Minto 2015 Groundwater Model Update

Prepared for

Minto Explorations Ltd.

Prepared by

SRK Consulting (Canada) Inc.
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List of Abbreviations

2014GM – 2014 groundwater model completed for Water License QZ14-031 application
A2S2 – Area 2 Stage 2
A2S3 – Area 2 Stage 3
DSTSF – Dry Stack Tailings Storage Facility
EMSRP – Environmental Monitoring, Surveillance and Reporting Plan
K – Hydraulic Conductivity
Mbgs – Meters below ground surface
Masl – Meters above sea level
MSUG – Minto South Underground
MZUG – M Zone Underground
MVFE – Mill Valley Fill Extension
MWD – Main Waste Dump
MWDE – Main Waste Dump Expansion
WLB model – Water and load balance model
WSP – Water Storage Pond
SO_4 – Sulphate

1 Introduction

This report presents an update of the Minto Explorations Ltd. (MEL) Minto Mine groundwater model as required per conditions of Water Licence QZ14-031, issued to MEL on August 5, 2015. Specifically, the water licence includes Condition 107 in Section 5.4- Groundwater Model, which states:

107) The Licensee shall submit to the Board an updated Groundwater Model within 90 days of the effective date of this License. This update shall include, but not be limited to:

(a) Recent monitoring results from all existing wells;

(b) Results from the longitudinal path tracer study, and

(c) The monitoring results from all new wells (installed as required in accordance with this license).

107(b) and 107(c) relate to licence requirements listed in Condition 90 under Section 5.1.3 (Groundwater Monitoring Program), The Groundwater Monitoring Program is one component of the larger Environmental Monitoring, Surveillance and Reporting Plan (EMSRP), which is to be updated within 120 days of the effective date of the licence (per Condition 83). The updated EMSRP will contain plans for conducting the tracer study (referenced in Condition 107(b)) and for installation of new wells (referenced in Condition 107(c)); however, results from neither the required tracer study nor the required new wells are available to inform the 2015 groundwater model update.

This report includes a summary of monitoring data available for the model update, an updated hydrogeological conceptual model for the site, a description of the updated groundwater numerical model, and results from the updated model.

1.1 Background

The Minto Mine is located 240 km north of Whitehorse in central Yukon Territory, approximately 9 km west of the Yukon River. The mine is situated in the headwaters of Minto Creek, a tributary to the Yukon River, and includes open pits, an underground mine, a mill, waste rock dumps, a dry stack tailings storage facility and a surface water management system. Figure 1 is a map of the mine site as it exists in 2015, including mine components, groundwater monitoring locations and key surface water monitoring stations.

In 2014, MEL submitted a water use licence application for expansion of the mine (the Phase V/VI application). That application included supporting studies to show how geochemical loading from the site to downgradient surface water would occur, what the magnitude of that loading would be, how it would be monitored, and how it would be managed through operations and closure. One of the supporting documents was a report on the development of a groundwater numerical model for the project. This model, developed by SRK, is described in a model report

(SRK 2014a), and for reference in this 2015 model update report, is termed the 2014 groundwater model (2014GM).

A primary objective of the 2014GM was to provide bounding estimates of how loading from the site could move through the groundwater system and subsequently discharge to down gradient surface water receptors. Previous estimates of mine loading to surface water receptors were completed using the site water and load balance model (WLB model), which assumed that all groundwater (and all load carried by groundwater) would report to Minto Creek in relatively close proximity to the mine site. The WLB model treated groundwater as runoff with water quality equivalent to the relevant source concentrations (e.g. waste rock or undisturbed ground), so this estimate was conservative in terms of total loading from the mine to surface water, but it did not reflect the potential for geochemical load to leave the immediate mine area via a groundwater pathway. The 2014GM explored the implications of a groundwater loading pathway to surface water quality in Minto Creek, and thereby provided a more refined assessment of the groundwater system and the overall hydrologic system of the catchment.

The 2014GM utilized a simple distribution of hydraulic conductivity. Calibration was made to hydraulic head and estimates of baseflow, and attempts were made to calibrate to observed sulphate (SO_4) concentrations at monitoring wells (SO_4 is commonly adopted as a proxy for solutes in groundwater modelling). The 2014GM had two hydrostratigraphic units, overburden and bedrock (each with one fixed value of hydraulic conductivity), plus a relatively high conductivity zone representing a hypothetical fault oriented along the Minto Creek valley and connecting with the Main Pit (included to evaluate the risk posed by groundwater loadings if a source was connected to Minto Creek by a fast groundwater pathway). Permafrost was not included in the numerical model.

The 2014GM was calibrated reasonably well to water levels and baseflow, but it didn't calibrate well to observed sulphate (SO_4) concentrations, particularly at MW12-05, the monitoring well furthest down gradient of the mine in the Minto Creek valley (downstream of the Water Storage Pond [WSP]). Even with a hypothetical high conductivity conduit from the Main Pit to this monitoring well, modelled SO_4 concentrations at MW12-05 underestimated the observed concentrations.

Results of the 2014 groundwater modelling work suggested that some groundwater from the mine site may in fact travel further down the Minto Creek valley than assumed in the WLB model, that the full effect of discharge of mine loadings to Minto Creek would only by realized after an extended period of time, and that the total loading to surface water receptors would be lower than (or at most equivalent to) the loadings predicted by the WLB model. In essence, the 2014GM confirmed that, even if a hypothetical high conductivity conduit oriented along Minto Creek was included in the groundwater model, the WLB model was providing conservative estimates of loading to surface water receptors.

1.2 Modelling Objectives and Approach

The 2015 groundwater model for the site has been updated to reflect additional understanding of the groundwater conditions at site. The objectives of this model update were to:

- Incorporate results from monitoring completed since development of the 2014GM;
- Incorporate an updated hydrogeological conceptual model, including the discontinuous permafrost observed at site and new information on bedrock surface elevations;
- Assess sensitivity of model results to the inclusion of permafrost;
- Provide assumptions for groundwater flow quantities and source loadings along groundwater flow paths that can be used in the next update of the site water balance and load model; and
- Provide further information that could be used for planning new groundwater monitoring wells and for designing a longitudinal tracer test.

The approach used for this model update included revising the hydrogeological conceptual model based on new data and additional site reconnaissance, refining the groundwater numerical model with inputs from the conceptual model (including permafrost), and updating estimations of the amount and timing of loading from the mine site that could reach surface water receptors, namely Minto Creek and the Yukon River. The model is calibrated to current conditions (i.e., mine components and boundary conditions (including current pit and underground water levels) as of September 2015) and provides loading assumptions for current conditions.

Models were constructed and run under both permafrost and no-permafrost conditions. Comparison of results from these two scenarios indicates the sensitivity of model results to the presence of permafrost.

2 Monitoring Data

Groundwater monitoring data available for the site includes water levels and water quality from groundwater monitoring wells. Additional information on the groundwater system can be inferred from data collected from the Minto South underground mine.

With respect to groundwater quality, the primary focus of the discussion in this report is SO_4 concentration. From a mine site groundwater perspective, SO_4 is typically the parameter of greatest interest for two reasons:

- It is a major ion that is characteristically elevated in mine sources relative to background concentrations, and therefore SO_4 can act as a tracer for water influenced by those sources; and
- It is typically not attenuated to a significant degree in the subsurface (i.e. it is a conservative parameter), and it therefore generally moves through the groundwater system at the same speed as the groundwater and can be considered to be a proxy for other solutes originating from the same sources.

Summary details regarding selected trace element concentrations are also provided for copper (Cu), cadmium (Cd) and selenium (Se). These three trace elements are contaminants of potential concern for the Minto project, are also present at greater-than-background concentrations in mine sources, and are considered to be reasonable proxies for other trace elements for the purposes of this report.

Table 1 summarizes key aspects of available monitoring data and changes that have been observed since submission of the 2014GM report (SRK 2014a).

Sections 2.1 and 2.2 discuss key changes in the data that have occurred since development of the 2014GM. The complete record of groundwater level and quality data are compiled in Appendices A and B, respectively.

Table 1: Summary of Changes in Monitoring Data

Station	Location	Groundwater Levels	Groundwater Quality
MW12-05 7 ports monitored for level* 4 ports monitored for quality	Minto Creek valley down gradient of Water Storage Pond	• No change – All ports stable • Minor seasonal fluctuation and/or influence of WSP discharge	• Port 1 (132 mbgs): SO4 increasing slowly (895 mg/L – Aug 2015) • Port 3 (94 mbgs): SO4 stable in 2015 (798 mg/L 2015 average) • Port 5 (52 mbgs): SO4 stable and low (58 mg/L) • Port 7 (15 mbgs): SO4 stable and low (44 mg/L) • Cu, Cd and Se concentrations at all ports: no consistent trends Concentrations are low and stable (similar to or lower than nearby DSTSF seepage (W8A) and surface water quality (W3, W37) stations)
MW12-06 6 ports monitored for level 3 ports monitored for quality	Minto Creek valley up gradient of Water Storage Pond, down gradient of pits, waste dumps, Dry Stack Tailings Storage Facility (DSTSF), mill area, and Mill Valley Fill Extension (MVFE) Stage 1	• No change – All ports stable	• Port 2 (123 mbgs): SO4 stable (207 mg/L 2015 average) • Port 4 (66 mbgs): SO4 stable (170 mg/L 2015 average) • Port 6 (18 mbgs): SO4 stable (145 mg/L 2015 average) • Cu, Cd and Se concentrations at all ports: no consistent trends Concentrations are low and similar to or lower than nearby DSTSF seepage (station W8A) and surface water quality stations)
MW12-DP4 **MW13-DP5**	Drivepoints down gradient of DSTSF and MVFE Stage 1	• No change – Typically frozen or inaccessible due to ice	• Few samples available • SO4, Cu, Cd and Se concentrations in 2015 similar to 2014
MW11-01a Standpipe piezometer **MW12-07** 3 ports monitored for level 2 ports monitored for quality	Immediately downhill from Main Pit, near mill	• MW11-01a: Frozen • MW12-07: No change at ports 2 & 3 (shallow and intermediate depths) Increase in level at port 1 (deepest port) is stabilizing at levels similar to ports 2 & 3.	• Port 1 (115 mbgs): SO4 decreasing slightly (392 mg/L – Sept 2015) • Port 2 (88 mbgs): SO4 stable in 2015 (647 mg/L 2015 average) • Cd and Se concentrations low and stable in 2015 • Cu concentrations in both ports slightly higher in Sept 2015, but within previously observed range
MW09-01 3 ports monitored	Immediately uphill from Main Pit, downgradient of Main Waste Dump	• No change – All ports dry	• Monitored per GMP; No sample collected since 2014
MW11-02 **MW11-03** **MW11-04A**	Ridgetop area (baseline conditions)	• No change • MW11-02 – dry • MW11-03 – dry • MW11-04A – no change – stable water levels but insufficient recharge for sampling	• No samples
MW12-DP1 **MW-DP2** **MW-DP3**	Drivepoints immediately down gradient of Southwest Waste Dump	• No change – All dry, frozen or occasional trace water	• No samples
MW09-03 3 ports monitored for level 3 ports monitored for quality	Down gradient of Minto North pit (baseline conditions prior to August 2015)	• Water levels may be declining slightly	• Port 1 (38 mbgs): SO4 stable (22 mg/L 2015 average) • Port 2 (24 mbgs): SO4 consistently below detection limit • Port 3 (11 mbgs): SO4 stable (11 mg/L 2015 average) • Cu, Cd and Se concentrations at all ports: low and stable with no consistent trends

Note: * wells identified as having multiple ports are Westbay multi-level wells. By convention, Port 1 is deepest and the highest-numbered port for each well is shallowest.

2.1 Water Levels

Aside from water levels in MW09-03, which may be starting to show a decline as mining of the Minto North Pit progresses (mining began in August 2015), the only other trend of note is in the deep port of monitoring well MW12-07. This port, port 1 at a depth of 115 meters below ground, has shown different behaviour than the two shallower ports that are monitored (port 2 at 87.5 mbgs, and port 3 at about 67 mbgs).

Figure 2 presents data from the three ports, as well as water levels for the Main Pit and Area 2 Stage 2 (A2S2) Pit. In March 2015, transfer of water began from the Main Pit to the A2S2 Pit. Regular measurements of water levels in the A2S2 Pit began at this time, but it is likely that filling began prior to water being actively pumped into the pit.

Water levels at MW12-07-01 (port 1) started to increase at about the same time that the A2S2 Pit was starting to fill. The water level in the Main Pit was decreasing at this time. Water levels in the two shallower ports do not change similarly to port 1. This may indicate a hydraulic connection between port 1 and the Area 2 pit, though the data collected during drilling of MW12-07 does not provide any insight into what feature or fractures may be providing this connection.

These results suggest either differences in fracture connectivity between the ports in MW12-07, or that the two shallower ports are monitoring a separate hydraulic system than the deeper port.

2.2 Groundwater Quality

In general, groundwater quality at monitoring wells have not changed significantly since 2014. For the most part, concentrations are stable and/or low. One observation of note is the SO_4 concentration in the deep and intermediate ports at MW12-05, the monitoring well downstream of the WSP that has been mentioned previously.

Figure 3 presents data from MW12-05 and MW12-06 (just upstream of the WSP), as well as selected nearby surface water monitoring points for comparison. SO_4 concentrations from the deep and intermediate ports (132 mbgs and 84 mbgs, respectively) remain elevated, above the concentration of any surface water in the area. Sulphate concentrations in the intermediate depth port (MW12-05-03) may have stabilized in 2015, but concentrations at the deepest port (MW12-05-01) continue to show an increasing trend. Concentrations at both ports are more than three times higher than any observed concentrations at MW12-06, which is upstream of MW12-05 and closer to the mine.

The relatively elevated SO_4 concentrations at MW12-05 are also higher than concentrations measured nearby in Minto Creek (W3), the WSP (W16) or the seepage monitoring point just downgradient of the Dry Stack Tailings Storage Facility (DSTSF (W8A). The shallow ports in MW12-05 (port 5 at 52 mbgs, and port 7 at 15 mbgs) show SO_4 concentrations similar to surface water in Minto Creek (W3) and the WSP (W16), though still lower than the monitoring point down gradient of the DSTSF (W8).

Concentrations of copper, cadmium and selenium do not show the same trends as for SO_4, in either MW12-05 or MW12-06 (Figure 3). Concentrations at all monitoring ports are low, at or below typical surface water concentrations, and not showing any increasing trends.

3 Hydrogeological Conceptual Model

The hydrogeological conceptual model is a simplified representation of the essential features of the physical hydrogeological system and its hydraulic behavior. A conceptual model rarely explains all field observations and the development of the conceptual model must be an iterative process; it should continually be updated as new data become available, as the understanding of the system is improved, or as questions and modelling objectives evolve (Wels et al. 2012).

The following sections present key information used to refine the conceptual model for the Minto Mine site. The overall conceptual model is described in Section 3.6.

3.1 Mine Plan

The different components of the mine and how they have changed over time have a significant influence on the groundwater system. The current (2015) mine layout was shown in Figure 1. Figure 4 summarizes the sequence of mining and water management actions and the planned future sequence of mining activity.

The most significant changes from a hydrogeological perspective that have occurred since submission of the 2014GM are that the A2S2 Pit is filling and mining of the Minto North Pit has commenced. The A2S2 Pit is filling from a combination of natural run-in, active pumping of water from the Main Pit, Minto South Underground (MSUG) dewatering and discharge of tailings from milling. The water level has risen approximately 32 m since filling began in March 2015. While filling of the A2S2 Pit will change the groundwater system once it has been significantly filled, at this time (Q4 2015) the water level in the pit is still about 75 m below the pit rim and the pit still acts as a sink for groundwater flows.

The water level in the Main Pit is about the same as it was in July 2014, the time period for data used in the 2014GM.

Mining of Minto North had only reached a depth equivalent to a few benches (about 50 m) as of October 2015.

3.2 Overburden

The distribution of overburden across the site can influence groundwater flow by providing pathways for groundwater flow, where it is permeable and not frozen. Overburden characteristics have been reviewed as part of past hydrogeological studies (SRK 2013) and the recent of the Main Dam (SRK 2014b).

Overburden thickness across the site is correlated with geomorphological features. Near topographic highs (or ridges) there is little to no overburden, while overburden thickness increases down valley slopes and is generally thickest in valley bottoms. Unconsolidated material deposited along the valley bottom varies in thickness. Typically, the ridge tops are dominated by sandy, residual soils grading to weathered bedrock. It is generally observed that fine weathering products have been washed down slope. Overburden in the valley bottoms consists of fine materials dominated by sandy silts and clays.

Fill has been placed in the mine's central area near the Main Pit, the mill, the administration and the camp buildings and extends up to 8 m below current ground surface. The fill overlies overburden consisting of sandy silt, with gravel and some cobbles throughout. The overburden transitions to weathered bedrock between 15 and 20 m below ground surface.

Below the DSTSF, overburden is generally fine-grained silt or silt and sand overlying ice rich layers of silts and clays. This layered type of overburden continues along the valley to the east, which overlies residual sandy soils and weathered bedrock with depth. In the mine area, the low point in the bedrock surface is offset to the south from the surface expression of Minto Creek; this low point in the bedrock surface has been referred to as a paleochannel in geotechnical work related to the DSTSF, the Main Dam, and the overburden stability in the south wall of the Main Pit.

Additional field reconnaissance was completed in 2015 to provide better constraint on overburden thickness to the south of the WSP and along the Minto Creek valley. Bedrock outcrops were located as control points, but there remains some uncertainty regarding the depth of overburden on the southern valley flank where no outcrops were identified in the 2015 reconnaissance. Figure 5 is a photo collage including observations of bedrock in the Minto Creek valley near the WSP and at the Minto Creek canyon approximately 6 km downstream of the mine. Figure 6 is a map showing the updated distribution and thickness of overburden.

3.3 Bedrock

The following text describing bedrock lithology and geologic structures is taken from SRK (2013).

The Minto Mine site is underlain predominantly by igneous rocks of granodiorite composition. The granodiorite is generally categorized based on textures which are associated with foliation and crystal size. Rock texture ranges from massive granodiorite to foliated granodiorite, with foliated granodiorite typically characterized by increased biotite content. The biotite-rich foliated granodiorite hosts mineralized zones of copper sulphide. Crystal textures range from equigranular to porphyritic.

Other minor lithologies consisting of small dykes of simple quartz-feldspar pegmatite, aplite, and an aphanitic textured intermediate composition rock are also observed. Bodies of all of these units are relatively thin and rarely exceed one metre core intersections. These dykes are relatively late, generally postdating the peak ductile deformation event; however, some pegmatite and aplite bodies observed in a rock cut located north of the mill complex are openly folded. There has been evidence of conglomerate and volcanic flows in drill core by past operators, and drilling has demonstrated that a conglomerate unit bearing local granodiorite pebbles occurs across much of the southern part of the project area.

Structure can have a significant impact on groundwater flow if structures have a higher or lower hydraulic conductivity than that of the surrounding rock. Although there is evidence both regionally and locally of multiple structures and structure types, structures have not been mapped across the entire site.

The position of geologic structures is best constrained in the vicinity of the open pits, where mining has occurred. The presence or location of other potential structures is not well constrained; lineament analysis was completed as part of the 2014 groundwater modelling study (SRK 2014a) to provide an indication of potential structures, but whether or not any actually exist is uncertain. Figure 7 shows results of that study.

Hydraulic conductivity (K) data for bedrock are available from locations where monitoring wells have been completed. Bedrock hydraulic conductivity were also inferred from calibration of the model. Figure 8 shows available K data by depth of measurement. Data is categorized by rock type of the testing zone. Also shown on the figure is the running geometric mean of data by depth.

Figure 8 also includes a dashed line which estimates the decrease in hydraulic conductivity with increasing depth, after a model proposed by Jiang et al. (2010). The method estimates K at a given depth based on an empirical relationship between the hydraulic conductivity of a fractured system and the lithostatic stress. There is reasonable agreement between the Jiang et al. model and the geometric mean of hydraulic conductivity measurements at Minto.

3.4 Permafrost

Discontinuous permafrost is present across the site. Where permafrost is present, it can be expected to act as a barrier to the vertical infiltration of water; water infiltrating above permafrost will not reach the deeper groundwater system, at least not in the area where the permafrost is present.

The distribution of discontinuous permafrost at site was estimated based on site thermal data, ground observations and air photo interpretation. Distribution of permafrost is not known precisely for the entire site, but in general, permafrost is more likely to occur on north aspects and in valley bottoms. On south aspects or on ridge tops, permafrost is generally not present. The estimated permafrost distribution is shown on Figure 9, modified from EBA (2011).

Generally, the west to east trend of the upper Minto Creek valley bottom (extending from down gradient of the Southwest Waste Dump, past the mill and administration buildings, the DSTSF, and along the north facing slopes of the Minto Creek drainage upstream of the Water Storage Dam) coincides with the permafrost region. The north facing slopes (at the southern edge of the property) have geomorphic and vegetation evidence suggesting the presence of permafrost or discontinuous permafrost, except along the crests of the ridges which are generally free of permafrost. The south facing slopes and ridges may or may not have permafrost, based on observations of both frozen and unfrozen ground conditions in these areas.

3.5 Recharge and Discharge

Groundwater recharge is expected to occur as:

- Infiltration of precipitation;
- Seepage out of flooded pits, when the gradient direction allows;
- Seepage out of waste materials once they are saturated or allowing water to be released; and
- Seepage out of the Water Storage Pond.

Groundwater discharge is expected to occur at the following locations:

- To open pits if the gradient allows;
- To the underground mine, while it is being actively dewatered;
- Shallow discharge to sumps or water management structures; and
- Discharge to creeks (i.e., baseflow).

Average annual precipitation at site is 329 mm/year. The runoff coefficient calculated for the site is 99 mm/yr, or 30% of annual average precipitation (SRK 2015).

In the immediate area of the mine itself, surface water flow is managed. Flow data for Minto Creek provide the best indication for groundwater flow quantity and are considered a primary calibration target for the groundwater model, after considering the influence of managed discharge from the Water Storage Pond.

Based on review of available hydrology data, groundwater recharge is expected to fall between 10 and 40 mm/yr, or an average for the site of 13 to 53 L/s. This was estimated based on available flow data for Minto Creek. Flow measurements were reviewed (considering managed discharges) to determine a period that would best represent baseflow, when groundwater is assumed to be the dominant contributor to stream flow. The September/October period was found to best represent baseflow. During the winter, Minto Creek is often frozen to its base and flow measurements are not possible (and there may be little to no flow). Baseflow cannot be zero, so the September/October period is used, when conditions are relatively dry but winter has not set in. The baseflow amounts equate to 3% to 12% of annual average precipitation.

3.6 Flow System

In general, groundwater within the Minto Creek and McGinty creek watersheds is expected to flow in the same directions as surface water, with flow direction in certain areas modified by mine activities under current conditions:

- The Main Pit is both a sink and a source for groundwater. Groundwater flowing from uphill of the pit (north and west of the pit) flows towards the pit. Groundwater flows out from east side of the pit lake, towards Minto Creek to the east and towards the A2S2 Pit to the south.
- The A2S2 Pit is a groundwater sink.
- The underground mine represents a groundwater sink.
- The Water Storage Pond is a sink and a source. Groundwater discharges to the upgradient end of the pond and also discharges to the creek downgradient of the WSP.

Figure 10 presents schematic cross sections showing the different conceptual models for groundwater flow.

4 Groundwater Numerical Model

The groundwater numerical model was constructed using FEFLOW v. 6.2 (DHI, 2015). The model includes the entire Minto Creek watershed, a portion of the McGinty Creek watershed, and it incorporates mine components as they existed in September 2015.

The following sections summarize model construction and results of the calibrated model.

4.1 Model Construction

Updates to the groundwater model are presented in Table 2. Solute transport assumptions are presented in Table 3 and Table 4. Figure 11 to Figure 15 show the overall model layout and boundary conditions.

The model was run for groundwater flow and transport. The flow model was run in steady-state. The steady-state model reflects a snap shot of the system for that time period.

Table 2: Key Features of 2015 Updated Model

Component	Revisions or Updates
Topography	Incorporates current mine features.
Mine Plan	Updated to September 2015, including pit water levels and the Minto North Pit
Model Extent	Entire Minto Creek and a portion of McGinty Creek watershed Total area of 46 km^2 2,876,160 elements and 1,515,382 nodes
Model layers	21 layers extending from surface to a depth of 430 m below ground.
Boundary Conditions	Main Pit: constant head 785 masl for lake; seepage face elsewhere A2S2 Pit: constant head 720 masl for lake; seepage face elsewhere WSP: constant head 716 masl MSUG : seepage face Minto North Pit: seepage face Minto Creek & McGinty Creek: seepage face based on topographic elevation Yukon River: constant head 445 masl
Overburden Distribution	Updated distribution based on existing data, previous mapping, and new observations of bedrock outcrops
Permafrost	Included in model with a thickness of 40 m where present Active layer is 2 m thick
Hydraulic Conductivity	Overburden = $1x10^{-6}$ m/s (homogeneous/isotropic) Bedrock: decreases with depth based on available data and model of Jiang et al. (2010) Minto Creek watershed (vertical K from $2x10^{-7}$ m/s to $6x10^{-9}$ m/s) Bed of Minto Creek = $5x10^{-5}$ m/s McGinty Creek watershed (vertical K from $1x10^{-8}$ m/s to $2x10^{-10}$ m/s; discussed in calibration).
Recharge and Baseflows	Areal recharge of 5.5% of annual precipitation (18 mm/yr) Minto Creek baseflow is 20 L/s, based on monthly data for September/October. Creek is frozen in winter months.
Calibration	Water levels at multi-level wells for September 2015 Minto Creek baseflow Inflows to underground mine

Transport simulations were run to steady-state using the steady-state flow model; mine components retain the September 2015 layout. However, after careful review of the water quality monitoring results, it was concluded that a calibrated transport model could not be achieved given the current understanding of sources. This and related points are discussed in further detail in Section 4.3.

