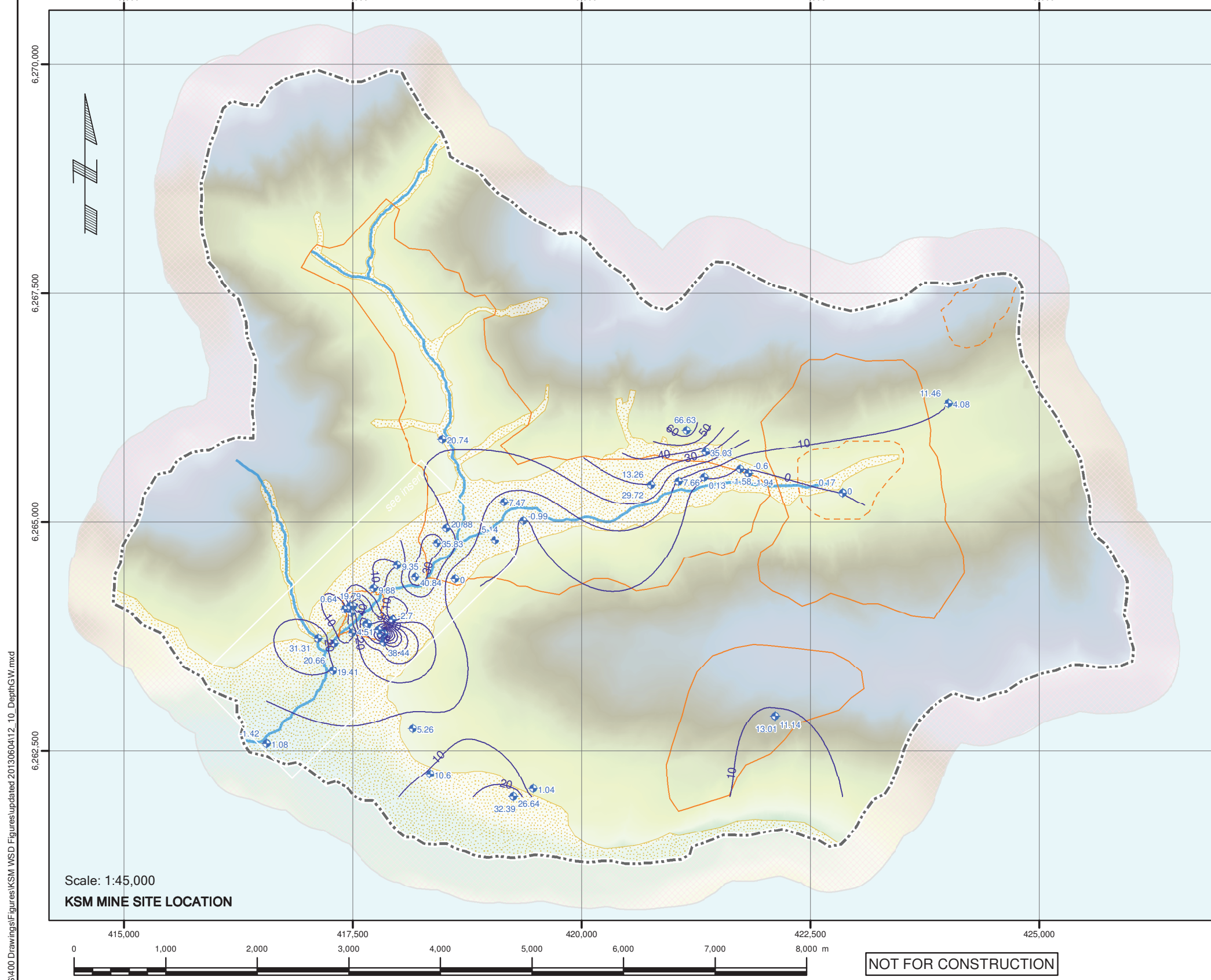
CLIENT

SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE OBSERVED ANNUAL AVERAGE GROUNDWATER LEVELS			
DATE JUNE 2013	PROJECT No. M09480A04	DWG No. 09	REV. B

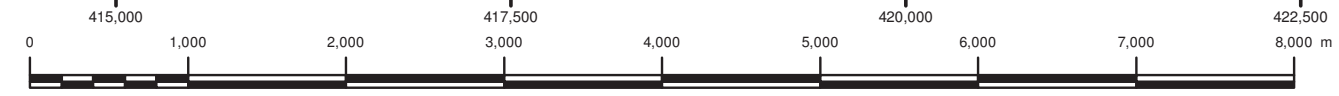
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Scale: 1:45,000
KSM MINE SITE LOCATION

Direction: North East (45°)
Scale: 1:15,000
SF SITE LOCATION



NOT FOR CONSTRUCTION

- Legend**
- Model Boundary
 - Drill Site
 - Mixed Moraine Deposits and Colluvium
 - Terrace Deposits
 - UG Infrastructure Footprint
 - Groundwater Depth 10m interval
 - Till Deposits
 - Secondary Terrace Deposits
 - Infrastructure Footprint
 - Primary Drainage
 - Alluvium
 - Overburden Boundary

- Notes:**
1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. LIDAR Composite DEM (n.d.)

Scale: 1:45,000

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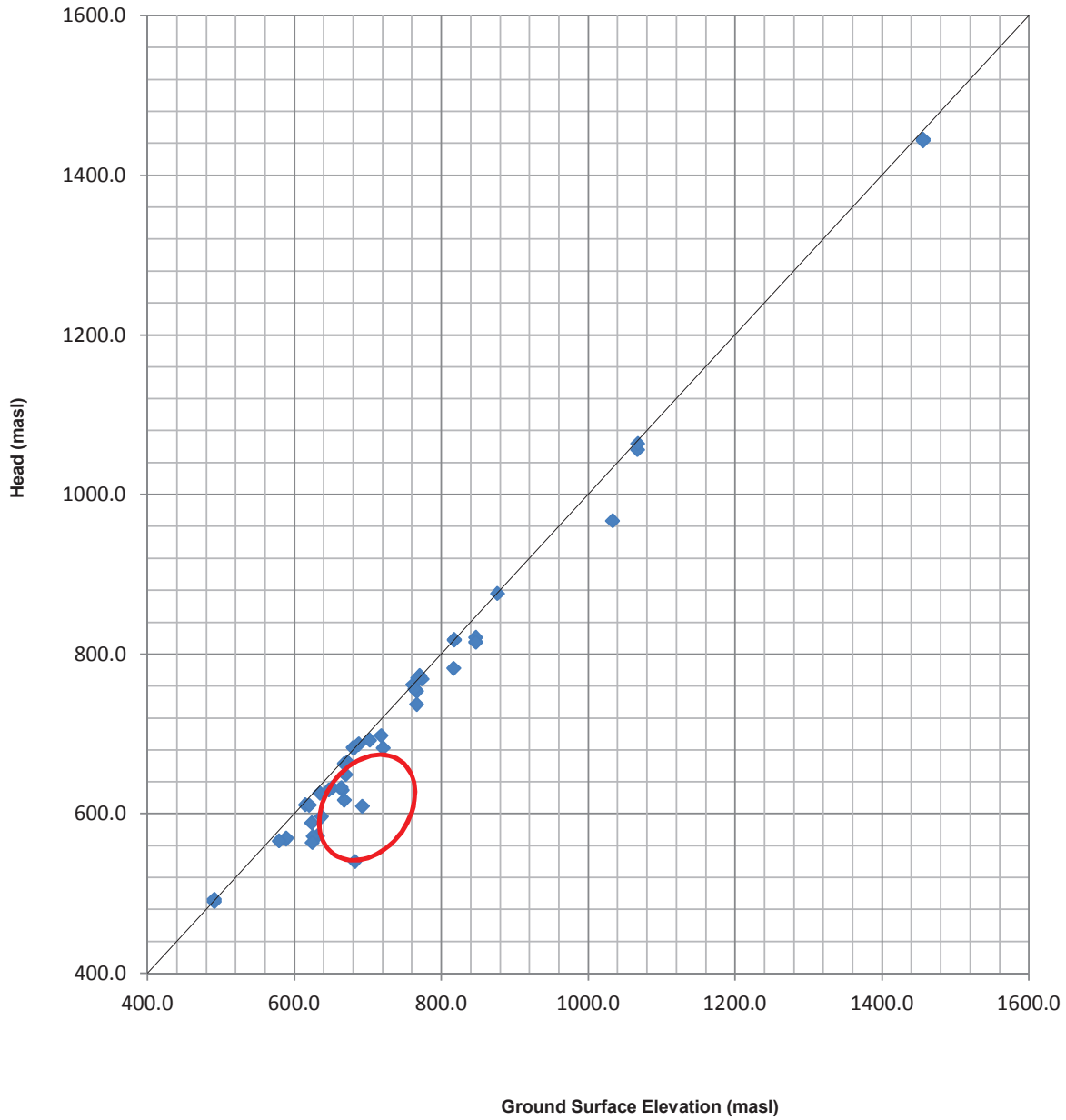
SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT			
KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE			
DEPTH TO GROUNDWATER BASED ON ANNUAL AVERAGE VALUES			
DATE	PROJECT No.	DWG No.	REV.
JUNE 2013	M09480A04	10	B

NO.	DATE	ISSUE / REVISION	DRAWN	CHK'D	DESIGN	APP'D
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Hydraulic Head versus Ground Surface Elevation



