GOLDCORP

Coffee Gold Mine

YESAB Project Proposal

Appendix 7-B Groundwater Intermediate Component Analysis Report

VOLUME II

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File: A362-5

Ver. 1.0

March 2017

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ACRONYMS AND ABBREVIATIONS, SYMBOLS, AND UNITS OF MEASURE

Acronym / Abbreviation Symbol / Unit of Measure	Definition
µg/L	micrograms per litre, unit of concentration
µS/cm	micro-Siemens per centimeter, unit of specific conductance
As	arsenic
Al	aluminum
ºC	degrees Celsius
Ca	calcium
CCME	Canadian Council of Ministers of the Environment
CCSA	Cumulative changes study area
Cd	cadmium
CEA	Canadian Environmental Assessment Act
Co	cobalt
CO_2	carbon dioxide
Cu	copper
DC	direct circulation
DDH	diamond drill hole
DO	dissolved oxygen
EBA TT	EBA Tetra Tech (now Tetra Tech Canada)
EP	Event Pond
Fe	iron
GCL	geosynthetic clay liner
HCO_3^-	bicarbonate
HDPE	High density polyethylene
Hg	mercury
HLF	heap leach facility
HQ	diamond drill tooling producing hole diameter of 96 mm or 3.78 inches
HWT	drill casing of 114.3 mm or 4.5-inch outer diameter
IC	Intermediate component
ICP/MS	inductively coupled plasma / mass spectrometry
IP	inertial pump
IPCC	Intergovernmental Panel on Climate Change
K	hydraulic conductivity
K	potassium
km	kilometre
KP	Knight Piésold
LSA	Local Study Area

Acronym / Abbreviation Symbol / Unit of Measure	Definition
L/s	Litres per second
L/s/km^2	litres per second per square kilometre
m	metre
m AH	metres along hole
m asl	metres above sea level
m bgs	metres below ground surface
m bTOC	metres below top of casing
MAP	mean annual precipitation
m/s	metres per second, unit of hydraulic conductivity
MDL	method detection limit
Mg	magnesium
mg/L	milligram per litre, unit of concentration
mm	millimetre
mm/yr	millimetres per year
Mn	manganese
Mt	megatonne
N	North
Na	sodium
NAR	Northern Access Route
NH3	ammonia
Ni	nickel
NO_3^-	nitrate
NQ2	diamond drill tooling producing hole diameter of 75.8 mm or 2.98 inches
NRMSE	normalized root mean squared error
O_2	oxygen
^oC	degrees Celsius
ORP	oxidation-reduction potential
Pb	lead
PMP	Probable Maximum Precipitation
POC	parameter of concern
PQ	diamond drill tooling producing diameter of 122.6 mm or 4.83 inches
the Project	the Coffee Gold Project
RC	reverse circulation
RQD	rock quality designation
RSA	Regional Study Area
S	South

Acronym / Abbreviation Symbol / Unit of Measure	Definition
S^{2-}	sulphide
Sb	antimony
Se	selenium
SNAP	Scenarios Network for Alaska and Arctic Planning
SO_4^{2-}	sulphate
SRES	Special Report on Emissions Scenarios
SU1	Supremo Phase 1 Pit
SU2	Supremo Phase 2 Pit
SU3N	Supremo Phase 3 North Pit
SU3W	Supremo Phase 3 West Pit
SU4N	Supremo Phase 4 North Pit
SU4S	Supremo Phase 4 South Pit
SU5N	Supremo Phase 5 North Pit
SU5S	Supremo Phase 5 South Pit
SZ	shear zone
T	Thermistor (typically coinstalled with vibrating wire piezometer)
TSS	total suspended solids
U	uranium
UTM NAD83	Universal Transverse Mercator projection, North American Datum 1983
v m bgs	vertical metres below ground surface
VC	Valued Component
VWP	vibrating wire piezometer
WAD-CN	weak acid dissociable cyanide
WB	Westbay, (Suffix P-#) indicates port number
WRSF	waste rock storage facility
YESAA	Yukon Environmental and Socio-economic Act
YESAB	Yukon Environmental and Socio-economic Assessment Board
Zn	zinc

1.0 INTRODUCTION

This report, prepared on behalf of Kaminak Gold Corporation (Kaminak or Proponent), presents an analysis of potential changes on groundwater hydrogeology resulting from activities associated with the proposed Coffee Gold Mine (Project). The Project located in west-central Yukon, approximately 130 kilometres (km) south of Dawson City and is scoped as an open pit gold mine using a cyanide heap leach process to extract gold from the ore. The groundwater analysis herein pertains to the Construction, Operation, Closure and Post-Closure phases of the Project.

The location and general arrangement of facilities associated with the Project are shown in **Figure 1.1-1**. The Project comprises the Latte, Double Double, Supremo and Kona Pits which are planned to be mined by conventional, open-pit shovel and truck methods. Most waste rock from the open pits is planned to be deposited in the Alpha waste rock storage facility (WRSF), the exception being waste rock from the Kona Pit, which will be temporarily stored in the Beta WRSF and later backfilled into the pit shell. Some waste rock will be backfilled into mined out pits of Latte, Supremo and Double Double in order to create causeways and to minimize the WRSF footprint.

The Proponent has retained Lorax Environmental Services Ltd. to undertake an analysis of the Groundwater Intermediate Component (IC) for the Coffee Project. The information provided in this analysis report supports the Project Proposal to be submitted to the Yukon Environmental and Socio-economic Assessment Board (YESAB) Executive Committee for screening under the *Yukon Environmental and Socio-Economic Assessment Act* (YESAA), and applications to be submitted for a Quartz Mining Licence and a Type A Water Licence from the Yukon Water Board, among other permits and licences.

The Yukon Environmental and Socio-economic Assessment Board defines Valued Environmental and Socio-economic Components (VCs) as elements of the environmental and/or socio-economic systems valued for environmental, scientific, social, aesthetic, or cultural reasons. An IC is defined as a component in an intermediate position along a pathway of effects leading to one or more receptors or VCs. This report provides an analysis of potential Project-related changes and cumulative changes to the Groundwater IC. The assessment is structured much the same as a VC assessment, except an IC analysis does not include a determination of significance – significance is determined for the assessment of the receptor VC.

Groundwater is a key component of the hydrologic system, biophysical environment, and operational water balance for the Project. Recharge to the groundwater systems occurs when the amount of precipitation that infiltrates soil exceeds losses from evapotranspiration. Prime recharge areas typically occur in upland areas while discharge typically occurs in low-lying areas where groundwater flow paths converge, supplying baseflow to creeks, rivers and lakes. Changes to ground cover and runoff patterns influence recharge to the groundwater system. Likewise, changes in groundwater discharge areas can impact terrain stability. Groundwater carries the signature of minerals and chemicals it encounters along its flowpath and, as such, is a vector for transporting chemical loads from the Project to the receiving environment. Groundwater has the potential to interact with aquatic and riparian ecosystems and may therefore directly influence surface water quantity and quality and may indirectly influence the Fish and Fish Habitat VC. Fish serves as an important food sources to local First Nations, and as such provides a link between groundwater and Land and Resource Use, Community Health and Wellbeing, and Social Economy. As the Project has the potential to affect both groundwater quality and quantity, the following assessment is provided:

- **Section 1** presents the scope of the analysis and the rationale for the selection of the Groundwater IC, discusses indicators through which the IC will be assessed and introduces the spatial and temporal boundaries for the assessment.
- **Section 2** identifies any IC-specific analysis methods that differ from the methods set out in **Section 5.0 Assessment Methodology** of the Project Proposal. This section summarizes the groundwater modeling that underpins the IC assessment and informs the Water Balance Model and Water Quality Model (described in **Appendix 12-C**).
- **Section 3** summarizes the baseline hydrogeological conditions within the local and regional study areas (LSA and RSA) (see also **Appendix 7-A**).
- Future conditions and changes resulting from the Project are assessed in **Sections 4** through **7**.
    - **Section 4** identifies and explores potential interactions between Project components, Project-related activities and groundwater through a screening process. Furthermore, Section 4 proposes and evaluates mitigation measures that reduce or avoid the changes to groundwater as a result of Project-related activities.
    - **Section 5** assesses potential cumulative changes on groundwater from the Project in combination with past, present, and reasonably foreseeable future projects located within the LSA and RSA.
    - **Section 6** provides a summary discussion of future conditions and changes associated with the Project.
- **Section 7** outlines the monitoring programs that will be implemented to verify predicted changes and effectiveness of proposed mitigation measures for the IC. Further, this section describes the adaptive management strategies that will be in place to address changes falling outside the range of prediction presented in this application.

COFFEE PROJECT

Location Map, General Arrangement for the Coffee Project

Legend

- Municipality
- Highway
- Project Footprint

N

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0 5 10 15

Kilometres

NAD 1983 UTM Zone 8N

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Figure 1.1-1	Date: Mar 17, 2017	Drawn by: G.M.	Reviewed: J.S./L.F.

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1.1 ISSUES SCOPING

This section of the analysis describes the IC selection process and builds a rationale for including groundwater as an IC within the Project Proposal. This section of the report also presents the information sources and inputs considered in the selection process (e.g., Traditional Knowledge, regulation of water resources) and discusses potential Project-related changes in the context of groundwater quantity and quality and mining projects.

The indicators that will be used to evaluate potential adverse changes, guide the selection of mitigation measures and characterize the potential residual changes to the Groundwater IC are presented in the following sections. Finally, the spatial and temporal boundaries of the Groundwater IC change analysis are outlined, along with a justification for their selection.

The Proponent has undertaken an engagement and consultation process, as defined under section 50 (3) of YESAA, to support the scoping of issues for the Project (refer to **Sections 3.0** through **3.6** for detail on the consultation program). The Proponent continues to consult and engage with affected First Nations and communities, government agencies, and interested persons and/or other stakeholders who may be interested in the Project and its related activities. This consultation and engagement process has included technical working groups established with First Nations, government departments, community meetings, one-on-one and small group meetings, and ongoing communications such as print communication, newsletter, and website updates, including specific presentations and discussions regarding key themes of interest and exploration of candidate VCs to represent the themes.

Key themes of interest identified through the consultation process include temporary closure of the Project, effects on wildlife, economic opportunities, the access route, heap leach operation and cyanide, and water quality and effects to fish.

Groundwater may ultimately discharge to surface water receptors and as such, is intimately linked to surface water quantity and quality. Groundwater presents a pathway for Project effects to be realized in the receiving environment. Some local First Nations have raised concern regarding the potential for contamination of surrounding waterways (Bates and de Roy 2014); identification and quantification of the linkages between groundwater and surrounding waterways is a key focus of this assessment.

1.2 SELECTION OF THE GROUNDWATER IC

The proposed ICs and VCs that were selected for assessment for the Project are summarized in **Section 5 Assessment Methodology** for Project Proposal. The selection process followed the guidelines set up in **Section 5.1.2**, and ultimately determined that groundwater would be most effectively assessed as an IC. This analysis considers two groundwater subcomponents (quantity and quality), whereby changes to the subcomponents are evaluated using indicators that are relevant, practical, measurable, responsive, accurate, and predictable.

As summarized in **Table 5.1-1** in **Section 5.0**, groundwater is linked to four physical environment and biophysical environment VCs identified for this Project – Surficial Geology, Terrain and Soils; Surface Water Quality; and Fish and Fish Habitat. Groundwater also informs and is informed by the physical environment IC – Surface Hydrology. Groundwater is also linked to three human environment VCs (Social Economy, Land and Resource Use, Community Health and Well-being). In this regard, the evaluation of potential Project induced changes to groundwater forms an integral component of several other effects assessments evaluated under this Project Proposal.

1.2.1 CANDIDATE AND SELECTED ICS

This analysis considered and selected two candidate subcomponents for the Groundwater IC: groundwater quantity and groundwater quality. Groundwater quantity refers to the distribution of groundwater and related volumetric fluxes; groundwater quality refers to its chemical composition. Groundwater and its linked components (surface water, fish, etc.) are regulated by several pieces of legislation, including Final Agreements that Yukon First Nations have with the federal and territorial governments, which guarantee protection of water on Settlement Lands, and use of water in Yukon for trapping, non-commercial harvesting, and traditional heritage, cultural, and spiritual purposes.

Various Project activities are expected to alter the groundwater system. For instance, excavation of open pits below the water table necessitates water handling requirements, sometimes resulting in transfer of groundwater from one catchment to another. Mine development exposes bedrock to atmosphere and precipitation which may result in the oxidation and/or leaching of minerals into surface and groundwater flowpaths. Chemicals used for operating machinery, blasting of rock, and leaching gold during the processing circuit have the potential to enter the groundwater system if not managed properly. Mined out pits coincide with groundwater recharge areas along ridgetops. Open pits will invariably accumulate surface water and may thereby provide enhanced recharge to groundwater systems. These processes may be inhibited by permafrost, which has been shown to be extensive in some areas of the Project footprint (**Appendix 11-A - Surficial Geology, Permafrost, and Terrain Stability**). Disturbed materials may also be subject to enhanced infiltration if not specifically designed to limit the ingress of precipitation and/or runoff. These Project-induced changes may result in modified groundwater quantity and quality that may in turn influence surface water receptors. Therefore, groundwater directly impacts the Surface Hydrology IC (**Appendix 8-B**) and the Surface Water Quality VC (**Appendix 12-B**), and by extension, the Fish and Fish Habitat VC (**Appendix 14-B**). In addition, Surface Hydrology and Surface Water Quality inform the Groundwater IC, specifically in losing reaches of creeks and streams.

The Groundwater IC is linked to the Surficial Geology, Terrain and Soils VC (**Appendix 11-B**). Activities such as excavation and ponding of surficial water in pits, placement of waste rock and disturbance of surficial materials alters the ground thermal regime. This can lead to degradation (or aggradation) of permafrost underlying these disturbed areas, which can impact groundwater recharge and discharge rates and distribution.

Consultation with First Nations has revealed that the Coffee Creek area hosts an important fishery (e.g., Bates and DeRoy 2014, Tr'ondëk Hwëch'in 2012a, Dawson Indian Band 1998, Easton et al. 2013). Through consumption of fish, groundwater presents a pathway of effects to Community Health and Well-being, Land and Resource Use and Social Economy VCs. Bates and de Roy (2014) assert that concern about contaminants can have many of the same impacts as actual contamination of the environment, animals and plants, effectively removing these resources from WRFN use.

Table 1.2-1 summarizes the evaluation of groundwater quality and quantity as IC subcomponents, given that these components are susceptible to alteration by the Project, affect other valued and intermediate components, are subject to legislation and are a common component of the environmental assessment process. According, groundwater quantity and quality satisfy all the required attributes for an IC, as well as the requirements for robust indicators as defined by the BC Environmental Assessment Office (EAO) (2013).

Table 1.2-1 Candidate Intermediate Components – Evaluation Summary

Candidate IC	Project Interaction			Third Party Input		Supports the Analysis / Assessment of Which Other IC or VC?	Selected as an IC?	Decision Rationale
	Interaction?	Project Phase / Project Component / Project Activity	Nature of Interaction	Source	Input			
Groundwater Quantity	Yes	Project related activities may potentially interact with the IC during different phases of the Project life (e.g., pit dewatering during operations and pit flooding during closure).	The Project has the potential to alter the amount of recharge to the groundwater system, which impacts groundwater flowpaths and discharge volumes.	First Nations Yukon Territorial Government Federal Government Public Stakeholder	Limited concerns raised specific to groundwater; however, many TK database entries underscore the value and importance First Nations place on air, land and water resources. Many references in the TK database acknowledge the interconnectedness of water and biota (fish, wildlife) and the value place on healthy fisheries on Coffee Creek and the Yukon River. Several pieces of territorial legislation govern groundwater. (see Table 3-1). Several pieces of federal legislation govern groundwater (see Table 3-1). No public stakeholder comments were received.	The analysis of Groundwater Quantity will support the Surface Hydrology IC assessment and the Surficial Geology, Terrain, and Soils VC assessment. By extension it will inform the Fish and Fish Habitat VC and Human Environment VCs (Social Economy, Community Health and Well Being, Land and Resource Use).	Selected as a sub-component to a Ground-water IC	Groundwater quantity was selected as a subcomponent due to its strong linkages with other ICs/VCs, and the potential for Project related activities to alter groundwater fluxes.
Groundwater Quality	Yes	Project related activities may potentially interact with the IC during different phases of the Project life (e.g., pit development during operations and pit flooding during closure).	The Project has the potential to introduce chemical loads to groundwater system, which impacts groundwater quality.			The analysis of Groundwater Quality will support the Surface Water Quality VC assessment. By extension it will inform the Fish and Fish Habitat VC and Human Environment VCs (Social Economy, Community Health and Well Being, Land and Resource Use).	Selected as a sub-component to a Ground-water IC	Groundwater quality was selected as a subcomponent due to its strong linkages with other ICs/VCs, and the potential for Project related activities to alter groundwater quality.

1.2.2 INDICATORS

Indicators are quantitative or qualitative measures used to describe existing IC conditions and trends, and to evaluate potential Project-related changes and cumulative changes to the IC. The methods used to identify and select indicators are described in **Section 5** of the Project Proposal.

Proposed indicators for groundwater quantity and groundwater quality are listed in **Table 1.2-2** and **Table 1.2-3**. Measurement of these indicators is a routine part of any groundwater monitoring program.

1.2.2.1 Groundwater Quantity Indicators

Two indicators for groundwater quantity have been identified in **Table 1.2-2** groundwater levels and surface water low flows. Groundwater levels are used to calculate hydraulic gradients and water table maps, from which flow directions and quantities can be estimated. Surface water low flows are a direct measures of groundwater discharge. To illustrate the application of the groundwater quantity indicators, two examples of Project activities which have potential to influence the groundwater system are provided below:

- Development of open pits – groundwater ingress into open pits advanced below the water table may redirected to other pits and/or be used in processing. This will result in reduction of groundwater levels in and around the pit. Conversely, redirection of water *to* or accumulation of meteoric water *in* a disused pit may raise water levels in and around the pit. The addition or removal of water to/from pits can potentially alter the amount of groundwater baseflow reporting to downgradient creeks.
- Placement of waste rock – disturbed materials are liable to allow different rates of infiltration than natural ground. This may result in changes to groundwater levels and creek baseflows.

Low flow monitoring in creeks falls under the discipline of surface hydrology and this has been included as an indicator in the Surface Hydrology IC report (**Appendix 8-B**). The groundwater monitoring network established in and around proposed Project facilities (discussed in **Section 3.3.1**) is well positioned to capture water levels changes.

Table 1.2-2 Indicators for Groundwater Quantity IC

Indicator	Rationale for Selection
Groundwater levels	Pit dewatering, collection of meteoric water (rain, snow) in pit shells, enhanced recharge in disturbed areas may manifest as changes in groundwater levels. Water levels are easy to measure and can be used to determine groundwater flow directions and fluxes.
Surface water low flows	Alteration to groundwater recharge patterns resulting from the Project may result in changes to groundwater volume discharging at creeks. Surface water low flows are included as a Surface Hydrology IC indicator (**Appendix 8-B**).

1.2.2.2 Groundwater Quality Indicators

Proposed indicators for evaluating Project changes to groundwater quality are summarized in **Table 1.2-3.** These indicators are essentially quality parameters that are routinely analysed for in groundwater samples by well established laboratory methods. Key water quality parameters for all indicators include field parameters (e.g., pH and temperature), anions, nitrogen species including cyanide, and total and dissolved metals. To illustrate the application of the groundwater quality indicators, two examples of Project activities which have potential to influence the groundwater system are provided below:

- Development of open pits - excavation of material from pits exposes pit walls to the atmosphere. Minerals in the pit walls are liable to oxidize, solubilizing metals and potentially releasing acidity. Dissolved metals may enter the groundwater system at concentrations above background levels, unless they are diluted by meteoric water that collects in the pits. Pit lakes are also influenced by contact water generated from in-pit waste rock backfill.
- Placement of waste rock – Minerals in excavated material may oxidize when exposed to the atmosphere and may leach constituents (e.g., sulfate and metals) when flushed with incident precipitation. In addition, waste rock is likely to contain finite quantities of explosive residues that will leach nitrogen (e.g., nitrate). The only facility where placement of waste rock is considered is that of the Double Double pit backfill. Project design measures are in place to minimize generation of contact water from the Alpha and Beta ex-pit WRSFs (and backfilled Kona Pit) to limit loss of contact water to ground (see **Section 4.4.1** for a discussion of design mitigations).

Mine contact water that infiltrates into the groundwater system can undergo a host of chemical reactions and processes which changes the signature of the mine water as it travels through the groundwater system. The indicators listed in **Table 1.2-3**, will help identify linkages between groundwater and surface water. Monitoring will be done to confirm the model results and effectiveness of mitigation.

Table 1.2-3 Indicators for Groundwater Quality IC

Indicator	Rationale for Selection
Non-traditional Land and Resource Use	
Predicted / observed pit lake water quality (parameters listed in Error! Not a valid result for table.)	Water that accumulates in open pits represents the integrated effect of pit development and, where applicable, waste rock backfill. Pit water may also serve to recharge groundwater flowpaths and/or may discharge to surface water receptors. As a result, pit lake water quality serves as a key indicator of Project changes to groundwater quality. Disturbed materials, when exposed to the atmosphere, can oxidize and release metals into solution and other ions. In broad terms, total and dissolved metals, anions, nitrogen species and field parameters (pH and temperature) are key parameters of pit lake water quality. The presence of certain metals in solution can indicate redox conditions, which can impart controls metal mobility in groundwater.
Predicted / observed waste rock seepage quality (Double Double) (parameters listed in Error! Not a valid result for table.)	Minerals in excavated material may oxidize when exposed to the atmosphere and/or may leachate constituents (e.g., sulfate and metals) when flushed with incident precipitation. In addition, waste rock is likely to contain finite quantities of explosive residues that will leach nitrogen (e.g., nitrate). The backfilled Double Double pit is only facility where waste rock is anticipated to interact with groundwater, therefore, Double Double waste rock seepage is proposed as a representative analog or indicator for potential Project-related changes to groundwater quality. In broad terms, key WRSF seepage parameters include total and dissolved metals, anions, nitrogen species and field parameters (pH and temperature).
Baseflow and observation well water quality (parameters listed in Error! Not a valid result for table.)	Baseflow in surface streams is an expression of groundwater discharge and therefore an indicator of groundwater quality. Groundwater quality from observation wells is a direct measurement of groundwater quality. Both of these groundwater quality indicators function to establish baseline conditions from which potential Project-related changes are compared. Changes in these indicators may also be used to verify and/or validate predicted changes to groundwater quality and associated linkages to surface water systems, as described above.

1.3 Establishment of Analysis Boundaries

The analysis boundaries define the limits within which the analysis of changes and supporting studies (e.g., baseline monitoring, predictive modeling) for the Groundwater IC will be conducted. These boundaries encompass where and when the Project is reasonably expected to interact with groundwater; with consideration of any administrative or technical constraints encountered in the baseline characterization; and limitations in predicting or measuring Project-related changes (e.g., modeling or measurement accuracy relative to magnitude of predicted change). The spatial and temporal boundaries relevant to groundwater are described below. The definition of these spatial and temporal boundaries is a key component of the change analysis, as it informs the choice of baseline monitoring locations and numerical model setup *(*e.g., **Appendix 7-B-1**).

1.3.1 SPATIAL BOUNDARIES

Groundwater flow systems occur on various scales. At the largest scale, deep groundwater drains towards major regional water bodies. At smaller scales, groundwater that originates in local catchments will drain towards local creeks and streams which ultimately feed into larger surface water systems.

The local study area (LSA) for groundwater is the same for both groundwater quantity and groundwater quality subcomponents. The LSA encompasses the maximum geographical area within which the Project is expected to interact with and potentially result in a direct or indirect change to groundwater. This includes areas directly underlying mine units and nearby reaches of downgradient creeks where changes to the Groundwater IC may manifest as measurable changes in the surface water regime. The LSA extends to include the proposed Northern Access Route (NAR) with a 1 km buffer on either side. The groundwater regional study area (RSA) is established to provide regional context for the analysis of Project-related changes (**Table 1.3-1**). The RSA also encompasses the area within which residual changes due to the Project are likely to interact with the residual changes from other past, present, or future projects or activities to result in a cumulative change or changes. The RSA encompasses the LSA, with the area south of the Yukon River expanded to encompass the entire drainage area bounded by Coffee Creek and Independence Creek. The Groundwater LSA and RSA are shown in **Figure 1.3-1** with the area south of Yukon the focus of **Figure 1.3-2.**

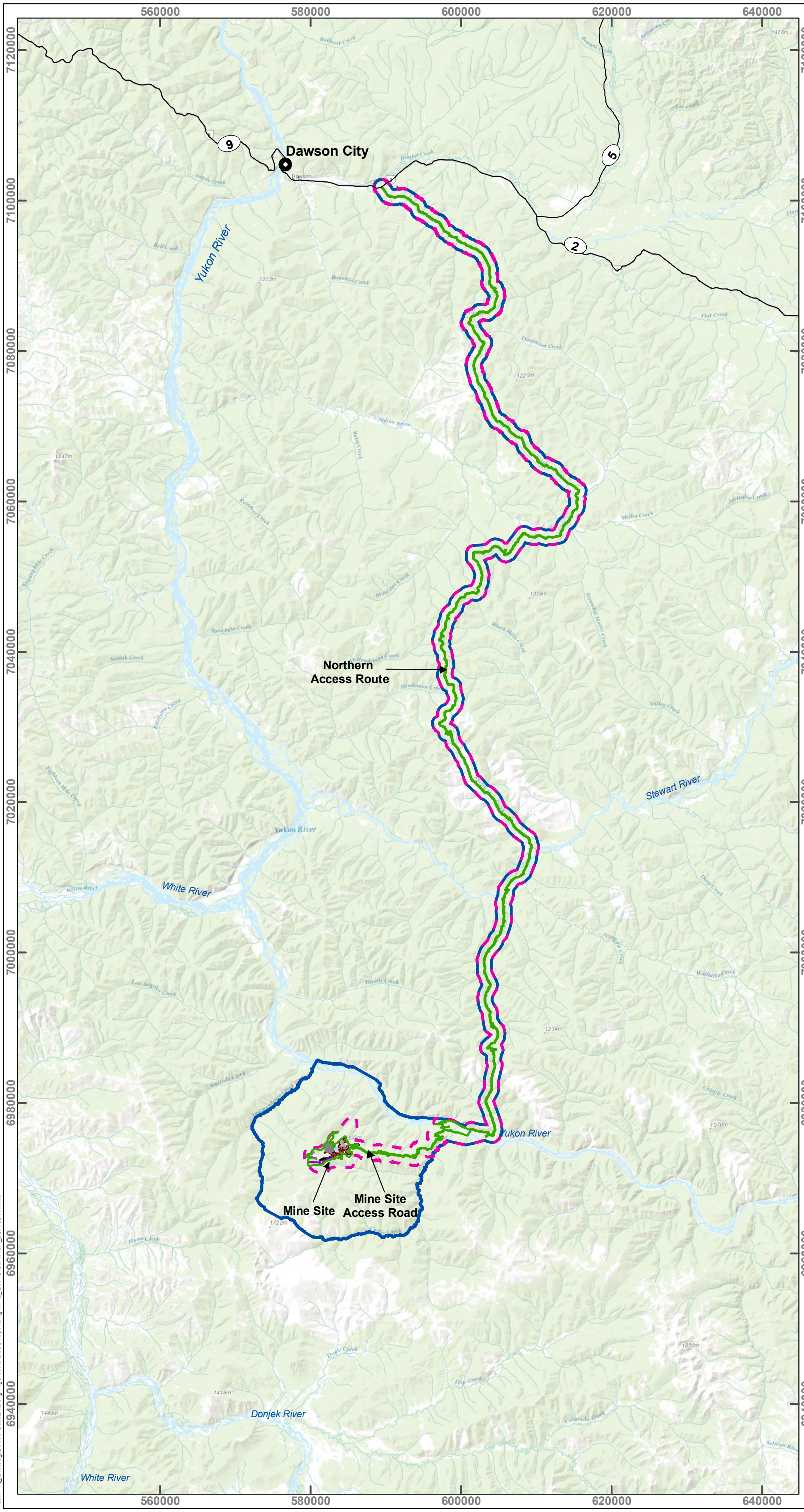
Through the scoping exercise presented in **Section 4.3**, it was determined that Project related development and use of the NAR would not cause residual changes to the Groundwater IC. For this reason, the LSA and RSA for the NAR are the same. As well, the Cumulative Changes Study Area (CCSA) is limited to the RSA area south of the Yukon River. As a result, the boundary of the numerical Groundwater Model used for the change analysis presented in this report coincides with the CCSA (**Figure 1.3-2**).

Table 1.3-1 Spatial Boundary Definitions for Groundwater

Spatial Boundary	Description of Assessment Area
Local Study Area	Area surrounding the major mine units (pits, waste rock facilities, heap leach). Includes immediately downgradient reaches of Halfway Creek (to lineament), YT-24 headwaters, and Latte Creek to the confluence with the Latte Tributary. The LSA also includes the alignment of the proposed Northern Access Route, with a 1 km buffer on either side.
Regional Study Area	The span of the Yukon River between Coffee Creek and Independence Creek and the area defined by drainage traces of Independence Creek and Coffee Creek and the intervening height of land between the headwaters of these two drainages. The RSA also includes the proposed Northern Access Route corridor and buffer.
Cumulative Changes Study Area	Coincides with RSA south of the Yukon River. The Northern Access Route is scoped out of the CCSA through the discussion presented in **Section 4.3.**

COFFEE GOLD MINE

Groundwater IC Local and Regional Study Areas



Legend

- Municipality
- Highway
- Project Footprint
- Local Study Area
- Regional Study Area

N

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0 5 10 15

Kilometres

NAD 1983 UTM Zone 7N

Page Size: 8 ½" x 11"

Figure 1.3-1	Date: Mar 21, 2017	Drawn by: GM	Reviewed: CF

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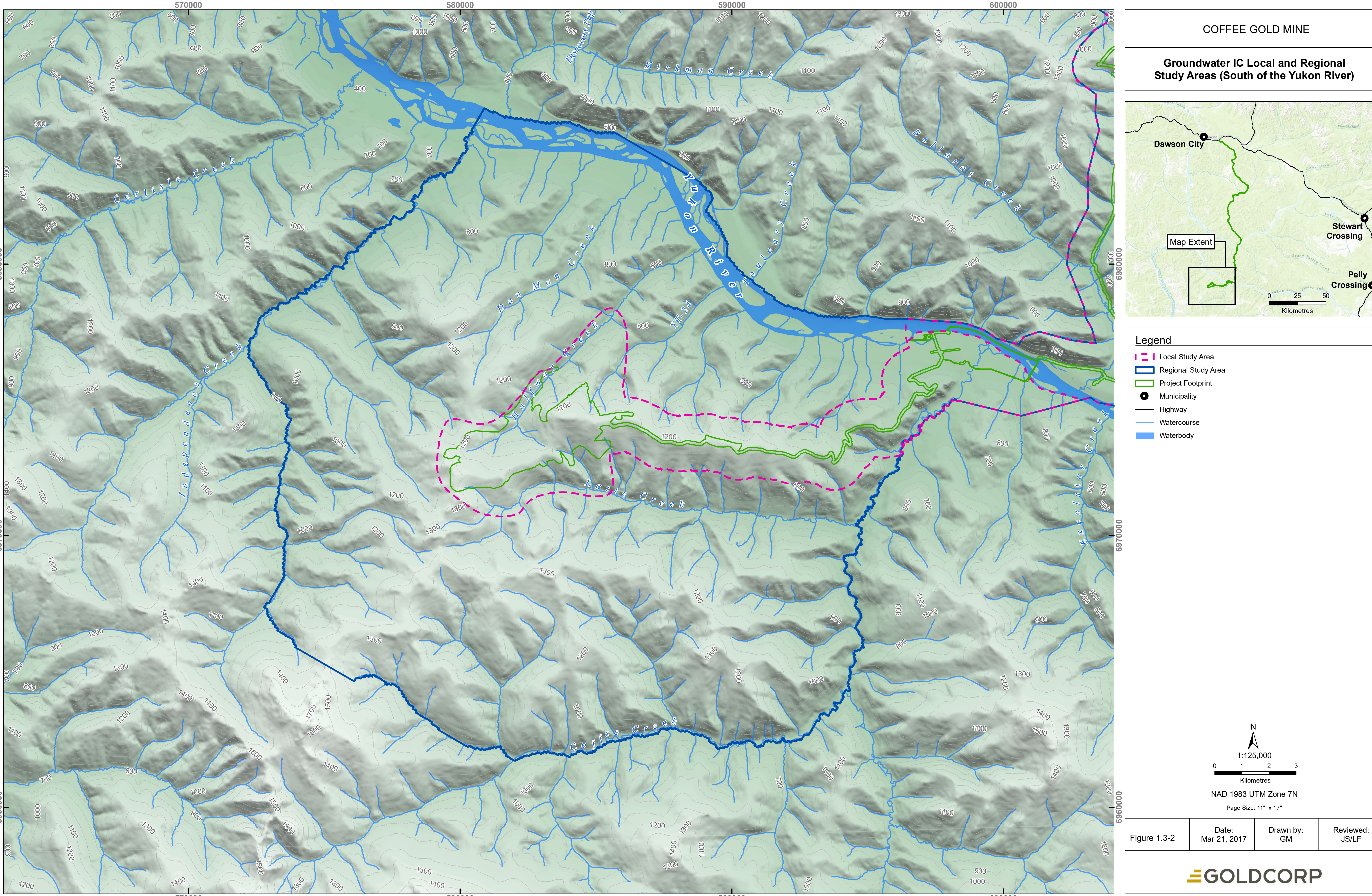
COFFEE GOLD MINE

Groundwater IC Local and Regional Study Areas (South of the Yukon River)



Legend

- Local Study Area
- Regional Study Area
- Project Footprint
- Municipality
- Highway
- Watercourse
- Waterbody

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0 1 2 3 Kilometres

NAD 1983 UTM Zone 7N

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Figure 1.3-2	Date: Mar 21, 2017	Drawn by: GM	Reviewed: JS/LF

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1.3.2 TEMPORAL BOUNDARIES

The specifics pertaining to the Project's Construction (Q2 Year –3 to end of Year –1 (30 months)), Operation (Year 1 to Year 12), Reclamation and Closure (Year 13-23), and Post-closure phases (Year 24 onwards) are described in the Project Proposal (**Section 2.0 Project Description**). The Reclamation and Closure Phase consists of Post-Mining Closure (Year 13 to Year 18) and Active Closure (Year 19 to Year 23). The Post-Closure phase coincides with Year 24 onward and consists of monitoring

The phases are depicted graphically in **Figure 1.3-3;** shading in the upper panel demarcates the phases of the Project; the lower panel summarizes the main activities in each phase. Changes to the Groundwater IC are expected to extend through Post-Closure.

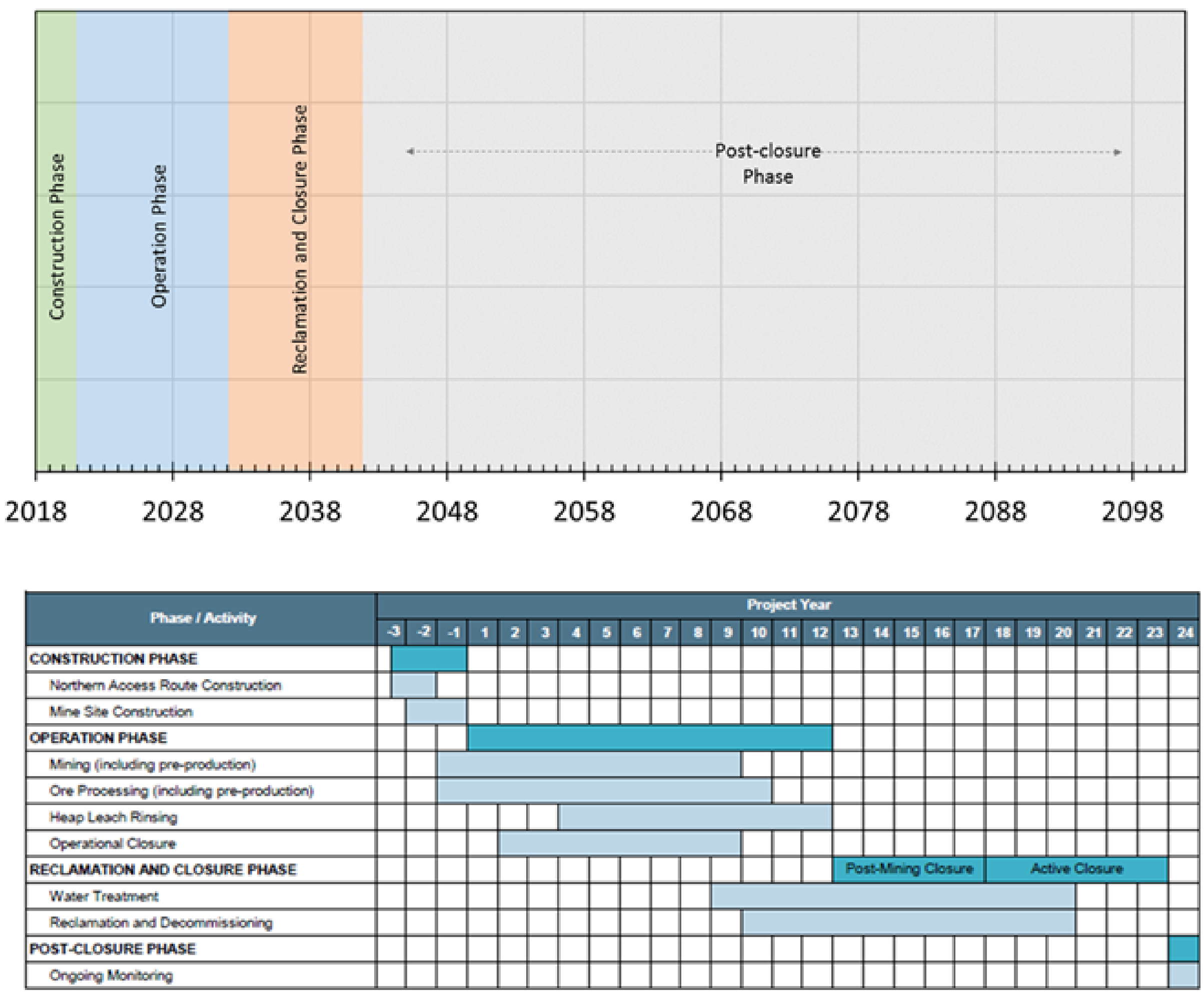


Figure 1.3-3 Temporal Boundaries for the Coffee Gold Mine
Shading in the upper and lower panels demarcates the main phases of the Project. The temporal boundaries in the schematic are scaled in calendar years where year 2018 is assumed to equate to Year -3 of the Coffee Gold Mine Plan.

The temporal boundaries of the groundwater analysis must reflect those periods during which the planned Project activities can reasonably be expected to potentially affect this IC. Changes to groundwater quantity are anticipated to be slow to actualize given the deep water levels encountered in most pit footprint areas and the time it necessarily takes for those changes to manifest in surface water systems. For this reason, groundwater quantity has been assessed for two “snapshots” in the mine life, one at the end of the Operation Phase (Year 12) and one during the Post-closure phase. As discussed in **Section 2**, these snapshots are believed to represent the maximum extent of changes resulting from the mine configuration.

Groundwater quality has been assessed qualitatively using water quality generated for source areas (pit lakes, waste rock facilities) using a Water Balance and Water Quality Model constructed in GoldSim (**Appendix 12-C**). The GoldSim output used for this analysis covers all mine periods from the Construction phase through the Post-closure phase.

1.3.3 Administrative Boundaries

No administrative boundaries were encountered during the collection of baseline groundwater data, or during the modelling and prediction of potential Project related changes to groundwater.

1.3.4 Technical Boundaries

Collection of groundwater quality samples for the Project requires large amounts of heavy equipment to accommodate the different instrumentation types installed on site. Methods are also dictated by physical aspects of the groundwater system (i.e. shallow versus deep water levels, fast versus slow water level recovery, whether the water column partially freezes, etc.). Some of the required groundwater sampling equipment is temperature sensitive and cannot be used in sub-zero conditions. In addition, some wells require several hours to sample. These factors limit the amount of data that can be practicably collected outside of the operating period of the exploration camp (which closed between September 2015 and May 2016) when the window of daylight is small, and temperatures are below freezing. For this reason, groundwater wells were only sampled between May and September of 2015. As a result, the full cycle of the well hydrographs could not be captured in the water quality data. However, these limitations do not pose restrictions on the assessment of groundwater changes. Given that groundwater baseline data collection (including sampling) will be ongoing during permitting, there will be an ongoing effort to establish, evaluate, and demonstrate background groundwater elevations and quality.

2.0 ANALYSIS METHODS

The groundwater analysis, including the analysis of Project-related changes and cumulative changes was conducted according to the methods set out in **Section 5.0 Assessment Methodology** of the Project Proposal. An initial screening of the potential interaction between activities associated with the Northern Access Route and the Groundwater IC showed negligible interaction overall. However, the initial screening of potential interactions between activities local to the Coffee Gold Mine (e.g., open pit development, management of waste rock) and the Groundwater IC showed potential interaction. Given the potential for Project interaction at and downstream of mine footprints, a detailed groundwater numerical model was constructed and calibrated using MODFLOW-2005 operated using the Groundwater Vistas pre-/post-processing software (**Appendix 7-B-1**). The Groundwater Model enabled quantification of groundwater quantity residual changes.

A semi-quantitative approach has been used to assess Project changes to groundwater quality. This approach entails a comparison between measured groundwater quality and estimates of future pit lake quality and WRSF drainage water quality computed using the combined Water Balance/Water Quality Model developed in GoldSim (**Appendix 12-C Coffee Gold Mine: Water Balance and Water Quality Model Report**). The comparison flags parameters which may become elevated in Project groundwater due to the influence of mine contact water.

The following sections describe details of the methods used to evaluate Project changes to groundwater quantity and groundwater quality. Further, the methods outline below describe the quantification and integration of Project changes to surface flows (hydrology) and surface water quality via groundwater.

2.1 GROUNDWATER QUANTITY ANALYSIS

A three-dimensional numerical groundwater has been developed in order to predict potential Project changes to groundwater. The numerical model incorporates Project activities that may alter groundwater quantity, namely open pit development and placement of waste rock. The model simulates changes to groundwater levels and creek baseflow as a result of these activities and is used to inform the analysis of Project-related changes to groundwater quantity. The modeling effort can be described in three stages:

I. Development and calibration of a steady-state model to simulate baseline (i.e. pre-mine) conditions;
II. Modification of the baseline model to simulate end of Operation Phase (Year 12) for open pit and waste rock extents and associated pit lake water levels; and
III. Modification of the end of Operation Phase model to simulate long-term pit lake elevations and surrounding groundwater elevations at Post-Closure.

A detailed account of model setup, calibration, sensitivity analyses, and results is provided in **Appendix 7-B-1**. The reviewer should note that Groundwater Model has been revised from its original version, which utilized a previous mine plan. The report describing the original model comprises the main text of **Appendix 7-B-1**. Revisions to the Groundwater Model made in 2017 are summarized in an addendum to the main report, contained as Appendix A of **Appendix 7-B-1**. The 2017 update includes a revised baseline model calibration informed by recent field results, as well as revised predictions based on the current mine plan. The baseline and predictive models are summarized in the sections below.

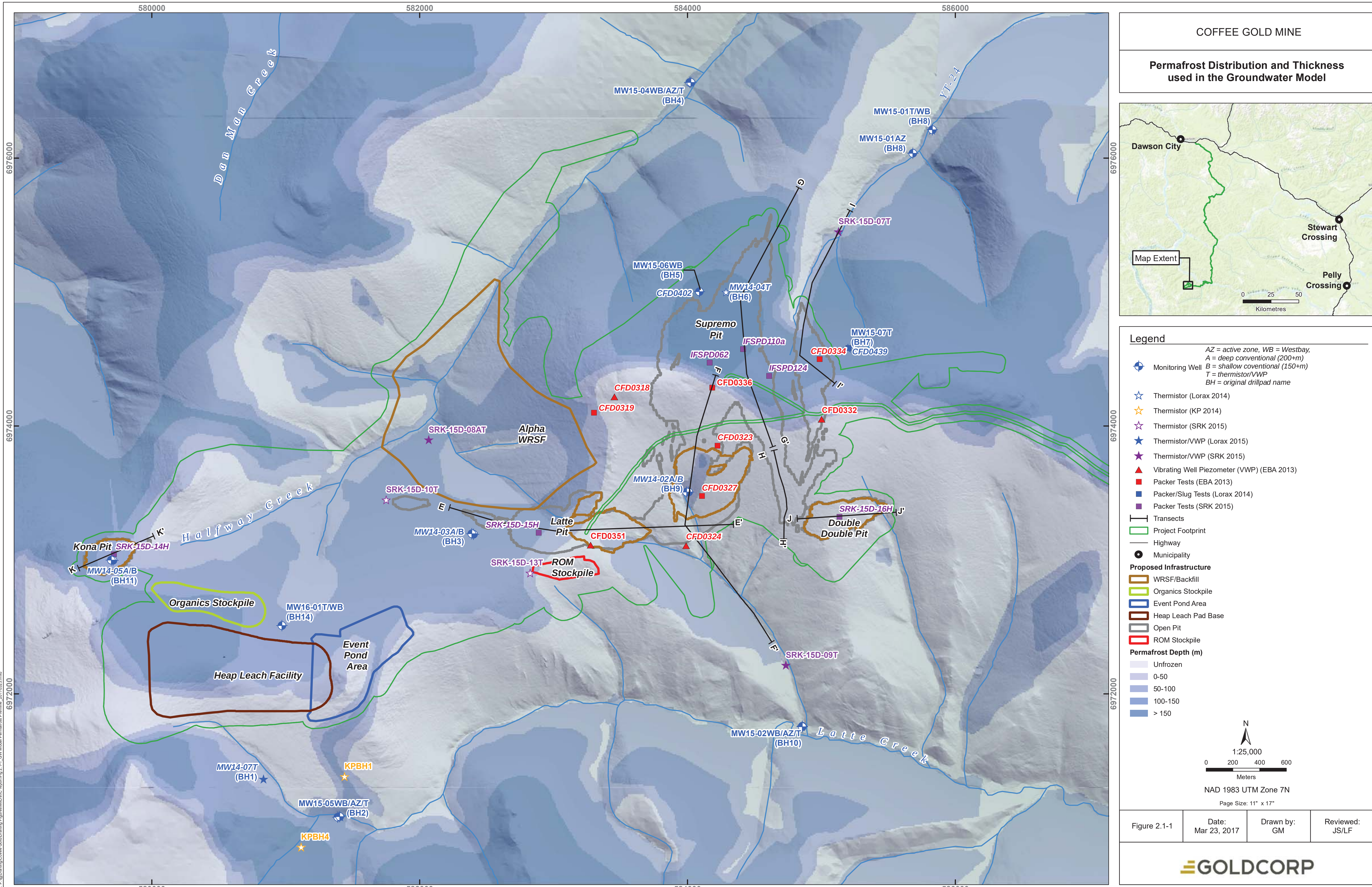
2.1.1 BASELINE MODEL

2.1.1.1 Model Development

The Groundwater Model was built using the Groundwater Vistas platform (Rockware®), operating the finite difference groundwater modeling code MODFLOW-2005 (Harbaugh, 2005). The Groundwater Model domain coincides with the RSA boundary south of Yukon River (**Figure 1.3-2**). The model boundary extends from the Yukon River in the northeast to Independence Creek in the northwest. Coffee Creek comprises the eastern and southeastern boundary. The southwestern edge of the model follows smaller tributaries to Independence and Coffee Creeks, with an approximately 2.5 km portion of the model boundary that is not associated with a stream channel. Constant head boundary conditions were applied to major creeks along the perimeter of the model boundary, while drain conditions were applied to interior creeks. Recharge rates on non-frozen areas vary with topographic elevation, consistent with observed precipitation gradients **(Appendix 8-A**). Recharge rates on non-frozen ground between elevations of 600 m to 1400 m asl are equivalent to 15% mean annual precipitation (MAP). A nominal recharge rate of 5 mm/yr was applied to upland areas underlain by permafrost while frozen ground below this elevation was assumed to coincide with groundwater discharge zones and thus received no recharge.

Permafrost is inferred to be of very low hydraulic conductivity (Woo, 2012; Kane et al. 2013, Walrood et al. 2012) and is used to define the top layer of the model. While the top layer in the model represents a contiguous permafrost distribution, in actuality, permafrost occurrence within the LSA is discontinuous. A low hydraulic conductivity representing permafrost was only applied to areas mapped as permafrost by geomorphologists and geocryologists. The lateral distribution of permafrost in the model domain was based on field reconnaissance and air-photo interpretation performed by EBA TT (2016b, 2017) and AECOM (2012). Permafrost presence outside of the mapped areas was inferred based on aspect. The overall distribution of permafrost incorporated into the model is shown in **Figure 2.1-1**.

The thickness of the top layer was determined from an analysis of permafrost thickness in the mine area. An average, linear relationship was derived from the data where permafrost thickness is observed to increase with increasing elevation (**Figure 3.3-3**; **Section 3.3.2.2**). Within the LSA point measurements of permafrost thickness were contoured both manually and digitally. Outside of the LSA permafrost thickness was assumed to follow the linear correlation. At the lowest elevations, a nominal layer thickness of 5 m was maintained.


COFFEE GOLD MINE
Permafrost Distribution and Thickness used in the Groundwater Model
Dawson City
Stewart Crossing
Pelly Crossing
Map Extent
0 25 50
Kilometres
Legend
Monitoring Well
AZ = active zone, WB = Westbay, A = deep conventional (200+m) B = shallow conventional (150+m) T = thermistor/VWP BH = original drillpad name
Thermistor (Lorax 2014)
Thermistor (KP 2014)
Thermistor (SRK 2015)
Thermistor/VWP (Lorax 2015)
Thermistor/VWP (SRK 2015)
Vibrating Well Piezometer (VWP) (EBA 2013)
Packer Tests (EBA 2013)
Packer/Slug Tests (Lorax 2014)
Packer Tests (SRK 2015)
Transects
Project Footprint
Highway
Municipality
Proposed Infrastructure
WRSF/Backfill
Organics Stockpile
Event Pond Area
Heap Leach Pad Base
Open Pit
ROM Stockpile
Permafrost Depth (m)
Unfrozen
0-50
50-100
100-150
> 150
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GOLDCORP
580000
582000
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586000
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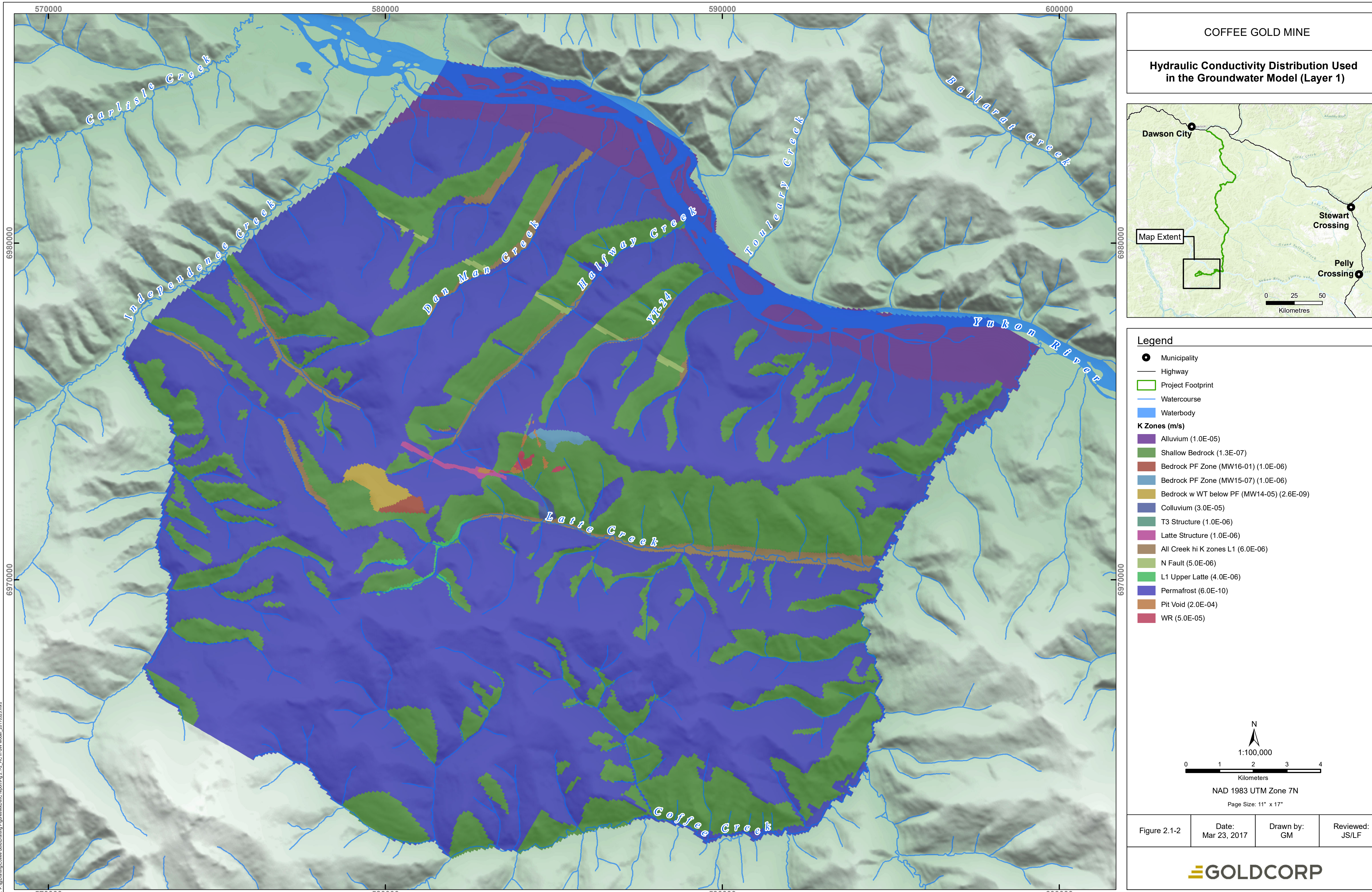
6972000
Dan Man Creek
Halfway Creek
Latte Creek
YT-24
MW15-04WB/AZ/T (BH4)
MW15-01T/WB (BH8)
MW15-01AZ (BH8)
MW15-06WB (BH5)
CFD0402
MW14-04T (BH6)
SRK-15D-07T
Supremo Pit
IFSPD110a
IFSPD062
IFSPD124
MW15-07T (BH7) CFD0439
CFD0334
CFD0336
CFD0318
CFD0319
CFD0332
CFD0323
CFD0327
MW14-02A/B (BH9)
Alpha WRSF
SRK-15D-08AT
SRK-15D-10T
SRK-15D-15H
Latte Pit
CFD0351
CFD0324
SRK-15D-16H
Double Double Pit
MW14-03A/B (BH3)
Kona Pit
SRK-15D-14H
MW14-05A/B (BH11)
SRK-15D-13T
ROM Stockpile
Organics Stockpile
MW16-01T/WB (BH14)
Event Pond Area
Heap Leach Facility
SRK-15D-09T
MW15-02WB/AZ/T (BH10)
MW14-07T (BH1)
KPBH1
MW15-05WB/AZ/T (BH2)
KPBH4

The model grid spacing is variable with cell width ranging from 12 to 70 m with tighter spacing used in areas of structural complexity and inferred faulting, as informed by the geological model **(Section 3.3.2.1; Kaminak (2015)).** The model domain is divided vertically into four layers.

Hydraulic conductivity is variable over the model domain and varies with depth. Non-frozen bedrock shallower than 100 m below ground surface is assigned a higher hydraulic conductivity value than deeper bedrock, consistent with measured trends (**Section 3.3.2.3**). Several high hydraulic conductivity features were implemented in areas of drilled structures, regional faults and along creek traces where hydrogeological testing indicated enhanced bedrock permeability **(Figure 2.1-2**). These permeable features include the following:

- Independence Creek Fault
- North Lineament
- Latte pit structure
- T3 structure
- HLF structure
- Latte Creek
- Halfway Creek
- YT-24 Drainage
- Latte Tributary.

The North Lineament is a northwest-southeast trending feature which cross-cuts Halfway Creek, YT-24 and other drainages in the Project area **(Figure 2.1-2**, **Figure 3.3-2**). The HLF structure is a feature that has been recently incorporated into the model as a result of a hydrogeological program undertaken in the fall of 2016 (see sub-appendix P-1 of **Appendix 7-A**). Drilling results indicated productive water-bearing zones in the area of a previously identified magnetic anomaly. As such, the magnetic anomaly was treated as a zone with enhanced permeability in the groundwater model (**Figure 2.1-2)**. Other permeable features incorporated in the model include alluvium near the Yukon River, and a lens of thicker than average colluvium observed in the lower reaches of the Latte Tributary (**Section 3.3.2.1**). Outside of these two areas, shallow surficial sediments (specifically colluvium) are not included given their limited thickness. As such, the active layer is not simulated in the Groundwater Model.



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Hydraulic Conductivity Distribution Used in the Groundwater Model (Layer 1)

Figure 2.1-2	Date: Mar 23, 2017	Drawn by: GM	Reviewed: JS/LF

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2.1.1.2 Baseline Model Calibration

The Groundwater Model was run in steady-state mode and was calibrated to creek baseflows and water levels measured on or around June 23, 2015. The water level targets are provided in **Table 3.3-7** and generally represent low points in the groundwater level hydrographs (**Section 3.3.2.4**).

The baseflow targets were derived from measured basin yields which typically ranged from 0.4 to 0.9 L/s/km^2 (**Table 2.2-1**). The exceptions to this are YT-24 and Latte Tributary, where the June 23rd baseflow measurements are used to constrain the lower end of the basin yield. Baseflow targets are discussed in more detail in **Section 3.3.2.5**. Baseflows used to calibrate the Groundwater Model are also consistent with those used to constrain the Water Balance Model (**Appendix 12-C**) and thus provide a basis of integration between groundwater, surface hydrology, and water balance for the Project.

Recharge and hydraulic conductivity were varied to match calibration targets through a combination of manual and model-automated parameter optimization. Overall, the calibrated hydraulic conductivity values were found to be reasonably consistent with measured data, although the optimization of hydraulic conductivity for mineralized structures were generally higher than measured in the field (**Figure 2.1-3**). A single value of hydraulic conductivity was used for each shallow and deep unfrozen bedrock; pit and valley structures were modeled using a range of values.

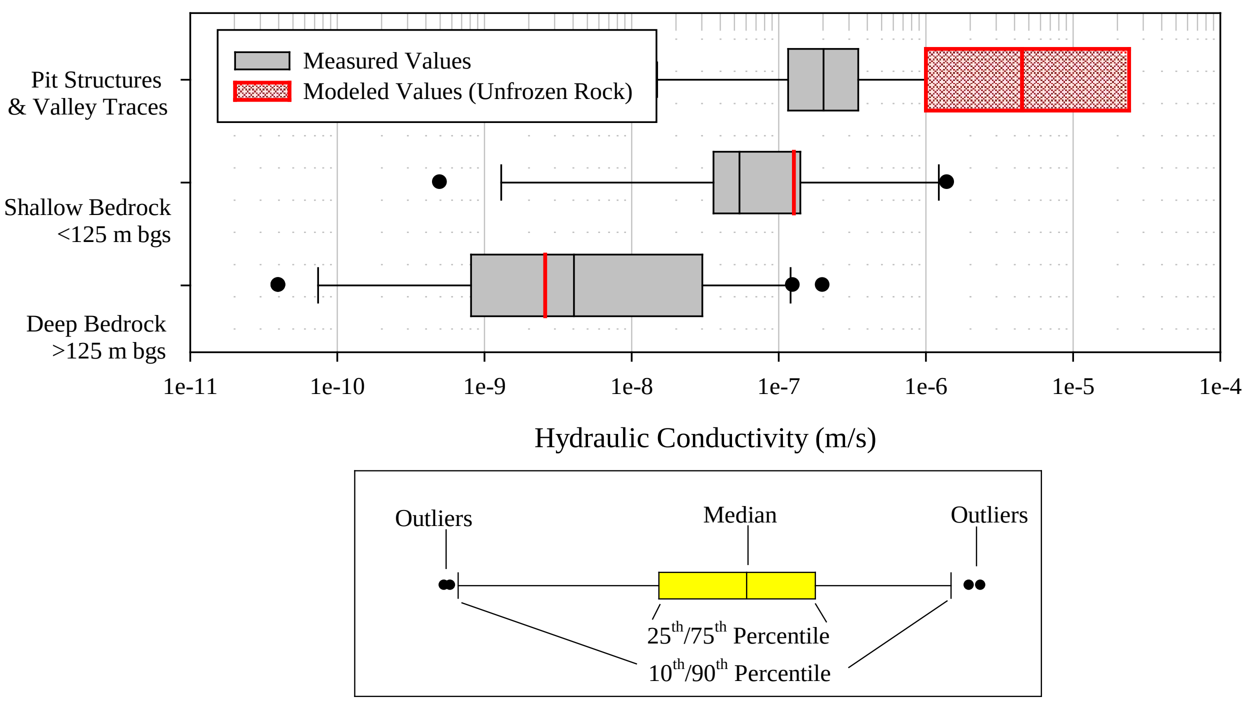


Figure 2.1-3 Box and Whisker Plots of Calibrated and Measured Hydraulic Conductivity Values for Shallow and Deep Bedrock and Permeable Features

Over much of the model domain, permafrost is treated as a highly impermeable unit with a hydraulic conductivity of 6×10^{-10} m/s. There are three areas falling along ridgelines, where permafrost is mapped and a higher hydraulic conductivity value was used in order to improve head matching. Recharge applied over these modified frozen zones remains consistent with that applied to other permafrost areas (i.e. 0 mm/yr below 1200 m asl, 5 mm/yr above 1200 m asl).

- MW14-05 (Kona). MW14-05 has a water table that is below permafrost, and the hydraulic conductivity of the fractured bedrock below permafrost was set to be equal to the hydraulic conductivity of the bedrock below the permafrost at this location in Layer 2. Because of the thickness of the layer, this area was assigned the hydraulic conductivity of deep bedrock.
- MW16-01 (HLF). Hydraulic heads in this area are much higher than at MW14-05. A mechanism was required to draw recharge from south-facing slopes to the north-facing, permafrost-covered slopes. The drilling information from this location (**Appendix 7-A**) indicates that groundwater occurs in transmissive features below permafrost. To simulate the presence of a high-permeability layer at the bottom at the bottom of permafrost, Layer 1 in these areas was assigned a hydraulic conductivity of 1×10^{-6} m/s. This enabled the elevated water levels at MW16-01 to be simulated more accurately.
- MW15-07 (Supremo 5 Pit). Water levels in this area are also somewhat elevated (~120 to 130 m bgs) compared to other areas along this ridgeline, where water levels can be greater than 200 m bgs. A similar high hydraulic conductivity zone (1×10^{-6} m/s) is simulated in layer 1 near this installation to draw recharge from south-facing slopes to the north-facing, permafrost-covered slopes.