Table 3: Source Terms Used for Solute Transport

Component	Current Conditions (mg sulphate/L)
Main Pit	225
Area 2 Pit (Stage 2)	225
Area 118 Pit	225
Minto North Pit	None
Main Waste Dump	225
Southwest Dumps	225
Mill Valley Fill Expansion (Stage 1)	225
Dry Stack Tailings Storage Facility	225
Water Storage Pond	70
Background	20

Table 4 Transport Parameters

	Porosity	Longitudinal Dispersivity	Transverse Dispersivity
Hydrostratigraphic Unit	(-)	(m)	(m)
Overburden	0.2	10	4
Bedrock	0.001	60	20

4.2 Model Results

4.2.1 Calibration

As presented in Table 2, the model was calibrated to water level data from September 2015, average flows in Minto Creek for the months of September and October, and average inflow to the underground mine. Figure 16 presents calibration information. Calibration of the model for water levels and flow is good, with the following considerations.

For the Minto Creek watershed, bedrock hydraulic conductivity reflects the Jiang model for decreasing K with depth, fit to available data. Hydraulic conductivity at the depth of the underground mine (~300 mbgs) is $7x10^{-9}$ m/s.

To calibrate water levels at MW09-03 down gradient of the Minto North pit, hydraulic conductivity had to be decreased. The model for decreasing K with depth was shifted to lower values ($1x10^{-8}$ m/s to $2x10^{-10}$ m/s). There is little K data available for this area, but lower K values are considered plausible because the Minto North pit is at higher elevation, where erosion could have reduced the thickness of relatively high K weathered bedrock. Observations of relatively competent (though fractured) bedrock in the Minto North pit, and the minor observed groundwater inflow, provide some support for this assumption.

Data available for calibration of flow is limited to Minto Creek and the underground mine.

4.2.2 Groundwater Flow Directions and Discharge to Surface Water

Figure 16 includes the simulated water table or potentiometric surface for the calibrated model. Results are in agreement with the conceptual flow directions presented in Section 3.6.

In general, groundwater flows from high elevations to lower elevations, with flow directions modified locally by the presence of mine components such as the open pits. Flows from the Southwest Waste Dump, Main Waste Dump (and MWDE), and Main Pit Dump are captured by the Main Pit, A2S2 Pit, or the underground mine. Flows from other areas of the mine converge on the Minto Creek Valley.

Cumulative groundwater discharge (baseflow) from the model are listed in Table 5.

Table 5: Modelled Cumulative Groundwater Discharge by Model Node

Catchment	Model Node	Model Node Description	Cumulative Groundwater Discharge (L/s)
Minto Creek	WSP_u	Upgradient (W) end of WSP	1.7
	WSP_{dg}	Downgradient (E) end of WSP	2.4
	W3	Surface water monitoring station W3	3.6
	W46	Surface water monitoring station W46	8.4
	MC1	Surface water monitoring station MC1	15.6
	YR	Yukon River near mouth of Minto Creek	20.4
McGinty Creek	McG	McGinty Creek at downgradient edge of model domain	2.4

For the Minto Creek watershed, about 75% of the groundwater discharge occurs by MC1, the surface water monitoring station located at the canyon about 6 km downstream of the mine. For the McGinty Creek watershed included in the model, all of the flow reports to McGinty Creek by the edge of the model domain. The next section discusses how loading from the site is simulated to reach these creeks.

4.2.3 Transport Simulations

Conservative (i.e. not attenuated) solute transport simulations were completed to assess how load could be moving in groundwater, assuming that sources are the waste dumps, pit lakes and DSTSF. Source terms and transport properties from the 2014GM were adopted. The objective of this was to improve understanding of how sulphate load could travel and how long it might take, rather than to achieve calibration.

Figure 17 and Figure 18 present cross sections through different parts of the mine with simulated solute (SO_4) concentrations. Concentrations near source term values only exist in relatively close proximity to sources themselves. The inclusion of permafrost in the model restricts the movement of most load coming from the waste dumps and DSTSF to generally remain near surface. In the case of the Southwest Waste Dump, all load reports to the open pits or underground mine.

Figure 19 is a map showing average travel time for water at any point to reach Minto Creek. This is the same as “lifetime expectancy” in hydrogeological and FEFLOW terminology. Lifetime expectancy is the time required for a water molecule entering anywhere in the groundwater system to reach an outlet in the system (in this case surface water, open pits or the underground).

What this map shows is that, on average, water with total transit times on the order of 5 to 10 years (about how long Minto Mine has been in operation) originates in fairly close proximity to the discharge location, be it surface water, an open pit or the underground mine. In other words, most water that discharges in short time frames does so not that far from the source.

4.2.4 Model Sensitivity

The updated model with permafrost was compared to a model without permafrost to illustrate sensitivity of results. Results are shown in Figure 20.

Flow directions change slightly, but overall there is no significant difference; water still flows towards creek valleys. Model calibration does not change significantly when permafrost is removed.

From the perspective of solute transport, the overall loading doesn’t change (i.e. sources and recharge to sources does not change), but the distribution of loading changes slightly. In the area of the DSTSF, modelled concentrations are more distributed without permafrost compared to when permafrost is present, but load still reports to the same places. Overall the presence of permafrost does influence the system, but does not fundamentally change any conclusions.

4.3 Discussion of Results

4.3.1 Flow Model

The updated groundwater model presents an incrementally better representation of the system as we understand it compared to the 2014GM. At the conceptual level, groundwater recharge occurs at relatively high elevations, with discharge to surface water occurring at relatively lower elevations. The open pits and underground mine represent model sinks for groundwater; the Main Pit can also act as a source of groundwater to the overall model system. In the Minto Creek watershed model, water (or load) that is not collecting in the model sinks (the underground mine or the pits) is travelling down the Minto Creek valley.

The groundwater numerical model provides a reasonable mathematical solution for groundwater flow that is in agreement with the conceptual model. In the Minto Creek watershed, the numerical model shows groundwater discharge occurs in close proximity to the mine; this is what is expected from monitoring observations and from the conceptual model.

For the Minto North region of the model, it was necessary to decrease bedrock hydraulic conductivity relative to other parts of the model domain to achieve calibration to observed water levels. This was also necessary for the 2014GM. The Minto North Pit (and the down gradient monitoring well, MW09-03) are located at relatively high elevations compared to other parts of the site, and it is plausible that erosion has removed relatively more (high K) weathered bedrock at Minto North compared to other areas. In general, this would suggest relatively less groundwater flow in this area, which is supported qualitatively by observations that there isn't much water flowing into the current pits.

For this reason, in Section 5 we recommend that any predictions of future conditions made with the water and load balance model should conservatively assume that all flow from the pit reports to McGinty Creek.

4.3.2 Solute Transport

For Minto Mine, modelling of solute transport should only be used from a water management planning perspective to provide guidance for on-going monitoring. Solute transport modelling in fractured rock is mechanistically complex and may not be properly quantified for the Minto site with currently available modelling tools. For the 2015 groundwater model update work, transport modelling is further complicated by observations in local areas that do not fit the geochemical model for the site, and which, if used for calibration, alter the conceptual model in ways that do not fit the understanding of flow. The following points present some specific reasons why calibration to observed concentrations would not be constructive at this time:

- Observed sulphate concentrations at ports MW12-05-01 and MW12-05-03 (east of the WSP) are higher than any known mine source. These ports are situated at significant depth in bedrock and the observed concentrations are much lower for relatively shallower monitoring ports (close to background). The high sulphate concentrations observed at depth, and low concentrations at shallow depths, could indicate many things, such as: a highly variable system in which discrete fractures play a dominant role (the current model cannot simulate this) in connecting a high concentration source; or, an unknown source of sulphate (which the model would need as an input in order to achieve calibration).
- Observed sulphate concentrations for all ports at MW12-06 (west of the WSP, and east of the MVFE) are similar to concentrations observed for station W8A, which monitors DSTSF seepage within the MVFE footprint just down gradient of the DSTSF. Even if the DSTSF (as represented by water quality at station W8A) is assumed to be the source, it would still not be possible to explain the 3-to-4 fold higher concentrations in the deeper zones at MW12-05, which is further down gradient (i.e. further away) from the source than MW12-06.
- Observed sulphate concentrations in the deeper zones at MW12-07 (near the mill) are higher than any known mine source (Appendix B). Hypothetically, the observed concentrations could reflect load from the Main Pit, but sulphate concentrations in the Main Pit water (monitoring station W12) are only about half as large as those at MW12-07 (312 mg/L at W12 in August 2015, vs 400 to 650 mg/L at MW12-07).

The model is a good tool for testing hypothetical "what-if" scenarios, but those scenarios need to be plausible. An example is the high conductivity feature used in the 2014GM to connect the Main Pit with the Minto Creek valley. The scenario being tested was whether the Main Pit could be the source for elevated concentrations observed at MW12-05 and MW12-06 and could potentially provide a pathway for loading to reach lower elevations in the Minto Creek Valley. It can be beneficial to understand the consequences of such a scenario for planning purposes, but it must be remembered that the “what-if” scenario represents a hypothesis, and that it should not be construed as reality.

MW12-05 and MW12-06 were installed in 2012 and showed elevated SO_4 concentrations in the earliest monitoring results. The Main Pit only started to be actively filled in Q3 2011 and the pit level did not reach an elevation greater than head values measured at MW12-07 (located just down gradient of the Main Pit) until summer 2013, so the pit remained a sink until this time. The pit could not have been providing load to the Minto Creek valley because, even in the direction of the valley, the gradient (at least locally) was towards the pit itself; it was likely acting as only a sink for groundwater flow.

We should keep in mind that sulphate concentrations are only one indicator of loading from the mine, simulated in the model because it is typically assumed to act conservatively (i.e to not be attenuated as discussed in Section 2). Observed concentrations of other key parameters of concern provide a different picture of solute transport. At MW12-06, MW12-05 and MW12-07, copper, cadmium and selenium concentrations are low and have not shown any increasing trends over time. While it is possible that attenuation mechanisms along groundwater pathways could be decreasing concentrations of trace metals relative to sources, multiple different attenuation mechanisms would be required to occur either at the same time or sequentially to remove the trace element signature (including both oxyanions and cations) from all mine sources,.

An alternative explanation (and source) may be possible. The observed sulphate concentrations could be a result of weathering of the known mineral deposits and transport of weathering products via groundwater over geologic time. The mineral deposits (some of which are now mined out) had elevated sulphur concentrations relative to the unmineralized country rock. It is even possible that localized sulphur mineralization (either sulphide or sulphate minerals) in the vicinity of the wells (at least MW12-05) is the cause of observed SO_4 concentrations.

The current groundwater model is considered to reasonably represent the groundwater flow system for the site. It utilizes available data and does not include hypothetical features in an attempt for perfect calibration. The model cannot currently explain some of the observed sulphate concentrations, but does provide a robust picture of how the overall groundwater system is likely working. Permafrost and material distributions do have an effect on modelled flow direction, but the overall gradients and flow directions are similar to topography. A conservative approach to estimating potential loading to downstream receptors is prudent considering uncertainty, and on-going monitoring at MW12-05 and MW12-06 (as well as other locations) will provide data over time that can be used to confirm assumptions.

5 Inputs to Water and Load Balance

Results of the groundwater modelling can be used to define groundwater flow paths for use in future revisions of the site water and load balance model.

For the McGinty Creek watershed, all load from the Minto North Pit should report to surface water in McGinty Creek.

Table 6 presents the percentage of load from each source that will report to various sub-catchments of the Minto Creek watershed via a groundwater pathway.

Table 6: Source Seepage Allocations to Minto Creek Modelling Stations

Model Node for Inclusion of Load		Percentage of source seepage allocated to surface waters down gradient of pits (remainder reports to pits or underground mine)			
		Dumps	**Pits and Pit Lakes**	**DSTSF/MVFE**	**Water Storage Pond**
Minto Creek	WSP_u	7.1%	13.0%	100%	0%
	WSP_{dg}	0%	0.2%	0%	100%
	W3	0%	0.2%	0%	0%
	W46	0%	0%	0%	0%
	MC1	0%	0%	0%	0%
	YR	0%	0%	0%	0%
	Total	**7.1%**	**13.4%**	**100.0%**	**100.0%**

6 Conclusions and Recommendations

This model update has been completed to satisfy Condition 107 of Water Licence QZ14-031, issued to MEL on August 5, 2015.

The groundwater model for the Minto Mine has been updated with revised overburden and bedrock parameters, and permafrost has been included. The model has been calibrated to observed water levels and baseflow estimates, and provides a reasonable estimation of groundwater flow across the site. Groundwater flow generally follows topography, with overprinting effects of open pits and the underground mine.

Model results indicate that seepage from the Southwest and Main waste dumps mostly reports to the open pits and underground mine. The Main Pit is both a source and a sink, capturing water from up gradient areas, but also starting to act as a source for loading towards the Minto Creek valley. Loading from the Main Pit is not estimated to be reaching Minto Creek via groundwater any further east (downgradient) than the Water Storage Pond.

Seepage from the Dry Stack Tailings Storage Facility is likely discharging to the Minto Creek valley from groundwater no further down gradient than the WSP.

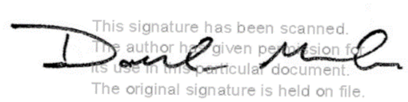
Calibration of the model to observed sulphate concentrations was not attempted. The observed concentrations in the deeper zones at MW12-05 (east of the WSP) are higher than any known mine sources, and calibration to site conditions is simply not possible when observed downgradient concentrations exceed observed source concentrations. Trace element concentrations at both MW12-05 and MW12-06 have remained low and stable since well installation in 2012.

Conservative assumptions for loading along groundwater pathways based on outputs from the groundwater model should be included in the next update of the site water and load balance model.

The following recommendations are made based on the modelling work:

- Monitoring of MW12-05 and MW12-06, as well as other existing monitoring wells, should continue. These wells are in appropriate locations to observe loading down the Minto Creek valley via groundwater.
- Monitoring of MW09-03 in the McGinty Creek watershed should continue, to provide further information on the groundwater system down gradient of the Minto North Pit during development and after mining is complete.
- Results of the 2015 groundwater model update should be used to inform design of the Groundwater Monitoring Plan and the longitudinal tracer study.

This report, Minto Groundwater Model Update, was prepared by



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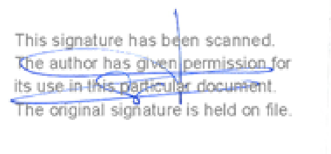

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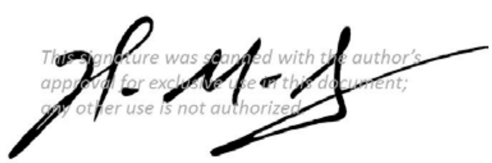

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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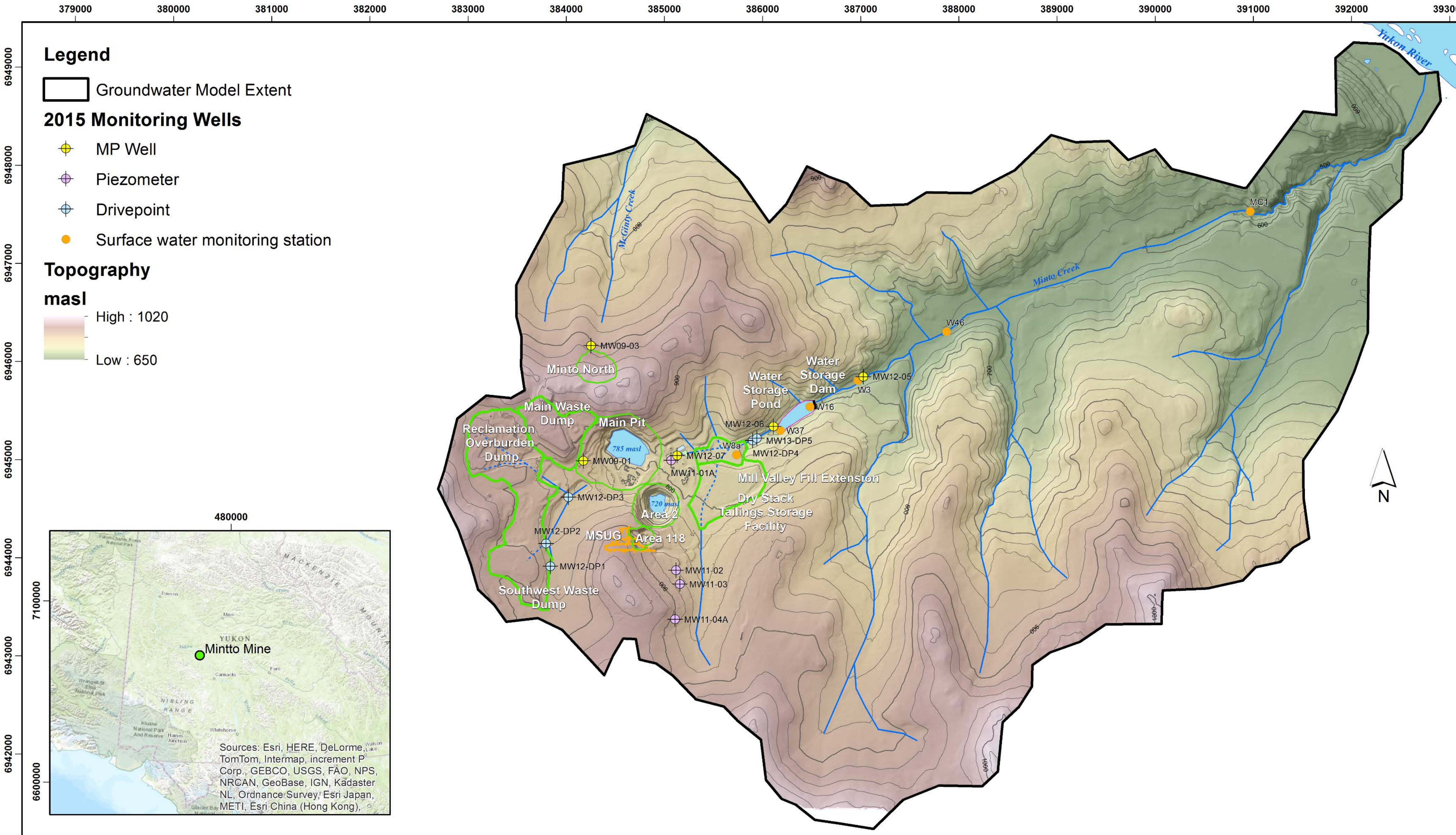
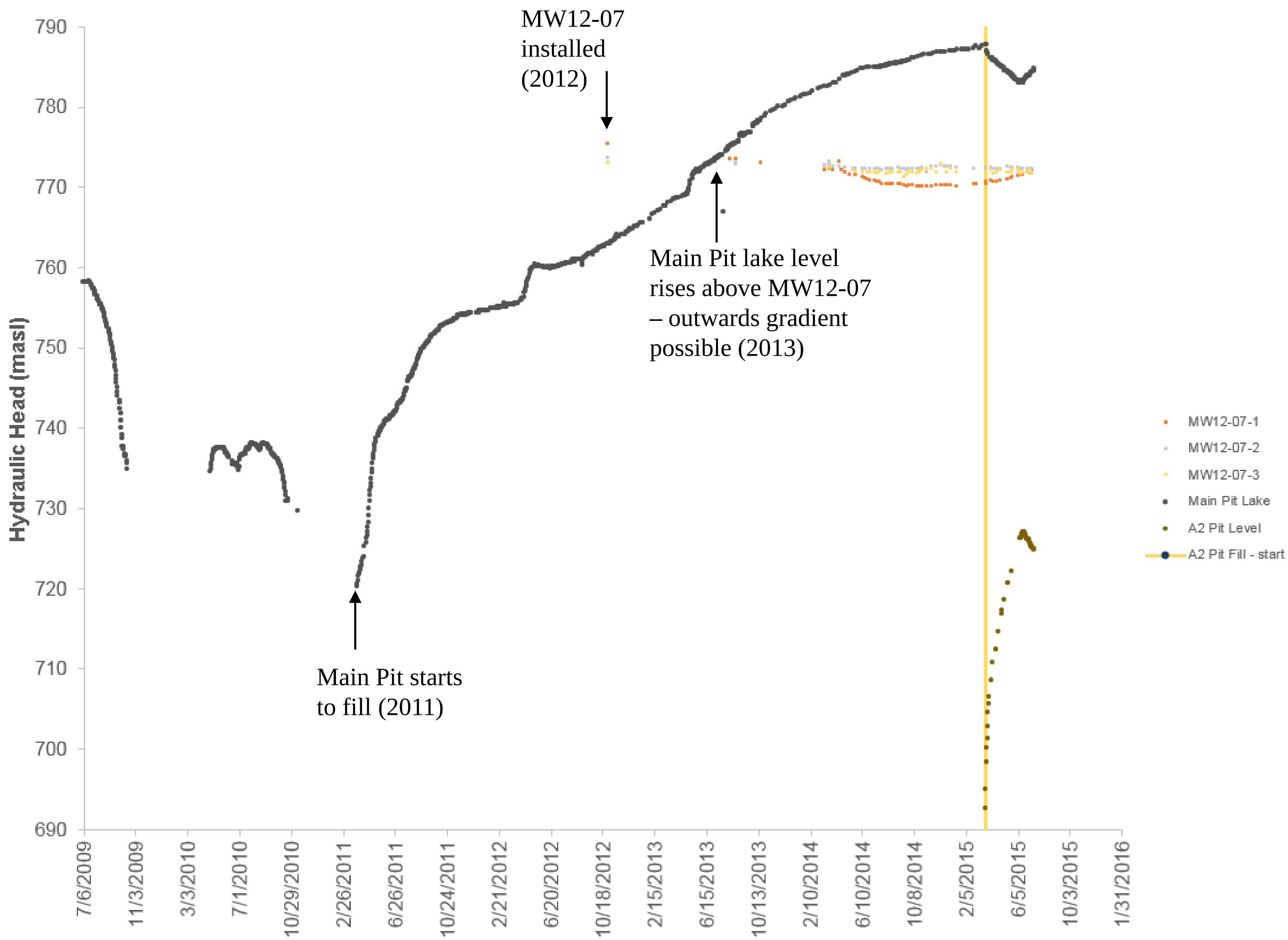
Figures



Notes:
1. Data presented in NAD 1983 UTM Zone 8N.
2. Contours in 20 m intervals.

srk consulting	capstone MINTO MINE (OPERATED BY MINTO EXPLORATIONS LTD.)	2015 Groundwater Model Update
		Site Arrangement and Location of Monitoring Wells
Job No: 1CM002.041 Filename: Fig_SiteLocation_rev1.mxd	Minto Mine	Date: Oct. 2015 / Approved: GF / Figure: 1