TO BE READ WITH KLOHN CRIPPEN BERGER REPORT DATED JUNE 2013

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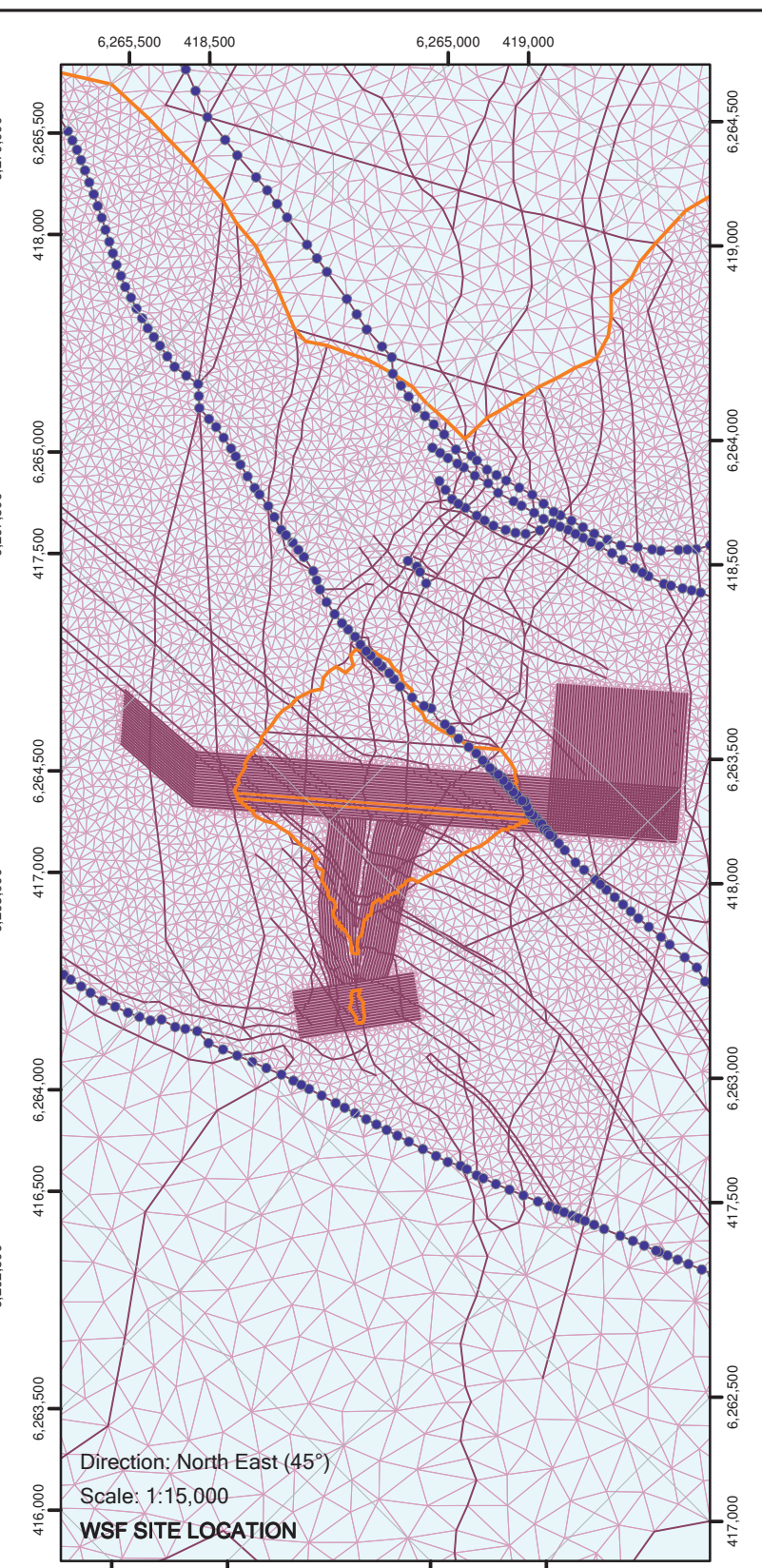
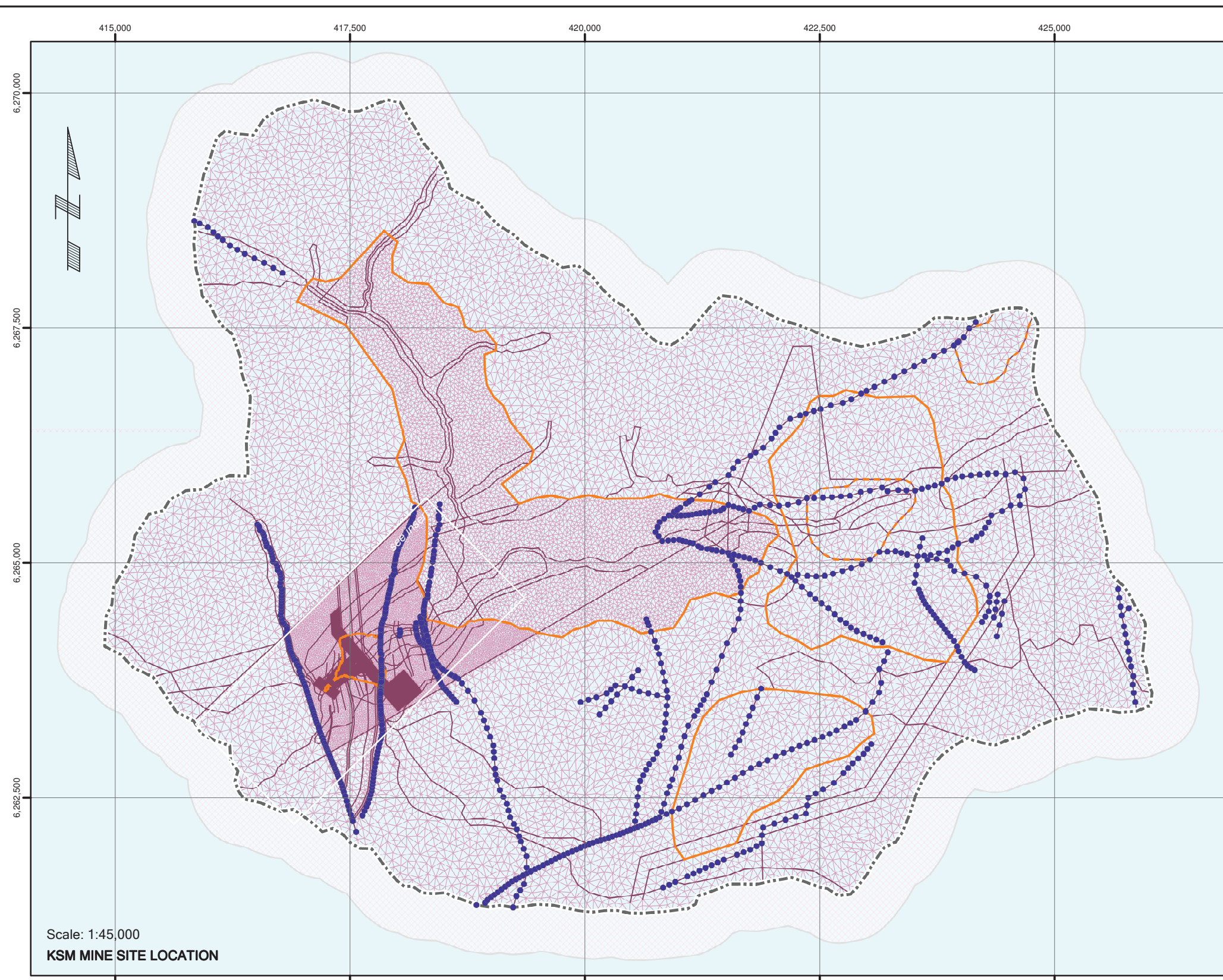
CLIENT

SEABRIDGE GOLD



PROJECT	KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling	
TITLE	KSM Water Storage Facility (WSF) Scatter Plot of Hydraulic Head versus Ground Surface Elevation	
PROJECT NO.	M09480A04	FIGURE NO. FIGURE 11

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Scale: 1:45,000
KSM MINE SITE LOCATION

Direction: North East (45°)
Scale: 1:15,000
WSF SITE LOCATION



NOT FOR CONSTRUCTION

Legend

- Model Boundary
- Fault Discrete Features
- UG Infrastructure Footprint
- Infrastructure Footprint
- Primary Mesh Elements
- Model Mesh

- Notes:
1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. LIDAR Composite DEM (n.d.)