Baseflows simulated by the calibrated model are provided in **Table 2.1-1** and standard measures of fit for water levels are provided in **Table 2.1-2**. A normalized root mean squared error (NRMSE) less than 10% for water levels is generally considered acceptable for resource industry groundwater models (Wels et al. 2012). Overall, the Groundwater Model is considered well-calibrated for the following reasons**:**

- Both the NRMSE and absolute residual mean error is low
- Head residuals at elevation are not biased in any one direction (Figure 2.1-4)
- Simulated creek fluxes are within target ranges (Table 2.1-1)
- The model captures high and low hydraulic conductivity features, but does not introduce unnecessary heterogeneity to achieve calibration targets.

Given the factors listed above, and the fact that the model is informed by robust hydrological and hydrogeological data sets, the calibrated model is considered an appropriate tool to inform the analysis of Project changes to groundwater quantity.

Table 2.1-1 Simulated and Target Creek Baseflows from the Baseline Groundwater Model

Hydrology Station	Basin Area km^2	Groundwater Model Calibration Target[1] L/s		Simulated Baseflow GoldSim) L/s	Simulated Baseflow (MODFLOW) L/s	Comment
CC-1.0	3.4	0.0	3.1		2.1	Inside LSA
CC-1.5	23	9.3	21	14	14	Inside LSA
CC-3.5	70	28	63	22	48	
CC-6.0	9.6	3.8	8.6		4.4	Inside LSA
HC-2.5	15	5.9	13	6.1	8.2	Inside LSA
HC-5.0	27	11	24	11	17	
IC-2.5	17	6.9	16		4.7	
IC-3.0	18	7.3	16		10	
YT-24	12	3.8	11	8.6	7.3	Inside LSA

Note:

1. Computed from a basin yield of 0.4 to 0.9 L/s/km^2 except at YT-24 and CC-1.0, where June 23, 2015 low flows used as lower bound.

Table 2.1-2 Summary of Model Calibration Statistics for the Water Level Observations

Calibration Metric	Entire Domain	Halfway Creek Catchment	Latte Creek Catchment	YT-24 Catchment	Duplicates (Group 6)
Number of calibration points	42	17	12	6	7
Absolute residual mean (m)	5.5	5.3	8.5	4.7	1.5
Root mean square	7.3	7.2	9.9	5.5	1.8
Normalized root mean squared error	1.13%	0.63%	2.08%	1.97%	0.36%

Note:

1. Residual equals observed value minus computed value.

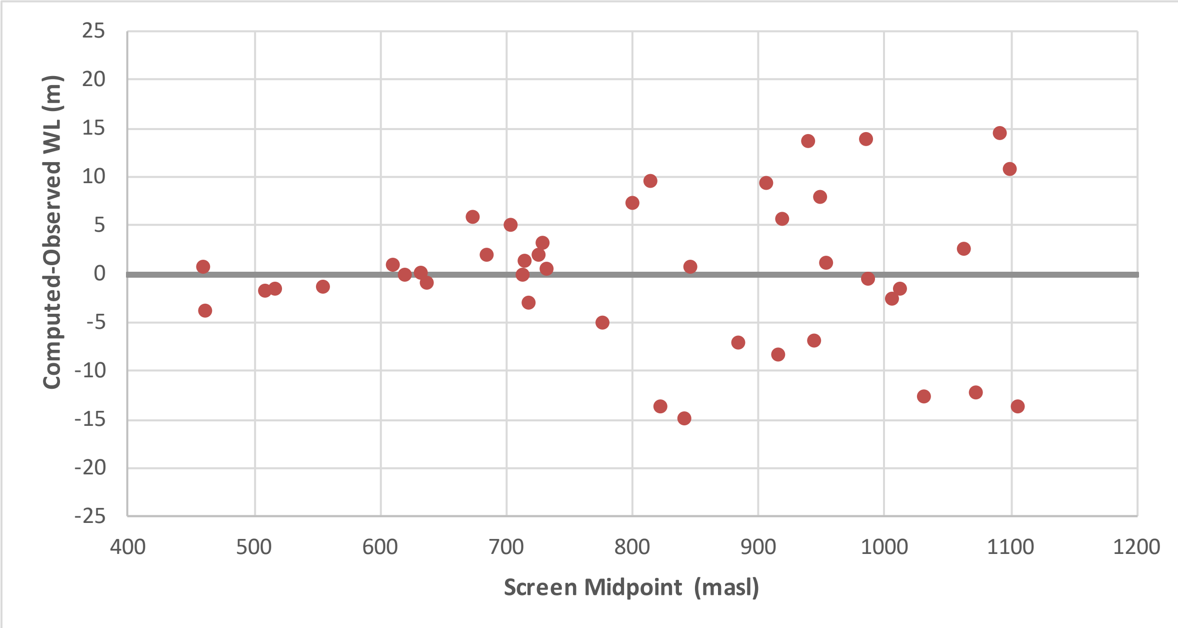


Figure 2.1-4 Difference between Computed and Observed Water Levels versus Screen Midpoint Elevation of Calibration Target

2.1.2 END OF OPERATION PHASE MODEL

The baseline Groundwater Model was reconfigured to assess groundwater levels and creek baseflows at the end of the Operation Phase (Year 12). This was achieved by implementing the boundary conditions outlined in **Table 2.1-3** and running the model in steady-state mode. By running the model in steady-state mode at full buildout, the Groundwater Model conservatively estimates the maximum extent of Project changes. In other words, the model simulates a condition in equilibrium with the hydrogeological changes brought about by pit development and waste rock placement when, in actuality, the full impact of these changes may not be realized within the 12-year Operation timeframe.

The boundary conditions utilized in the Operation Phase model include constant heads simulating pit lakes on unfrozen ground and general head boundaries simulating pit lakes on permafrost. The pit areas listed in **Table 2.1-3** are illustrated in **Figure 2.1-5**. A map of end of Operation Phase permafrost thickness is provided for context in **Figure 2.1-6**.

An iterative exercise between the Groundwater Model and Water Balance Model was conducted to integrate groundwater flowpaths and rates into the Water Balance Model. Leakage versus pit lake stage curves were determined for key pits using the Groundwater Model. These leakage curves were coded into the Water Balance Model along with meteoric water inputs and other diversions. The Water Balance Model computes a resultant pit lake elevation which is then fed back into the Groundwater Model as the ultimate boundary condition.

New recharge boundary conditions were applied in HLF and Alpha WRSF to account for design mitigation measures (see **Section 4.4.1.6 Groundwater Protection and Management)** and changes to recharge on disturbed ground. The following changes to the baseline recharge distribution were implemented in the end of Operation Phase model:

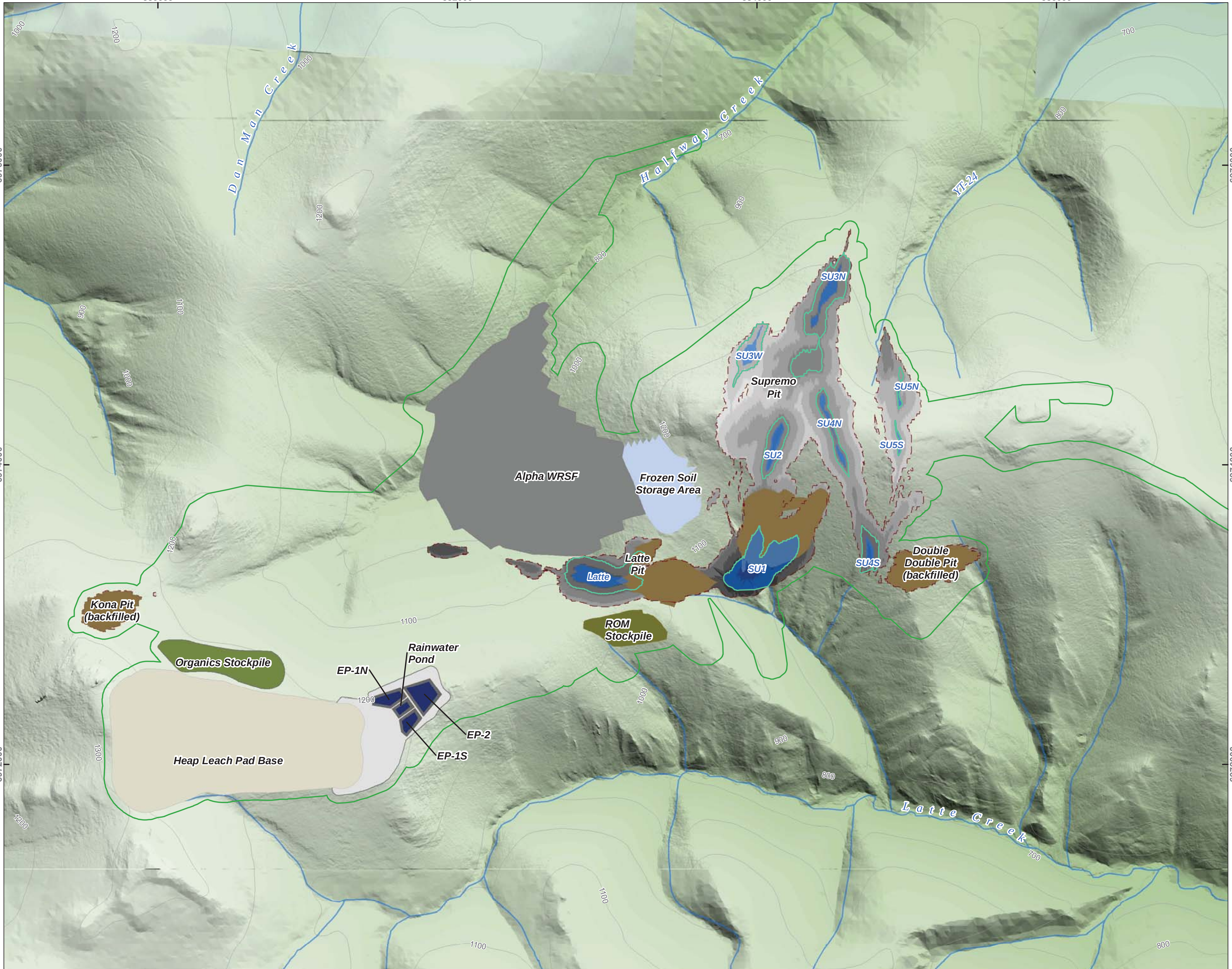
- Zero recharge was applied to the HLF footprint (including event and storage ponds) to account for a robust liner system.
- Zero recharge was applied to the footprint area of the Alpha WRSF. This simulates the effect of rock drains, which allow water to flow through the base of the waste rock pile and report to the sediment pond. Given the topographic relief of the Alpha WRSF and prevalence of permafrost, it is believed that the rock drains will be highly effective and that WRSF seepage will report to the water collection systems and sedimentation ponds and not to groundwater. Furthermore, it is more conservative from a surface water quality effects standpoint to assume that WRSF seepage reports to the sediment ponds rather than groundwater.
- Zero recharge was applied to waste rock placed in the Supremo pits. Given the steep slope of the Supremo pits, it is assumed that recharge that infiltrates the mine waste will immediately drain towards the lowest point in the pit, where it will form a lake or be dewatered.
- Zero recharge was applied to waste rock in the Kona Pit. Kona Pit is situated in permafrost, and backfill of mine waste is planned during winter, to trap cold air at the base of the pit. It is anticipated that any water that infiltrates the backfilled mine waste will freeze.
- An enhanced recharge rate equivalent to 35% of MAP was applied to the backfilled Double Double pit. This pit is planned to advance in unfrozen, saturated ground and infiltration through the mine waste is not expected to freeze. The infiltration rate of 35% MAP is consistent with infiltration rates assumed in the Water Balance Model.

Table 2.1-3 Summary of Mine Unit Boundary Conditions Applied in the Groundwater Model

Pit	Pit Advanced Through Permafrost	Pit Lake Elevation Year 12 (m asl)	Pit Lake Elevation Post-Closure (m asl)	Groundwater Model Boundary Condition (Year 12)	Groundwater Model Boundary Condition (Post-Closure)
SU1[1]	Permafrost Absent	942	942	Constant Head	Constant Head
SU2	Yes	1061	1081	Constant Head	Constant Head
Latte[1]	Yes	998	1040	Constant Head	Constant Head
SU3W[2]	No	1176	1200	General Head	Constant Head
SU3N	Yes	1050	1090	Constant Head	Constant Head
SU4N[1]	Yes	1083	1105	Constant Head	Constant Head
SU4S	Permafrost Absent	1013	1048	Constant Head	Constant Head
SU5S[2]	No	1165	1165	General Head	Constant Head
SU5N[2]	No	1140	1140	General Head	Constant Head
Double Double[3]	Permafrost Absent	Not specified	Not specified	Recharge = 151 mm/yr	Recharge = 151 mm/yr
Kona[3]	No	None	None	Recharge = 0 mm/yr	Recharge = 0 mm/yr

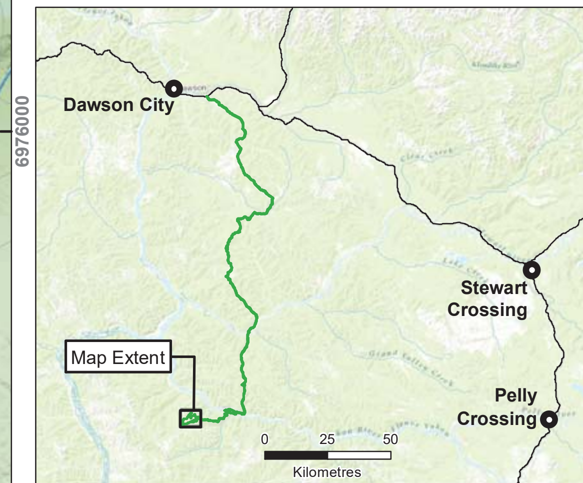
Notes:

1. Pit partially backfilled with mine waste, recharge = 0 mm/yr in footprint of mine waste
2. In Post-Closure, bedrock hydraulic conductivity underlying pit is converted from a permafrost value to a shallow bedrock value.
3. Pit completely backfilled with mine waste, recharge as indicated.



COFFEE GOLD MINE

Pit and Waste Rock Storage Facilities at End of Operation Phase



Legend

- Municipality
- Project Footprint
- Highway
- Waterbody
- Watercourse

Proposed Infrastructure

- WRSF
- Backfill
- Total Pit Outline
- ROM Stockpile
- Organics Stockpile
- Frozen Soil Storage Area
- Event Pond
- Heap Leach Access Disturbance Footprint
- Heap Leach Pad Base
- Post-Closure Pit Lake (Dry at End of Operation)

N

1:25,000

0 500 1,000 1,500

Meters

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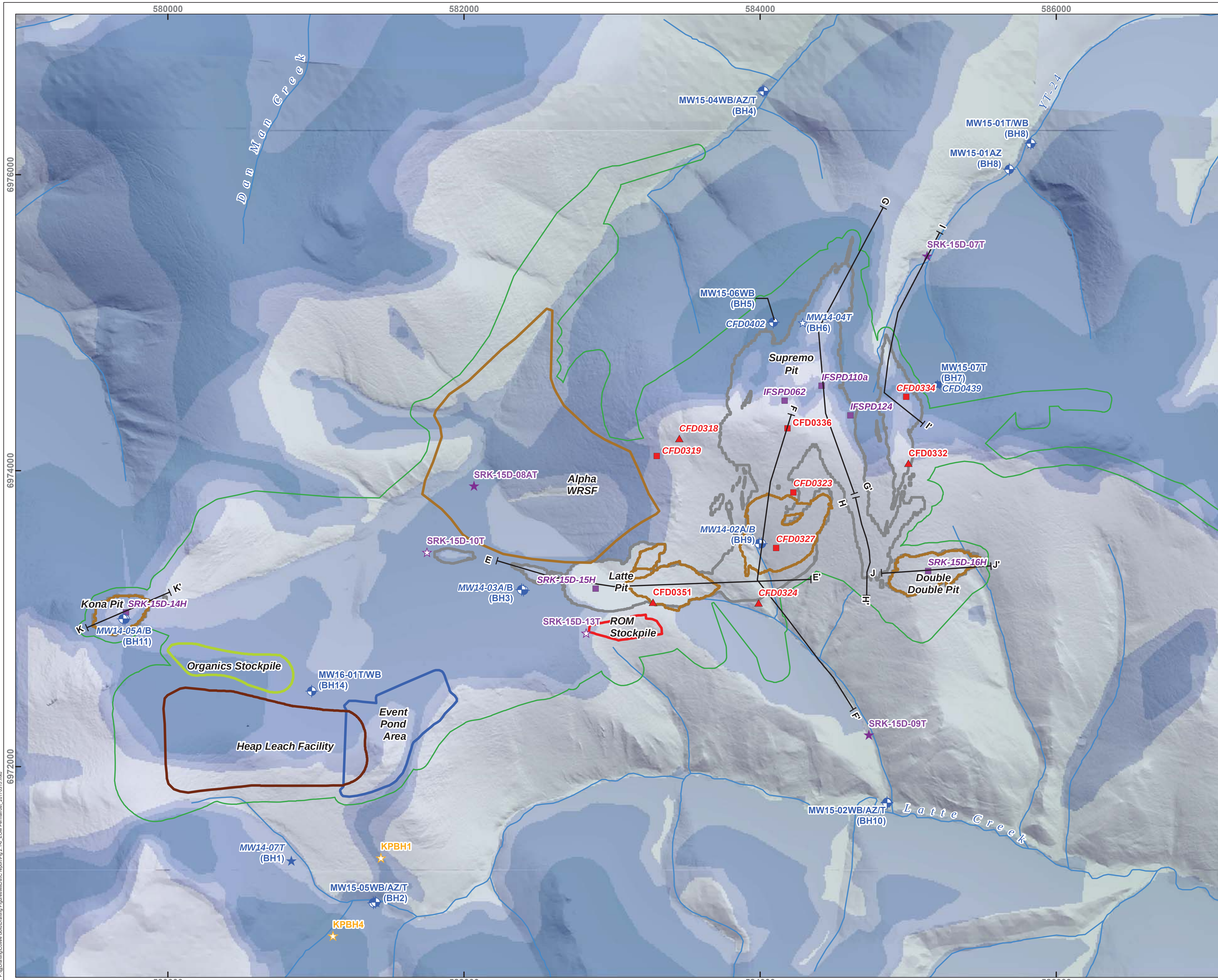
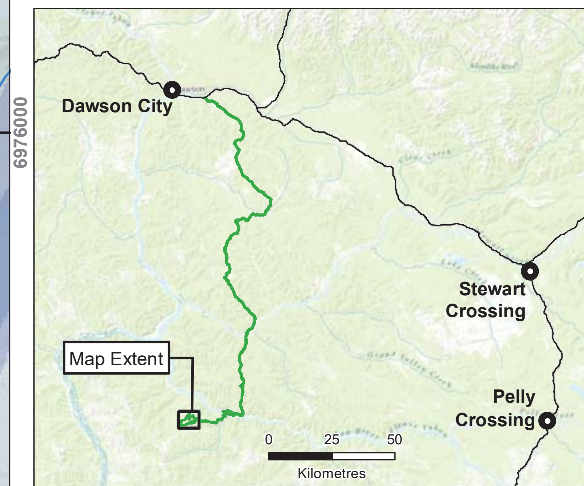


COFFEE GOLD MINE

End of Operation Phase Permafrost Thickness in Project Footprint



Legend

- Monitoring Well — AZ = active zone, WB = Westbay, A = deep conventional (200+m), B = shallow conventional (150+m), T = thermistor/VWP, BH = original drillpad name
- Thermistor (Lorax 2014)
- Thermistor (KP 2014)
- Thermistor (SRK 2015)
- Thermistor/VWP (Lorax 2015)
- Thermistor/VWP (SRK 2015)
- Vibrating Well Piezometer (VWP) (EBA 2013)
- Packer Tests (EBA 2013)
- Packer/Slug Tests (Lorax 2014)
- Packer Tests (SRK 2015)
- Transects
- Project Footprint
- Municipality
- Highway

Proposed Infrastructure

- WRSF/Backfill
- Organics Stockpile
- Event Pond Area
- Heap Leach Pad Base
- Open Pit
- ROM Stockpile

Permafrost Depth (m)

- Unfrozen
- 0-50
- 50-100
- 100-150
- > 150

N

1:25,000

0 200 400 600

Meters

NAD 1983 UTM Zone 7N

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Figure 2.1-6	Date: Mar 24, 2017	Drawn by: GM	Reviewed: JS/LF

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2.1.3 POST-CLOSURE MODEL

The end of Operation Phase Groundwater Model was reconfigured to assess groundwater levels and creek baseflows during Post-Closure. While the Operation Phase model considers loss of permafrost thickness due to excavation of pits, the Post-Closure model also considers thaw of permafrost due to formation of pit lakes.

A conceptual model of permafrost thaw beneath a pit lake is presented in **Figure 2.1-7** and **Figure 2.1-8**. A thaw front is likely to form below the pit lake which will migrate downward until a through talik forms to sub-permafrost ground (**Figure 2.1-7**). The boundary between thawed and frozen ground will become near vertical through time. Laterally, the thaw front is not expected to extend far from the edge of the pit lake. Depending on the thickness of permafrost underlying the pit (among other factors), it is conceivable that through taliks may form under some pit lakes within the post-closure time frame. The hydrogeological properties of the through talik would be that of unfrozen ground. In terms of the Groundwater Model, the hydraulic conductivity assigned to the through talik is consistent with shallow bedrock, which is significantly more permeable than deep bedrock and permafrost (**Figure 2.1-3**).

All pits (except Kona and Double Double) are expected to reach their spill point during Post-Closure. If overland flow from the pit lakes were to be concentrated in a channel, some permafrost thaw/degradation would be expected. This is denoted by a thawed (red) layer of colluvium and a small lens of thawed bedrock in **Figure 2.1-8**. The Groundwater Model does not include the active layer or thin colluvial veneer that covers the property. In the Water Balance Model, pit overflow is treated as a surface discharge and it either reports to a settling pond or creek (if ponds are decommissioned).

In the Post-Closure Groundwater Model, all pit lakes located on permafrost are assumed to form through taliks. Accordingly, all pit lakes are assigned as constant heads, with hydraulic conductivity of the underlying permafrost adjusted upwards to simulate unfrozen, shallow bedrock. Boundary conditions used in the Post-Closure model are listed in **Table 2.1-3**.

The boundary conditions implemented in the Post-Closure Groundwater Model do not correspond to a specific year of the Water Balance Model. All pit lakes reach their spill point (elevations listed in **Table 2.1-3**) within 22 years of cessation of mining. Thermal modeling of permafrost under the pit lakes has not been undertaken, professional experience from other sites indicates through taliks could form within years to decades (K. Jones, pers. communication). Therefore, the Post-Closure Groundwater Model loosely represents an unspecified year after Year 34. By running the model in steady state mode, the model simulates that the drainages are in equilibrium with the hydrogeological changes brought about by pit lakes, through talik formation and waste rock placement. Realistically, these changes could take many years, if not decades to manifest. Therefore, the simulation is more likely to represent a long-term, rather than near-term, average Post-Closure condition.

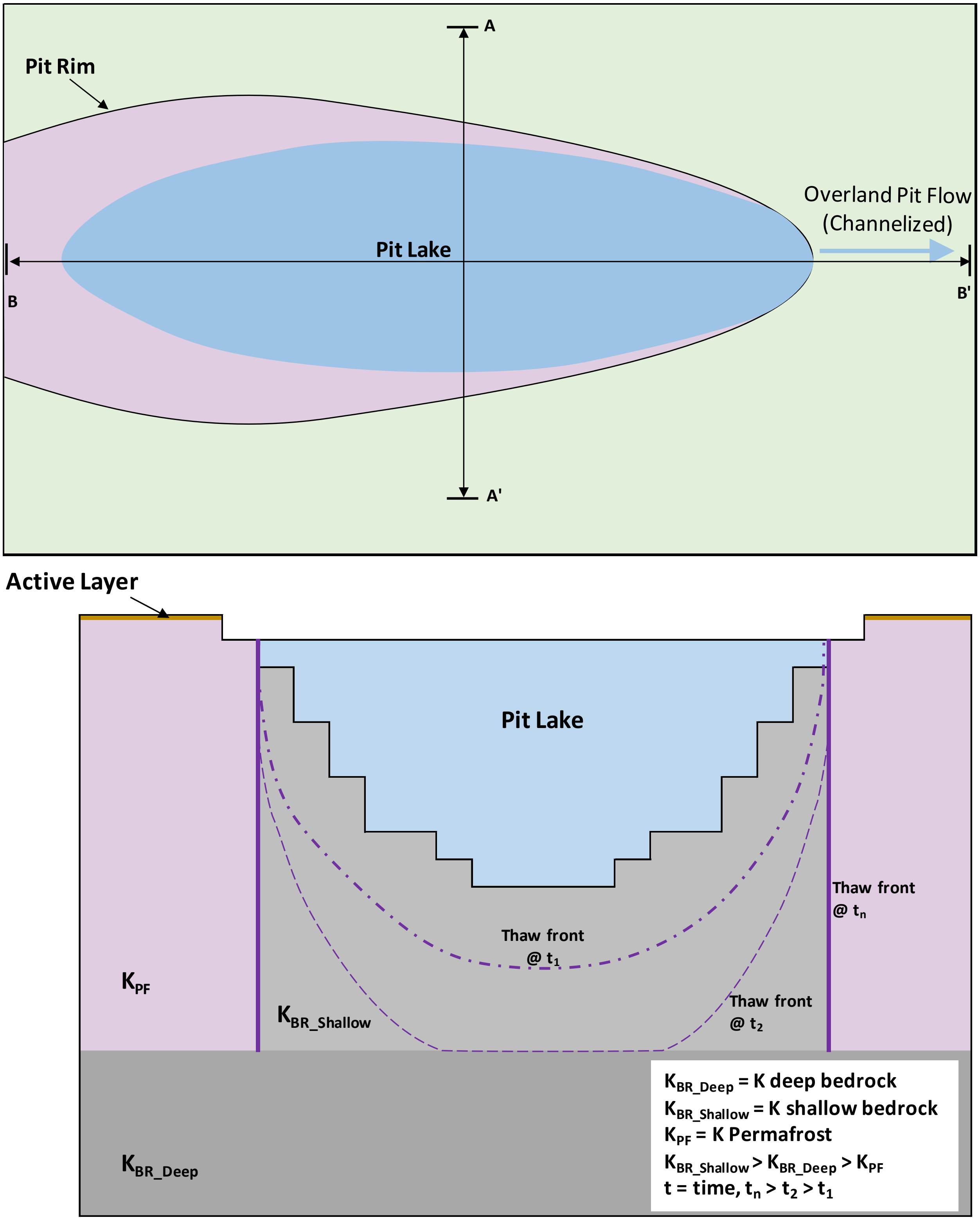


Figure 2.1-7 Cross-section A-A' of a pit lake on permafrost

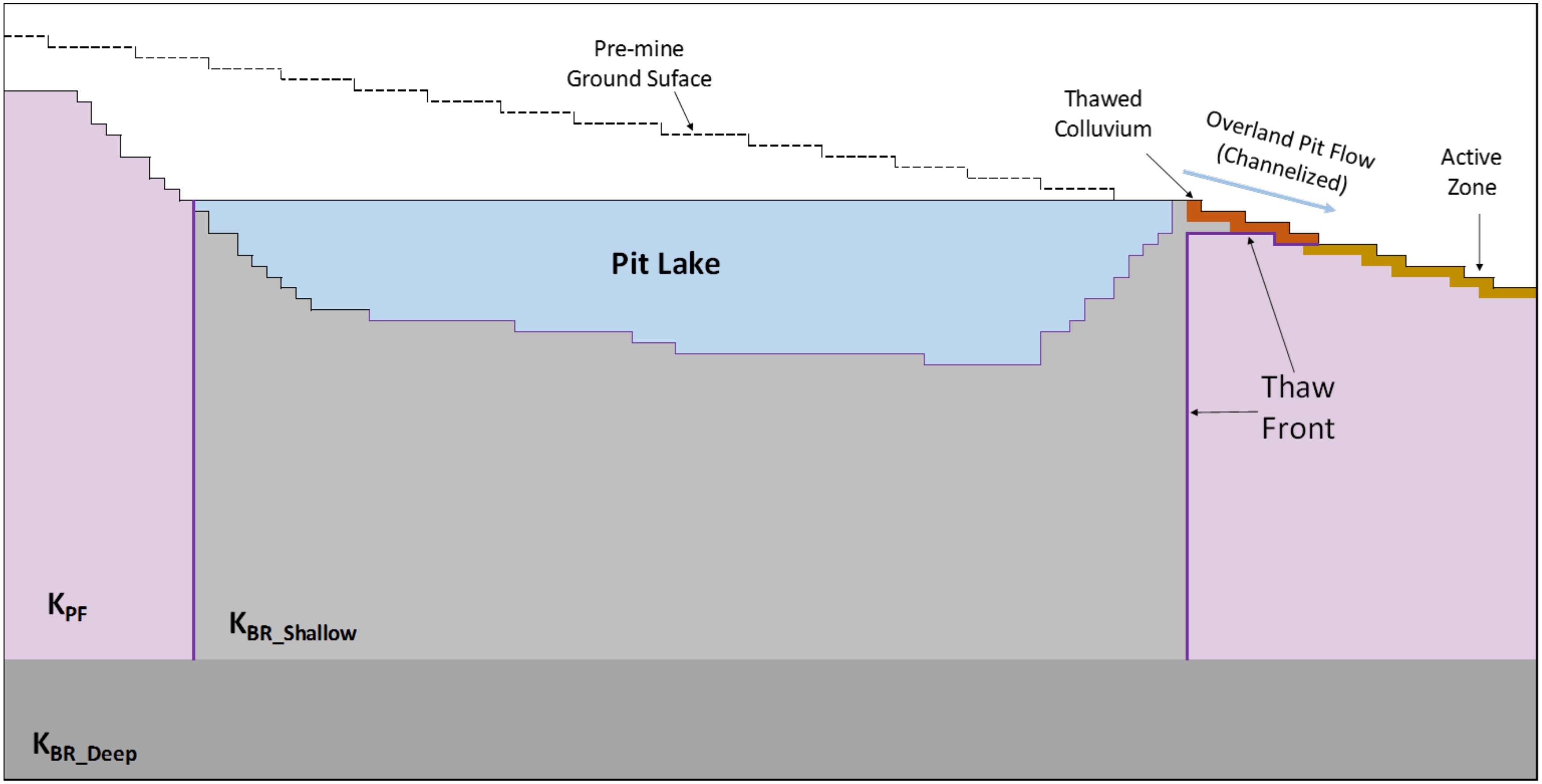


Figure 2.1-8 Cross-section B-B' of a pit lake on permafrost.

2.1.4 GROUNDWATER MODEL SENSITIVITY ANALYSIS

A detailed sensitivity analysis was undertaken the previous version of the Groundwater Model which employed a slightly different calibrated baseline model and an older version of the mine plan. In the sensitivity analysis, several parameters were independently varied to the same degree in the baseline, Operation Phase and Post-closure models (**Table 2.1-4**). Resultant changes to model calibration and predictions were documented (**Appendix 7-B-1**). While the mine plan has changed, it is felt that the sensitivities performed using the previous model are still informative. An abridged sensitivity analysis has been undertaken with the revised Groundwater Model. The key objective of the sensitivity analyses is to identify which parameters significantly alter model predictions and are not constrained by the calibration process. These parameters would be classified as 'Type IV' parameters according to the classification scheme developed by Brown (1996) and presented by Wels et al. (2012).

Table 2.1-4 Summary of Sensitivity Analysis Performed on Groundwater Model

Model Version	Parameter	Parameter Changes Applied	Effect on Model Calibration (Low - L, Medium - M, High - H)	Effect on Model Predictions (Low - L, Medium - M, High - H)
1	Recharge on Permafrost	Increased by 2-5 mm/yr Decreased to 0 mm/yr	L	L
	Permafrost K	Increased 10-fold Decreased 2-fold	L	L
	Recharge on unfrozen areas	Increased 30% Decreased 30%	M	M
	General Creek Structure K	Increased 10-fold Decreased 10-fold	M	M
	Highest K units (Latte Ck Structure, CC-1.0 Colluvium, Independence Ck Fault)	K Increased 10-fold in all units coincidentally K Decreased 10-fold in all units coincidentally	M	M
	Shallow Bedrock K	Increased 2-fold, 5-fold Decreased 2-fold	H	H
	Deep Bedrock K	Increased 5-fold Decreased 5-fold	H	H
	T3 Structure K	Increased 10-fold Decreased 10-fold	L	H
	Latte Structure K	Increased 10-fold Decreased 10-fold	L	H
2	Permafrost K zone (MW14-05)	Increased 10-fold Decreased 10-fold	M	L
	Permafrost K zone (MW16-01)	Increased 10-fold Decreased 10-fold	M	L
	Permafrost K zone (MW15-07)	Increased 10-fold Decreased 4-fold	M	H
	Taliks under Pit Lakes	Taliks not simulated (permafrost intact)	n/a	H

Note:
K = hydraulic conductivity

The sensitivity analysis using the original model revealed that the hydraulic conductivity of the T3 structure and Latte structure (highlighted rows in **Table 2.1-4)** fall under the 'Type IV' category. The sensitivity analysis involving the Latte Structure hydraulic conductivity revealed that this structure has a pronounced effect on flows into and out of the Latte pit and the baseflows to Halfway Creek. When the Latte Structure hydraulic conductivity is increased, Post-Closure baseflow to HC-2.5 is predicted to increase and inflows to Supremo 1 and Supremo 2 pits are affected. The T3 Structure hydraulic conductivity has a profound effect on the pit lake-groundwater interactions at the Supremo 1 and Supremo 2 pit lakes. Increasing the T3 Structure hydraulic conductivity induced more flow from the topographically higher Supremo 2 pit lake to the Supremo 1 pit lake. The primary practical influence of this parameter is the final likely pit lake elevation in the Supremo 2 pit lake.

The sensitivity analysis on the updated Groundwater Model tested model sensitivity to the three, newly introduced, higher permeability permafrost areas in the vicinity of MW14-05, MW16-01 and MW15-07 (**Section 2.1.1.2**). Overall, changes to the hydraulic conductivity areas have a moderate impact on the baseline calibration (primarily on heads), but in the case of the zones at MW14-05 and MW16-01, there was little impact on model predictions. Changes to the zone near MW15-07 understandably has a large impact on predictions as this area intercepts the SU5N and SU5S pit complex. Increasing the hydraulic conductivity of this area causes more flow between the SU5S and SU5N/SU4N pits - so much flow that it would be unlikely for pit lakes to even form in the SU5N/S pits in the first place. Despite the increase in flows between the pits, the seepage losses from the pits to the creeks are very similar to the base case. In fact, the base case predicts slight more flow from the pit complex to Latte and YT-24.

The final sensitivity performed with the updated Groundwater Model revolved around the assumption of through taliks forming beneath pit lakes. A run was performed whereby permafrost underneath the pit lakes was kept intact (with associated low hydraulic conductivity and a general head boundary condition simulating the lake). The reviewer may recall that the previous version of the model assumed permafrost being present at closure as a base case. The inter-pit flows, particularly from Supremo 5S, are significantly lower when no taliks are assumed to form; however, seepage losses from the pits to the creeks are essentially the same. Pit seepage losses to Halfway Creek and Latte Creek are more or less unchanged, but the model simulating through taliks (i.e. the new base case) predicts higher flow to YT-24 (0.5 L/s vs 0.1 L/s).

The GoldSim Water Balance/Water Quality Model does not incorporate any of the Groundwater Model sensitivity analyses, rather, it captures variability in surface water flow, groundwater flow and interflow through incorporation of climate variability (i.e. wet year versus dry year) and long-term climate trends (i.e. climate change). The Water Balance Model is set up to run cycle through a 28-year synthetic climate record 28 times, such that for any one year, 28 flow scenarios are computed. A longer term climate record (84 years) onto which conservative climate trends can be imposed was created by combining three consecutive 28-year records. While multiple realizations are simulated, the Water Balance Model has been run as a single, expected but conservative case. Therefore, Groundwater Model predictions based on the calibrated model and not the sensitivity runs have been used to inform the Water Balance Model and the change analysis provided herein.

2.1.5 GROUNDWATER MODEL LIMITATIONS

The Groundwater Model used to determine Project changes to groundwater quantity has been developed based on robust hydrogeological and hydrological data sets. Having undergone a rigorous calibration process, the baseline Groundwater Model is believed to provide an reasonable representation of baseline groundwater conditions onto which Project changes can be estimated.

The reader should be aware that the mine models have been run in steady-state mode, which assumes that changes to groundwater are realized within the time period modeled. In reality, changes to groundwater quantity are expected to take years to decades to manifest. Therefore, the mine models present a conservative estimate of the magnitude of the Project changes to groundwater for the snapshots in time indicated. In their current form (i.e. as steady-state models), the Groundwater Model cannot predict timing or reversibility of these changes.

While the Post-Closure Groundwater Model accounts for thaw of permafrost under pit lakes, changes to the permafrost regime resulting from climate change are not simulated. Climate change, however, has been incorporated into the GoldSim Water Balance Model (**Appendix 12-C**). The lake levels produced in the GoldSim model take into account projected trends in precipitation and evaporation and are informed by pit leakage rates estimated from the Groundwater Model. While the Groundwater Model represents a useful, broad stroke instrument for determining baseflow volumetric changes, the GoldSim Water Balance and Water Quality Model remains the most appropriate tool for quantifying Project changes to surface water quantity and quality in the near- and long-term time frame.

2.2 GROUNDWATER QUALITY ANALYSIS

A semi-quantitative approach has been used to assess Project changes to groundwater quality. This approach entails a comparison between measured groundwater quality and estimates of future pit lake quality and waste rock source terms. Pit lake water quality has been computed using the combined Water Balance/Water Quality Model developed in GoldSim (**Appendix 12-C)**. The analysis deriving source terms for waste rock is presented in **Appendix 12-D** (**Geochemical Characterization Report**). The comparison identifies groundwater quality parameters of interest which may become elevated due to the influence of mine development and mine contact water. Further, resulting effects on surface water quality are assessed within the surface water quality assessment (**Section 12**) and inform future groundwater monitoring.

2.2.1 BACKGROUND

Project changes to groundwater flow and quality are assessed through the integration of the numerical Groundwater Model (**Appendix 7-B-1**) into the Water Balance Model and Water Quality Model (**Appendix 12-C**). The Water Balance Model is a detailed interpretation of the mine and water management plans, with consideration of climate, hydrometric, and hydrogeological data collected for the Project. The Water Balance Model was developed in GoldSim and is the foundation upon which the Water Quality Model has been developed. The Water Balance Model encodes the mine plan and all associated major Project footprints, water management activities (i.e., pit dewatering, diversions, storage and release of water (and loads) from the sediment control ponds, and associated mitigation measures. The Water Balance Model assesses mine development from Operation Phase through Post-closure. Further, the Water Balance Model encompasses an 84-year duration and incorporates foreseeable changes to climate, including increased temperature, precipitation, and evaporation.

The Water Quality Model incorporates flow (Water Balance Model) and water quality components into a single interface. The temporal and spatial scope of the Water Quality Model is defined by the Water Balance Model and is thus identical to the Water Balance Model. The Water Quality Model expands upon the linkages and flow rates defined in the Water Balance Model. Water quality components include background measures of water quality and geochemical source term predictions for mine affected disturbances (**Appendix 12-C**). The water quality model conservatively mixes these water quality components and produces water quality predictions for nodes internal to the mine footprint (e.g., open pit lakes) and at nodes in the receiving surface water environment (e.g., receiving creeks). The linkages between groundwater quality indicators (pit lakes and WRSF seepage) are defined by the drainages in which the associated facilities are constructed. These linkages are encoded into the water balance and water quality model such that Project effects on groundwater quality described herein are incorporated into the overall assessment of Project effects on surface water quality and associated receptor VCs. Linkages between groundwater quality indicators and receiving drainages are summarized for pit lakes and WRSF seepage in **Table 2.2-1**.

For the purpose of estimating surface water quality impacts, the Water Balance Model assumes that all seepage from the Alpha WRSF reports to the Alpha Pond and all seepage from the Beta WRSF is used as process water. The backfilled Kona pit is not anticipated to interact with groundwater due the pit bottom remaining well above groundwater and within permafrost, and backfill practices promoting freezing of infiltrating water. Accordingly, the Groundwater Model has been configured to reflect zero recharge to groundwater from these facilities.

Table 2.2-1 Linkages Between Pit Lake and WRSF Facilities and Catchments by Mine Phase

Catchment	Pit Lake									WRSF
	S3W	SU3N	SU4S	SU4N	SU5N	SU5S	SU2	SU1	Latte	Double Double
End of Operations										
Halfway Creek	x	x		x		x	x		x	
YT-24 Drainage					x					
Latte Creek			x					x	x	x
Post-Closure (Long-Term)										
Halfway Creek	x	x		x					x	
YT-24 Drainage		x			x	x				
Latte Creek			x			x		x	x	x

Note: x **=** linkage present where flow is expected to exceed 0.01 L/s

Pit lake water quality represents the integrated effect of pit development and, where applicable, waste rock backfill. Open pits may also receive diverted runoff as dictated by surface water management, including the routing of post-draindown seepage from the HLF to the Latte Pit at Post-Closure. Pit flooding commences after pit development is complete, which coincides with the final stages of Operation Phase for all pits except Kona and Double Double (**Figure 2.2-1**). Pit lake water may recharge groundwater flowpaths and is an indicator of potential Project changes to groundwater quality.

The backfilled Double Double pit presents an opportunity for waste rock seepage to interact with the groundwater system. The pit is advanced near the baseline water table (below the water table in some areas) and infiltration may occur through the waste rock. Therefore, seepage from the backfilled Double Double pit is considered an indicator of Project changes to groundwater quality and is compared to background groundwater quality in this assessment.

Water quality predictions from mid-Operations through Post-Closure mine phases were generated for a Base Case, an Upper Case and an Upper Geochemistry Case in the Water Quality Model (see **Section 4** of **Appendix 12-C**). All of the model cases are based upon data generated from 28 different climate realizations such that variable flow conditions have been applied to each mine year. Changes to temperature and precipitation resulting from climate change are incorporated into all modelled scenarios. The three water quality cases are summarized as follows:

- The Base Case incorporates base case geochemical source terms for mine-related inputs (**Appendix 12-D**), expected flow conditions and conservative assumptions regarding climate change. Monthly base case water quality predictions are calculated from the mean of the model output generated from 28 different climate realizations applied to each mine year.
- The Upper Case incorporates the same input as the Base Case; however, monthly water quality predictions are calculated from the 95th percentile model output generated from 28 different climate realizations applied to each mine year.
- The Upper Geochemistry Case incorporates upper case geochemical source terms for mine-related inputs (**Appendix 12-D**), expected flow conditions and conservative assumptions regarding climate change. Monthly Upper Geochemistry Case water quality predictions are calculated from the mean of the model output generated from 28 different climate realizations applied to each mine year.

The Base Case is considered to represent a robust expected case and, as such, forms the basis for the surface water quality effects assessment (**Appendix 12-B**) and the groundwater quality change analysis presented in Section 4.4.

Figure 2.2-1 Timeline for Development and Management of Open Pits

2.2.2 GROUNDWATER QUALITY ASSESSMENT METHODS

The comparison of background groundwater quality to mine contact water is limited to parameters of concern (POCs) in the receiving environment. Parameters of concern have been identified in the surface water quality effects analysis (**Appendix 12-B**). Briefly, Base Case water quality model estimates in receiving waters over the entire mine life were compared to their corresponding long-term water quality objective, or to the short-term objective if a long-term objective has not been derived. Water quality parameters with concentrations predicted to fall below their objective were screened out of the assessment for residual effects. Water quality objectives are determined by CCME (2004, 2014) and the BC Ministry of Environment (2015a,b) to be protective of freshwater aquatic life receptors, the most sensitive users in the Project area. Parameters exceeding their objectives were flagged for further consideration in the surface water quality assessment and groundwater analysis. The list of POCs includes nitrate, dissolved aluminum, and total metals arsenic, copper, chromium, uranium and zinc (**Section 4.4.2.2**).

Maximum concentrations of POCs for pit lakes and selected waste rock seepage, taken from Operation Phase onward, have been compared to mean baseline groundwater quality for the receiving groundwater. The receiving groundwater system is classified by lithology and the mean groundwater quality for all samples from that rock type are used, even if the samples were collected from wells outside of the mineralized area. POC concentrations which exceed mean groundwater concentrations are flagged for the consideration in the surface water quality assessment (**Section 12**) and for future groundwater monitoring.

2.2.3 GROUNDWATER QUALITY ASSESSMENT LIMITATIONS

The groundwater quality assessment is limited to a semi-quantitative evaluation of POCs which may become elevated in groundwater as a result Project development and associated mine contact water. The assessment identifies POCs for further evaluation in the surface water quality assessment as well as future monitoring and environmental management plans. Future groundwater POC concentrations have not been predicted in the Groundwater Model (which simulates flow only); but chemical loads carried via groundwater flowpaths are integrated into the water quality model and are incorporated into the surface water quality effects assessment (**Section 12**).

3.0 EXISTING CONDITIONS

The information in this section establishes the context for the analysis of Project-related changes to the Groundwater IC. This includes the regulatory and legislative structure that will guide the Project assessment and licensing processes, as well as guidance and technical standards that inform the work undertaken to support the relevant applications. Also relevant is the information collected as part of the Traditional Knowledge surveys conducted on the Proponent's behalf in support of the Project Proposal. Several sources of scientific information were referenced to assist characterization of the existing groundwater conditions in the LSA.

Baseline groundwater data collection in the LSA was initiated in 2013, with additional programs in 2014 and 2015 establishing an extensive groundwater monitoring network in the LSA. The hydrogeological data collected through these field programs, along with baseline data collected for other disciplines, has enabled a detailed characterization of the groundwater conditions on site. This, in turn, has been used to inform the development of a numerical Groundwater Model, through which Project-related changes to groundwater are assessed (**Section 4**).

3.1 REGULATORY CONTEXT

Table 3.1-1 lists the federal and territorial regulatory and legislative instruments that apply to Project groundwater; it includes a list of guidelines and technical standards that have informed the work supporting the groundwater assessment. The most relevant provincial guidelines and guidance documents have been referenced in lieu of available territorial documentation.

The guidelines listed in **Table 3.1-1** have been considered in various stages of the analysis. As discussed in **Section 2.1.1**, the groundwater model was constructed and calibrated in accordance with recommended industry practice. Groundwater quality samples were collected in accordance with recommended industry practice (**Sections 3.2.3, 3.3.3**). While not applied to groundwater quality data, guidelines for the protection of freshwater aquatic life have been used in the initial screening of water quality parameters of concern in the receiving environment (**Appendix 12-B**), and it is these parameters of concern which have been further scrutinized in the groundwater quality analysis (**Section 2.2.2, 4.4.2.2**).

Table 3.1-1 Summary of Applicable Legislation and Regulatory Frameworks for Groundwater, Coffee Gold Mine

Territorial Acts and Regulations	Citation	Description
Public Health and Safety Act Camp Sanitation (CO 1961/38) Drinking Water Regulation (OIC 2007/139) Sewage Disposal Systems Regulation (OIC 1999/82)	RSY 2002 c. 176	Provides legal framework for protection of public health, including creation of health officers. Stipulates camp drainage must be arranged to prevent pollution of any water supply, lake, stream or watercourse. Regulates location, testing and general assessment of drinking water systems including those derived from groundwater. Regulates discharge of sewage.
Environment Act Contaminated Sites Regulation (O.I.C. 2002/171)	RSY 2002 c.76	Defines of contaminated sites (of which groundwater may be comprised), stipulates contaminated site restoration or rehabilitation and sets forth generic numerical soil and water standards. Legislates reporting of spills and protection orders related to spills.
Quartz Mining Act Quartz Mining Land Use Regulation (OIC 2003/64)	SY 2003 c. 14	Act outlines process for undertaking mining activities in Yukon, including issuance of Quartz Mining License. Regulation provides operating conditions for management of solid waste, hazardous materials, fuel storage, spills, waste rock.
Waters Act Waters Regulation (OIC 2003/58)	SY 2003 c. 19	Waters Act establishes the Yukon Water Board, issuer of water use licenses that ensure that appurtenant uses of water or deposits of waste do not adversely affect other users. Waters Regulation defines water management areas, classification of undertakings and licensing criteria for mines.
Federal Acts and Regulations	**Citation**	**Description**
Canada Water Act	RSC 1985 c. C-11	Provides for the sustainability and ongoing productivity of commercial, recreational, and Aboriginal fisheries. Regulates activities that may affect fish or fish habitat, including modification of flows, alteration or destruction of habitat, and deposition of deleterious substances.
Canadian Environmental Protection Act, 1999 Environmental Emergency Regulations (SOR/2003-307) Interprovincial Movement of Hazardous Waste and Hazardous Recyclable Material Regulations (SOR/2002-301) Storage Tank Systems for Petroleum Products and Allied Petroleum Products Regulations (SOR/2008-197)	S.C. 1999 c. 33	Regulations defining hazardous wastes and how and where they are stored and transported. Sets out requirements for transport manifests and emergency plans. Sets out requirements for size, operation and maintenance of storage tank systems as well as requirements for leak detection and release reports.
Fisheries Act Metal Mining Effluent Regulations (SOR/2002-222)	R.S.C. 1985 c.F-14	Provides the framework for the joint federal-provincial management of Canada's water resources, including discharge of wastes into water, including groundwater.

Guidelines	Citation	Description
BC Ministry of Environment (BC MOE) British Columbia Approved Water Quality Guidelines.	BC MOE 2015a	Establishes water quality guidelines (criteria) for a range of parameters to protect various water uses, including drinking water and fresh water aquatic life.
BC Ministry of Environment (BC MOE) British Columbia Working Water Quality Guidelines for British Columbia	BC MOE 2015b	Draft water quality guidelines (criteria) for a range of parameters to protect various water uses, including drinking water and fresh water aquatic life.
Canadian Water Quality Guidelines for the Protection of Aquatic Life.	CCME 2014	Establishes water quality guidelines for a range of parameters to protect freshwater aquatic life.
Canadian Water Quality Guidelines for the Protection of Aquatic Life: Phosphorus	CCME 2004	Establishes water quality guidelines for phosphorus to protect freshwater aquatic life.
British Columbia Field Sampling Manual, BC Ministry of Water, Land and Air Protection Water, Air and Climate Change Branch	Clark 2002	Provides guidance for groundwater sampling, including protocol, methods, equipment, and quality control.
Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities, BC Ministry of Environment, Water Protection & Sustainability Branch	Wels et al. 2012	Provides guidelines for numerical groundwater flow and transport modelling to identify and assess the impacts of proposed natural resource projects.

3.2 BACKGROUND INFORMATION AND STUDIES

3.2.1 TRADITIONAL KNOWLEDGE

The Proponent has undertaken an extensive engagement and consultation process, as defined under section 50 (3) of the *Yukon Environmental and Socio-economic Assessment Act* (YESAA). Through this consultation process, they have compiled a database of Traditional Knowledge specific to the Project area. First Nations are aware that groundwater presents a pathway for contamination from a mine to reach the receiving environment and impact fish and vegetation, and they have borne witness to other mining operations in the territory causing impacts on the environment (Bates and de Roy 2014). The database, however, does not contain quantitative information on groundwater occurrence or quality in the Project area. For this reason, Traditional Knowledge has not been incorporated into the discussion of baseline groundwater conditions in the Project area.

3.2.2 SCIENTIFIC AND OTHER INFORMATION

In addition to the relevant baseline studies conducted for the Project outlined in **Section 3.2.3** below, other sources of information have informed the groundwater assessment. This information can be grouped broadly into two categories: Yukon quartz mining applications to YESAB and the Yukon Water Board (and associated follow-up documentation) and scientific literature on groundwater systems.

In the first category, the nearby Casino Project serves as recent and relevant example of a YESAB Project Proposal where groundwater conditions have been characterized and impacts assessed. Given its close proximity (approximately 30 km southwest of the Project), there is potential for there to be similarities between the Casino and Project groundwater systems. The Casino Project Proposal was not reviewed as a source of technical information, per se, but rather an example of regulatory feedback on a groundwater assessment. Reviewers from Natural Resources Canada and Environment Canada recognized that permafrost affects groundwater flow and both expressed concerns regarding the presentation of permafrost information in the submission and how it was considered in the numerical Groundwater Model. While the need to consider permafrost became apparent in light of outcomes from the 2014 hydrogeology program, the reviewer comments on the Casino submission reinforced efforts to thoughtfully incorporate and present its thickness and distribution in the Groundwater Model.

Scientific literature has been reviewed in preparation of this assessment. The literature review covers three themes: (i) characterization and behavior of groundwater systems influenced by permafrost; (ii) effects of climate change on these systems, and (iii) impacts of road construction on groundwater systems. Scientific papers, reports and texts on these topics are listed below:

- Bosson, E., J.O. Selroos, M. Stigsson, L.G. Gustafsson, and G. Destouni. 2013. Exchange and pathways of deep and shallow groundwater in different climate and permafrost conditions using the Forsmark site, Sweden, as an example catchment, Hydrogeology Journal (2013) 21: 225–237.

- Forman, R.T. and Alexander, L.E. (1998) Roads and their major ecological effects. Annual Review of Ecology and Systematics 29, 207-231.
- Daigle, P. 2010. A summary of the environmental impacts of roads, management responses, and research gaps: A literature review. BC Journal of Ecosystems and Management 10(3):65–89.
- Gruber, S. and W. Haeberli. 2007. Permafrost in steep bedrock slopes and its temperature-related destabilization following climate change, Journal of Geophysical Research, Vol. 112.
- Jaquet, O., R. Namar, P. Siegel, and P. Jansson. 2012. Groundwater flow modelling under ice sheet conditions in Greenland (Phase II), 2012 report for Swedish Nuclear Fuel & Waste Mgt Co.
- Kane, D.L. and J. Stein. 1983. Field evidence of groundwater recharge in interior Alaska. In proceedings of Permafrost: 4th International Conference. National Academy Press, Washington, D.C., pp. 572-577.
- Kane, D.L.; K. Yoshikawa and J.P. McNamara. 2013. Regional groundwater flow in an area mapped as continuous permafrost, NE Alaska (USA), Hydrogeology Journal, Vol. 21.
- Lemieux, J.M., E.A. Sudicky, W.R. Peltier and L. Tarasov. 2008. Dynamics of groundwater recharge and seepage over the Canadian landscape during the Wisconsinian glaciation, J. Geophys. Res., 113.
- Lorax. 2015. Climate Change Projections for Coffee Creek Region, Yukon. Lorax memo to Kaminak Gold Corp., September, 2015. Bense, V. F., G. Ferguson, and H. Kooi (2009), Evolution of shallow groundwater flow systems in areas of degrading permafrost, Geophys. Res. Lett., 36
- Niu, G.-Y., and Z.-L. Yang. 2006. Effects of frozen soil on snowmelt runoff and soil water storage at a continental scale, Journal of Hydrometeorology, 7, 937–952.
- Pike, R.G., T.E. Redding, R.D. Moore, R.D. Winker and K.D. Bladon (editors). 2010. Compendium of forest hydrology and geomorphology in British Columbia. B.C. Min. For. Range, For. Sci. Prog., Victoria, B.C. and FORREX Forum for Research and Extension in Natural Resources, Kamloops, B.C. Land Manag. Handb. 66.
- Scheidegger, J. 2013. Impact of permafrost dynamics on Arctic groundwater flow systems with application to the evolution of spring and lake taliks. Ph.D thesis University of East Anglia December 2013.
- Smerdon, B.D., T.E. Redding, and J. Beckers. 2009. An overview of the effects of forest management on groundwater hydrology. B.C. J. Ecosyst. Manag. 10(1):22–44.
- Smith, S.L, V.E. Romanovsky, A.G. Lewkowicz ,C.R. Burn , M. Allard ,G.D. Clow, K. Yoshikawa and J. Throop. 2010. Thermal State of Permafrost in North America: A Contribution to the International Polar Year, Permafrost and Periglac. Process. 21: 117–135
- Streicker, J., 2016. Yukon Climate Change Indicators and Key Findings 2015. Northern Climate Exchange, Yukon Research Centre, Yukon College, 84 p.
- Teles, V., E. Mouche, C. Grenier, D. Regnier, J. Brulhet and H. Benaberrahmane. 2008. Modeling Permafrost Evolution and Impact on Hydrogeology at the Meuse/Haute-Marne Sedimentary Site (Northeast France) During the Last 120,000 Years. In Extended Abstracts for 9th International Conference on Permafrost, Fairbanks, AK, 2008.

- Walvoord, M. A., C. I. Voss, T. P. Wellman. 2012. Influence of permafrost distribution on groundwater flow in the context of climate-driven permafrost thaw: Example from Yukon Flats Basin, Alaska, United States, Water Resour. Res., Vol. 48.
- Walvoord, M. A. and R.G. Striegl. 2007. Increased groundwater to stream discharge from permafrost thawing in the Yukon River basin: Potential impacts on lateral export of carbon and nitrogen. Geophysical Research Letters, Vol. 34.
- Weaver, J. 2003. Assessment of sub-permafrost groundwater conditions at the Red Dog Mine, Alaska. In Permafrost Phillips, Springman and Arenson (eds).
- Woo, M.K. 2012. Permafrost Hydrology. Springer, Heidelberg, 563 pp

3.2.3 Baseline Studies Conducted during the Project's Feasibility Program

Table 3.2-1 summarizes all the field and desktop studies that have informed the Project groundwater assessment. The list of studies includes targeted hydrogeological field programs performed in the groundwater LSA and subsequent numerical model analysis of the groundwater RSA. **Table 3.2-1** also includes geotechnical programs which have provided additional instrumentation of the groundwater system. The geomorphological and permafrost assessments listed in the table have also informed the conceptualization of the groundwater system and how it is represented in the numerical Groundwater Model.

Detailed results of the Lorax hydrogeological investigations are discussed in the baseline hydrogeological assessment of the Project, included as **Appendix 7-A** to this document. Other interim memos generated from these programs are listed in **Table 3.2-1**.The results from the EBA Tetra Tech (EBA TT) and SRK hydrogeological field programs have been incorporated into the baseline analysis with the SRK hydrogeological investigation report included as an appendix to the report. The hydrogeological field investigations have typically involved some form of drilling, hydraulic testing and/or instrument installation. The methods and scope of these programs are discussed in **Chapter 3 of Appendix 7-A**. Hydraulic testing methods are similar across the investigations and are consistent with industry standards. The different consulting groups also used similar, industry-standard methods for installation of instrument types common to the different field programs.

The first of the field hydrogeological field programs was conducted under the direction of EBA TT in 2013. The program piggybacked on the exploration program and packer tested diamond drillholes advanced in Supremo and Latte mineralization areas. The program included the installation of four single point vibrating wire piezometers (VWPs) which provided first indications of groundwater levels on site.

Table 3.2-1 Summary of Desktop and Field Studies Related to Groundwater

Study Name	Study Purpose, Duration and Spatial Boundaries
AECOM Geomorphological Study	August 2011 field program consisting of ground traverses, helicopter flyovers and test pitting. Production of a detailed geomorphological map series of entire Proponent claim area based on air photo interpretation and field reconnaissance. Maps includes areas of inferred permafrost presence. • AECOM, 2012. Geomorphological mapping and landscape model development for Strategic Soil geochemical sampling at the Coffee Gold Project, Yukon Territory. Report prepared for Kaminak Gold Corporation, March 2012.
EBA Tetra Tech Preliminary Hydrogeological Program 2013	Summer/Fall 2013. Preliminary hydrogeological data collection to support a detailed work plan for the hydrogeological baseline assessment. Four vibrating wire piezometer (VWP) installations in the proposed Supremo and Latte pit footprint areas. Hydraulic testing performed. • EBA Tetra Tech, 2014. Hydrogeological Data Collection, Coffee Gold Project, Yukon. Report submitted to Kaminak Gold Corp. March 2014.
Knight Piésold Geotechnical Program 2014	Summer 2014. Geotechnical site investigations and laboratory testing to assess: (1) subsurface conditions within the footprint of the HLF (former valley fill location; refer to Section 2.9 of the Project Proposal) and stockpile and (2) the geotechnical engineering material properties of the materials encountered. Two thermistor strings installed in previously proposed valley HLF footprint area. • Knight Piésold, 2015. Kaminak Gold Corporation Coffee Gold Project: Report on Feasibility Study Level Geotechnical Investigations, March 12, 2015.
Lorax Baseline Hydrogeology Program Phase 1 (2014)	Summer/Fall 2014. First phase of a detailed hydrogeological baseline program establishing groundwater sampling locations in and around proposed pits. Conventional monitoring wells and thermistor in pit area; thermistor/VWP in formerly proposed HLF area. Hydraulic testing performed. Wells developed/sampled following installation. • Lorax, 2016a. Coffee Gold Mine Baseline Hydrogeological Assessment. Report to Kaminak Gold. (**Appendix 7-A**) • Lorax, 2014. Coffee Creek Hydrogeological Drilling Program – Program Summary, Memorandum to Kaminak Gold dated October 17th, 2014.
Lorax Baseline Hydrogeology Program Phase 2 (2015)	March 2015. Second phase of a detailed hydrogeological baseline program establishing ground conditions, permafrost conditions and groundwater pressures downgradient of waste facilities ahead of a larger, subsequent field program. Thermistor/VWP installations in Halfway and Latte creeks. • Lorax, 2016a. Coffee Gold Mine Baseline Hydrogeological Assessment. Report to Kaminak Gold. (**Appendix 7-A**) • Lorax, 2015b. 2015 Phase I Baseline Hydrogeology Field Program – Program Summary, Memorandum to Kaminak Gold dated April 7th, 2015.
Lorax Baseline Hydrogeology Program Phase 3 (2015)	May/June 2015. Third phase of a detailed hydrogeological field program establishing remaining groundwater quality, groundwater pressure and ground temperature stations downgradient of mine site facilities. Thermistor/VWP; Westbay groundwater monitoring systems (sub-permafrost groundwater); shallow monitoring wells (overburden). Hydraulic testing performed. • Lorax, 2016a. Coffee Gold Mine Baseline Hydrogeological Assessment. Report to Kaminak Gold. (**Appendix 7-A**)

Study Name	Study Purpose, Duration and Spatial Boundaries
SRK Hydrogeological and Geotechnical Programs (2015)	June/July 2015. Hydrogeological investigation targeting principal structures that will be mined in the open pits, combined with a geotechnical program characterizing permafrost in proposed Mine Site facility footprint areas. Thermistor/VWP installations in proposed WRSFs and stockpile locations. Hydraulic testing performed. • SRK Consulting, 2015. Hydrogeologic Investigations Report Coffee Project, Yukon, December 18, 2015. (contained in **Appendix 7-A**) • SRK Consulting, 2016. 2015 Geotechnical Field Investigation Report Coffee Gold Project, Yukon, Canada, January 4, 2016.
Palmer Geohazard Assessment	August 2015. Field reconnaissance of Mine Site and NAR for assessing terrain stability and geohazards. Geohazard and terrain map produced based on field data from Palmer, AECOM, aerial photography plus other sources. Informs EBA Tetra Tech permafrost map in areas of overlap. • Palmer Environmental Consulting Group, 2016. Terrain Stability and Hazard Mapping for the Coffee Gold Project. Report to Kaminak Gold Corporation dated March 19, 2016. (**Appendix 11-A**)
EBA Tetra Tech Permafrost Study 2015	September 2015. Field program to map permafrost conditions at the Mine Site. Included measurement of active layer thickness, test pits, helicopter flyovers. Map of permafrost occurrence within the mine area produced using aerial photographs, author field reconnaissance plus data from Lorax, SRK and Palmer. • EBA Tetra Tech, 2016a. Permafrost and Related Geohazard Mapping within the Coffee Mine Site Area. Technical memorandum to Kaminak Gold Corp. dated February 16, 2016. • EBA Tetra Tech, 2016b. Environmental Baseline Report, Mine Area: Surficial Geology, Permafrost, and Terrain Stability. Report to Kaminak Gold Corp. dated May 2, 2016. (**Appendix 11-A**)
Lorax 2015 Hydrogeology Baseline Monitoring	Four separate Mine Site groundwater sampling events conducted between late May and mid-September, 2015. October 2015 site visit undertaken to download all instrumentation. • Lorax, 2017b. Coffee Gold Mine Baseline Hydrogeological Assessment. Report to Goldcorp. (**Appendix 7-A**)
Lorax Baseline Hydrogeology Program Phase 4 (2016)	August/September 2016. Fourth phase of hydrogeological field program involving the installation of a thermistor/VWP string and Westbay system on the northeast margin of the HLF. • Lorax, 2017b. Coffee Gold Mine Baseline Hydrogeological Assessment. Report to Goldcorp (**Appendix 7-A**, sub-appendix P-1)
Tetra Tech Canada Permafrost Study 2016	Fall 2016. Drilling and test-pitting program characterizing shallow permafrost conditions in areas of proposed mine infrastructure. • Tetra Tech Canada, 2017. Fall 2016 Geotechnical Investigation Data Report., Coffee Mine Site, Coffee Gold Project. Draft Report (Issue for Review) to Goldcorp, February 17th, 2017.
Hydrology and Climate Baseline Data Collection	Multiple programs conducted at the Mine Site first by Access Consulting and then by Lorax which collected baseline hydro-meteorological data between 2010 and 2015. • Lorax, 2017a. Coffee Gold Mine: Hydro-meteorology Baseline Report. Report to Goldcorp. (**Appendix 8-A**).
Lorax Groundwater Modeling	October 2015-March 2017. Numerical groundwater modeling of Mine Site informed by data collected in the above studies. Simulation of baseline groundwater conditions and predictions of project impacts on groundwater system. • Lorax, 2017. Coffee Gold Mine Numerical Groundwater Model Report. Report to Kaminak Gold. (**Appendix 7-B-1**)

The EBA TT program informed the design of detailed hydrogeological baseline program conducted by Lorax over three phases in 2014 and 2015. The purpose of the Lorax programs was to collect additional hydraulic testing data downgradient of mine facilities and establish long-term groundwater sampling locations. The 2014 phase of the baseline program was limited to upland areas in and around planned pits and the formerly proposed valley-fill HLF footprint. This program included installation of conventional (stand-pipe) monitoring wells, a stand-alone thermistor string and a combination thermistor/VWP string. A number of challenges encountered during the 2014 program prompted the re-evaluation of instrumentation planned for the remaining locations. A modified approach was applied in the 2015 programs which included installation of state-of-the-art Westbay technology for monitoring sub-permafrost groundwater. The first Lorax program in March 2015 focussed on constraining water levels and permafrost and overburden thickness in two valley areas so that materials and methods could be refined ahead of a large field program advanced in May-June of the same year. The second 2015 Lorax drilling program established remaining monitoring installations downgradient of mine facilities. Sampling of all 2014 and 2015 monitoring wells and Westbay installations occurred on four occasions between May and September of 2015. Groundwater samples were collected from conventional monitoring wells according to standards outlined in Clark (2002), while Westbay wells were sampled in compliance with training provided by Westbay technicians.