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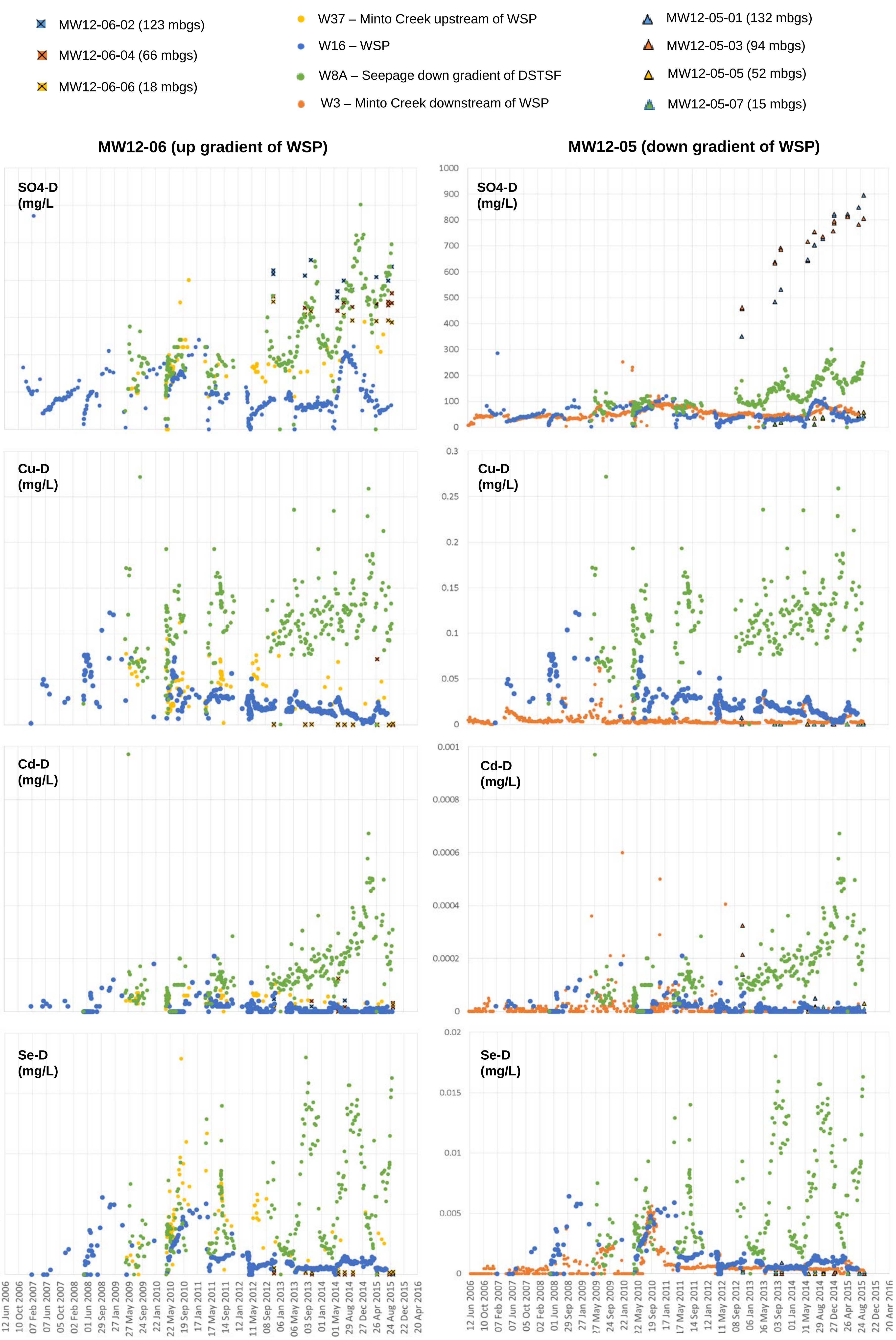
Job No: 1CM002.041 Filename Figure 2.pptx	Minto Mine	Date: Oct. 2015 / Approved: DM / Figure: 2



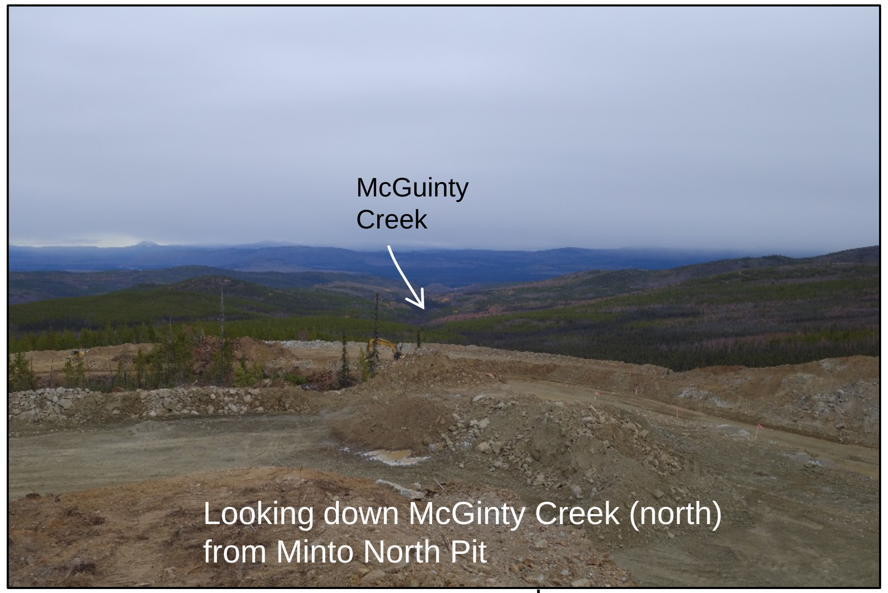
Date ranges are the same for all graphs

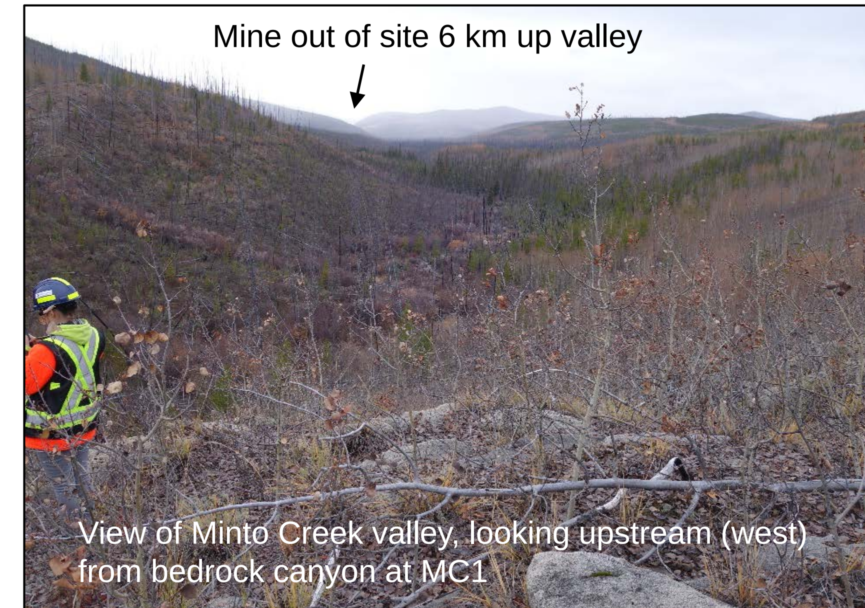
srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	2015 Groundwater Model Update **Groundwater Quality at MW12-05 and MW12-06**
Job No: 1CM002.041 Filename: Water quality comparison_rev02.pptx	Minto Mine	Date: Oct 2015 / Approved: DM / Figure: 3

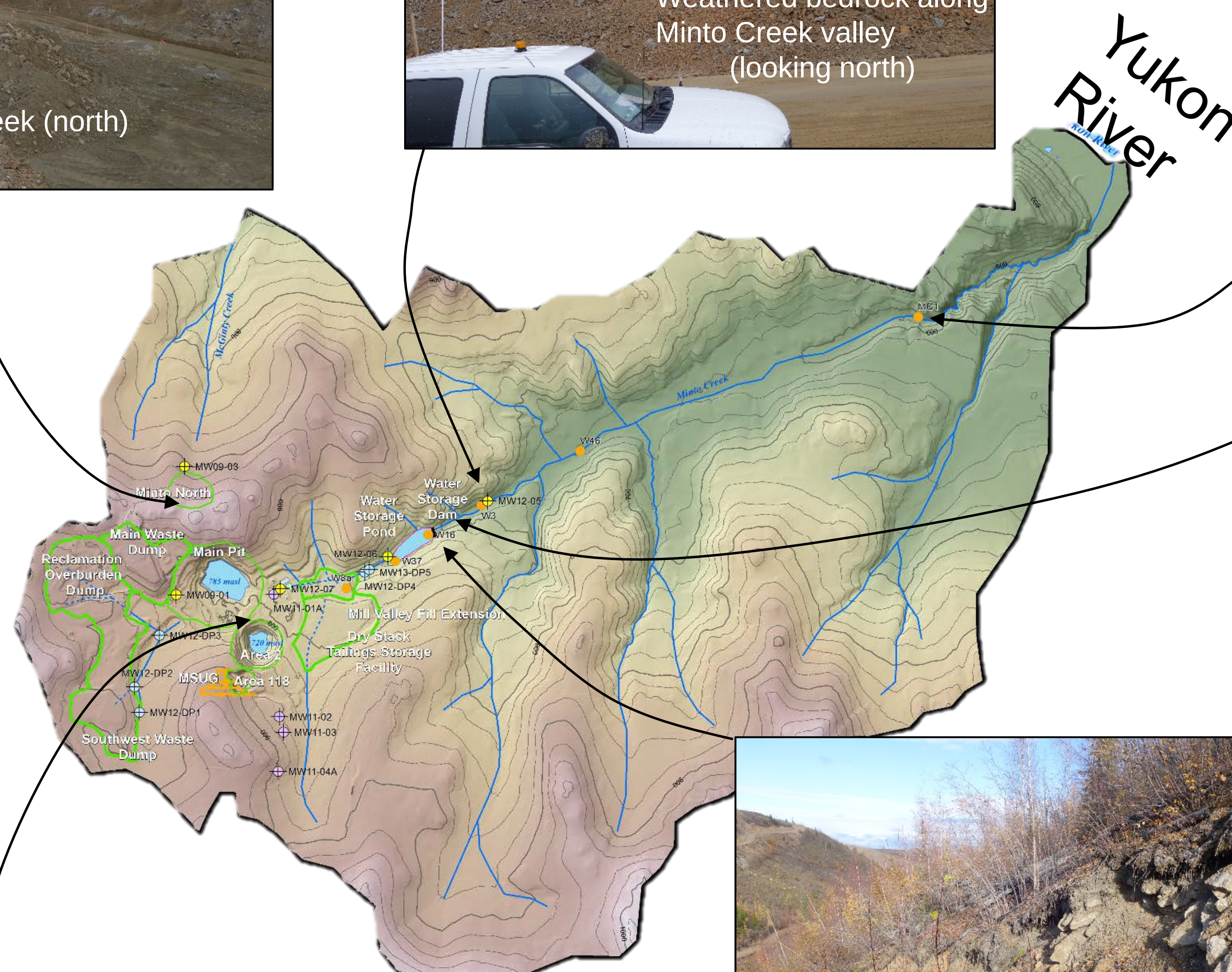
Date		Main Pit (MP)	Area 2 Stage 2 (A2S2)	Area 2 Stage 3 (A2S3)	Area 118 (118)	Minto North (MN)	M-Zone UG (MZUG)	Minto South UG (MSUG)
2005	Q1							
	Q2							
	Q3							
	Q4							
2006	Q1	*Mining*						
	Q2	*Mining*						
	Q3	*Mining*						
	Q4	*Mining*						
2007	Q1	*Mining*						
	Q2	*Mining*						
	Q3	*Mining*						
	Q4	*Mining*						
2008	Q1	*Mining*						
	Q2	*Mining*						
	Q3	*Mining*						
	Q4	*Mining*						
2009	Q1	*Mining*						
	Q2	*Mining*						
	Q3	*Mining*						
	Q4	*Mining*						
2010	Q1	*Mining*						
	Q2	*Mining*						
	Q3	*Mining*						
	Q4	*Mining*						
2011	Q1	*Mining*						
	Q2	*Mining*	*Mining*					
	Q3	*W*	*Mining*					
	Q4	*W*	*Mining*					
2012	Q1	*W*	*Mining*					
	Q2	*W*	*Mining*					
	Q3	*W*	*Mining*					*Mining*
	Q4	*T+W*	*Mining*					*Mining*
2013	Q1	*T+W*	*Mining*					*Mining*
	Q2	*T+W*	*Mining*		*Mining*			*Mining*
	Q3	*T+W*	*Mining*		*Mining*			*Mining*
	Q4	*T+W*	*Mining*					*Mining*
2014	Q1	*T+W*					*Mining*	*Mining*
	Q2	*T+W*					*Mining*	
	Q3	*T+W*					*Mining*	
	Q4	*T+W*					*Mining*	
2015	Q1	*T+W*					*Mining*	
	Q2	*T+W, P to A2S2*	*R from MP*					*Mining*
	Q3	*T+W, P to A2S2*	*R from MP*			*Mining*		*Mining*
	Q4	*T+W, P to A2S2*	*R from MP*			*Mining*		*Mining*
2016	Q1					*Mining*		*Mining*
	Q2					*Mining*		*Mining*
	Q3			*Mining*		*Mining*		*Mining*
	Q4			*Mining*				*Mining*
2017	Q1			*Mining*				*Mining*
	Q2			*Mining*				*Mining*
	Q3			*Mining*				*Mining*
	Q4							*Mining*
2018	Q1							*Mining*
	Q2							*Mining*
	Q3							*Mining*
	Q4							*Mining*
2019	Q1							*Mining*
	Q2							*Mining*
	Q3							*Mining*
	Q4							*Mining*
2020	Q1							*Mining*
	Q2							*Mining*
	Q3							*Mining*
	Q4							*Mining*
2021	Q1							*Mining*
	Q2							*Mining*
	Q3							*Mining*
	Q4							*Mining*
2022	Q1							*Mining*
	Q2							*Mining*
	Q3							*Mining*
	Q4							

Current time

Note:
"T+W", Deposition of tailing (T) and collection of water (W).
"P to A2S2", Pumping water from Main Pit to Area2 Pit.
"R from MP", Receiving water pumped from Main Pit.







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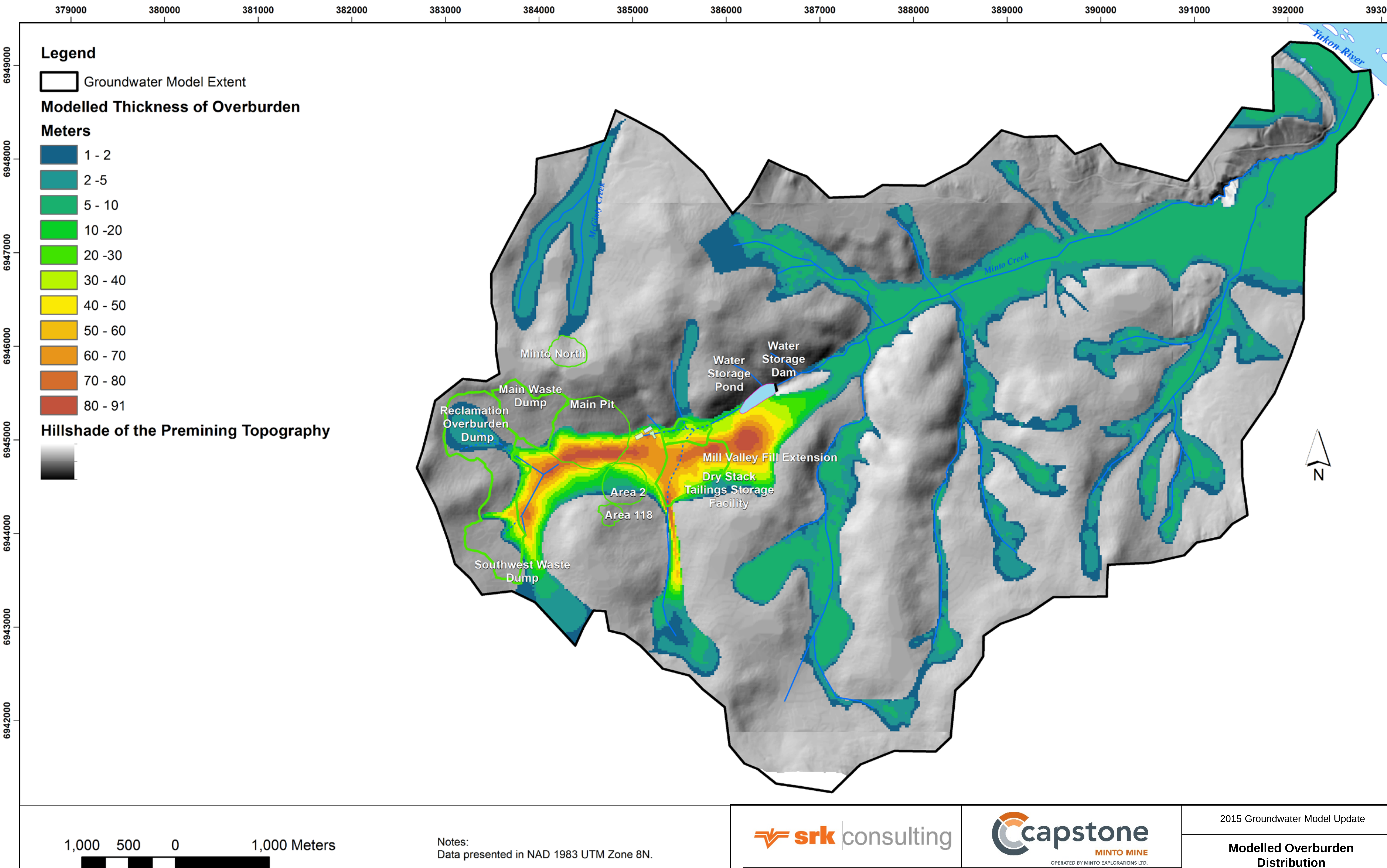
2015 Groundwater Model Update

Photo Collage of Minto Creek valley and Bedrock Outcrops

Job No: 1CM002.041 Filename: Photo collage.pptx	Minto Mine	Date: Oct. 2015	Approved: GF	Figure: 5



Notes:
Data presented in NAD 1983 UTM Zone 8N.

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Job No: 1CM002.041

Filename: Fig_OVB_Thickness.mxd

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Minto Mine

2015 Groundwater Model Update

Modelled Overburden Distribution

Date:	Approved:	Figure:
Oct. 2015	GF	6

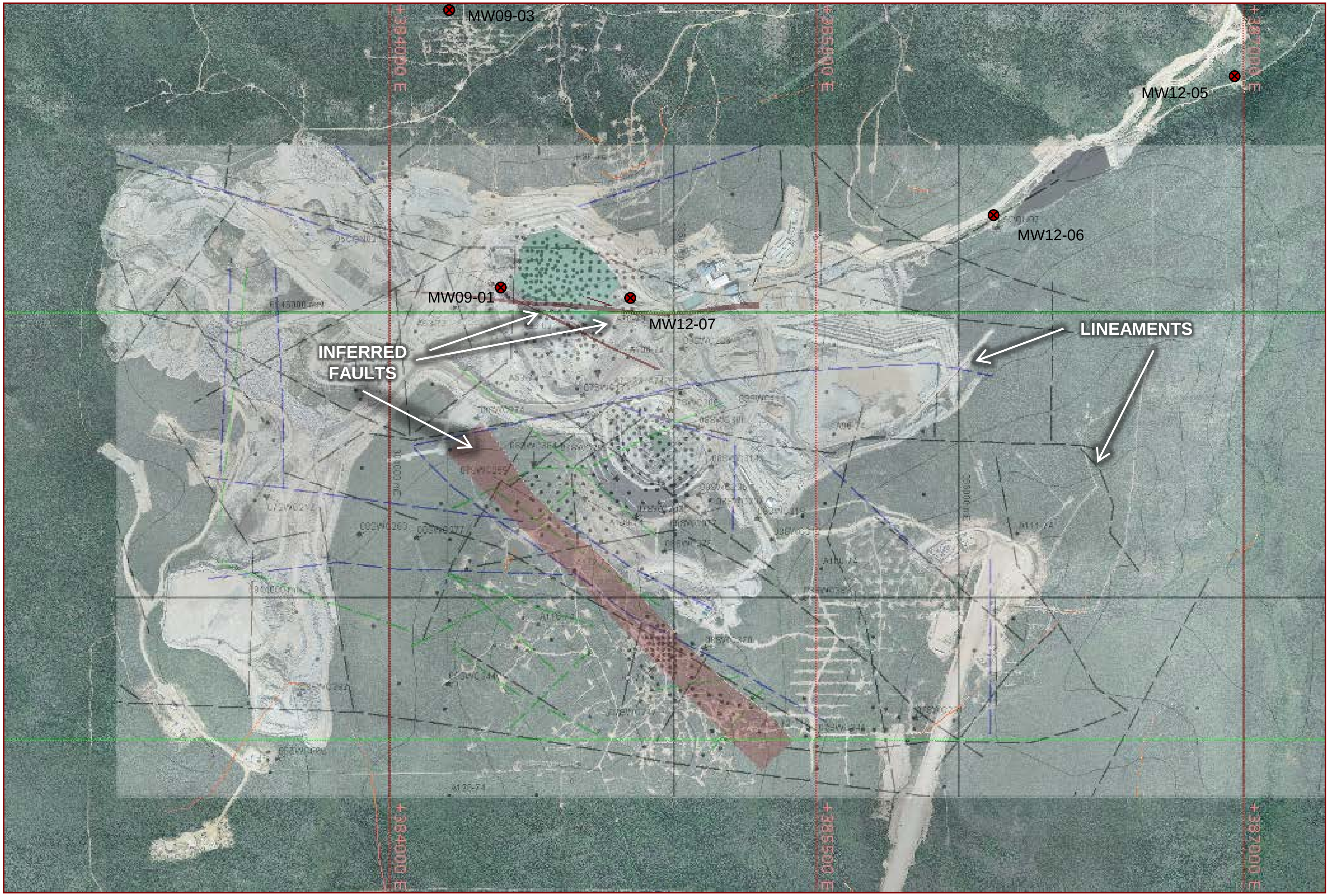

Figure 4.3 from SRK 2014a

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2015 Groundwater Model Update

Geologic Structures and Lineament Mapping

Job No: 1CM002.041

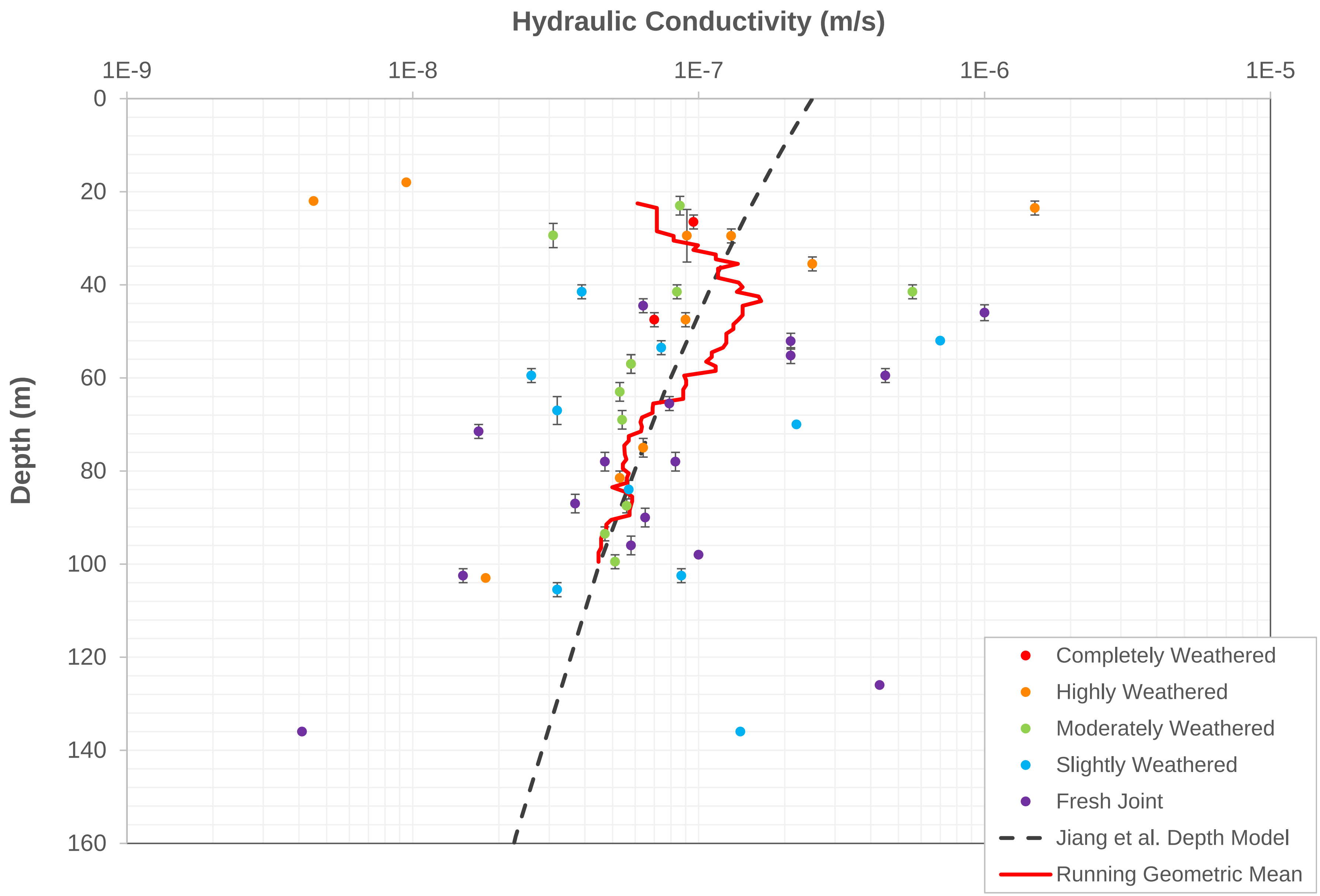
Filename: Figure 7 structures and lineaments.pptx