Scale: 1:45,000

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A	DECEMBER 2012	DRAFT - ISSUED FOR CLIENT REVIEW	SJ	TE	SJ	CD

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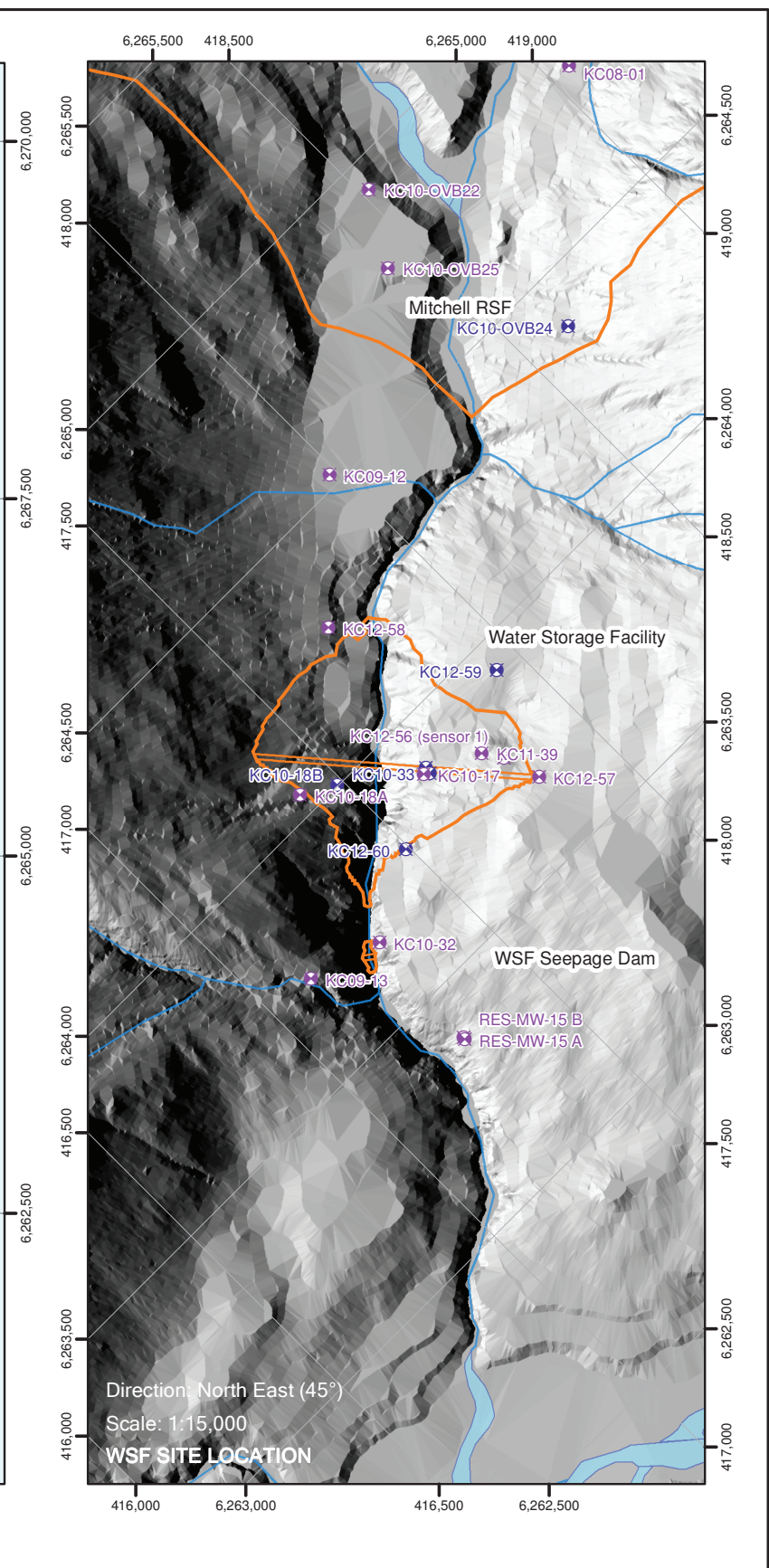
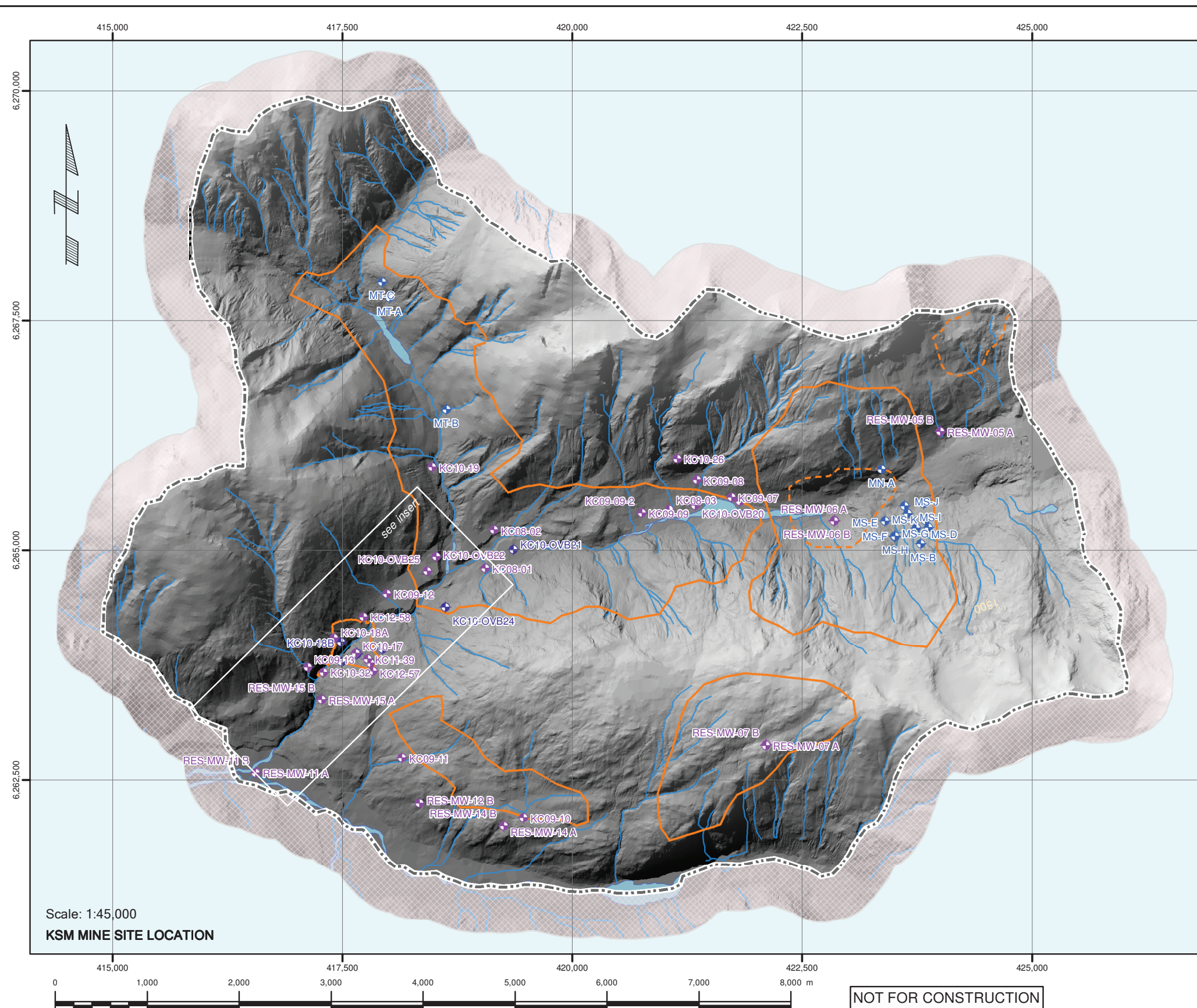
CLIENT

SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT			
KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE			
KSM WATER STORAGE FACILITY (WSF) SUB-REGIONAL AND REGIONAL FAULT REPRESENTED AS DISCRETE FEATURES			
DATE	PROJECT No.	DWG No.	REV.
JUNE 2013	M09480A04	12	B

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NOT FOR CONSTRUCTION

Legend

- Model Boundary
- - - UG Infrastructure Footprint
- ▭ Infrastructure Footprint
- ◆ Primary Head Calibration Targets
- ◆ Secondary Head Calibration Targets
- ◆ Seep Discharge Targets
- ⊞ Glacier
- ⊞ Icefield
- ⊞ Natural Water Body
- ⊞ Natural Water Course

Notes:
1. UTM Zone 9N, NAD83
2. Topographic Data from BC TRIM (n.d.)
3. LIDAR Composite DEM (n.d.)