SRK conducted a hydrogeological investigation specifically focussed on hydraulic testing of pit structures. This supplemented a site-wide geotechnical assessment where stand-alone thermistors and combination thermistor/VWP strings were established in the footprint areas of proposed mine infrastructure. The hydraulic testing program and installations augmented characterization of groundwater in the LSA.

AECOM conducted a geomorphological assessment of the entire Coffee Property in 2011. This assessment included field reconnaissance (ground traverses, flyovers, test pitting) and air photo interpretation. The final product was a map series which provided guidance for suitability of soil sampling for geochemical sampling (for exploration). Areas of frozen and unfrozen ground were indicated on the map series.

EBA TT conducted a baseline study characterizing surficial geology, permafrost and terrain stability over a smaller area centred on the proposed mine footprint. This program included a comprehensive review of literature, previous studies at the site, air photo interpretation and field reconnaissance in September 2015. Updated maps of frozen and unfrozen ground were produced for their study area. The EBA permafrost maps also incorporate observations of frozen ground collected by Palmer group in 2015 (**Appendix 11-A**) who were tasked with documenting terrain characteristics and drainage conditions along the road route. The AECOM and EBA TT maps of frozen ground were ultimately combined (and extrapolated) such that permafrost could be mapped in the Groundwater Model (**Section 2.1.1**). The extents of permafrost were slightly revised by Tetra Tech (formerly EBA TT) in 2017 in light of results from a 2016 detailed field investigation of (shallow) permafrost conditions in proposed infrastructure footprint areas (Tetra Tech, 2017). Changes to the permafrost distribution in the upper Halfway Creek catchment were brought forward into the groundwater model.

The remaining studies informing the groundwater assessment of Project constitute the meteorological and hydrological baseline data collection undertaken initially by Access Consulting and later by Lorax. The reader is referred to **Appendix 8-A** and its supporting sub-appendices for a detail discussion of these programs. Precipitation and creek baseflow estimates informed the calibration of the numerical Groundwater Model developed for the Project (**Appendix 7-B-1**).

3.3 Description of Existing Conditions

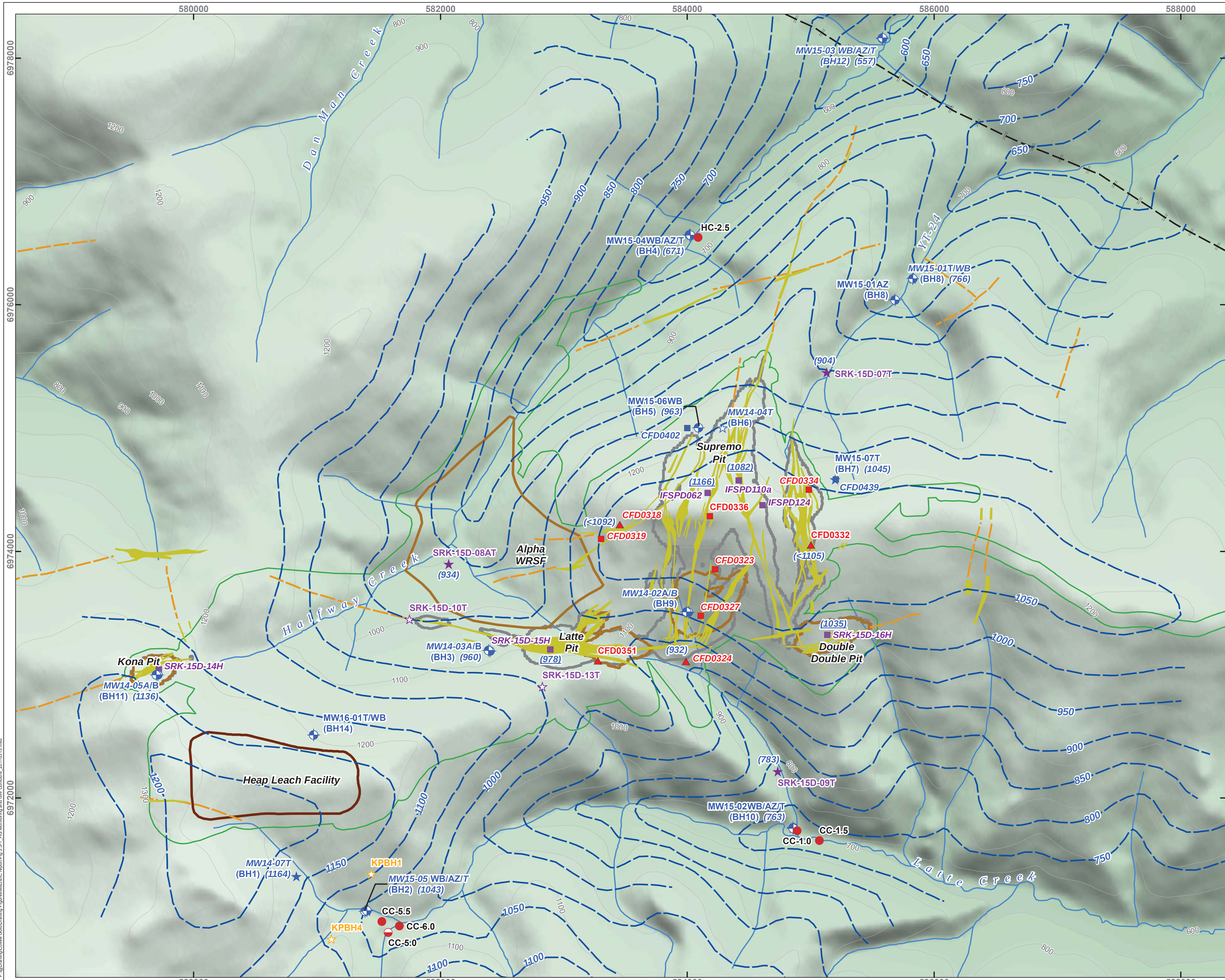
The following discussion describes existing conditions for groundwater quantity and quality in the LSA. No other projects or activities in the area are believed to be perceptibly influencing the groundwater system in the LSA or RSA. Groundwater extraction in the RSA is limited to a single drinking water well at the former Project exploration camp flanking the Yukon River. As such, the existing conditions described herein reflect the natural variation of the groundwater system. As indicated in the Yukon Climate Change Indicators and Key Findings 2015 Report (Streicker 2016), climate change is affecting and will continue to affect the hydrologic regime in Yukon, and this includes groundwater flow patterns. The period of record for hydrogeological data in the LSA is of insufficient duration to infer climate change driven trends. In general, groundwater systems in discontinuous permafrost areas are an understudied topic and information related to impacts from climate change is limited. A literature review on this topic has been undertaken, and where possible, inferences made on potential Project groundwater trends. The findings of the literature review are summarized in **Section 3.5**.

3.3.1 Instrumentation

The hydrogeological/geotechnical field programs described in the previous section have established a robust hydrogeological monitoring network in, adjacent to and downstream of proposed major mine units in the LSA (**Figure 3.3-1**). The instrumentation is summarized as follows:

- Eleven conventional monitoring wells (five wells less than 10 metres (m) deep; six wells between 150 and 220 m deep)
- Seven individual Westbay installations monitoring groundwater 10 to 286 m deep
- Seven stand-alone thermistor strings ranging from 25 to 300 m deep
- Four stand-alone VWP installations ranging from 120 to 185 m deep, and
- Ten combination VWP/thermistor installations ranging from 52 to 268 m deep.

Completion details of the conventional monitoring wells, Westbay systems and thermistor/VWP installations are provided in **Table 3.3-1**, **Table 3.3-2** and **Table 3.3-3**, respectively.



COFFEE GOLD MINE

Hydrogeological Monitoring Network and June 2015 Bedrock Groundwater Head Contours

Legend

(1082) Static water level elevation June-July 2015
(1082) WL measured during packer test (July2015)
Italics in name indicates location was hydraulic tested (packer or airlift)

- Surface WQ Monitoring Stations
- Surface and Hydrology Monitoring Stations
- Monitoring Well — *AZ = active zone, WB = Westbay, A = deep conventional (200+m), B = shallow coventional (150+m), T = thermistor/VWP, BH = original drill pad name*
- Thermistor (Lorax 2014)
- Thermistor (KP 2014)
- Thermistor (SRK 2015)
- Thermistor/VWP (Lorax 2015)
- Thermistor/VWP (SRK 2015)
- Vibrating Well Piezometer (VWP) (EBA 2013)
- Packer Tests (EBA 2013)
- Packer/Slug Tests (Lorax 2014)
- Packer Tests (SRK 2015)
- Groundwater Equipotential Contour
- Lineament (Huscroft, 2002)
- Drilled Structure
- Inferred Structure
- Project Footprint
- Highway
- Municipality

Proposed Infrastructure

- WRSF/Backfill
- Open Pit
- Heap Leach Pad Base

N

1:30,000

0 400 800 1,200
Meters

NAD 1983 UTM Zone 7N

Page Size: 11" x 17"

Figure 3.3-1	Date: Mar 21, 2017	Drawn by: GM	Reviewed: JS/LF

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Table 3.3-1 Summary of Conventional Monitoring Well Installations at the Coffee Project

Pad ID	Units[4]	BH5	BH5	BH9	BH9	BH3	BH3	BH11	BH11	BH7	BH7	BH8-AZ	BH10-AZ	BH12-AZ	BH04-AZ	BH02-AZ
Mine ID		CFD-0419	CFD-0434	CFD-0428	CFD-0418	CFD-0432	CFD-0442	CFD-0444	CFD-0455	CFD-0453	CFD-0463	CFR-0982	CFR-0998	CFR-0986	CFR-0992	CFR-0995
Monitoring Well ID		MW14-01A	MW14-01B	MW14-02A	MW14-02B	MW14-03A	MW14-03B	MW14-05A	MW14-05B	MW14-06A	MW14-06B	MW15-01AZ	MW15-02AZ	MW15-03AZ	MW15-04AZ	MW15-05AZ
Mine Area[1]		N. Supremo Pit	N. Supremo Pit	S. Supremo Pit	S.Supremo Pit	Latte Pit	Latte Pit	Kona Pit	Kona Pit	N. Supremo Pit	N. Supremo Pit	N. Supremo Pit	S. Supremo Pit	N. Supremo Pit & Alpha WRSF D/S	N. Supremo Pit & Alpha WRSF D/S	Heap Leach D/S
Drainage		Halfway Ck	Halfway Ck	Latte Tributary	Latte Tributary	Halfway Ck	Halfway Ck	Halfway Ck	Halfway Ck	YT-24	YT-24	YT-24	Latte Tributary	Halfway Ck	Halfway Ck	Latte
Installation Status		collapsed	collapsed	open/frozen	open/frozen	open	open	open	open	collapsed	collapsed	Functioning	Functioning	Functioning	Functioning	Functioning
Drilling Start Date		20-Aug	01-Sep	25-Aug	19-Aug	29-Aug	08-Sep	12-Sep-14	17-Sep-14	16-Sep	22-Sep-14	05-May-15	24-May-15	09-May-15	14-May-15	20-May-15
Drilling Completion Date		27-Aug	03-Sep	28-Aug	24-Aug	05-Sep	12-Sep	16-Sep-14	19-Sep-14	21-Sep	24-Sep-14	05-May-15	24-May-15	09-May-15	14-May-15	20-May-15
Easting[2]	m	583,995	583,995	583,994	584,008	582,401	582,388	579,708	579,695	585,202	585,195	585,683	584,858	585,583	584,016	581,387
Northing[2]	m	6,975,003	6,975,003	6,973,508	6,973,507	6,973,191	6,973,197	6,972,998	6,972,999	6,974,583	6,974,583	6,976,038	6,971,754	6,978,157	6,976,566	6,971,079
Ground Elevation[2]	m	1177.0	1177.0	1029.5	1030.9	1097.6	1095.2	1268.5	1270.3	1183.0	1183.3	809.8	737.2	557.9	672.5	1068.9
Estimated depth to bedrock	m bgs			5	5							4.7	8.8	not encountered	5.1	4.8
Casing Depth	m bgs	38.6	5.0	6.0	6.5	6.0	5.0	2.0	2.0	9.0	9.0	n/a	n/a	n/a	n/a	n/a
Casing ID/OD	inch											4.5 OD	4.5 OD	4.5 OD	4.5 OD	4.5 OD
Casing Method												ODEX	ODEX	ODEX	ODEX	ODEX
Borehole ID	inch	3.78	3.78	3.78	3.78	3.78	3.78	3.78	3.78	4.83	4.83	4.5	4.5	4.5	4.5	4.5
Borehole Method[2]		DDH/HQ	DDH/HQ	DDH/HQ	DDH/HQ	DDH/HQ	DDH/HQ	DDH/HQ	DDH/HQ	DDH/PQ	DDH/PQ	ODEX	ODEX	ODEX	ODEX	ODEX
Borehole Drilled Depth	m bgs											5.9	10.3	5.6	5.7	5.7
Borehole Measured Depth	m bgs	212.0	160.0	197.0	200.0	198.5	152.0	220.5	179.5	215.7	164.4	5.9	10.3	5.5	5.7	5.7
Stickup (Steel Surface Casing)	m ags	0.46				0.37	0.48		-				0.68	0.6		
Installations																
Start Date		27-Aug-14	03-Sep-14	27-Aug-14	23-Aug-14	05-Sep-14	08-Sep	16-Sep-14	17-Sep-14	21-Sep-14	24-Sep-14	05-May-15	24-May-15	09-May-15	14-May-15	20-May-15
Completion Date		27-Aug-14	04-Sep-14	28-Aug-14	24-Aug-14	07-Sep-14	12-Sep	17-Sep-14	20-Sep-14	22-Sep-14	24-Sep-14	05-May-15	24-May-15	09-May-15	14-May-15	20-May-15
2" PVC Install		Sch. 40	Sch. 40	Sch. 40	Sch. 40	Sch. 40	Sch. 80	Sch. 80	Sch. 80	Sch. 80	Sch. 80	Sch. 40	Sch. 40	Sch. 40	Sch. 40	Sch. 80
stickup (PVC)	m	0.5	0.3	1.0	1.3	1.0	0.9	1.1	0.7	0.9	1.0	0.6	0.7	0.7	0.5	0.6
Screened lithology		Gneiss	Gneiss / Schist	Hydrothermally altered rock/Crackle Breccia	Biotite Feldspar Schist	Biotite Feldspar Schist & Shear Zone	Biotite Feldspar Schist with Weak Zone	Granite	Granite	Mixed Felsic Gneiss	Gneiss with some occasional schist	Colluvium	Colluvium	Colluvuim / Alluvium	Colluvium	Colluvium
bottom of screen (installed)	m bgs	210.3	160.0	195.5	150.8	198.5	150.6	220.5	179.2	220.5	164.4	4.9	10.3	5.5	5.7	4.7
top of screen	m bgs	201.1	150.3	186.4	144.7	189.4	144.5	202.2	160.8	202.2	155.3	1.8	2.3	2.5	2.7	1.7
bottom of screen (installed)	m asl	966.7	1017.0	834.0	880.1	899.1	944.6	1048.0	1091.1	962.6	1018.9	804.9	726.9	552.4	666.8	1064.1

Pad ID	Units[4]	BH5	BH5	BH9	BH9	BH3	BH3	BH11	BH11	BH7	BH7	BH8-AZ	BH10-AZ	BH12-AZ	BH04-AZ	BH02-AZ
Mine ID		**CFD-0419**	**CFD-0434**	**CFD-0428**	**CFD-0418**	**CFD-0432**	**CFD-0442**	**CFD-0444**	**CFD-0455**	**CFD-0453**	**CFD-0463**	**CFR-0982**	**CFR-0998**	**CFR-0986**	**CFR-0992**	**CFR-0995**
Monitoring Well ID		**MW14-01A**	**MW14-01B**	**MW14-02A**	**MW14-02B**	**MW14-03A**	**MW14-03B**	**MW14-05A**	**MW14-05B**	**MW14-06A**	**MW14-06B**	**MW15-01AZ**	**MW15-02AZ**	**MW15-03AZ**	**MW15-04AZ**	**MW15-05AZ**
top of screen	m asl	975.9	1026.7	843.2	886.2	908.2	950.7	1066.3	1109.5	980.9	1028.1	807.9	735.0	555.4	669.8	1067.2
depth to bottom (measured)	m btoc			196.8	148.4	199.8	154.2	221.6	180.4	217.1	165.5	5.2	10.7	6.2	6.3	5.3
bottom of sand	m bgs	210.3	160.0	196.1	150.8	198.5	151.1	220.5	179.5	215.7	164.4	5.9	10.3	5.6	5.7	5.7
top of sand	m bgs	199.6	149.0	180.4	142.4	184.0	140.2	192.3	162.5	197.1	151.5	0.8	0.8	1.0	1.7	0.6
bottom of sand	m asl	966.7	1017.0	833.5	880.1	899.1	944.1	1048.0	1090.8	967.3	1018.9	803.8	726.9	552.3	666.8	1063.1
top of sand	m asl	977.4	1028.0	849.1	888.5	913.6	955.0	1076.2	1107.8	985.9	1031.8	809.0	736.4	556.9	670.8	1068.2
bottom of bentonite chips/pellets	m bgs	199.6	149.0	180.4	142.4	184.0	140.2	192.3	158.9	197.1	151.5	0.8	0.8		1.7	
top of bentonite chips/pellets	m bgs	193.9	144.9	176.5	140.3	172.0	136.7	190.3	156.1	194.7	149.1	0.0	0.0		0	
bottom of grout	m bgs	41.5	144.9	176.5	140.3	172.0	140.2	190.3	156.1	194.7	149.1			1.0		
top of grout	m bgs	0.0	92.0			0.5	1.2	0.9	3.0	5.4	5.5			0.0		

Notes:

1. D/S = downstream; WRSF =waste rock storage facility, N = north, S = South.
2. Measured by RTK (real time kinematic) (UTM NAD83 Zone 7). All holes drilled vertical.
3. DDH – diamond drill hole, HQ = borehole diameter of 96.0 mm; PQ = borehole diameter of 122.6 mm.
4. m bgs – metres below ground surface, m asl – metres above sea level, m btoc = metres below top of casing.

Table 3.3-2 Summary of Westbay System Installations at the Coffee Project

Pad ID	Units[4]	BH8	BH10	BH12	BH4	BH2	BH5	BH14
Mine ID		CFR-0977	CFR-0997	CFR-0987	CFR-0993	CFR-0996	CFR-0999	CFR1206
Westbay ID		MW15-01WB	MW15-02WB	MW15-03WB	MW15-04WB	MW15-05WB	MW15-06WB	MW16-01WB
Mine Area[1]		N. Supremo Pit D/S	S. Supremo Pit D/S	Alpha WRSF & N. Supremo Pit D/S	Alpha WRSF & N. Supremo Pit D/S	Heap Leach Facility D/S	North Supremo	Heap Leach Facility D/S
Drainage		YT-24	Latte Tributary	Halfway Ck	Halfway Ck	Latte Ck	Halfway Ck	Halfway Ck
Consultant		Lorax	Lorax	Lorax	Lorax	Lorax	Lorax	Lorax
Easting[2]	m	585,829	584,858	585,581	584,024	581,402	584,090	580,971
Northing[2]	m	6,976,212	6,971,758	6,978,165	6,976,566	6,971,084	6,975,003	6,972,511
Ground Elevation[2]	m	803.6	737.1	557.9	671.5	1067.7	1184.9	1,203.9
Estimated depth to bedrock	m bgs	not logged	9.0	4.3	2.4	5.5	1.2	5
Surface Casing Depth	m bgs	21.3	10.1	10.4	7.0	6.7	162/ 203.6	7.0
Surface Casing ID/OD	inch	5.07/ 5.5	5.07/ 5.5	5.07/ 5.5	5.07/ 5.5	5.07/ 5.5	4.06/4.63	5.07/ 5.5
Protective Casing Depth[3]	m bgs	78	none	33.5	30.4	56.3	203.6	68.4
Protective Casing ID/OD[3]	inch	3.06/3.5 (HQ)	(-)	3.06/3.5 (HQ)	3.06/3.5 (HQ)	3.06/3.5 (HQ)	3.06/3.5 (HQ)	3.06/3.5 (HQ)
Borehole ID	inch	4.5	4.5	4.5	4.5	4.5	4.5" to 200.3/3.8" to 293	4.5
Borehole Depth	m bgs	116.72	66.2	99.52	61.1	82.9	291.8	120.1
Completion Date		05-May-15	24-May-15	05-Dec-15	19-May-15	22-May-15	05-Jun-15	03-Oct-16

Pad ID	Units[4]	BH8	BH10	BH12	BH4	BH2	BH5	BH14
Mine ID		CFR-0977	CFR-0997	CFR-0987	CFR-0993	CFR-0996	CFR-0999	CFR1206
Westbay ID		MW15-01WB	MW15-02WB	MW15-03WB	MW15-04WB	MW15-05WB	MW15-06WB	MW16-01WB
Westbay Primary Sampling Zones								
Zone 1	m bgs	109-112	60.8-65.7	93.9-96.7	54.5-56.7	77.9-82.7	280.7-285.9	110.1-113.8
Zone 1 Lithology		Felsic Gneiss	Biotite Schist	Gneiss	Felsic Gneiss	Fresh Granite	Mixed Mafic Gneiss	Fresh Granite
Zone 2	m bgs	82-87.5	25.7-30.9	81.7-86.9	38.1-40.2	63.6-67.3	247.1-250.8	85.7-89.4
Zone 2 Lithology		Mixed Mafic Gneiss	Schist with chlorite alteration	Mixed Felsic Gneiss	Mixed Felsic Gneiss	Oxidized Granite	Mixed Felsic Gneiss	Fresh Granite
Zone 3	m bgs	-	-	46.7-50.3	-	-	238.0-243.2	71.4-73.5
Zone 3 Lithology		-	-	Mixed Mafic Gneiss	-	-	Mixed Felsic Gneiss	Fresh Granite
Zone 4	m bgs	-	-	-	-	-	221.2-226.4	66.8-70.5
Zone 4 Lithology		-	-	-	-	-	Mixed Felsic Gneiss	Fresh Granite
Zone 5	m bgs	-	-	-	-	-	210.6-220.3	-
Zone 5 Lithology		-	-	-	-	-	Mixed Felsic Gneiss	-

Notes:

1. D/S = downstream; WRSF =waste rock storage facility.
2. Measured by RTK (real time kinematic) (UTM NAD83 Zone 7). All holes drilled vertical.
3. Protective steel casing (typically HQ rods) left in hole to blind off permafrost zones.
4. m bgs – metres below ground surface, m asl – metres above sea level

Table 3.3-3 Thermistor and Vibrating Wire Piezometer Installations at the Coffee Project. Note that two 2016 thermistor installations by Tetra Tech are not included in this table.

Pad ID	Units[1]	BH1	BH2	BH4	BH6	BH7	BH8	BH10	BH12	BH14											
Mine ID		CFD-0462	CFR-0994	CFR-0990	CFD-0439	CFD0596	CFR-0941	CFR-0948	CFR-0983	CFR1137	CFD-0600	CFD-0595	CFD-0599	CFD-0593	CFD-0594	CFD-0451	CFD-0454	CFD-0318	CFD-0324	CFD-0332	CFD-0351
Station ID		MW14-07T	MW15-05T	MW15-04T	MW14-04T	MW15-07T	MW15-01T	MW15-02T	MW15-03T	MW16-01T	SRK-15D-07	SRK-15D-08	SRK-15D-09	SRK-15D-10T	SRK-15D-13T	KPBH-01	KPBH-04	CFD-0318	CFD-0324	CFD-0332	CFD-0351
Mine Area[2]		HLF D/S	HLF D/S	Alpha WRSF & N. Supremo Pit D/S	N. Supremo Pit	N. Supremo Pit	N. Supremo Pit D/S	S. Supremo Pit D/S	Alpha WRSF & N. Supremo Pit D/S	HLF D/S	N. Supremo Pit D/S	Alpha WRSF	S. Supremo Pit D/S	HLF D/S	ROM Stockpile	HLF D/S	HLF D/S	W. Supremo	S. Supremo	E. Supremo	Latte Pit
Drainage		Latte Ck	Latte Ck	Halfway Ck	Halfway Ck	YT-24	YT-24	Latte Tributary	Halfway Ck	Halfway Ck	YT-24	Halfway Ck	Latte Tributary	Halfway Ck	Latte/Halfway Ck Divide	Latte Ck	Latte Ck	Halfway Ck	Latte Tributary	Latte Ck.	Latte Ck.
Consultant		Lorax	Lorax	Lorax	Lorax	Lorax/SRK	Lorax	Lorax	Lorax	Lorax	SRK	SRK	SRK	SRK	SRK	KP	KP	EBA	EBA	EBA	EBA
Easting[3]	m	580,832	581,406	584,027	584,287	585,198	585,826	584,855	585,584	580,988	585,124	582,057	584,734	581,752	582,825	581,438	581,115	583,450	583,993	585,000	583,275
Northing[3]	m	6,971,365	6,971,083	6,976,568	6,975,001	6,974,583	6,976,210	6,971,756	6,978,168	6,972,503	6,975,415	6,973,891	6,972,215	6,973,455	6,972,904	6,971,384	6,970,857	6,974,220	6,973,100	6,974,050	6,973,115
Ground Elevation[3]	m	1,156.3	1,067.1	670.9	1,185.8	1,183.1	803.9	737.1	557.7	1203.7	948.9	925.1	784.3	1008.2	1136.9	1122.7	1121.3	1233.0	956.0	1246.6	1120.5
Azimuth[4]	degrees	0	125	40	0	0	0	0	39	0	0	0	0	0	0	0	0	175	280	275	0
Dip[4]	degrees	-90	-80	-80	-90	-90	-90	-90	-80	-90	-90	-90	-90	-90	-90	-90	-90	-45	-45	-45	-65
Borehole ID	inch	3.78	4.5	4.5	3.78	3.78	4.5	4.5	4.5	4.5 / 3.5	3.78	3.78	3.78	3.78	3.78	3.78	3.78	2.99	2.99	2.99	2.99
Drilling Method[5]		DDH/HQ	RC	RC	DDH/HQ	DDH/HQ	DC	DC	RC	RC	DDH/HQ	DDH/HQ	DDH/HQ	DDH/HQ	DDH/HQ	DDH/HQ	DDH/HQ	DDH/NQ2	DDH/NQ2	DDH/NQ2	DDH/NQ2
Borehole Depth	m AH	124.7	83.8	53.3	301	268	90.5	34.4	98.14	189.3	149	149	101	26	26	50	50	200	200	200	200
Installation Date		24-Sep-14	20-May-15	14-May-14	12-Sep-14	06-Jul-15	24-Mar-15	26-Mar-15	10-May-15	27-Aug-16	09-Jul-15	03-Jul-15	07-Jul-15	Jun/Jul - 15	Jun/Jul-15	Sep-14	Sep-14	Jul-13	Aug-15	Aug-15	Oct-13
Logging Freq.		4 hrs	4 hrs	1 hr	4 hrs	1 hr	4 hrs	4 hrs	4 hrs	12 hrs	12 hrs	12 hrs	12 hrs	12 hrs	12 hrs	12 hrs	12 hrs	1 hr	1 hr	1 hr	4 hrs
Thermistor Sensors																					
Therm 1-1	v. m bgs	0.6	0.75	1.7	3.1	7	0.5	1.2	0.53	0.3	0.7	1	1.1	0.5	0.5	-1.5	-1.5	-	-	-	-
Therm 1-2	v. m bgs	1.4	1.5	13.8	26.1	8	1.3	3.2	1.2	0.9	2.2	4	2.6	3.0	3.0	0.0	0.0	-	-	-	-
Therm 1-3	v. m bgs	2.1	2.2	26.1	51.1	11	2.0	5.2	1.9	1.8	3.7	9	4.1	5.5	5.5	0.8	0.8	-	-	-	-
Therm 1-4	v. m bgs	2.9	3.0	38.1	76.1	26	2.8	10.2	2.6	3.8	5.2	16	7.1	8.0	8.0	1.5	1.5	-	-	-	-
Therm 1-5	v. m bgs	3.7	3.7	50.3	101.1	41	3.5	15.2	3.4	7.8	6.7	26	10.1	13.0	13.0	2.3	2.3	-	-	-	-
Therm 1-6	v. m bgs	4.4	4.5	-	126.1	56	4.3	24.2	4.1	12.8	8.2	41	15.1	15.5	15.5	3.1	3.1	-	-	-	-
Therm 1-7	v. m bgs	5.1	5.2	-	151.1	86	5.0	-	4.9	20.0	9.7	61	22.1	18.0	18.0	4.6	4.6	-	-	-	-
Therm 1-8	v. m bgs	17.4	17.2	-	176.1	106	12.3	-	16.9	29.7	12.7	81	32.1	20.5	20.5	7.6	7.6	-	-	-	-
Therm 1-9	v. m bgs	29.7	29.5	-	201.1	121	19.8	-	28.9	56.6	17.7	101	47.1	23.0	23.0	13.7	13.7	-	-	-	-
Therm 1-10	v. m bgs	42.5	41.8	-	226.1	136	27.3	-	41.0	89.5	24.7	121	77.1	25.5	25.5	19.8	19.8	-	-	-	-
Therm 1-11	v. m bgs	54.9	54.0	-	251.1	151	34.8	-	53.1	119.5	34.7	-	97.1	-	-	29.0	29.0	-	-	-	-
Therm 1-12	v. m bgs	67.4	66.3	-	276.1	166	42.3	-	65.1	149.5	49.7	-	-	-	-	38.1	38.1	-	-	-	-
Therm 1-13	v. m bgs	80.0	78.4	-	301.1	181	49.8	-	77.2	179.5	69.7	-	-	-	-	48.8	48.8	-	-	-	-
Therm 1-14	v. m bgs	-	-	-	-	-	-	-	-	-	89.7	-	-	-	-	-	-	-	-	-	-
Therm 1-15	v. m bgs	-	-	-	-	-	-	-	-	-	109.7	-	-	-	-	-	-	-	-	-	-

Pad ID	Units[1]	BH1	BH2	BH4	BH6	BH7	BH8	BH10	BH12	BH14											
Mine ID		CFD-0462	CFR-0994	CFR-0990	CFD-0439	CFD0596	CFR-0941	CFR-0948	CFR-0983	CFR1137	CFD-0600	CFD-0595	CFD-0599	CFD-0593	CFD-0594	CFD-0451	CFD-0454	CFD-0318	CFD-0324	CFD-0332	CFD-0351
Station ID		MW14-07T	MW15-05T	MW15-04T	MW14-04T	MW15-07T	MW15-01T	MW15-02T	MW15-03T	MW16-01T	SRK-15D-07	SRK-15D-08	SRK-15D-09	SRK-15D-10T	SRK-15D-13T	KPBH-01	KPBH-04	CFD-0318	CFD-0324	CFD-0332	CFD-0351
Therm 1-16	v. m bgs	-	-	-	-	-	-	-	-	-	129.7	-	-	-	-	-	-	-	-	-	-
Therm 2-1	v. m bgs	100.0	-	-	-	-	-	-	-	-1.2	-	-	-	-	-	-	-	-	-	-	-
VWP1	v. m bgs	124.36	55.4	38.8	-	239.0	76.0	33.9	48.8	97.5	103.6	103.6	99.7	-	-	-	-	118	178	117	184
VWP2	v. m bgs	-	81.4	51.62	-	267.8	89.1	-	94.7	131.5	149.2	149.2	-	-	-	-	-	-	-	-	-

Notes:

1. m AH – metres along hole, v. m bgs – vertical metres below ground surface
2. HLF – heap leach facility, WRSF – waste rock storage faclity, D/S – downstream, U/S – upstream
3. Measured by RTK (real time kinematic) (UTM NAD83 Zone 7).
4. Dip and azimuth are estimated. Hole survey not performed.
5. DDH – diamond drill hole, HQ = borehole diameter of 96.0 mm, PQ = borehole diameter of 122.6 mm, NQ2 = borehole diameter of 75.8 mm; RC – reverse circulation open hole; DC- direct circulation open hole.

3.3.2 GROUNDWATER QUANTITY

This section discusses physical groundwater data collected at the Mine Site during the field programs outlined in **Section 3.2**. The discussion starts with a brief overview of the physiography and surface and bedrock geology, and then covers study results related to permafrost characterization, hydraulic testing results and water level time trends and gradients.

Data presented in this section have undergone various forms of quality assurance/quality control. Hydraulic testing data have been vetted to ensure results only from saturated test interval are presented; analyses have also been verified by multiple parties. Unusual hydraulic gradients recorded at vibrating wire piezometers have been field verified to ensure sensors are correctly identified. Unusual thermistor data has been flagged as suspicious and not used for subsequent analysis.

3.3.2.1 Physiography and Geology

The Project is located in the northern Dawson Range of the Yukon-Tanana terrane, forming a moderate plateau that escaped Pleistocene glaciation. The landscape has evolved through erosional and periglacial processes. The topography generally consists of rounded ridges with incised v-shaped valleys (AECOM 2012). Elevations across the Mine Site range from 400 to 1,500 m above sea level with the majority of the Mine Site above the tree line and supporting short shrubby vegetation (JDS 2016).

A surficial geology map of the Coffee Creek area has been compiled by the Geological Survey of Canada (Huscroft 2002) with further refinement across the Proponent property provided by AECOM (2012). Both maps identify colluvium as the most widespread surficial material within the Mine Site. Bedrock exposures on the property are rare (< 5%) (AECOM 2012). The ridgetops and upper slopes are generally dominated by in-situ residual soils and colluvium derived from weathering of bedrock. The colluvial material is variable, and typically contains mixtures of gravels, sands and silts with organic materials in the upper 0.1 to 0.2 m layer. The ridgetop soils are up to approximately 1.8 m deep and generally ice-poor. The thickness of the strongly weathered bedrock is variable but is generally less than a metre. Colluviation is greatest on lower slopes, which tend to be steeper than upper slopes. Dominant colluvial processes include slope creep, debris slides and minor rock fall.

The thickest colluvium encountered during the 2015 Lorax drilling programs was on the order of 10 m at MW15-02T/WB/AZ at the foot of the Latte Tributary and 17 m at MW15-01T on a hillside above the YT-24 drainage (**Figure 3.3-1**). The colluvium at MW15-02T has been classified by AECOM (2012) as a poorly drained apron of colluvial complex (xzsC1a:p). It was found to be unfrozen and saturated around 6 m below ground surface. The colluvium at MW15-01T is has been classified as poorly drained colluvial veneer modified by solifluction (xszCv-S:p-i) (AECOM 2012). A landslide headscarp is observed uphill from this location (EBA 2016b).

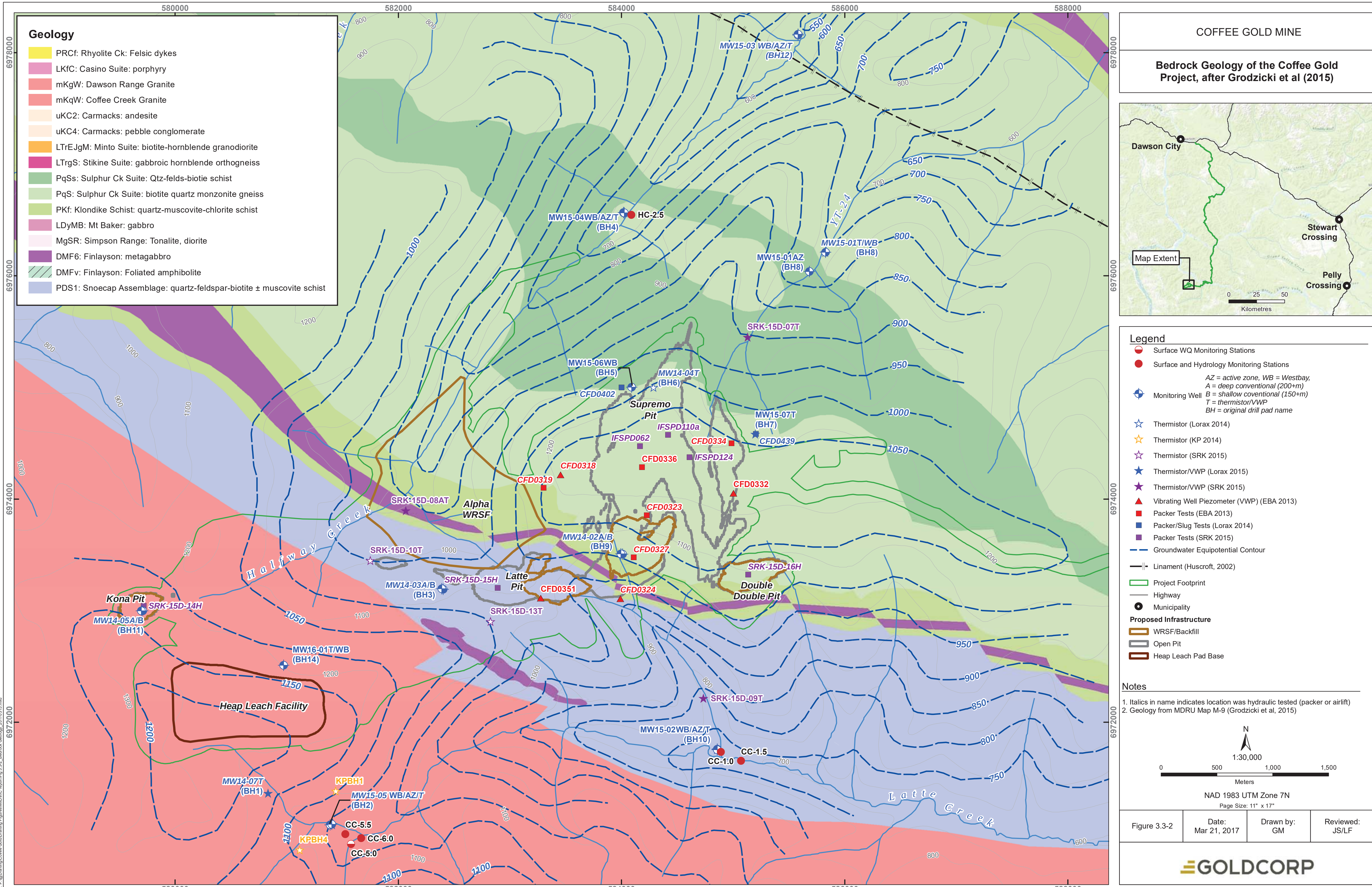
The Project is underlain by a package of metamorphosed Paleozoic rocks of the Yukon-Tanana terrane that was intruded by a large granitic body in the Late Cretaceous. The Paleozoic rock package is predominantly a biotite (+ feldspar + quartz + muscovite ± carbonate) schist that overlies an augen orthogneiss (**Figure 3.3-2**). Gold mineralization is associated with an extensional deformation event that occurred during the Cretaceous. This event resulted in formation of steep-to-vertical brittle fractures and normal faults cross-cutting all lithologies at Coffee (Berman et al*.* 2007). A CO_2-rich fluid flowed through the region and travelled upwards in the system into the epizonal domain of the Coffee Gold Mine, where it was controlled by the structural framework of the Coffee fault system and reacted with favorable host rocks (Buitenhuis et al. 2015, Buitenhuis 2014). The fluid travelled along brittle structures and deposited gold-rich arsenian pyrite through sulphidation, and in high-energy pulses, formed gold-rich hydrothermal breccias (Buitenhuis 2014).

The planar gold mineralized zones at Coffee exhibit a number of strike orientations, dominated by east-west, north-south, and east-northeast–west-southwest strike directions. The Proponent has prepared a map of all confirmed mineralized structures currently known on the property (Kaminak 2015). The map identifies structures confirmed by drilling, trenching, or soil sampling and does not include regional-scale inferred faults. Structures identified in this map have been included in **Figure 3.3-1.**

3.3.2.2 Permafrost

The Coffee Project is located in an area classified as extensive discontinuous permafrost (50% to 90% of land area underlain by permafrost) according to National Resources Canada (1995). Permafrost distribution determined from mapping (EBA 2016a,b) indicates that approximately 62% of the Mine Site is underlain by permafrost.

Ground temperatures have been recorded at thermistors installed by Lorax, SRK and KP. In addition, there are anecdotal observations of ground ice from drilling and sampling. The two sets of information have been compiled in **Table 3.3-4** which summarizes measured and inferred depth of permafrost across the groundwater LSA. Ground thermal profiles measured at all the thermistors are provided in **Appendix 7-A** (sub-**appendix 4-A**). Overall, permafrost extends to greatest depths in ridge areas and appears to thin towards areas of lower elevation; north facing slopes tend to have thicker permafrost than south-facing slopes. An average relationship of permafrost thickness versus ground surface elevation is provided in **Figure 3.3-3** for installations where permafrost depths can be more confidently estimated. Data from MW16-01T is plotted on the graph, however, only data from 2015 were used to compute the regression. The only drilling locations where permafrost was absent were the two instruments established in the lower reaches of the Latte tributary (MW15-02T, SRK-15D-09T). The thickest permafrost (~165 m) is encountered near the north end of the proposed Supremo pit at MW14-04T. Permafrost at the Mine Site is warm (between 0 and -2^{o}C) and at 20 m depth (i.e. beyond the depth of zero amplitude), is coolest (-1.4^{o}C to -1.9^{o}C) on north facing slopes.


COFFEE GOLD MINE
Bedrock Geology of the Coffee Gold Project, after Grodzicki et al (2015)
Geology
PRCf: Rhyolite Ck: Felsic dykes
LKfC: Casino Suite: porphyry
mKgW: Dawson Range Granite
mKqW: Coffee Creek Granite
uKC2: Carmacks: andesite
uKC4: Carmacks: pebble conglomerate
LTrEJgM: Minto Suite: biotite-hornblende granodiorite
LTrgS: Stikine Suite: gabbroic hornblende orthogneiss
PqSs: Sulphur Ck Suite: Qtz-felds-biotie schist
PqS: Sulphur Ck Suite: biotite quartz monzonite gneiss
PKf: Klondike Schist: quartz-muscovite-chlorite schist
LDyMB: Mt Baker: gabbro
MgSR: Simpson Range: Tonalite, diorite
DMF6: Finlayson: metagabbro
DMFv: Finlayson: Foliated amphibolite
PDS1: Snoecap Assemblage: quartz-feldspar-biotite ± muscovite schist
Dawson City
Stewart Crossing
Pelly Crossing
Map Extent
Kilometres
Legend
Surface WQ Monitoring Stations
Surface and Hydrology Monitoring Stations
Monitoring Well
AZ = active zone, WB = Westbay, A = deep conventional (200+m) B = shallow conventional (150+m) T = thermistor/VWP BH = original drill pad name
Thermistor (Lorax 2014)
Thermistor (KP 2014)
Thermistor (SRK 2015)
Thermistor/VWP (Lorax 2015)
Thermistor/VWP (SRK 2015)
Vibrating Well Piezometer (VWP) (EBA 2013)
Packer Tests (EBA 2013)
Packer/Slug Tests (Lorax 2014)
Packer Tests (SRK 2015)
Groundwater Equipotential Contour
Linament (Huscroft, 2002)
Project Footprint
Highway
Municipality
Proposed Infrastructure
WRSF/Backfill
Open Pit
Heap Leach Pad Base
Notes
1. Italics in name indicates location was hydraulic tested (packer or airlift)
2. Geology from MDRU Map M-9 (Grodzicki et al, 2015)
1:30,000
Meters
NAD 1983 UTM Zone 7N
Page Size: 11" x 17"
Figure 3.3-2
Date: Mar 21, 2017
Drawn by: GM
Reviewed: JS/LF
GOLDCORP
Supremo Pit
Latte Pit
Kona Pit
Double Double Pit
Alpha WRSF
Heap Leach Facility
Halfway Creek
Latte Creek
YT-24
MW15-03 WB/AZ/T (BH12)
MW15-04WB/AZ/T (BH4)
HC-2.5
MW15-01T/WB (BH8)
MW15-01AZ (BH8)
SRK-15D-07T
MW15-06WB (BH5)
MW14-04T (BH6)
CFD0402
MW15-07T (BH7)
CFD0439
IFSPD062
IFSPD110a
CFD0334
CFD0336
IFSPD124
CFD0318
CFD0319
CFD0332
CFD0323
SRK-15D-08AT
MW14-02A/B (BH9)
CFD0327
SRK-15D-10T
SRK-15D-16H
SRK-15D-15H
CFD0351
CFD0324
MW14-03A/B (BH3)
SRK-15D-13T
SRK-15D-14H
MW14-05A/B (BH11)
MW16-01T/WB (BH14)
SRK-15D-09T
MW15-02WB/AZ/T (BH10)
CC-1.5
CC-1.0
MW14-07T (BH1)
KPBH1
MW15-05 WB/AZ/T (BH2)
KPBH4
CC-5.5
CC-6.0
CC-5.0
580000
582000
584000
586000
588000
6978000
6976000
6974000
6972000

The active zone, the supra-permafrost layer that seasonally thaws, is generally shallow across the site (less than 2 m deep), except in areas where insulating vegetation has been stripped (i.e. road cuts) (**Table 3.3-4**). **Table 3.3-5** provides the period of record for which shallow temperature sensors record above zero readings, providing insight into when the active layer is 'active'. Time series plots of the shallow temperature data are found in **Appendix 7-B**. Of note, MW15-03T records above zero ground temperatures for all sensors within 5 m of ground surface for essentially the entire period of record for the instrument (May 10 through October 31st, 2015). MW15-03T is also the lowest elevation thermistor on site, and is at the fringe of permafrost coverage. Farther upstream, at MW15-04T, the shallowest thermistor sensor (1.7 m bgs) remains frozen throughout the entire data record. Of the higher elevation sensors, KPBH01 (elevation 1123 m) records the earliest shallow thaw (at 0.76 m bgs) starting May 21st, 2015. Overall, the period of thaw for shallow temperature sensors within 5 m of ground surface is highly variable across the site in both timing and duration.

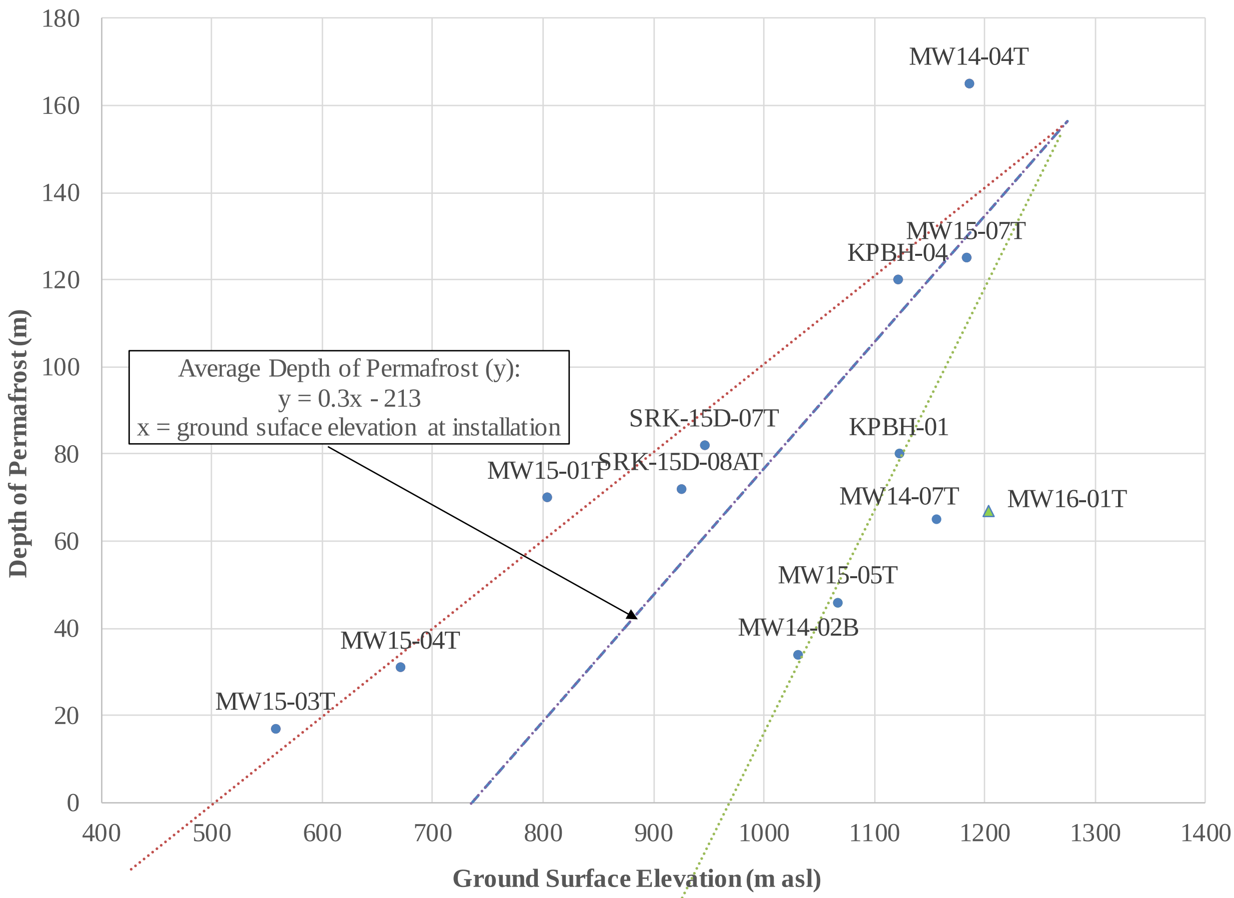


Figure 3.3-3 Thickness of Permafrost Plotted as a Function of Ground Surface Elevation at Installations where Depth to 0°C is Well Constrained. Data from MW16-01T was not used to compute trendlines.

Table 3.3-4 Observations of Permafrost Depth from Thermistor Installations, Exploration Drilling and Monitoring Well Sampling

Monitoring ID	Mine ID	Ground Surface (m asl)	Active Zone Thickness (m)	Base of Permafrost (m bgs)	Temperature at 20 m bgs (ºC)	Comment
KPBH-01	CFD0451	1122.7	1.5	>50 m, approx. 80 m	-0.92	Projected trend as thermistor string terminates at 50 m bgs.
KPBH-04	CFD0454	1121.3	1.5	>50 m, approx. 120 m	-1.04	Projected trend as thermistor string terminates at 50 m bgs.
MW14-02B	CFD0418	1030.9		34		Base of ice in conventional MW after several months of inactivity.
MW14-03B	CFD0432	1097.6		61.8 ≤ x ≤ 133		Small ice lens observed in core at 61.8 m, water in well is unfrozen at ~133 m bgs.
MW14-04T	CFD0439	1185.8	>3	168	-1.4	In road cut, vegetation stripped.
MW14-05B	CFD0455	1270.3		<134		Water level in well remains unfrozen to 134 m.
MW14-07T	CFD0462	1156.3	<0.6	62	-1.1	
MW15-01T	CFR0941	803.9	<0.6	70 to 75	-1.4	
MW15-02T[1]	CFR0948	737.1	n/a	0	0.6	Permafrost absent.
MW15-03T[2]	CFR0983	557.7	?	~20	0	Ice shards observed in rock chips 8.8-10.4 m, near zero temperatures observed at 16.7 m.
MW15-03WB[2]	CFR0987	557.9	?	x ≥ 10.4		Ice shards observed in rock chips 7.7, 8.2 and 8.5-10.4 m.
MW15-04T	CFR0990	670.9	<1.7	30 to 31	-0.4 to -0.35	
MW15-05T	CFR0994	1067.1	1.5	46 to 47	-0.6	
MW15-07T	CFD0596	1183.1	<7	140	-1.3	In road cut, vegetation stripped.
MW16-01T[3]	CFR1137	1203.7	TBD	67	-0.3	
SRK-15D-07T	CFD0600	946.0	<1.5	85	-1.85	
SRK-15D-08AT	CDF0595	925.0	~1.1	75	-0.9	
SRK-15D-09T	CFD0599	784.0	n/a	0	0.8	Permafrost absent.
SRK-15D-10T	CFD0593	1008.2	~2	40 to 50	-1.85	Projected trend as thermistor string terminates is frozen to depth at 25 m bgs.
SRK-15D-13T	CFD0594	1136.9	~2	41 to 50	-0.2	Projected trend as thermistor string terminates is frozen to depth at 25 m bgs.
	CFD0376	1052.1	n/a	x ≥ 85	n/a	Exploration hole in Kona North; ice lens observed around 85 m.

Notes:

m asl = metres above sea level, m bgs = metres below ground surface

1. n/a: not applicable, active zone necessarily requires presence of permafrost
2. Unable to determine active zone thickness from plot due depth of sensors; base of permafrost is also questionable.
3. Insufficient data record to determine active zone thickness.

Table 3.3-5 2015 Period of Record with Above 0°C Temperatures at Shallow Thermistor Sensors

Instrument	Ground Surface El. (m asl)	Sensor Depth (m bgs)	Start of >0ºC Temperatures	Stop of >0ºC Temperatures	Comments
Halfway Creek					
SRK-15D-10T	1008	0.5	20-Sep-15	19-Oct-15	>0 intermittently through range
SRK-15D-10T	1008	3.0	Always below zero		
SRK-15D-10T	1008	5.5	Always below zero		
SRK-15D-08T	925	1.0	9-Jul-15[1]	22-Sep-15	
SRK-15D-08T	925	4.0	9-Jul-15[1]	29-Jul-15	
MW14-04T	1186	3.1	1-Jul-15	31-Oct-15	In road cut
MW15-04T	671	1.7	Always below zero		
MW15-03T	558	0.5	10-May-15[1]	27-Oct-15	
MW15-03T	558	1.2	10-May-15[1]	31-Oct-15[2]	
MW15-03T	558	1.9	10-May-15[1]	31-Oct-15[2]	
MW15-03T	558	2.6	10-May-15[1]	31-Oct-15[2]	
MW15-03T	558	3.4	10-May-15[1]	31-Oct-15[2]	
MW15-03T	558	4.1	10-May-15[1]	31-Oct-15[2]	
MW15-03T	558	4.9	10-May-15[1]	31-Oct-15[2]	
YT-24 Drainage					
MW15-07T	1183	7.0	Always below zero		
SRK-15D-07T	949	0.7	Always below zero		Below zero after initial grout curing
SRK-15D-07T	949	2.2	Always below zero		Below zero after initial grout curing
SRK-15D-07T	949	3.7	Always below zero		Below zero after initial grout curing
SRK-15D-07T	949	5.2	Always below zero		Below zero after initial grout curing
MW15-01T	804	0.5	21-May-15	24-Oct-15	
MW15-01T	804	1.3	Always below zero		
Upper Latte Creek					
MW14-07T	1156	0.6	Always below zero		
MW14-07T	1156	1.4	Always below zero		
KPBH01	1123	0.8	21-May-15	1-Oct-15	
KPBH01	1123	1.5	8-Aug-15	20-Sep-15	
KPBH04	1121	0.8	17-Jun-15	30-Sep-15	
KPBH04	1121	1.5	20-Aug-15	22-Sep-15	
MW15-05T	1067	0.8	16-Jul-15	11-Oct-15	
MW15-05T	1067	1.5	13-Sep-15	16-Sep-15	
SRK-15D-13T	1137	0.5	10-Sep-15	22-Sep-15	
SRK-15D-13T	1137	3.0	Always below zero		
SRK-15D-13T	1137	5.5	Always below zero		
Latte Tributary					
SRK-15D-09T	784	1.1	9-Jul-15[1]	31-Oct-15[2]	
SRK-15D-09T	784	2.6	9-Jul-15[1]	31-Oct-15[2]	
SRK-15D-09T	784	4.1	9-Jul-15[1]	31-Oct-15[2]	
MW15-02T	737	1.2	29-May-15	25-Oct-15	
MW15-02T	737	3.2	13-Apr-15	29-Apr-15	Sensor essentially records 0ºC for entire data period.
MW15-02T	737	5.2	13-Apr-15	9-Jul-15	

Notes:

m asl = metres above sea level, m bgs = metres below ground surface
1. Above zero temperatures coincide with start of record.
2. Above zero temperatures until end of record.

3.3.2.3 Bedrock Hydraulic Conductivity

Over 40 successful measurements of bedrock hydraulic conductivity have been collected throughout the various field programs undertaken at the site. Hydraulic testing results are summarized in **Table 3.3-6** and plotted versus vertical depth below ground surface in **Figure 3.3-4**. The reader is referred to **Appendix 7-A** (sub-**appendix 3-E**) for a description of hydraulic testing methods and interpretation. Slug tests were performed on two overburden wells MW15-03AZ (lower Halfway Creek) and MW15-02AZ (Latte tributary); however, the tests could not be analyzed. Note that figures, tables and quoted averages in this section have not been updated to reflect the most recent hydraulic testing undertaken at the HLF drillholes (MW16-01T, MW16-01WB).

A regression line though the bedrock hydraulic testing data (**Figure 3.3-4**) indicates a broad trend of decreasing hydraulic conductivity with depth with exception to a cluster of higher hydraulic conductivity values at over 200 m depth. Most of these values are attributed to SRK's testing program which specifically targeted structures intersecting the proposed pits. They report a narrow range (1E-07 m/s to 3E-06 m/s) of hydraulic conductivity values for the structures with an arithmetic mean value of 7E-07 m/s. The arithmetic mean of tests performed in valley locations (**Table 3.3-6**) is 1E-06 m/s, which is consistent with SRK's pit structure results and supports the inference that valley traces represent fault structures. An arithmetic mean of all valley and pit structure hydraulic conductivity results is 9E-07 m/s. There is a wide spread in hydraulic conductivity values for the major rock types encountered across the LSA (**Appendix 7-A**); rock type does not appear to play a large control on hydraulic properties. Rather, structural features, which cross-cut all lithologies, impart the dominant control on bedrock hydraulic conductivity.

Figure 3.3-5 presents statistics for the hydraulic conductivity data set as box and whisker plots (legend in lower pane). For the upper box, a mean hydraulic conductivity value was computed for each hole where multiple hydraulic tests were performed, and then statistics were computed on the resultant data set of 22 values. Multiple tests on fractured holes (valley and SRK tests) were computed as an arithmetic average, while multiple tests on other boreholes were averaged geometrically. For the bottom box, all tests were treated individually (43 values). Predictably, the pre-processed data set in the upper box shows a tighter spread in the values, with 25^{th} to 75^{th} percentile hydraulic conductivity values ranging from 2E-08 to 2E-07 m/s, with a geometric mean of all boreholes of 5E-08 m/s. When all tests are treated individually, the geometric mean of the entire 43-value data set is 2E-08 m/s.