Minto Mine

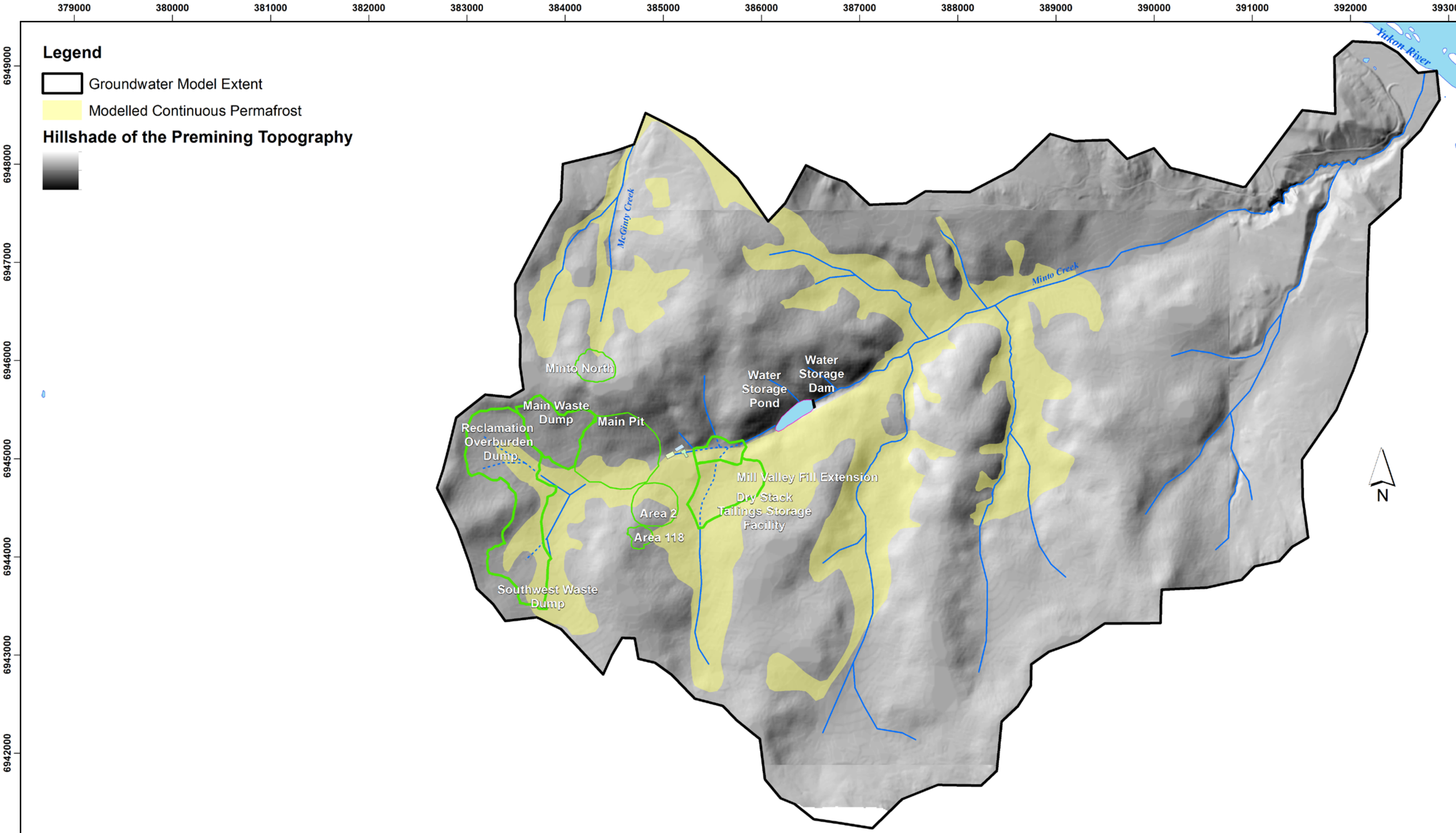
Date: Oct. 2015

Approved: DM

Figure: 7



srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	2015 Groundwater Model Update **Relationship between depth and hydraulic conductivity**
Job No: 1CM002.041 Filename: Minto_2015_Hydro_Database _1CM002.041_rev03.xlsx	Minto Mine	Date: Oct. 2015 / Approved: GF / Figure: 8



1,000 500 0 1,000 Meters

Notes:
1. Data presented in NAD 1983 UTM Zone 8N.
2. Modelled permafrpst distribution based on permafrost mapping conducted by Knight Piezold (1995) and SRK (2014)

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Job No: 1CM002.041

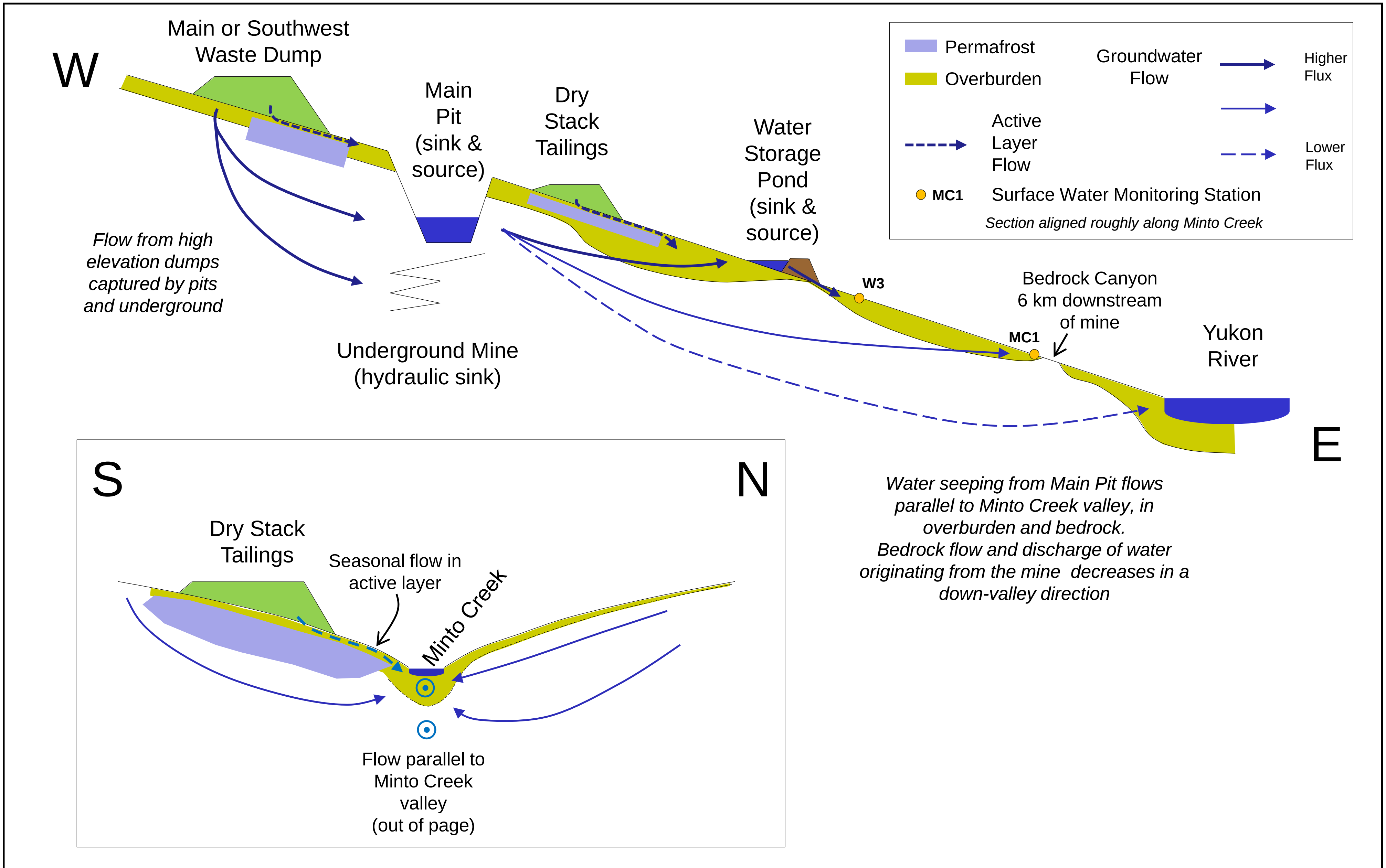
Filename: Fig_Permfrost_Distribution.mxd

Minto Mine

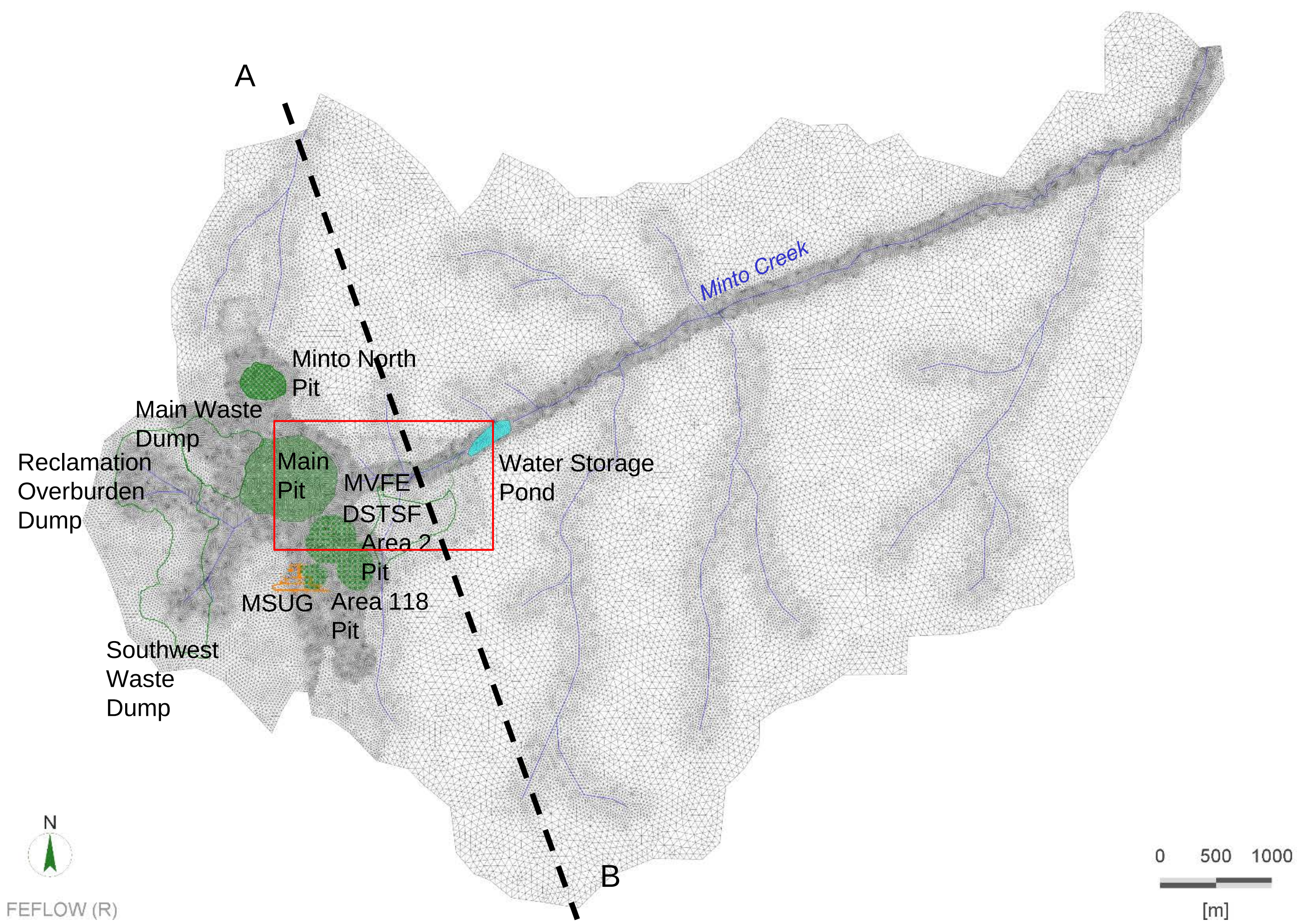
2015 Groundwater Model Update

Modelled Permafrost Distribution

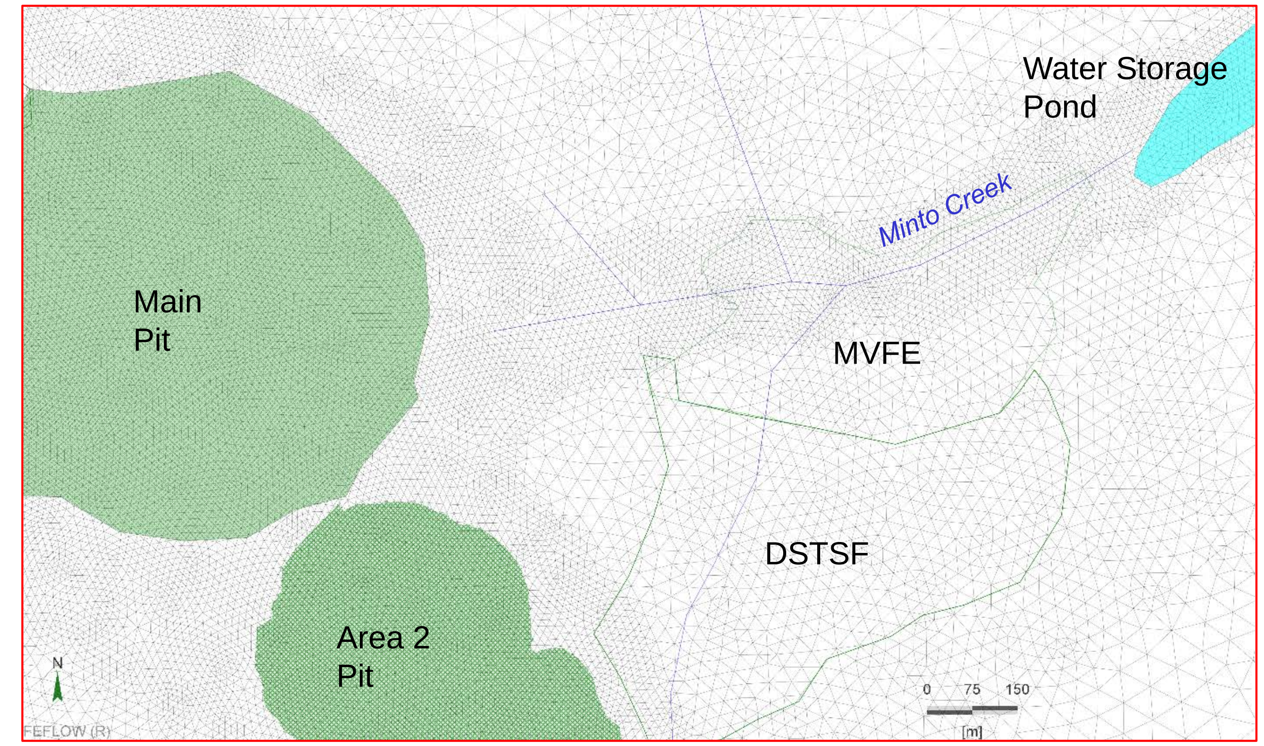
Date:	Approved:	Figure:
Oct. 2015	GF	9



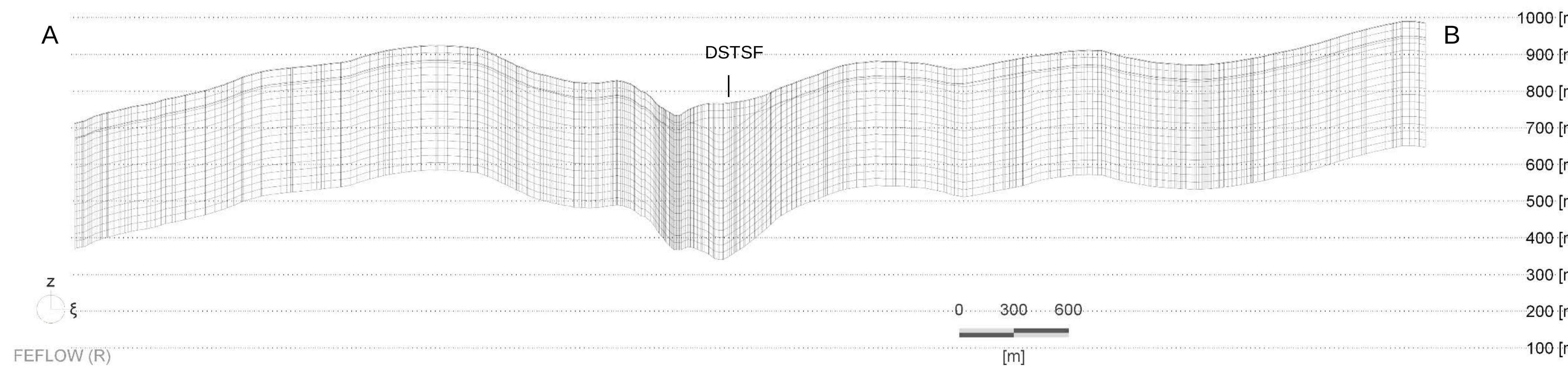
srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	2015 Groundwater Model Update
		Schematic Conceptual Models for Groundwater Flow
Job No: 1CM002.041 Filename: Conceptual_Schematics.pptx	Minto Mine	Date: Oct. 2015 | Approved: GF | Figure: **10**



Plan view of entire model domain.
Cross section line denoted as AB (below) and zoomed mesh view highlighted by red box (right)

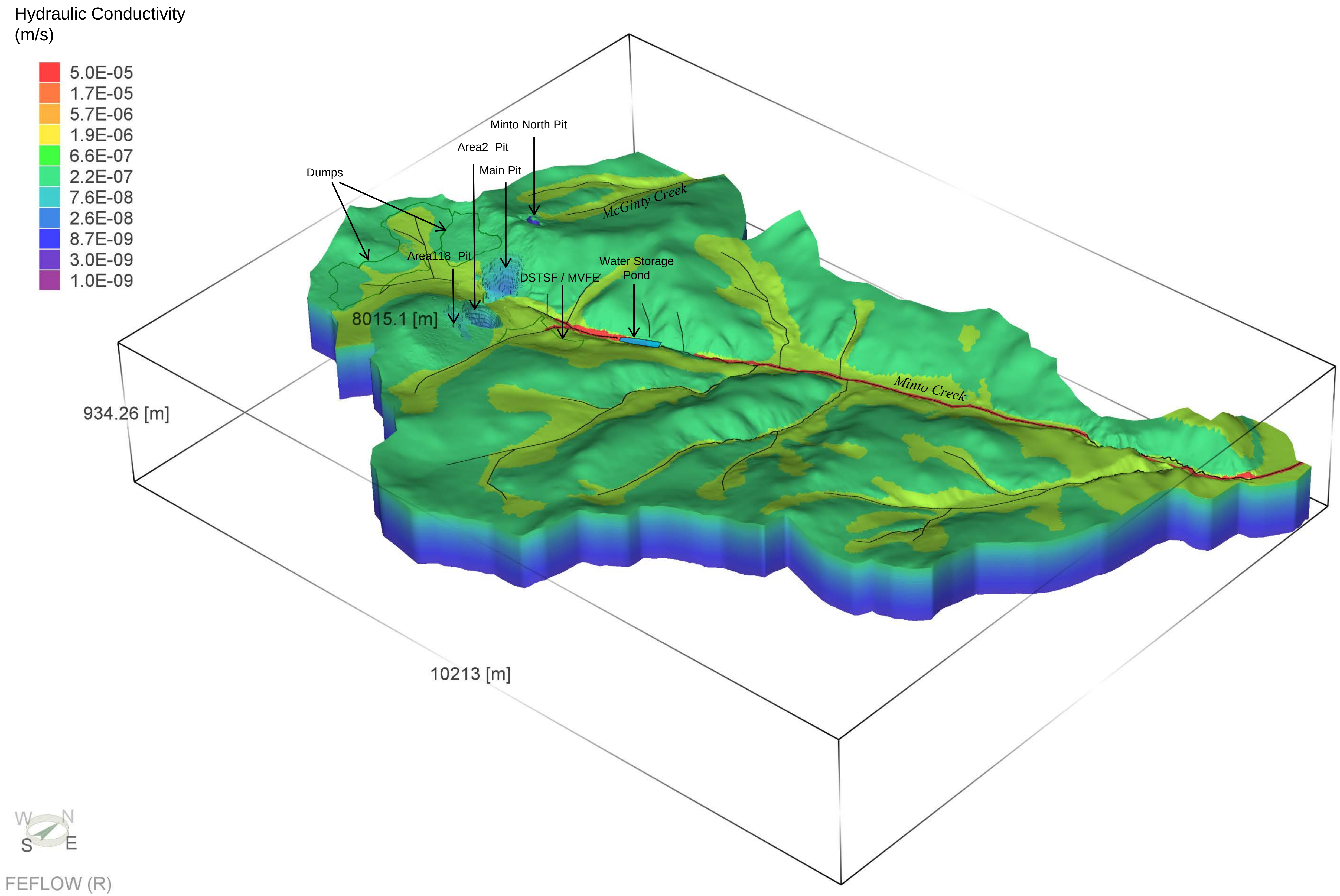


Detailed view of increased mesh elements near pits and along creeks

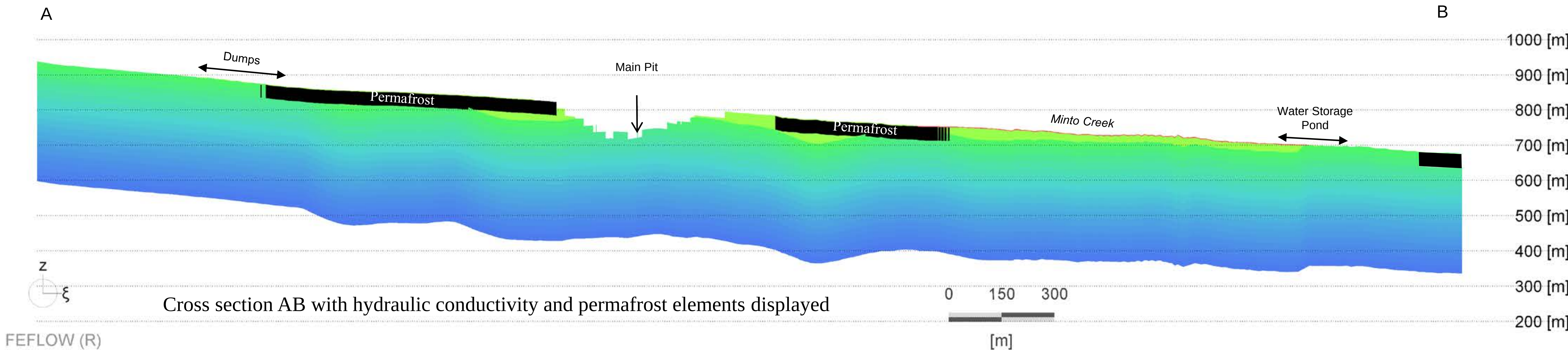


Cross section of model with density of layers displayed

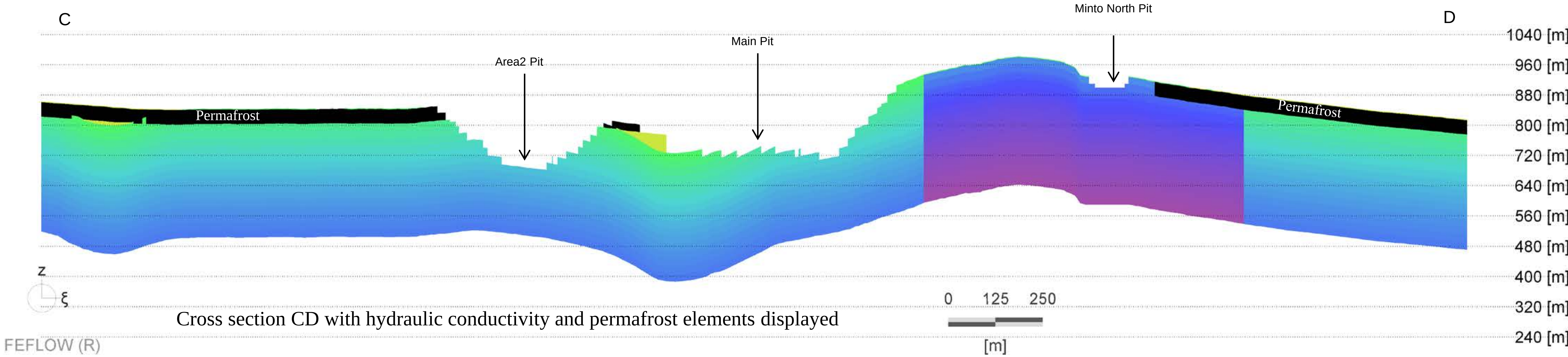
srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	2015 Groundwater Model Update
Job No: 1CM002.041 Filename: MintoUPD_rev7_CURRENT_TrsnsprtStdSt_[6b]_Adj_MintoN_K.dac	Minto Mine	**Model Mesh**
		Date: Oct. 2015 / Approved: GF / Figure: 11