Scale: 1:45,000

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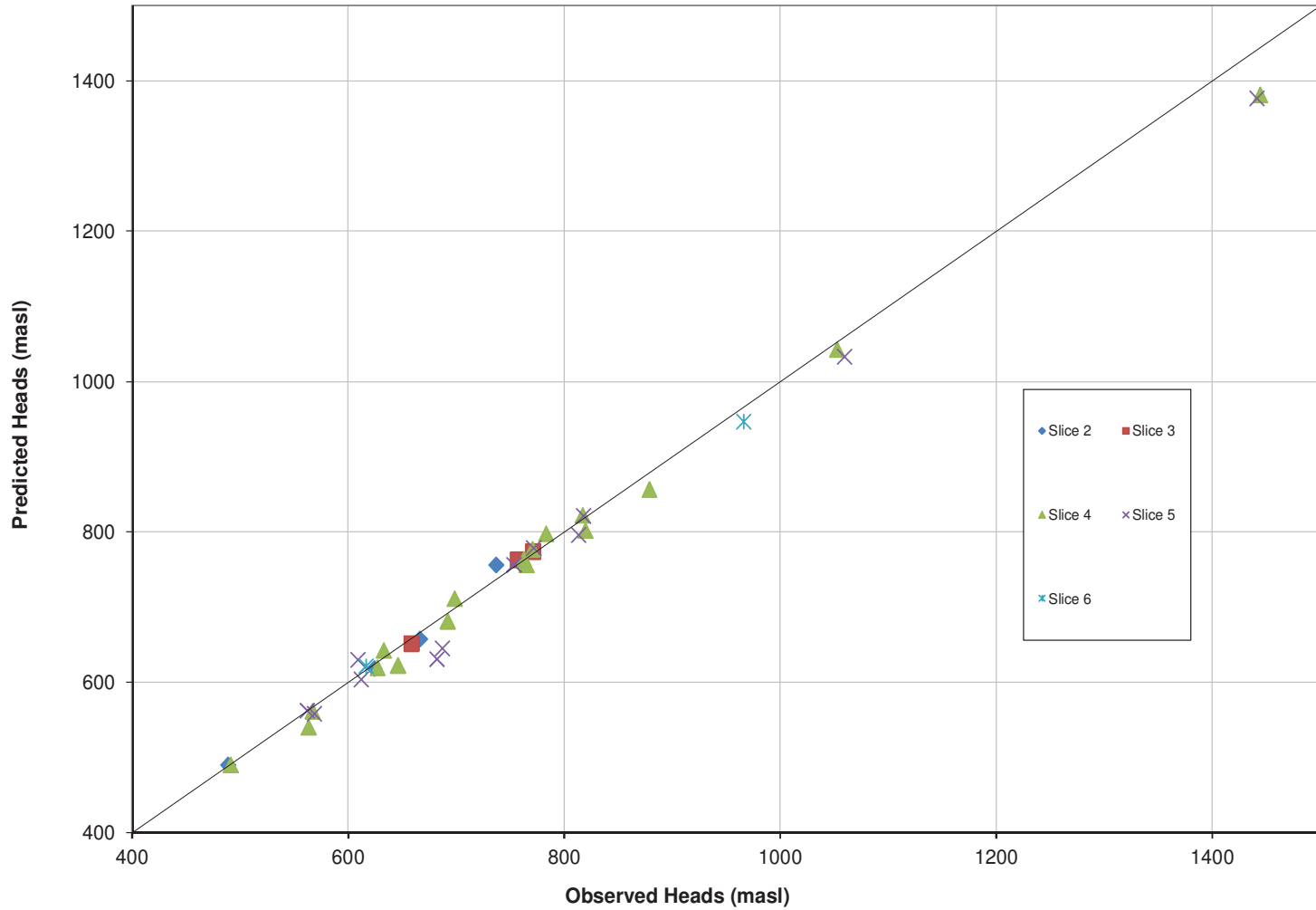
CLIENT

SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE KSM WATER STORAGE FACILITY (WSF) CALIBRATION TARGET LOCATIONS			
DATE JUNE 2013	PROJECT No. M09480A04	DWG No. 13	REV. B

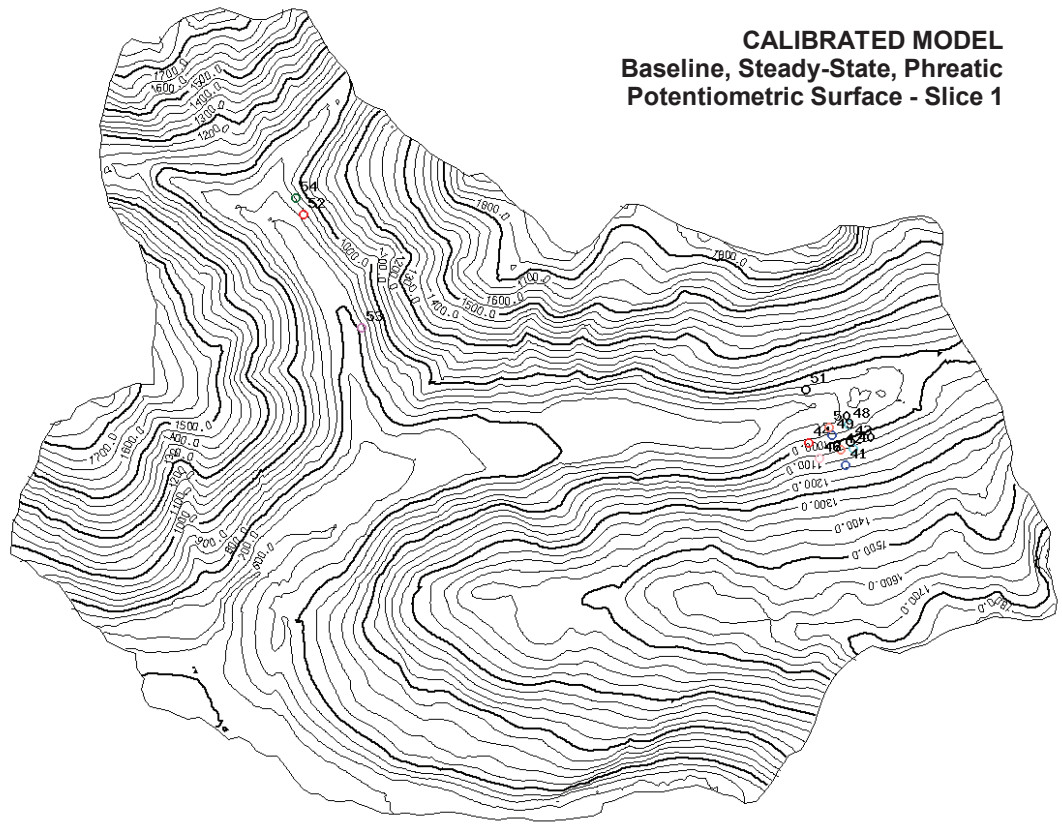
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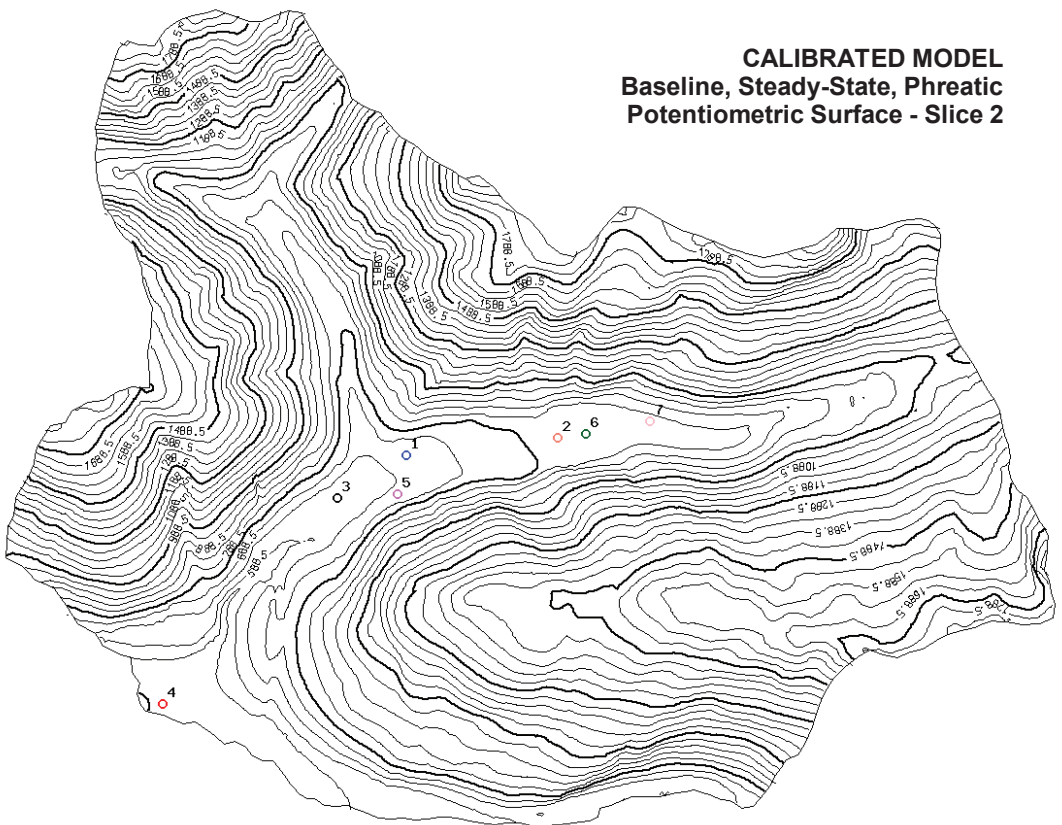
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		KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling
	TITLE KSM Water Storage Facility (WSF) Scatter Plot of Baseline Predicted versus Observed Hydraulic Heads	
	PROJECT NO. M09480A04	FIGURE NO. FIGURE 14