Table 3.3-6 Hydraulic Testing Results for the Coffee Project

Hole ID	Consultant	Azimuth	Dip	Test Interval[1] (v. m bgs)		Test Method	Test Type[2]	K[3,4] (m/s)	Geologic Unit[5]
				From	To				
Supremo									
MW14-01A	Lorax	0	-90	155	166	Packer	CHI	4E-08	GN
MW14-01A	Lorax	0	-90	179	202	Packer	CHI	3E-08	GN/BFS/GN
MW14-04T	Lorax	0	-90	182	202	Packer	CHI	2E-10	BFS
MW14-04T	Lorax	0	-90	164	202	Packer	Lugeon	6E-10	GN/BFS
MW14-04T	Lorax	0	-90	203	232	Packer	Lugeon	1E-09	BFS/GN
MW14-04T	Lorax	0	-90	233	256	Packer	Lugeon	4E-09	GN
MW14-04T	Lorax	0	-90	251	280	Packer	CHI	3E-10	GN
MW14-04T	Lorax	0	-90	281	301	Packer	CHI	4E-11	GN
MW14-06A	Lorax	0	-90	197	216	Slug Test	RH Slug	1E-07	GN
MW15-06T	Lorax	0	-90	281	286	Westbay	Pulse Test	1E-09	GN
MW15-06T	Lorax	0	-90	238	243	Westbay	Pulse Test	2E-07	GN
MW15-06T	Lorax	0	-90	227	237	Westbay	Pulse Test	1E-08	GN
CFD-0318	EBA	175	-45	89	91	Packer	Lugeon	5E-07	Dikes/GN
CFD-0318	EBA	175	-45	105	108	Packer	Lugeon	1E-06	Amph
CFD-0318	EBA	175	-45	118	122	Packer	Lugeon	5E-08	GN
CFD-0319	EBA	0	-45	76	83	Packer	Lugeon	7E-08	GN/Dikes
CFD-0323	EBA	280	-70	93	118	Packer	Lugeon	4E-08	GN/BtS
IFSPD124	SRK	270	-50	36	125	Slug Test	FH Slug	2E-07	GN
IFSPD110a	SRK	270	-50	220	239	Slug Test	FH Slug	2E-07	GN
CFD-0324	EBA	280	-45	54	60	Packer	Lugeon	4E-08	BtS_Carb
CFD-0324	EBA	280	-45	72	105	Packer	Lugeon	1E-07	BtS_Carb
CFD-0327	EBA	275	-60	73	86	Packer	Lugeon	5E-08	GN
MW14-02B	Lorax	0	-90	85	104	Packer	CHI	5E-09	GN
MW14-02B	Lorax	0	-90	103	125	Packer	CHI	8E-08	GN
MW14-02B	Lorax	0	-90	130	137	Packer	CHI	3E-08	SZ/BFS
MW14-02B	Lorax	0	-90	139	152	Packer	CHI	1E-07	BFS/CB
MW14-02B	Lorax	0	-90	157	173	Packer	CHI	1E-08	CB/HAR/CB
MW14-02B	Lorax	0	-90	181	200	Packer	CHI	1E-08	BFS

Hole ID	Consultant	Azimuth	Dip	Test Interval[1] (v. m bgs)		Test Method	Test Type[2]	K[3,4] (m/s)	Geologic Unit[5]
				From	To				
Latte									
MW14-03A	Lorax	0	-90	157	199	Packer	CHI	5E-09	BFS/SZ/BFS
SRK-15D-15P	SRK	0	-90	200	274	Airlift	Airlift Recovery	3E-07	GN/BtS/Cl-LiB
Kona									
MW14-05A	Lorax	0	-90	156	179	Packer	CHI	4E-11	GR
MW14-05A	Lorax	0	-90	183	200	Packer	CHI	3E-09	GR
MW14-05A	Lorax	0	-90	201	221	Packer	CHI	1E-09	GR
MW14-05A	Lorax	0	-90	156	221	Packer	CHI	1E-09	GR
MW14-05B	Lorax	0	-90	139	118	Slug Test	RH Slug	5E-10	GR
SRK-15D-14P	SRK	345	-70	173	212	Packer	CHI/FH Slug	1E-07	GR
Double Double									
SRK-15D-16P	SRK	165	-70	137	150	Packer	CHI/FH Slug	2E-07	CB/dyke
SRK-15D-16P	SRK	165	-70	167	214	Packer	Airlift Recovery	1E-07	dyke/GN
Valley									
MW14-07T	Lorax	0	-90	64	89	Packer	Lugeon	3E-08	GR
MW14-07T	Lorax	0	-90	83	125	Packer	Lugeon	1E-08	GR
MW15-05T	Lorax	125	-80	51	83	Airlift	Airlift Recovery	3E-06	GR
MW15-03T	Lorax	39	-80	32	97	Airlift	Airlift Recovery	3E-07	BN/BtS
MW15-04T	Lorax	40	-80	40	53	Packer	Shut-In/CHI	4E-06	GN

Notes:

m AH = m along hole, v mbgs = vertical m below ground surface, K = hydraulic conductivity

1. Depth below ground surface for inclined tests has been calculated by Lorax to take surface topography into account.

2. CHI = constant head injection, FH = falling head test

3. *Red italicized* values are an inferred upper value computed based on injection pressures and resolution of flow gauge

4. Multiple tests at valley drillholes and pit structures (SRK tests) averaged arithmetically; all other holes with multiple tests averaged geometrically

5. Tests straddling two or more geologic units denoted by a '/' (*e.g.* BFS/CB). Amph = Amphibole rich rock, BtS = Biotite Schist, BFS = Biotite Feldspar Schist, CB = Crackle Breccia, Carb = Carbonates, D = Dacite, GN = Gneiss, GR = Granite, HAR = Hydrothermally Altered Rock, M = Metacarbonate, SZ = Shear Zone, Cl-LiB = Chlorite limonite breccia

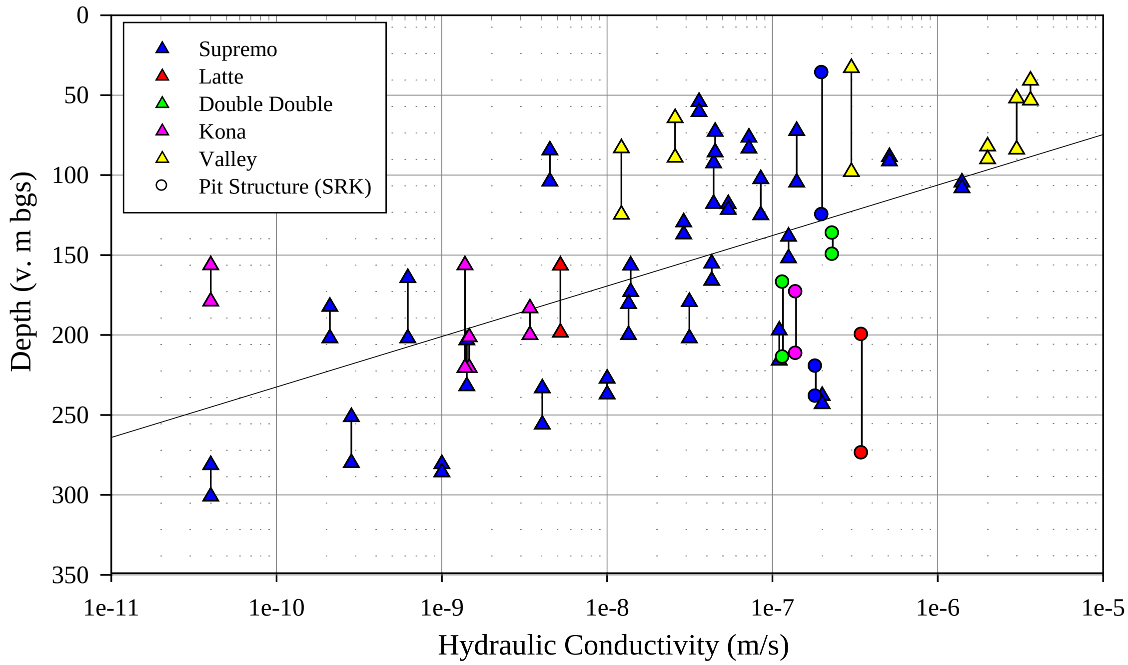


Figure 3.3-4 Bedrock Hydraulic Conductivity versus Vertical Depth Below Ground Surface at the Coffee Project

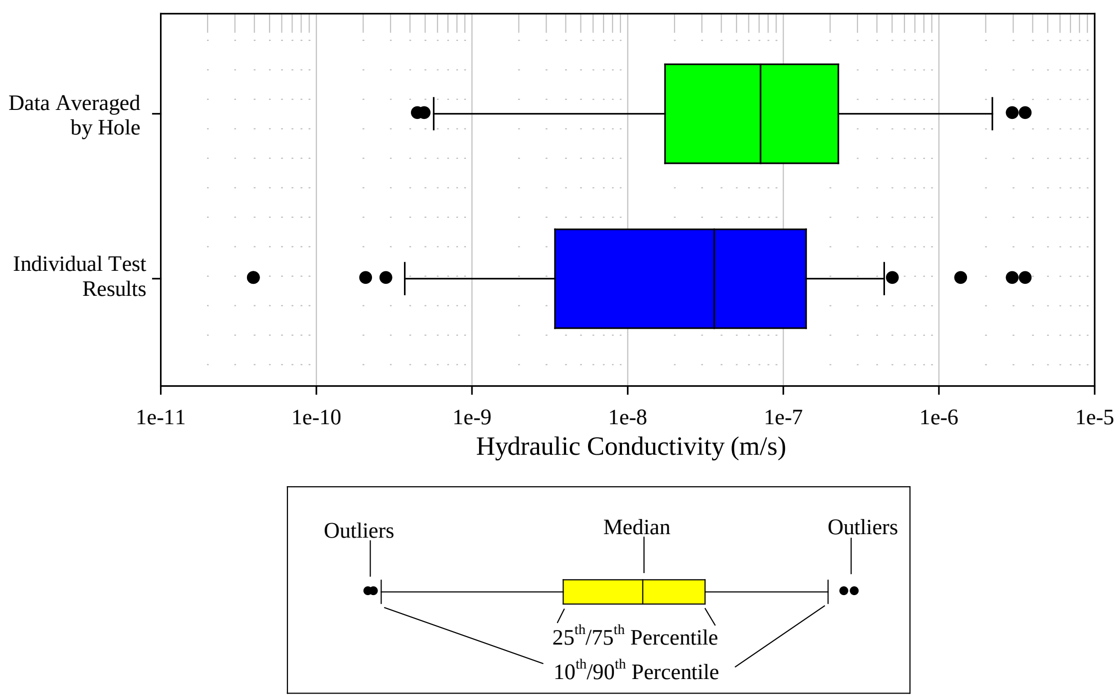


Figure 3.3-5 Box and Whisker Plot of Hydraulic Testing Results with Legend in Bottom Pane

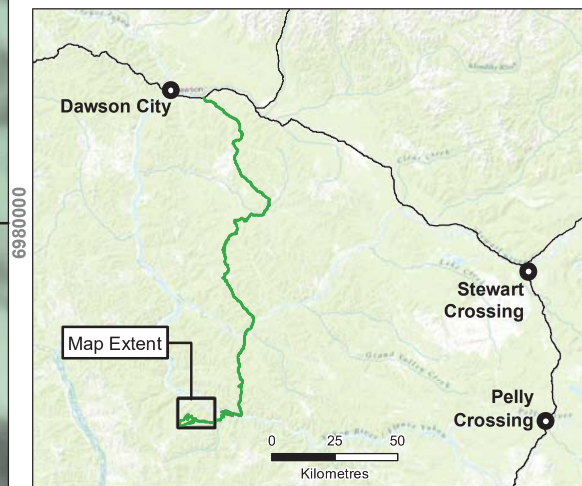
3.3.2.4 Water Levels and Hydraulic Gradients

A summary of groundwater level monitoring results at the proposed Coffee Gold Mine is provided in **Table 3.3-7**. A continuous water level record is available from most instruments on site (except Westbay wells) from June 2015 onwards, with spot measurements available as early as the fall of 2013. The record discussed herein includes data collected up to October 31, 2015. Bedrock water levels measured in June 2015 are presented in **Table 3.3-7** and are contoured in **Figure 3.3-1**. Water levels measured in the fall of 2016 at MW16-01T/WB are included in **Table 3.3-7** since they have been used to inform the groundwater model, but otherwise have not been incorporated into the discussion below, which focuses on data collected up until October 31, 2015. Vertical and horizontal hydraulic gradients measured at conventional wells pairs and nested VWP sensors are summarized in **Table 3.3-8** and **Table 3.3-9**. Water level hydrographs are provided, organized by drainage, along with conceptual groundwater cross-sections. A plan map showing surface traces of the conceptual cross-sections is provided in **Figure 3.3-6**.

In general, water levels are very deep (from 130 m to over 220 m below ground surface) in ridge areas, but artesian conditions are encountered even at moderate to high elevations in the drainages. Water level hydrographs indicate variable response to seasonal recharge patterns, with fluctuations ranging from a couple of m to over 30 m. Nested instrumentation reveals both upward and downward vertical hydraulic gradients in both upland and low-lying areas. In some instances, horizontal hydraulic gradients exceed topographic gradients. Overall, the physical hydrogeological data reveal a complex groundwater system influenced by both discontinuous permafrost and a well-developed fracture system. Individual water level hydrographs are discussed below, grouped by drainage area, with focus on 2015 data.

COFFEE GOLD MINE

Plan Map Showing Permafrost Distribution and Conceptual Hydrogeological Cross-Section Traces



Legend

- Monitoring Well — AZ = active zone, WB = Westbay, A = deep conventional (200+m), B = shallow conventional (150+m), T = thermistor/VWP, BH = original drillpad name
- Thermistor (Lorax 2014)
- Thermistor (KP 2014)
- Thermistor (SRK 2015)
- Thermistor/VWP (Lorax 2015)
- Thermistor/VWP (SRK 2015)
- Vibrating Well Piezometer (VWP) (EBA 2013)
- Packer Tests (EBA 2013)
- Packer/Slug Tests (Lorax 2014)
- Packer Tests (SRK 2015)
- Transects
- Project Footprint
- Mine Site Access Road
- Northern Access Route
- Highway
- Municipality

Proposed Infrastructure

- WRSF/Backfill
- Organics Stockpile
- Event Pond Area
- Heap Leach Pad Base
- Open Pit
- ROM Stockpile
- Support Infrastructure
- Haul Roads

Permafrost

- Unfrozen
- Permafrost Present

N

1:45,000

0 500 1,000 1,500

Meters

NAD 1983 UTM Zone 7N

Page Size: 11" x 17"

Figure 3.3-6	Date: Mar 21, 2017	Drawn by: GM	Reviewed: JS/LF

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Table 3.3-7 Selected Water Level Information for the Coffee Project

Monitoring ID[1]	Pad	Class[2]	Period of Record[3]	Monitoring Depth[4] (m bgs)	Base of Permafrost (m bgs)	Water Level[5]			WL Fluctuation[6] (m)
						m bgs	m asl	date	
MW14-02A	BH9	MW	sporadic Sep/14, continuous Jun/15 onward	188.2	34	11.9	1017.7	23-Jun-15	13.0
MW14-02B	BH9	MW	sporadic Sep/14, continuous Jun/15 onward	146.6	34	21.4	1009.6	23-Jun-15	12.2*
MW14-03A	BH3	MW	since Oct/14	191.3	62≤ x ≤133	137.8	959.8	23-Jun-15	5.4
MW14-03B	BH3	MW	since Oct/14	145.7	62≤ x ≤133	135.3	959.8	23-Jun-15	5.4
MW14-05A	BH11	MW	sporadic Sep/14, continuous Jun/15 onward	206.4	<134	132.3	1136.2	23-Jun-15	0.5
MW14-05B	BH11	MW	sporadic Sep/14, continuous Jun/15 onward	171.0	<134	134.1	1136.2	23-Jun-15	0.5
MW15-02 AZ	BH10	OW	since May 31/15	5.6	none	6.1	731.2	23-Jun-15	-0.9
MW15-03 AZ	BH12	OW	since Jun 16/15	3.3	10 ≤ x ≤ 20	1.6	556.3	23-Jun-15	0.0*
MW15-01WB-P1	BH8	WB	4 spot measurements Jun-Sep, 2015	90.5	70	36.2	767.4	07-Jun-15	
MW15-01WB-P6	BH8	WB	4 spot measurements Jun-Sep, 2015	77.8	70	36.1	767.4	07-Jun-15	
MW15-02WB-P1	BH10	WB	4 spot measurements Jun-Sep, 2015	63.3	0	9.2	727.9	07-Jun-15	
MW15-02WB-P4	BH10	WB	4 spot measurements Jun-Sep, 2015	19.2	0	2.5	734.6	07-Jun-15	
MW15-03WB-P1	BH12	WB	4 spot measurements Jun-Sep, 2015	98.7	10 ≤ x ≤ 20	-2.0	559.9	15-Jun-15	
MW15-03WB-P7	BH12	WB	4 spot measurements Jun-Sep, 2015	40.9	10 ≤ x ≤ 20	0.4	557.5	15-Jun-15	
MW15-04WB-P1	BH4	WB	4 spot measurements Jun-Sep, 2015	61.7	31	-0.9	672.3	13-Jun-15	
MW15-04WB-P5	BH4	WB	4 spot measurements Jun-Sep, 2015	35.1	31	-1.1	672.5	13-Jun-15	
MW15-05WB-P1	BH2	WB	4 spot measurements Jun-Sep, 2015	80.3	47	23.1	1044.6	17-Jun-15	
MW15-05WB-P4	BH2	WB	4 spot measurements Jun-Sep, 2015	62.7	47	23.0	1044.7	17-Jun-15	
MW15-06WB-P3	BH5	WB	4 spot measurements Jun-Sep, 2015	265.8	168	228.1	956.8	19-Jun-15	
MW15-06WB-P7	BH5	WB	4 spot measurements Jun-Sep, 2015	232.2	168	222.3	962.7	19-Jun-15	
MW16-01WB-P1	BH14	WB	1 spot measurement Oct, 2016	114.9	67	-1.53	1205.4	03-Oct-16	
MW16-01WB-P6	BH14	EB	1 spot measurement Oct, 2016	71.6	67	-1.63	1205.5	03-Oct-16	
MW14-07T	BH1	T/VWP	since Oct 2014	124.4	62	-8.0	1164.2	23-Jun-15	1.3
MW15-01T	BH8	T/VWP	since May 25/15	76.0	70	37.4	766.6	23-Jun-15	4.8
MW15-01T	BH8	T/VWP	since May 25/15	89.0	70	37.8	766.2	23-Jun-15	4.8
MW15-02T	BH10	T/VWP	since Mar 26/15	33.9	0	10.3	726.8	23-Jun-15	1.3
MW15-03T	BH12	T/VWP	since Jun 15/15	48.8	10 ≤ x ≤ 20	0.0	557.0	23-Jun-15	-0.9
MW15-03T	BH12	T/VWP	since Jun 15/15	94.7	10 ≤ x ≤ 20	-5.1	561.2	23-Jun-15	1.5
MW15-04T	BH4	T/VWP	since May 14/15	51.6	31	-0.6	670.9	23-Jun-15	2.7*
MW15-04T	BH4	T/VWP	since May 14/15	38.8	31	-0.5	670.8	23-Jun-15	2.7*
MW15-05T	BH2	T/VWP	since May 22/15	55.4	47	24.3	1042.7	23-Jun-15	0.8
MW15-05T	BH2	T/VWP	since May 22/15	81.4	47	37.9	1029.1	23-Jun-15	3.6
MW15-07T	BH7	T/VWP	since Jul 10/15	267.8	140	136.8	1046.4	10-Jul-15	10.7
MW15-07T	BH7	T/VWP	since Jul 10/16	239.0	140	138.2	1045.0	10-Jul-15	11.3
MW16-01T	BH14	T/VWP	since Aug 27/16	131.5	67	-0.8	1204.5	29-Sep-16	n/a

Monitoring ID[1]	Pad	Class[2]	Period of Record[3]	Monitoring Depth[4] (m bgs)	Base of Permafrost (m bgs)	Water Level[5]			WL Fluctuation[6] (m)
						m bgs	m asl	date	
MW16-01T	BH14	T/VWP	since Aug 27/16	97.5	67	-2.3	1206.0	29-Sep-16	n/a
SRK-15D-07T		T/VWP	since Sep 8/15	149.2	85	50.5	898.4	08-Sep-15	0.0
SRK-15D-07T		T/VWP	since Sep 8/15	103.6	85	44.7	904.1	08-Sep-15	0.0
SRK-15D-08AT		T/VWP	since Jul 9/15	149.2	75	-2.2	927.3	09-Jul-15	3.9*
SRK-15D-08AT		T/VWP	since Jul 9/15	103.6	75	-9.1	934.2	09-Jul-15	3.7
SRK-15D-09T		T/VWP	since Jul 9/15	99.7	0	1.4	782.9	09-Jul-15	3.3
CFD318		VWP	Sporadic Oct/13, continuous Oct/14 onward	118.0	?	118.0	1092.0	23-Jun-15	28**
CFD324		VWP	Sporadic Oct/13, continuous Oct/14 onward	178.3	?	61.3	931.6	23-Jun-15	5.0
CFD332		VWP	Sporadic Oct/13, continuous Oct/14 onward	116.6	?	(-)	(-)	(-)	dry from start
CFD351		VWP	Sporadic Oct/13, continuous Oct/14 onward	184.4	?	155.9	967.8	23-Jun-15	32*

Notes:

1. MW15-01WB-P1 – P1 indicates the port number in the Westbay system, not all ports are presented.
2. MW-conventional monitoring well (deep), OW-conventional overburden monitoring well, WB – Westbay monitoring system, VWP-vibrating wire piezometer, T-thermistor
3. Last download of VWPs and conventional monitoring well loggers occurred late October 2015.
4. Monitoring depth equivalent to sand pack midpoint for conventional monitoring wells, zone midpoint in Westbay, vertical depth below ground surface for VWP sensor.
5. Water levels used for Groundwater Model calibration, roughly coincides with low point in the 2015 well hydrograph.
6. Water level fluctuation as measured from June/July 2015 to end of period of record (late October 2015). Computed for continuously logged instruments only (wells with loggers and VWPs). May not capture full magnitude of changes except where indicated by asterisk*.
** indicates 2014 fluctuation.

Table 3.3-8 Vertical Hydraulic Gradients Measured at Selected Installations Across the Coffee Project

Monitoring Location	Shallow Monitoring Point[1] (m bgs)	Deep Monitoring Point[1](m bgs)	Vertical distance (m)	Approximate Gradient Range[2,3] (m/m)
MW15-01T	76.0	89.1	13.1	0.03 to 0.035
MW15-02WB	13.7	9.2	4.5	-0.39
MW15-02WB	32	61	29	0.24
MW15-03T	49.6	96.2	46.7	-0.08 to -0.11
MW15-04T	38.8	51.6	12.8	-0.01 to 0.033
MW15-05T	55.4	81.4	26.0	0.56 to 0.42
MW15-06WB	241.3	251.9	10.6	0.72
MW15-06WB	251.9	287	35.1	-0.18
MW15-07T	239	267.8	28.8	-0.02 to -0.04
SRK-15D-07T	103.6	149.2	45.6	-0.18 (steady)
SRK-15D-08AT	103.6	149.2	45.6	0.13 to 0.16
MW14-02A/B	146.6	188.2	41.6	-0.20 to -0.26
MW14-03A/B	145.7	191.3	45.6	0.005 to -0.002
MW14-05A/B	171	206.4	35.4	0.0 to -0.01

Notes:

1. Monitoring point depths as follows: VWP sensor depth in vertical metres below ground surface; Westbay port depth; conventional monitoring well screen midpoint.
2. Positive values indicate downward gradient, negative values indicate upward gradient.
3. Based on 2015 data only for continuously logged locations ignoring initial readings after installation; gradient at Westbay installations computed for September 2015 readings only.

Table 3.3-9 Horizontal Hydraulic Gradients Measured in June 2015 across the Coffee Project

Well Pair	Horizontal Distance	Topographic Gradient	Hydraulic Gradient[1,2]
YT-24 Drainage			
MW15-07T – SRK-15D-07T	835	28%	18%
SRK-15D-07T – MW15-01T	1,061	14%	12%
Halfway Creek Drainage			
MW14-03B - SRK-15D-08AT	3,522	4%	1%
MW14-05B - SRK-15D-08AT	5,943	5%	4%
MW15-06WB (P7) – Halfway Ck	1,256	39%	21%
SRK-15D-08AT – MW15-04T	1,592	17%	16%
MW15-04T – MW15-03T	2,233	5%	5%
South Waste Rock Facility Drainage			
CFD0351 – CFD0324	718	23%	5%
MW14-02B – CFD0324	408	18%	21%
CFD324 – SRK-15D-09T	1,154	15%	13%
SRK-15D-09T – MW15-02T	475	10%	12%
Latte Creek Drainage			
MW14-07T – MW15-05T	639	14%	19%

Notes:

1. Water levels from SRK VWPs are measured in July and September, 2015; all other water levels measured in June, 2015.
2. Where two or more monitoring levels are available at an installation, the measurement from the shallower install is used.

Halfway Creek

There are several installations that fall within the Halfway Creek catchment. Monitoring locations MW14-05A/B, MW14-03A/B and SRK-15D-08T fall in the southern extent of the drainage and are grouped together in **Figure 3.3-7**. All other installations, including those completed near the proposed Supremo pit and in the lower reaches of the drainage are shown in **Figure 3.3-8**.

Vertical gradients between the shallow and deep wells at MW14-03A/B and MW14-05A/B are essentially negligible (<1%). The hydrographs at MW14-03A/B start climbing in response to seasonal recharge in mid-July, a few weeks after the onset of summer precipitation, and do not respond to individual rainfall events suggesting confined conditions. The water levels in the footprint area of the proposed Kona Pit (MW14-05A/B) are of similar depth as at the well pair MW14-03A/B; however, there is a much more subdued response to seasonal recharge (<1 m) from August to October 2015. There is some noise in the record, which appears to be an artefact of barometric compensation of the files. Besides this, there is an increase in the deep well water level that starts in early July and recovers by mid-August 2015, suggesting a short-term response to early summer rainfall.

SRK-15D-08AT is located at the confluence of the east and west forks of Halfway Creek. Groundwater pressures measured at both shallow and deep VWP sensors are strongly artesian (2 to 13 m above ground surface) although the vertical gradient is markedly downward (~15%). This could suggest that a deep permeable feature is under-draining the area. Permafrost, as measured by the accompanying thermistor string, extends to 75 m below ground surface at this location and likely contributes as a confining unit. Horizontal hydraulic gradients measured between MW14-05B and SRK-15D-08AT in the summer of 2015 are reasonably consistent with the topographic gradient of 5% (**Table 3.3-9**). The horizontal hydraulic gradient between MW14-03B and SRK-15D-08AT is more subdued at 1%.

MW15-06WB and CFD0318 characterize groundwater draining the northwest and southwest slopes surrounding the proposed Supremo Pit, respectively. As MW15-06WB is a Westbay install, only spot measurements are available (**Figure 3.3-8**). The readings taken during the 2015 sampling rounds indicate a very deep water table (>220 m below ground surface). Bedrock ~252 m below ground surface appears to be draining more readily, as vertical hydraulic gradients are towards this zone (70% downward from an upper port at 241 m, and 18% upward from a lower port at 287 m). The horizontal hydraulic gradient measured between one of the shallower ports at MW15-06WB and Halfway Creek is approximately 21% or half of the topographic gradient. The water level at CFD0318 has continually declined since September 2014; the sensor became dry in March/April 2015 and has not re-wetted. If the 2014 measurements are reliable, then water levels are much closer to ground surface on this side of the ridge (90 to >120 m bgs) as compared to MW15-06WB (>220 m bgs).

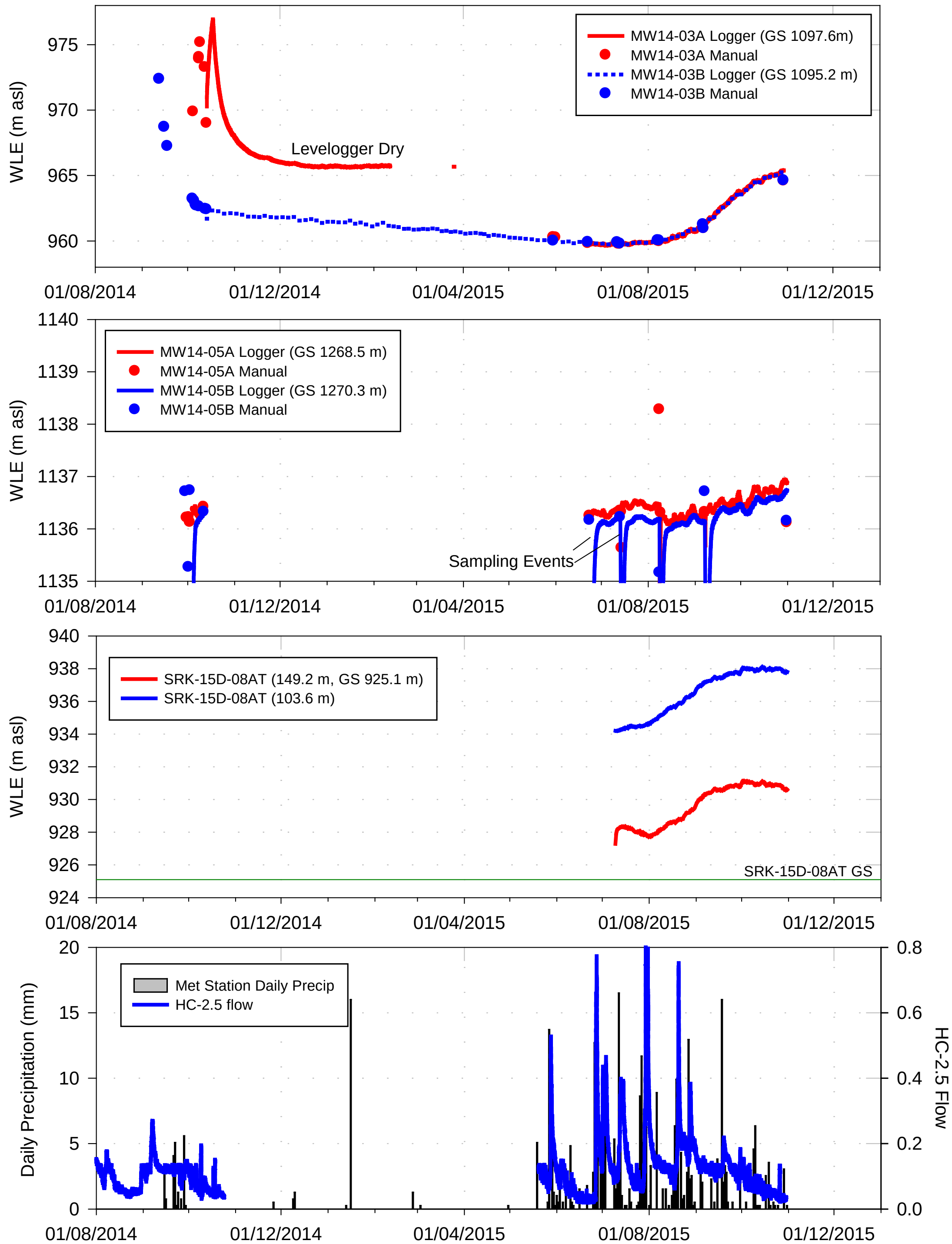


Figure 3.3-7 Groundwater Level Hydrographs Measured in Halfway Creek Drainage, South Extent

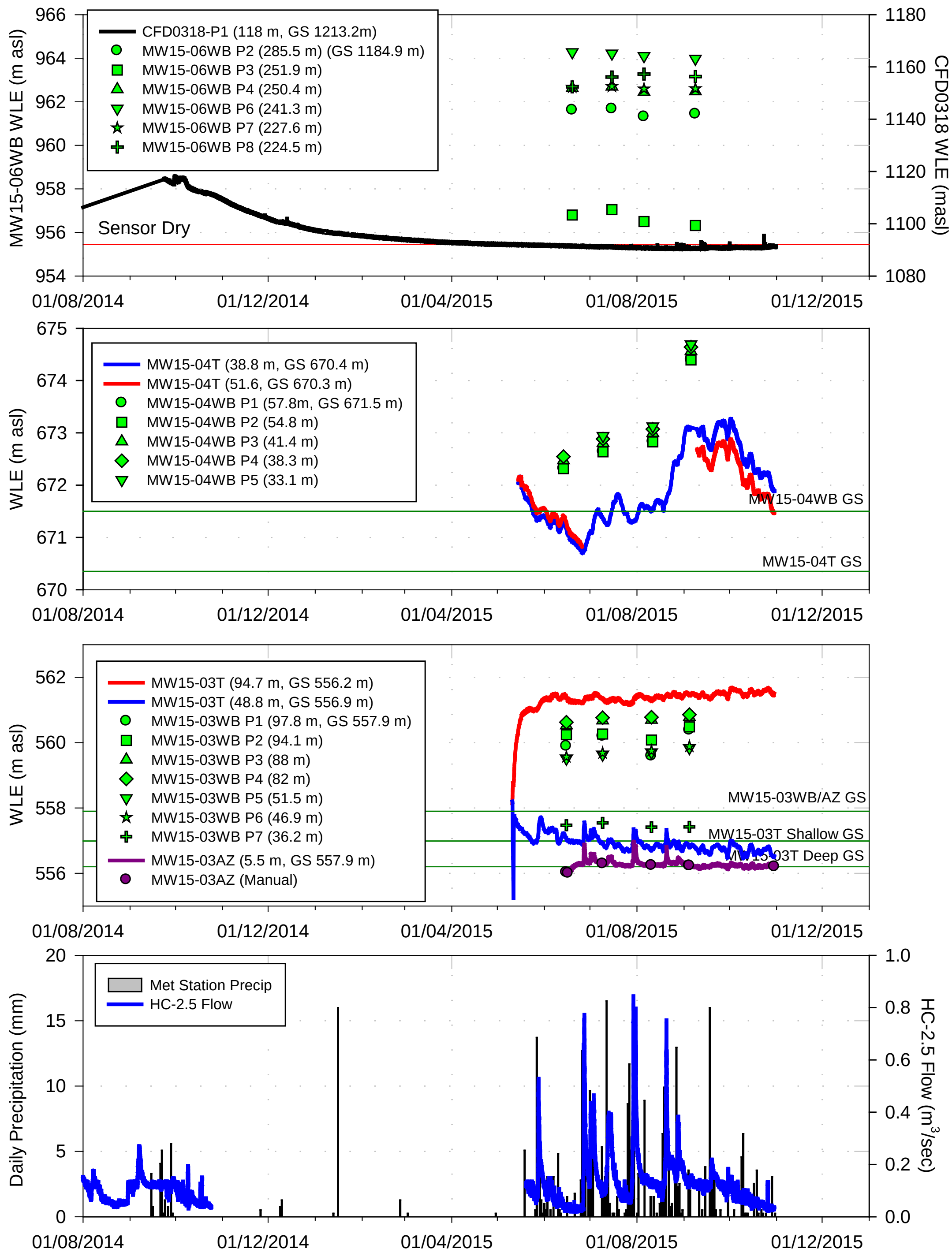
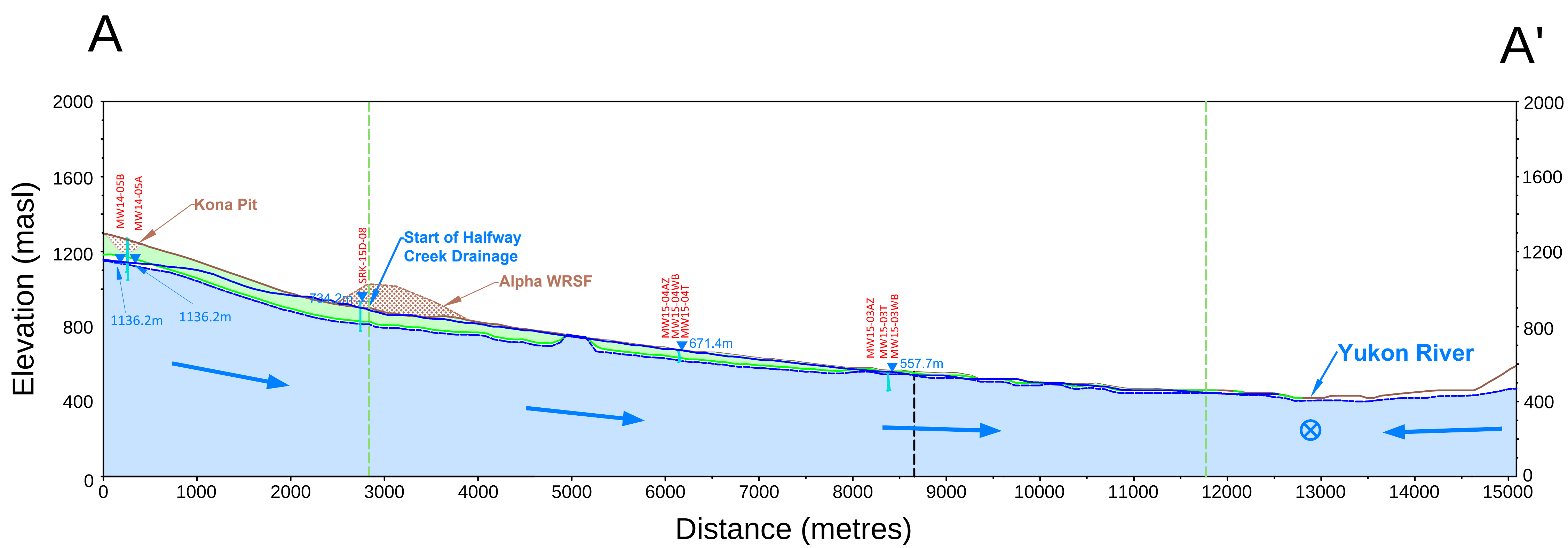


Figure 3.3-8 Groundwater Level Hydrographs Measured in Halfway Creek Drainage, West and North Extent

MW15-04T is located immediately adjacent to the Halfway Creek channel in close proximity to the hydrometric station HC-2.5. The hydrograph at MW15-04T responds to both short term rainfall events and is overprinted by a longer term seasonal trend. An early decline in the hydrographs starting in mid-May 2015 appears to coincide with recovery from freshet. Groundwater levels measured by both VWP sensors have been artesian (~3 m above ground) since inception of the instrument, indicating confined conditions, possibly arising from permafrost. Vertical gradients computed from VWP sensors were essentially negligible in May/June 2015, but have become more strongly downward (3%) through the summer of 2015. The horizontal hydraulic gradient measured between this VWP and SRK15D-08AT upstream is 16% and equivalent to the topographic gradient. The active zone well at this location has remained dry since inception.

MW15-03T and MW15-03WB were installed to characterize groundwater downgradient of a lineament (inferred to be a fault) that crosscuts Halfway Creek and adjacent drainages (**Figure 3.3-1**). The VWP sensors indicate an upward hydraulic gradient at this location which strengthened through September/October of 2015 (10%). The deeper pressure sensor has recorded artesian pressures since inception, while artesian pressures measured at the shallower sensor have receded to just shy of ground surface. Marginal permafrost may contribute to groundwater confinement in this area. The shallow/active zone well has contained water since May and remained unfrozen through October 2015; the well hydrograph reflects some of the flashiness of the HC-2.5 hydrograph. The horizontal hydraulic gradient between MW15-03T and MW15-04T is equivalent to the topographic gradient (5%).

A conceptual diagram of groundwater flow along Halfway Creek is shown in **Figure 3.3-9** (see **Figure 3.3-6** for a plan view of section lines). The trace of Halfway Creek is believed to follow an inferred fault and also coincides with the boundary between frozen and non-frozen areas. The northwest side of the drainage is largely unfrozen (**Figure 3.3-6**). Groundwater flows from high elevation (recharge areas) to low elevation, discharging along major drainages. In this figure, a deeper groundwater flow path is shown that ultimately flows towards the Yukon River and deflects northwest (into the page) towards a regional topographic low point. Shallower groundwater flow paths discharge along Halfway Creek as demonstrated by artesian groundwater conditions at MW15-04T and MW15-03T and accumulations of aufeis (frozen groundwater seepage that accumulates within- and adjacent to local watercourses) in this drainage (see also **Section 3.2.2.5**). A hydrogeological cross-section perpendicular to Halfway Creek (C-C’) is discussed in the Latte Tributary discussion below.



COFFEE GOLD MINE

Conceptual Hydrogeological Cross-Section along Section A-A' (Halfway Creek)

Legend

- Pre-mine topography
- Waste Rock
- Pit
- Water Table (obs)
- Permafrost
- Inflection Point
- Inferred Fault
- Drillholes
- Water Level (obs)
- GW flow direction
- GW flow into page

V.E. = 2X

Figure 3.3-9	Date: Mar 22, 2017	Drawn by: SSS	Reviewed: JS

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YT-24 Drainage

Groundwater level data is available for three installations in the upper YT-24 drainage (**Figure 3.3-10**). Considerable permafrost thickness is observed at all locations and is thought to confine water levels, as none of the hydrographs respond to short term rainfall events.

At the headwaters of YT-24, water levels measured by both pressure sensors at MW15-07T climbed nearly 12 m by the end of October 2015 and are several meters above the inferred base of permafrost (~140 m bgs). The gradient thus far has been consistently upward, slightly increasing (to 4%) into the fall/winter. Farther downgradient, the water levels measured at SRK-15D-07T have remained very flat over the short period of record (September 9th to October 31st, 2015). At this location, there is a much stronger upward gradient (~18%) and groundwater pressures are approximated 35 to 40 m above the base of permafrost, but still well below ground surface (over 50 m bgs). The horizontal hydraulic gradient measured between MW15-07T and SRK-15D-07T is 18%, about two thirds of the topographic gradient.

As opposed to installations completed further upgradient, MW15-01T has a downward vertical gradient (~3%). The hydrographs have risen three metres since the end of July 2015. The groundwater pressures at this location are over 30 m above the base of permafrost, but still remain 20 m below the elevation of the nearby creek (installation is on hillside). The horizontal hydraulic gradient measured between MW15-07T and MW15-01T is 12%, nearly equal to the topographic gradient (**Table 3.3-9**). The active zone well MW15-01AZ intercepted water at some point in June/July 2015, which froze the logger in place and has since remained unavailable.

A conceptual diagram of groundwater flow along YT-24 drainage is shown in **Figure 3.3-11** (see **Figure 3.3-6** for a plan view of section lines). Similar to Halfway Creek, the drainage itself is believed to follow a fault trace and the northwest side of YT-24 is largely permafrost free (**Figure 3.3-6**). The water table at the headwaters of this drainage is shown to be below the base of permafrost, but quickly transitions to where it is confined by permafrost. The deeper groundwater flowpath shown illustrates convergence of groundwater from upland areas north and south of the Yukon River, with flow ultimately deflecting northwest (into the page) towards a regional topographic low point. Shallow groundwater is observed to discharge in lower reaches of the YT-24 drainage (not shown) as evidenced by observations of aufeis.

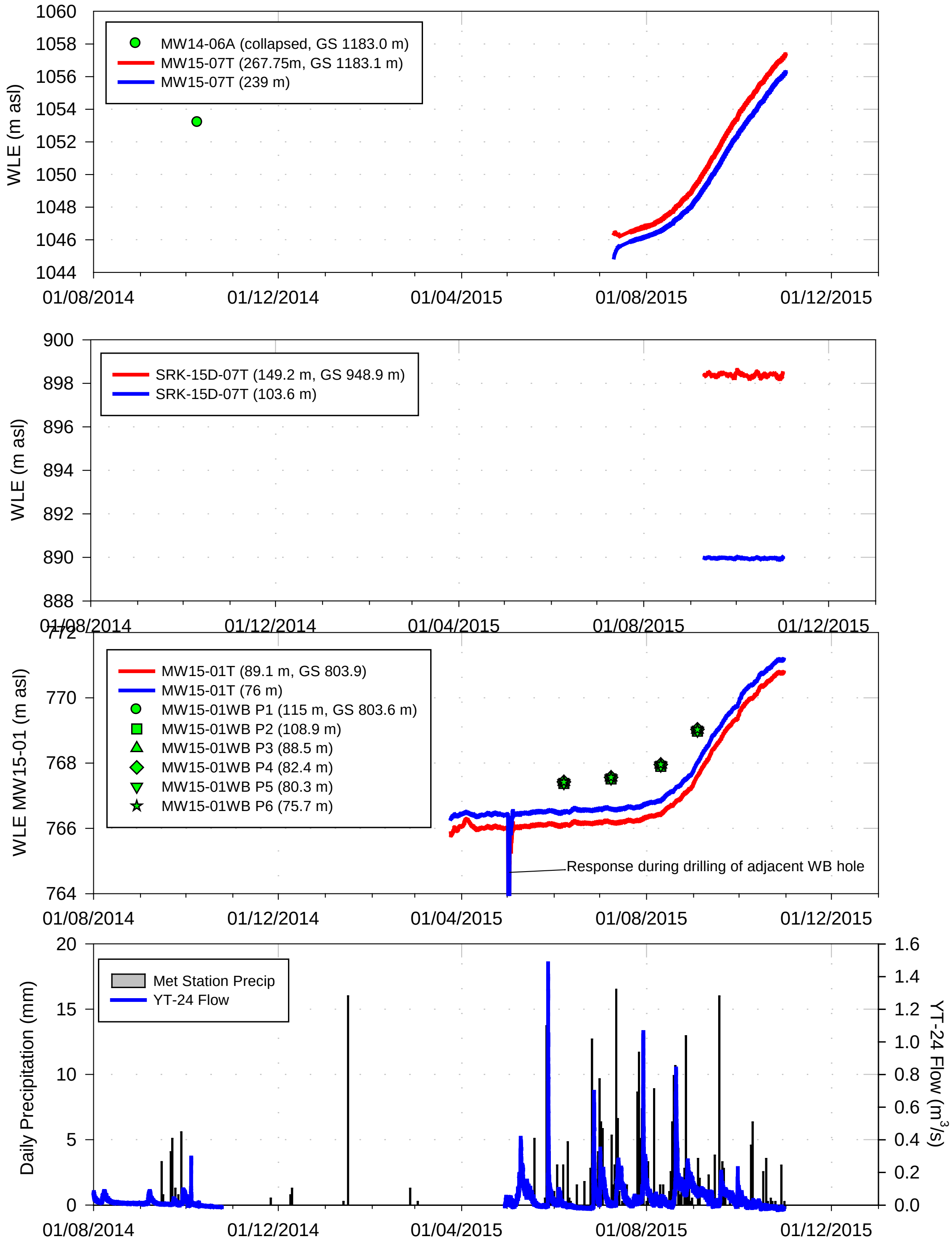
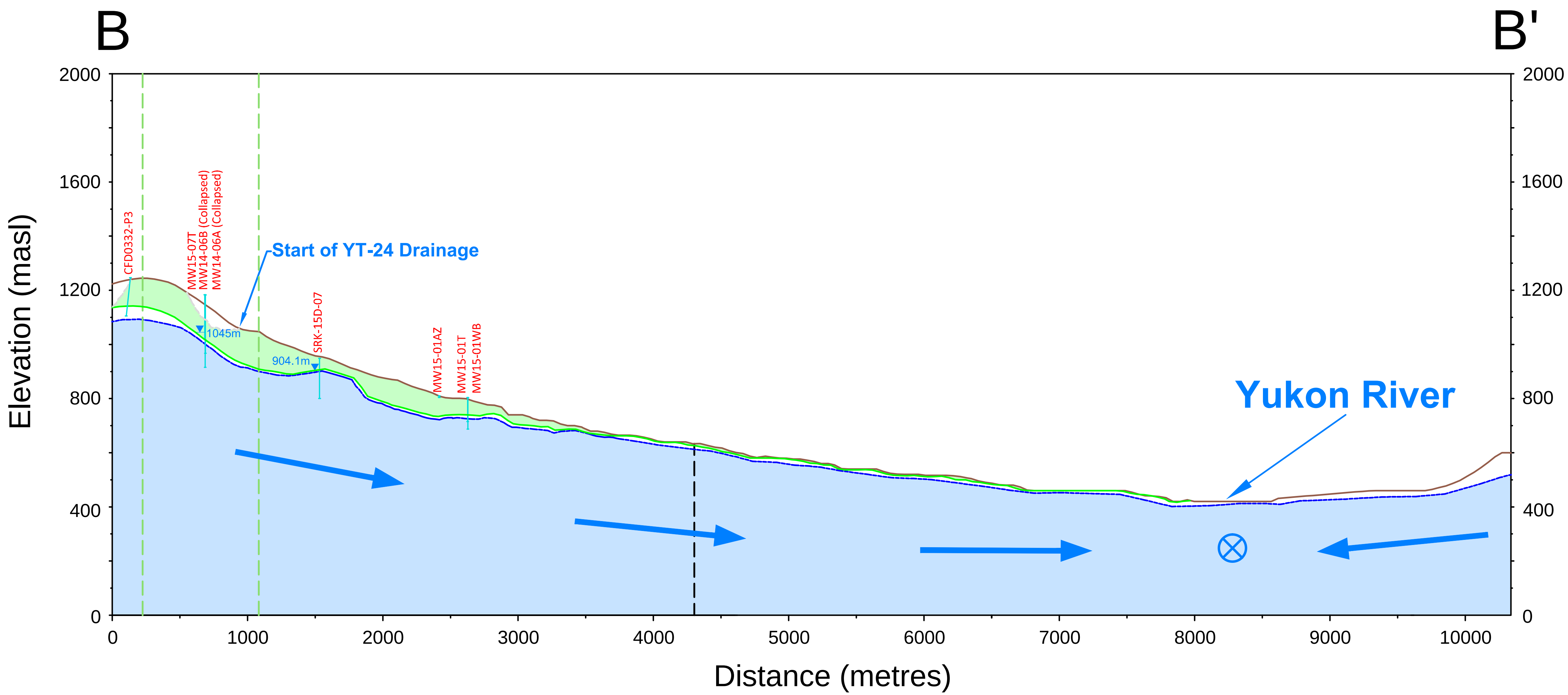


Figure 3.3-10 Groundwater Level Hydrographs Measured in YT-24 Drainage



COFFEE GOLD MINE

Conceptual Hydrogeological Cross-Section along Section B-B' (YT-24 Drainage)

Legend

- Pre-mine topography
- Waste Rock
- Pit
- Water Table (obs)
- Permafrost
- Inflection Point
- Inferred Fault
- Drillholes
- Water Level (obs)
- GW flow direction
- GW flow into page

V.E. = 2X

Figure 3.3-11	Date: Mar 22, 2017	Drawn by: SSS	Reviewed: JS

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Latte Tributary

The Latte Tributary is instrumented in its upper reaches with a conventional monitoring well pair (MW14-02A/B) on the north fork and VWP CFD0351 on the west fork. Both locations demonstrate a strong response to seasonal recharge; on the order of ~13 m and 30 m, respectively (**Figure 3.3-12**). Water levels start to climb at both locations between early to mid-July 2015. Despite similar hydrograph responses, the water level at CFD0351 is deep (~125 to 155 m bgs) compared to the water levels at MW14-02A/B which are near ground surface. MW14-02A ultimately became artesian in September 2015 and remained flowing at surface through October 2015. Once MW14-02A started to flow, the bedrock started to depressurize as evidenced by declining water levels at MW14-02B. Up to this point, vertical gradients at this well pair were ~18% upward. Both permafrost and good quality rock may serve as confining units at MW14-02A/B.

The water level at CFD0324 is around 60 m bgs and is also likely confined, with a relatively small seasonal increase (5 m) compared to upgradient locations. The horizontal hydraulic gradient between CFD0351 and CFD0324 is 5%, much less than the topographic gradient (23%). The horizontal hydraulic gradient between CFD0324 and MW14-02B is 21% and exceeds the topographic gradient (18%).

Father down the drainage, the instrumentation indicates that permafrost is absent. The water level at SRK-15D-09T has climbed modestly (~3 m) since inception in early July 2015, following a similar hydrograph shape as CFD0324. The hydraulic gradient between SRK-15D-09T and upgradient install CFD-0324 is 13% and nearly equal to the topographic gradient (15%). Groundwater pressures at SRK-15D-09T became artesian in August 2015 and remained two metres above ground surface as of October 2015.

Farther still down the drainage, near the confluence of Latte Creek, bedrock groundwater pressure at MW15-02T is not artesian, but is greater than that measured in overburden. The hydrograph at MW15-02T is generally subdued than other locations and is more synchronous to the timing of recharge, suggesting a quick connection to surface recharge. The Westbay ports indicate a strong downward gradient (~24%) across deeper bedrock (32 and 61 m bgs) which may suggest a feature at depth under-draining the area. The horizontal hydraulic gradient between SRK-15D-09T and MW15-02T is 12% and exceeds the topographic gradient (10%) (**Table 3.3-9**).

The shallow well, MW15-02AZ, screens several metres of a cobbly/bouldery package of colluvial sediments Finer intervals in the upper 4 m appeared frozen in March 2015, when the adjacent VWP hole was advanced. The water level has remained flat at this hole and responds to discrete rainfall events.

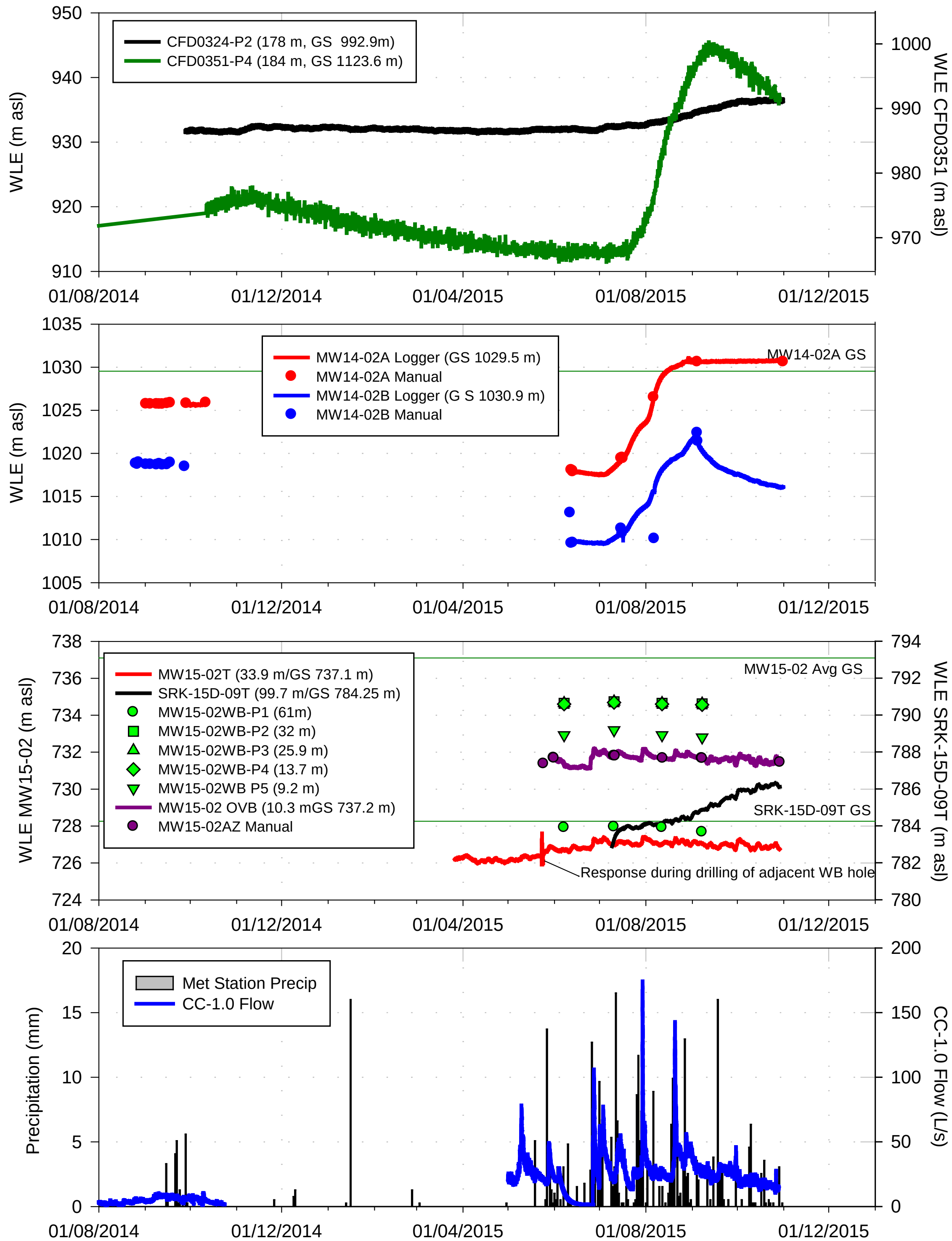


Figure 3.3-12 Groundwater Level Hydrographs Measured in the Latte Tributary.

A conceptual diagram of groundwater flow along the Latte Tributary is shown in **Figure 3.3-13** (see **Figure 3.3-6** for a plan view of section lines). The section extends over the ridge and terminates at Halfway Creek. The section illustrates how the southern (left) slope of the ridge is largely permafrost free with water levels close to ground surface. A deep groundwater flow path flows towards Latte Creek and then deflects out of the page towards a topographic low point. This deflection of flow is facilitated by an inferred permeable fault coincident with the trace of Latte Creek. The water table is deeper on the north side of the ridge, and, according to the current permafrost interpretation, believed to be below the base of permafrost. Deep groundwater drains towards Halfway Creek and deflects northward (out of the page) towards the Yukon River, also facilitated by a permeable fault inferred to occupy the Halfway Creek drainage.

Latte Creek

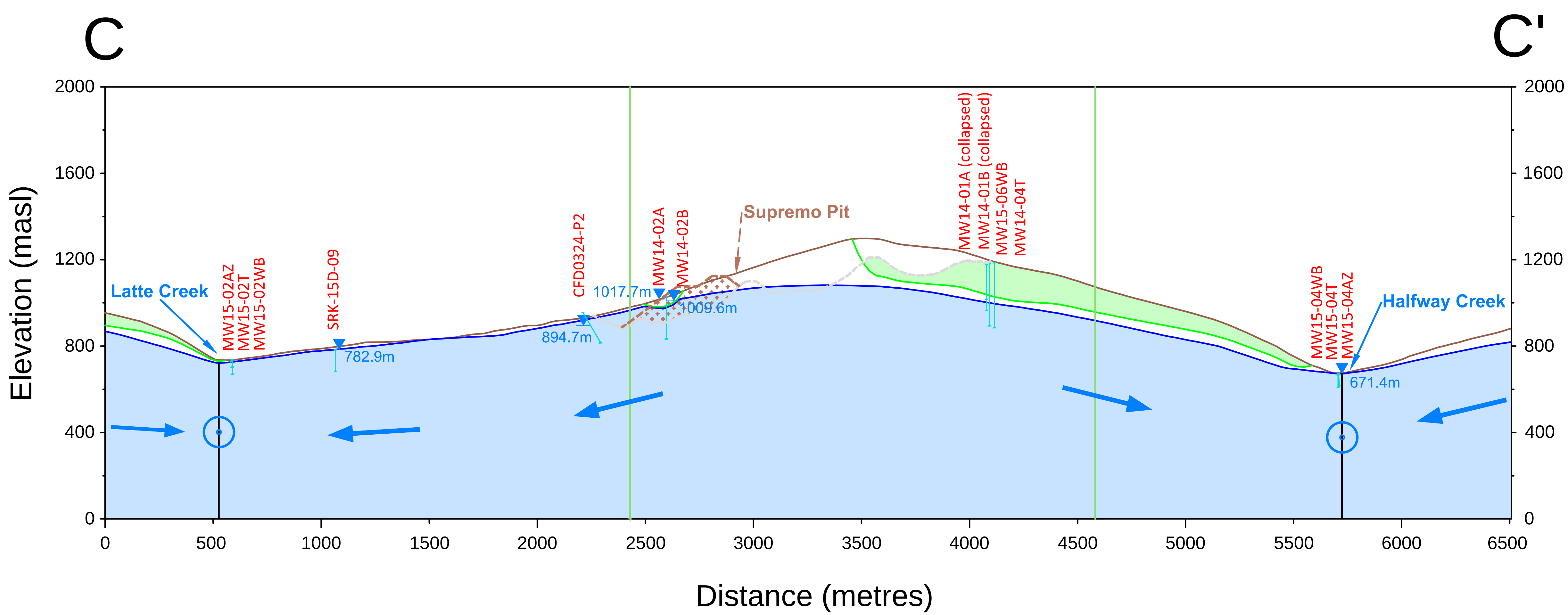
There are three hydrogeological installations along Latte Creek. The first, MW14-07T is several hundred metres downgradient of the proposed heap leach facility. Groundwater pressures are strongly artesian (several metres above ground surface) and thought to be confined by permafrost (~60 m thick) (**Figure 3.3-14**).

MW15-05T lies another ~600 m downgradient of MW14-07T. The horizontal hydraulic gradient between these two locations is 19%, which exceeds the topographic gradient of 14%. Groundwater pressures at MW15-05T are above the base of permafrost but unlike MW14-07T, are on the order of 20 to 30 m below ground surface. The deeper sensor at MW15-05T records flashier pressures which track well with discharge measured at hydrometric station CC-6.0; there is a strong downward gradient (40-55%) between the upper and lower sensors. A strong downward gradient is also measured several kilometres downstream at MW15-02WB as well as in the headwaters of Halfway Creek (SRK-15D-08AT). This may suggest a permeable structure under-draining bedrock at these locations.

A conceptual diagram of groundwater flow along the upper portion of Latte Creek is shown in **Figure 3.3-15** (see **Figure 3.3-6** for a plan view of section lines). Northwest (left) of the section inflection point, the upland area drains largely towards the Halfway Creek drainage (into the page). East of the inflection point, groundwater drains towards a topographic low point. Latte Creek coincides with the boundary between frozen and non-frozen areas, with the north side of the drainage largely permafrost free. The drainage itself is inferred to follow a fault which underdrains the area, causing downward gradient observed at MW15-05T and MW15-02WB.