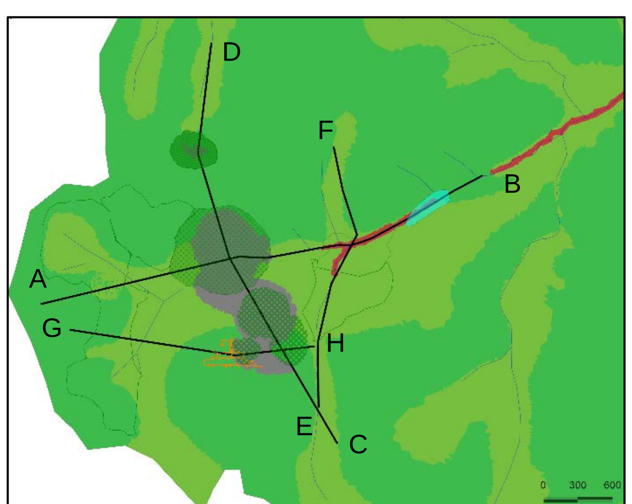
srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	2015 Groundwater Model Update
		Hydraulic Conductivity Distribution in 3D
Job No: 1CM002.041 Filename: MintoUPD_rev7_CURRENT_TrsnsprtStdSt_[6b]_Adj_MintoN_K.dac	Minto Mine	Date: Oct. 2015 / Approved: GF / Figure: 12



Cross section AB with hydraulic conductivity and permafrost elements displayed



Cross section CD with hydraulic conductivity and permafrost elements displayed



Hydraulic Conductivity
(m/s)

- 5.0E-05
- 1.4E-05
- 4.2E-06
- 1.2E-06
- 3.5E-07
- 1.0E-07
- 2.9E-08
- 8.3E-09
- 2.4E-09
- 6.9E-10
- 2.0E-10

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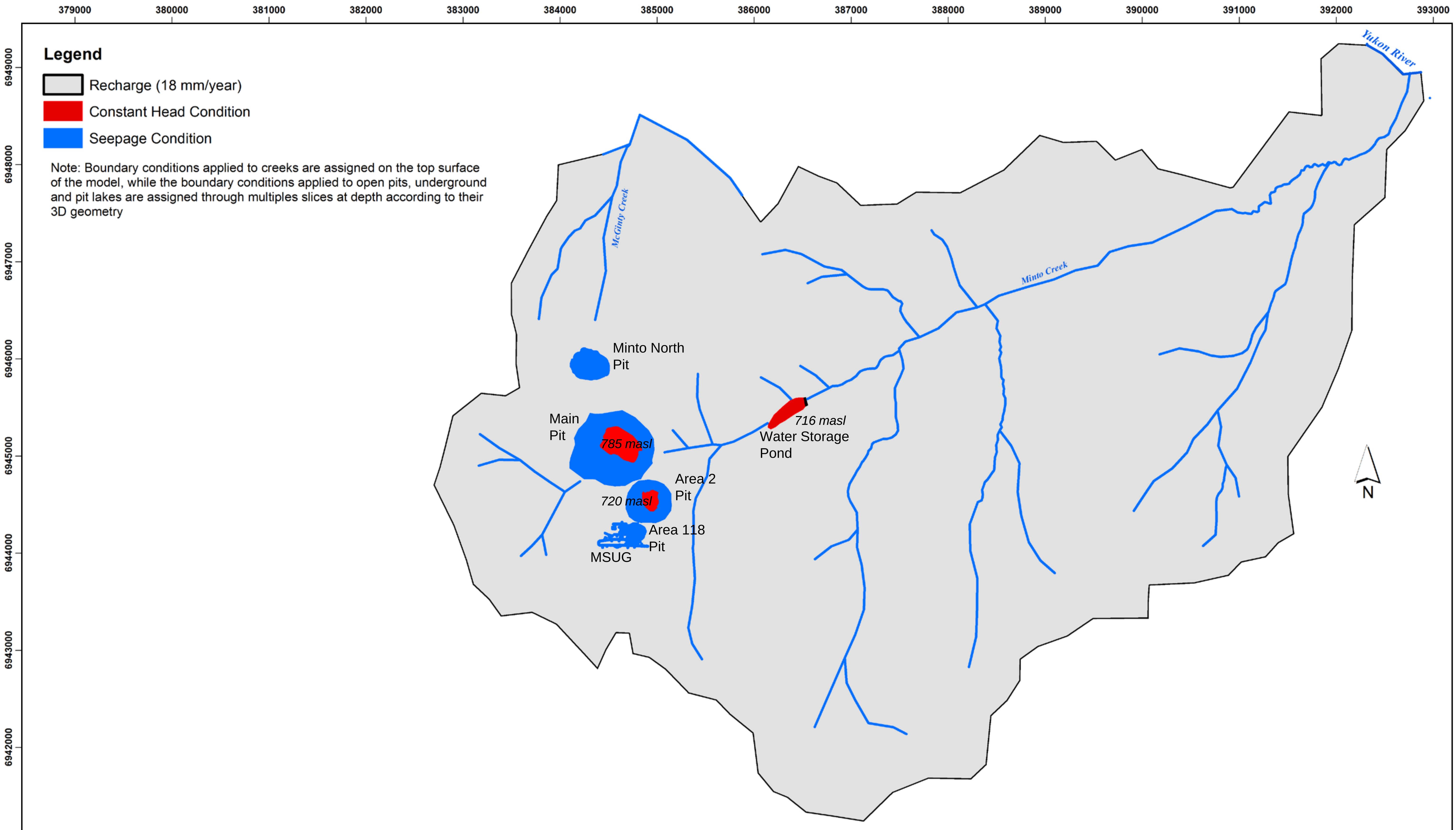
2015 Groundwater Model Update

Hydraulic Conductivity Distribution in 2D Sections

Job No: 1CM002.041
Filename: MintoUPD_rev7_CURRENT_TrsnsprtStdSt_[6b]_Adj_MintoN_K.dac

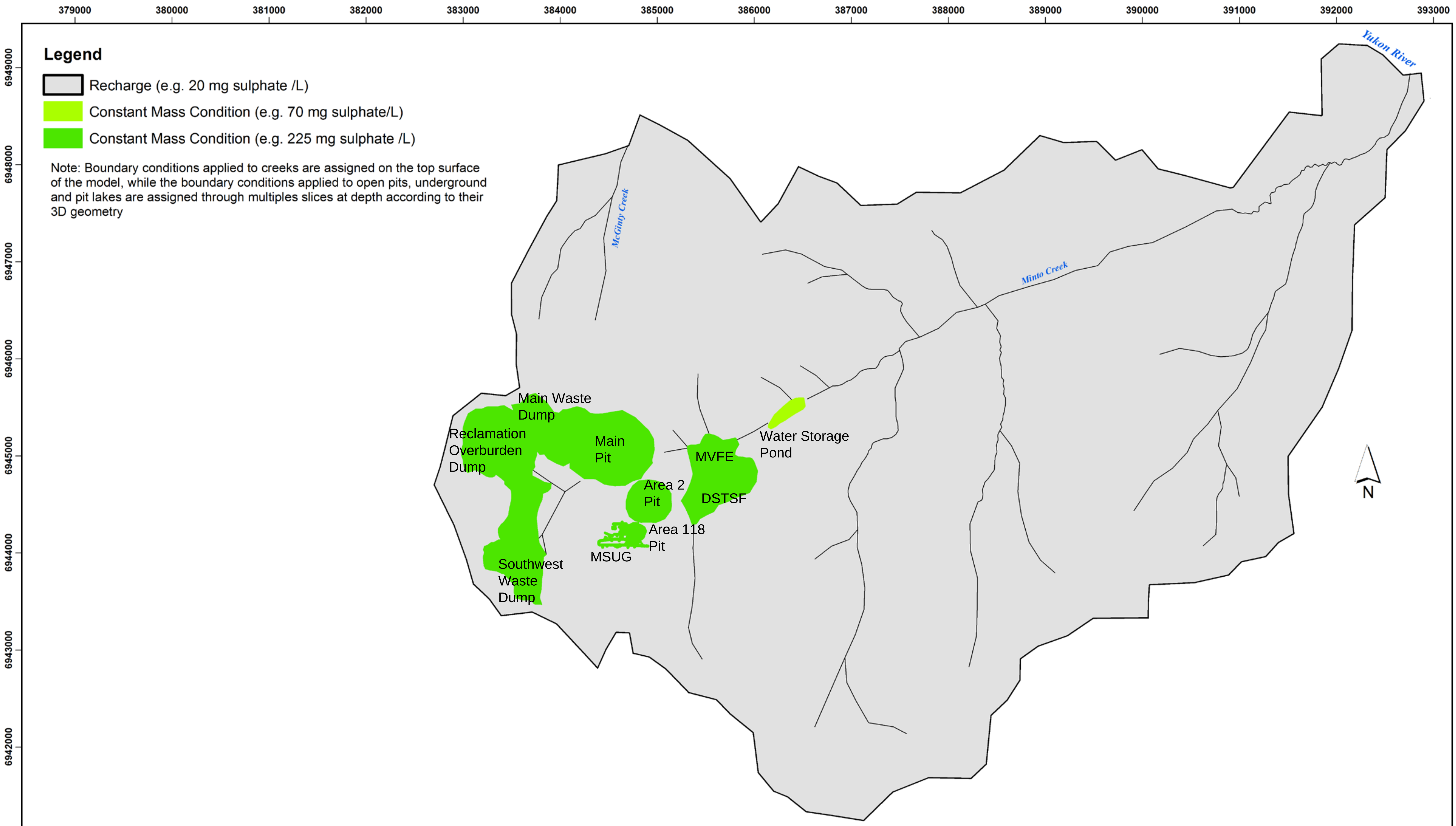
Minto Mine

Date:	Approved:	Figure:
Oct. 2015	GF	13



Notes:
Data presented in NAD 1983 UTM Zone 8N.

srk consulting	capstone MINTO MINE	2015 Groundwater Model Update
Job No: 1CM002.041		**Head Boundary Conditions**
Filename: Model_BC.mxd	Minto Mine	Date: Oct. 2015 · Approved: GF · Figure: 14



Notes:
Data presented in NAD 1983 UTM Zone 8N.

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Job No:	1CM002.041
Filename:	Model_MC.mxd

Minto Mine

2015 Groundwater Model Update

Mass Boundary Conditions

Date:	Approved:	Figure:
Oct. 2015	GF	15

Legend

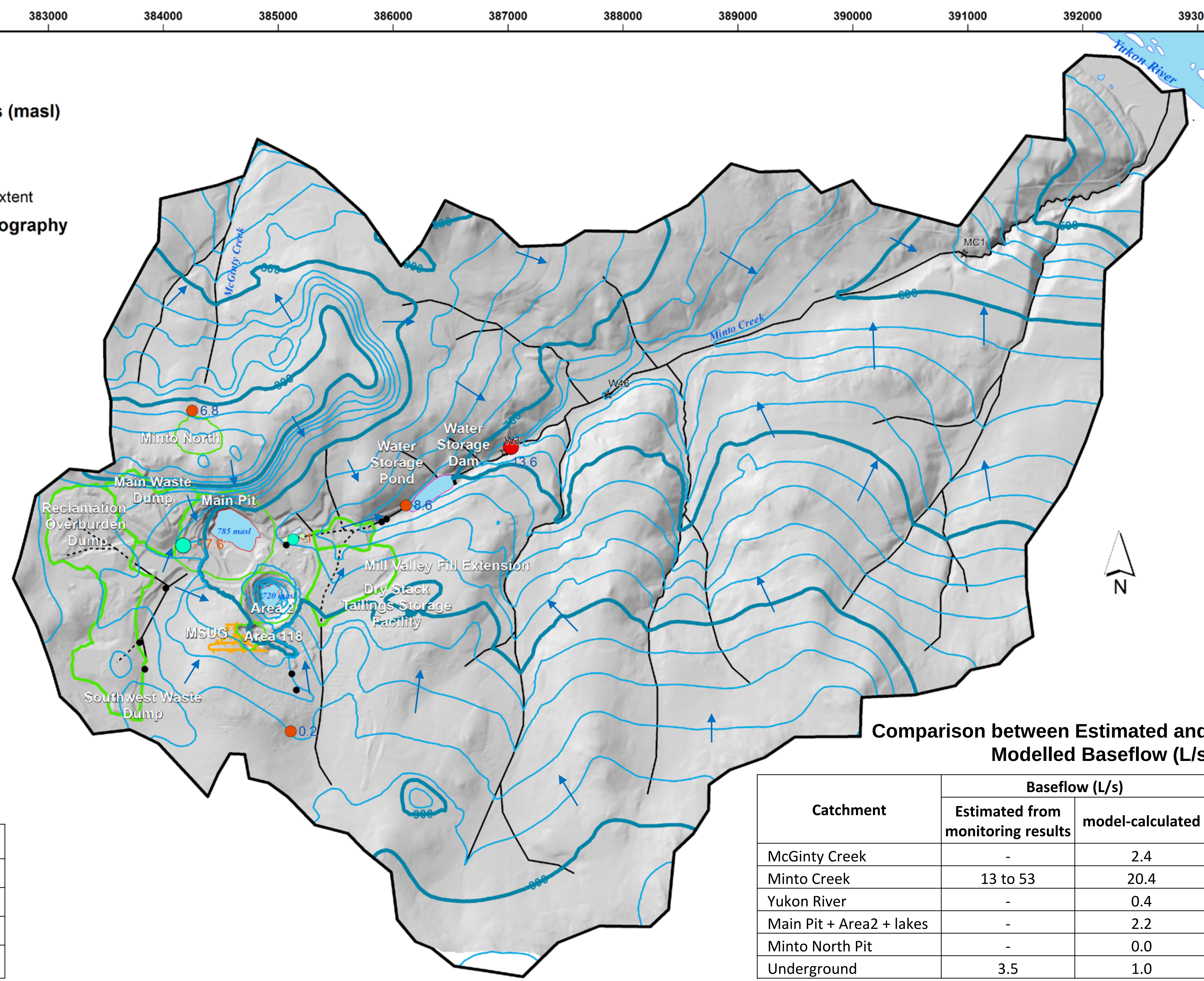
Average Residual Head

- • Not available
- -20 to -10 m
- -10 to 0 m
- 0 to 10 m
- 10 to 20 m
- ☆ Surface Water stations

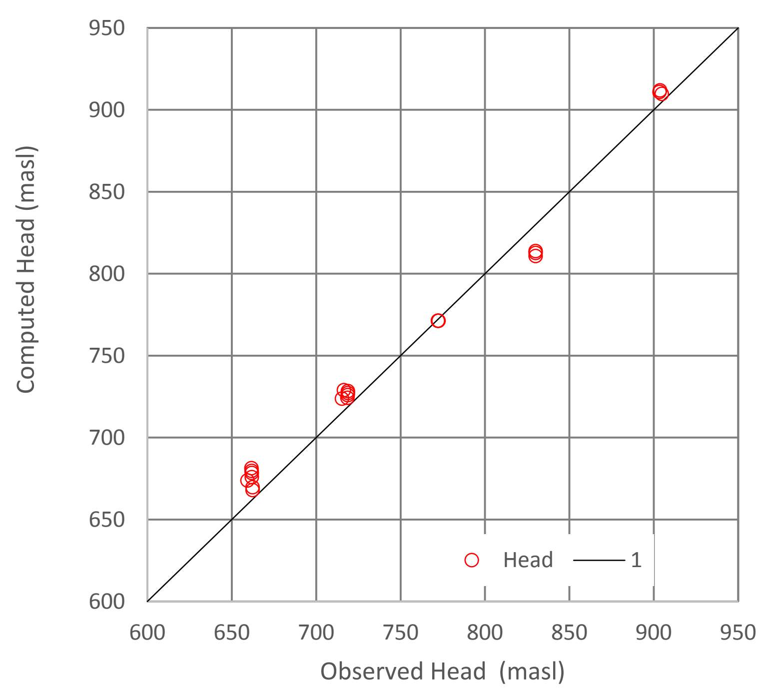
Modelled head contours (masl)

- Major head contour
- Minor head contour
- Groundwater Model Extent

Hillshade of current topography



Modelled Head Chart and Statistics



Mean Error (m)	4.9
Mean Absolute Error (m)	8.5
Root Mean Squared Error (m)	0.8
Normalized Root Mean Squared Error (%)	0.3%
Coefficient of Determination [R^2]	0.99

Comparison between Estimated and Modelled Baseflow (L/s)

Catchment	Baseflow (L/s)	
	Estimated from monitoring results	model-calculated
McGinty Creek	-	2.4
Minto Creek	13 to 53	20.4
Yukon River	-	0.4
Main Pit + Area2 + lakes	-	2.2
Minto North Pit	-	0.0
Underground	3.5	1.0

1,000 500 0 1,000 Meters

Notes:
1. Data presented in NAD 1983 UTM Zone 8N.
2. Contours in 20 m intervals.

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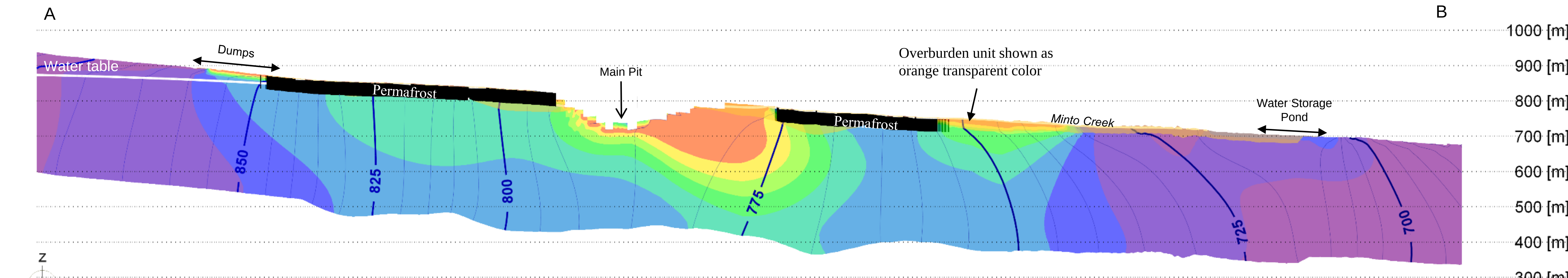
2015 Groundwater Model Update

Model Calibration

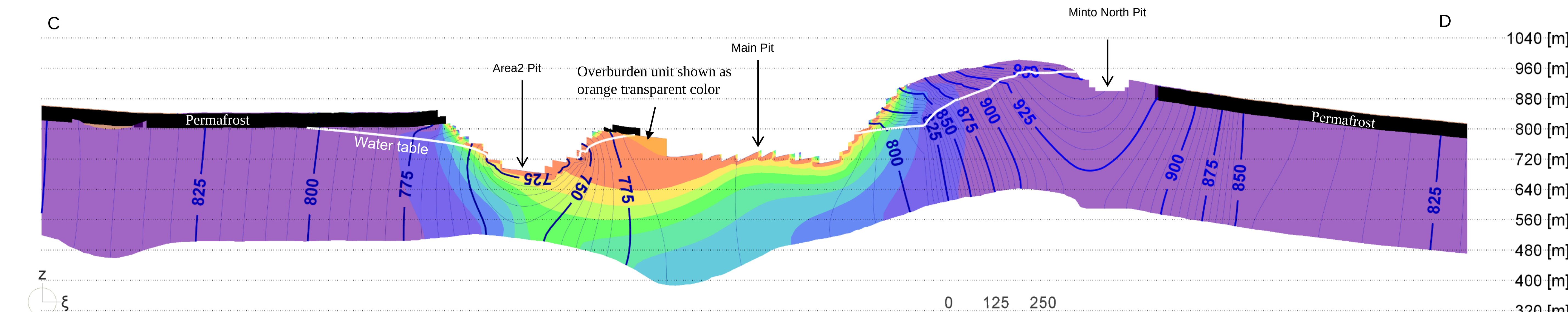
Job No: 1CM002.041
Filename: Fig_ModeledHead_Baseflows_Calibration.mxd

Minto Mine

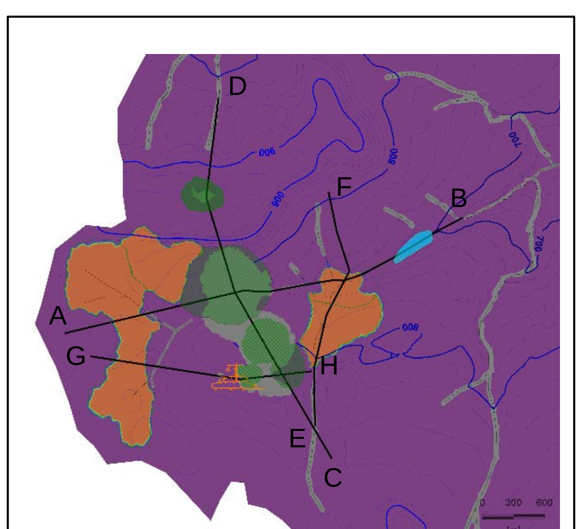
Date: Oct. 2015 | Approved: GF | Figure: 16



Cross section AB with sulphate concentration, head contours, water table and permafrost elements displayed



Cross section CD with sulphate concentration, head contours, water table and permafrost elements displayed



Sulphate Concentration (mg/L)

- 200 ... 225
- 175 ... 200
- 150 ... 175
- 125 ... 150
- 100 ... 125
- 75 ... 100
- 50 ... 75
- 25 ... 50
- 20 ... 25

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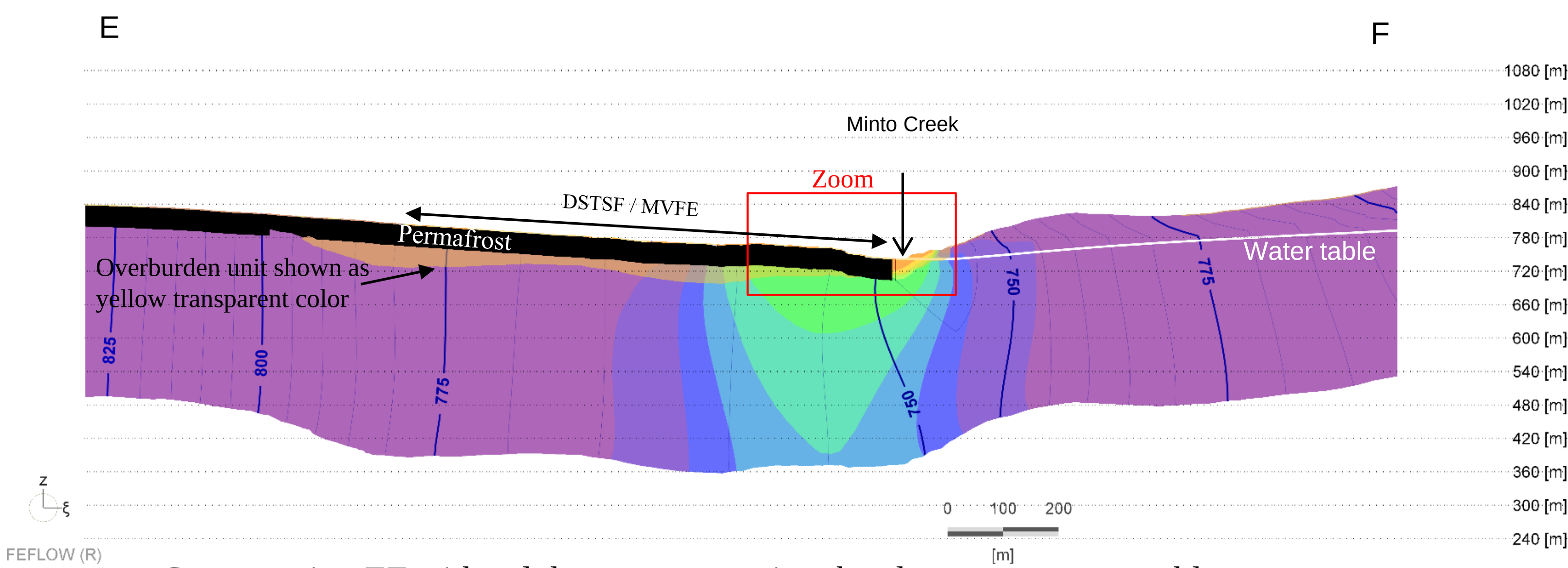
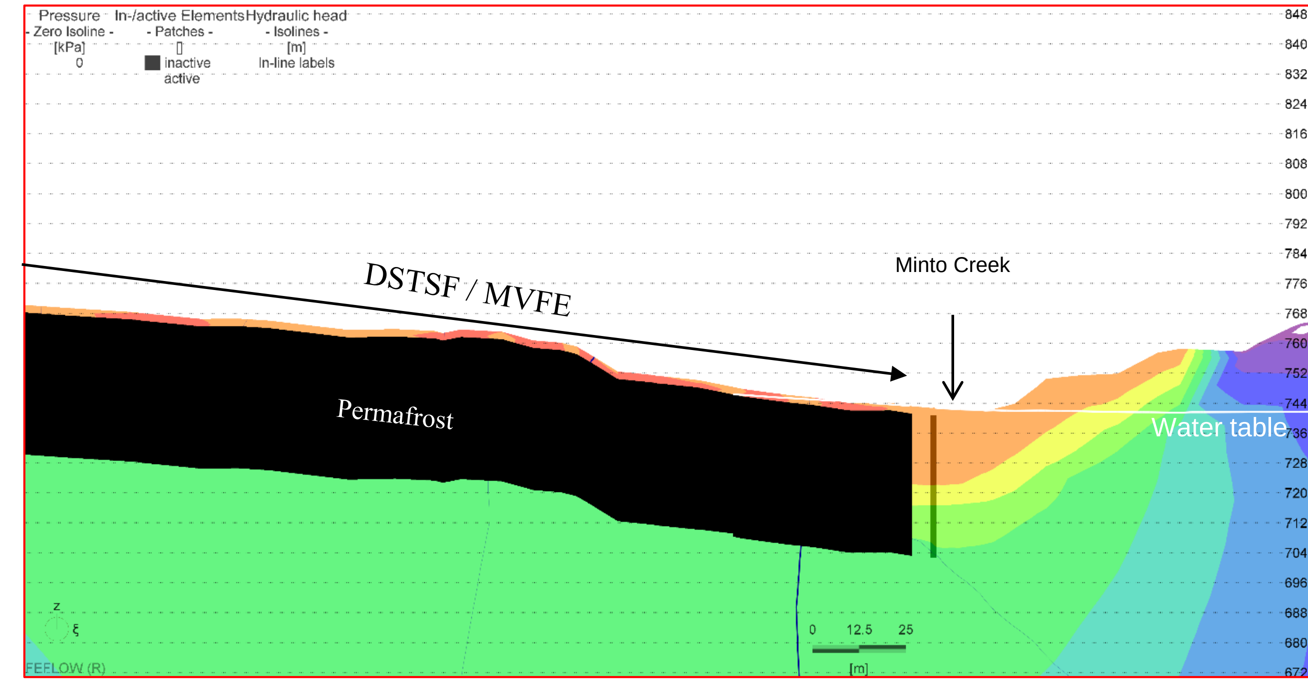
2015 Groundwater Model Update