**CALIBRATED MODEL
Baseline, Steady-State, Phreatic
Potentiometric Surface - Slice 1**



**CALIBRATED MODEL
Baseline, Steady-State, Phreatic
Potentiometric Surface - Slice 2**



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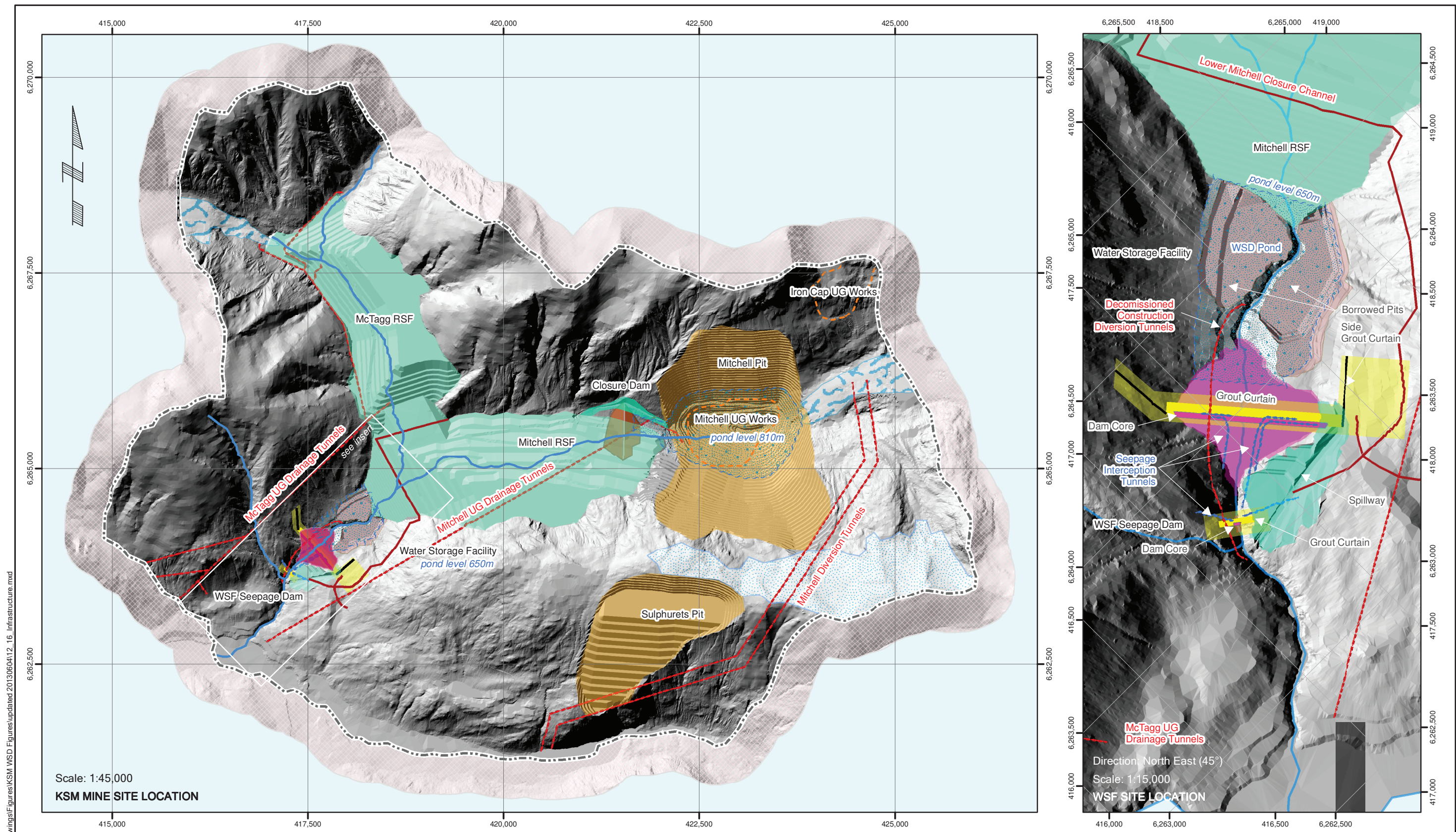
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SEABRIDGE GOLD

Klohn Crippen Berger

PROJECT	KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling	
TITLE	KSM Water Storage Facility (WSF) Predicted Baseline, Steady-State, Confined Potentiometric Surface - Calibrated Model	
PROJECT NO.	M09480A04	FIGURE NO. FIGURE 15



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- Legend**
- Model Boundary
 - Pond Level
 - Closure Dam
 - Underground Tunnel
 - Seepage Dam
 - Grout Curtain
 - Ice Field
 - UG Infrastructure Footprint
 - RSF Footprint
 - Open Pit
 - Dam Core
 - Seepage Interception Tunnel
 - Natural Watercourse
 - Elevation (m)
 - Ditch & Channels
 - Closure Dam Crest
 - Dam Embankment
 - Spillway Footprint
 - Side Grout Curtain
 - Glacier
 - Borrowed Pit

- Notes:**
1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. LIDAR Composite DEM (n.d.)

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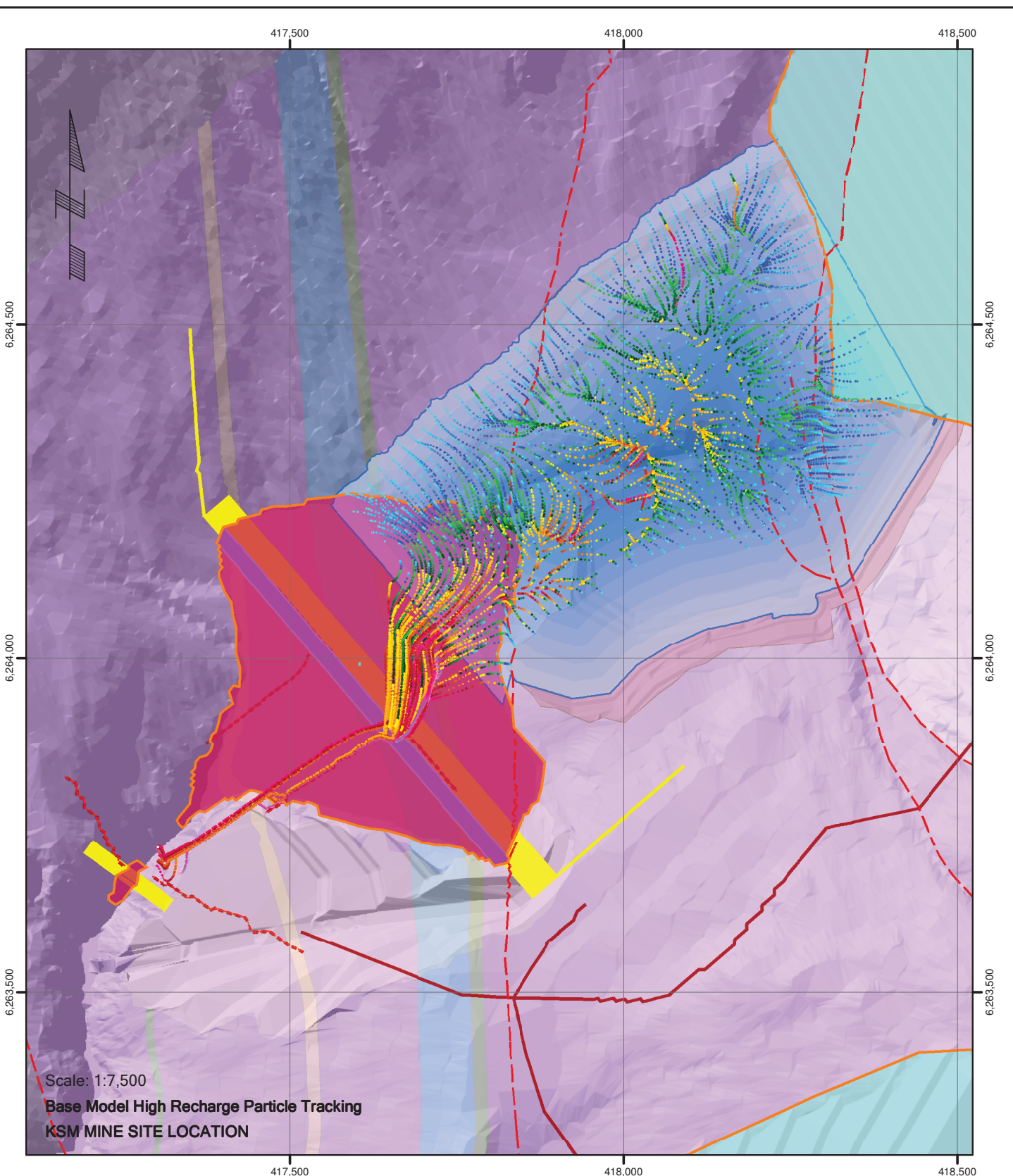
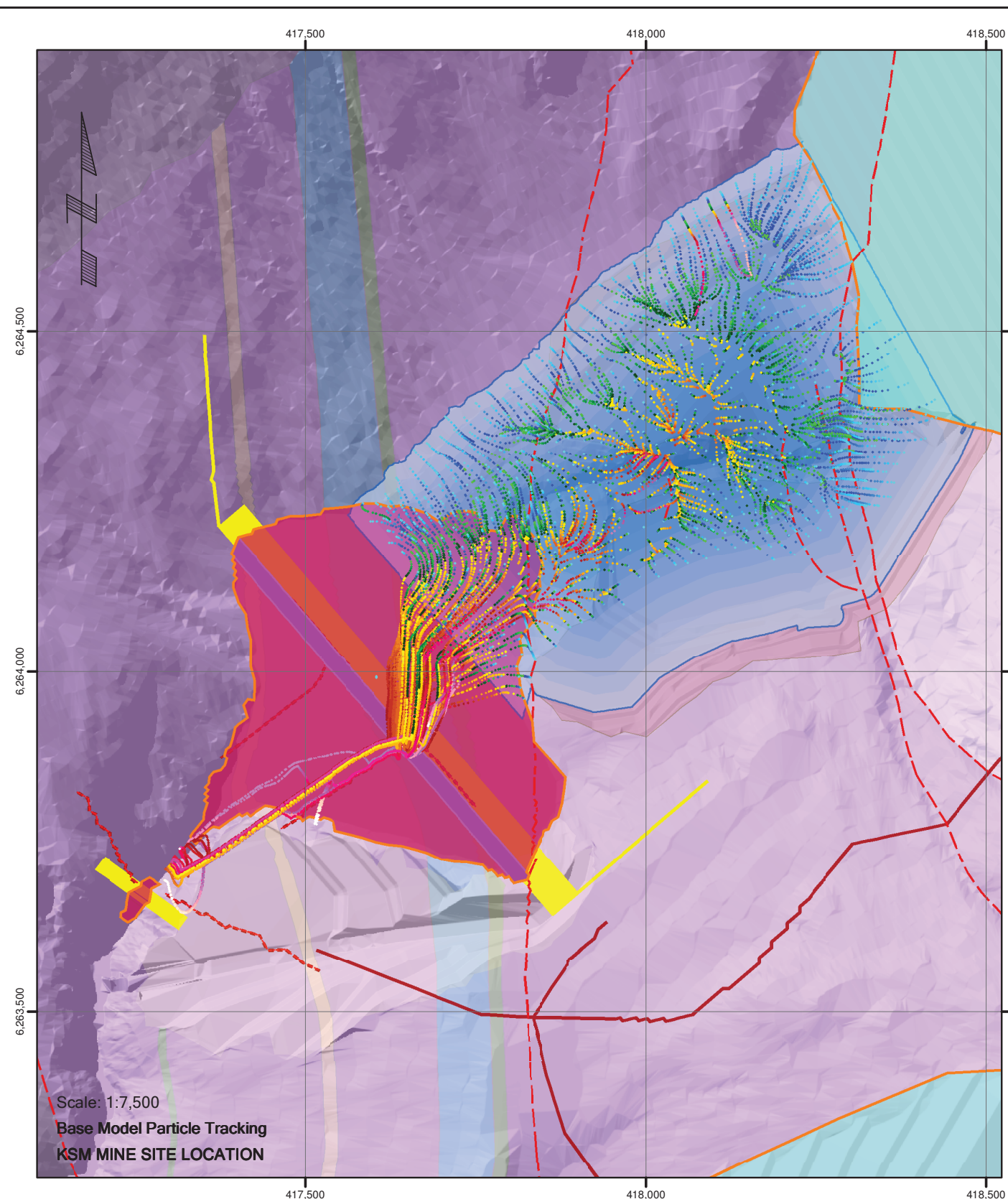
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PROJECT KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE KSM WATER STORAGE FACILITY (WSF) INFRASTRUCTURE MAP			
DATE JUNE 2013	PROJECT No. M09480A04	DWG No. 16	REV. B