COFFEE GOLD MINE

Conceptual Hydrogeological Cross-Section along Section C-C'



Legend

- Pre-mine topography
- Waste Rock
- Pit
- Water Table (obs)
- Permafrost
- Inflection Point
- Inferred Fault
- Drillholes
- Water Level (obs)
- GW flow direction
- GW flow into page

V.E. = 1X

Figure 3.3-13	Date: Mar 22, 2017	Drawn by: SSS	Reviewed: JS

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For Discussion Purposes Only

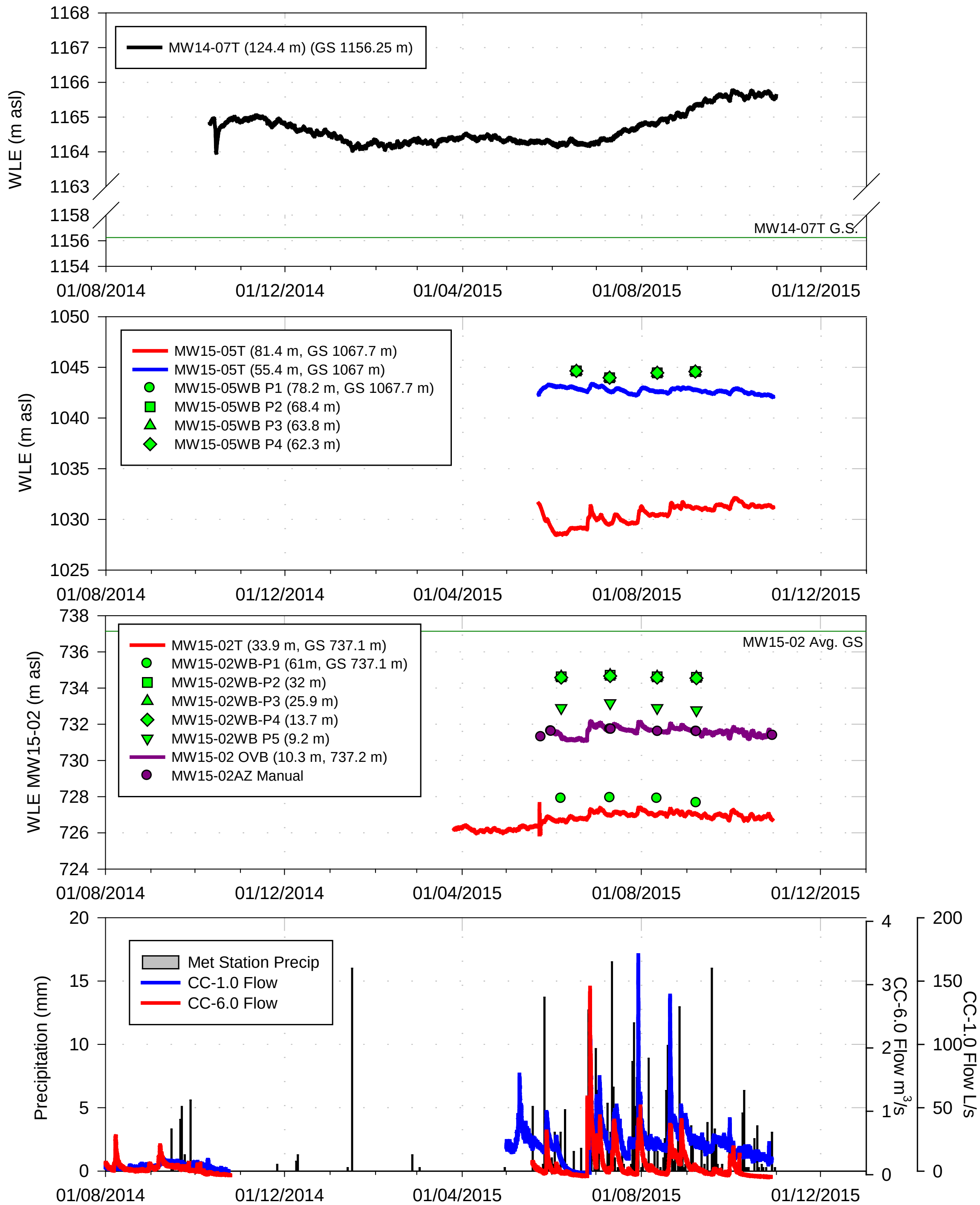
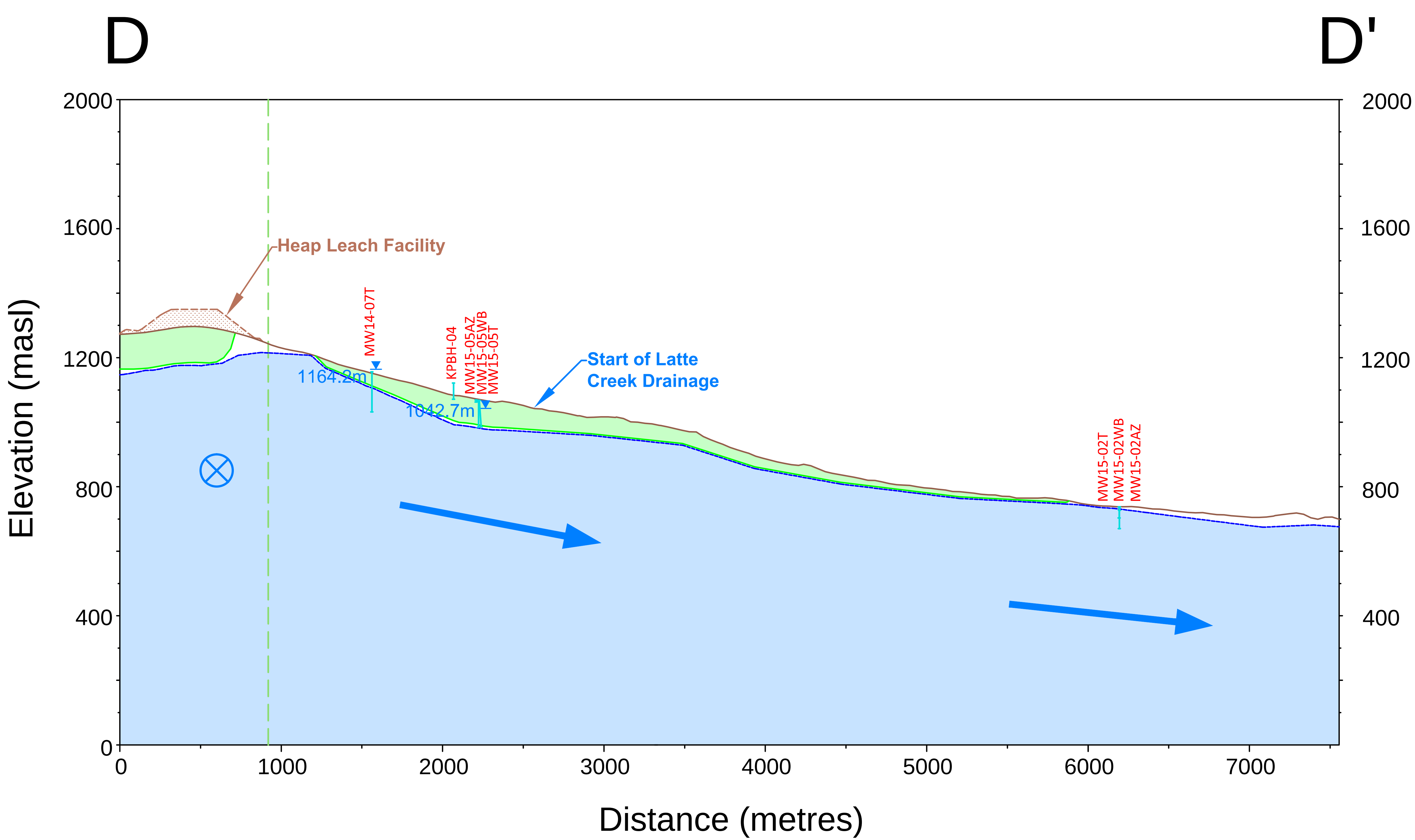


Figure 3.3-14 Groundwater Level Hydrographs Measured in Latte Creek

COFFEE GOLD MINE

Conceptual Hydrogeological Cross-Section along Section D-D' (Latte Creek)



Legend

- Pre-mine topography
- Waste Rock
- Water Table (obs)
- Permafrost
- Inflection Point
- Drillholes
- Water Level (obs)
- GW flow direction
- GW flow into page

V.E. = 2X

Figure 3.3-15	Date: Mar 22, 2017	Drawn by: SSS	Reviewed: JS

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3.3.2.5 Groundwater fluxes to Surface Water Receptors

Groundwater flowpaths converge along major drainage traces, forcing groundwater to come to surface and discharge. This is evidenced by seepage at surface and upward, artesian groundwater pressures registered at piezometers along drainage traces. Artesian groundwater conditions are encountered along drainages in the LSA (**Table 3.3-8**), most notably along Halfway Creek (MW15-04T and MW15-03T) and the Latte Tributary (SRK-15D-09T).

Baseflow is typically understood to constitute the portion of streamflow that is derived from groundwater discharge, and is often considered to be equal to the minimum winter low flow, or the minimum summer flow following an extended dry period (Smakhtin 2001). The baseflow regimes of Project basins are of particular interest since they show elevated concentrations for some parameters, most notably uranium, but also calcium, magnesium and strontium (see **Appendix 12-A**). This is illustrated in the upper pane of **Figure 3.3-16**, which shows time series of total uranium and observed basin yield for stations CC-1.5 and HC-2.5. Observed basin yields and uranium concentrations are also plotted by month in the middle and lower panes of **Figure 3.3-16**. The high surface water concentrations are commensurate with local groundwater quality, discussed in more detail in **Section 3.3.3**. For instance, MW15-02WB, located in near CC-1.5 (**Figure 3.3-1**), records groundwater uranium concentrations in the range of 28 to 37 ug/L (**Table 3.3-11)**, which is commensurate with peak surface water concentrations at CC-1.5 (25 to 35 ug/L). MW15-04WB, which adjacent to the HC-2.5 site, reports groundwater uranium concentrations of 150 to 180 ug/L (**Table 3.3-12**), while HC-2.5 reports peak surface water concentrations in the range of 80 to 110 ug/L.

At the Mine Site, summer baseflows are enhanced by active layer melt which, based on 2015 thermistor data, is observed to occur anywhere between May and October (**Table 3.3-5**). Therefore, lows flows measured during the winter, when the active zone is frozen, are most representative of deeper groundwater discharge. Unit yields for all Project drainages drop to 0.5 to 1.5 L/s/km^2 in all project drainages by November, and zero flow conditions become widespread by late January and are accompanied by extensive aufeis formation. Aufeis is the result of shallow groundwater discharge and/or baseflow in the stream channel freezing. This ice impedes subsequent flow, which is forced on top of the existing ice sheet, where it freezes. This process repeats continuously throughout the winter, and results in laminated ice sheets that can approach 2 m in thickness and 50+ m in width in the Project channels. The aufeis process also acts as a storage reservoir for winter baseflows, and can store up to a third of the cumulative annual baseflow in sub-Arctic watersheds (Yoshikawa et al. 2007).

Over the course of the 5+ years of baseline study, all available winter spot flow measurements (October through April) were averaged by month and are presented in **Table 3.3-10**. Site data show that yields range from 1.2 – 3.3 L/s/km^2 in October, and decrease steadily to their annual minima by March (0 – 0.7 L/s/km^2), before increasing again in April in response to low-elevation snow melt and spring rainfall. Based on the site data alone, winter low flows are expected to range from 0 to 0.7 L/s/km^2.

For the purpose of calibrating the baseline groundwater flow model, low flow values corresponding to basin yields of 0.4 to 0.9 L/s/km^2 were used for all project stations except CC-1.0 and YT-24 (see **Table 2.1-1**). This range was selected based on scrutiny of flow and surface water chemistry observations at HC-2.5 and CC-1.5. Both HC-2.5 and CC-1.5 show an inverse relationship between flow and parameter concentrations as illustrated in **Figure 3.3-16** and **Figure 3.3-17**. Closer inspection of monthly basin yields for CC-1.5 and HC-2.5 (**Figure 3.3-16**) indicates that CC-1.5 and HC-2.5 reach their minima between February and April. Uranium concentrations also reach their maxima during the same period. For CC-1.5, the maximum 10% of total uranium concentrations range from ~31 to 32 ug/L and correspond to measured basin yields of 0.4 to 0.9 L/s/km^2. At HC-2.5, maximum 10% of total uranium concentrations range from ~84 to 102 ug/L and correspond to basin yields of 0.5 to 0.9 L/s/km^2 (note that a flow measurement was not taken at the time the 102 ppb U-T concentration was recorded). Based on these results, a baseflow target range of 0.4 to 0.9 L/s/km^2 was applied to most station project stations.

The lower bound of baseflow targets at YT-24 and CC-1.0, were adjusted downward from 0.4 L/s/km^2 to reflect streamflow measurements made around June 20th, 2015. The site experienced a prolonged warm, dry spell prior to these measurements. CC-1.0 was found to be dry and YT-24 reported flow of 0.3 L/s/km^2.

Table 3.3-10 Winter Spot Flow Measurements Presented as Monthly Averages for Project Hydrometric Stations

Station	Basin Area (km^2)	Average Winter Baseflow (L/s/km^2)						
		OCT	NOV	DEC	JAN	FEB	MAR	APR
CC-0.5	385.6	2.58	0.43	NA	0.07	0.07	0.03	1.36
CC-1.5	23.1	2.71	0.78	NA	0.91	0.63	0.48	0.76
CC-3.5	69.8	1.61	0.3	0.2	0.14	0	0.01	0.95
HC-2.5	14.8	3.29	1.18	1.17	1.32	0.7	0.65	1.61
HC-5.0	27	2.19	0.21	NA	0	0	0	0.57
IC-1.5	81.1	2.84	0.64	0.76	0.65	0.31	NA	NA
IC-2.5	17.3	1.19	0	NA	NA	0	NA	4
IC-4.5	222.3	2.16	0.2	0.34	NA	NA	NA	2.42

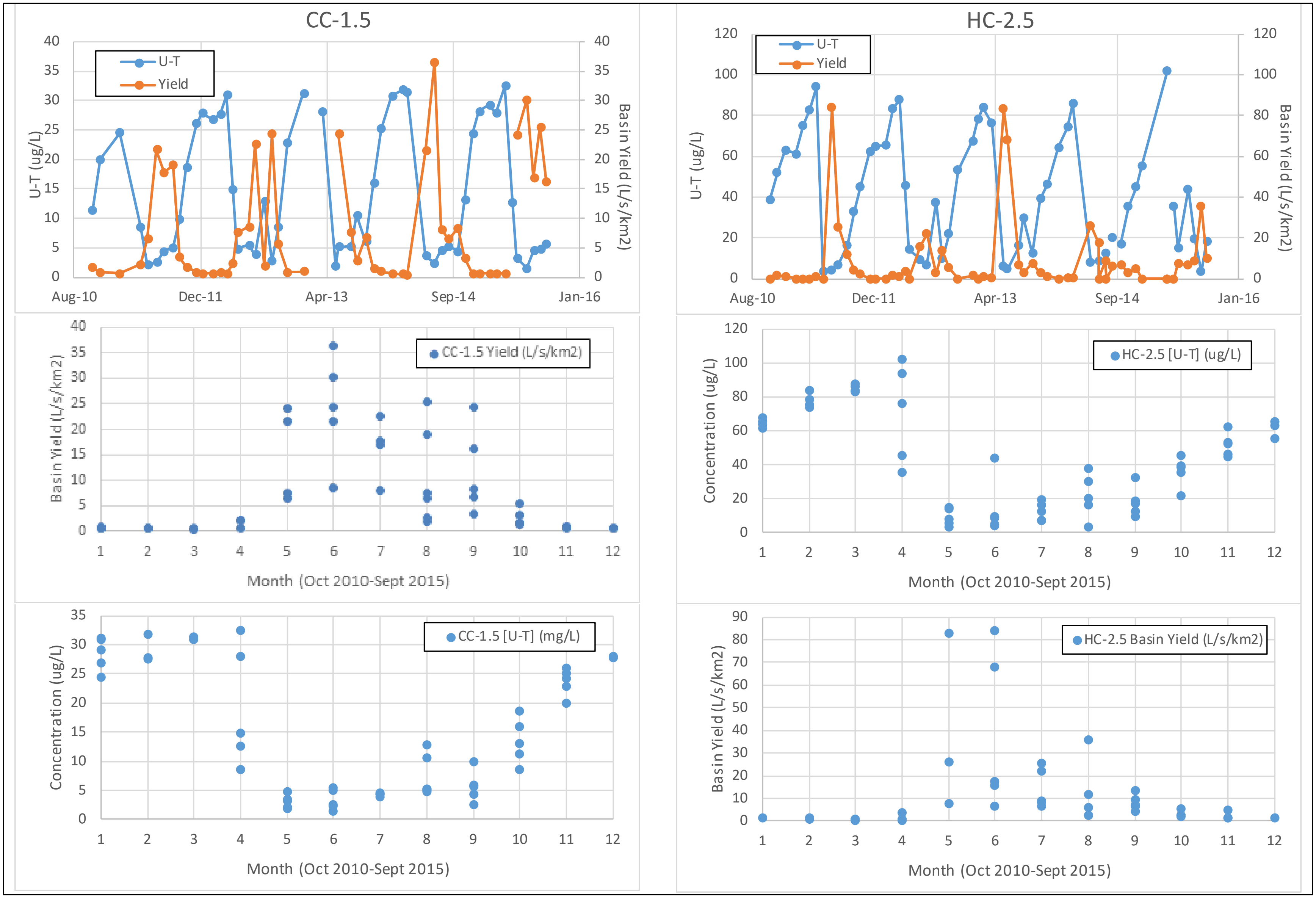


Figure 3.3-16 Observed basin yield and total uranium concentrations for CC-1.5 and HC-2.5.

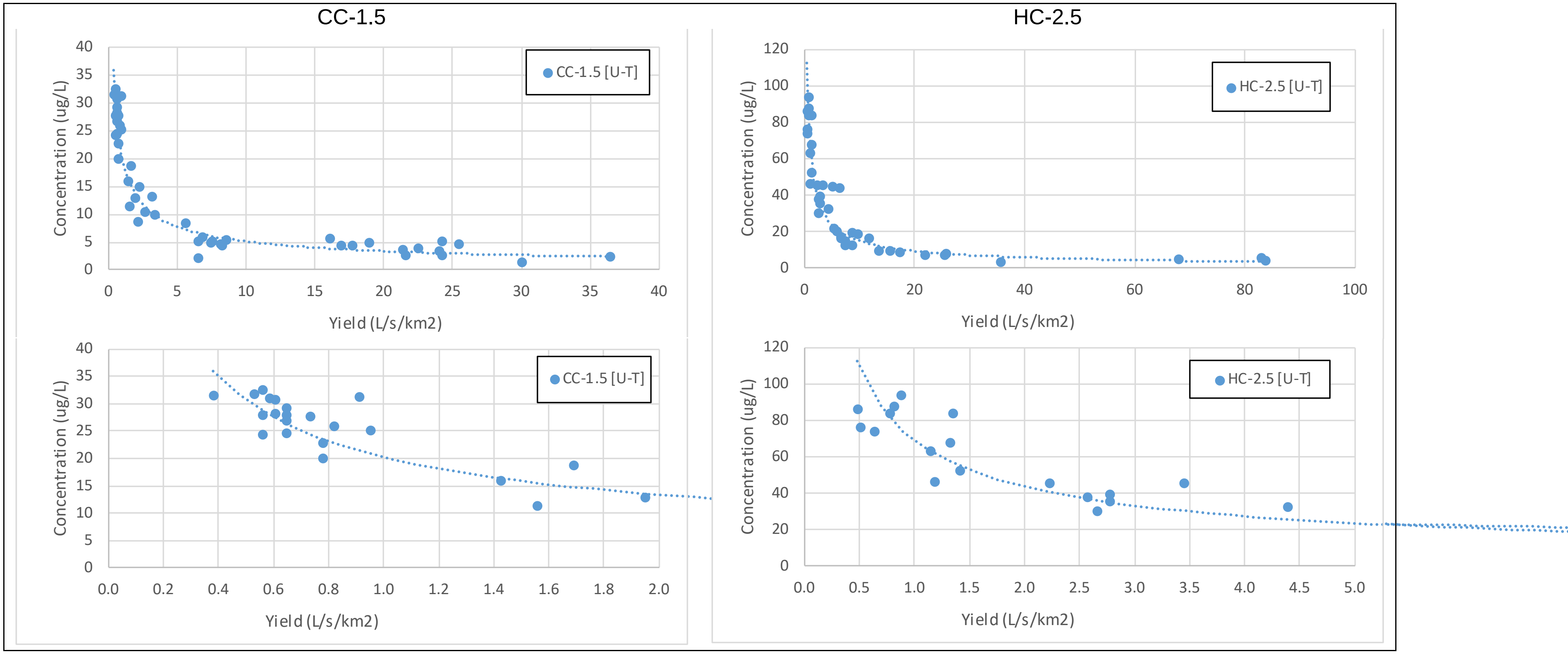


Figure 3.3-17 Total uranium concentrations versus observed basin yield for CC-1.5 and HC-2.5.

3.3.3 GROUNDWATER QUALITY

Groundwater quality in the Mine Site is discussed in terms of major ion chemistry with reference to physical parameters (pH, specific conductance) followed by oxidation-reduction (redox) conditions and trace element geochemistry. Where analytical results are non-detect, the method detection limit (MDL) values are used for graphing purposes. Groundwater quality is discussed in relation to the principal lithology at the screened interval of each monitoring well: overburden, gneiss, granite, breccia and schist.

The groundwater quality data set has undergone a rigorous QA/QC analysis (**sub-appendix 5-D of Appendix 7-A**). Samples inferred to be influenced by drilling artefacts have been screened out of the data. The analysis has not identified any systemic issues in sampling or laboratory analysis that affect the interpretation of the data set.

3.3.3.1 Major Ions

Groundwater is predominantly circum-neutral (pH 6 to 8), with most samples characterized by pH 7 to 8. Groundwater wells show variable influence from weathering of sulfide minerals and/or dissolution of sulfate minerals, either from the deposits or other disseminated mineralization across the Mine Site. This is evidenced by low to substantial sulfate (SO_4) concentrations which range from 12 to 954 mg/L and variable salinity with specific conductance ranging from 28 to 2269 µS/cm. A trilinear plot of major ion equivalents is provided in **Figure 3.3-18**.

Groundwater encountered in overburden wells (orange symbols in **Figure 3.3-18**) is calcium-bicarbonate-type (Ca-HCO_3), irrespective of the type of deposit screened (colluvium, colluvium/bedrock interface). Overburden groundwater contains variable amounts of sulfate (up to 49% at MW15-02AZ at the base of the South WRF drainage), electrical conductivity ranging from 28 to 874 µS/cm and pH values ranging from 5.9 to 7.5.

Monitoring wells screened in gneiss are located on the north side of the Mine Site (black symbol in **Figure 3.3-18**). Groundwater sampled from these wells presents a wide range of hydrogeochemical compositions that range from Ca-HCO_3 to mixed magnesium-calcium-sodium-sulfate-type (Mg-Ca-Na-SO_4). In the Supremo area (MW15-06WB) and in Halfway Creek (MW15-04T), specific conductance ranges from 600-690 µS/cm. The pH range is narrower at MW15-06WB (pH 7.7 to 8.0) than MW15-04T (pH 6.3 to 8.3). Groundwater screened in the YT-24 drainage (MW15-01WB) and downgradient of the lineament in Halfway Creek (MW15-03WB) is the most saline in the Mine Site (maximum 1,980 µS/cm and 2,220 µS/cm, respectively) with pH ranging from 6.8 to 7.9.

Monitoring wells screened in granite (pink symbols in **Figure 3.3-18**) are located adjacent to Latte Creek downstream from the proposed HLF (MW15-05WB) and in the Kona Pit (MW14-05A and MW14-05B). Groundwater sampled from these wells ranges from Ca-HCO_3-type to sodium-bicarbonate-type (Na-HCO_3).

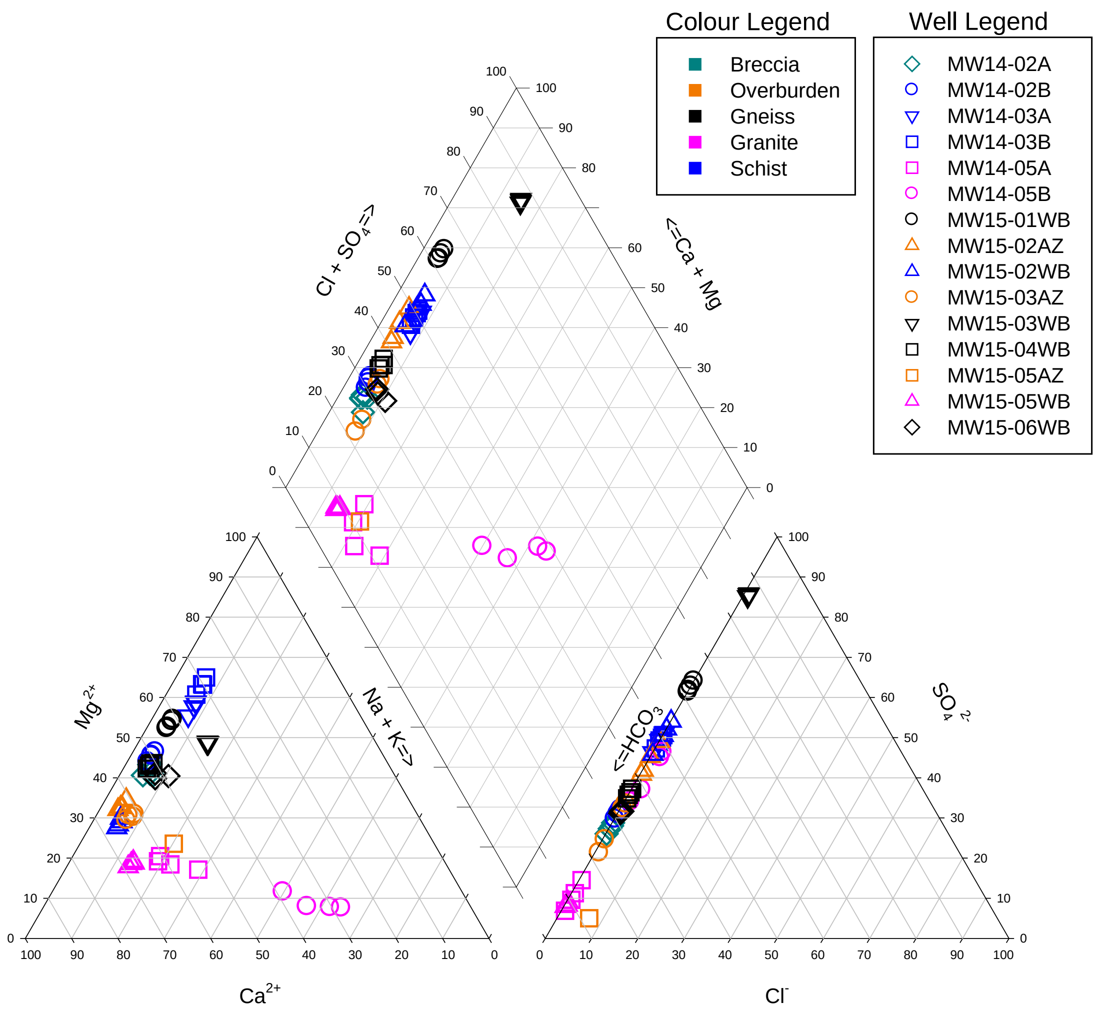


Figure 3.3-18 Piper Plot of Coffee Groundwater Quality Data (2014 and 2015)

The groundwater at MW15-05WB is Ca-HCO_3-type and displays uniform composition; it is fresh (specific conductance of 291 to 306 µS/cm) and has circum-neutral pH (6.6 to 7.6). Groundwater at MW14-05A is Ca-HCO_3-type, while that at MW14-05B presents a more intermediate chemistry, classified predominantly as Na-HCO_3-type with significant SO_4 influence in two samples. Groundwater at MW14-05B is more saline than that at MW14-05A with specific conductance values of 569 to 709 µS/cm and 329 to 379 µS/cm, respectively.

MW14-02A is the only well screening hydrothermal breccia. The groundwater at this location is Ca-HCO_3 type with significant Mg influence. Groundwater at MW14-02A is fresh (specific conductance of 349 to 400 µS/cm) neutral to slightly alkaline (pH 7.3 to 8.2).

Schist is screened at four monitoring wells whose groundwater compositions range from Ca-HCO_3 to Mg-SO_4-type. In the upper reaches of the Latte Tributary, MW14-02B has circum-neutral field pH (7.5 to 7.6) and is slightly more saline (specific conductance of 481 to 509 µS/cm) than deeper groundwater sampled at MW14-02A (screening breccia). Farther downgradient at the mouth of the Latte Tributary, groundwater at MW15-02WB is more saline (specific conductance 863 to 898 µS/cm), and has circum-neutral (field pH 7.3 to 7.5). It is classified as calcium-sulfate-type ($Ca\text{-}SO_4$) with significant HCO_3 influence. Adjacent to the proposed Latte Pit, the composition of groundwater screened at MW14-03A and MW14-03B ranges from magnesium-bicarbonate-type with significant SO_4 influence and $Mg\text{-}SO_4$-type with significant HCO_3 influence. The groundwater is slightly more saline in the shallow well than the deeper well, 1,604 to 1,717 µS/cm versus 1,376 to 1,620 µS/cm at MW14-03B and 14-03A, respectively.

3.3.3.2 Redox Conditions

Redox conditions within a groundwater system can be assessed based on the presence and concentration of oxidized and reduced inorganic compounds in groundwater samples. Key indicators of suboxia include: absence of O_2, removal of NO_3^- and/or NO_2^- accompanied by elevated concentrations of ammonia (NH_3), elevated concentrations of dissolved iron (Fe^{2+}) and manganese (Mn^{2+}) at circum-neutral pH, and presence of dissolved sulphide (S^{2-}).

Groundwater sampled from overburden wells was oxic to mildly suboxic. Groundwater at MW14-02A, screening hydrothermal breccia, is also oxic with very low to negligible concentrations of reduced species.

Redox conditions at monitoring wells screened in the gneiss range from oxic to moderately suboxic. Near the proposed Supremo pit at MW15-06WB, groundwater is mildly to moderately suboxic; NH_3, Mn^{2+} and Fe^{2+} are consistently measured in samples. Likewise, groundwater at MW15-04WB is oxic to mildly suboxic with NO_3^-, NO_2-, NH_3 and dissolved Mn routinely measured. Groundwater sampled downgradient of the lineament in the Halfway Creek drainage (MW15-03WB), as well as in the YT-24 drainage at MW15-01WB is suboxic and mildly to moderately reducing. Recall that groundwater measured at these two locations is also the most saline measured in the LSA.

Groundwater redox conditions at monitoring wells screened in granite are mildly to strongly anoxic. Monitoring wells MW14-05A and MW14-05B at Kona had measurable concentrations of dissolved Mn, Fe and S^{2-} indicating moderately to strongly reducing conditions, although trends in some parameters may indicate that water quality at MW14-05B has not completely stabilized. The groundwater at MW15-05WB is classified as anoxic and mildly to moderately reducing with measurable concentrations of dissolved Mn, Fe but no measurable S^{2-}.

Monitoring wells screened in schist span the entire range of redox conditions from oxic to strongly reducing. The well pair adjacent to the proposed Latte pit, MW14-03A/B, screens anoxic and moderately to strongly reducing groundwater. The deeper well (MW14-03A) is more strongly reducing with very elevated Fe (median 8385 µg/L), but dissolved Fe, Mn and S^{2-} are consistently measured at both wells. Along the Latte

Tributary, groundwater at MW14-02 A/B is mildly reducing with measurable concentrations of NO_3^- and low levels of dissolved Fe, Mn and S^{2-}. Groundwater at MW15-02WB, at the mouth of the drainage, is oxic to mildly reducing; shifting towards less reducing conditions in the last (September) sampling event as evidenced by measurable NO_3^-.

3.3.3.3 Trace Elements

This section presents a review of selected trace element concentrations across the groundwater LSA. Complete groundwater quality results are presented in **Appendix 7-A** (sub-**Appendix 5-**A). Minimum and maximum groundwater concentrations of selected dissolved metals are presented in **Table 3.3-11** and **Table 3.3-12**. The highest concentration of each parameter of concern, measured across all groundwater samples, is highlighted green in the tables below.

Dissolved As is measurable in a number of monitoring wells at the site. The highest concentrations of measured As are typically associated with deep groundwater beneath ridge top areas. Arsenic mobility is groundwater is often increased under suboxic to anoxic conditions and is generally associated with increased Fe and Mn solubility under reducing conditions. The highest As concentrations in the Mine Site were observed in the granitic bedrock beneath Kona at MW14-05A (median 1690 µg/L). Recall from **Section 5.4.2** that MW14-05A was characterized by strongly reducing conditions with dissolved Fe, Mn and sulphide (S^{2-}) measured. It is also notable that granite material at Kona has the highest solid-phase As concentrations measured in the Mine Site (see **Appendix 12-C Geochemical Characterization Report**). Arsenic concentrations are also elevated in MW14-02A (median 53.8 µg/L), MW14-02B (median 37.4 µg/L) and MW14-03A (median 63.7 µg/L). These wells were also characterized as having anoxic to strongly reducing conditions. Conversely, much lower As concentrations were measured in monitoring wells characterized as oxic. Specifically, well MW15-02WB, located downgradient of MW14-02A, had median dissolved As concentrations of only 2.2 µg/L and characterized as oxic conditions. Similarly, MW15-04WB, located downgradient of both MW14-05A and MW14-03A, is characterized as oxic and had median dissolved As concentrations of 1.3 µg/L. These data point to an important relationship between As concentrations and redox conditions in groundwater.

Concentrations of dissolved Sb are generally below 1 µg/L in overburden and bedrock groundwater, but do exceed this level at selected wells screening granite, schist and gneiss. The highest concentration of dissolved Sb (6.6 µg/L) is recorded at MW14-02B, screening schist.

Dissolved Cd measured in overburden and bedrock groundwater is predominantly in the 0.006 to 0.06 µg/L range, except at MW15-02AZ and MW15-04WB. The highest concentration of cadmium (0.125 µg/L) is measured at MW15-02AZ screening overburden; however non-detect levels have also been recorded at this well.

Table 3.3-11 Ranges of Selected Dissolved Metals of Concern Measured in Groundwater Screening Overburden, Breccia and Schist

Well ID	MW15-02AZ		MW15-03AZ		MW15-05AZ	MW14-02A		MW14-02B		MW14-03A		MW14-03B		MW15-02WB	
Lithology	Overburden					Crackle Breccia		Schist							
Sample Count	5		5		1	6		7		5		5		4	
Statistics	Min	Max	Min	Max	Value	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Dissolved Metals (ug/L)															
Aluminum (Al)	3.6	15	19	38	190	4	17	<1.0	15	3.4	53	2.8	19	1.9	6.9
Antimony (Sb)	0.14	0.44	0.14	0.2	0.084	0.7	0.92	<0.10	6.6	0.31	1	0.085	0.13	0.076	0.38
Arsenic (As)	0.91	1.1	0.41	0.55	2.3	52	71	<0.10	39	49	76	7.6	9.2	0.5	2.5
Cadmium (Cd)	<0.0050	0.13	0.01	0.026	0.022	<0.0050	<0.010	<0.0050	<0.010	<0.0050	0.055	<0.0050	0.063	0.011	0.042
Chromium (Cr)	<0.10	0.2	0.1	0.28	0.7	0.45	0.6	<0.10	0.42	<0.10	0.3	<0.10	0.16	<0.10	1.9
Cobalt (Co)	0.029	0.21	0.05	0.086	2.5	0.013	0.11	<0.10	2.5	1.3	2.5	6.1	7.6	0.068	0.18
Copper (Cu)	0.95	1.3	1.4	2	1.9	<0.050	0.31	<0.050	<0.20	0.068	1.7	0.43	1.6	0.2	1.7
Iron (Fe)	4.9	11	9.3	21	930	<1.0	27	1.5	<10	7300	9400	1000	2100	3.9	360
Lead (Pb)	<0.0050	0.021	<0.0050	0.026	0.033	<0.0050	<0.050	<0.0050	<0.050	0.006	0.21	0.015	0.08	0.0052	0.31
Mercury (Hg)	<0.0020	0.0029	<0.0020	0.0028	0.0054	0.0025	<0.010	<0.0020	<0.010	0.0021	0.0098	0.0028	0.0066	<0.0020	<0.0020
Nickel (Ni)	0.55	1.3	1	1.4	1.2	0.082	<0.50	<0.50	15	0.34	2.4	17	22	0.89	2.2
Selenium (Se)	0.16	1.1	0.041	0.064	0.069	0.22	0.26	<0.10	0.33	<0.040	0.097	0.12	0.25	0.1	0.37
Uranium (U)	24	26	17	37	0.9	45	70	<0.010	93	44	69	38	43	28	37
Zinc (Zn)	0.55	8.6	0.41	7.6	1.1	0.27	3.8	<1.0	10	0.29	16	0.75	10	10	45

Notes:

Highlighted values are the maximum of element measured across all monitoring wells in the LSA.

Table 3.3-12 Ranges of Selected Dissolved Metals of Concern Measured in Groundwater Screening Granite and Gneiss

Well ID	MW14-05A		MW14-05B		MW15-05WB		MW15-01WB		MW15-03WB		MW15-04WB		MW15-06WB	
Lithology	Granite						Gneiss							
Sample Count	5		5		5		4		4		6		3	
Statistics	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Dissolved Metals (ug/L)														
Aluminum (Al)	0.56	24	0.67	29	1.7	23	<0.50	14	3.5	36	3.2	44	7.2	68
Antimony (Sb)	<0.020	0.69	<0.020	1.2	0.22	<0.50	0.35	0.81	0.042	0.099	2.6	3.1	0.76	2.8
Arsenic (As)	0.047	1900	<0.020	160	0.88	1.3	22	42	0.27	0.49	1.3	1.5	10	26
Cadmium (Cd)	<0.0050	0.012	<0.0050	0.042	0.016	0.029	0.014	0.061	<0.0050	0.048	0.037	0.1	0.013	0.037
Chromium (Cr)	<0.10	0.2	<0.10	<1.0	<0.10	<1.0	<0.10	0.94	<0.10	0.22	<0.10	<1.0	<0.10	0.66
Cobalt (Co)	<0.0050	1.2	<0.0050	1.3	0.037	<0.50	0.66	0.89	0.055	0.12	0.2	<0.50	2.1	3.2
Copper (Cu)	<0.050	1.2	<0.050	2.5	0.083	0.36	0.098	0.41	0.074	0.24	0.96	2.3	0.19	1.2
Iron (Fe)	<1.0	3600	<1.0	1600	2.3	11	2.6	560	5.6	570	5.4	13	57	850
Lead (Pb)	<0.0050	0.26	<0.0050	<0.20	0.01	<0.20	<0.0050	0.23	<0.0050	0.02	0.15	0.37	0.017	0.098
Mercury (Hg)	<0.0020	<0.0020	<0.0020	<0.010	<0.0020	<0.010	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.010	0.022	0.095
Nickel (Ni)	0.068	1.4	<0.020	7.2	0.22	<1.0	1.8	2.4	1.1	2	0.8	1.2	2.7	3.4
Selenium (Se)	<0.040	0.1	<0.040	0.42	0.1	0.37	0.075	0.13	<0.040	0.43	0.13	0.34	0.17	0.5
Uranium (U)	<0.0020	33	0.019	16	66	75	530	590	7.6	9.1	150	180	100	100
Zinc (Zn)	0.16	11	0.1	17	38	97	54	180	4.9	110	9.6	58	21	250

Notes:

The sample collected at MW14-03A on Oct. 12, 2014 has been excluded from statistical calculations

The sample collected at MW14-03B on Oct. 6, 2014 has been excluded from statistical calculations

The sample collected at MW14-05A on Oct. 2, 2014 has been excluded from statistical calculations

The sample collected at MW14-05B on Oct. 3, 2014 has been excluded from statistical calculations

The sample collected at MW15-06WB on Jun. 21, 2015 has been excluded from statistical calculations

Highlighted values are the maximum of element measured across all monitoring wells in the LSA

Dissolved Co concentrations are generally higher in schist than in other screened units. The highest concentrations of dissolved Co are measured at MW14-03B (6.1 to 7.6 µg/L).

Concentrations of dissolved Cu are generally higher in overburden groundwater (0.95 to 2.0 µg/L), however the highest concentrations are measured in bedrock. Both MW14-05B, screening granite, and MW15-04WB, screening gneiss, have recorded dissolved Cu concentrations exceeding 2.0 µg/L.

Dissolved Pb concentrations are low in the overburden and bedrock groundwater. Concentrations are lowest in the overburden (< 0.005 to 0.033 µg/L) and more variable in bedrock. The highest concentration of lead (0.366 µg/L) is measured at MW15-04WB screening gneiss; however, non-detect levels have also been recorded at this well.

Dissolved Hg concentrations are below the method detection limit in the majority of overburden and bedrock groundwater samples. All wells with measurable dissolved Hg were characterized by concentrations <0.01 µg/L, except MW15-06WB (0.02 to 0.10 µg/L) where the highest concentrations were detected.

Concentrations of dissolved Ni in groundwater are generally below 5 µg/L, except at MW14-05B, MW14-2B and MW14-03B. Dissolved Ni concentrations were highest at MW14-03B, screening schist (17 to 22 µg/L).

Dissolved Se was generally low in overburden and bedrock groundwater, with concentrations ranging from below detection limit (0.04 µg/L) to 0.5 µg/L. One sample at MW15-02AZ, screening overburden had the highest Se concentration measured in the LSA (1.1 µg/L); however, all other samples collected at MW15-2AZ were consistently between 0.16 and 0.20 µg/L.

Dissolved U is generally elevated (> 15 µg/L) across the LSA, with a couple of exceptions. Dissolved U concentrations are highest in gneiss at MW15-01WB (530 to 589 µg/L), MW15-04WB (154 to 176 µg/L) and MW15-06WB (100 to 103 µg/L). Notably, the concentrations of dissolved U are lower (<10 µg/L) in MW15-03WB, which screens gneiss downgradient of the lineament in Halfway Creek. The overburden well MW15-03AZ has higher concentrations of dissolved U (17 to 35 µg/L) than the bedrock at this location.

Dissolved Zn was consistently measured across the Mine Site with higher and more variable concentrations measured in Westbay installations screened in the bedrock. Dissolved Zn levels were lowest in the overburden and bedrock groundwater collected from conventional wells, with concentrations ranging between 0.27 and 16.5 µg/L. In contrast, the groundwater concentrations at MW15-06WB, ranged between 20.9 µg/L and 253 µg/L.

3.4 NORTHERN ACCESS ROUTE

Hydrogeological data collection has focussed on the Mine Site (**Figure 1.3-2**) and has not included the Northern Access Route. Given that a portion of the road is pre-existing, that the new portion of the road will be built and operated according to best practices (**Section 4.3**; Access Route Construction Management Plan, **Appendix 31-A**; Access Route Operation Management Plan **Appendix 31-B**), changes to the Groundwater IC resulting attributable to the road are expected to be negligible and localized to the shallow groundwater regime (**Section 4.0**). Potential changes to the shallow groundwater system are expected to manifest in surface water receptors following short timelines. Therefore, changes to the shallow groundwater regime are best captured by monitoring of the surface water system.

3.5 CLIMATE CHANGE

Groundwater systems in Yukon are liable to experience changes arising from climate change. Multiple authors (Streicker 2016, Walvoord et al. 2012, Bense et al. 2009, Walvoord and Striegl 2007) recognize that groundwater behavior in permafrost dominated regimes is generally an understudied topic. This is due to the oft remoteness of these systems and the general lack of reliance on these systems for water supply. Furthermore, connections between permafrost degradation and large scale changes in hydrologic fluxes are not well understood (Streicker 2016, Walvoord et al. 2012). That being said, some changes in high latitude groundwater systems related to climate change have been observed in Yukon and beyond. This section outlines current climate trends predicted for Yukon and the Project as they relate to groundwater systems. Examples of observed and modeled groundwater system changes are provided.

Two key documents that provide assessments of climate change for the Project include The Yukon Climate Change Indicators Report by Streicker (2016) and Climate Change Projections for Coffee Creek Region, Yukon, an assessment performed by Lorax (2015a) (contained as a sub-appendix of **Appendix 8-A**). The Streicker (2016) report outlines climate change indicators (objective measures of climate change) and provides ten key findings (simple, high-level conclusions of current research and Traditional Knowledge) as they apply to the Yukon Territory. Both the Streicker (2016) and Lorax (2015a) reports present climate projections based on climate forcing scenarios that were published by Intergovernmental Panel on Climate Change in the Special Report on Emissions Scenarios (SRES) in 2000 (IPCC 2000). The SRES A2 scenario, which defines the most rapid increases in emissions trajectories over the next 100 years, was used for projections in both reports. Modeled historical climate averages and future projections are from the Scenarios Network for Alaska and Arctic Planning (SNAP) at the University of Alaska. The main findings of these reports, as they relate to groundwater are summarized below.

Annual precipitation has increased by 6% over the past 50 years in Yukon (Streicker 2016). Average annual precipitation is projected to increase only marginally for a valley location modeled at the project site by 2100; however, a larger increase of 20% is forecast for the broader region by 2100 (Lorax 2016). Most of the increase in precipitation is expected to occur in summer and winter, with little change occurring in spring or fall. Streicker (2016) indicates that there is medium confidence that evapotranspiration will increase over the foreseeable future, and that this increase may outpace increases in precipitation. A forecast for evapotranspiration for the Project area has not been conducted, therefore it is unclear whether increased precipitation will result in increased recharge to the groundwater system.

Streicker (2016) indicates that the average annual temperature in Yukon has risen by over 2ºC over the past 50 years. The current annual average temperature at the Coffee Gold Mine is -3ºC and is forecast to rise by 3ºC to 5ºC by 2100 (Lorax 2015a). The warming is anticipated to be particularly pronounced in the summer and will lead to a later freeze-up in the fall and earlier thaw in the spring. This increase in temperature is expected to have implications on permafrost integrity, which in turn, has implications on groundwater flow paths. Streicker (2016) cites this as a key finding – that permafrost is degrading and more thaw is projected, typically resulting in an increase in the depth of the active layer. Streicker (2016) further concludes that climate change is altering streamflow and groundwater flow patterns, and that degrading permafrost increases pathways for groundwater, increasing winter low flows.

Increases in winter low flows have been observed in streamflow records in the Canadian Northwest Territories (St. Jacques and Sauchyn 2009), in northern Eurasian rivers (Smith et al. 2007), and in the Yukon River Basin (YRB) (Walvoord and Striegl 2007). Walvoord and Striegl (2007) analysed long-term streamflow records within the YRB and found that winter low flow (i.e. groundwater baseflow) had demonstrated an upward trend of 0.4% to 2.6% per year (normalized to the mean) with an average of 0.9% increase in low flows per year. The increase in winter low flows was not accompanied by an increasing trend in annual flow or precipitation and was consequently attributed to enhanced groundwater pathways arising from melting permafrost. The largest increases were observed in the Porcupine and Koyukuk watersheds, large portions (90-100%) of which are underlain by permafrost. Note that the Coffee Project lies in an area of discontinuous permafrost (NRCan 1995), and permafrost mapping indicates that 62% of the mapped Mine Site is underlain by permafrost (EBA 2016 a,b).

A regional groundwater model of the Yukon Flats Basin was constructed by Walvoord et al. (2012) using the groundwater numerical modeling code MODFLOW. The purpose of the model was to study the influence of spatial patterns of permafrost and potential pattern changes due to a warming climate on groundwater flow. The Yukon Flats Basin lies mostly within Alaska and is largely underlain (~89%) by permafrost which was modeled to be ~90 m thick. The model domain covers an area of 118,340 km^2 simulates a basin of 400 m thickness. The authors varied the hydraulic conductivity of various units to simulate a permafrost thaw sequence, including the growth of taliks under progressively smaller rivers and lakes, as well as thickening of the active layer and progressive disappearance of permafrost in bedrock. They found the following:

- Small taliks comprising ~1% of model domain exerts a proportionately large effect on localized circulation patterns.

- A 50% increase in active layer thickness resulted overall in a 7% increase in total YFB baseflow, but locally, baseflow increases of 40 to 65% were observed in rivers that receive a large proportion of supra-permafrost flow to baseflow (i.e. larger increases in baseflow were observed in river basins were permafrost largely confines deeper groundwater paths).
- As permafrost degrades from continuous to discontinuous coverage, longer and deeper groundwater flow paths with greater travel times develop; although some longer flowpaths may truncate as vertical connectivity increases.
- The magnitude of baseflow increases substantially, nearly an order of magnitude as permafrost coverage declines from 95% to 0%.
- The proportion of active zone contribution to groundwater baseflow declines rapidly from over 90% to ~20% when permafrost coverage declines from 100% to 89%. When permafrost coverage declines from 67% to 0%, the proportion of active layer flow to total groundwater baseflow decreases very marginally (~9% to ~4%).
- Changes in groundwater flow patterns and fluxes were most pronounced as permafrost coverage transitioned from continuous to discontinuous permafrost coverage (i.e. around 89% coverage).

The model supports earlier findings from Walvoord and Striegl (2007) and from Janowicz (2008) who found that (i) the greatest changes in winter low flows appear to be occurring within the continuous permafrost zone, and (ii) winter low flows trends in streams within the discontinuous permafrost zone generally exhibit positive significant trends, but are more variable. Walvoord et al*.* (2012) surmise that the transition from continuous to discontinuous permafrost coverage (~90%) is a more important threshold for groundwater system transformation than perhaps, degradation of warm permafrost in already discontinuous regions, such as that encountered at the Coffee Project. However, it remains difficult to compare the Project groundwater system to that modeled by Walvoord et al. (2012), as the scale of the systems is markedly different (Project groundwater RSA is ~50 km^2 compared to the ~120,000 km^2 modeled area of the Yukon Flats Basin). It appears reasonable to assume groundwater baseflow contribution to drainages in the Project RSA will increase as a result of climate change induced permafrost degradation, but the magnitude of this increase is difficult to constrain. Any changes brought about by permafrost degradation will be further confounded by changes in net infiltration; noting that forecasted increases in precipitation may be cancelled out by increases in evapotranspiration.

Timing of changes to groundwater systems arising from permafrost degradation have been explored by Bense et al. (2009), who set up models to simulate transient fluid and heat flow. They modeled a simple 2-dimensional, homogeneous system with low topographic relief initially in equilibrium with surface temperatures of -2^{o}C, -1.5^{o}C and -1^{o}C resulting in permafrost thicknesses of 85 m, 55 m, and 30 m, respectively. In all three scenarios, the surface temperature was increased by 3^{o}C over a period of 100- years and then held constant for another 1100 years. The simulated temperature increase is less than that which is projected for the Mine Site (Lorax 2015a). Key findings from the modeling performed by Bense et al. (2009) include the following:

- For all scenarios, the modeling indicated that groundwater discharge increased almost linearly with growing thickness of the shallow, supra-permafrost aquifer during the first 100 years.
- Discharge increases were found to slow down for a period before accelerating towards a steady state rate which was achieved anywhere between ~200 to 1100 years. Late time acceleration in baseflow discharge coincides with the disappearance of deep permafrost and establishment of deep groundwater flow patterns.
- Marked delays in discharge response are positively linked to initial permafrost thickness and aquifer ice-content (i.e. aquifer porosity); and
- Overall, most of the baseflow increases are due to the shallow, supra-permafrost groundwater system.

The work by Bense et al. (2009) suggests that even if surface temperatures stabilize in the near future, substantial increases in groundwater discharge are predicted to occur over the next few centuries. The authors indicate that more modeling is required to explore the influence of more detailed surface temperature distributions related to the presence of surface water, topography, vegetation and snow cover. Future modeling of these types of systems requires development algorithms allowing the coupling of groundwater flow and surface hydrological and climate models in sub-Artic regions (Bense et al. 2009). As such, extension of the recent modeling efforts by Bense et al. (2009) and Walvoord et al. (2012) to the Coffee project remains difficult, particularly since topography and aspect appear to exert large controls on permafrost extent.

As permafrost thaws, surface water dominated systems are expected to transition towards groundwater-dominated systems (Prowse, 2009). For the Yukon River Basin, increased groundwater contribution to baseflow is predicted to cause decreases in exports of dissolved organic carbon (DOC) and nitrogen (DON) and increases in exports of dissolved inorganic carbon (DIC) and nitrogen (DIN) (Walvoord and Striegl 2007). As cited in Streicker (2016), Schuster et al. (2011) predict that thawing permafrost due to climate warming will accelerate mobilization of bio-available mercury. Walvoord et al. (2012) suggest that surface water systems experiencing increased increasing groundwater contributions as a result of permafrost thaw may also experience changes in seasonal temperature (cooler summers and warmer winters in fish habitat), decreased river ice thickness and decreased seasonal variability in discharge. While these impacts may arise through active zone thickening, the impacts are expected to intensify as the interaction between sub-permafrost groundwater and surface water is enhanced.

In summary, permafrost-dominated groundwater systems are currently exhibiting changes that are linked to climate change. The most pronounced changes in this type of groundwater systems are expected to occur in areas where permafrost coverage is more extensive than the Mine Site; observed trends and modeling results are difficult to extend to a localized, high relief groundwater system situated in an area of discontinuous permafrost. Pronounced changes are expected to occur as a deeper active zone or supra-permafrost groundwater systems are enhanced; however, these changes are expected to intensify as deeper, sub-permafrost groundwater paths communicate have increased interaction with surface water. It is anticipated that these changes will occur over decades and hundreds of years, even if surface temperatures remain stable past year 2100. As surface water dominated systems transition towards groundwater dominated systems, changes in discharge variability, temperature and chemistry are expected to occur. Already, the proportion of dissolved inorganic nutrients (C, N) to dissolved organic counterparts is increasing in the Yukon River Basin as a result of climate driven changes. Groundwater systems in permafrost areas are generally understudied and numerical modeling of these systems that incorporates multiple processes associated with climate change is in its infancy.

The Groundwater Model presented in this analysis does not incorporate changes to recharge quantity and/or distribution of permafrost arising from climate change. Given that the Project occupies and area of discontinuous permafrost, it is felt that changes to the groundwater regime resulting from climate change will be small and overwhelmed by changes brought about by the Project. Ultimately, climate change has been incorporated into the GoldSim Water Balance Model (**Appendix 12-C**). The lake levels produced in the GoldSim model take into account projected trends in precipitation and evaporation and are informed by pit leakage rates estimated from the Groundwater Model.

3.6 OTHER PROJECTS INFLUENCE ON EXISTING CONDITIONS (PAST AND PRESENT)

While there are quartz mining exploration activities in the general vicinity of the Coffee Gold Mine, there are currently no known projects located within the RSA that would have the potential to appreciably alter the groundwater regime from its ‘natural’ condition. Therefore, the baseline data collected is assumed to reflect the true natural groundwater regime. The cumulative changes on the Groundwater IC due to past, present and future projects are discussed in more detail in **Section 5.0** of this IC analysis.

4.0 FUTURE CONDITIONS WITH THE PROJECT

4.1 OVERVIEW

Changes to groundwater quality and quantity are anticipated to occur as a result of development of the Project. This section identifies and describes potential interactions between Project activities and groundwater quantity and quality during Project Construction, Operation, Reclamation and Closure, and Post-closure phases.

As summarized in **Table 1.2-1,** the Groundwater IC is intimately linked to the Surface Hydrology IC and Surface Water Quality VC (Physical Environment). It is also linked to the Surficial Geology, Terrain and Soils VC (Physical Environment). Given its linkage to surface water components (Surface Water Quality and Surface Hydrology), the Groundwater IC is also linked to Fish and Fish Habitat (Biophysical VC) upon which three Human Environment VCs (Social Economy, Land and Resource Use, Community Health and Well-being) are incumbent. In this regard, the evaluation of potential Project induced changes to groundwater forms an integral component of several other effects assessments evaluated under this Project Proposal.

Potential interactions between Project activities and groundwater are screened and discussed in **Section 4.2**. **Section 4.3** screens and discusses potential Project interactions associated with the Northern Access Route activities. **Sections 4.4** discusses mitigations and potential residual changes between the Mine Site and the Groundwater IC. A summary of residual changes that are predicted to result from the Project are discussed in **Section 4.5**.

4.2 SCREENING OF PROJECT INTERACTIONS WITH GROUNDWATER QUANTITY AND QUALITY

For the Groundwater IC analysis, potential Project interaction is assessed in the context of the terminology presented in **Table 4.2-1.** Definitions provided for *No Interaction*, *Negligible Interaction* and *Potential Interaction* are formally presented in **Section 5.0 Effects Assessment Methodology** of the Project Proposal, and are applied to all activities listed in the Project Activities Matrix and considered in all phases of the proposed undertaking. In **Table 4.2-2**, the Project Activities Matrix is screened for the Groundwater IC. Where *No Interaction* between the Project and IC is anticipated, or the interaction is considered *Negligible Interaction* (i.e., not expected to have a substantive influence on the short- or long-term integrity of the IC), a rationale for the interaction rating is presented and the interaction is not considered further in the assessment.

Table 4.2-1 Potential for an Interaction between Groundwater and the Project

Term	Definition
No Interaction	Project activity will not interact with the IC.
Negligible Interaction	Interaction with the Project activity will not have a substantive influence on the short or long-term integrity of the IC (i.e., not measurable / not detectable using the identified indicator).
Potential Interaction	Interaction between the Project activity and the IC may have a substantive influence on the short- or long-term integrity of the IC (i.e., measurable or detectable using the identified indicator). The potential change due to the interaction is considered further in the change analysis.

Table 4.2-2 Potential Project Interactions with Groundwater Quantity and Quality

Project Component	#	Project Activity	Groundwater Quantity		Groundwater Quality	
			Interaction Rating	Nature of Interaction and Potential Effect	Interaction Rating	Nature of Interaction and Potential Effect
Construction Phase						
Overall Mine Site	C-0	Confirmatory geotechnical drilling in select areas at the mine site, as necessary	No interaction	No change to groundwater quantity is anticipated from this activity	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-1	Mobilization of mobile equipment and construction materials	No interaction	No change to groundwater quantity is anticipated from this activity	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-2	Clearing, grubbing, and grading of areas to be developed within the mine site	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration. Change not discernible in groundwater level measurements.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-3	Material handling	No interaction	No change to groundwater quantity is anticipated from this activity	No Interaction	No change to groundwater quality is anticipated from this activity.
Open Pits	C-4	Development of Latte pit and Double Double pit	Negligible Interaction	Early pit development is above water table. May result in minor changes to groundwater recharge rate due to changes in infiltration. Change not discernible in groundwater level measurements.	Negligible Interaction	Infiltration of early contact water is not expected to discernibly alter groundwater quality.
	C-5	Dewatering of pits (as required)	Negligible Interaction	Early pit development is above water table. Pumped water is likely meteoric water. Change not discernible in groundwater level measurements.	Negligible Interaction	Water will be pumped to sumps and/or drainage ditches. Interaction with groundwater limited to shallow, active layer.
WRSFs	C-6	Development and use of Alpha WRSF	Negligible Interaction	Minor changes to groundwater levels are expected from this activity, due to limited impacts on groundwater recharge rates. WRSF is constructed on steep slope underlain largely by permafrost. Under natural conditions, recharge rates to groundwater are anticipated to be small. Enhanced recharge to groundwater is not expected as WRSFs will be engineered to reduce seepage to groundwater system as detailed in Waste Rock and Overburden Management Plan (**Appendix 31-D**). BMPs include the construction of rock drains at the base of WRSF to allow water to flow through base of waste rock pile and report to sediment ponds.	Negligible Interaction	Activity is not expected to result in measurable changes to groundwater quality due to ground conditions and best management practices outline under groundwater quantity effects (left).
Stockpiles	C-7	Development and use of temporary organics stockpile for vegetation and topsoil	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration. Changes to groundwater levels anticipated to be small and within natural variations. As detailed in the Waste Rock and Overburden Management Plan (**Appendix 31-D**), runoff collection trenches will be constructed on the downgradient edge of the ROM stockpile; drainage from the ROM pile and crusher pad will be directed to the Ore Pond.	Negligible Interaction	Negligible interaction is anticipated between the ROM Stockpile, crushed ore and soil stockpiles and groundwater quality. As detailed in the Waste Rock and Overburden Management Plan (**Appendix 31-D**), runoff collection trenches will be constructed on the downgradient edge of the ROM stockpile; drainage from the ROM pile and crusher pad will be directed to the Ore Pond.
	C-8	Development and use of frozen soils storage area	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration.	Negligible Interaction	Interactions with groundwater quality, if any, are inferred to be limited to shallow groundwater (active zone).
	C-9	Development and use of ROM stockpile for temporary storage of ROM ore	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration. Changes to groundwater levels anticipated to be small and within natural variations. As detailed in the Waste Rock and Overburden Management Plan (**Appendix 31-D**), runoff collection trenches will be constructed on the downgradient edge of the ROM stockpile; drainage from the ROM pile and crusher pad will be directed to the Ore Pond.	Negligible Interaction	Negligible interaction is anticipated between the ROM Stockpile and groundwater quality. As detailed in the Waste Rock and Overburden Management Plan (**Appendix 31-D**), runoff collection trenches will be constructed on the downgradient edge of the ROM stockpile; drainage from the ROM pile and crusher pad will be directed to the Ore Pond. Interactions, if any, are inferred to be limited to shallow groundwater (active zone) given that the deep groundwater resides on the order of 130 m below ground surface.
Crusher System	C-10	Construction and operation of crushing circuit	No interaction	No change to groundwater quantity is anticipated from this activity	No Interaction	No change to groundwater quality is anticipated from this activity.

Project Component	#	Project Activity	Groundwater Quantity		Groundwater Quality	
			Interaction Rating	Nature of Interaction and Potential Effect	Interaction Rating	Nature of Interaction and Potential Effect
	C-11	Construction and operation of crushed ore stockpile	Negligible interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration. Changes to groundwater levels anticipated to be small and within natural variations	Negligible Interaction	Interactions with groundwater quality, if any, are inferred to be limited to shallow groundwater (active zone).
Heap Leach Facility	C-12	Staged heap leach facility (HLF) construction, including associated event ponds, rainwater pond, piping, and water management infrastructure	Potential Interaction	Construction of fully lined HLF (pad and ponds) will result in a permanent reduction in recharge to groundwater system, potentially decreasing groundwater levels from construction through post-closure.	No interaction	Complete lining of HLF and ponds, as detailed in Project Description (Chapter 2), will limit infiltration of HLF contact water.
	C-13	Heap leach pad loading	No interaction	No change to groundwater quantity is anticipated from this activity	No Interaction	No change to groundwater quantity is anticipated from this activity
Plant Site	C-14	Construction and operation of process plant	No interaction	No change to groundwater quantity is anticipated from this activity	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-15	Construction and operation of reagent storage area and on-site use of processing reagents	No interaction	No change to groundwater quantity is anticipated from this activity	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-16	Construction and operation of laboratory, truck shop, and warehouse building	No interaction	No change to groundwater quantity is anticipated from this activity	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-17	Construction and operation of power plant	No interaction	No change to groundwater quantity is anticipated from this activity	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-18	Construction and operation of bulk fuel/LNG storage and on-site use of diesel fuel or LNG	No interaction	No change to groundwater quantity is anticipated from this activity	Negligible Interaction	Construction and operation of a fuel storage area and on-site use of fuel are not expected to change groundwater quality if best management practices are followed. Best management practices for fuel farm construction will be detailed in a Mine Development and Operations Plan (**Section 31.0**), to be prepared in support of the Quartz Mine Licence application, and are introduced in the Access Road Construction and Operation Management Plans (Appendix 31-A, Appendix 31-B). Diesel spills are not anticipated, unless as a result of an accident or malfunction. See **Chapter 28** (Accidents and Malfunctions Assessment).
Camp Site	C-19	Construction and operation of dormitories, kitchen, dining, and recreation complex buildings; mine dry and office complex; emergency response and training building; fresh (potable) water and fire water use systems; and sewage treatment plant	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-20	Construction and operation of waste management building and waste management area	Negligible Interaction	Wastewater treatment facility discharges to Halfway Creek. No discernible changes in nearby groundwater levels anticipated.	Negligible Interaction	Wastewater treatment facility discharges to Halfway Creek. No discernible changes in groundwater quality anticipated.
Bulk Explosive Storage Area	C-21	Construction of storage facilities for explosives components and on-site use of explosives	No Interaction	No change to groundwater quantity is anticipated from this activity.	Negligible Interaction (Storage Areas)	Operation of an explosives storage area are not expected to result in changes to groundwater if best management practices (lining of storage facilities) are followed. These best management practices will be outlined in a Mine Development and Operations Plan (Section 31) to be prepared in support of the Quartz Mine Licence application.
					Potential Interaction (Diffuse Areas – Explosives)	Residue of explosives may remain in blasted rock and alter levels of nitrogen species in nearby groundwater and in baseflow reporting to downgradient creeks. Explosive use to be minimized, where possible, and will be defined through a detailed Explosives Management Plan which will be prepared in support of the Quartz Mine License application.