Modelled Sulphate Concentration for Cross Sections AB and CD

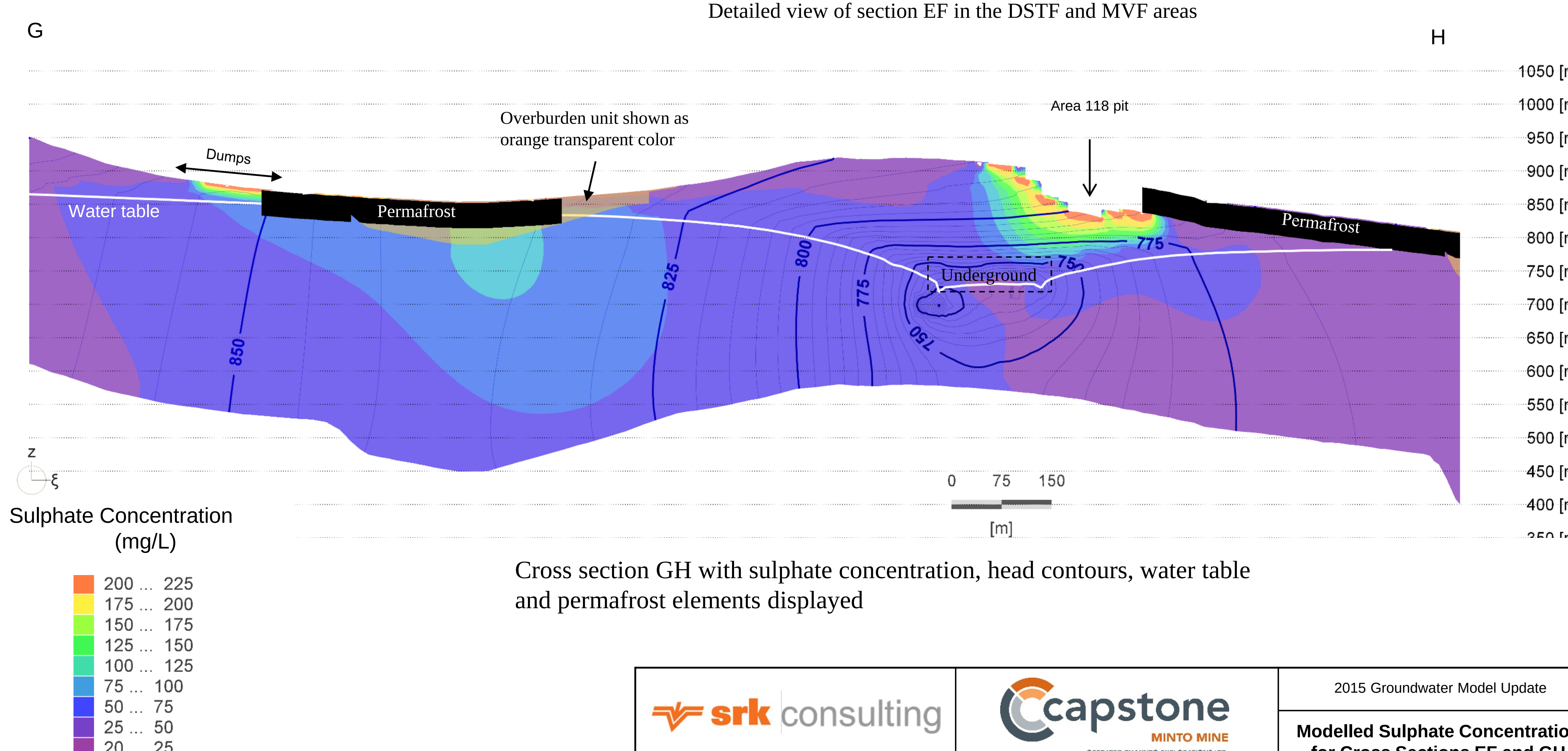
Job No: 1CM002.041	Minto Mine	Date: Oct. 2015	Approved: GF	Figure: 17	
Filename: MintoUPD_rev7_CURRENT_TrsnsprtStdSt_[6b]_Adj_MintoN_K.dac					

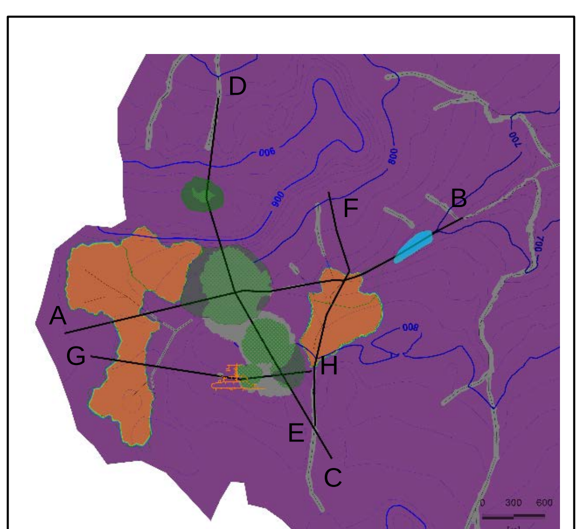


Cross section EF with sulphate concentration, head contours, water table and permafrost elements displayed. Zoomed view indicated by red box (right)



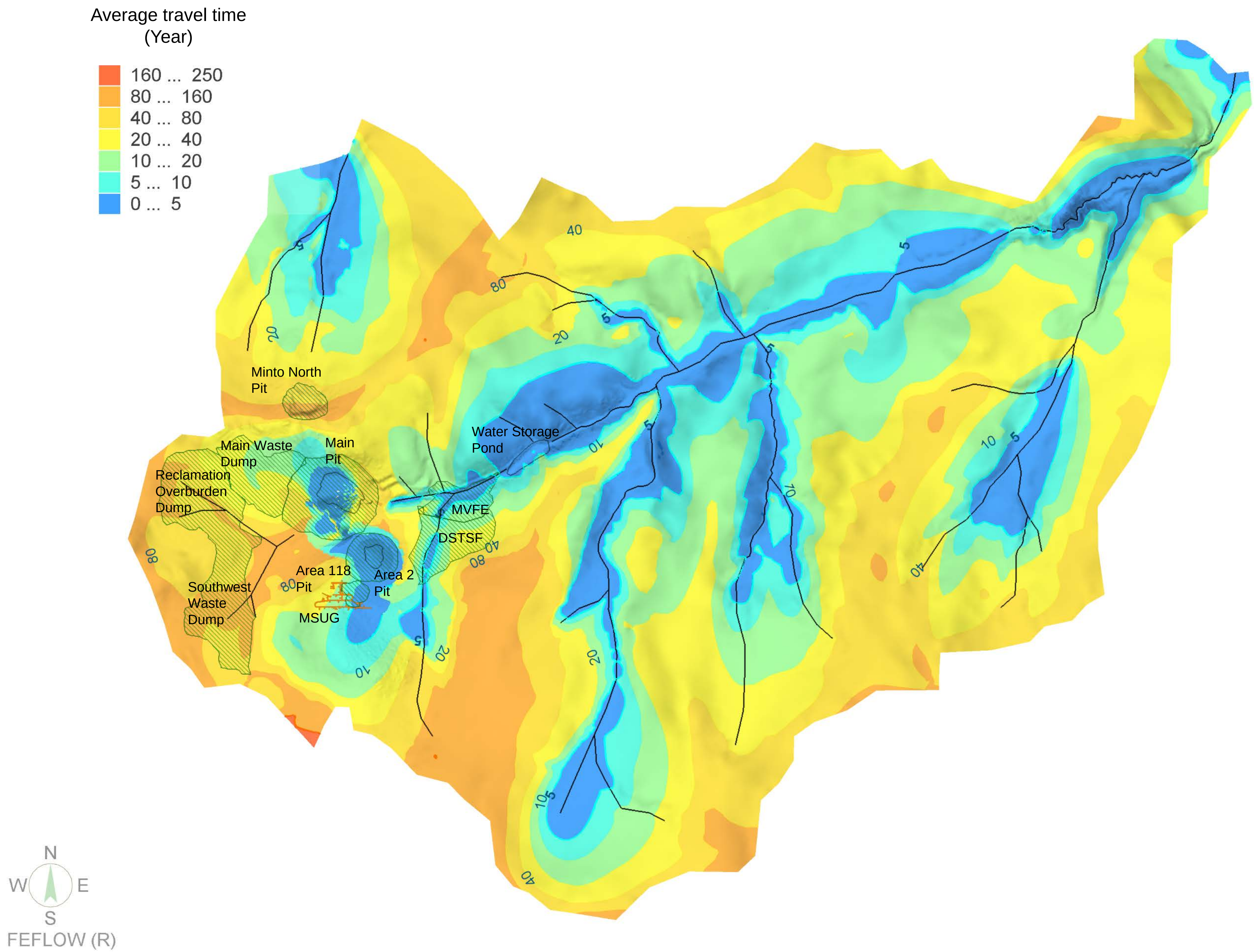
Detailed view of section EF in the DSTF and MVF areas





Cross section GH with sulphate concentration, head contours, water table and permafrost elements displayed

srk consulting	capstone MINTO MINE	2015 Groundwater Model Update
Job No: 1CM002.041 Filename: MintoUPD_rev7_CURRENT_TrsnsprtStdSt_[6b]_Adj_MintoN_K.dac	Minto Mine	**Modelled Sulphate Concentration for Cross Sections EF and GH** Date: Oct. 2015 · Approved: GF · Figure: 18



Note: The average travel time is also called "Mean Lifetime Expectancy" in Feflow. It is defined as the average time groundwater must travel between its entry point and before exiting via an outlet, such as creeks, pits, underground or pit lakes. Zones with longer travel times indicate groundwater divides whereas areas close to creeks show shorter travel times.

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2015 Groundwater Model Update

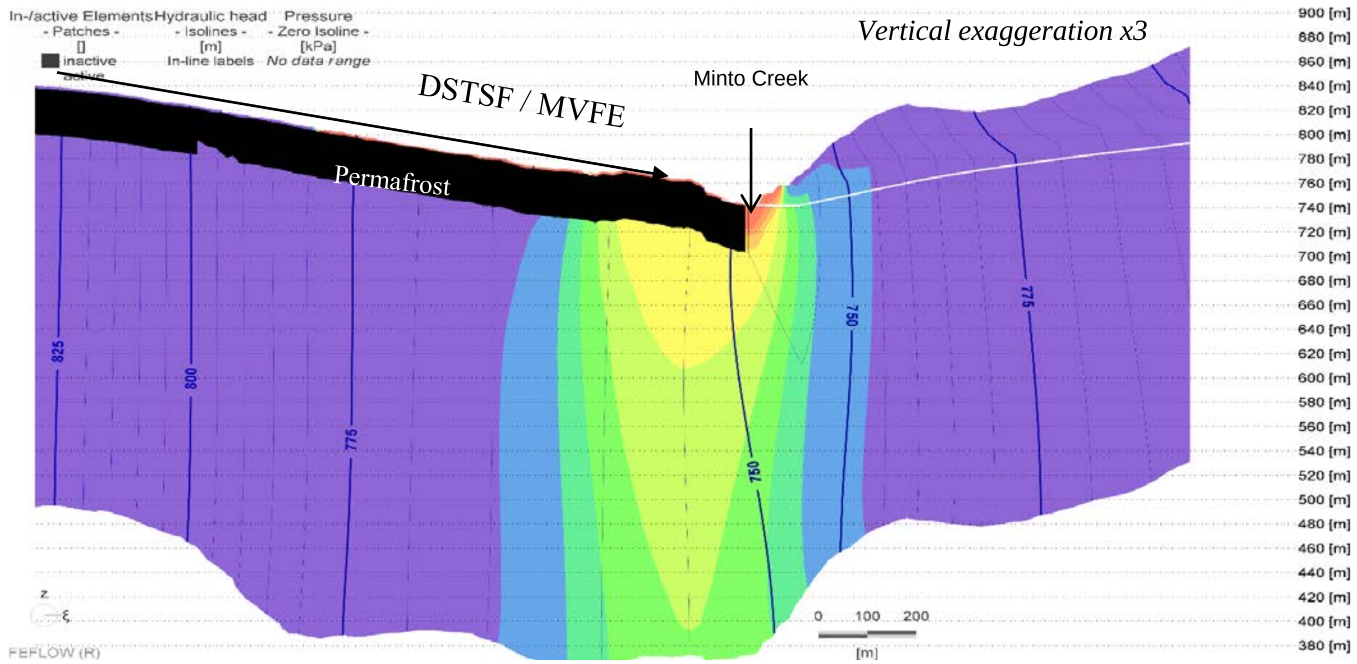
Average Travel Time

Job No: 1CM002.041
Filename: MintoUPD_rev7_CURRENT_TrsnsprtStdSt_[6b]_Adj_MintoN_K.dac

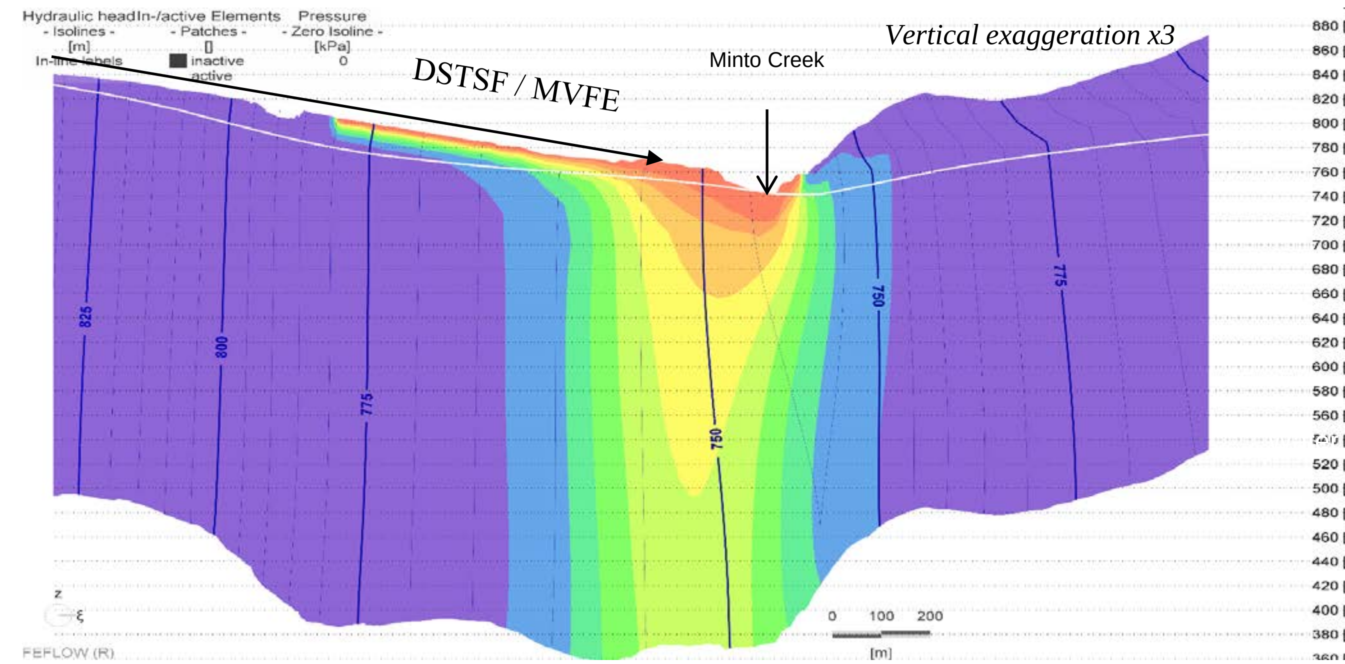
Minto Mine

Date: Oct. 2015
Approved: GF
Figure: 19

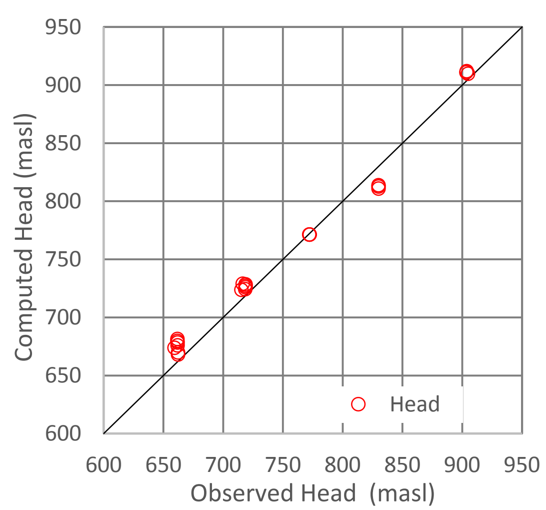
Detailed view of section EF in the DSTSF and MVFE areas; Scenario with permafrost



Detailed view of section EF in the DSTSF and MVFE areas; Scenario without permafrost



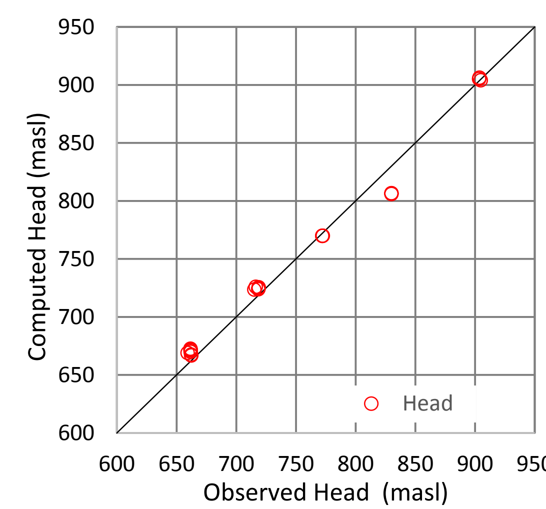
Calibration statistics for the scenario with permafrost



Mean Error (m)	4.9
Mean Absolute Error (m)	8.5
Root Mean Squared Error (m)	0.8
Normalized Root Mean Squared Error (%)	0.3%
Coefficient of Determination [R^2]	0.99

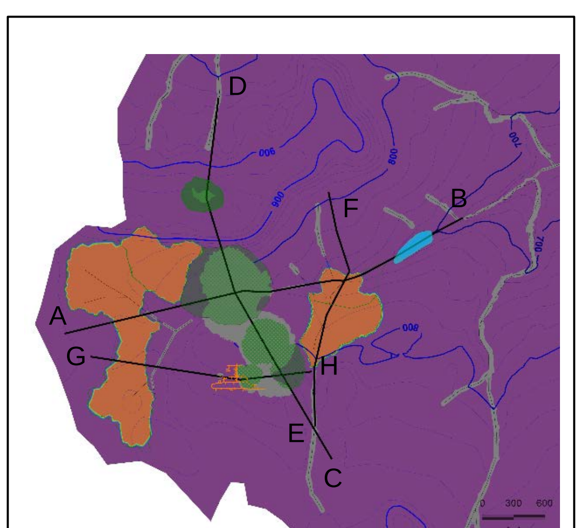
Catchment	Baseflow (L/s)	
	Estimated from monitoring results	model-calculated
McGinty Creek	-	2.4
Minto Creek	13 to 53	20.4
Yukon River	-	0.4
Main Pit + Area2 + lakes	-	2.2
Minto North Pit	-	0.0
Underground	3.5	1.0

Calibration statistics for the scenario without permafrost



Mean Error (m)	0.9
Mean Absolute Error (m)	8.3
Root Mean Squared Error (m)	2.3
Normalized Root Mean Squared Error (%)	0.9%
Coefficient of Determination [R^2]	0.99

Catchment	Baseflow (L/s)	
	Estimated from monitoring results	model-calculated
McGinty Creek	-	2.4
Minto Creek	13 to 53	20.9
Yukon River	-	0.4
Main Pit + Area2 + lakes	-	1.9
Minto North Pit	-	0.0
Underground	3.5	1.0



Sulphate Concentration (mg/L)

- 200 ... 225
- 175 ... 200
- 150 ... 175
- 125 ... 150
- 100 ... 125
- 75 ... 100
- 50 ... 75
- 25 ... 50
- 20 ... 25

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Model Sensitivity to Permafrost

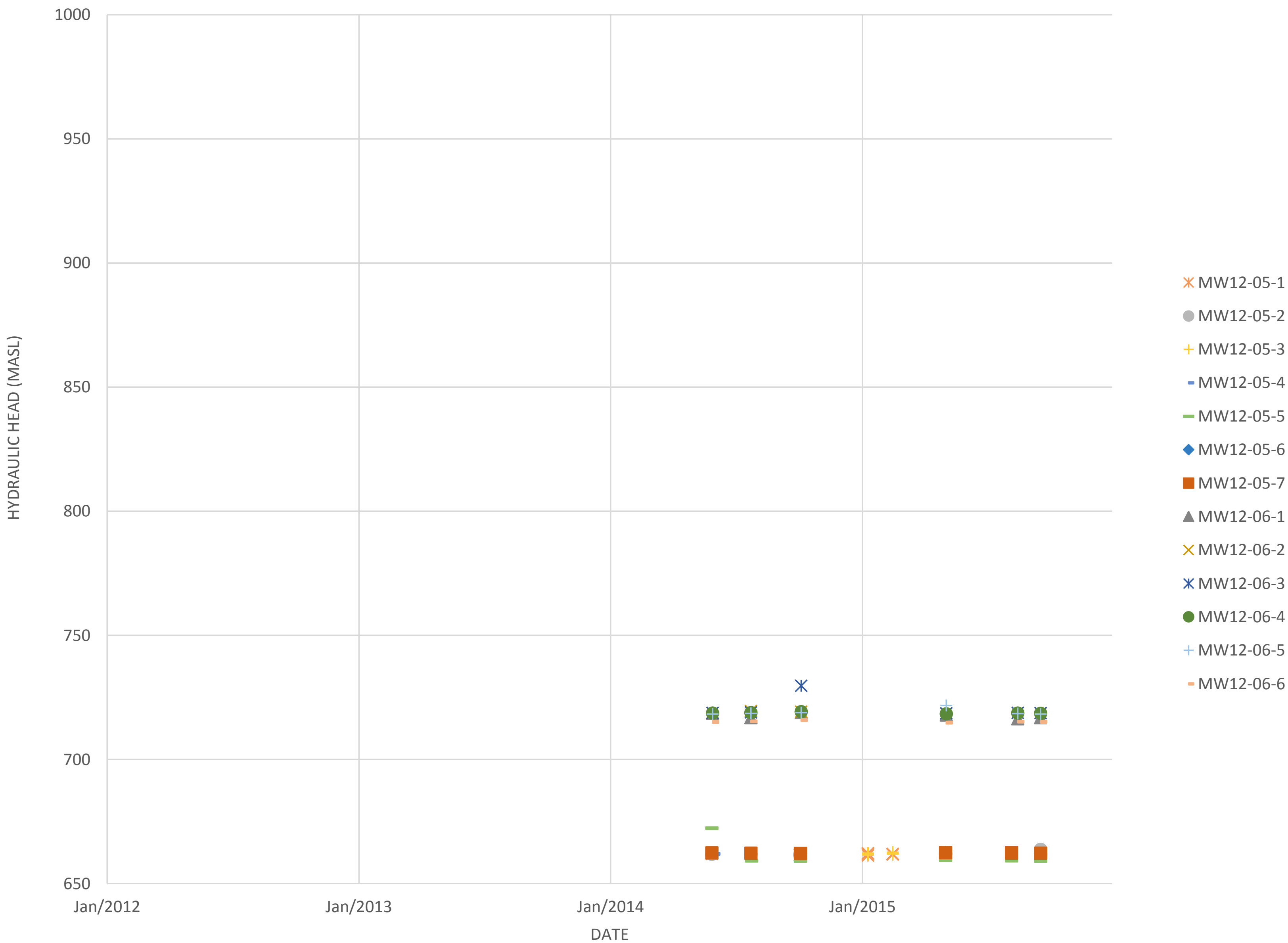
Job No: 1CM002.041
Filename: Prmf_Vs_NoPrmf.pptx