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Legend			
--- Model Boundary	Altered Volcanic Rocks	Calcareous Siltstone and Sandstone and Minor Calc-Silicate Hornfels	Regional Undifferentiated Stuhini
--- UG Infrastructure Footprint	Calc-Silicate Hornfels	Siltstone and Shale with Lesser Calcareous Siltstone and Sandstone and Hornfels	Undifferentiated Hazelton Volcanics
--- Infrastructure Footprint			
--- Faults			

- Notes:
1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. LIDAR Composite DEM (n.d.)

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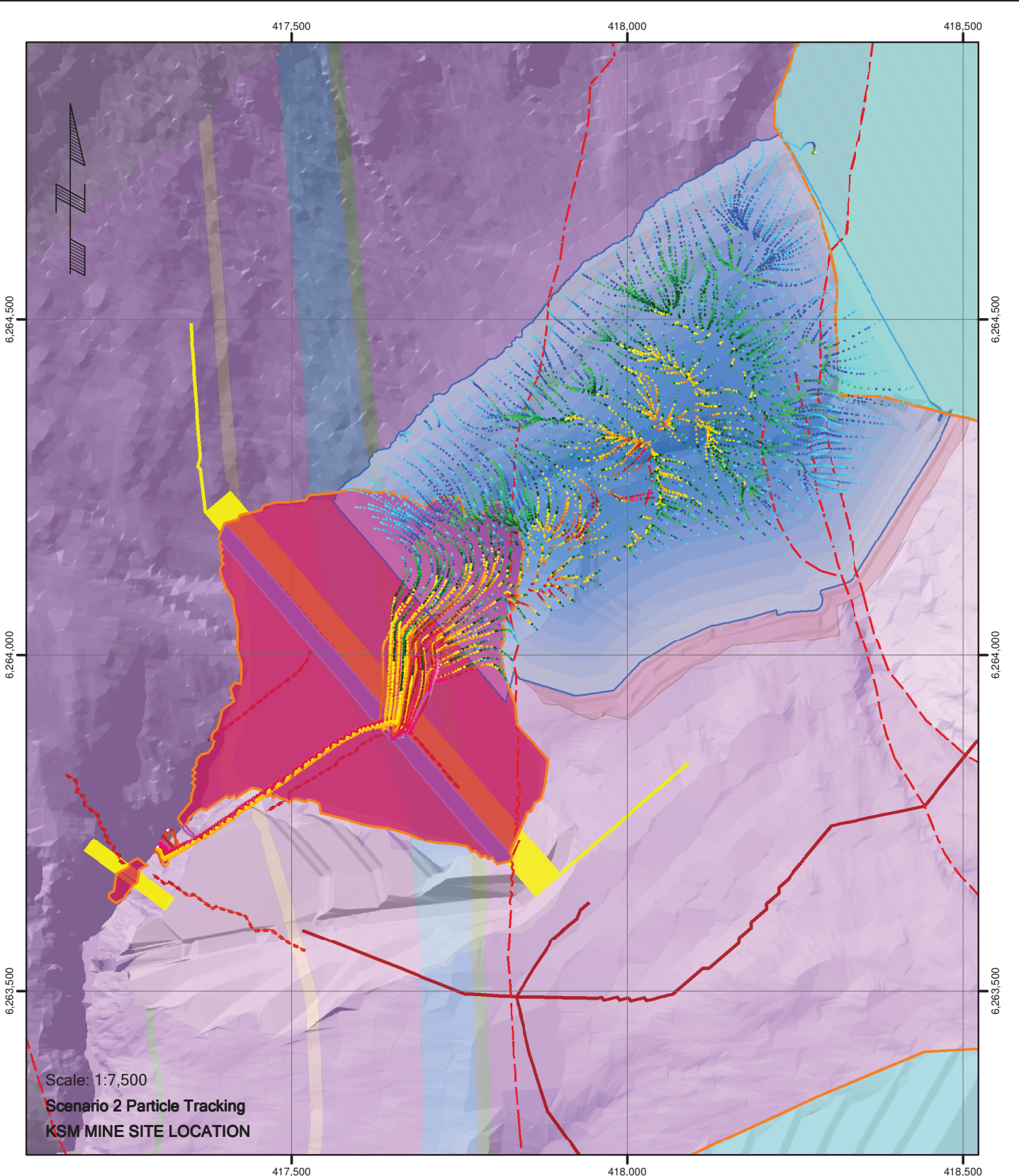
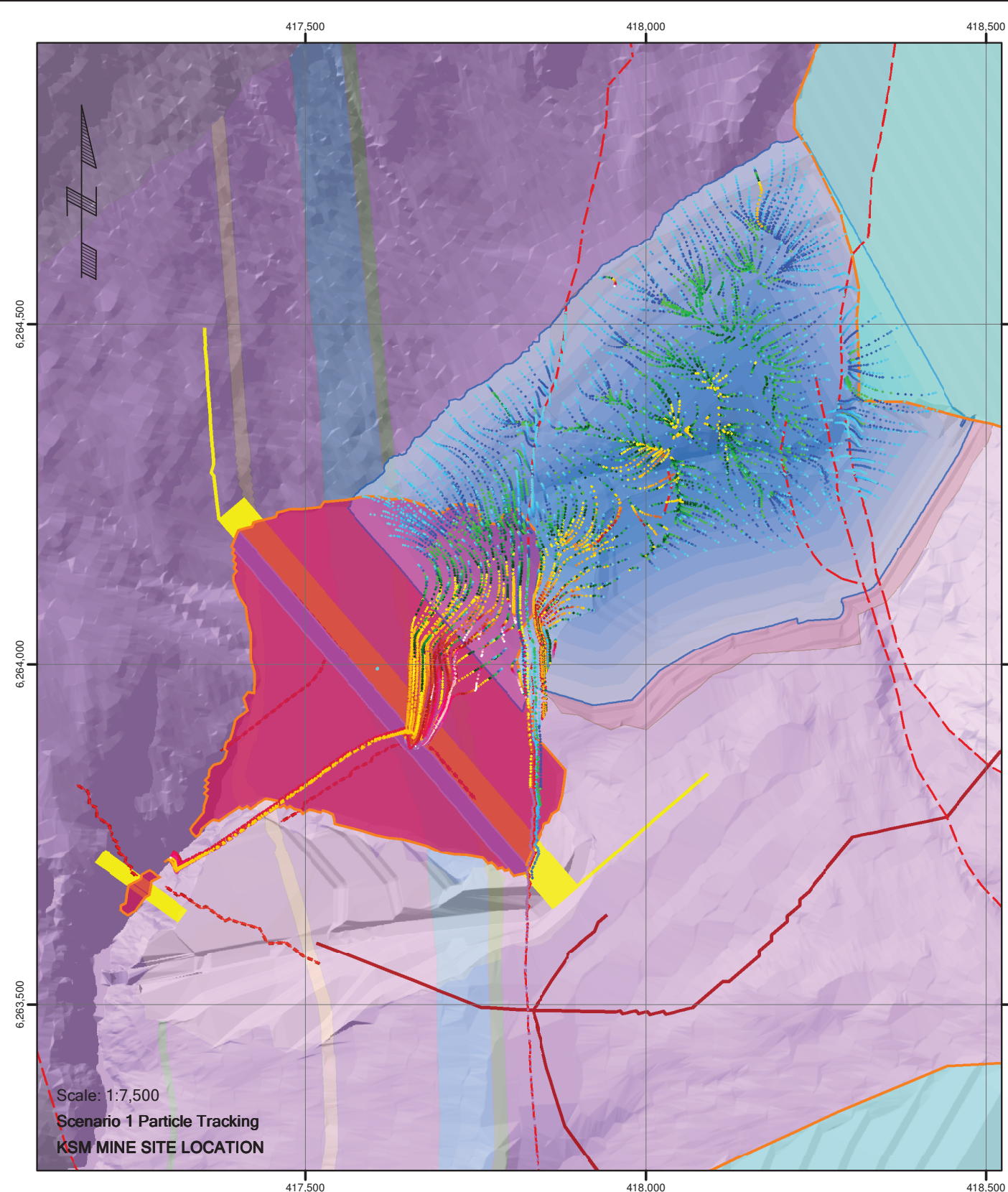
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Klohn Crippen Berger