Project Component	#	Project Activity	Groundwater Quantity		Groundwater Quality	
			Interaction Rating	Nature of Interaction and Potential Effect	Interaction Rating	Nature of Interaction and Potential Effect
Mine Site and Haul Roads	C-22	Upgrade, construction, and maintenance of mine site service roads and haul roads	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration patterns.	Negligible Interaction	Interactions are limited to shallow groundwater only and include weathering of geologic materials, leaching of nitrogen residues generated from blasting (if required) and use of chemicals in dust suppression that may result in elevated physical parameters, nutrients, and/or dissolved metals. Interactions are mitigated through BMPs outlined in Access Route Construction Management Plan (Appendix 31-A), Access Route Operational Management Plan (Appendix 31-B). BMPs include minimizing material movement via cut and fill construction methods and geochemical monitoring to ensure construction materials do not pose an ML-ARD risk (**Section 31.0**).
Site Water Management Infrastructure	C-23	Development and use of sedimentation ponds and conveyance structures, including discharge of compliant water	Negligible Interaction	May result in changes to groundwater recharge rate and distribution. Changes in groundwater levels are expected to be localized to the sediment pond footprint areas. Conveyance structures may result in localized mounding of water levels in the shallow, active layer aquifer.	Negligible Interaction	Seepage of contact water from conveyance structures and sedimentation ponds may result in minor changes to shallow groundwater quality.
	C-24	Initial supply of HLF process water	Negligible Interaction	May result in minor decrease in groundwater recharge in reaches where water is extracted, if those reaches lose water to the groundwater system. No discernible changes in groundwater levels anticipated.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-25	Ongoing use of site contact water (i.e., precipitation, stored rainwater) as HLF process water	Negligible Interaction	May result in reduction of water available to recharge groundwater system. No discernible reduction in groundwater levels anticipated.	No Interaction	No change to groundwater quality is anticipated from this activity.
Ancillary Components	C-26	Upgrade of existing road sections for Northern Access Route (NAR), including installation of culverts and bridges	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration patterns. Interactions are mitigated through BMPs outlined in Access Route Construction Management Plan (Appendix 31-A). BMPs include implementation of relief culverts to minimize damming effects during over bankfull flood flows; surface roughening / cat-tracking on slopes to help trap runoff and encourage infiltration through the ground; ditch clearing to remove debris which impedes water flow and limiting disturbance to riparian vegetation. Clearing of areas will be minimized by situating staging areas at depleted borrow sites, pullouts, spoil sites and previously cleared areas within the road right of way. Disturbance to ground underlain by permafrost will be minimized through the placement of fill on top of a liner; this will serve to reduce active layer melt and subsequent changes to low flows.	Negligible Interaction	Interactions are limited to shallow groundwater only and include weathering of geologic materials, leaching of nitrogen residues generated from blasting (if required) and use of chemicals in dust suppression that may result in elevated physical parameters, nutrients, and/or dissolved metals. Interactions are mitigated through BMPs outlined in Access Route Construction Management Plan (**Appendix 31-A**), Access Route Operational Management Plan (**Appendix 31-B**). BMPs include minimizing material movement via cut and fill construction methods and geochemical monitoring to ensure construction materials do not pose an ML-ARD risk (**Appendix 31-A**). Enforcement of speed limits, regular road inspections and regular grading will be used to help minimize dust generation (**Appendix 31-B**).
	C-27	Construction of new road sections for NAR, including installation of culverts and bridges	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration patterns. Interactions are mitigated through BMPs outlined in Access Route Construction Management Plan (**Appendix 31-A**). BMPs include implementation of relief culverts to minimize damming effects during over bankfull flood flows; surface roughening / cat-tracking on slopes to help trap runoff and encourage infiltration through the ground; ditch clearing to remove debris which impedes water flow and limiting disturbance to riparian vegetation. Clearing of areas will be minimized by situating staging areas at depleted borrow sites, pullouts, spoil sites and previously cleared areas within the road right of way. Disturbance to ground underlain by permafrost will be minimized through the placement of fill on top of a liner; this will serve to reduce active layer melt and subsequent changes to low flows.	Negligible Interaction	Interactions are limited to shallow groundwater only and include weathering of geologic materials, leaching of nitrogen residues generated from blasting (if required) and use of chemicals in dust suppression that may result in elevated physical parameters, nutrients, and/or dissolved metals. Interactions are mitigated through BMPs outlined in Access Route Construction Management Plan (**Appendix 31-A**), Access Route Operation Management Plan (**Appendix 31-B**). BMPs include minimizing material movement via cut and fill construction methods and geochemical monitoring to ensure construction materials do not pose an ML-ARD risk (**Appendix 31-A**). Enforcement of speed limits, regular road inspections and regular grading will be used to help minimize dust generation (**Appendix 31-B** and Dust Management Plan, **Section 31.0**). Chemical dust suppressants will only be added/employed if watering activities prove ineffective.

Project Component	#	Project Activity	Groundwater Quantity		Groundwater Quality	
			Interaction Rating	Nature of Interaction and Potential Effect	Interaction Rating	Nature of Interaction and Potential Effect
	C-28	Development, operation, and maintenance of temporary work camps along road route	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration patterns.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-29	Vehicle traffic, including mobilization and re-supply of freight and consumables	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity. Inadvertent release or spill of hazardous materials is not anticipated, unless as a result of an accident or malfunction, and will be avoided, minimized and managed through implementation of standard BMPs outlined in the Access Route Construction Management Plan (**Appendix 31-A**) and Operation Management Plan (**Appendix 31-B**).
	C-30	Development, operation, and maintenance of barge landing sites on Yukon River and Stewart River	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-31	Barge traffic on Stewart River and Yukon River, including barge mobilization of equipment for NAR construction	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-32	Annual construction, operation, maintenance, and removal of Stewart River and Yukon River ice roads	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-33	Annual construction and operation of winter road on the south side of the Yukon River	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-34	Construction, operation, and maintenance of permanent bridge over Coffee Creek	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-35	Construction and maintenance of gravel airstrip	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration. Change not discernible in groundwater level measurements.	No Interaction	As refueling of passenger aircraft will not occur on site, there is minimal opportunity for hydrocarbon contamination of groundwater system.
	C-36	Air traffic	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-37	Use of all laydown areas	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
	C-38	Use of Coffee Exploration Camp	Negligible Interaction	Use of camp well may result in minor changes to groundwater levels in close proximity to the well.	Negligible Interaction	Potential minor changes to groundwater quality via use of sewage facilities.
Operation Phase						
Overall Mine Site	O-1	Material handling	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
	O-2	Excavation of contaminated soils followed by on-site treatment or temporary storage and off-site disposal	No Interaction	No change to groundwater quantity is anticipated from this activity.	Negligible Interaction	Small volumes of soils will be placed in sealed containers which will be secured inside a sea can. Larger volumes of soil will be stored/remediated within a lined land farm. Contamination of groundwater due to on-site treatment of soils is not anticipated.
	O-3	Progressive reclamation of disturbed areas within mine site footprint	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration. Change not discernible in groundwater level measurements.	Negligible Interaction	Interactions are limited to shallow groundwater only due to changes in the nature of contact water due to further disturbance of materials that may contain weathering, blasting and chemical residues. May result in changes to physical parameters, nutrients, and/or dissolved metals.

<table>
<tr><th rowspan="2">Project Component</th><th rowspan="2">#</th><th rowspan="2">Project Activity</th><th colspan="2">Groundwater Quantity</th><th colspan="2">Groundwater Quality</th></tr>
<tr><th>Interaction Rating</th><th>Nature of Interaction and Potential Effect</th><th>Interaction Rating</th><th>Nature of Interaction and Potential Effect</th></tr>
<tr><td rowspan="9">Open Pits</td><td rowspan="2">O-4</td><td rowspan="2">Development of Kona pit and Supremo pit and continued development of Double Double pit and Latte pit</td><td>Potential Interaction (Double Double/Latte)</td><td>Supremo, Double Double and Latte pits will be advanced below the water table and may require removal of water during operation of the pits. Potential reduction in surrounding groundwater levels near pits and mounding of water levels where pumped water is managed. Potential alteration in baseflow in creeks draining these areas.</td><td rowspan="2">Negligible Interaction (all pits)</td><td rowspan="2">During development, open pits will be dewatered and are not anticipated to recharge bedrock groundwater. Negligible impact on groundwater quality during the pit development phase in these areas is expected.</td></tr>
<tr><td>Negligible Interaction (Kona)</td><td>The base of Kona pit will remain tens of meters above the water table with contact water used at the HLF; negligible impacts on groundwater quantity expected.</td></tr>
<tr><td rowspan="2">O-5</td><td rowspan="2">Cessation of mining at Double Double pit, Latte pit, Kona pit, and Supremo pit</td><td>Potential Interaction (Supremo, Double Double, Latte)</td><td>Collection of meteoric water in Supremo and Latte Pit will potentially cause an increase in surrounding groundwater levels and an increase in baseflow in downgradient drainages. Collection of meteoric water and enhancement of infiltration through waste rock backfilled in Double Double may result in mounding of groundwater levels in and around Double Double and potential increase in baseflow in downgradient stream reaches.</td><td>Potential Interaction (Double Double, Latte)</td><td>Latte and Double Double pit lake water quality may be markedly different than surrounding groundwater quality, potentially resulting in measurable changes in downgradient groundwater quality.</td></tr>
<tr><td>Negligible Interaction (Kona)</td><td>Surface water will be managed to prevent ponding in Kona Pit. Measurable changes to Kona groundwater levels, which are tens of meters below the base of Kona pit, are not anticipated due to limited opportunity for groundwater recharge.</td><td>Negligible Interaction (Kona)</td><td>Surface water will be managed to prevent ponding in Kona Pit. Measurable changes to Kona groundwater quality are not anticipated due to limited opportunity for recharge of contact water.</td></tr>
<tr><td>O-6</td><td>Partial backfill of Latte pit and Supremo pit</td><td>Potential Interaction</td><td>Partial backfill of pits may affect ponding levels and therefore effect nearby groundwater levels. May result in volumetric changes in baseflow at downgradient stream reaches.</td><td>Potential Interaction</td><td>Pit lake water quality may be altered as a result of contact with mine waste. May result in measurable changes in groundwater quality downgradient of pits.</td></tr>
<tr><td rowspan="2">O-7</td><td rowspan="2">Backfill of Double Double pit and Kona pit</td><td>Potential Interaction (Double Double)</td><td>Backfilling of Double Double will alter infiltration of meteoric water. May result in changes in nearby groundwater levels. May result in volumetric changes in baseflow at downgradient stream reaches.</td><td>Potential Interaction (Double Double)</td><td>Interstitial water in backfilled Double Double may be markedly different that surrounding groundwater quality; potentially resulting in measurable changes in downgradient groundwater quality.</td></tr>
<tr><td>Negligible Interaction (Kona)</td><td>Bottom of Kona pit will be tens of metres above groundwater table in an area of permafrost. Contact water will not be allowed to accumulate at Kona prior to backfill. Backfill is planned to occur during winter, which will trap freezing air at base of pit. Should enhanced infiltration through waste rock occur, it is expected to freeze in place. See Waste Rock and Overburden Management Plan (Section 31.0).</td><td>Negligible Interaction (Kona)</td><td>Bottom of Kona pit will be tens of metres above groundwater table in an area of permafrost. Contact water will not be allowed to accumulate at Kona prior to backfill. Backfill is planned to occur during winter, which will trap freezing air at base of pit. Should enhanced infiltration through waste rock occur, it is expected to freeze in place. See Waste Rock and Overburden Management Plan (Section 31.0).</td></tr>
<tr><td>O-8</td><td>Dewatering of pits (as required)</td><td>Potential Interaction</td><td>If accumulated water in pits represents groundwater (and not solely meteoric water), then dewatering of the pit may cause drawdown of groundwater levels and a potential decrease in baseflow in downgradient stream reaches.</td><td>Negligible Interaction (Pit areas)</td><td>Negligible impact on groundwater quality in the vicinity of the pits is expected for this activity.</td></tr>
<tr><td rowspan="2">WRSFs</td><td>O-9</td><td>Continued development and use of Alpha WRSF</td><td>Negligible Interaction</td><td>This interaction is previously defined under C-6.</td><td>Negligible Interaction</td><td>This interaction is previously defined under C-6.</td></tr>
<tr><td>O-10</td><td>Development and use of Beta WRSF</td><td>Negligible Interaction</td><td>Negligible interaction with groundwater quantity anticipated. WRSF is located in an area of steep topography with deep (>120 m bgs) water levels. WRSF will be engineered to reduce seepage to groundwater system as per Waste Rock and Overburden Management Plan (Appendix 31-D). Rock drains will be installed at base of WRSF to allow water to flow through base of waste rock pile, minimizing seepage to groundwater. Seepage will be collected in a pond and used as process water. Lifetime of WRSF is also short as WRSF will be backfilled into pit (R-5).</td><td>Negligible Interaction</td><td>Activity is not expected to result in measurable changes to groundwater quality due to steep terrane, deep groundwater water levels, and best management practices outline under groundwater quantity effects (left).</td></tr>
</table>

Project Component	#	Project Activity	Groundwater Quantity		Groundwater Quality	
			Interaction Rating	Nature of Interaction and Potential Effect	Interaction Rating	Nature of Interaction and Potential Effect
Stockpiles	O-11	Continued use of temporary organics stockpile for vegetation and topsoil	Negligible Interaction	This interaction is previously defined under C-7.	Negligible Interaction	This interaction is previously defined under C-7.
	O-12	Continued use of frozen soils storage area	Negligible Interaction	This interaction is previously defined under C-8.	Negligible Interaction	This interaction is previously defined under C-8.
	O-13	Continued use of ROM stockpile for temporary storage of ROM ore	Negligible Interaction	This interaction is previously defined under C-9.	Negligible Interaction	This interaction is previously defined under C-9.
Crusher System	O-14	Crusher operation	No Interaction	This interaction is previously defined under C-10.	No Interaction	This interaction is previously defined under C-10.
	O-15	Continued use of crushed ore stockpile	Negligible Interaction	This interaction is previously defined under C-11.	Negligible Interaction	This interaction is previously defined under C-11.
Heap Leach Facility	O-16	Continued staged HLF construction, including related water management structures and year-round operation	No Interaction	Loading of heap leach pad is not expected to further influence water levels beyond the initial establishment of impermeable liners over the HLF footprint during Construction.	No Interaction	Complete lining of HLF and ponds will mitigate against infiltration of HLF contact water. The Heap Leach Facility and Process Management Plan (**Section 31.0**), to be included in the Quartz Mine License application, will provide details on early leak detection measures that will allow for early identification and repair of leaks prior to entering the groundwater system.
	O-17	Progressive closure and reclamation of HLF	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
Plant Site	O-18	Process plant operation	No Interaction	This interaction is previously defined under C-14.	No Interaction	This interaction is previously defined under C-14.
	O-19	Continued on-site use of processing reagents	No Interaction	This interaction is previously defined under C-15.	No Interaction	This interaction is previously defined under C-15.
	O-20	Continued on-site use of diesel fuel or LNG	No Interaction	This interaction is previously defined under C-18.	Negligible Interaction	This interaction is previously defined under C-18.
Camp Site	O-21	Continued use of facilities	No Interaction	This interaction is previously defined under C-19	No Interaction	This interaction is previously defined under C-19
Bulk Explosive Storage Area	O-22	Continued on-site use of explosives	No Interaction	This interaction is previously defined under C-21.	Potential Interaction	This interaction is previously defined under C-21.
Mine Site and Haul Roads	O-23	Use and maintenance of mine site service roads and haul roads	Negligible Interaction	This interaction is previously defined under C-22.	Negligible Interaction	This interaction is previously defined under C-22.
Site Water Management Infrastructure	O-24	Continued use of sedimentation ponds conveyance structures	Negligible Interaction	This interaction is previously defined under C-23.	Negligible Interaction	This interaction is previously defined under C-23.
	O-25	Ongoing use of site contact water (i.e., precipitation, stored rainwater) as HLF process water	Negligible Interaction	This interaction is previously defined under C-25.	No Interaction	This interaction is previously defined under C-25.
	O-26	Installation and operation of water treatment facility for HLF rinse water	Negligible Interaction	HLF treatment facility discharges to Halfway Creek. Additional flow in the creek is not expected to cause discernible changes to groundwater levels in and around the creek	Negligible Interaction	HLF treatment facility discharges to Halfway Creek which is inferred to be an area of groundwater discharge. No discernible changes in groundwater quality are expected, except in localized areas where the creek may be a losing stream.
Ancillary Components	O-27	NAR road maintenance (e.g., aggregate re-surfacing, sanding, snow removal)	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration patterns.	Negligible Interaction	Contact water from road may result in minor, local changes to shallow groundwater quality, depending on type and use of chemical dust suppressants. Chemical dust suppressants will only be added/employed if watering activities prove ineffective. Enforcement of speed limits, regular road inspections and regular grading will be used to help minimize dust generation (Access Route Operation Management Plan Appendix **31-B** and Dust Management Plan, **Section 31.0**).
	O-28	NAR vehicle traffic, including mobilization and re-supply of freight and consumables	No Interaction	This interaction is previously defined under C-29.	No Interaction	This interaction is previously defined under C-29.
	O-29	Operation and maintenance of barge landing sites on Stewart River and Yukon River	No Interaction	This interaction is previously defined under C-30	No Interaction	This interaction is previously defined under C-30.

Project Component	#	Project Activity	Groundwater Quantity		Groundwater Quality	
			Interaction Rating	Nature of Interaction and Potential Effect	Interaction Rating	Nature of Interaction and Potential Effect
	O-30	Barge traffic on Stewart River and Yukon River	No Interaction	This interaction is previously defined under C-31.	No Interaction	This interaction is previously defined under C-31.
	O-31	Annual construction, operation, maintenance, and removal of Stewart River and Yukon River ice roads	No Interaction	This interaction is previously defined under C-32.	No Interaction	This interaction is previously defined under C-32.
	O-32	Annual construction and operation of winter road on the south side of the Yukon River	No Interaction	This interaction is previously defined under C-33.	No Interaction	This interaction is previously defined under C-33.
	O-33	Operation and maintenance of gravel air strip	Negligible Interaction	This interaction is previously defined under C-35.	No Interaction	This interaction is previously defined under C-35.
	O-34	Air traffic	No Interaction	This interaction is previously defined under C-36.	No Interaction	This interaction is previously defined under C-36.
	O-35	Use of all laydown areas	No Interaction	This interaction is previously defined under C-37.	No Interaction	This interaction is previously defined under C-37.
	O-36	Use of Coffee Exploration Camp if required	Negligible Interaction	This interaction is previously defined under C-38.	Negligible Interaction	This interaction is previously defined under C-38.
Reclamation and Closure Phase						
Overall Mine Site	R-1	Reclamation of disturbed areas within mine site footprint	Negligible Interaction	This interaction is previously defined under O-3.	Negligible Interaction	This interaction is previously defined under O-3.
	R-2	Excavation of contaminated soils followed by on-site treatment or temporary storage and off-site disposal	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration patterns.	Negligible Interaction	Treatment of soil will be in lined facility. The soil will be used for industrial use (i.e. as fill within the mine site) when it meets applicable soil quality standards. Soils that do not meet use criteria will be shipped off-site.
Open Pits	R-3	Reclamation of Double Double pit, Latte pit, Supremo pit, and Kona pit	Potential Interaction (Supremo Pits, Double Double)	Ponding of meteoric water in the Supremo Pits may result in measurable changes to groundwater levels in and around the facilities. May result in volumetric changes in baseflow at downgradient stream reaches. Reclamation of the mine waste in Double Double pit may result in changes to infiltration patterns through the mine waste which could manifest in changes to water levels and/or downgradient creek baseflow.	Potential Interaction (Supremo Pits, Double Double)	Supremo pit lake water quality may evolve through closure and manifest as measurable changes in groundwater quality downgradient of the pits. Reclamation of the mine waste in Double Double pit may result in changes to infiltration patterns and hence, the amount of contact water reporting to groundwater.
			Negligible Interaction (Kona)	Reclamation of the Kona Pit is not expected to measurably change groundwater quantity as the bottom of Kona pit will be tens of metres above groundwater table in an area of permafrost. Contact water will not be allowed to accumulate at Kona prior to backfill. Backfill is planned to occur during winter, which will trap freezing air at base of pit. Should enhanced infiltration through waste rock occur, it is expected to freeze in place. See Waste Rock and Overburden Management Plan (**Section 31.0**).	Negligible Interaction (Kona)	Reclamation of the Kona Pit is not expected to measurably change groundwater quality as the bottom of Kona pit will be tens of metres above groundwater table in an area of permafrost. Contact water will not be allowed to accumulate at Kona prior to backfill with the Beta WRSF. Backfill is planned to occur during winter, which will trap freezing air at base of pit. Should enhanced infiltration through waste rock occur, it is expected to freeze in place. See Waste Rock and Overburden Management Plan (**Section 31.0**).

Project Component	#	Project Activity	Groundwater Quantity		Groundwater Quality	
			Interaction Rating	Nature of Interaction and Potential Effect	Interaction Rating	Nature of Interaction and Potential Effect
WRSFs	R-4	Reclamation of Alpha WRSF	Negligible Interaction	Reclamation of Alpha WRSF is expected to result in negligible changes to groundwater quantity. The location and design of the facility (see C-6) is expected to result in negligible recharge to the groundwater system, which is consistent with baseline conditions. Additional reclamation measures are not anticipated to alter recharge the groundwater system.	Negligible Interaction	Reclamation of Alpha WRSF is expected to result in negligible changes to groundwater quality. The location and design of the facility (see C-6) is expected to result in negligible recharge to the groundwater system, which is consistent with baseline conditions. Additional reclamation measures are not anticipated to alter recharge the groundwater system.
	R-5	Reclamation of Beta WRSF	Negligible Interaction	Negligible interaction with groundwater quantity anticipated in former WRSF footprint area as negligible interactions were anticipated during use of the facility due to steep topography, deep groundwater levels and BMPS outlined in activity O-10. Backfill of WRSF into Kona pit is not expected to alter groundwater quantity as pit is completed tens of metres above the water table. BMPs listed under the Waste Rock and Overburden Management Plan (Appendix 31-D) include deposition of waste during winter, which promotes subzero conditions in the pit, causing infiltration to freeze thereby limiting inputs to groundwater system.	Negligible Interaction	Negligible changes to groundwater quality are anticipated from this activity due to limited infiltration from mine waste to groundwater (see groundwater quantity, left).
Stockpiles	R-6	Reclamation of temporary organics stockpile, frozen soils storage area, and ROM stockpile	Negligible Interaction	Reclamation of stockpiles and frozen soils storage area may result in minor changes to groundwater recharge rates.	Negligible Interaction	Interactions with groundwater quality, if any, are inferred to be minor and limited to shallow groundwater (active zone).
Crusher System	R-7	Dismantling and removal of crusher facility and stockpile	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration in stockpile area. Changes to groundwater levels anticipated to be small and within natural variations.	Negligible Interaction	Interactions with groundwater quality, if any, are inferred to be limited to shallow groundwater (active zone).
Heap Leach Facility	R-8	Closure of HLF and related water management structures	Negligible Interaction	Removal of lined pond(s) may result in alteration of groundwater recharge in this area. This may cause was levels to partially recover back to back to background levels.	No Interaction	No change to groundwater quality is anticipated from this activity.
Plant Site	R-9	Dismantling and removal of process plant, reagent storage area, laboratory, truck shop and warehouse building, power plant, and bulk fuel storage	No Interaction	No change to groundwater quantity is anticipated from this activity.	Negligible Interaction	Operation of fuel storage area is not expected to have caused changes to groundwater quality due to best management processes outlined in C-18. Discontinued use of this area may improve groundwater quality in this area if changes have occurred.
Camp Site	R-10	Dismantling and removal or dormitories and kitchen, dining, and recreation complex buildings, mine dry and office complex, emergency response and training building, fresh (potable) water and fire water systems, sewage treatment plant, and waste management building	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.
Bulk Explosive Storage Area	R-11	Dismantling and removal of explosives storage facility	No Interaction	No change to groundwater quantity is anticipated from this activity.	Negligible Interaction	Operation of explosive storage area is not expected to have caused changes to groundwater quality due to best management processes outlined in C-21. Discontinued use of this area may improve groundwater quality in this area if changes have occurred.
Mine Site and Haul Roads	R-12	Decommissioning and reclamation of mine site service roads and haul roads	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration. Change not discernible in groundwater level measurements.	Negligible Interaction	Change in nature of contact water from road may result in minor, local changes to shallow groundwater quality.

Project Component	#	Project Activity	Groundwater Quantity		Groundwater Quality	
			Interaction Rating	Nature of Interaction and Potential Effect	Interaction Rating	Nature of Interaction and Potential Effect
Site Water Management Infrastructure	R-13	Decommissioning and reclamation of selected water management infrastructure, construction of long-term water management infrastructure, including water deposition to creek systems	Negligible Interaction	Alterations to water management infrastructure may alter groundwater recharge patterns in the vicinity of ponds. Changes to groundwater levels are expected to localized to the facility footprints.	Negligible Interaction	Minor changes to shallow groundwater quality may results from change in groundwater recharge patterns.
	R-14	Operation and maintenance of HLF water treatment facility	Negligible Interaction	This interaction is previously defined under O-26.	Negligible Interaction	This interaction is previously defined under O-26.
	R-15	Decommissioning and removal of HLF water treatment plant	Potential Interaction	Drainage from HLF to gravity drain to Latte Pit. May result in perceptible changes to water level in Latte pit.	Potential Interaction	Drainage from HLF to gravity drain to Latte Pit. May result in measurable changes Latte pit lake chemistry and in turn cause measurable changes in downgradient groundwater quality and baseflow water quality.
Ancillary Components	R-16	NAR road maintenance (e.g., aggregate re-surfacing, sanding, snow removal)	Negligible Interaction	This interaction is previously defined under O-27.	Negligible Interaction	This interaction is previously defined under O-27.
	R-17	NAR vehicle traffic	No Interaction	This interaction is previously defined under O-28.	No Interaction	This interaction is previously defined under O-28.
	R-18	Operation and maintenance of barge landing sites on Stewart River and Yukon River	No Interaction	This interaction is previously defined under O-29.	No Interaction	This interaction is previously defined under O-29.
	R-19	Annual resupply of consumables and materials for active closure via barge on the Yukon River	No Interaction	This interaction is previously defined under O-30.	No Interaction	This interaction is previously defined under O-30.
	R-20	Annual construction, maintenance, and decommissioning of Stewart River and Yukon River ice roads	No Interaction	This interaction is previously defined under O-31.	No Interaction	This interaction is previously defined under O-31.
	R-21	Decommissioning of new road portions	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration patterns.	Negligible Interaction	May result in change of the nature of contact water from the road surface. Impacts to groundwater are expected to be minor and limited to the shallow groundwater system.
	R-22	Air traffic	No Interaction	This interaction is previously defined under O-34.	No Interaction	This interaction is previously defined under O-34.
	R-23	Decommissioning and reclamation of airstrip	Negligible Interaction	May result in minor changes to groundwater recharge rate due to changes in infiltration patterns.	No Interaction	No change to groundwater quality is anticipated from this activity.
	R-24	Operation of Coffee Exploration Camp to support monitoring activities	Negligible Interaction	This interaction is previously defined under C-38.	Negligible Interaction	This interaction is previously defined under C-38.
Post-closure Phase						
Overall Mine Site	P-1	Long-term monitoring	No Interaction	No change to groundwater quantity is anticipated from this activity.	No Interaction	No change to groundwater quality is anticipated from this activity.

4.3 NORTHERN ACCESS ROUTE ANALYSIS

4.3.1 OVERVIEW

The proposed access to the Mine Site is via the Northern Access Route (NAR), which will extend over a total distance of approximately 213 km south from Dawson City (**Figure 1.3-1**). The access route will use both new and existing roads south from Dawson City, to reach the mine site. The access will include crossings over the Stewart and Yukon Rivers on ice roads in winter, and by barge in summer.

The Northern Access Route begins at the Hunker Creek road turnoff from the Alaska Highway a short distance southeast of Dawson City. From the Alaska Highway, the first 60 km of the NAR is a publicly maintained road that will require little or no modification. From this point, the road will extend for approximately 131 km to the mine site. Of this distance, roughly 80 km will be comprised of existing roads and trails that will be upgraded, 15 km of existing roads used with little or no modification, and approximately 36 km of new road will need to be constructed.

The road alignment will extend from the terminus of the existing public road southeast to cross the Indian River, crossing new bridges over Sulphur Creek and the Indian River. It will then run west, parallel with, and on the south side of Indian River, and then turn south up the Eureka Creek drainage. From here it will go up onto the height of land to the west of Eureka Creek, and remain on the height of land, travelling south through the headwaters of Henderson Creek (to the west) and Dome Creek (to the east). It will then travel south down the Maisy May drainage, crossing bridges over a tributary and Maisy May main stem, to the confluence of Maisy May at Stewart River. From the east side of the Stewart River crossing, the road will travel up the Barker Creek drainage, crossing four new bridges, cross the height of land, and descend the Ballarat Creek drainage, crossing two new bridges. It will then cross Ballarat Creek main stem via a new bridge to reach the Yukon River west of the Ballarat confluence. The last section of road extends west from the landing on the south side of the Yukon River, crosses Coffee Creek over a new bridge, to reach the mine site. A total of 12 bridges and 9 major culverts will be installed.

Road design includes large cuts (excavations greater than 4,000 m^3) for the roadbed and regularly spaced pits / quarries along the road for subgrade fill sources (i.e., to fill troughs in the roadbed) and for resurfacing and riprap material. As described in Access Route Construction Management Plan (**Appendix 31-A**), all construction materials will utilize local material sources produced in association with the construction of the NAR. Several sources of borrow material have been identified.

4.3.2 POTENTIAL ROAD-RELATED INTERACTIONS WITH GROUNDWATER QUANTITY AND QUALITY

As summarized in **Table 4.2-1**, activities associated with the development and use of the NAR that may interact with groundwater quantity and quality include the following:

- Upgrade of existing road sections (177 km), including installation of culverts and bridges (C-26)
- Construction of new road sections (37 km), including installation of culverts and bridges (C-27)

- Development, operation, and maintenance of temporary work camps along road route (C-28)
- Road maintenance (e.g., aggregate re-surfacing, sanding, snow removal) (O-27, R-16), and
- Decommissioning of new road portions (37 km) (R-21).

The above activities have been assigned a 'negligible interaction' rating in **Table 4.2-1** as interactions are expected to be minor and localized to the shallow, seasonally active groundwater system. In some cases, the minimal nature of these potential interactions is achieved through the implementation of best management practices outlined in the Access Route Construction Management Plan and Access Route Operation Plan (**Appendices 31-A** and **31-B**, respectively). The relevant BMPs are listed in **Table 4.2-1.** The discussion below provides general background information on how resource access roads typically may interact with groundwater; the best management practices/mitigations associated with the NAR are discussed in **Section 4.3.3**.

4.3.2.1 Groundwater Quantity

The influence of road(s) on hillslope hydrology and watershed response has garnered some attention in the open scientific literature (Spellerberg 1998, Forman and Alexander 1998). For example, fisheries and surface water quality issues related to road development (e.g., changes in water temperature, turbidity, contaminant loading, potential for spills) are well documented (e.g., Jones et al. 2000, Gibson et al. 2005). However, few studies have focused on the direct link between roadbuilding and groundwater (Smerdon et al. 2009, Daigle 2010). Nevertheless, the forestry practice literature has presented the following potential interactions on groundwater quantity from road construction:

- Groundwater flow interception: In steep, coastal mountain settings in BC, Megahan and Clayton (1983) have found that a seepage face forms along the road cut where roads cut into the hillside. This causes the groundwater flow to be redirected, occurring as surface water in ditches rather than as shallow subsurface flow. Such an alteration can influence the timing and magnitude of peak flows because the surface water moving through ditches typically reaches a stream more rapidly than subsurface water does. The interception of shallow groundwater may also reduce groundwater flow to downslope environments (e.g., springs and seepage areas).
- Groundwater flow redirection: In more gently sloped terrain, the potential for road cuts to intersect groundwater flow systems is typically lower than in steep terrain (Smerdon et al. 2009). However, when a road is built near a groundwater discharge area where the water table is shallow, there is increased potential for interaction between the road and the shallow groundwater system. Roads are typically constructed of compacted material with limited permeability and low drainage capacity (Forman and Alexander 1998). Compacted road surfaces can limit infiltration; they can also force seepage to occur and potentially alter groundwater flow to downslope streams and wetlands. This may result in formation of artificial wetlands upgradient of the road, and drainage of natural wetlands downgradient of the road (Daigle 2010). Altered groundwater conditions are sensitive to road density (Stoekeler 1965, Swanson et al. 1988).

The effect of flow interception by roads depends on how much groundwater flow is intercepted and how much is conveyed directly to the stream network (Pike et al. 2010). Overall, the proportion of intercepted groundwater due to road construction is a function of many factors including those specific to the road and those specific to the watershed (Pike et al. 2010). These factors include soil depth, permeability of the bedrock underlying the soil, depth of the road cut/ditch surface, permeability of the roadbed material, and location of the road on the slope. Watershed characteristics include bedrock geology, surficial geology, soil type, and topography. In the case of the Project, local occurrence of permafrost occurrence will also affect the degree to which road construction alters groundwater flow patterns.

4.3.2.2 Groundwater Quality

Groundwater flows are critical to maintaining aquatic health since these flows buffer nutrients and temperature fluctuations, especially in riparian and hyporheic zones (the region below and adjacent to the streambed where surface water and groundwater mix) (Pike et al. 2010). The following potential interactions on groundwater quality from road construction and use have been identified in the literature:

- Alteration of groundwater temperature: Disruption in groundwater recharge/discharge patterns brought about by road construction may alter stream temperature and potentially alter nutrient delivery to riparian zones and wetlands (Smerdon et al. 2008).
- Alteration of groundwater composition: Contact water from road can pond and infiltrate the groundwater system. Contact water may contain nitrogen residues from blasting, weathering products of fill materials, and residues from chemical dust suppression and spills. This may result in elevated levels of total and dissolved metals, nutrients, hydrocarbons and salinity.

4.3.3 NORTHERN ACCESS ROUTE MITIGATION MEASURES

As indicated in **Table 4.2-1,** potential interactions between the NAR and the Groundwater IC are expected to be negligible and localized to the shallow groundwater regime. This rating is, in part, achieved through the implementation of best management practices that will be outlined in various management plans. Therefore, the overarching mitigation associated with the NAR is the implementation of the associated plans. Specifically, the mitigations are as follows:

- Mitigation 1: Development and Implementation of the Access Route Construction Management Plan (**Appendix 31-A)**
- Mitigation 2: Development and Implementation of the Access Route Operation Management Plan (**Appendix 31-B)**
- Mitigation 3: Development and Implementation of a Dust Management Plan (**Section 31.0**)

The Access Route Construction Management Plan (Appendix 31-A) and Access Route Operation Management Plan (Appendix 31-B) are being developed in accordance with Best Management Practices for Works Affecting Water in Yukon (Government of Yukon, 2011). These plans will be included in the YESAB submission. The main BMPs relevant to the Groundwater IC covered in these two plans include the following:

- Where practical, in areas underlain with undisturbed, shallow, ice rich permafrost, the existing surface material will be left intact, with the road constructed by filling over a geotextile separation layer. This will serve to reduce active layer melt and subsequent changes to low flows (**Appendix 31-A**).
- Conventional cut and fill construction will be utilized to minimize material movementThis will help minimize the sourcing of placement of new material along the road, which is protective of groundwater and surface water quality (**Appendix 31-A**).
- If the road approaches require fill on floodplains, relief culverts will be placed to minimize damming effects during over bankfull flood flows. This will reduce the potential for backed up water to cut through the road bed and increase peak flow discharges downstream (**Appendix 31-A).**
- Efforts will be made to limit disturbance to riparian vegetation, which serves to maintain infiltration patterns and improve infiltration water quality (**Appendix 31-A**).
- Clearing of areas will be minimized by situating staging areas at depleted borrow sites, pullouts, spoil sites and previously cleared areas within the road right of way. This will help minimize disruption to infiltration patterns and reduce potential changes to groundwater quality associated with disturbance of materials (**Appendix 31-A**).
- Assessing the ML/ARD potential of bedrock prior to disturbance, including areas where bedrock may need to be removed along the road alignment, as well as potential quarry and borrow material sites, so as to minimize disturbance of potentially acid-generating (PAG) bedrock (**Appendix 31-A**).

A Dust Management Plan (Section 31.0) will be developed in support of the Quartz Mine License application.

Potential interactions between the road and groundwater are expected to be negligible and localized to the shallow groundwater regime. Potential changes to the shallow groundwater system are expected to manifest in surface water receptors following short timelines. Therefore, potential changes to the shallow groundwater regime will be captured by monitoring of the surface water system (**Section 7** of Surface Hydrology IC (**Appendix 8-B**). Monitoring and surveillance of the surface water drainage system in close proximity to stream crossings and sensitive habitats/areas will be carried out by the Proponent over the life of the Project.

4.3.4 Potential Residual Change on Groundwater, Northern Access Route

With the implementation of best management practices in the Management Plans described in **Section 4.3.3**., the Northern Access Route is not expected to result in residual changes in groundwater quantity and quality.

4.4 Coffee Gold Mine Site Analysis

The section presents an analysis of potential changes to groundwater for the mine site proper. All mitigation measures incorporated in the Project Description (**Section 2.0**) have been incorporated into the groundwater flow model (MODFLOW) and the Water Balance and Water Quality models (GOLDSIM), upon which the analysis has been made. Therefore 'potential changes on groundwater' are presented as 'potential residual changes to groundwater'. No groundwater specific mitigation measures have been proposed outside of those included in the Project Description, which are discussed in Section 4.4.1 below. Project design measures are considered effective and sufficient to minimize potential changes to the Groundwater IC.

As indicated in **Table 4.2-2**, there are several Project activities which may result in potential changes to groundwater quantity. These activities may result in increased or decreased recharge to groundwater, which may result in changes to water levels and changes to groundwater fluxes reporting to downgradient stream reaches. The activities span Construction Phase through the Reclamation and Closure Phase and are summarized as follows:

- Construction and use of lined HLF and associated ponds (C-12)
- Development of Latte, Supremo and Double Double pits(O-4)
- Cessation of mining of Latte, Supremo, Double Double pits (O-5)
- Partial backfill of Latte pit and Supremo Pit (O-6)
- Partial backfill of Double, Double Pit (O-7)
- Dewatering of Pits (O-8)
- Reclamation of Double Double, Latte and Supremo Pits (R-3)
- Decommissioning and removal of HLF water treatment plant (R-15)

As discussed in **Section 2.1** and **Section 4.4.2.1**, changes to the groundwater system can take years to decades to manifest. Therefore, changes initiated by construction activities are not anticipated to manifest until Operation Phase or later. For this reason, changes to the physical groundwater system are assessed for two time periods only: end of Operation Phase (Year 9) and Post-Closure Phase.

Table 4.2-2 also indicates that several Project activities spanning Construction Phase through Reclamation and Closure phase which may result in potential interactions on groundwater quality. These activities may introduce or alter the nature of mine contact water potentially recharging the groundwater system. The activities are summarized as follows:

- On-site use of explosives (C-21, O-22)
- Cessation of mining at Double Double, Latte and Supremo Pits (O-5)
- Partial backfill of Latte pit and Supremo Pit (O-6)
- Backfill of Double Double pit (O-7)
- Reclamation of Double Double, Latte and Supremo pits (R-3)
- Decommissioning and removal of HLF water treatment plant (R-15)

The nature of mine contact water is introduced in **Section 1.2.2** and expanded upon further in **Section 4.4.2.2**. The Water Quality Model (**Appendix 12-C**) has been used to inform the groundwater quality analysis (**Section 2.2** and **Section 4.4.2.2**) and considers all Project phases.

4.4.1 MITIGATION MEASURES

Due to the inherent linkages in the water balance between groundwater and surface water flows, the mitigation measures that are relevant to the Groundwater IC are also relevant to surface water hydrology and surface water quality. These measures have been built into the Project design and include a combination of Project phasing and development schedules, waste handling options, and water management infrastructure and planning commitments as outlined in various Management Plans supporting the application. Specific mitigation measures relevant to the Groundwater IC are described in the sub-sections below.

4.4.1.1 Phased Mine Development and Progressive Reclamation

In addition to providing flexibility in the schedule, maximizing ore grade, and allowing the HLF to be maintained at full production capacity, phased development of the mine will reduce pre-stripping requirements in the early years. By reducing pre-stripping, the development footprint is reduced, thereby limiting the potential alteration to surface runoff and groundwater recharge. Progressive reclamation and closure activities will begin as soon as mining is completed and will continue throughout the mine life.

4.4.1.2 Alpha WRSF Site Selection and Design

Mine waste that is not backfilled into pits will be stored in the Alpha WRSF. Placement of the majority of mine waste in a single ex-pit dump minimizes the extent of ground disturbance. By minimizing ground disturbance, alteration to the runoff and groundwater recharge regimes is limited. Minimizing ground disturbance also minimizes potential footprint areas generating mine contact water.

Waste rock benches will be designed to slope inwards from the WRSF crest and runoff will be collected in a ditch and conveyed to ditches along the perimeter of the WRSF. In addition, a flow-through rock drain will be installed at the base of the Alpha WRSF to route all flows emanating from the upgradient catchment through the base of the WRSF, thus limiting the contact time with WRSF contact flows.

Water that infiltrates the WRSF will preferentially flow towards the sediment ponds and not recharge groundwater system. Given the topographic relief of the sites and permafrost occurrence underlying the proposed Alpha WRSF, it is believed that the rock drain will be highly effective. Furthermore, it is more conservative to assume that WRSF seepage reports to the sediment ponds rather than to groundwater for the purpose of assessing surface water quality effects. To simulate the effect of rock drains in the Groundwater Model, zero recharge has been applied in the footprint of the Alpha WRSF (see Section 2.1).

4.4.1.3 ROM Stockpile Design

To minimize potential effects of ARD associated with the ROM stockpile, the ROM pad will be lined and the drainage will be collected throughout LOM. Runoff collection ditches and sediment basins will be constructed along the down-gradient boundary of the ROM stockpile footprint. The ROM stockpile will have a diversion channel downhill to convey water to the Facility Pond. Collected drainage will be used as process make-up water to minimize contact water that reports to the receiving environment.

Lining of the ROM stockpile and the collection and use of its runoff and drainage will limit the opportunity for ROM contact water to recharge the groundwater system or report as an uncontrolled release to the surface water system.

4.4.1.4 Kona Pit

The Kona pit is completed tens of metres above the ambient groundwater table. Meteoric water that collects in the pit during operations will be pumped and used as make-up water for HLF. Likewise, seepage collected from the temporary Beta WRSF will also be used as make-up water. These measures limit the opportunity for Kona contact water to recharge the groundwater system or report as an uncontrolled release to the surface water system.

Backfill of the Kona pit is slated to occur during the winter which will trap cold air into the backfilled pit. This will aid in preservation of permafrost and facilitate freezing of subsequent infiltration. This will also limit the opportunity for Kona pit wall and waste rock contact water to recharge the groundwater system.

4.4.1.5 Backfilling of Pits

Waste rock will be used to backfill mined out pits at Latte, Supremo, and Double-Double, to create causeways that shorten the ore haul distance to the crusher (compared to having to haul material around the pits), and to minimize contact water catchment area. Further, backfilling of pit reduces the overall footprint of the Alpha WRSF. By minimizing ground disturbance and associated footprints, alteration to the runoff and groundwater recharge regimes is limited. Minimizing ground disturbance and size of ex-pit WRSFs also minimizes potential footprint areas generating mine contact water.

4.4.1.6 HLF Design to Facilitate Progressive Closure

The heap leach pad will be constructed in 5 stages, separated into cells, and closed progressively. Each pad stage will be separated from the adjacent stage by a ditch or berm and drainage pipe, providing hydraulic (solution) isolation between stages. In addition, cells will be created within each stage by constructing a drainage ditch or berm with a drainage pipe every 100 m. The berms and ditches will allow high-resolution tracking of solution chemistry (especially gold tenor) and will aid in progressive closure by allowing rinsing of the older portions of the heap beginning by Year 4. Progressive reclamation of the heap leach pad will entail rinsing individual sections of the heap leach ore once they have undergone the complete gold recovery cycle. The heap will be rinsed (via solution from the rinse pipelines) and capped in stages; as each stage is capped, the raincoats for that area will be removed and used in other areas or incorporated as part of the closure capping.

Progressive closure of the HLF reduces the footprint area available to generate contact water and also presents an opportunity to test water treatment efficacy prior to full buildout of the HLF. Both measures are directly protective of surface water quality and indirectly protective of groundwater quality.

4.4.1.7 HLF Liner System

Liner system design will provide for collection of process and rinse solutions and protection of surface and groundwater quality through heap leach pad operation and active closure. The liner system is comprised of a 2.0-millimetre (mm)-thick linear low density polyethylene (LLDPE) geomembrane over a reinforced geosynthetic clay liner (GCL) liner. The bottom side of the LLDPE liner will be aggressively textured to provide a close bond with the GCL. A 500-mm-thick drainage layer composed of crushed gravel and drainage pipes will be installed over the synthetic liners. This overliner system will protect the geomembrane liner from damage during ore stacking and operations, and will drain process and rinse waters out of the system in a manner that will minimize hydraulic head over the liner.

Leak detection will be accomplished by three separate systems: electrical leak location surveys performed after construction of each stage of the leach pad, horizontal wick drains installed under each collection ditch or berm to operate as large-scale lysimeters, and monitoring wells installed away from the pad.

The HLF liner system is designed to maximize recovery of pregnant solution by minimizing any losses to the groundwater system. To account for the presence of multiple liners under the HLF, recharge to groundwater through the liners is assumed to equal zero in the Groundwater Model.

4.4.1.8 HLF Water Balance

HLF water balance will be operated to minimize demand for withdrawal of make-up water from external sources and to avoid need to treat surplus water until near the end of the mine life. Process water for use in heap pad leaching will be preferentially sourced from site contact water. Geomembrane covers referred to as raincoats will be used over the heap to reduce the volume of meteoric water infiltrating into the heap and entering the process solution. Water diverted by the raincoats will be temporarily stored in the rainwater pond and used for makeup water during drier periods, as well as for freshwater for rinsing during progressive reclamation of the pad stages. The mine and HLF water balance will be actively managed through best management practices regarding raincoat use and timing of use, thereby, reducing the need to withdraw water from area creeks.

4.4.1.9 Management of Non-Contact Water

Surface water and rainwater will be kept away from the HLF and process circuit to the maximum extent possible through:

- Installation of permanent and interim perimeter diversion channels and berms around perimeter of heap leach pad.
- Expected to begin in Year 3, placement of raincoats (i.e., exposed geomembrane covers) over portions of the heap leach pad to minimize infiltration of rainwater and snowmelt into the heap leach pad and process circuit, and to increase heat retention in the winter.
- Progressive closure of HLF will reduce length of time that HLF is at its maximum footprint size.

Limiting the generation of contact water is protective of both surface water and groundwater systems.

4.4.1.10 HLF Event and Rainwater Ponds

Three event ponds (EP-1S, EP-1N, EP2) and a rainwater pond will be built between the heap leach pad and the process plant. The event ponds are designed to contain a combination of upset conditions, including:

- Heap draining during an extended power or pumping outage
- Extreme precipitation and freshet events
- Cumulative water storage during wet years or temporary shut-downs.

The rainwater pond is designed to temporarily store clean water diverted by the raincoats for use as makeup water during drier periods, as well as for freshwater for rinsing during progressive reclamation of the pad stages. All ponds will be lined with two HDPE geomembranes, separated by a drainage layer and underlain by a GCL.

Pond design will minimize the potential for HLF contact water to infiltrate groundwater. All lined ponds associated with the HLF are assumed to provide zero recharge to the groundwater system in the Groundwater Model.

4.4.1.11 Sediment Pond Design, Capacity and Discharge

Runoff from the Mine Site will be routed to sediment retention ponds located downstream of proposed mining areas: Alpha Pond and Facility Pond. The ponds will serve 2 purposes: 1) settlement of TSS load prior to discharge, and 2) reduction in peak discharge rate of a storm by attenuating (storing and releasing) runoff and discharging it at a lower peak rate. Design details related to the sediment ponds are contained in the **Water Management Plan** (**Appendix 31-E**).

4.4.1.12 Rock Drains and Diversion Channels

Rock drains are flow-through drains which will be used to drain pit lakes that may develop during the Operation Phase or later in mine life. They convey water through the base of the WRSF and are constructed of coarse waste rock. Diversion channels will be located near the spill point of the pit lakes (near the connection with the flow-through drains) to accommodate overflow should the flow-through drains clog or freeze.

In addition, a flow-through rock drain will be installed at the base of the Alpha WRSF to route all flows emanating from the upgradient catchment through the base of the WRSF, thus limiting the contact time with WRSF contact flows. The Alpha WRSF rock drain will be designed to accommodate up to 2 times the 100-year, 24-hour flow.

4.4.1.13 Summary of Mitigation Measures

As listed above, the mitigation measures incorporated into the Project design serve to substantially reduce the potential changes to groundwater and streamflows that might otherwise be expected to result from the development of a mines. An extensive groundwater and surface water monitoring program will be in place, as outlined in **Section 7.0** of this IC report and the Surface Hydrology IC report (**Appendix 12-B**) and Section 7 of Surface Water Quality VC report (**Appendix 12-B**). These monitoring programs will serve to assess the efficacy of proposed mitigation measures and the need for modifications to those measures to ensure change predictions remain valid.

4.4.2 POTENTIAL RESIDUAL CHANGES TO THE GROUNDWATER IC

4.4.2.1 Changes to Groundwater Quantity

The main drivers of groundwater quantity changes are pit development and implementation of large, lined areas (i.e. under the HLF and associated facilities). Removal or ponding of water that discharges to and/or collects in pits can increase or decrease recharge to the groundwater system and this may manifest as changes in water levels and creek baseflows. Changes that occur in one pit complex may enhance or diminish changes resulting from development of another pit complex. These changes are further confounded by diminished recharge under mine waste and HLF facilities. These activities are considered in tandem in the Groundwater Model (**Section 2.1**).

As indicated in **Table 4.2-2**, potential interactions with groundwater quantity are first identified during the Construction phase and carry through Reclamation and Closure, and Post-closure. The Groundwater Model was run in steady-state mode for two snapshots in time: end of Operation Phase (Year 12) and Post-Closure. By running the model in steady-state for these two time periods, it conservatively estimates the maximum extent of Project changes to groundwater. The model simulates that the drainages are in instantaneous equilibrium with the hydrogeological changes brought about by pit development, pit flooding and waste rock placement. These changes to groundwater quantity can take years to decades to manifest and equilibrate.

Operation Phase

To simplify the assessment, the Groundwater Model has been set up to simulate groundwater conditions at the end of Operation Phase (see **Section 2.0**). Pit lake elevations have been determined by the Water Balance Model which considers meteoric inputs and pit leakage rates estimated by the Groundwater Model.

Potential Changes to Groundwater Levels

A map of contoured groundwater drawdown and mounding for end of Operation Phase is shown in **Figure 4.4-1**, with changes in water levels at selected calibration targets provided in **Table 4.4-1**. Drawdown refers to a depression in water levels compared to baseline, while mounding refers to an increase in water levels compared to baseline. Water levels in pit areas are illustrated further in cross-sections presented in **Figure 4.4-2** to **Figure 4.4-8** (section lines shown **Figure 4.4-1**). Groundwater seepage fluxes from pit areas to creeks are provided in **Table 4.4-2**, groundwater fluxes between pits are provided in **Table 4.4-3**.

Appreciable groundwater mounding occurs (20 meters or higher) occurs under several of the pit lakes, including, Latte, Supremo Phase 3 North and West pits (SU3N, SU3W) and Supremo Phase 5 North (SU5N) pit (**Figure 4.4-1)**. This mounding results from accumulation of meteoric water and diversion of mine contact water that causes pit lakes to form above the elevation that would otherwise be dictated by the water table alone. A depression of the water table occurs under the HLF (and associated event ponds), Supremo Phase 1 (SU1) pit and backfill, Supremo Phase 4 North (SU4N) pit. The drawdown in these areas is due to advancement of pits below the water table and removal of groundwater recharge due to the presence of liners in the HLF footprint.

Cross-section E-E' (**Figure 4.4-2**) extends through Latte and SU1 pits. Part of the Latte Pit is excavated through permafrost, while the SU1 excavation is in unfrozen ground. Both pits are advanced through the pre-mine water table. Once meteoric water inputs are considered, the end of Operation Phase lake which forms in Latte Pit (998 m asl) is ~25 m higher than the pre-mining water level in this area. This causes ~18 m mounding at nearby MW14-03A/B (off-section). Farther downgradient in the Halfway Creek drainage, the water level at SRK-15D-08AT increases by ~5 m. The Alpha WRSF, which is simulated as a zero-recharge facility, has relatively little impact on water levels since most of the facility is underlain by permafrost, which limits recharge under natural conditions. Seepage from the Latte pit drains both towards Halfway Creek (0.9 L/s) and Latte Creek (0.2 L/s), with a nominal amount draining towards the SU1 pit (0.1 L/s) (**Table 4.4-2, Table 4.4-3**).

The SU1 pit lake level is up to 40 m below the baseline groundwater levels in this area, which happen to be artesian at MW14-02A (**Figure 4.4-2, Figure 4.4-3**). SU1 loses 0.3 L/s to Latte Creek and 0.3 L/s to the Latte tributary; however, there is a net groundwater inflow to the pit (1.3 L/s), which is in part due to inflow from the SU2 pit. Near the Latte/SU1 pit complex, VWP CFD-0351 records a marginal (~ 11 m) increase in water levels.

Cross-section F-F' **(Figure 4.4-3)** extends through the SU2 and SU1 pits. The area is largely permafrost free, save a small portion of frozen ground excavated at the north end of SU2 and an isolated lobe of permafrost at the MW14-02A/B location. The SU2 pit is advanced below the baseline water table, although development of the SU1 pit ahead of SU2 may limit the amount of groundwater accumulating in SU2 as it is developed. At the end of mining, a shallow pit lake is expected to form in the SU2 pit that is 19 m lower than the pre-mine water table. The SU2 pit lake is predicted to lose a minimal (0.03 L/s) amount of seepage to the Halfway Creek drainage, otherwise, a small net inflow of groundwater is anticipated for the facility. The SU1 pit lake is at its spill point by the end of Operation Phase and this controls water levels downgradient of the facility. Water levels at SRK15D-09T and MW15-02T are essentially unchanged (**Table 4.4-1**).

Cross-section G-G' (**Figure 4.4-4)** extends through the Supremo Phase 3 North (SU3N) and Phase 4 North (SU4N) pits. The SU3N pit partially resides in permafrost, 40 to 50 m above the pre-mining water table at its deepest point. End Operation Phase water levels are up to 70 m higher than baseline under the SU3N pit. The Supremo Phase 3 West (SU3W) also contributes to mounding in the area. The water level at MW15-06WB, located off-section and north of the SU3W pit, is predicted to increase on the order of 20 m. Seepage from the SU3N/SU3W complex collectively contributes ~ 0.3 L/s of seepage towards Halfway Creek. SU4N is largely excavated below the base of permafrost and intercepts the pre-mining water table. Groundwater discharge to SU4N is minor (<0.1 L/s) and a very small seepage loss (0.02 L/s) to Halfway Creek is predicted.

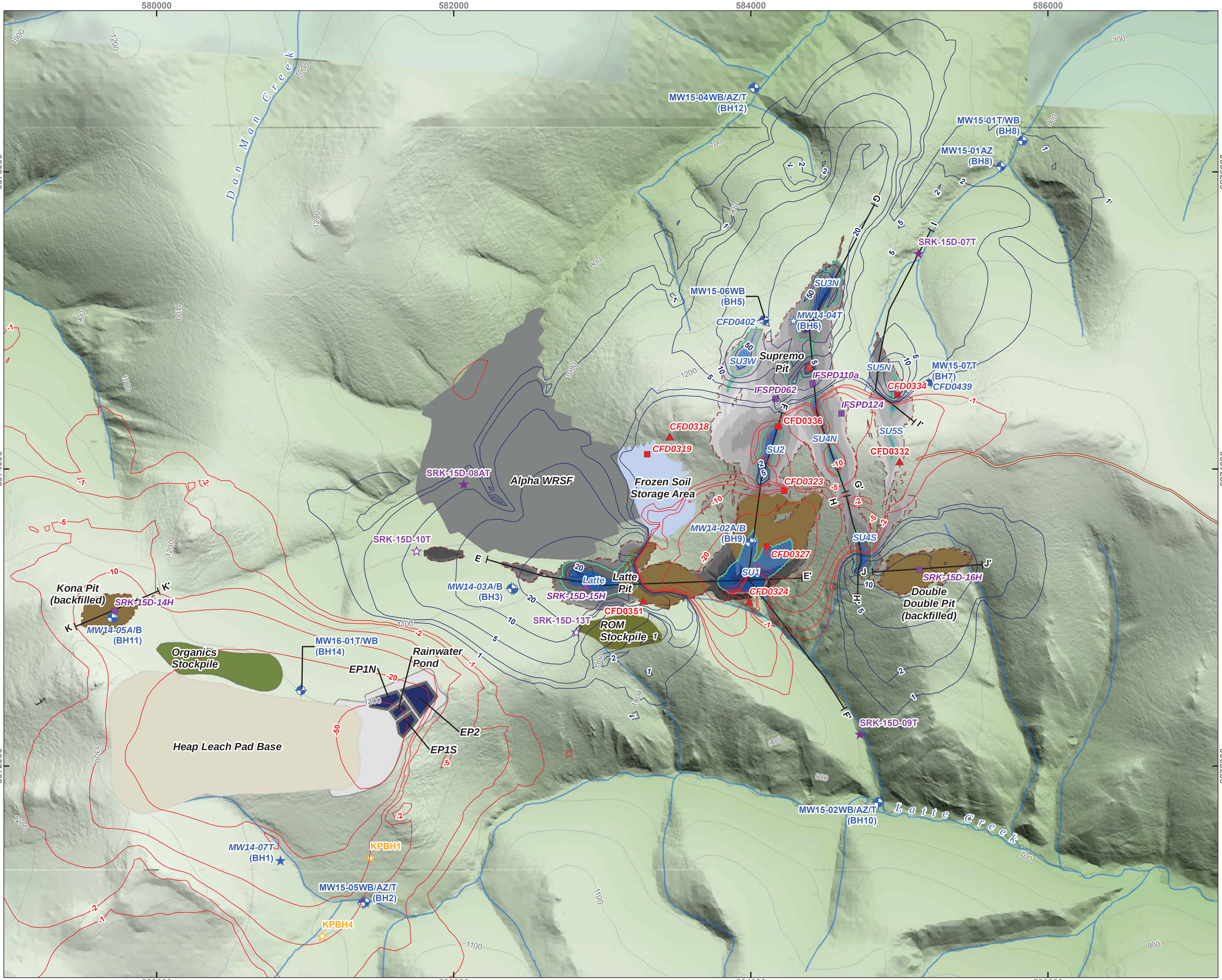
Cross-section H-H' (**Figure 4.4-5**) extends through the SU4S pit. This pit is advanced in unfrozen ground up to 15 m below the pre-mine water table. The pit lake that forms in SU4S is below the pre-mine water table at the north end of the pit, but is above the pre-mine water table at the south end. Some groundwater (~0.2 L/s) is expected to report to the pit, but there remains a seepage loss from the pit towards Latte Creek on the order of 0.5 L/s.

Cross-section I-I' **(Figure 4.4-6**) extends through the Supremo Phase 5 North pit (SU5N). Due to the revised mine plan, the section no longer extends through the Supremo Phase 5 South pit (SU5S). The SU5N pit resides in permafrost. Both the SU5N and SU5S pits are small and are expected to reach their spill point by the end of Operation Phase (**Figure 2.2-1**). Despite reaching their spill point, interaction between these pits and the groundwater system is low, with less than 0.01 L/s of seepage reporting to the YT-24 and Halfway Creek drainages. A small increase in water levels is predicted at MW15-07T (2 m), due east of the SU5N pit. Father downgradient in the YT-24 drainage, a larger increase in groundwater levels is predicted (~4 m) which is partly due to influence from the SU3N pit. At the most downgradient installation in YT-24, MW15-01T, groundwater levels are only slightly above background (~1 m).

The Double Double Pit is advanced in unfrozen ground below the pre-mine water table (cross-section J-J', **Figure 4.4-7**). At the end of Operation Phase, the pit is completely backfilled with no active management of the water table.**)**. Water table mounding on the order of 10 m is expected in the footprint of this facility which is caused by enhanced infiltration through the backfilled mine waste (35% of MAP vs 15% on natural, unfrozen ground). This enhanced infiltration through the pit reports to Latte Creek at a rate of 0.7 L/s.

Development of the lined HLF and associated infrastructure is predicted to result in a decrease in groundwater levels of up to ~50 m at the eastern margin of the facility. This is due to removal of recharge over an area which receives a high amount of recharge (~71 mm/yr) under baseline conditions. The associated decline in recharge causes water levels in Kona (MW14-05A/B) and upper Latte Creek (MW14-07T) to decline on the order of 14-19 m. Father downgradient in Latte Creek, water levels are drawn down ~3 m at MW15-05T. Drawdown at Kona is illustrated in cross-section K-K' (**Figure 4.4-8)**. The pit is advanced in permafrost tens of metres above the pre-mine water table. Due to both permafrost and winter placement of waste rock backfill, it is assumed that any recharge that does infiltrate the backfilled waste rock will freeze at the base of the pit; therefore, no recharge is expected through the Kona pit.

Combined seepage losses from the pits to Latte Creek (including Latte Tributary), Halfway Creek, and YT-24 are 2.1 L/s, 1.2 L/s and 0.1 L/s. Pronounced changes in water levels are a result of a reasonably tight bedrock system. The tight bedrock system limits pit seepage rates. In some cases, pits are completed above the water table and seepage is limited both vertically and horizontally by low permeability permafrost. In all areas, vertical seepage rates are constrained by low permeability deep bedrock.



COFFEE GOLD MINE

Simulated Groundwater Drawdown and Mounding at the End of Operation Phase

Legend

- Monitoring Well: *AZ = active zone, WB = Westbay, A = deep conventional (200+m), B = shallow covnentional (150+m), T = thermistor/VWP, BH = original drillpad name*
- Thermistor (Lorax 2014)
- Thermistor (KP 2014)
- Thermistor (SRK 2015)
- Thermistor/VWP (Lorax 2015)
- Thermistor/VWP (SRK 2015)
- Vibrating Well Piezometer (VWP) (EBA 2013)
- Packer Tests (EBA 2013)
- Packer/Slug Tests (Lorax 2014)
- Packer Tests (SRK 2015)

End of Operation Phase Drawdown Contours

- <0m
- >0m
- Transects
- Project Footprint
- Municipality
- Highway
- Waterbody
- Watercourse

Proposed Infrastructure

- WRSF
- Backfill
- Total Pit Outline
- ROM Stockpile
- Organics Stockpile
- Frozen Soil Storage Area
- Event Pond
- Heap Leach Access Disturbance Footprint
- Heap Leach Pad Base
- Post-Closure Pit Lake

N

1:25,000

0 250 500 750

Meters

NAD 1983 UTM Zone 7N

Page Size: 11" x 17"

Figure 4.4-1	Date: Mar 23, 2017	Drawn by: GM	Reviewed: JS/LF

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Table 4.4-1 Simulated Groundwater Levels for Baseline, End of Operation (Year 12) and Post-Closure Phases

Target[1]	Baseline	End of Operation		Post-closure	
	m asl	m asl	Δm	m asl	Δm
Halfway Creek					
MW16-01T-1106	1,192.2	1,159.3	-32.9	1,159.3	-32.9
MW16-01T-1072	1,192.1	1,159.2	-32.9	1,159.2	-32.9
MW14-03B	967.7	985.9	18.2	1,029.3	61.6
MW14-03A	969.2	986.9	17.7	1,027.6	58.4
MW14-05B	1,147.0	1,128.3	-18.8	1,129.1	-17.9
MW14-05A	1,138.9	1,125.4	-13.5	1,126.2	-12.6
SRK-15D-08AT-822	920.6	925.5	4.9	938.0	17.4
SRK-15D-08AT-776	922.3	927.2	4.9	939.9	17.6
CFD318	1,106.5	1,106.6	0.0	1,110.7	4.2
MW15-06WB-P7	963.9	983.2	19.2	1,072.5	108.5
MW15-06WB-P3	962.4	980.0	17.6	1,055.1	92.7
MW15-03T-508	555.2	555.2	0.0	555.2	0.0
MW15-03T-461	557.4	557.4	0.0	557.4	0.0
MW15-04T-632	670.9	670.9	0.1	671.0	0.2
MW15-04T-619	670.9	670.9	0.1	671.0	0.2
YT-24 Drainage					
MW15-07T-944	1,038.2	1,039.7	1.5	1,083.1	44.9
MW15-07T-915	1,038.2	1,039.7	1.5	1,083.1	44.9
SRK-15D-07T-845	904.9	909.0	4.1	923.0	18.1
SRK-15D-07T-800	905.8	910.2	4.3	924.9	19.0
MW15-01T-728	769.8	770.9	1.1	774.8	5.0
MW15-01T-715	767.6	768.7	1.1	772.3	4.7
Latte Tributary					
CFD351	981.6	992.8	11.2	1,023.9	42.3
MW14-02B	1,002.5	969.1	-33.3	977.8	-24.7
MW14-02A	1,002.8	970.1	-32.7	978.8	-24.0
CFD324	941.1	934.5	-6.6	943.3	2.2
SRK-15D-09T	785.0	785.1	0.2	786.6	1.7
MW15-02T	731.8	731.8	0.0	732.0	0.1
Latte Creek					
MW14-07T	1,151.6	1,135.9	-15.7	1,136.3	-15.3
MW15-05T-1012	1,041.3	1,038.1	-3.2	1,038.2	-3.1
MW15-05T-986	1,043.1	1,039.5	-3.6	1,039.6	-3.5

Note:

Negative changes indicate a decrease in water levels from baseline, positive changes indicate an increase in water levels.