Minto Mine

Date: Oct. 2015 | Approved: GF | Figure: 20

Appendix A –Water Level Data

ID	Well	Zone	Location	Type	Depth (m)	Piezometer Location		
						Easting	Northing	Elevation
MW12-05-01	MW12-05	1	Downgradient of all mine workings	Westbay	132.5	387008.9	6945789.6	533.0
MW12-05-02	MW12-05	2	Downgradient of all mine workings	Westbay	109.7	387008.9	6945789.6	555.8
MW12-05-03	MW12-05	3	Downgradient of all mine workings	Westbay	94.4	387008.9	6945789.6	571.1
MW12-05-04	MW12-05	4	Downgradient of all mine workings	Westbay	68.5	387008.9	6945789.6	597.0
MW12-05-05	MW12-05	5	Downgradient of all mine workings	Westbay	51.7	387008.9	6945789.6	613.8
MW12-05-06	MW12-05	6	Downgradient of all mine workings	Westbay	25.6	387008.9	6945789.6	639.9
MW12-05-07	MW12-05	7	Downgradient of all mine workings	Westbay	14.9	387008.9	6945789.6	650.6
MW12-06-01	MW12-06	1	Downgradient of all mine workings	Westbay	142.3	386112.5	6945297.5	575.0
MW12-06-02	MW12-06	2	Downgradient of all mine workings	Westbay	122.5	386112.5	6945297.5	594.8
MW12-06-03	MW12-06	3	Downgradient of all mine workings	Westbay	92.6	386112.5	6945297.5	624.7
MW12-06-04	MW12-06	4	Downgradient of all mine workings	Westbay	66.1	386112.5	6945297.5	651.2
MW12-06-05	MW12-06	5	Downgradient of all mine workings	Westbay	35	386112.5	6945297.5	682.3
MW12-06-06	MW12-06	6	Downgradient of all mine workings	Westbay	18.2	386112.5	6945297.5	699.1
MW09-02-01	MW09-02	1	Downgradient of Dry Stack Tailings Storage Facility	Westbay	48.8	385676.1	6945034.5	708.7
MW09-02-02	MW09-02	2	Downgradient of Dry Stack Tailings Storage Facility	Westbay	53.3	385676.1	6945034.5	704.2
MW12-DP4-SP	MW12-DP4	SP	Downgradient of seepage collection pond in overburden	Drivepoint	3	385865.0	6945220.0	757.0
MW11-01A-sp	MW11-01A	Sp	Downgradient of Main Pit	Standpipe		385070.0	6944990.0	
MW12-07-01	MW12-07	1	Downgradient of Main Pit	Westbay	115.2	385136.9	6945043.3	668.5
MW12-07-02	MW12-07	2	Downgradient of Main Pit	Westbay	87.5	385136.9	6945043.3	696.2
MW12-07-03	MW12-07	3	Downgradient of Main Pit	Westbay	66.3	385136.9	6945043.3	717.4
MW09-01-01	MW09-01	1	Main Waste Dump area	Westbay	44.2	384177.3	6944983.9	813.4
MW09-01-02	MW09-01	2	Main Waste Dump area	Westbay	33.5	384177.3	6944983.9	824.1
MW09-01-03	MW09-01	3	Main Waste Dump area	Westbay	25.9	384177.3	6944983.9	831.7
MW11-02-SP	MW11-02	SP	NE of proposed Ridgetop North Pit	Standpipe	30.79	385120.0	6943870.0	830.9
MW11-03-SP	MW11-03	SP	SE of proposed Ridgetop North Pit	Standpipe	30.79	385160.0	6943730.0	836.4
MW11-04A-SP	MW11-04A	SP	S of proposed Ridgetop South Pit	Standpipe	31	385110.0	6943370.0	856.7
MW12-DP1-SP	MW12-DP1	SP	Downgradient of SW dump in overburden	Drivepoint	3	383841.0	6943911.0	877.0
MW12-DP2-SP	MW12-DP2	SP	Downgradient of SW dump in overburden	Drivepoint	3	383796.0	6944142.0	875.3
MW12-DP3-SP	MW12-DP3	SP	Downgradient of SW dump in overburden	Drivepoint	3	384024.0	6944614.0	857.0
MW09-03-01	MW09-03	1	Downgradient of Minto North Pit	Westbay	38.1	384253.3	6946158.5	870.2
MW09-03-02	MW09-03	2	Downgradient of Minto North Pit	Westbay	24.4	384253.3	6946158.5	883.9
MW09-03-03	MW09-03	3	Downgradient of Minto North Pit	Westbay	10.7	384253.3	6946158.5	897.6



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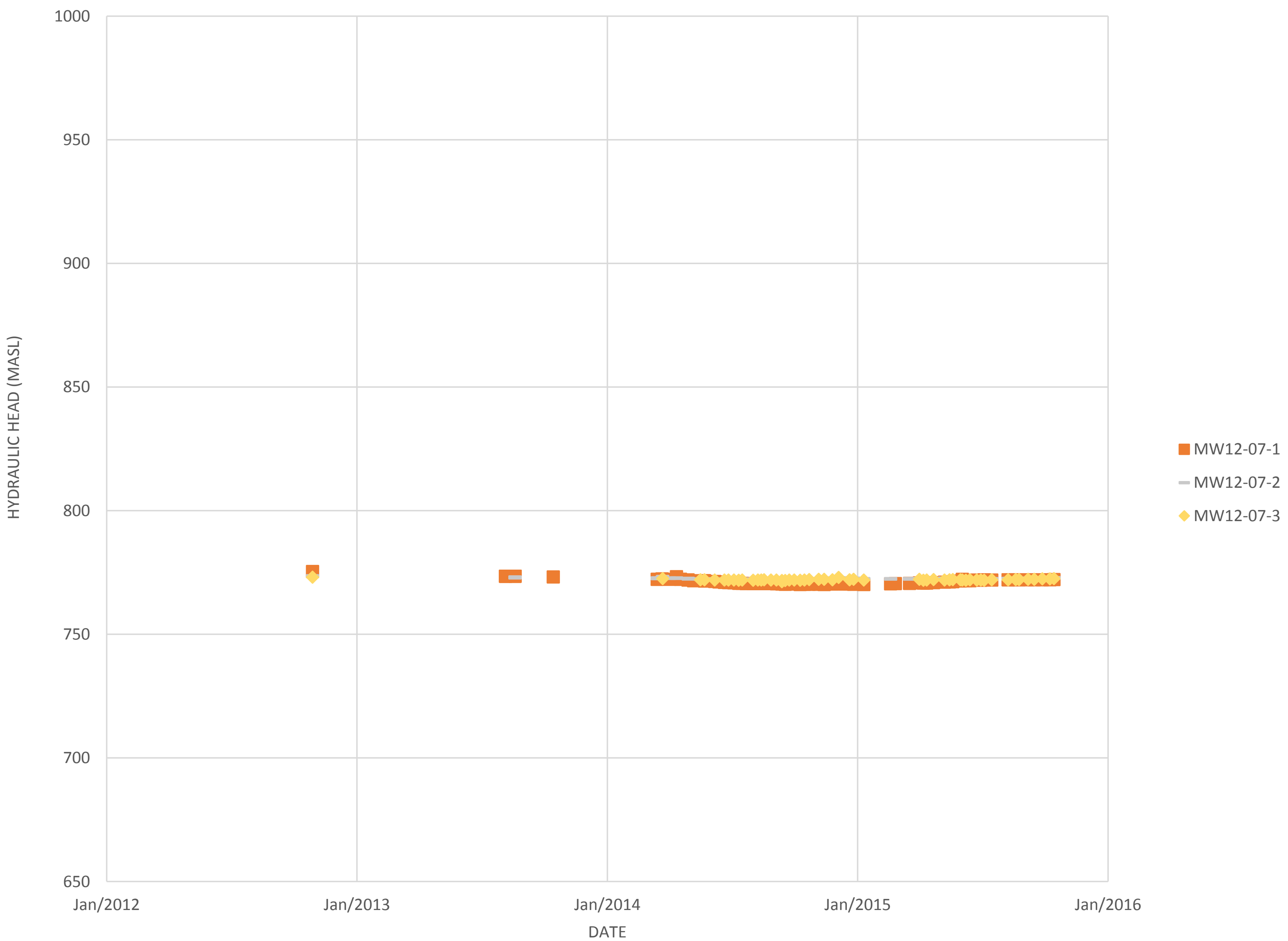
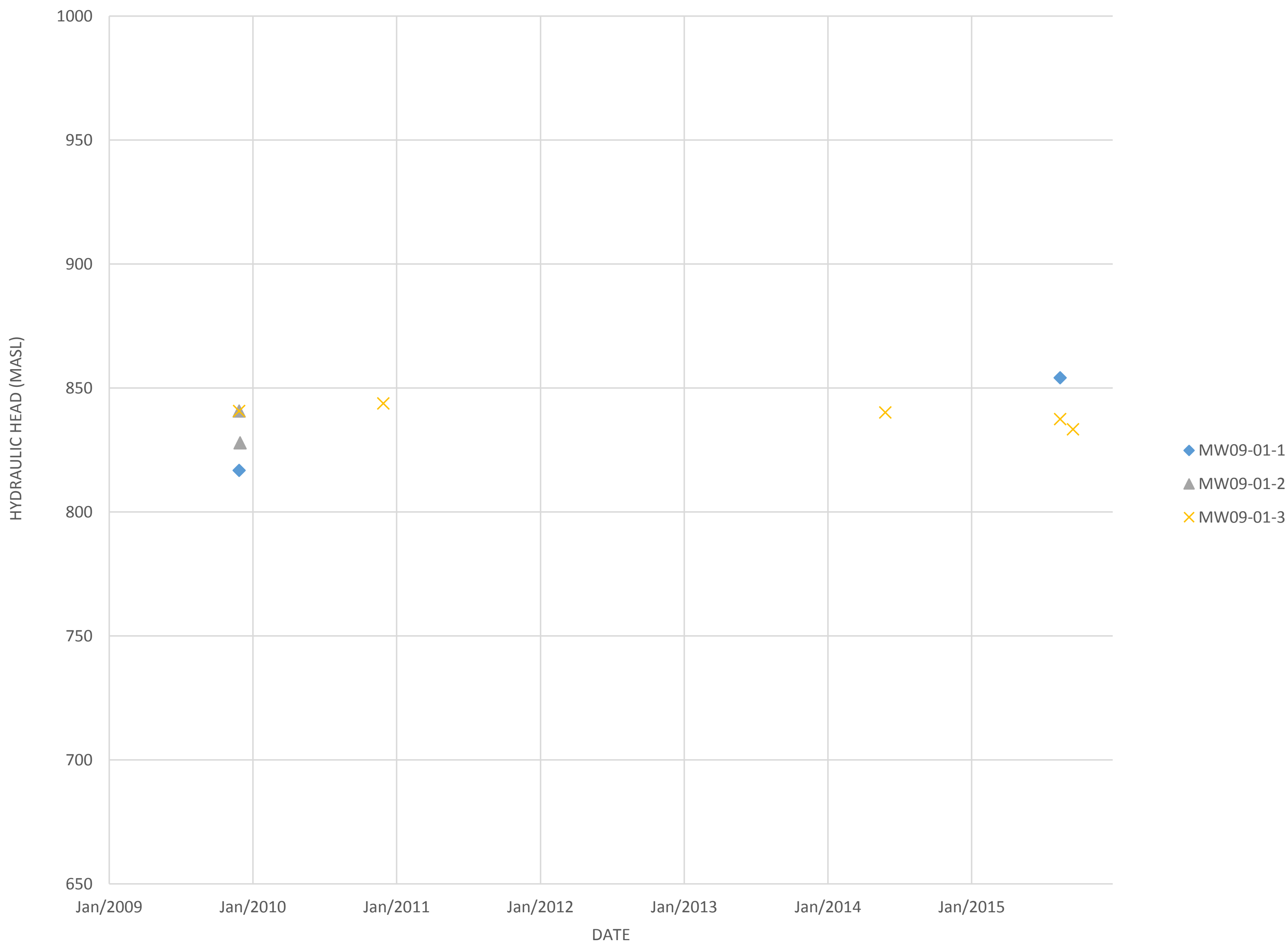
Job No: 1CM002.041 Filename: Minto_2015_Hydro_Database_1CM002.041_rev04_df	Minto Mine	2015 Groundwater Model Update **Water Level Data** Date: Nov 2015 · Approved: DCM · Figure: **A-1**

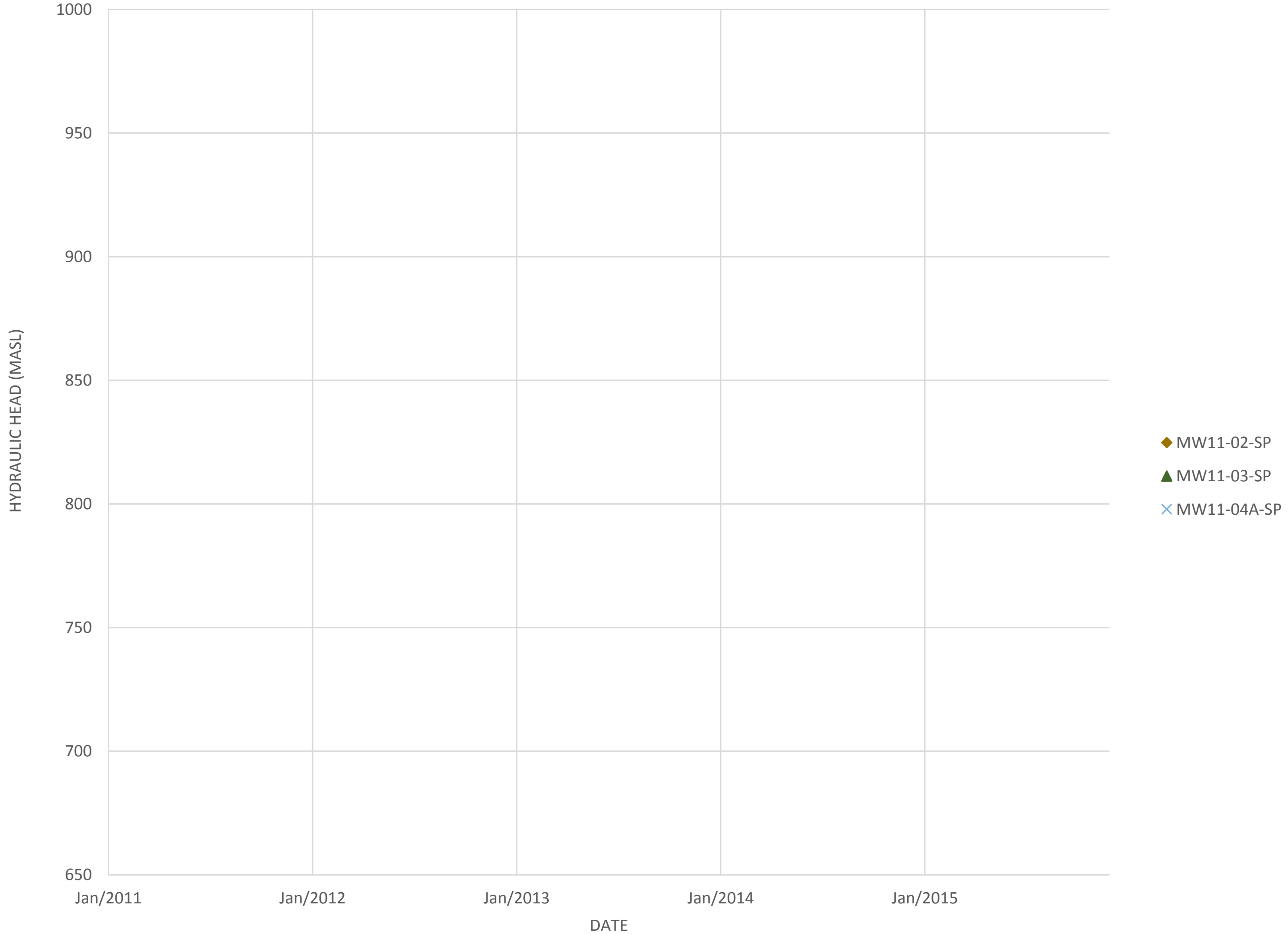
srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	2015 Groundwater Model Update
		Water Level Data
Job No: 1CM002.041 Filename: Minto_2015_Hydro_Database_1CM002.041_rev04_df	Minto Mine	Date: Nov 2015 / Approved: DCM / Figure: **A-2**



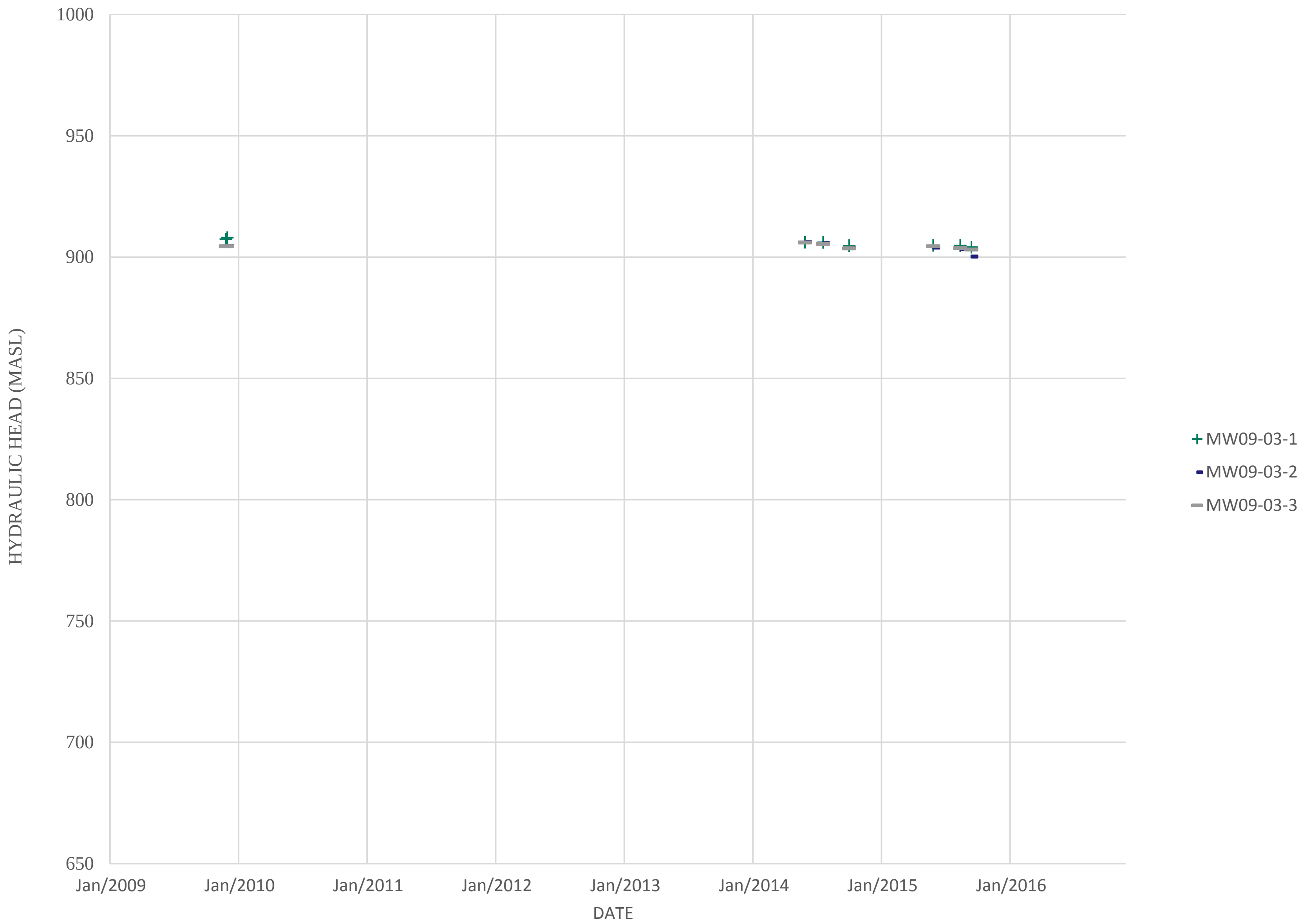
srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	2015 Groundwater Model Update		
		Water Level Data		
Job No: 1CM002.041 Filename: Minto_2015_Hydro_Database_1CM002.041_rev04_df	Minto Mine	Date: Nov 2015	Approved: DCM	Figure: **A-3**



srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	2015 Groundwater Model Update
		Water Level Data
Job No: 1CM002.041 Filename: Minto_2015_Hydro_Database_1CM002.041_rev04_df	Minto Mine	Date: Nov 2015 / Approved: DCM / Figure: **A-4**



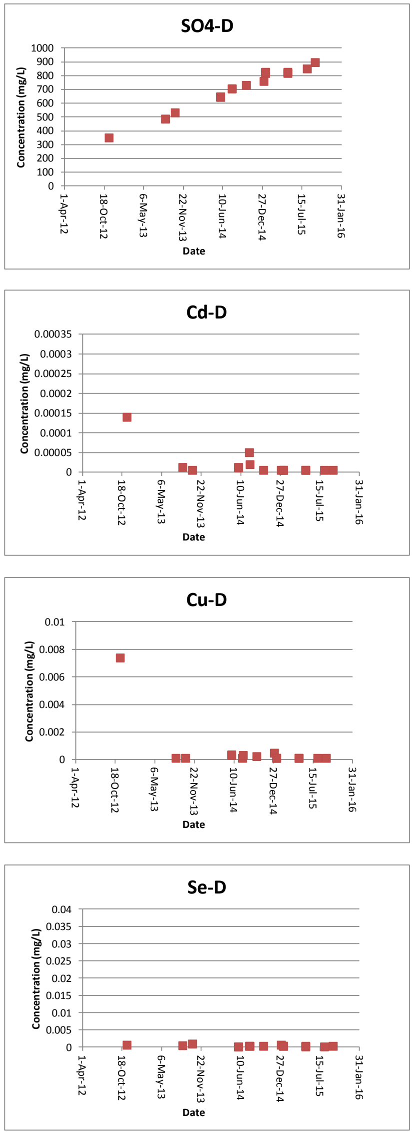
srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	2015 Groundwater Model Update
		Water Level Data
Job No: 1CM002.041 Filename: Minto_2015_Hydro_Database_1CM002.041_rev04_df	Minto Mine	Date: Nov 2015 / Approved: DCM / Figure: **A-5**



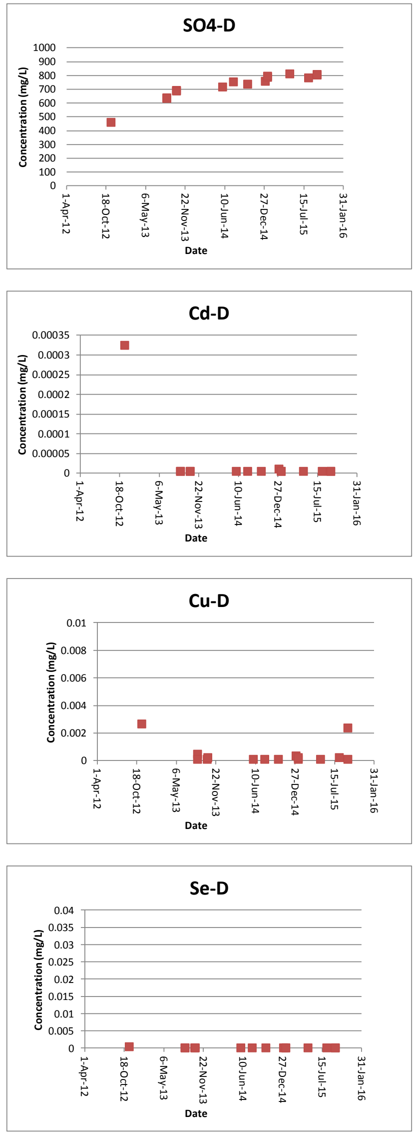
srk consulting	capstone MINTO MINE OPERATED BY MINTO EXPLORATIONS LTD.	2015 Groundwater Model Update **Water Level Data**
Job No: 1CM002.041 Filename: Minto_2015_Hydro_Database_1CM002.041_rev04_df	Minto Mine	Date: Nov 2015 · Approved: DCM · Figure: **A-6**