PROJECT			
KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE			
KSM WATER STORAGE FACILITY (WSF) PARTICLE TRACKING RESULTS FOR BASE MODELS			
DATE	PROJECT No.	DWG No.	REV.
JUNE 2013	M09480A04	17	B

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Legend			
--- Model Boundary	Altered Volcanic Rocks	Calcareous Siltstone and Sandstone and Minor Calc-Silicate Hornfels	Regional Undifferentiated Stuhini
--- UG Infrastructure Footprint	Calc-Silicate Hornfels	Siltstone and Shale with Lesser Calcareous Siltstone and Sandstone and Hornfels	Undifferentiated Hazelton Volcanics
--- Infrastructure Footprint			
--- Faults			

- Notes:
1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. LIDAR Composite DEM (n.d.)

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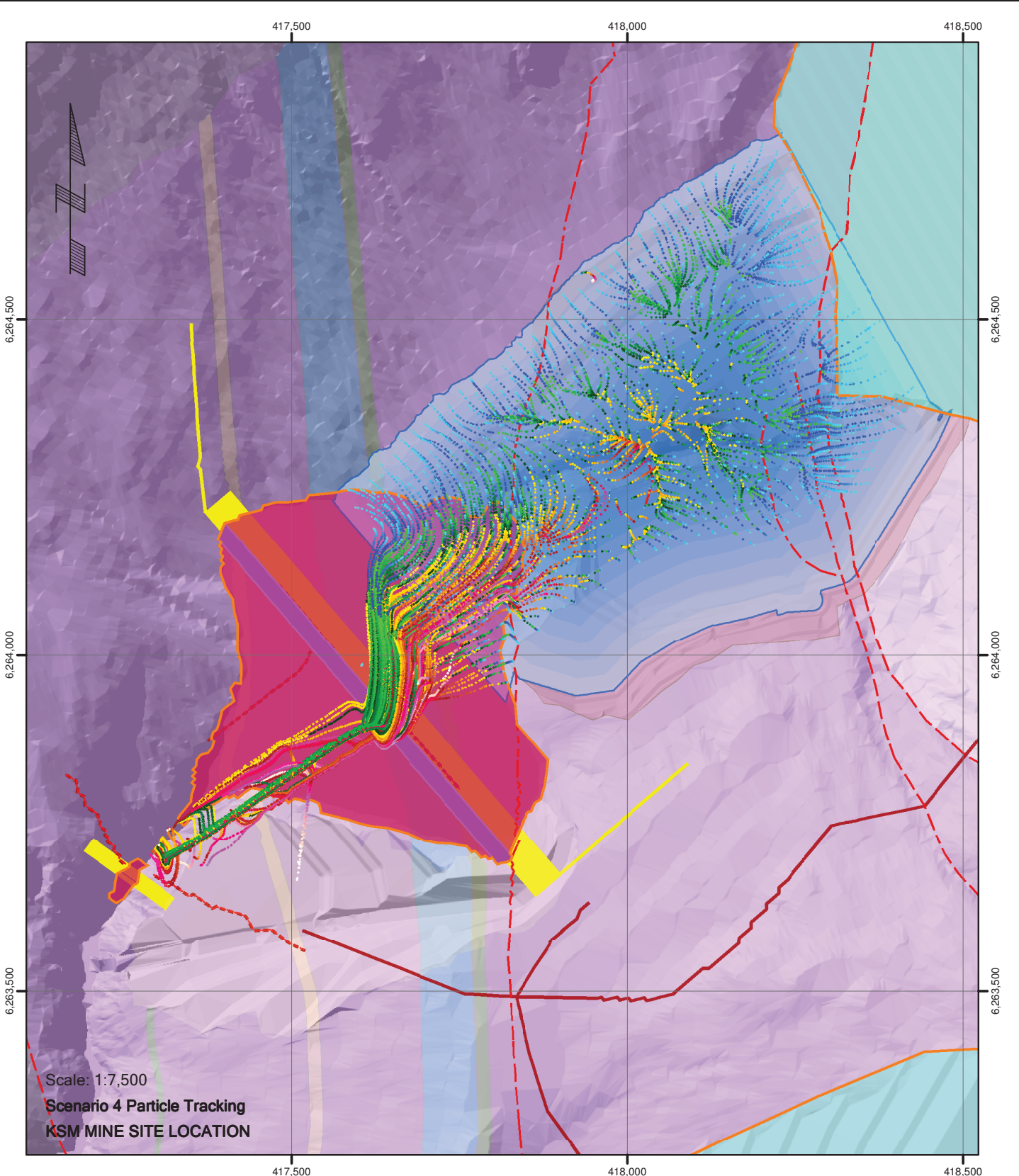
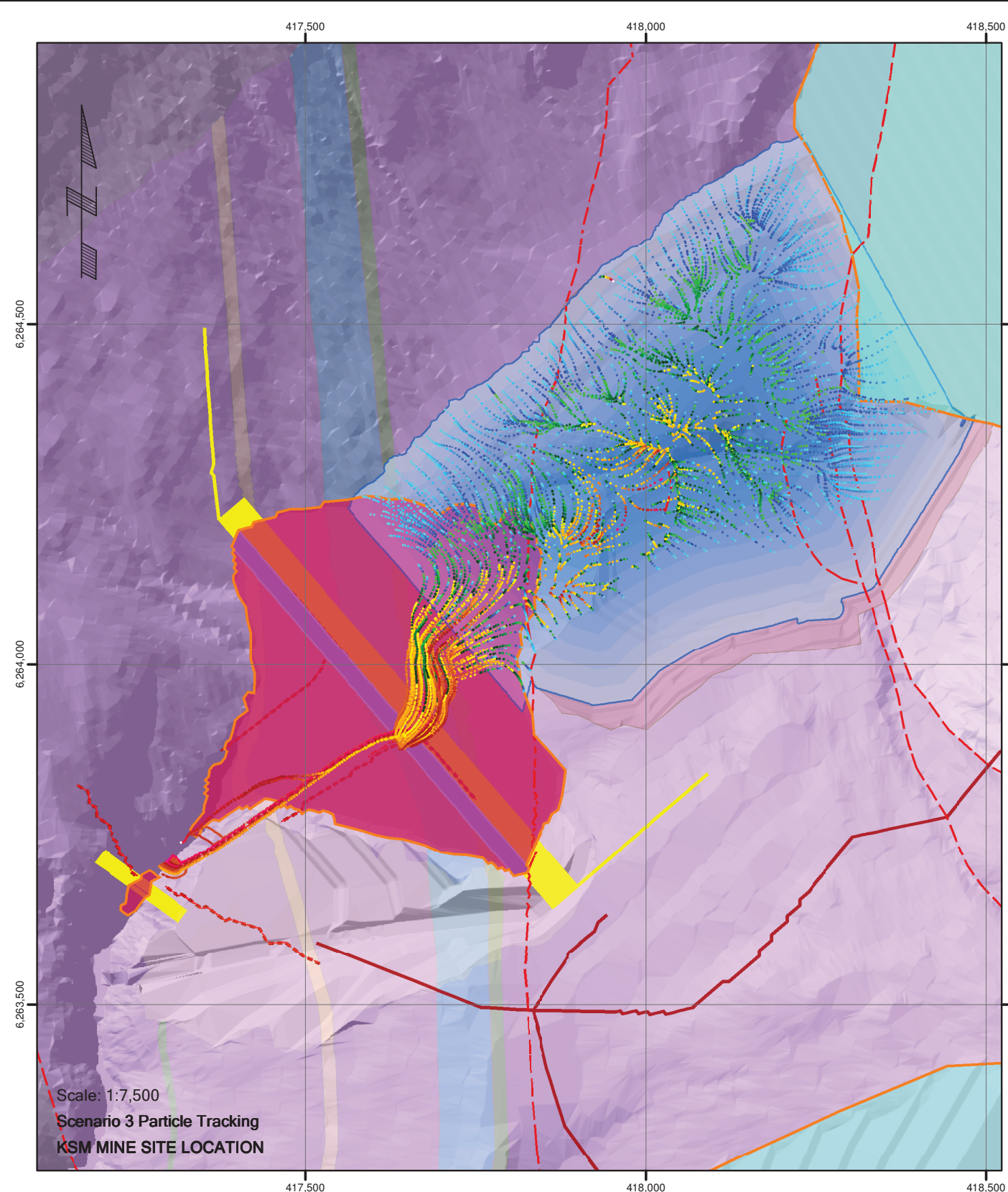
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Klohn Crippen Berger

PROJECT KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE KSM WATER STORAGE FACILITY (WSF) PARTICLE TRACKING RESULTS FOR SCENARIO MODELS 1 & 2			
DATE JUNE 2013	PROJECT No. M09480A04	DWG No. 18	REV. B

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Legend			
--- Model Boundary	Altered Volcanic Rocks	Calcareous Siltstone and Sandstone and Minor Calc-Silicate Hornfels	Regional Undifferentiated Stuhini
--- UG Infrastructure Footprint	Calc-Silicate Hornfels	Siltstone and Shale with Lesser Calcareous Siltstone and Sandstone and Hornfels	Undifferentiated Hazelton Volcanics
--- Infrastructure Footprint			
--- Faults			

- Notes:
1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. LIDAR Composite DEM (n.d.)