1. MW15-05T-1012: suffix number indicates elevation of measurement point (screen or Westbay zone midpoint or VWP sensor elevation)

Table 4.4-2 Groundwater Fluxes to/from Pit Lakes, End of Operation Phase (Year 12)

Pit Lake	Pit Spill Elevation	Pit Lake Elevation	Groundwater (GW) Flow[1] (L/s)					
			Net GW Inflow	GW Flow Into Pit	Seepage to Latte Creek	Seepage to Halfway Creek	Seepage to YT-24	Seepage to Latte Tributary
SU1	942	942	1.23	1.88	0.32			0.33
SU2	1081	1061	-0.32	0.21	<0.01	0.03		
Latte	1040	998	-1.15		0.21	0.85		
SU3W	1200	1176	-0.01			0.01		
SU3N	1090	1050	-0.24			0.24		
SU4N	1105	1083	0.08	0.11	<0.01	0.02		
SU4S	1048	1013	-0.27	0.20	0.47			
SU5S	1165	1165	-0.01			0.01		
SU5N	1140	1140	-0.01		<0.01	<0.01	0.01	
Double Double[3]		n/a			0.76			
				Totals	**2.1**	**1.2**	**0.01**	**(to Latte)[2]**

Note:

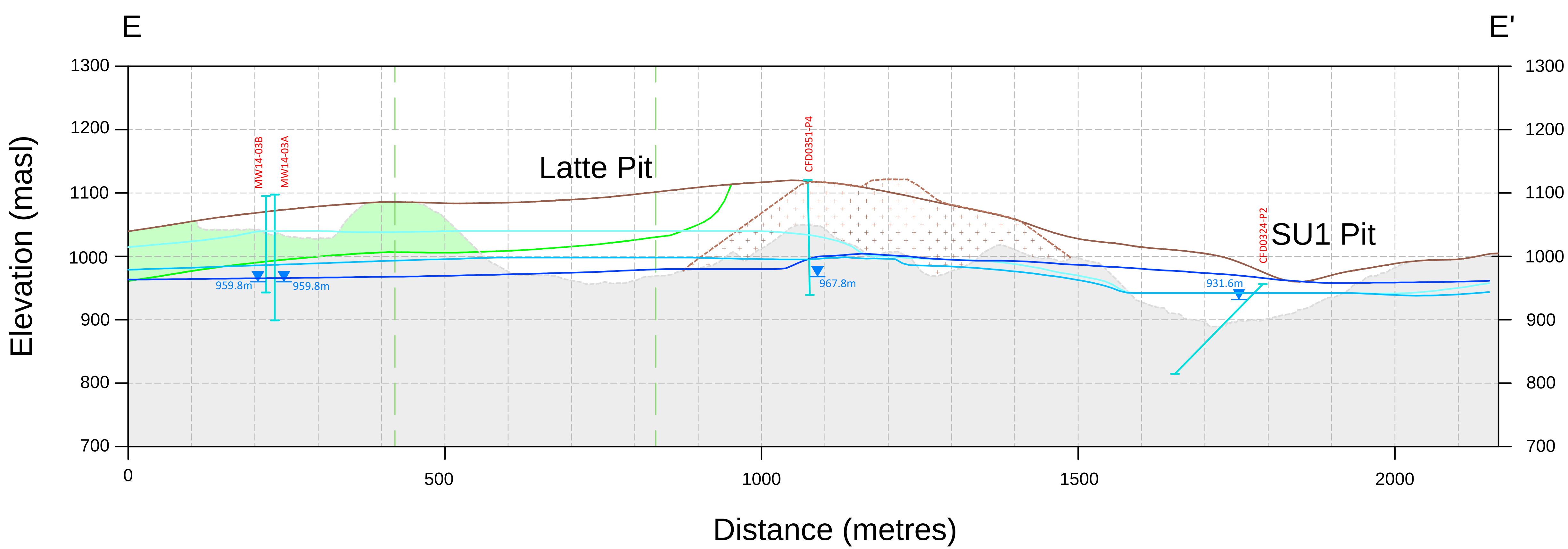
1. Negative values indicate recharge to groundwater system from pit lake.
2. Total seepage to Latte Tributary included in total for Latte Creek.
3. Double Double not simulated as a lake in model, but an area of enhance recharge that drains towards Latte Creek.

Table 4.4-3 Groundwater Fluxes (L/s) between Pits, End of Operation Phase (Year 12)

Receiving Pit →→ / Contributing Pit ↓↓	SU1	SU2	Latte	SU3W	SU3N	SU4N	SU4S	SU5S	SU5N
SU1									
SU2	0.50								
Latte	0.09								
SU3W									
SU3N									
SU4N	<0.01								
SU4S									
SU5S									
SU5N									

COFFEE GOLD MINE

Hydrogeological Cross-Section
E-E' through Latte Pit & SU1



Legend

- Pre-mine topography
- Bedrock
- Waste Rock
- Pit
- Permafrost
- Pre-mine GW
- End of Operation GW
- Post-Closure GW
- Inflection Point
- Drillholes
- Water Level (obs)

V.E. = 1X

Figure 4.4-2	Date: Mar 23, 2017	Drawn by: SSS	Reviewed: JS

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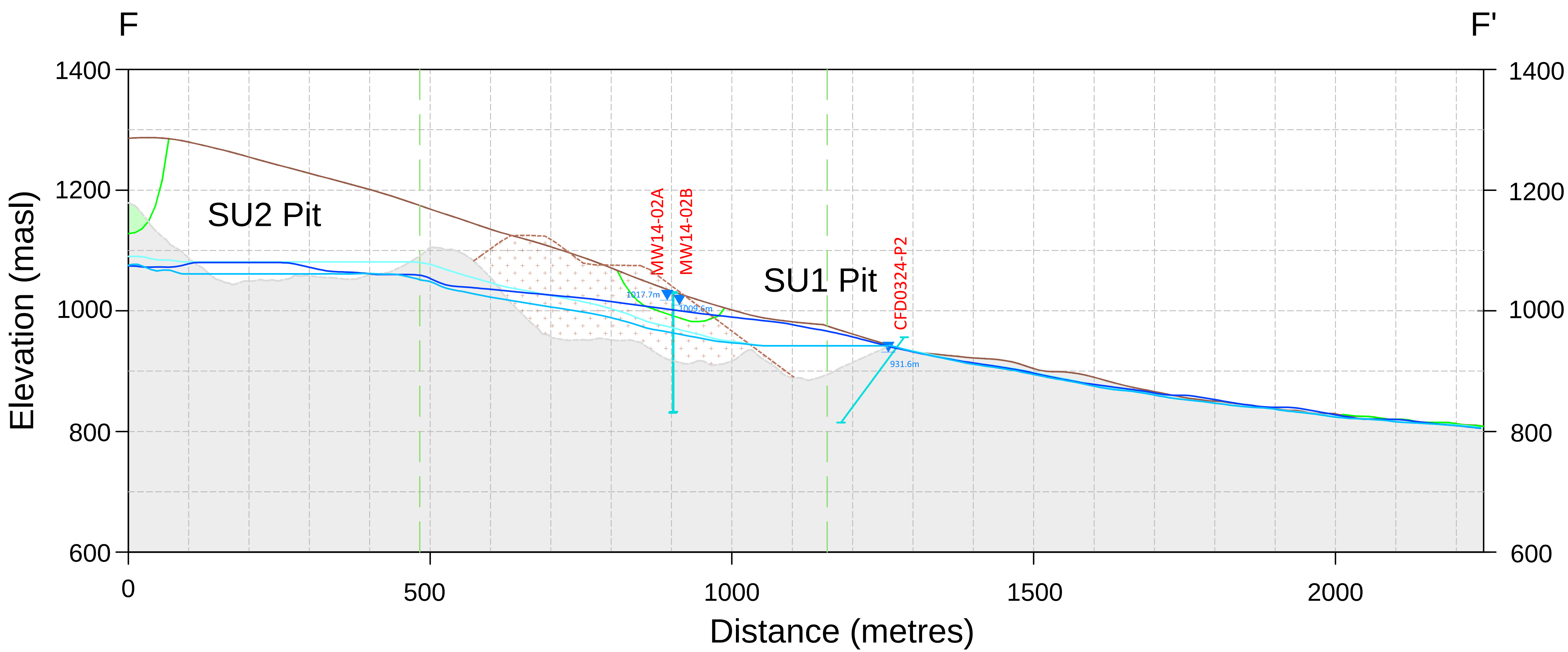
COFFEE GOLD MINE

Hydrogeological Cross-Section F-F' through Supremo Pit Lake SU1 & SU2



Legend

- Pre-mine topography
- Bedrock
- Waste Rock
- Pit
- Permafrost
- Pre-mine GW
- End of Operation GW
- Post-Closure GW
- Inflection Point
- Drillholes
- Water Level (obs)

V.E. = 1X

Figure 4.4-3	Date: Mar 23, 2017	Drawn by: SSS	Reviewed: JS

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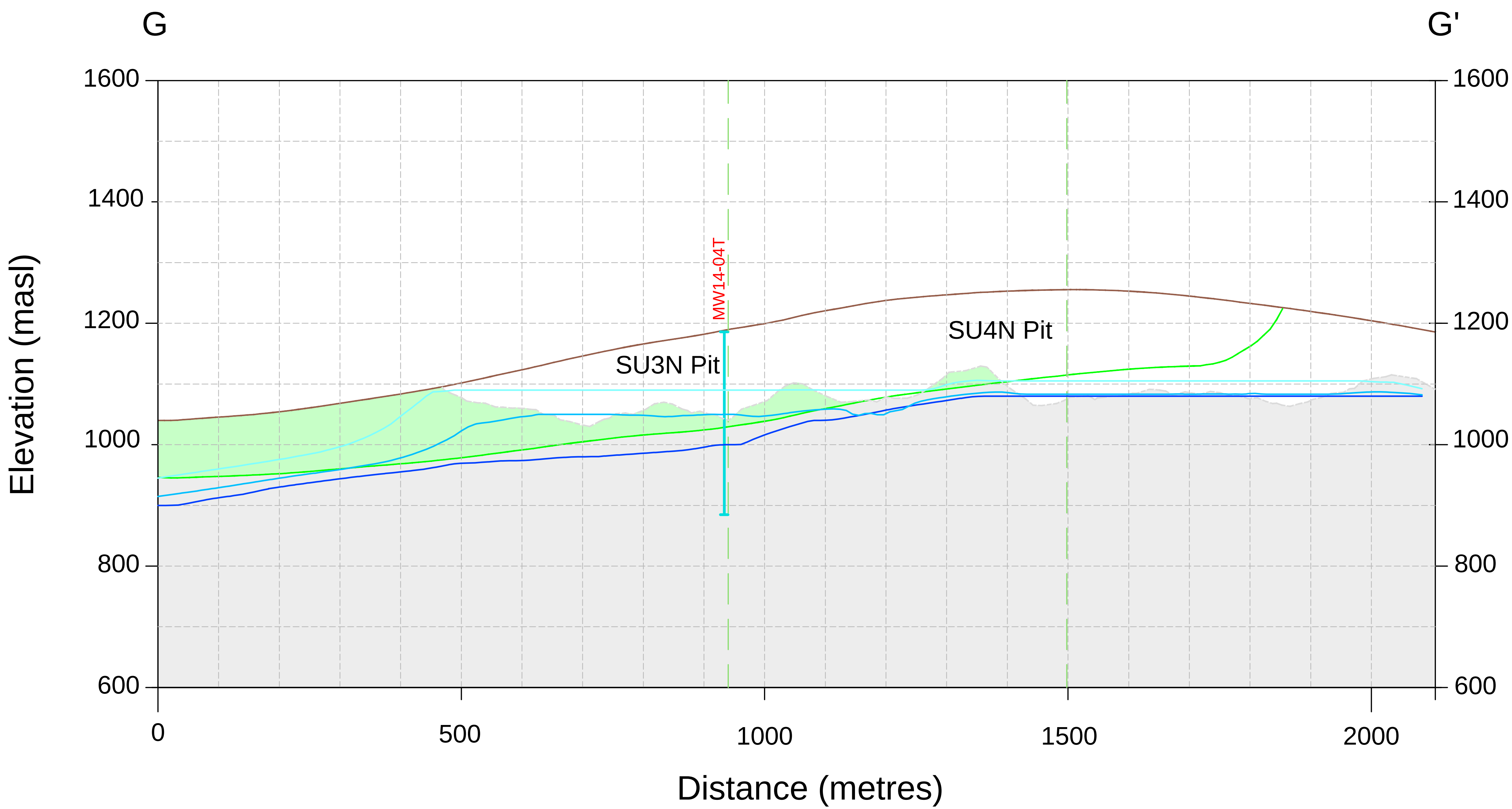
COFFEE GOLD MINE

Hydrogeological Cross-Section G-G' through Supremo Pit Lake SU3N & SU4N



Legend

- Pre-mine topography
- Bedrock
- Pit
- Permafrost
- Pre-mine GW
- End of Operation GW
- Post-Closure GW
- Inflection Point
- Drillholes

V.E. = 1X

Figure 4.4-4	Date: Mar 23, 2017	Drawn by: SSS	Reviewed: JS

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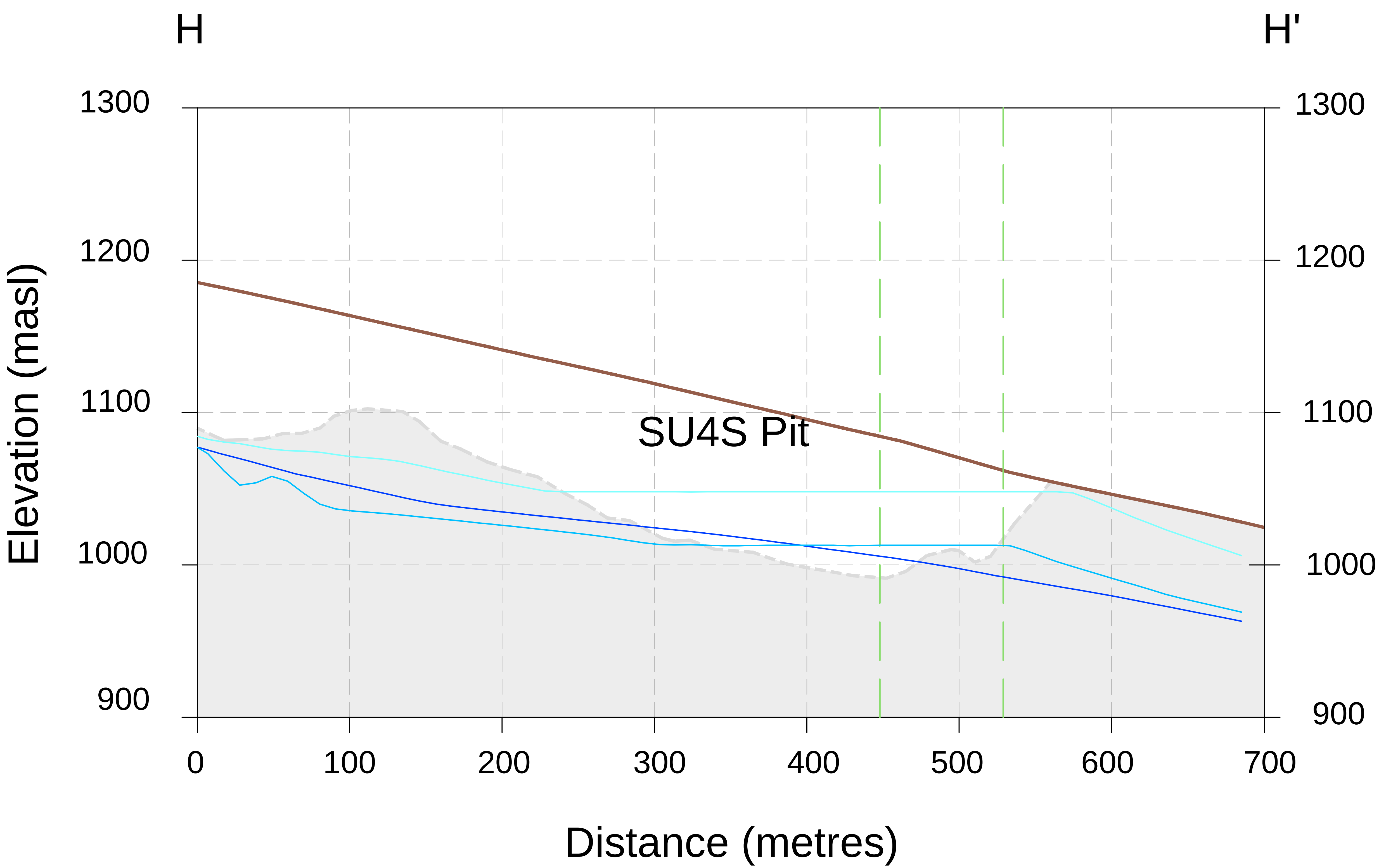
Hydrogeological Cross-Section H-H' through Supremo Pit Lake SU4S



Legend

- Pre-mine topography
- Bedrock
- Pit
- Pre-mine GW
- End of Operation GW
- Post-Closure GW
- Inflection Point

V.E. = 1X

Figure 4.4-5	Date: Mar 23, 2017	Drawn by: SSS	Reviewed: JS

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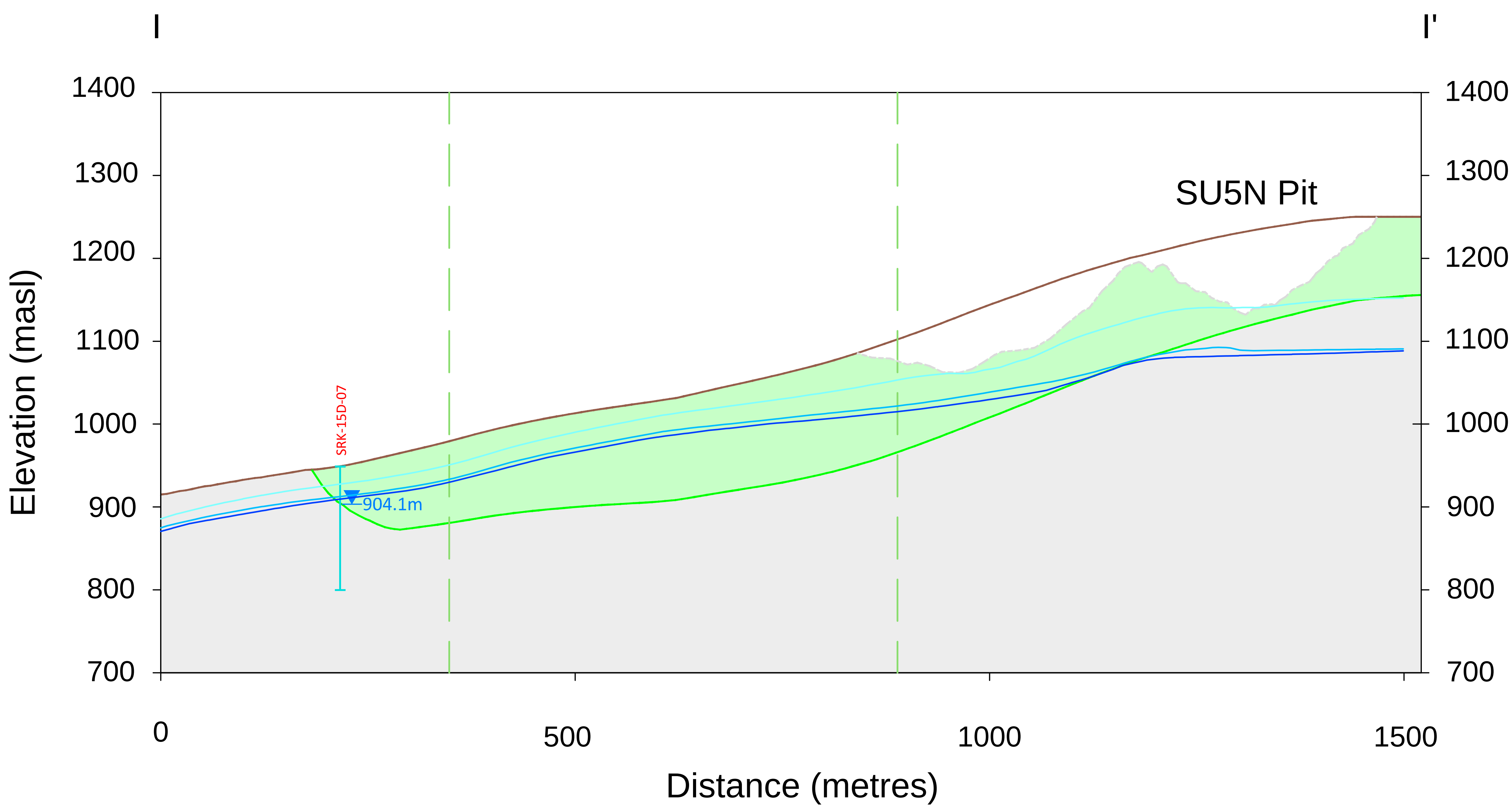
COFFEE GOLD MINE

Hydrogeological Cross-Section I-I' through Supremo Pit Lake SU5N & SU5S



Legend

- Pre-mine topography
- Bedrock
- Pits
- Permafrost
- Pre-mine GW
- End of Operation GW
- Post-Closure GW
- Inflection Point
- Drillholes
- Water Level (obs)

V.E. = 1X

Figure 4.4-6	Date: Mar 23, 2017	Drawn by: SSS	Reviewed: JS

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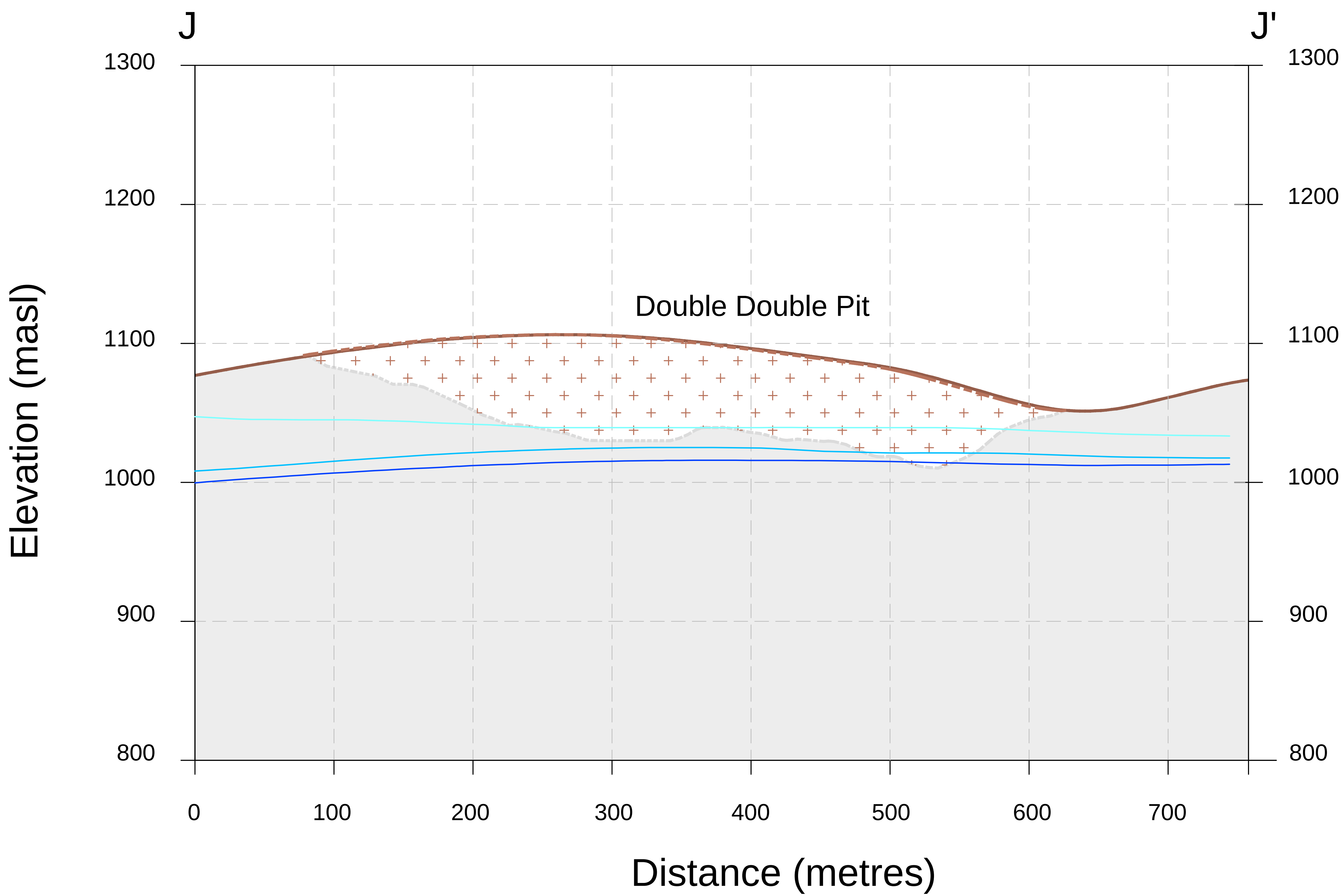

COFFEE GOLD MINE

Hydrogeological Cross-Section J-J' through Double Double Pit

Legend

- Pre-mine topography
- Bedrock
- Waste Rock
- Pit
- Pre-mine GW
- End of Operation GW
- Post-Closure GW

V.E. = 1X

Figure 4.4-7	Date: Mar 23, 2017	Drawn by: SSS	Reviewed: JS

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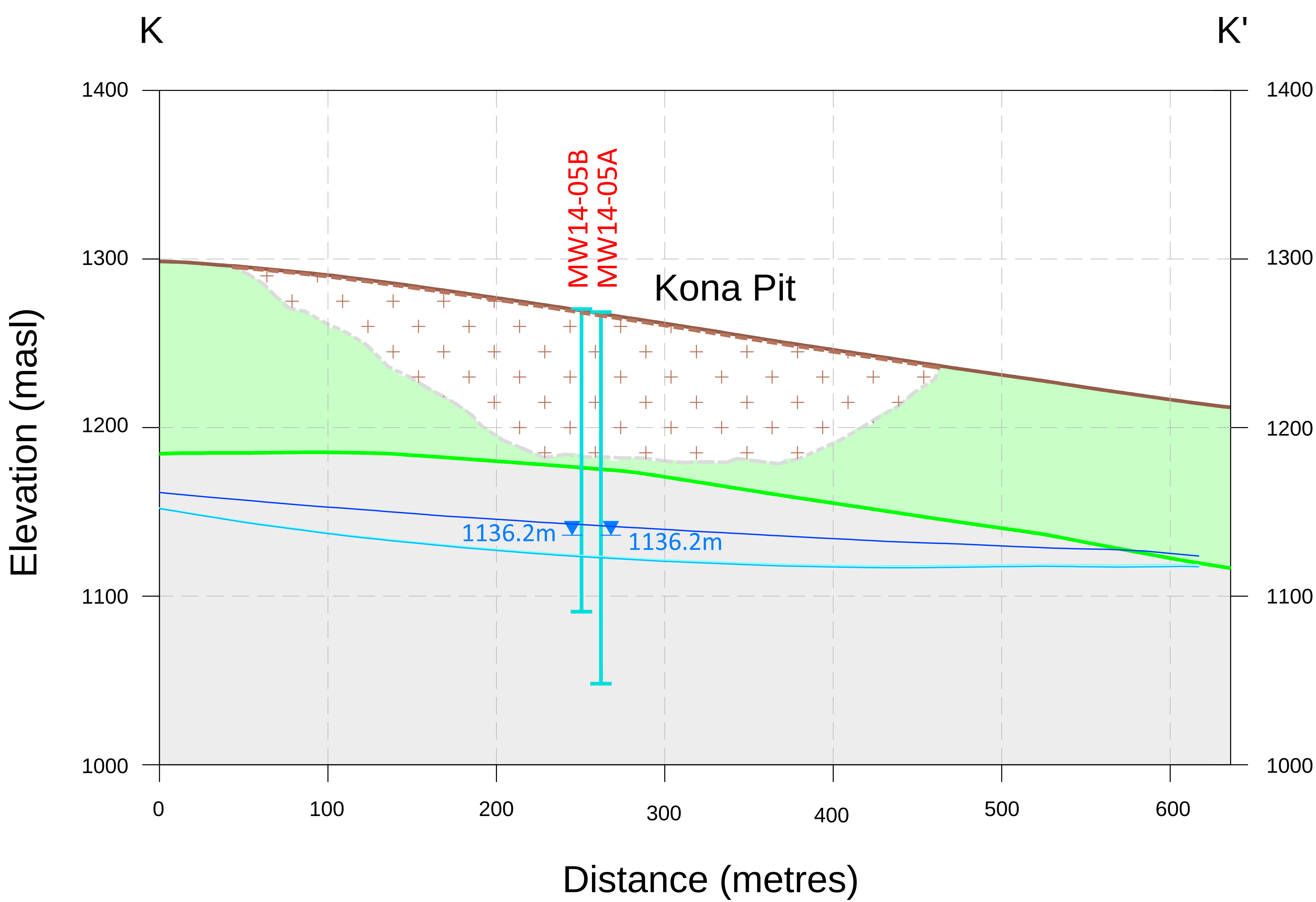

COFFEE GOLD MINE

Hydrogeological Cross-Section
K-K' through Kona Pit

Legend

- Pre-mine topography
- Bedrock
- Waste Rock
- Pit
- Permafrost
- Pre-mine GW
- End of Operation GW
- Post-Closure GW
- Drillholes
- Water Level (obs)

V.E. = 1X

Figure 4.4-8	Date: Mar 23, 2017	Drawn by: SSS	Reviewed: JS

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Potential Changes to Creek Baseflows

Simulated streamflows for end of Operation Phase are summarized in **Table 4.4-4**. **Table 4.4-4** lists baseline baseflow ranges (**Section 2.1.1, Section 3.3.2.5**) and the associated simulated baseflow targets from the calibrated baseline Groundwater Model (**Section 2.1.1**). Simulated baseflows for end of Operation Phase (and Post-Closure) are presented as rates (in L/s) and as a difference from simulated baseline flows (expressed as (ΔL/s) and percent (%)). Despite there being large changes in groundwater levels in the mine footprint area (**Figure 4.4-1**), changes in local creek baseflows are small due to generally tight bedrock conditions that limit pit/groundwater interactions. When end of Operation Phase baseflows are compared to simulated baseline baseflows, the differences are generally less than 5% of baseline levels and are well within the range of uncertainty associated with the measurement.

While the reduction in baseflow at CC-1.0 relative to baseline simulated flows is -40%, the simulated Operation Phase baseflow remains within the range of measured flows at this station. The Latte Tributary is ephemeral and has been occasionally dry in both open water and winter seasons throughout the period of record (June 2015 is a recent example). Reduction in baseflow at CC-1.0 contributes to a minor reduction (9%, or 1.2 L/s) in simulated baseflow at CC-1.5, the downgradient station on Latte Creek proper, which is also impacted by the loss of recharge in the headwaters of Latte Creek (due to lining of HLF footprint area). For reference, average monthly *total* flows measured at CC-1.5 (including runoff) over the ecologically critical period of April to October are reported to be 100 L/s to 560 L/s (**Appendix 8-B**). One in 20-year 7-day low flows ($7Q_{20}$) at CC-1.5 from June to September are estimated to be 1.57 L/s/km^2, which is equivalent to 36.3 L/s (**Appendix 8-B**). Therefore, a 1.2 L/s reduction in baseflow at CC-1.5 would equate to a <1% reduction in *total* creek flow in an average year, or <4% reduction in *total* creek flow during a $7Q_{20}$ low flow period.

Post-Closure Phase

The long-term Post-Closure condition simulated in the Groundwater Model simulates all pit voids at their spill point (except Kona and Double Double) and the complete thaw of permafrost underneath the footprint of the pit lakes to form through taliks (**Section 2.1.3**). To simulate permafrost thaw, the hydraulic conductivity of bedrock underlying the pits is increased to that of shallow bedrock and constant heads are applied in the pit lakes. The combined changes create a markedly pronounced picture of groundwater mounding in Post-Closure versus end of Operation Phase, as some Post-Closure pit lakes are 20 to 40 metres higher than at the end of Operation Phase (compare **Figure 4.4-9 to Figure 4.4-1**). More cross-flows between the pits are simulated, but net losses from the pits to respective creeks still remain small (**Table 4.4-5**, **Table 4.4-6**). The HLF and SU1 pit areas remain exceptions to the widespread mounding, both areas experience continued drawdown into closure.

Table 4.4-4 Simulated Creek Baseflows for Baseline, End of Operation and Post-Closure Conditions

Drainage	Hydrometric Station	Basin Area km²	Creek Baseflow[1] Calibration Target (L/s)		Simulated Creek Baseflow						
					Baseline	End of Operation Phase			Post-Closure Phase		
			Lower Bound	Upper Bound	L/s	L/s	ΔL/s[2,3]	% Change[2,3]	L/s	ΔL/s[2,3]	% Change[2,3]
Independence Creek	IC-2.5	17.3	6.9	16	4.7	4.6	-0.1	-3%	4.6	-0.1	-3%
	IC-3.0	18.3	7.3	16	10	10	0.0	0%	10	0.0	0%
Halfway Creek	HC-2.5	14.8	5.9	13	8.2	8.4	0.2	3%	10.0	1.8	22%
	HC-5.0	27.0	11	24	17.4	17.7	0.2	1%	19	1.9	11%
YT-24 Drainage	ML-1.0	11.8	3.8	11	7.3	7.4	0.1	1%	7.6	0.3	4%
Latte Creek	CC-6.0	9.6	3.8	8.6	4.4	4.3	-0.1	-2%	4.4	-0.1	-2%
	CC-1.0	3.4	0	3.1	2.1	1.2	-0.8	-40%	1.9	-0.1	-5%
	CC-1.5	23.1	9.3	21	14	12	-1.2	-9%	14	0.2	1%
	CC-3.5	69.8	28	63	48	47	-1.1	-2%	50	1.3	3%

Notes:

1. Lower and upper bound values computed from a basin yield of 0.4 to 0.9 L/s/km², respectively, except at ML-1.0 and CC-1.0, where June 23rd, 2015 low flows used as lower bound.
2. Change in flows (ΔL/s) computed as *ΔL/s = simulated mine phase baseflow - simulated baseline baseflow;* negative changes indicate a decrease in baseflow from simulated baseline levels, positive changes indicate an increase in baseflow from simulated baseline levels.
3. Change in flows (%) computed as *% Change* = (*simulated mine phase baseflow - simulated baseline baseflow)/(simulated baseline baseflow);* negative changes indicate a decrease in baseflow from simulated baseline levels, positive changes indicate an increase in baseflow from simulated baseline levels.

The Post-Closure results described below do not correspond to a specific year. Latte and the SU3N/W pits are the last to fill, some 20 years after end of Operation Phase (**Figure 2.2-1**). Timing of formation of through-taliks is not constrained, and could potentially happen in years to decades after pit lakes form. It should be noted that the through taliks simulated for the Post-Closure condition are not illustrated on the pit cross-sections (**Figure 4.4-2** to **Figure 4.4-8**). The reviewer is referred to **Figure 2.1-7** and **Figure 2.1-8** for a conceptual diagram of through talik formation under a pit lake.

Potential Changes to Groundwater Levels

Simulated groundwater levels during Post-closure are provided in **Table 4.4-1** with drawdown/mounding contoured in **Figure 4.4-9**. Areas of drawdown and mounding coincide with those previously identified in the end of Operation Phase model (**Figure 4.4-1)** although the degree of mounding is enhanced with additional pit recharge areas. Cross-sections presented in the previous section (**Figure 4.4-2** to **Figure 4.4-8**) include simulated Post-closure water levels.

Closure groundwater levels along the Latte-SU1 cross-section (**Figure 4.4-2**) necessarily increase in the vicinity of Latte pit, reflecting a higher stage predicted by the Water Balance Model (1040 m versus 998 m at end of Operation Phase). This is reflected in a groundwater mound centered on the Latte Pit with a maximum displacement of ~70 m over pre-mine conditions. Nearby monitoring points MW14-03A/B and CFD-0351 record groundwater level increases on the order of 60 m and 40 m, respectively. Farther afield in the Halfway Creek drainage, SRK-15D-08AT records water level increases of ~17 m over pre-mine levels. Overall, the Latte pit is expected recharge groundwater, with the bulk of the seepage (~2.3 L/s) reporting to the Halfway Creek drainage and 0.7 L/s reporting to the Latte Creek drainage (**Table 4.4-5**). The Latte pit lake also feeds the SU1 pit on the order of 0.8 L/s (**Table 4.4-6**).

Groundwater levels in the immediate vicinity of SU1 remain largely unchanged from end of Operation Phase (**Figure 4.4-2** and **Figure 4.4-3**) as the water level in the pit is limited by its spill elevation. Water levels in the SU1 pit remain up to ~40 m below pre-mine levels. The SU2 pit lake is 20 m higher than the end of Operation Phase pit lake, but the associated groundwater mound is limited in its southern extent by the drawdown created by the SU1 pit. Groundwater inflow to the SU1 pit is predicted to be 3.7 L/s, with 1.1 L/s of that being derived from seepage from the SU2 pit. The SU2 pit does not directly contribute measurable seepage to any of the nearby creeks; its only influence is on Latte via discharge into the SU1 pit. The SU1 pit experiences 0.5 L/s seepage losses towards Latte Creek. Downgradient of the SU1 pit, groundwater levels increase marginally (~2 m) in the Latte Tributary at SRK-15D-09T.

Table 4.4-5 Groundwater Fluxes to/from Pit Lakes, Post-Closure

Pit Lake	Pit Spill Elevation	Pit Lake Elevation	Groundwater (GW) Flow[1] (L/s)					
			Net GW Inflow	GW Flow Into Pit	Seepage to Latte Creek	Seepage to Halfway Creek	Seepage to YT-24	Seepage to Latte Tributary
SU1	942	942	3.18	3.68	0.19			0.30
SU2	1081	1081	-0.65	0.45	<0.01			
Latte	1040	1040	-3.80	<0.01	0.71	2.31		<0.01
SU3W	1200	1200	-0.29			0.28		
SU3N	1090	1090	-0.59	0.04		0.43	0.11	
SU4N	1105	1105	2.35	2.50	<0.01	0.01	<0.01	
SU4S	1048	1048	-0.84	0.93	1.67			
SU5S	1165	1165	-6.24		0.37		0.33	
SU5N	1140	1140	1.80	1.85			0.06	
Double Double[3]		n/a			0.76			
				Totals	4.0	**3.0**	**0.50**	**(to Latte)[2]**

Note:

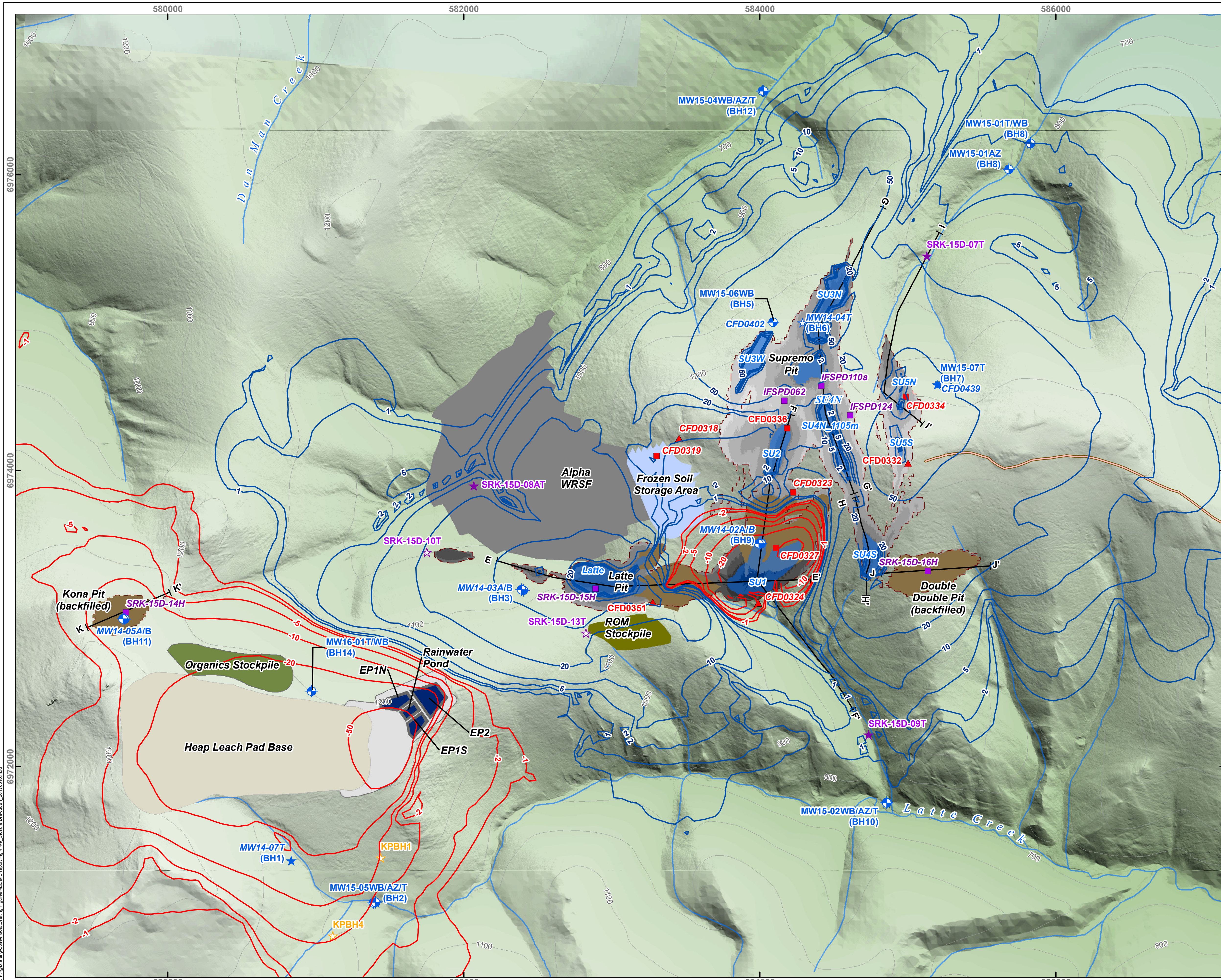
1. Negative values indicate recharge to groundwater system from pit lake.
2. Total seepage to Latte Tributary included in total for Latte Creek.
3. Double Double not simulated as a lake in model, but an area of enhance recharge that drains towards Latte Creek.

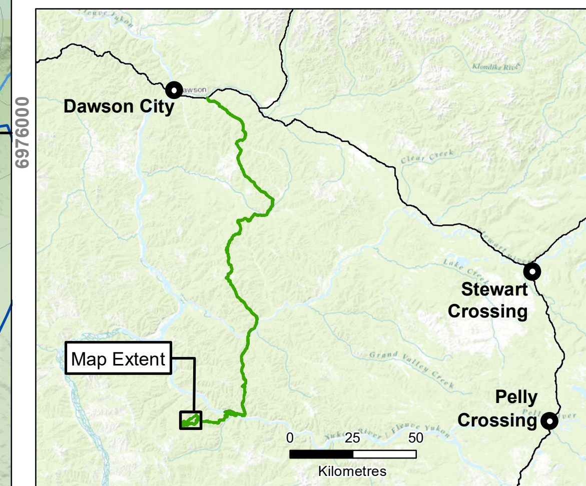
Table 4.4-6 Groundwater Fluxes between Pits (L/s), Post-Closure

Receiving Pit →→ / Contributing Pit ↓↓	SU1	SU2	Latte	SU3W	SU3N	SU4N	SU4S	SU5S	SU5N
SU1									
SU2	1.10								
Latte	0.77								
SU3W		0.01			<0.01				
SU3N		0.09							
SU4N	0.06	0.08							
SU4S	0.10								
SU5S						2.33	1.17		2.04
SU5N									

COFFEE GOLD MINE

Simulated Groundwater Drawdown and Mounding at Post-Closure





Legend

Monitoring Well — AZ = active zone, WB = Westbay, A = deep conventional (200+m), B = shallow coventional (150+m), T = thermistor/VWP, BH = original drillpad name

- Thermistor (Lorax 2014)
- Thermistor (KP 2014)
- Thermistor (SRK 2015)
- Thermistor/VWP (Lorax 2015)
- Thermistor/VWP (SRK 2015)
- Vibrating Well Piezometer (VWP) (EBA 2013)
- Packer Tests (EBA 2013)
- Packer/Slug Tests (Lorax 2014)
- Packer Tests (SRK 2015)

Post-Closure Drawdown Contours

- <0m
- >0m
- Transects
- Municipality
- Waterbody
- Watercourse
- Project Footprint
- Mine Site Access Route
- Highway

Proposed Infrastructure

- WRSF
- Backfill
- Total Pit Outline
- ROM Stockpile
- Organics Stockpile
- Frozen Soil Storage Area
- Event Pond
- Heap Leach Access Disturbance Footprint
- Heap Leach Pad Base

N

1:25,000

0 250 500 750

Meters

NAD 1983 UTM Zone 7N

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Figure 4.4-9	Date: Mar 21, 2017	Drawn by: GM	Reviewed: JS/LF

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Water levels in the SU3N and SU4N pit lakes are 40 m and 20 m higher, respectively, in Post-Closure relative to end of Operation Phase (**Figure 4.4-4**). Seepage losses from the SU3N pit lake are small, with less than 0.5 L/s reporting to Halfway Creek and an even smaller amount (0.1 L/s) reporting to YT24. Combined groundwater mounding from the SU3N and SU3W pits results in water levels climbing over 100 m at MW15-06WB at the north margin of the SU3W pit. Seepage rates from SU3W to Halfway Creek, also remain small at closure (<0.3 L/s). SU4N is a groundwater sink, it receives 2.3 L/s of seepage from the nearby SU5S pit, whose pit lake elevation is nearly 85 m higher than that of the SU4N pit lake. SU4N contributes minimal seepage (<0.1 L/s) to the SU1 and SU2 pits, and provides negligible (0.01 L/s) direct seepage to Halfway Creek. Altogether, mounding in the Halfway Creek drainage is much more pronounced. Drain conditions simulating the creek generally limit the extent of mounding to the east side of the drainage. Water level increase in the creek trace itself are almost negligible (0.2 m or less at MW15-03T, MW15-03T).

The elevation of the SU4S pit lake increases over 35 m during to reach its spill point Post-closure (**Figure 4.4-5**), compounding groundwater mounding caused by the Double Double pit (**Figure 4.4-9**). The SU4S pit loses a small amount of seepage (0.1 L/s) to the SU1 pit, but predominantly seeps towards Latte Creek at a rate of 1.7 L/s.

A large increase in the mounding of water levels is observed around the SU5S/N pit complex (**Figure 4.4-6**). While the pits are at their spill point as of end of Operation Phase, the formation of through taliks (and associated implementation of constant heads) forces the water table to rise up to the level of pit lakes, whereas they were perched above the water table when permafrost was present (at end of Operation Phase). This causes water levels at MW15-07T to increase by over 40 metres over Operation Phase. As a result of the changes, the fluxes out of the highest pit lake, SU5N, are much higher in Post-Closure (6.3 L/s versus 0.01 L/s at end of Operation Phase), but nearly all of the seepage reports in an even split to the SU4N, SU4S and SU5N pits. SU5S loses about 0.4 L/s to Latte Creek and 0.3 L/s to YT-24. SU5N in turn, loses only a minor amount of seepage (0.06 L/s) to YT-24. The combined influence of the SU5 and SU3N pits enhances groundwater mounding downgradient in the YT-24 drainage.

Water levels at Double Double and Kona remain largely unchanged between end of Operation and Post-closure phases (**Figure 4.4-7**, **Figure 4.4-8**). Downgradient of the HLF in the headwaters of Latte Creek, the water levels at MW14-07T and MW15-05T remain consistent between Post-Closure and end Operation Phase, with a ~15 m and 5 m decline anticipated, respectively, due to loss of recharge over the HLF footprint. Water levels farther down the drainage, at MW15-02T, are expected to remain at baseline levels. The Double Double facility receives enhanced recharge over its footprint area, which results in ~0.8 L/s of seepage towards Latte Creek.

Overall combined seepage losses from the pits to Latte Creek (including Latte Tributary), Halfway Creek, and YT-24 are 4 L/s, 3 L/s and 0.5 L/s. The seepage losses are over 100% higher than simulation results for the end of Operation Phase, but still remain small. Despite the underlying assumption of pit lake levels at their spill point and the formation of through-taliks under the pit lakes, seepage losses from the mine facilities are limited vertically by underlying low hydraulic conductivity deep bedrock and in some areas, laterally, by low conductivity permafrost. A sensitivity was conducted for the Post-Closure phase where taliks were not simulated and pit seepage losses to drainages were almost equivalent to the talik base case (**Section 2.1.4**).

Potential Changes to Creek Baseflows

Predicted changes to creek baseflows during Post-Closure are summarized in **Table 4.4-4**. An overall increase in seepage losses from the pit facilities contributes to enhanced baseflow in some drainages. Halfway Creek, which experienced a minimal (<5%) increase in baseflow at the end of Operation Phase, now experiences baseflow increases of 22% at HC-2.5 and 11% at downstream HC-5.0. Most of this increase is due to an increase of seepage losses from the Latte Pit, and to a lesser extent SU3N and SU3W (**Table 4.4-5**). The absolute change in baseflows in this drainage is ~1.9 L/s over the base case and remains within the uncertainty of baseflow targets (Columns 3 and 4, **Table 4.4-4)**. YT-24 experiences a more modest increase in baseflows of 4% (0.3 L/s), largely due to enhanced seepage from the SU5 pit complex (**Table 4.4-5**).

Latte Creek and its tributary (CC-1.0) experienced an overall decrease in baseflow at the end of operations due to drawdown associated with the SU1 pit and HLF liner system. While these influences remain at closure, higher pit seepage rates essentially offset the reductions as of station CC-1.5. CC-6.0 (downgradient of the HLF) and CC-1.0 (downgradient of SU1) record baseflow reductions of 5% or less, which is within the uncertainty of the targets. Overall, baseflow is shown to increase at the most down-gradient station, CC-3.5 (Latte Creek upstream of Coffee Creek), by only 3%. The largest contributors of seepage to Latte Creek include SU4S, Latte Pit and Double Double (**Table 4.4-5**).

4.4.2.2 Changes to Groundwater Quality

The primary mechanisms for potential Project changes to groundwater quality include open pit development and storage of mine waste. Potential Project changes to groundwater quality commence during Construction and continue through Closure and Post-Closure (**Table 4.2-2**).

Lakes that form in the open pits may provide seepage to the groundwater system. Through design measures, ground conditions and amenable topography, the Alpha WRSF, Beta WRSF and backfilled Kona Pit are considered to have negligible influence on the groundwater system (**Table 4.2-2**). The only waste rock facility considered to have a potential interaction with the groundwater system is that of the backfilled Double Double pit. As such, the resulting indicators of groundwater quality change are pit lake water quality and Double Double WRSF seepage water quality (**Table 1.2-3**). To assess potential changes to groundwater quality from mine activities, background groundwater quality data are compared to pit lake water quality computed by the Water Balance/Water Quality Model and source terms developed for waste rock stored in the Double Double pit (**Section 2.2**).

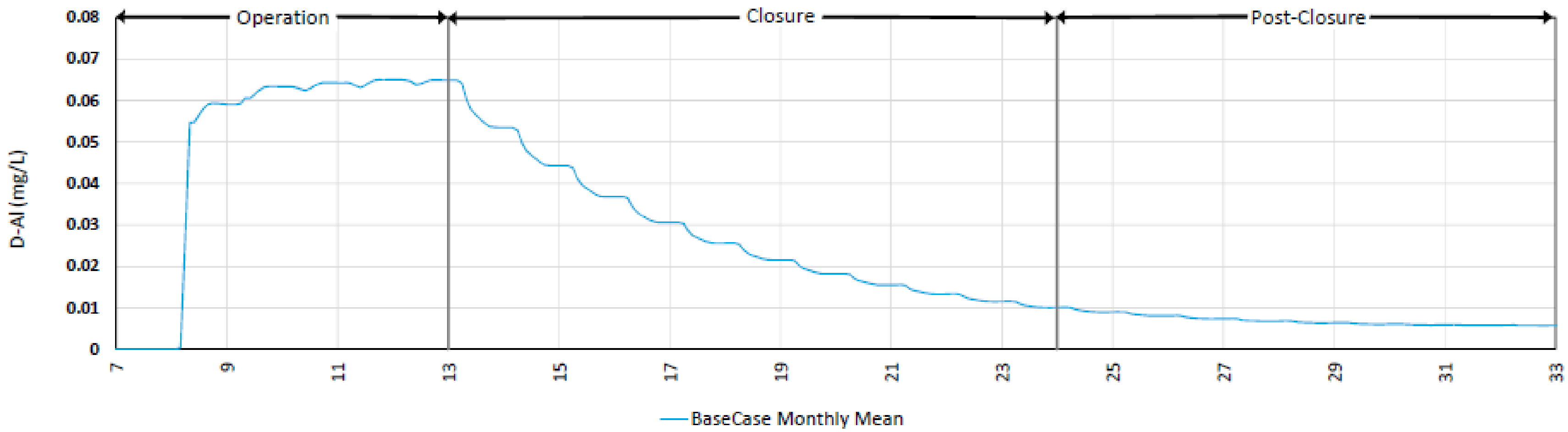
Pit lake water quality represents the integrated effect of pit development and, where applicable, waste rock backfill. Open pits may also receive diverted runoff as dictated by surface water management, including the routing of post-draindown seepage from the HLF to the Latte Pit. All pits are predicted to accumulate water prior to the end of Operation Phase (**Figure 2.2-1**). The evolution of pit lake water quality is illustrated in **Figure 4.4-10** and **Figure 4.4-11**, which show Base Case model concentrations of selected parameters for the SU1 and Latte pit lakes, respectively. Changes to pit lake water quality are not predicted to occur until the later stages of Operation Phase or until the early stages of Closure.

Potential interactions from the backfilled waste rock in the Double Double pit are predicted to coincide with waste rock deposition, with peak changes occurring toward the end of Operation Phase or early Closure. Peak changes are conservatively assumed to persist through Post-Closure with the exception of predicted changes to nitrogen levels. Nitrogen sources originate from blasting residue, are relatively finite, and are expected to decline through Closure and Post-closure.

As outlined above for WRSF and pit lake water quality, potential Project interactions with groundwater quality indicators are not anticipated to commence until the later stages of Operation or the early stages of Closure. Changes to groundwater quality are expected to progress on annual to decadal time scales. As a result, potential Project interactions with groundwater quality are generally not expected to be realized until Closure or Post-closure.

As indicated in **Section 2.2.2**, the comparison of background groundwater quality to pit lake and Double Double WRSF seepage water quality is limited to parameters of concern (POCs) in the receiving environment which have been identified through the surface water quality effects assessment (**Appendix 12-B**). These parameters include nitrate, dissolved aluminum and total metals arsenic, chromium, copper, uranium and zinc. Concentrations of these parameters in background groundwater quality are summarized in **Table 4.4-7**.

Table 4.4-8 summarizes maximum concentrations of the POCs in pit lakes and Double Double WRSF seepage. The pit lake concentrations are Base Case Water Balance Model estimates through mine life and include the Post-Closure period (**Section 2.2**). The Double Double WRSF seepage concentrations are simply the source terms generated for this facility. Concentrations of POCs that are above mean background groundwater quality are highlighted in grey in **Table 4.4-8.** The factor by which mine area concentrations exceed (or fall below) background is shown in **Table 4.4-9**.



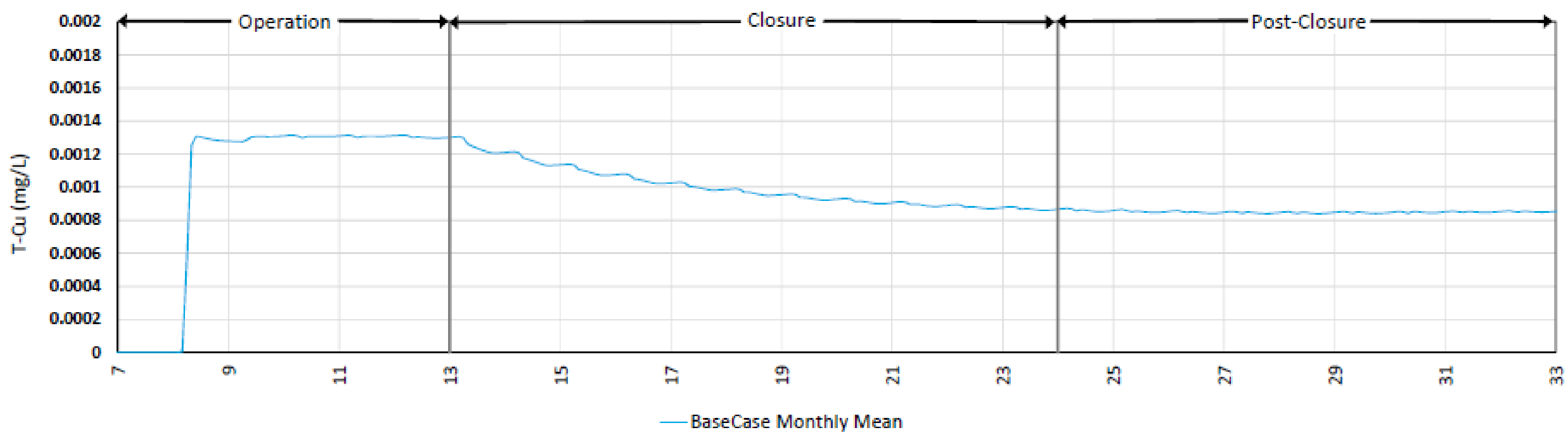


Figure 4.4-10 Base Case Time Series of Monthly Dissolved Aluminum and Total Copper for SU1 Pit Lake.

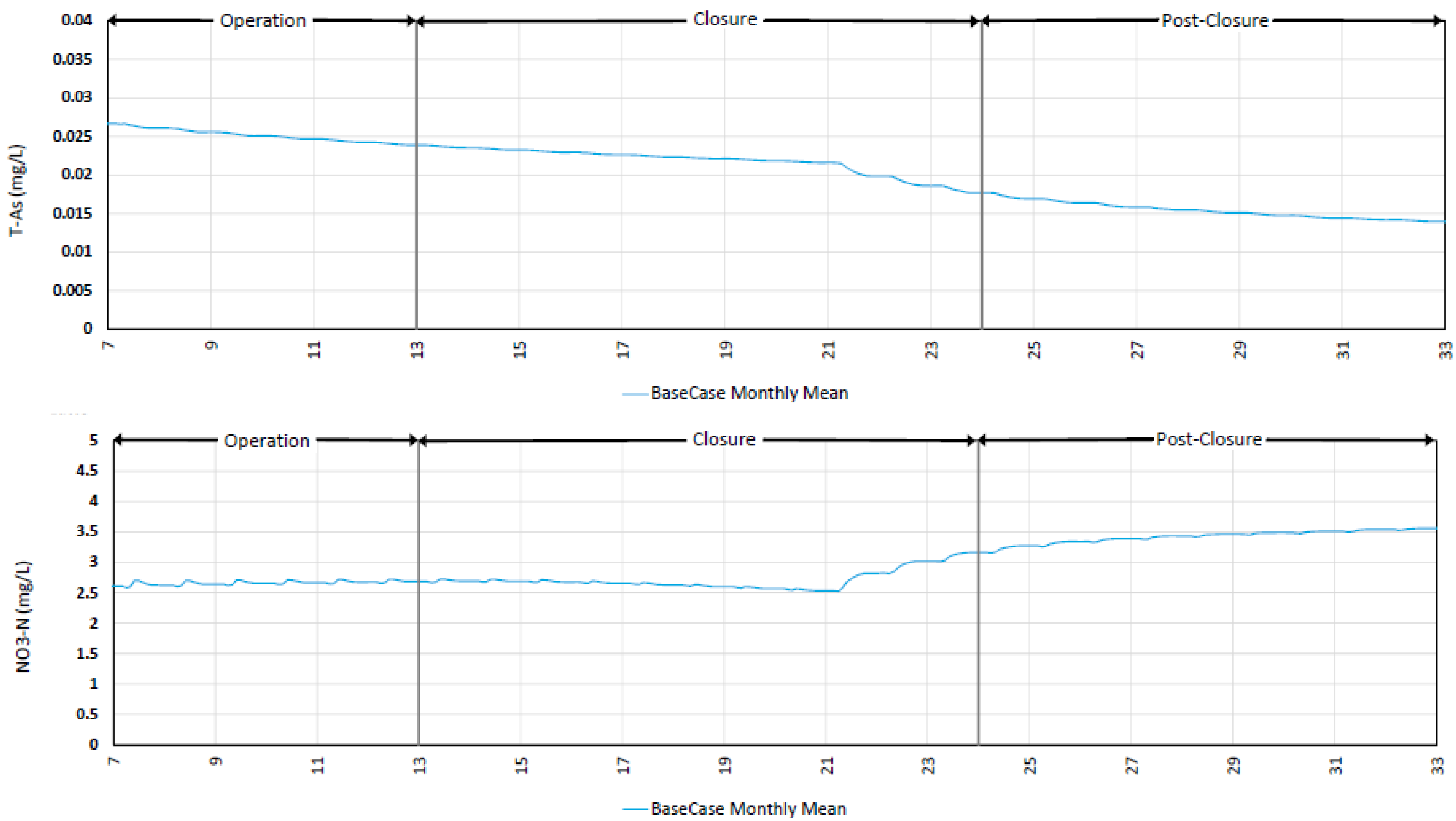


Figure 4.4-11 Base Case Time Series of Monthly Total Arsenic and Nitrate for Latte Pit Lake.