Appendix B – Groundwater Quality Data

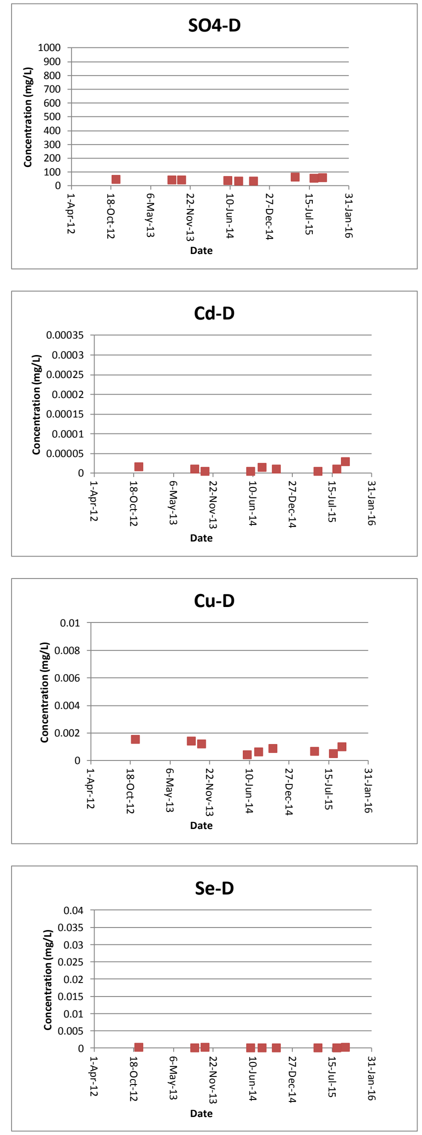
Zone 1 (Depth 132.5 mbgs)



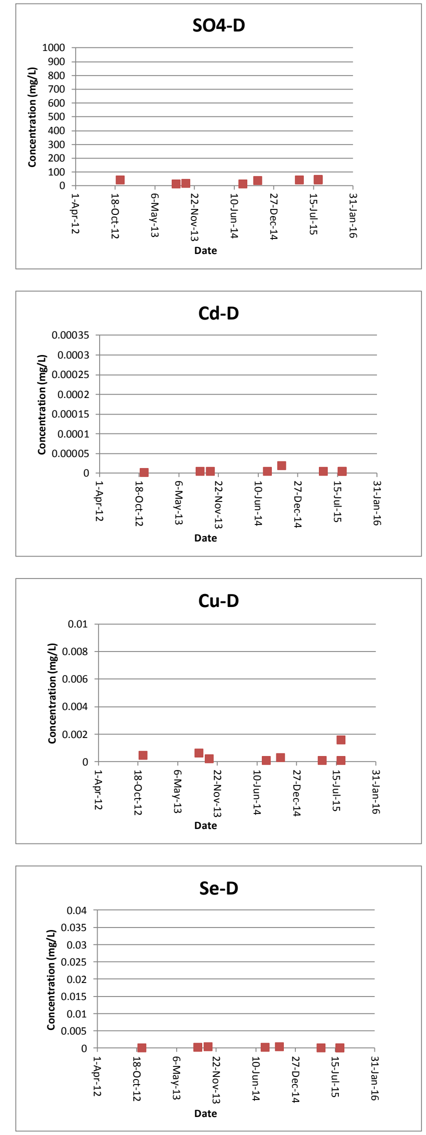
Zone 3 (Depth 94.4 mbgs)



Zone 5 (Depth 51.7 mbgs)



Zone 7 (Depth 14.9 mbgs)



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2015 Groundwater Model Update

MW12-05

Job No: 1CM002.041
Filename: WQ_Check_W16_W2_W12_REV04_df

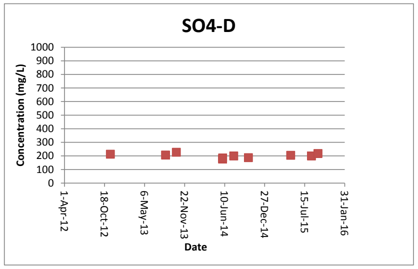
Minto Mine

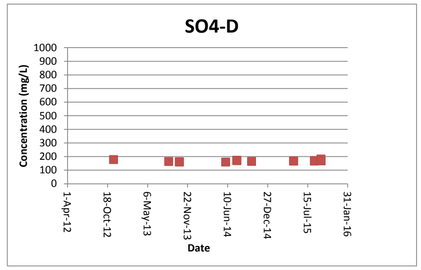
Date:	Approved:	Figure:
Nov 2015	DCM	**B-1**

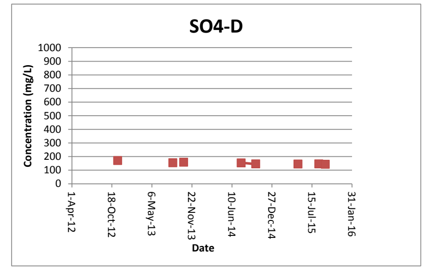
Zone 2 (Depth 122.5 mbgs)

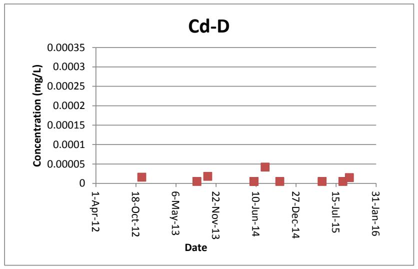
Zone 4 (Depth 66.1 mbgs)

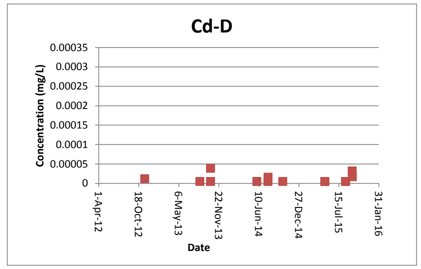
Zone 6 (Depth 18.2 mbgs)

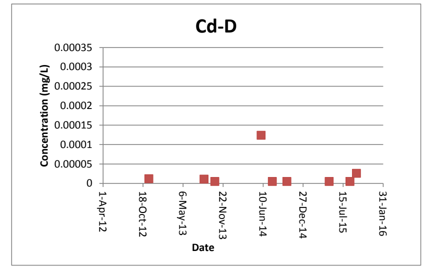


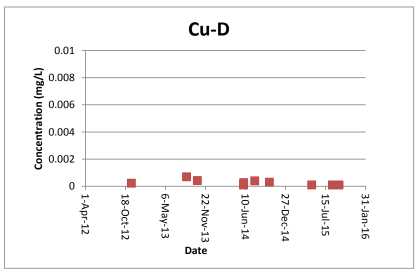


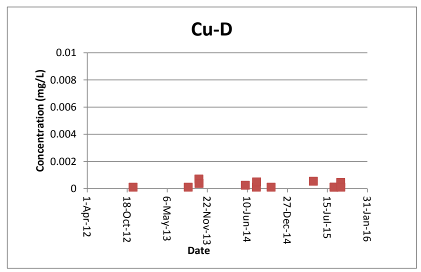


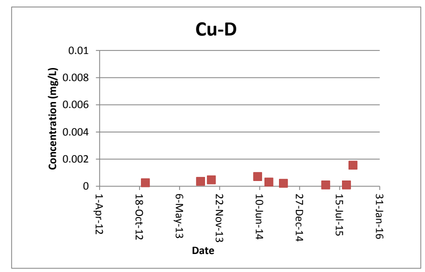


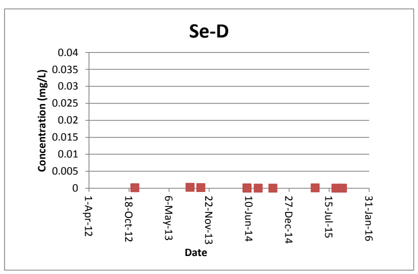


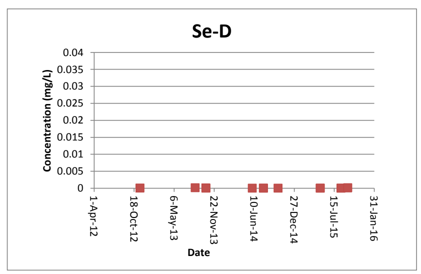


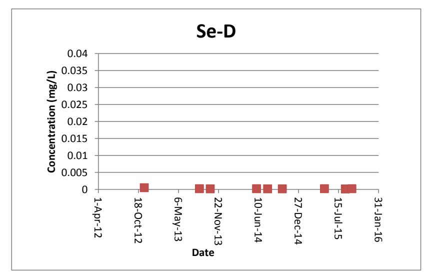












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2015 Groundwater Model Update

MW12-06

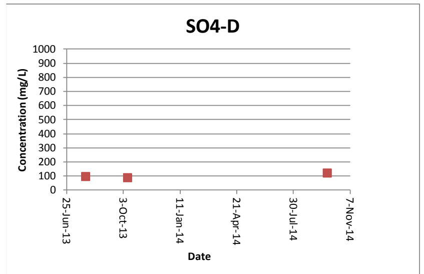
Job No: 1CM002.041
Filename: WQ_Check_W16_W2_W12_REV04_df

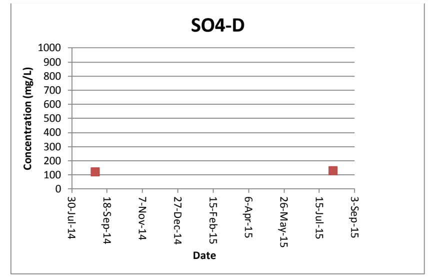
Minto Mine

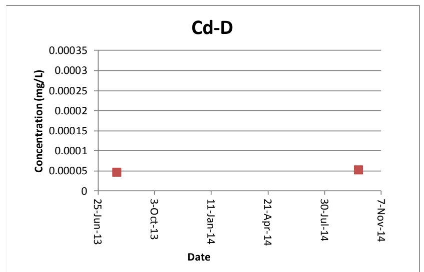
Date: Nov 2015 | Approved: DCM | Figure: **B-2**

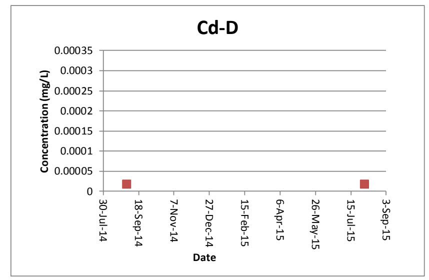
MW12-DP4
(Depth 3 mbgs)

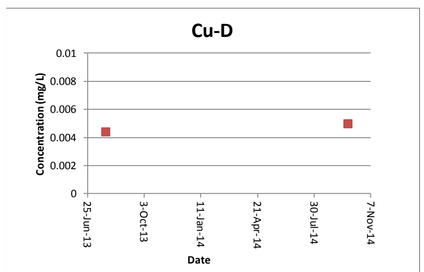
MW13-DP5
(Depth – mbgs)

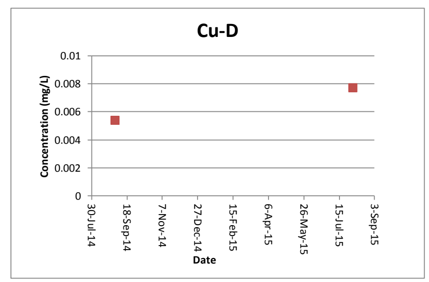


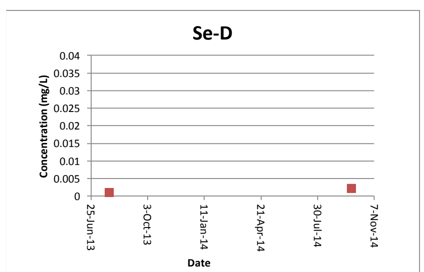


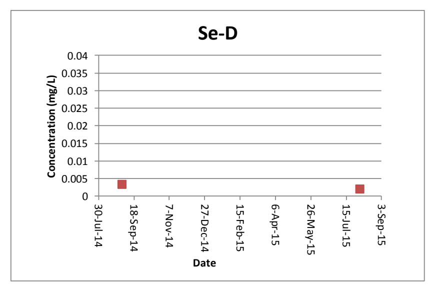












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2015 Groundwater Model Update

MW12-DP4, MW13-DP5

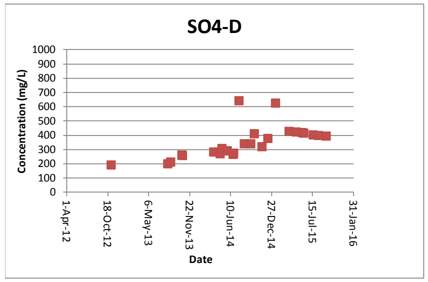
Job No: 1CM002.041
Filename: WQ_Check_W16_W2_W12_REV04_df

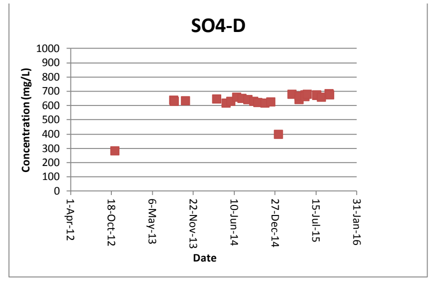
Minto Mine

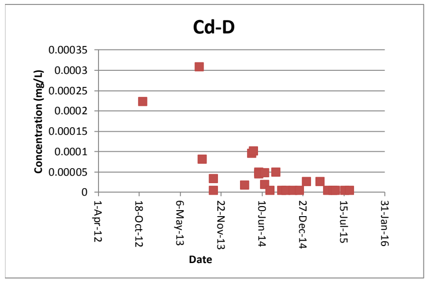
Date: Nov 2015
Approved: DCM
Figure: **B-3**

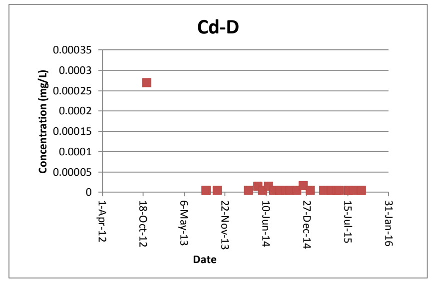
Zone 1 (Depth 115.2 mbgs)

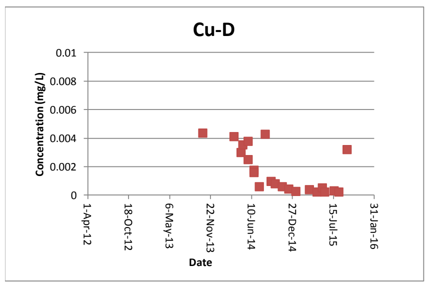
Zone 2 (Depth 87.5 mbgs)

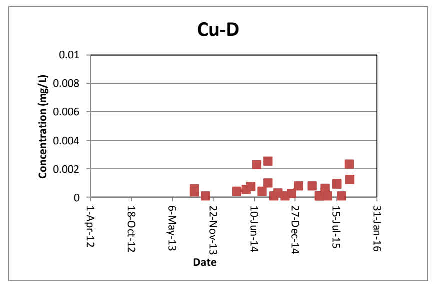


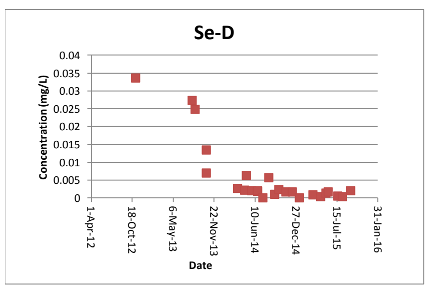


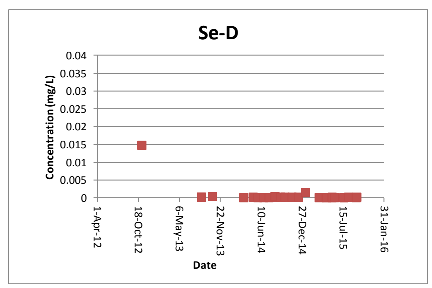












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2015 Groundwater Model Update

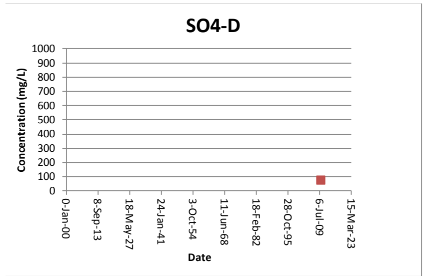
MW12-07

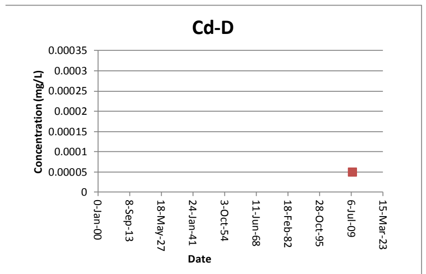
Job No: 1CM002.041
Filename: WQ_Check_W16_W2_W12_REV04_df

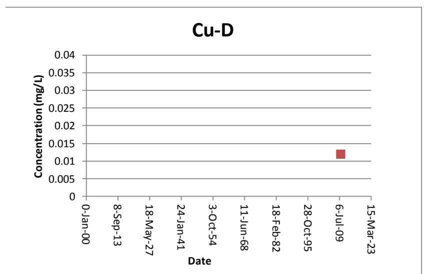
Minto Mine

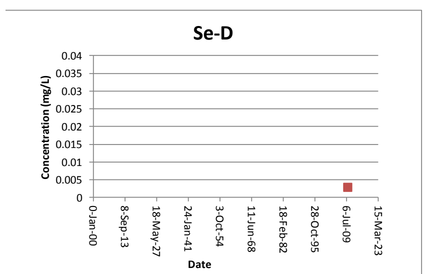
Date: Nov 2015
Approved: DCM
Figure: **B-4**

Zone 2 (Depth 33.5 mbgs)

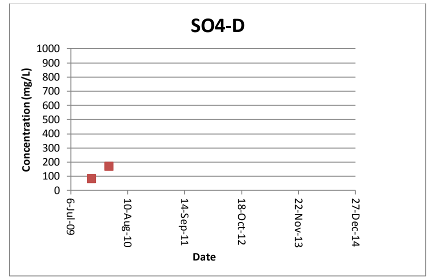


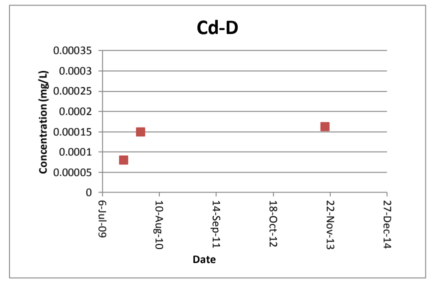


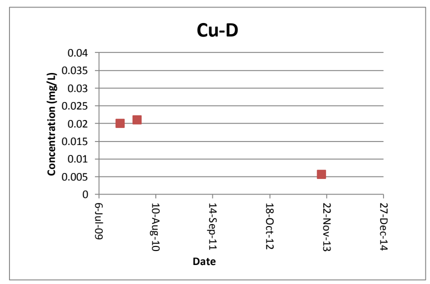


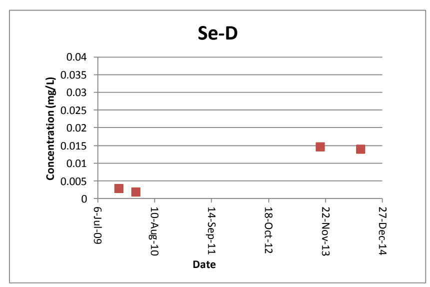


Zone 3 (Depth 25.9 mbgs)









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2015 Groundwater Model Update

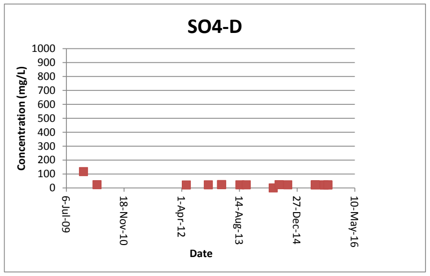
MW09-01

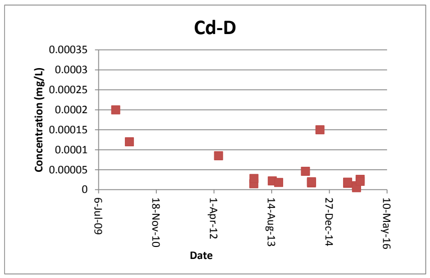
Job No: 1CM002.041
Filename: WQ_Check_W16_W2_W12_REV04_df

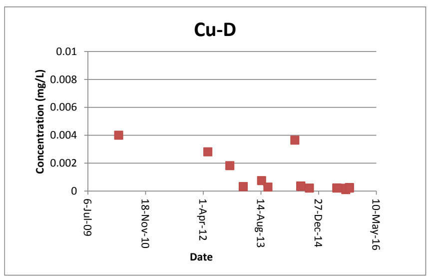
Minto Mine

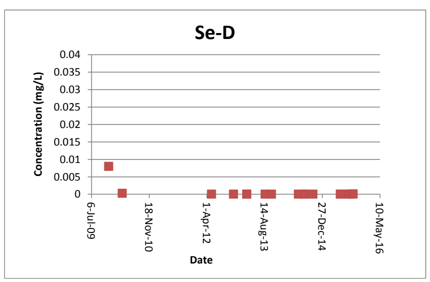
Date: Nov 2015
Approved: DCM
Figure: **B-5**

Zone 1 (Depth 38.1 mbgs)

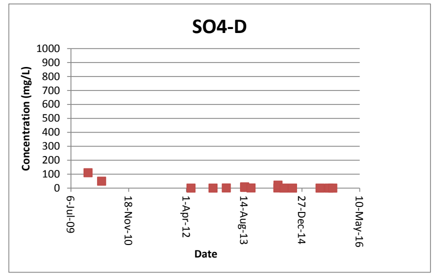


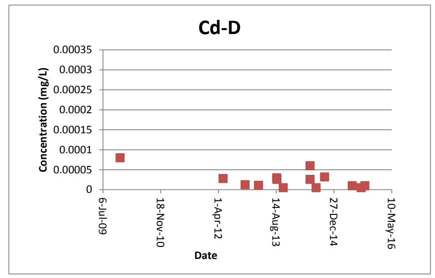


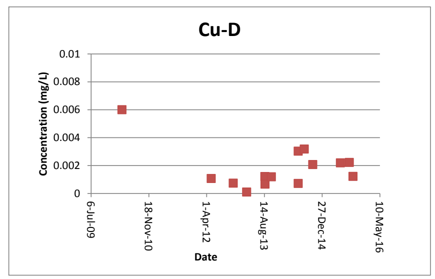


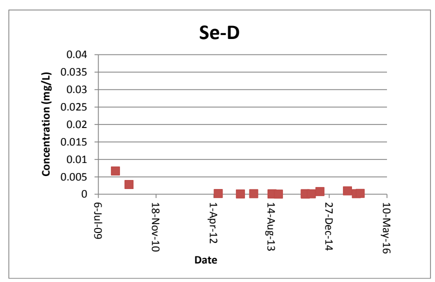


Zone 2 (Depth 24.4 mbgs)

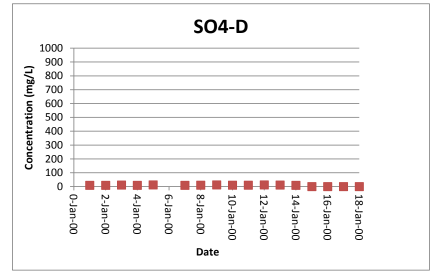


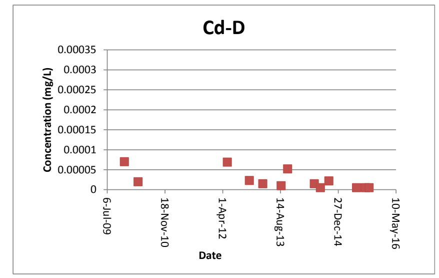


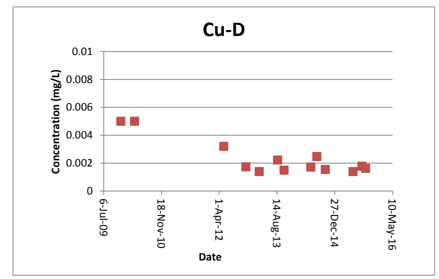


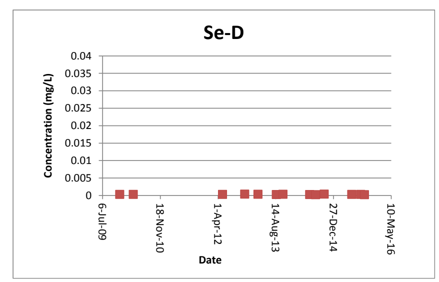


Zone 3 (Depth 10.7 mbgs)









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2015 Groundwater Model Update

MW09-03

Job No: 1CM002.041

Filename: WQ_Check_W16_W2_W12_REV04_df

Minto Mine

Date: Nov 2015

Approved: DCM

Figure: **B-6**