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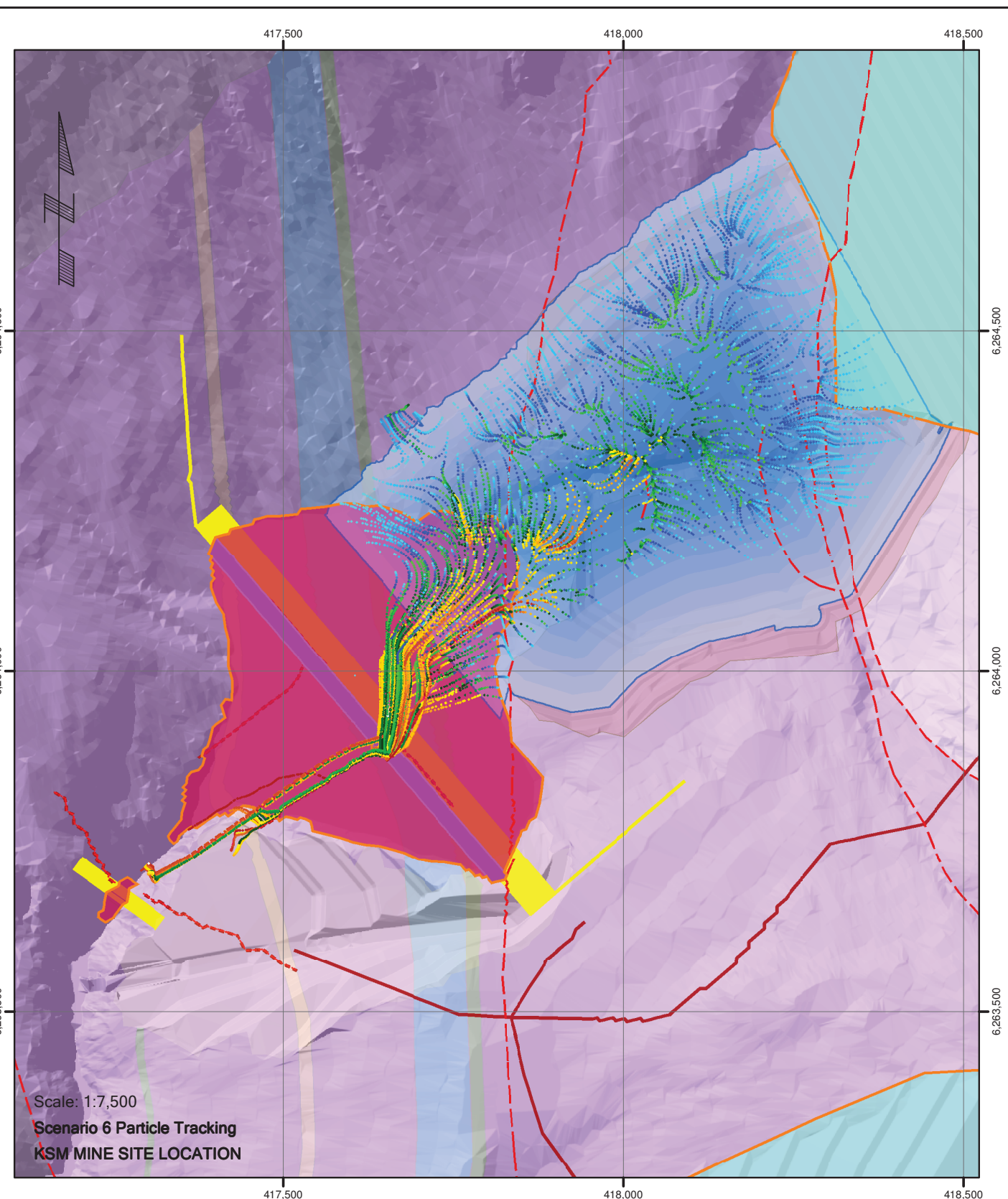
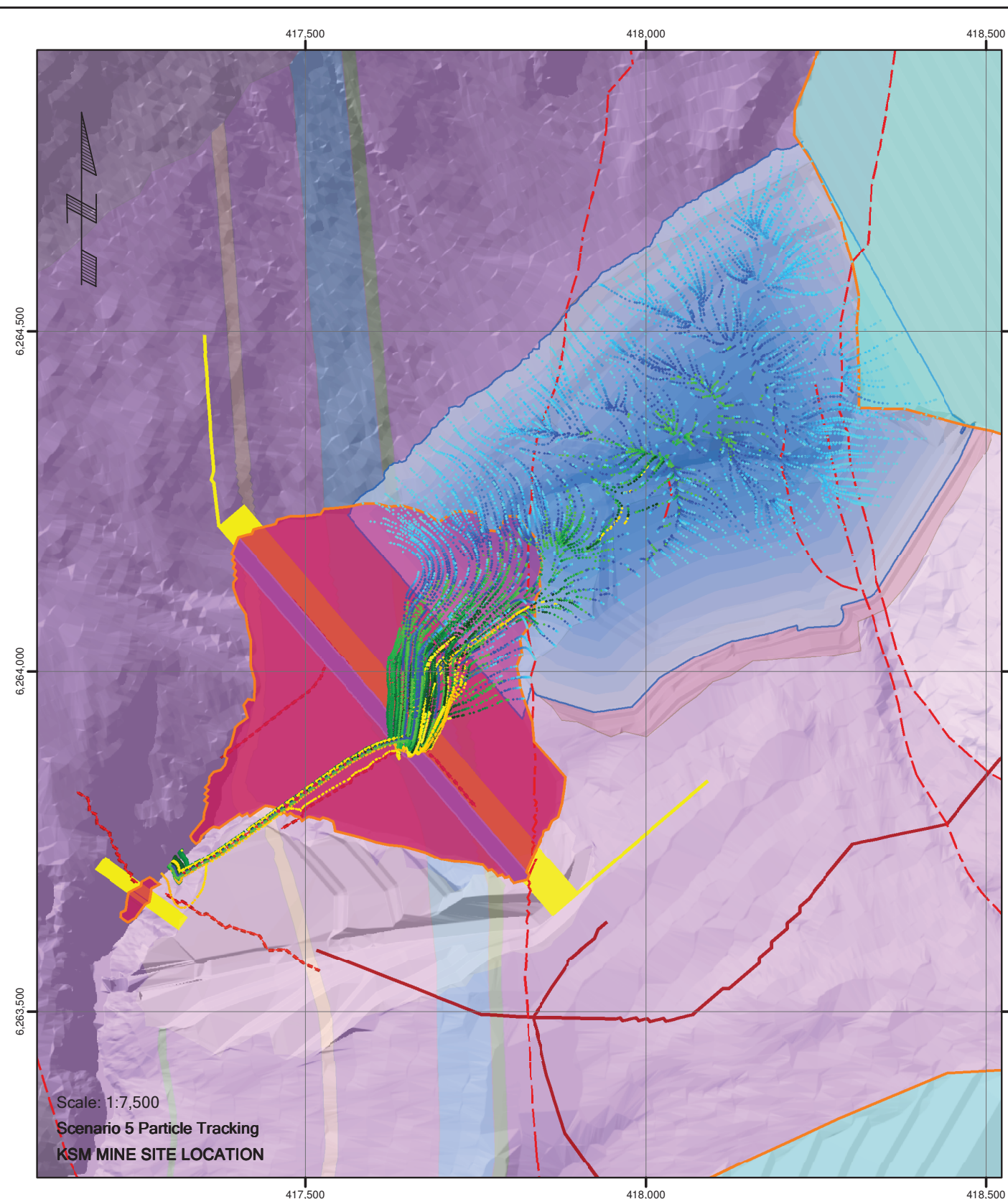
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PROJECT KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE KSM WATER STORAGE FACILITY (WSF) PARTICLE TRACKING RESULTS FOR SCENARIO MODELS 3 & 4			
DATE JUNE 2013	PROJECT No. M09480A04	DWG No. 19	REV. B

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Legend	
--- Model Boundary	Altered Volcanic Rocks
--- UG Infrastructure Footprint	Calc-Silicate Hornfels
--- Infrastructure Footprint	Siltstone and Shale with Lesser Calcareous Siltstone and Sandstone and Hornfels
--- Faults	Calcareous Siltstone and Sandstone
	Regional Undifferentiated Stuhini
	Undifferentiated Hazelton Volcanics

- Notes:
1. UTM Zone 9N, NAD83
 2. Topographic Data from BC TRIM (n.d.)
 3. LIDAR Composite DEM (n.d.)

Scale: 1:7,500

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PROJECT			
KSM 2012 FS Project Water Storage Facility Seepage Mitigation Modelling			
TITLE			
KSM WATER STORAGE FACILITY (WSF) PARTICLE TRACKING RESULTS FOR SCENARIO MODELS 5 & 6			
DATE	PROJECT No.	DWG No.	REV.
JUNE 2013	M09480A04	20	B