Table 4.4-7 Baseline Groundwater Quality by Lithology

Lithology		Schist			Granite			Gneiss		
Sample Count		17			12			20		
Statistic		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Nitrate (N)	mg/L	<0.002	0.037	0.14	<0.002	0.002	0.003	<0.002	0.073	0.228
Metals										
Dissolved Aluminum (Al)	ug/L	1.0	10	53	1.7	10	29	<0.5	14	68
Total Arsenic (As)	ug/L	0.58	29	75	0.89	642	1910	0.45	24	68
Total Chromium (Cr)	ug/L	<0.1	0.39	2.1	0.13	0.85	2.7	0.21	0.66	1.9
Total Copper (Cu)	ug/L	0.14	1.4	5.4	0.12	2.7	13.4	<0.05	0.76	2.9
Total Uranium (U)	ug/L	31	51	92	9.67	39	76.9	7.39	174	598
Total Zinc (Zn)	Ug/L	1.1	9.1	36	4.6	28	102	0.33	81	604

In general, metal concentrations are within two times background levels for most of the pit lakes, save Latte. The exceptions in the other pits include dissolved aluminum at SU4 and SU1, which is elevated 10-fold and 5-fold in pit water, respectively. Nitrate, associated with blasting residues, is elevated across all pit lakes, particularly Latte and SU1, whose nitrate concentrations exceed background levels by 98- and 86-fold, respectively.

Besides blasting residues, Latte pit water quality is associated with the most exceedances of metal concentrations over background, with dissolved chromium and total aluminum the most elevated at 11-fold and 6-fold, respectively. Post-draindown seepage from the HLF is directed to the Latte pit during active closure and this results in water quality trends that are markedly different at this facility compared to others (compare **Figure 4.4-11** to **Figure 4.4-10**). For some POCs, including aluminum, arsenic, uranium and zinc, the addition of HLF draindown water causes concentrations to drop markedly in Year 21. Other POCs experience a marked increase upon HLF routing, including cyanide decay products (nitrate), copper and chromium.

Double Double WRSF seepage water quality is elevated over background for several POCs. Changes arising from blasting and associated nitrogen leaching are evident, as illustrated in **Table 4.4-9**. Metals leaching is manifested in elevated chromium, copper, and uranium. Metal behaviour associated with WRSF seepage differs from pit lake water quality in that waste rock storage facilities are highly-oxidizing environments and exhibit different mineral solubility controls than pit wall runoff (**Appendix 12-C**). These characteristics help to explain the disparate behaviour of arsenic and uranium in these depositional environments.

Table 4.4-8 Predicted Maximum Base Case Monthly Pit Lake and Backfill Pit Water Quality (All Mine Phases) Screened Against Measured Mean Baseline Groundwater Quality by Lithology

		Pit Lake								Waste Rock
Mine Facility		S3W	SU3N	SU4S	SU5N	SU5S	SU2	SU1	Latte	Double Double
Underlying Lithology		Gneiss	Gneiss	Gneiss	Gneiss	Gneiss	Gneiss	Gneiss	Schist	Gneiss
Nitrate (N)	mg/L	0.5	0.5	0.42	0.5	0.5	0.5	6.2	3.6	30
Metals										
Dissolved Aluminum (Al)	ug/L	7.3	7.2	137	7.2	7.2	7.0	66	62	7.9
Total Arsenic (As)	ug/L	27	26	19	23	23	20	13	33	7.0
Total Chromium (Cr)	ug/L	0.4	0.4	0.6	0.4	0.4	0.4	0.6	4.3	1.5
Total Copper (Cu)	ug/L	1.0	1.0	1.8	1.0	1.0	1.0	1.3	2.1	2.0
Total Uranium (U)	ug/L	64	64	46	64	64	60	103	42	376
Total Zinc (Zn)	ug/L	10.3	10.2	10.9	10.4	10.4	9.9	13.6	14.2	41

Note: shaded values are greater than mean observed baseline by lithology (**Table 4.4-7**)

Table 4.4-9 Predicted Change (Multiplication Factor) For Maximum Base Case Pit Lake and Backfilled Pit Water Quality Estimates Compared To Mean Baseline Groundwater Quality by Lithology

		Predicted Pit Lake Maximum Base Case Monthly Water Quality								Waste Rock
Mine Facility		S3W	SU3N	SU4S	SU5N	SU5S	SU2	SU1	Latte	Double Double
Underlying Lithology		Gneiss	Gneiss	Gneiss	Gneiss	Gneiss	Gneiss	Gneiss	Schist	Gneiss
Nitrate (N)	mg/L	6.9x	6.9x	5.8x	6.9x	6.9x	6.9x	86x	98x	410x
Metals										
Dissolved Aluminum (Al)	ug/L	0.5x	0.5x	9.5x	0.5x	0.5x	0.5x	4.6x	6.4x	0.6x
Total Arsenic (As)	ug/L	1.1x	1.1x	0.8x	1.0x	1.0x	0.8x	0.5x	1.2x	0.3x
Total Chromium (Cr)	ug/L	0.6x	0.6x	0.9x	0.6x	0.6x	0.6x	1.0x	11x	2.3x
Total Copper (Cu)	ug/L	1.3x	1.3x	2.3x	1.3x	1.3x	1.3x	1.7x	1.4x	2.7x
Total Uranium (U)	ug/L	0.4x	0.4x	0.3x	0.4x	0.4x	0.3x	0.6x	0.8x	2.2x
Total Zinc (Zn)	ug/L	0.1x	0.1x	0.1x	0.1x	0.1x	0.1x	0.2x	1.6x	0.5x

Note: shaded values are greater than mean observed baseline by lithology (**Table 4.4-7**) as indicated by a multiplication factor larger than 1.

Potential Project interactions with groundwater quality indicators are summarized in **Table 4.4-10** for the Operation Phase and **Table 4.4-11** for the Post-Closure Phase, based on the linkage between proposed mine facilities and their respective catchment (**Table 2.2-1**) and the timing of development (**Figure 2.2-1**). Groundwater quality parameters estimated above background are identified for potential effects on surface water quality. Parameters identified through this groundwater quality assessment have been flagged as parameters of concern for future monitoring of groundwater indicators, including pit lake water quality, WRSF seepage quality, base flow water quality, and observational monitoring well water quality.

Table 4.4-10 Summary of Project Changes to Groundwater Quality Indicators by Drainage During Operation Phase

Indicator	Pit Lake WQ			Double Double WRSF WQ
Drainage	**Halfway**	**YT-24**	**Latte**	**Latte**
Nitrate (N)	x	x	x	x
Metals				
Dissolved Aluminum (Al)	x		x	
Total Arsenic (As)	x		x	
Total Chromium (Cr)	x		x	x
Total Copper (Cu)	x	x	x	x
Total Uranium (U)				x
Total Zinc (Zn)			x	

Note: "X" denotes that parameter concentration in one or more pit lakes or Double Double WRSF source areas may cause concentration increases in receiving groundwater.

Table 4.4-11 Summary of Post-Closure Phase Project Changes to Groundwater Quality Indicators by Drainage

Indicator	Pit Lake WQ			Double Double WRSF WQ
Drainage	**Halfway**	**YT-24**	**Latte**	**Latte**
Nitrate (N)	x	x	x	x
Metals				
Dissolved Aluminum (Al)			x	
Total Arsenic (As)	x	x	x	
Total Chromium (Cr)	x		x	x
Total Copper (Cu)	x	x	x	x
Total Uranium (U)				x
Total Zinc (Zn)	x		x	

Note: "X" denotes that parameter concentration in one or more pit lake/WRSF source areas may cause concentration increases in receiving groundwater.

4.5 SUMMARY OF FUTURE CONDITIONS WITH THE PROJECT

Potential residual changes to groundwater quantity and groundwater quality are summarized in **Table 4.5-1** and **Table 4.5-2**. For groundwater quantity, only changes to creek baseflow are presented as these are most critical to other effects assessments (e.g. for the Fish and Fish Habitat VC). The changes to creek baseflow presented in **Table 4.5-1** indicate that changes to the surface water regime resulting from Project interactions on the groundwater system are minimal and within the uncertainty of the baseflow target range.

A summary of future potential Project-related changes to groundwater quality indicators is provided in **Table 4.5-2** for Operation and Post-Closure conditions. The assessment of Project effects on surface water quality (**Appendix 12-B)** includes the parameters of interest identified below. Further, parameters identified through this groundwater quality assessment have been flagged as parameters of concern for future monitoring of groundwater indicators, including pit lake water quality, WRSF seepage quality, base flow water quality, and observational monitoring well water quality.

Table 4.5-1 Summary of Potential Project-related Residual Changes to Groundwater Quantity (Creek Baseflow)

Project Component/Activity	Proposed Mitigation Measures	Potential Residual Adverse Change
Construction and Operation		
Construction and use of lined HLF and associated ponds (C-12) Development of Latte, Supremo and Double Double pits (O-4) Cessation of mining of Latte, Supremo, Double Double pits (O-5) Partial backfill of Latte pit and Supremo Pit (O-6) Partial backfill of Double, Double Pit (O-7) Dewatering of Pits (O-8)	Project mitigation by design, phased development, and progressive reclamation are the primary mitigation measures. Additional measures are described in **Section 4.4.1**.	*Halfway Creek:* HC-2.5 baseflow increase ~3% HC-5.0 baseflow increase ~1%
		YT-24 Drainage: YT-24 baseflow increase ~1%
		Latte Creek: CC-6.0 baseflow decrease ~2% CC-1.0 baseflow decrease ~40% CC-1.5 baseflow decrease ~9% CC-3.5 baseflow decrease ~2%
		Independence Creek: IC-2.5 baseflow decrease ~3%
Reclamation and Closure		
Reclamation of Double Double, Latte and Supremo Pits (R-3) Decommissioning and removal of HLF water treatment plant (R-15)	Project mitigation by design, phased development, and progressive reclamation are the primary mitigation measures. Additional measures are described in **Section 4.4.1**.	Halfway Creek: HC-2.5 baseflow increase ~22% HC-5.0 baseflow increase ~11%
		YT-24 Drainage: YT-24 baseflow increase ~4%
		Latte Creek: CC-6.0 baseflow decrease ~1% CC-1.0 baseflow decrease ~5% CC-1.5 baseflow increase ~1% CC-3.5 baseflow increase ~3%
		Independence Creek: IC-2.5 baseflow decrease ~3%

Table 4.5-2 Summary of Potential Project-related Residual Changes to Groundwater Quality

Project Component/Activity	Proposed Mitigation Measures	Potential Residual Adverse Change
Construction and Operation		
On-site use of explosives (C-21, O-22) Cessation of mining at Double Double, Latte and Supremo Pits (O-5) Partial backfill of Latte pit and Supremo Pit (O-6) Backfill of Double Double pit (O-7)	Project mitigation by design, phased development, and progressive reclamation are the primary mitigation measures. Additional measures are described in **Section 4.4.1**.	*Halfway Creek:* *Artificially elevated concentrations of POCs arising from pit lakes:* nitrate, aluminum, arsenic, chromium, copper
		YT-24 Drainage: *Artificially elevated concentrations of POCs arising from pit lakes:* copper, nitrate
		Latte Creek: *Artificially elevated concentrations of POCs arising from pit lakes and Double Double waste rock backfill seepage:* nitrate, aluminum, arsenic, chromium, copper, iron, uranium, zinc
Post- Closure		
Reclamation of Double Double, Latte and Supremo pits (R-3) Decommissioning and removal of HLF water treatment plant (R-15)	Project mitigation by design, phased development, and progressive reclamation are the primary mitigation measures. Additional measures are described in **Section 4.4.1**.	*Halfway Creek:* *Artificially elevated concentrations of POCs arising from pit lakes:* nitrate, arsenic, chromium, copper, zinc
		YT-24 Drainage: *Artificially elevated concentrations of POCs arising from pit lakes:* arsenic, copper, nitrate
		Latte Creek: *Artificially elevated concentrations of POCs arising from pit lakes and Double Double waste rock backfill seepage:* nitrate, aluminum, arsenic, chromium, copper, iron, uranium, zinc

5.0 FUTURE CONDITIONS WITH THE PROJECT AND OTHER PAST, PRESENT, AND FUTURE PROJECTS AND ACTIVITIES

This section of the IC analysis presents an analysis of potential cumulative changes to the Groundwater IC and the Project's contribution to these changes. For the purposes of this analysis, cumulative changes are assumed to result from interactions between Project-related changes and the incremental changes to the IC with other past, present, and future projects and activities.

Groundwater flow systems occur on various scales. At the largest scale, very deep groundwater drains towards major regional water bodies. At smaller scales, groundwater that originates in local catchments may discharge towards local creeks and streams which ultimately feed into larger surface water systems. Surface water systems thus cumulate all upstream influences, whether they be caused by natural processes, human-induced change or a combination of factors.

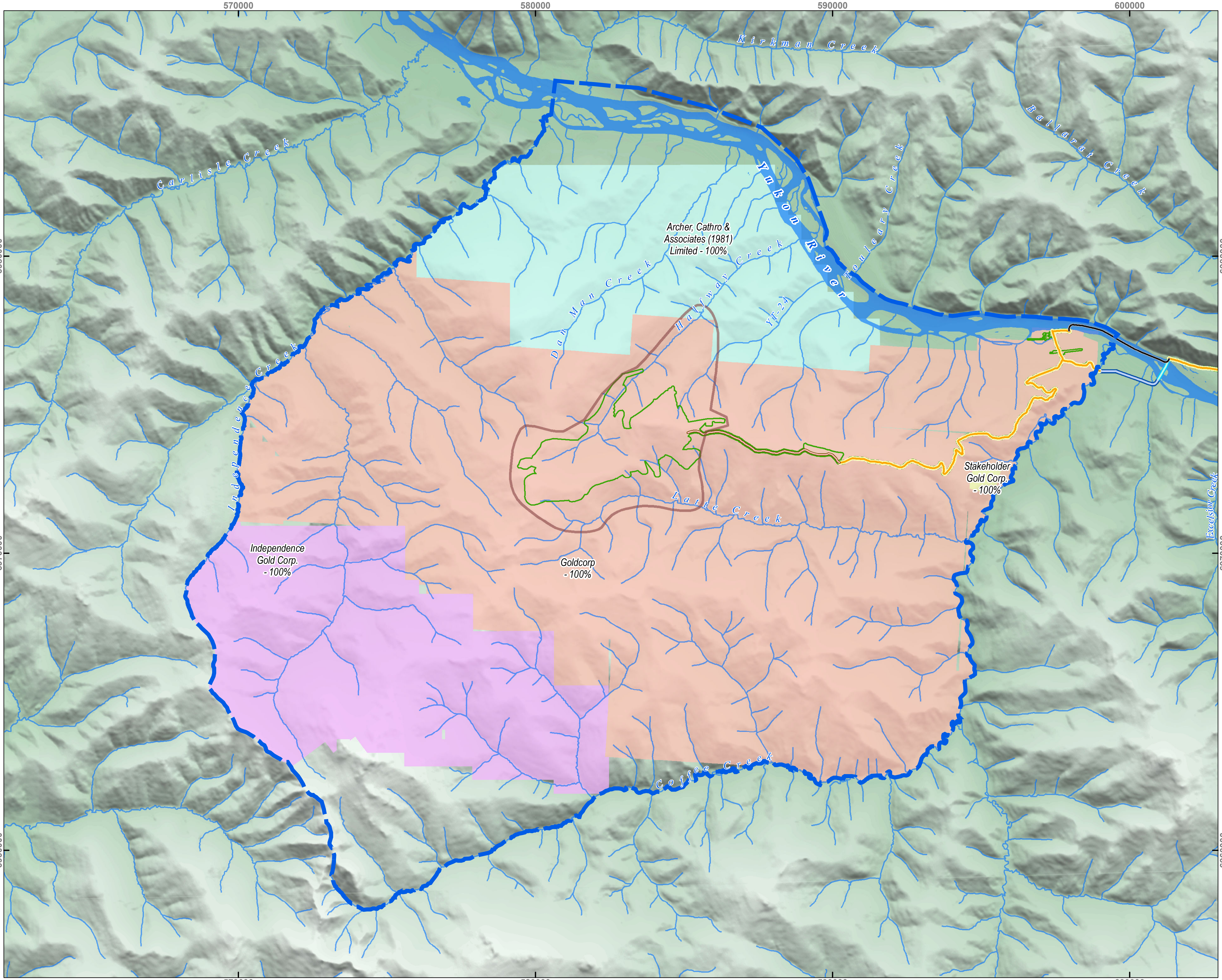
Guidance documents specific to the cumulative effects methodology are identified below:

- Draft Technical Guidance for Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012 (CEA Agency, December 2014);
- Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act 2012, Operational Policy Statement (CEA Agency 2013 a);
- Practitioners Glossary for the Environmental Assessment of Designated Projects under the Canadian Environmental Assessment Act 2012 (CEA Agency 2013b); and
- Reference Guide: Addressing Cumulative Environmental Effects (CEA Agency 1994a).

Project related changes were analyzed for the IC in **Section 4.0**, with screening guided by the Project and Activity Inclusion List provided in the Project Proposal (refer to **Section 5.0 Effects Assessment Methodology, Appendix 5-A**).

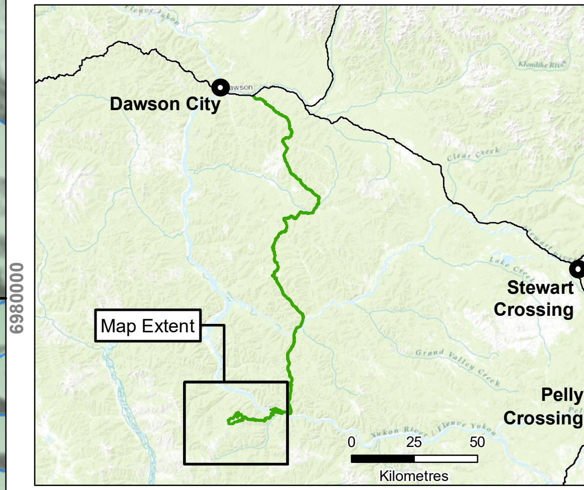
5.1 SPATIAL AND TEMPORAL SCOPE OF THE CUMULATIVE CHANGE ANALYSIS

Residual changes to groundwater quantity and quality that may occur as a result of Project activities are generally small and are predicted to occur at the local scale and not impact the larger, much deeper regional groundwater system. The preceding discussion in **Section 4** has also indicated that there are no residual changes on the Groundwater IC associated with the Northern Access Route through all Project phases, nor are there changes predicted at the boundaries of the Groundwater Model. For this reason, the spatial boundary for the Cumulative Changes Study Area (CCSA) has been selected to coincide with the Groundwater Model boundary, which is equivalent to the Groundwater RSA boundary south of the Yukon River (**Figure 5.1-1**).



COFFEE GOLD MINE

Groundwater Cumulative Changes Study Area – Coffee Gold Mine



Legend

Active Quartz Mineral Claim

- Archer Cathro & Associates (1981) Ltd.
- Independence Gold Corp.
- Goldcorp
- Stakeholder Gold Corp.
- Cumulative Changes Study Area
- Local Study Area
- Project Footprint
- Yukon River Barge Route
- Yukon River Ice Road
- Winter Road
- Mine Site Access Route
- Northern Access Route
- Highway
- Municipality
- Watercourse
- Waterbody

Sources

Quartz and Placer Claims data source - http://mapservices.gov.yk.ca/GeoYukon/. (March 9th, 2017)

N

1:125,000

0 2 4 6 Kilometers

NAD 1983 UTM Zone 7N

Page Size: 11" x 17"

Figure 5.1-1	Date: Mar 21, 2017	Drawn by: GM	Reviewed: JS/LF

GOLDCORP

Residual changes to groundwater quantity have been assessed for two time periods, End of Operation Phase (Year 12) and Post-Closure, while residual changes to groundwater quality are assessed through all Project phases (**Section 4.4.2**). For the purpose of identifying cumulative changes, all past, present and reasonably foreseeable future projects with residual changes occurring within the CCSA are considered in the analysis.

5.2 CHANGES DUE TO OTHER PAST, PRESENT, AND FUTURE PROJECTS AND ACTIVITIES

Past, present, and reasonably foreseeable future projects and activities within the CCSA are provided in **Table 5.3-1. Table 5.3-1** was developed from a wide variety of information sources, including municipal, regional, provincial, and federal government agencies; other stakeholders; and companies' and businesses' websites.

Several active quartz mineral claims exist within the CCSA (**Figure 5.1-1, Table 5.3-1**). No other activities were identified that overlap spatially or temporally with the Project-related residual changes. The business website for Independence Gold Corp. provides specific details on recent exploration activities at the Boulevard Project. The Dan Man Project, to the north of the Project, owned by Archer, Cathro and Associates, has reported exploration activities as recent as 2011, but specific plans for future exploration have not be cited. Likewise, no specific details on planned exploration activities for the Stakeholder Gold Corp. were found related to the area shown in **Figure 5.1-1**. For this analysis, it is assumed that exploration activities could entail drilling (either Reverse Circulation (RC) and/or diamond), trenching and some sort of support infrastructure (non-permanent camp).

Helicopter-supported drill pads are reasonably small (up to 16 m^2); larger pads may be associated with skid-rigs along with roads (essentially exploration trails) up to several 100's of metres in length. Road networks may cause negligible changes to groundwater infiltration patterns and groundwater quality as discussed in **Section 4.3**; however, these changes would be even smaller given that exploration trails are of smaller scale than commercially trafficked surfaces.

Water requirements for a standard diamond drill program typically range from 0.6 to 1.3 L/s per rig, depending on the drill type being used, depth of hole, rock type, etc. (Kaminak, pers. comm. 2015). This water is typically pumped from nearby creeks with return water either recycled, or more typically, directed to a sump where it infiltrates the ground. Groundwater may become locally mounded at the drillhole and sump. It is not expected that groundwater levels in and around creeks tapped for water supply would be altered, nor would there be a long-term or large scale impact from return water infiltrating ground near the drill pads.

Drilling additives are commonly used during diamond drilling to stabilize the hole and improve core recovery. A commonly used additive at the Project site, Pure-Vis, contains clay inhibiting and viscosifying polymers and vegetable based lubricants. Leach extraction tests on this and other typical drilling additives

(Core Well, UltraVis, G-Stop) indicate that these compounds may contain high concentrations of major cations, phosphorus, nitrogen species, organic carbon, chloride and sulfate. These compounds and rock flour generated by the drilling process would be contained in the return water. The rock flour may eventually oxidize at surface, potentially releasing a minimal amount of weathering products to the shallow groundwater/surface water regimes.

RC drilling typically occurs without the use of drilling additives or added water. Groundwater intercepted during RC drilling is typically directed to a sump where it infiltrates the ground. Depending on formation transmissivity, it may result in a temporary drawdown cone centered on the drillhole. RC drilling produces rock cuttings which are sampled at surface, with excess quantities either bagged or discarded on the ground. Trenching may involve excavation of the upper couple of meters of soil/weathered rock over a distance of hundreds of metres. Both activities will expose soils/rock to weathering and potentially cause a small release of weathering products to the environment. Trenches themselves may have a localized effect on drainage patterns in the shallow aquifer (active zone) system.

Exploration camp facilities may also draw on surface water resources or potentially groundwater if the camp is a semi-permanent structure. Typically, organic wastes would be burned and other wastes buried. Dug toilets, sewage lagoons and or contained treatment facilities may handle sewage. Some release of nutrients to surface and/or groundwater may be associated with these activities. Abstraction of water from creeks and/or ground may produce changes to the groundwater system similar to those described for drilling.

Overall, the activities associated with exploration drilling are expected to result in minimal changes to groundwater quantity and quality. These changes, if measurable, would be either short-lived and/or localized to the shallow aquifer system specific to the drainage in which the activity occurs. For this reason, none of the quartz exploration activities associated with leases in the southwest portion of the CCSA (**Figure 5.1-1**) are expected to confound Project changes to groundwater.

Even if exploration activities associated with the Dan Man Project occur within YT-24 or Halfway Creek drainages (overlapping the groundwater LSA), it is not expected that there would be confounding interactions between these activities and the Project on groundwater quantity or quality. This conclusion is based on the analysis provided in **Section 4**, which has indicated minimal changes to the groundwater system as a result of an open pit mining operation. Give that an exploration program is orders of magnitude smaller in scope than an open pit mine, it is not expected that exploration, even if it occurs in coincident drainages as the project, would produce residual changes that would confound Project interactions.

5.3 POTENTIAL CUMULATIVE CHANGES

As indicated in **Table 5.3-1**, there are no projects or activities anticipated to interact with the Project to produce cumulative changes in the Groundwater IC. Therefore, potential cumulative changes created by these activities and their mitigation are not discussed further.

Table 5.3-1 Other Projects and Activities Considered in the Analysis of Cumulative Change on Groundwater

Other Project / Activity	Description	Potential Residual Changes	Potential for Interaction Resulting in Cumulative Change (see Notes) and Rationale
Project Name			
Archer, Cathro & Associates Ltd. (Dan Man Project)	Quartz Exploration, Current, within Groundwater LSA. The last exploration activity at Dan Man in 2011 consisted of a five-hole diamond drill program totaling 935 m and targeted a 300 m by 100 m area.	Activities associated with quartz exploration are expected to create negligible changes to groundwater quality and quantity. Changes would be non-permanent and/or localized to shallow groundwater in the sub-catchment in which they occur.	**No**. Given that activity changes to groundwater are considered negligible, no cumulative change on groundwater quality or quantity would occur as a result of this interaction.
Independence Gold Corporation (Boulevard Project)	Quartz Exploration, Current, 4.8 km from Groundwater LSA. An exploration program consisting of 1400 m of RC drilling (15 drill holes) was completed in the Sunrise-Sunset area in 2016.	Activities associated with quartz exploration are expected to create negligible changes to groundwater quality and quantity. Changes would be non-permanent and/or localized to shallow groundwater in the sub-catchment in which they occur.	**No**. Given that activity changes to groundwater are considered negligible, no cumulative change on groundwater quality or quantity would occur as a result of this interaction.
Stakeholder Gold Corporation	Quartz Exploration, Future, 8.4 km from Groundwater LSA. No information on exploration activities found. Activities may include diamond drilling, RC drilling and/or trenching with some form of support camp.	Activities associated with quartz exploration are expected to create negligible changes to groundwater quality and quantity. Changes would be non-permanent and/or localized to shallow groundwater in the sub-catchment in which they occur.	**No**. Given that activity changes to groundwater are considered negligible, no cumulative change on groundwater quality or quantity would occur as a result of this interaction.

Note: **No:** no interaction or not likely to interact cumulatively; **Yes:** potential for cumulative change.

6.0 SUMMARY OF ANALYSIS OF CHANGES TO GROUNDWATER

This section of the IC analysis highlights overall results of the change analysis completed for the Groundwater IC. The scope of the analysis, including the rationale for IC selection, the indicators selected to measure potential changes to the IC, and the spatial and temporal boundaries relevant to the analysis are summarized in Section 1. The analysis considers future activities and potential interactions associated with the Northern Access Route and the Coffee Gold Mine (**Section 4.3** and **4.4** respectively), as well as potential interactions associated with past, present and future activities within a cumulative change study area defined specifically for the Groundwater IC (**Section 5**). **Section 2** introduces a MODFLOW numerical Groundwater Model that was constructed and calibrated to quantify Project-related groundwater quantity changes. This model was populated with the baseline hydrogeological and climate information and calibrated to groundwater levels and creek baseflows, as described in **Section 3**. **Section 2** also outlines a methodology for qualitatively describing changes to groundwater quality using output generated from GoldSim Water Balance and Water Quality models **(Appendix 12-C**) and groundwater quality measured during baseline monitoring (**Section 3**).

6.1 NORTHERN ACCESS ROUTE

An assessment of IC interaction with Project activities related to the Northern Access Route is presented in **Section 4.3.** No residual changes resulting from the construction and operation of the Northern Access Route are predicted to occur, assuming that best management practices and standard operating procedures are followed, as outlined in the associated management plans (**Section 4.3**; Appendices 31-A and 31-B).

6.2 COFFEE GOLD MINE SITE

A detailed numerical Groundwater Model has been used to determine potential changes of the proposed Project on the groundwater quantity subcomponent. The main drivers of change in groundwater quantity (both water levels and creek baseflow) arise from development of open pits. The Groundwater Model simulates three phases of mine life: pre-mine (baseline conditions), end of Operation Phase (Year 12) and Post-Closure. Maximum pit lake elevations computed by the GoldSim model for End of Operation Phase and Post-Closure were applied in the Groundwater Model. To enable conservative assessment of surface water quality effects, both the Groundwater Model and Water Balance Model assume that all infiltration into the WRSFs reports to downgradient sediment ponds. In the Groundwater Model, this was implemented as ‘zero recharge’ over the Alphas WRSF footprint area.

Both the Groundwater Model and Water Balance Model implement mitigations measures that have been incorporated into the Project design. As a result, modeled changes in groundwater levels and fluxes to creek reaches are considered residual changes. While operation and closure of the mine lead to pronounced changes in water levels, a reasonably tight bedrock system limits pit seepage losses and changes in creek baseflow. As a result, changes to groundwater baseflow at Project hydrometric stations are minimal, generally within 20% of simulated baseline baseflows, and well within the uncertainty associated with the measurement and selection of the streamflows used as the baseflow targets. Furthermore, these changes in baseflow represent an even smaller proportion of total streamflow that occurs during the ecologically critical open water season.

A Water Quality Model developed in GoldSim in tandem with the Water Balance Model was used in a qualitative assessment of Project-related changes to groundwater quality. Driven by the Water Balance Model, the Water Quality Model includes mitigations incorporated into the Project design. Pit lake and Double Double backfilled waste rock have been identified as the main drivers of potential changes to groundwater quality. Water quality predictions for these sources terms were evaluated from Operations through Post-Closure in the Water Quality Model. Parameters that were found to exceed water quality guidelines for protection of aquatic life in the receiving environment (as established in the Surface Water Quality VC Assessment Report, **Appendix 12-B**) were carried forward in the assessment of Project-related changes to groundwater quality. Maximum parameter concentrations computed for various pit lakes and mine waste facilities were compared to measured mean groundwater concentrations grouped by lithology. Those parameters with source term concentrations exceeding groundwater concentrations have been flagged for future monitoring as they may become artificially elevated in groundwater. The list of parameters includes nitrate, aluminum, arsenic, chromium, copper, uranium and zinc.

6.3 CUMULATIVE CHANGE ANALYSIS

The cumulative change assessment examined potential interactions between the proposed Project, and other nearby past, present and reasonably foreseeable future projects (**Section 5.0**). A handful of mineral exploration projects are located within the cumulative change study area (CCSA) defined for the Groundwater IC. Potential exploration activity at these sites in the future is assumed to require very small water abstractions (e.g., for drilling and support infrastructure) and produce negligible changes to groundwater quality. Given that changes to the Groundwater IC brought about by these activities are highly localized and short-lived, future exploration activities are not anticipated to have a measurable incremental effect on the Groundwater IC within the CCSA. As a result, no additional mitigation measures are required to minimize these changes outside of those that are already incorporated into the Project design. Therefore, cumulative residual changes to the Groundwater IC are attributed to the Coffee Gold Mine.

7.0 MONITORING AND ADAPTIVE MANAGEMENT

This assessment has identified potential changes to the Groundwater IC arising from Project activities. These changes have been evaluated through the combined use of a numerical Groundwater Model and Water Balance and Water Quality Model. These models have been developed and calibrated using information collected through robust baseline hydrogeological and hydro-meteorological monitoring programs. Predictions made through the use of these models are believed to represent a robust, conservative determination of Project changes. Nevertheless, it will be necessary to implement environmental management and monitoring programs to:

- Verify the accuracy of the residual change and residual cumulative change predictions, and the value of proposed mitigation measures;
- Assess the efficacy of proposed mitigation measures and the need for modifications to those measures to ensure change predictions remain valid;
- Identify problems that may arise related to the Groundwater IC, and;
- Implement additional mitigation measures, if necessary, as per adaptive management plans.

The relevant monitoring and management plans that will inform the adaptive management of the Project site as it relates to the Groundwater IC are:

- Access Route Construction Management Plan (**Appendix 31-A**)
- Access Route Operational Management Plan (**Appendix 31-B**)
- Conceptual Reclamation and Closure Plan (**Appendix 31-C**)
- Waste Rock and Overburden Facility Management Plan (**Appendix 31-D**)
- Water Management Plan (**Appendix 31-E**)

7.1 GROUNDWATER MONITORING PROGRAM OVERVIEW

A robust and spatially representative groundwater monitoring program is currently in place (**Section 3.3**, **Figure 3.3-1, Table 3.3-1, Table 3.3-2, Table 3.3-3**), and a high-quality baseline dataset exists from which to measure Project-related changes to groundwater and to confirm the predictions of the water-balance modelling exercise. The program will allow potential changes to all indicators used in this change analysis to be measured.

The current monitoring network will form the foundation of future monitoring; additional groundwater monitoring stations will be installed around key facilities to verify Groundwater Model assumptions and predictions. These include:

- A Westbay system (MW1#-01WB) to the southeast of the Latte pit to monitor groundwater pressures and groundwater quality along potential seepage pathways from Latte Pit towards the Latte Creek drainage

- A Westbay system (MW1#-02WB) west of the Latte Pit to monitor groundwater pressures and groundwater quality along potential seepage pathways from Latte Pit towards the Halfway Creek drainage
- A thermistor string in the backfilled Kona Pit (MW1#-03T), to confirm that the underlying ground and backfilled waste rock remain frozen, and
- A conventional bedrock monitoring well (MW1#-04) downgradient of the SU1 pit in the Latte Tributary. This will monitor groundwater quality (and pressure) and along a potential seepage pathway emanating from the SU1 pit and Double Double Pit.

In general, ground temperature and groundwater levels will be monitored continuously (except quarterly at Westbay installations). Baseflow monitoring in downgradient creeks will be undertaken as a part of the hydrology monitoring plan (**Section 7 of Appendix 8-B and Appendix 12-B**). Groundwater quality adjacent to, and immediately down-gradient from, mine facilities will be sampled quarterly. It will be sampled quarterly or semi-annually in receiving environments, depending on proximity to mine facilities.

Groundwater samples will be analyzed for physical parameters, major ions, nutrients, organic and inorganic carbon, total and dissolved metals and cyanide species. The parameter suite includes all parameters which may become elevated in groundwater as a result of infiltration of mine contact water (see **Table 4.5-2**, **Section 4.5**).

The groundwater monitoring program will be adjusted as necessary as more information becomes available. Continuation of the groundwater program is expected to form a requirement of both the Quartz Mining and Water Use Licenses for the Project, and the data collected will be included in the annual reporting requirements associated with these licenses.

Further detail on the points below is provided in the next sections:

- Monitoring methods
- Monitoring locations
- Monitoring program duration
- Monitoring program implementation
- Adaptive management.

The conceptual groundwater monitoring program as presented in this section will provide the data necessary to confirm and update the site water balance, allow for operational adjustments to the water management program, and meet all regulatory requirements. Successful implementation of the water management and monitoring plans will require the involvement of the regulatory agencies that have jurisdiction over water related issues, the First Nations and site staff. These stakeholders will be involved through all steps of the design, implementation and ongoing adjustments to the relevant monitoring and management plans.

7.2 GROUNDWATER MONITORING METHODS

Groundwater monitoring has been undertaken since 2013 at the Mine Site to 1) obtain pre-mining baseline groundwater quantity, quality and variability data to be used to assess potential changes associated with the mine, 2) identify any parameters that are naturally elevated, and may require special management, and 3) obtain baseline information for the purposes of groundwater modelling which will inform water quality modeling and water quality predictions for the Coffee Gold Project.

This section provides an overview of the methods to be employed for groundwater monitoring, as well as a summary of baseline conditions, monitoring locations and frequency, procedures and implementation, and adaptive management. Groundwater monitoring procedures are described in greater detail in the *Hydrogeology Baseline Study Report* (**Appendix 7-A**).

The proposed groundwater monitoring system will include thermistor strings to measure ground temperature, vibrating wire piezometers (VWPs) to measure depth to groundwater, and a series of shallow and deep groundwater monitoring wells, including existing and new wells, down-gradient of key mine facilities.

7.2.1 MONITORING PROCEDURE

Groundwater quality sampling will be undertaken in accordance with the *British Columbia Field Sampling Manual* (BC MOE, 2013), Part E: Water and Wastewater Sampling.

During each sampling visit, the technician will perform the following tasks:

- Inspect all instrumentation (VWPs, thermistors, wells, water level dataloggers) for signs of damage, moisture buildup, or any condition that could cause or lead to malfunction. Take photos to document any observed damage.
- Download the VWP and/or thermistor data and visually inspect data for abnormalities.
- Record the sampling station, time, weather, water level prior to conducting work at a well, time and water level corresponding to water level datalogger sensor removal and redeployment, general low-flow purging parameters (time, water level, cumulative volume purged, flow rate, field chemistry parameters) at regular time intervals, level of frozen water column, and any other observations that may be relevant to sample analysis and interpretation, including any deviation from the standard sampling protocol, and any anomalous conditions (such as water colour, turbidity, odour, presence of algae, sheen, effervescence, etc.).
- Conduct a complete pressure profile of all sample zones, prior to purging any groundwater, when working at Westbay installations.
- Field filter (with a 0.45 µm filter) and preserve groundwater samples as required for the different analyses.

- Ensure that duplicate samples, field blanks, and travel blanks are collected as per the established QA/QC requirements for the groundwater quality monitoring program (briefly summarized in Section 4.2.5 above).
- Complete Chain-of-Custody forms and ship samples to the specified laboratory, ensuring that they will reach the laboratory within the specified holding times.

7.2.2 GROUND TEMPERATURE MEASUREMENT

Ground temperature measurements and depth profiles are collected with thermistor strings and VWPs connected to dataloggers, respectively.

7.2.3 GROUNDWATER LEVEL MEASUREMENT

Groundwater level measurements are collected from VWP installations, conventional monitoring wells, and Westbay installations. VWPs are connected to dedicated dataloggers programmed to record hourly water pressure measurements, while conventional monitoring wells are equipped with water level dataloggers (pressure transducers with datalogging capability) which are also programmed to collect hourly measurements. Westbay installations are measured manually with a Westbay sampler prior to groundwater sampling events.

Water level data collected with VWPs, water level dataloggers in conventional monitoring wells, and the Westbay sampler, record absolute pressure (sum of water pressure and atmospheric pressure) and consequently require barometric compensation. All water level data recorded with water level dataloggers and the Westbay sampler are barometically compensated (corrected for atmospheric pressure), while pressure data from VWPs are not. Data collected with water level dataloggers is also calibrated with manual water level measurements made with a meter at the conventional monitoring wells during groundwater monitoring / sampling events.

7.2.4 GROUNDWATER SAMPLING

Groundwater sampling is conducted in accordance with methods outlined in the *British Columbia Field Sampling Manual* (Clark, 2002). Groundwater samples are collected using several different types of pumps. The pump used depends on the type of well installation, permeability of the geological unit being sampled, and depth to groundwater. Inertial pumps actuated with a Hydrolift-II and peristaltic pumps are used to sample monitoring wells screened in permeable formations. Bladder pumps are used to collect groundwater samples from deep wells screened in low permeability bedrock which do not permit sampling with conventional methods (*e.g.,* inertial pump). The Westbay sampler is used to collect groundwater samples from Westbay installations. Low-flow sampling methods are employed, and groundwater samples are collected after water levels in monitoring wells and purge water field parameters have stabilized.

Field parameters are continuously monitored with a multi-parameter probe (YSI 556 MPS or YSI Professional Plus) coupled to an in-line flow-through cell during groundwater purging. Field parameters are monitored to ensure collection of representative samples and to provide reliable field-based estimates of temperature, pH, specific conductance, dissolved oxygen (DO), and oxidation-reduction potential (ORP).

Groundwater samples are collected and preserved in the field with the appropriate laboratory supplied bottles and preservatives. Samples analyzed for dissolved parameters are filtered in the field with disposable in-line 0.45 micron filters. Groundwater samples are submitted to the Maxxam Analytics (Maxxam) laboratory in Burnaby, BC for chemical analysis.

7.2.5 Analytical Procedures

Groundwater samples are shipped to an accredited laboratory (Maxxam to date) and are analyzed for physical parameters, major ions, nutrients, organic and inorganic carbon, and total and dissolved metals. The full list of parameters that are analyzed, and detection limits, are provided in **Table 7.2-1** below. In addition, groundwater samples will also be analyzed for cyanide species, commencing in 2016.

As with surface water, analysis for conventional parameters, major ions and nutrients, and metals are analyzed in accordance with procedures described in APHA Standard Methods for the Examination of Water and Wastewater (2005). Cyanide analysis is undertaken using procedures adapted from APHA Method 4500-CN "Cyanide". WAD Cyanide is determined by sample distillation and analysis using the chloramine-t colourimetric method. Metals are analyzed using ICP/MS (inductively coupled plasma / mass spectrometry; EPA method 6020), which allows low detection levels to be realized in comparison with other methods. Mercury analysis in water is carried out by cold vapor atomic fluorescence spectrophotometry (EPA Method 245.7). This involves cold-oxidation of the acidified sample using bromine monochloride, prior to reduction with stannous chloride.

7.2.6 Quality Assurance/Quality Control

Quality Assurance / Quality Control (QA/QC) measures include the use of nitrile gloves during groundwater sampling and the collection of duplicate samples (approximately 1 in 10), field blanks (one per sampling event), and travel blanks (one per sampling event). Field blanks are prepared using deionized water supplied by Maxxam. Travel blanks are prepared by Maxxam and are brought out the field and shipped back to the laboratory (without being opened) with the groundwater samples. Field blanks are collected in the field by filling an empty set of bottles with the laboratory supplied deionized water. All samples are kept cool from the point of collection until delivery to the laboratory.

Table 7.2-1 Groundwater Quality Parameters and Detection Limits (Maxxam 2015)

Parameter	Symbol	Unit	Detection Limit
Physical Properties			
Conductivity	EC	µS/cm	1.0
Hardness (CaCO3)	H	mg/L	0.50
pH	pH	pH	N/A
Total Suspended Solids	TSS	mg/L	1.0
Total Dissolved Solids	TDS	mg/L	10
Turbidity	-	NTU	0.10
Anions and Nutrients			
Alkalinity (Total as $CaCO_3$)	-	mg/L	0.50
Alkalinity (PP as $CaCO_3$)	-	mg/L	0.50
Ammonia, Total (as N)	NH_3	mg/L	0.0050
Chloride	Cl	mg/L	0.50
Fluoride	F	mg/L	0.010
Nitrate	NO_2	mg/L	0.0020
Nitrite	NO_3	mg/L	0.0020
Nitrate plus Nitrite	-	mg/L	0.0020
Total Nitrogen	N	mg/L	0.020
Total Total Kjeldahl Nitrogen	TKN	mg/L	0.020
Phosphorus	P	mg/L	0.0020
Dissolved Sulfate	SO_4	mg/L	0.50
Sulfide	S	mg/L	0.0050
Cyanide			
Total CN	CN_T	mg/L	0.0010
WAD cyanide	CN_{WAD}	mg/L	0.0010
Cyanate	CNO	mg/L	0.20
Thiocyanate	SCN	mg/L	0.50
Inorganics			
Bicarbonate	HCO_3	mg/L	0.50
Carbonate	CO_3	mg/L	0.50
Hydroxide	OH	mg/L	0.50
Organic/Inorganic Carbon			
Dissolved Organic Carbon	DOC	mg/L	0.50
Total Organic Carbon	TOC	mg/L	0.50
Total and Dissolved Metals			
Aluminum	Al	µg/L	0.50
Antimony	Sb	µg/L	0.020

Parameter	Symbol	Unit	Detection Limit
Arsenic	As	µg/L	0.020
Barium	Ba	µg/L	0.020
Beryllium	Be	µg/L	0.010
Bismuth	Bi	µg/L	0.0050
Boron	B	µg/L	10
Cadmium	Cd	µg/L	0.0050
Calcium	Ca	mg/L	0.050
Chromium	Cr	µg/L	0.10
Cobalt	Co	µg/L	0.0050
Copper	Cu	µg/L	0.050
Iron	Fe	µg/L	1.0
Lead	Pb	µg/L	0.0050
Lithium	Li	µg/L	0.50
Magnesium	Mg	mg/L	0.050
Manganese	Mn	µg/L	0.050
Mercury	Hg	µg/L	0.0020
Molybdenum	Mo	µg/L	0.050
Nickel	Ni	µg/L	0.020
Phosphorus	P	µg/L	2.0
Potassium	K	mg/L	0.050
Selenium	Se	µg/L	0.040
Silicon	Si	µg/L	50
Silver	Ag	µg/L	0.0050
Sodium	Na	mg/L	0.050
Strontium	Sr	µg/L	0.050
Sulfur	S	mg/L	3.0
Thallium	Tl	µg/L	0.0020
Tin	Sn	µg/L	0.20
Titanium	Ti	µg/L	0.50
Uranium	U	µg/L	0.0020
Vanadium	V	µg/L	0.20
Zinc	Zn	µg/L	0.10
Zirconium	Zr	µg/L	0.10

7.3 GROUNDWATER MONITORING LOCATIONS AND FREQUENCY

Groundwater monitoring is proposed to detect any changes in groundwater pressure (i.e., water table elevations) or groundwater quality that may be caused by mine development and/or operation. In general, surface water quality will be used as the key indicator of changes in groundwater. A supplemental groundwater monitoring network is proposed down-gradient of open pits and WRSFs that makes best use of existing installations, and includes new installations where necessary.

In general, ground temperature and groundwater levels will be monitored continuously (except quarterly at Westbay installations), while groundwater quality will be sampled on a quarterly basis. Groundwater quality adjacent to, and immediately down-gradient from, mine facilities will be sampled quarterly. It will be sampled quarterly or semi-annually in receiving environments, depending on proximity to mine facilities.

A map illustrating the proposed construction and operations hydrogeological monitoring locations is provided in **Figure 7.3-1**. Similarly, **Table 7.3-1** summarizes the parameters and frequency proposed for each hydrogeological monitoring location.

7.3.1 MINE SITE – SOUTH (LATTE CREEK)

Mine site facilities from which contact water will be discharged to the Latte Creek drainage include:

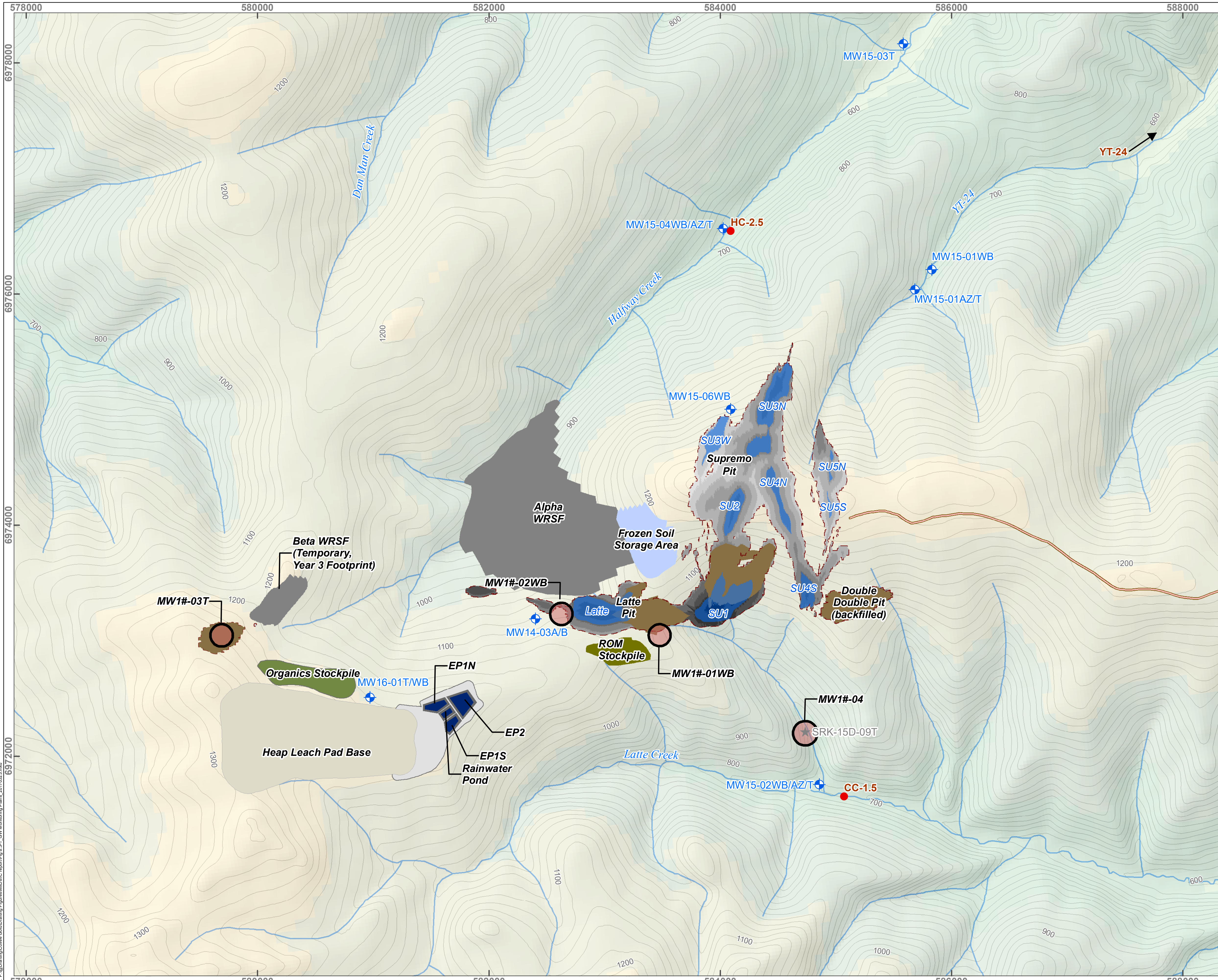
- Latte Pit
- Southern part of the Supremo Pit (ultimately the SU1, SU2, and SU4S pit lakes)
- Double Double Pit (prior to being backfilled) and Double Double WRSF thereafter, and
- Backfilled areas of mined out pits.

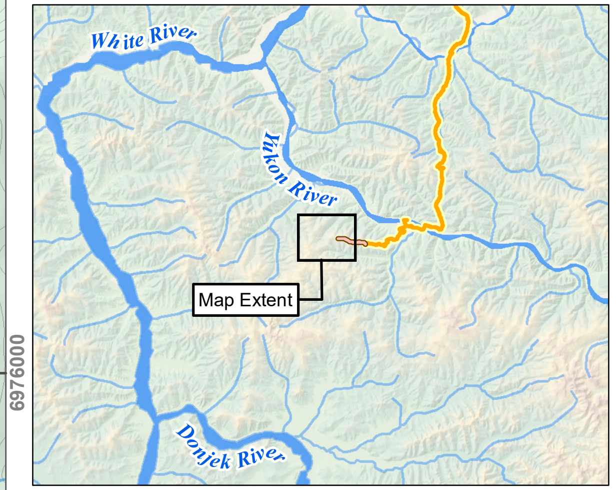
Any change to groundwater quantity or quality down-gradient of open pits and proposed backfill in the Latte Creek drainage will be monitored via:

- A new Westbay well (MW1#-01WB) to the southeast of the Latte pit, to monitor the quantity and quality of groundwater that could emanate from the Latte Pit (**Figure 7.3-1**)
- A new conventional groundwater well (MW1#-04) to be completed to the depth of the water table. This new well will be sited on the east side of the Latte Tributary in the vicinity of the existing SRK-15D-09T thermistor string.
- Existing MW15-02WB/AZ/T groundwater monitoring well
- Surface water quality monitoring at station CC-1.5 in Latte Creek below the confluence of the Latte Tributary.

COFFEE GOLD MINE

Groundwater Monitoring Stations





Legend

- Approximate Location of Additional GW Monitoring — WB = Westbay, T = Thermistor String
- Monitoring Well — AZ = Active Zone, WB = Westbay, A = Deep Conventional (200+m), B = Shallow Conventional (150+m), T = Thermistor String
- SWQ Monitoring Station
- Thermistor/VMP (SRK 2015)
- Mine Site Access Route
- Northern Access Route

Proposed Infrastructure

- WRSF
- Backfill
- Total Pit Outline
- ROM Stockpile
- Organics Stockpile
- Event Pond
- Heap Leach Access Disturbance Footprint
- Heap Leach Pad Base

N

1:32,000

0 500 1,000 1,500 2,000

Meters

NAD 1983 UTM Zone 7N

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Figure 7.3-1	Date: Mar 23, 2017	Drawn by: (A.L.)	Reviewed: (J.H.)

GOLDCORP

Table 7.3-1 Summary of Groundwater Monitoring Program

Type[1]	Station ID	Notes	Parameters[2] and Sampling Frequency[3]					
			Ground Temp.	GW Level	Field	General	Dissolved Metals	CN
Mine Site - South (Latte Creek)								
MW	MW1#-01WB	Latte Pit: infiltration to SE		Q	Q	Q	Q	Q
MW	MW1#-04	Supremo S, Double DoubleF: infiltration		C	Q	Q	Q	Q
TS / VWP	MW15-02T	Supremo S, Double Double: infiltration	C	C				
MW	MW15-02WB/AZ	Supremo S, Double Double: infiltration		Q	Q	Q	Q	Q
Mine Site – North (YT-24)								
TS / VWP	MW15-01T	Supremo N: infiltration	C	C				
MW	MW15-01WB/AZ	Supremo N: infiltration		Q (WB)/ C/M (AZ)	Q	Q	Q	Q
Mine Site – West (Halfway Creek)								
MW	MW1#-02WB	Latte Pit: infiltration to west to Halfway Cr		Q	Q	Q	Q	Q
MW	MW14-03A/B	Latte Pit: changes in upgradient groundwater		C	Q	Q	Q	Q
MW	MW15-06WB	Supremo N: infiltration		Q	Q	Q	Q	Q
MW	MW16-01WB	HLF: infiltration north to Halfway Creek		Q	Q	Q	Q	Q
TS / VWP	MW16-01T	HLF: downgradient ground temperature	C	C				
TS / VWP	MW15-04T	Alpha WRSF: infiltration	C	C				
MW	MW15-04WB/AZ	Alpha WRSF: infiltration		Q	Q	Q	Q	Q
TS	MW1#-03T	Kona Pit: ground temperature	C					

Notes:

1. MW = Monitoring Well; GW = Groundwater TS = Thermistor String
2. Parameters: Field = pH, ORP, DO, Conductivity, Temperature; CN = cyanide species; General (includes physical parameters, anions and nutrients, total and dissolved organic carbon)
3. Frequency: C = Continuous; W = Weekly; M = Monthly; Q = Quarterly; C / M = Continuous, Monthly in winter (Instrumentation removed at freeze up)

7.3.2 Mine Site – North (YT-24)

Mine site facilities from which contact water will be discharged to YT-24 include the northern part of the Supremo Pit (SU3W, SU3N, SU4N, SU5S).

Any change to groundwater quantity or quality down-gradient of these facilities will be monitored via:

- Existing groundwater well MW15-01/AZ/T
- Existing groundwater well MW15-01WB
- Surface water quality monitoring at station YT-24 near its confluence with the Yukon River, and YT-24-2, a flow and water quality monitoring station situated immediately downstream open pits in the north mine drainage.

7.3.3 Mine Site – West (Halfway Creek)

Mine site facilities from which contact water will be discharged to Halfway Creek are:

- Beta temporary WRSF
- Kona pit / permanent WRSF (once backfilled), and
- Alpha WRSF and Pond.

Any change to groundwater quantity or quality down-gradient of these facilities will be monitored via:

- A new groundwater Westbay installation (MW1#-02WB) just west of the Latte Pit to detect the quantity and quality of any groundwater emanating from the Latte Pit into the Halfway Creek drainage, as well as existing well MW14-03A/B
- Existing well MW15-06WB to monitor any groundwater flowing from the northern part of Supremo Pit into the Halfway Creek drainage
- Existing well MW15-04WB/AZ/T in Halfway Creek to monitor deeper groundwater draining the Alpha WRSF
- Surface water quality sampling in the Alpha Pond, and
- Surface water quality sampling at Station HC-2.5.

In addition, a new thermistor string (MW1#-03T) will be installed in the backfilled Kona Pit, to confirm that the underlying ground and backfilled waste rock remain frozen, as it is intended that permafrost aggrade into the backfilled Kona Pit, so as to limit infiltration into the pit.

7.3.4 Heap Leach Facility

No groundwater discharge from the HLF is expected. The HLF will be constructed and operated as a contained system. This system includes two layers of synthetic liners, with hydraulic head control above, and leak detection below. The leak detection system will be comprised of three separate systems; 1) unsaturated or vadose zone monitoring under the leach pad using an adaptation of lysimeter technology, 2) electrical leak location surveys performed after construction of each stage of the leach pad, and

3) monitoring wells installed down-gradient from the pad. In addition, a ditch will collect surface drainage and convey it to the Heap Pond, and should allow detection of any potential leak from the HLF. Permafrost is anticipated to be thick on these slopes, which will have the effect of limiting hydraulic conductivity in any case, and no significant degradation of the permafrost on these slopes is anticipated.

New monitoring stations MW16-01T and MW16-01WB have been installed downgradient of the HLF and serve to confirm permafrost thickness, enable continuous monitoring of groundwater pressures and allow for collection of groundwater samples. The siting of these instruments north of the HLF has been informed by hydraulic gradients simulated by the Groundwater Model, which indicates that the majority of groundwater residing underneath the HLF footprint reports to the Halfway Creek drainage.

7.3.5 PERMAFROST

The information obtained from thermistors at the mine site will be considered in the context of groundwater monitoring, as it pertains to potential decrease or increase in formation transmissivity. It will also inform monitoring and modelling studies relating to permafrost, mine infrastructure and climate change undertaken by others. In general, it is anticipated that permafrost will aggrade into WRSFs; however, pit lakes may develop taliks **(Section 2.1.3)**.

7.4 GROUNDWATER MONITORING PHASES

7.4.1 CONSTRUCTION PHASE MONITORING

The construction phase is expected to span 30 months (Q2 Year -3 to end Year -1). Within the mine site, once clearing and grubbing are completed, the following activities will be executed:

- Development of Latte and Double Double pits will commence
- Development and use of the Alpha WRSF and temporary run-of-mine (ROM) and crushed ore stockpiles
- Loading of the heap leach pad will commence
- Installation and operation of the fuel storage farm.

Where possible, monitoring of the new proposed stations should commence prior to the construction of the new mine facilities listed above to establish baseline conditions prior to operations. All construction phase monitoring will continue through operations, with the addition of water level and water quality sampling in pit sumps as they are developed.

7.4.2 Operation Phase Monitoring

The operation phase will span Year 1 through Year 12. At the mine site, the following activities will be conducted:

- Development of the Latte and Double Double pits and the Alpha WRSF will be continued
- Continued use of the temporary ROM and crushed ore stockpiles
- Staged construction of the HLF and continued operation
- Development of the Kona and Supremo pits
- Operation of the process plant
- Open pit dewatering
- Continued operation of the fuel storage farm.

Monitoring commenced during construction will be continued for the duration of operations, in addition to quarterly water level and water quality monitoring of pit sumps as they are developed. Groundwater quality effects can take a long time to appear as a result of relatively slow groundwater flow, therefore monitoring will continue until the end of operations even at and down gradient from facilities which will close during operations.

7.5 Monitoring Program Implementation

Responsibility for implementation of the groundwater monitoring program will be assigned to the Environmental Manager. Monitoring will be undertaken in a routine and systematic manner so as to ensure that reliable data is obtained.

7.5.1 Responsible Persons

It is anticipated that external consultants will continue to be responsible for groundwater sampling for a period of time, partly due to the relative complexity and specialized training required to sample the Westbay installations, which account for seven of the nine monitoring wells included in the monitoring program. It is anticipated that site personnel will eventually assume responsibility for the groundwater program with external consultants participating in quality assurance / quality control for groundwater data, and assisting with data interpretation and reporting.

7.5.2 Data Management

Once field and laboratory analytical data has been obtained, it will be entered by the responsible site personnel into a standardized groundwater database. This will form the primary record, and any adjustments or corrections that are performed on this data will be saved as separate files, to ensure that the original data records remain unaltered. The data will include groundwater levels, temperature and other measurements obtained at the well sites, as well as the results of laboratory analysis for groundwater quality. All data and associated field notes will be stored in standard electronic format. It is understood that groundwater data will likely be shared between the Proponent and its consultants for the purposes of refining permafrost mapping, water balance and water quality predictions, and other applications, as appropriate.

7.5.3 DATA ANALYSIS AND REPORTING

Groundwater data will be obtained on a quarterly basis. It will be entered into the groundwater database, and tabulated on a quarterly basis, primarily for the purpose of information exchange between the Proponent and its consultants.

7.5.4 ANNUAL INTERPRETIVE REPORTS

It is anticipated that groundwater data and interpretation will be documented on an annual basis for the purpose of reporting to regulators and other stakeholders. Annual interpretive reports will presumably be a permit or licence requirement for the proposed Project. It is anticipated that annual interpretive reports summarize groundwater monitoring data, including both field data and laboratory analyses. The reports will also identify trends, anomalies, and other relevant information.

Any significant changes to the monitoring network, such as addition or deletion of monitoring stations, or change to analytical parameters, for example, will be noted, along with a rationale for the changes. If necessary, recommendations will be made concerning upgrades or changes that are deemed necessary for the following year, along with the rationale.

7.6 PROPOSED GROUNDWATER QUALITY OBJECTIVES

Groundwater quality objectives / thresholds are not proposed at this time; however, surface water quality during baseflow periods will be used as the primary indicator of groundwater changes.

7.7 ADAPTIVE MANAGEMENT

The conceptual groundwater monitoring plan, introduced in **Section 7.3**, along with the monitoring plans developed for hydrology and surface water quality (see **Section 7** of **Appendix 8-B** and **Appendix 12-C**, respectively) will monitor the mine site, effluent and the receiving environment. In concert, these plans will serve to:

- Confirm the site water balance (both GoldSim and MODFLOW models)
- Verify and refine water quality predictions for the Construction and Operation phases, thereby assessing the efficacy of design mitigations, and
- Assess Project compliance with respect to applicable surface water quality standards, limits, and guidelines (e.g., CCME and MMER).

The change analysis present for the Groundwater IC in this document and the Hydrology IC in **Appendix 12-B** is underpinned by conservative assumptions from the perspective of the Surface Water Quality VC. Monitoring of groundwater and surface water quantity and quality will be used characterize and verify the respective contributions and pathways of groundwater and surface water. Since groundwater presents a less acute pathway of effects in the receiving environment, adaptive management of the Groundwater IC in itself is not proposed. Deviations from anticipated changes to groundwater levels and groundwater quality (**Section 4.5**) may warrant further investigation to confirm the mechanism of change; however, additional contingency measures are not suggested. Adaptive management of the Hydrology IC and Surface Water Quality VC is proposed, and monitoring plans contained in the associated appendices outline triggers/indicators designed to signify the need for implementation of remedial measures should surface water not meet release criteria.

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