APPENDIX 7-B-1

Groundwater Modelling Report

Preface

This report constitutes the findings of a groundwater numerical modeling exercise performed for the Coffee Gold Project. The findings are presented in two reports which comprise Appendix 7-B-1 of the Project Proposal. The first report, published in 2016, presents modeling results relevant to the previous Kaminak mine plan, developed prior to the acquisition of Kaminak Gold Corporation by Goldcorp. This document remains identical to the previous version distributed to First Nations at the end of January, 2017.

Under Goldcorp ownership, the 2016 mine plan was re-evaluated and modified. The main modifications associated with the mine plan, as they relate to groundwater, include slightly deeper open pits and consolidation of all ex-pit mine waste rock facilities (WRSFs) (formerly the North, South and West WRSFs) into a single facility – the Alpha WRSF, located in the Halfway Creek drainage. The development of the new mine plan under Goldcorp has necessitated an update to the 2016 groundwater model so as to enable quantification of Project effects on groundwater. These updated results are presented in the second document "Coffee Gold Mine: Numerical Groundwater Model 2017 Update" (Appendix P-1). Appendix P-1 should be reviewed in tandem with the 2016 report. The 2017 update presents an updated model calibration completed to accommodate new information from the 2016 field programs and predictions of potential groundwater impacts from the 2017 Goldcorp mine plan.

Coffee Gold Mine
Numerical Groundwater Model Report

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Project No. A362-5

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1. Introduction

1.1 Background

Kaminak Gold Corporation (Kaminak) is in the process of developing and permitting the Coffee Gold Mine (Project), a proposed heap leach operation located in west-central Yukon, approximately 180 km south of Dawson City.

The Project is located within the traditional territory of the Tr´ondëk Hwëch´in and the asserted traditional territory of the White River First Nation. A portion of Kaminak’s claim block is located in Selkirk First Nation’s traditional territory.

1.2 Objectives

A three-dimensional numerical groundwater model has been developed for the Project to satisfy licensing and permitting requirements. Section 1 of this report summarizes the data used to develop the model. Section 2 discusses the development and calibration of the baseline groundwater model and includes a discussion of the model sensitivities related to calibration. Section 3 presents model calibration and summarizes a sensitivity analysis on the baseline model. Section 4 presents the groundwater modeling simulations to evaluate potential Project effects on groundwater resources. A high level summary of model results and limitations is provided in Section 5.

2. Data Sources

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2. Data Sources

The following section provides a high level summary of data sources including physiography, geology, climate, hydrology, hydrogeology, permafrost, and proposed infrastructure.

2.1 Physiography

The Project is located in the northern Dawson Range of the Yukon-Tanana terrane, forming a moderate plateau that escaped Pleistocene glaciation. The landscape evolved through erosional and periglacial processes. The dominant periglacial processes at Coffee Gold site are cryoturbation, solifluction, slope wash and thermal erosion. The topography generally consists of rounded ridges with incised v-shaped valleys (AECOM, 2012). Elevations across the property range from 400 to 1,500 m above sea level with the majority of the property above the tree line and supporting short shrubby vegetation (JDS, 2016). The property has local mature pine forests with thick moss cover on the ground. Bedrock exposures on the property are rare (< 5%).

A surficial geology map of the Coffee Creek area has been compiled by the Geological Survey of Canada (Huscroft, 2002). AECOM (2012) was retained by Kaminak to compile a detailed geomorphological map to aid in the selection of appropriate sampling sites for soil geochemical characterization. Both maps identify colluvium as the most widespread surficial material within the project area. 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. Colluvium thicknesses are generally greatest in valley bottoms, which tend to be less steep than upper slopes. Dominant colluvial processes include slope creep, debris slides and minor rock fall.

2.2 Geology

A detailed account of the geologic setting and mineralization of the of the Coffee Gold Project is provided in the 2016 Feasibility Study (JDS, 2016). 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. Both the Paleozoic metamorphic rocks and Cretaceous granite are cut by intermediate to felsic dykes of andesitic to dacitic composition. Grodziki *et al.*,

(2015) have compiled the most up-to-date geological map of the Coffee Gold deposit area, informed by a combination of geological traverses, bedrock mapping, borehole data, soil geochemistry, and geophysics.

The main Coffee 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 Project, 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 Supremo zone is housed in several drill-tested T-structure gold corridors which are 5 to 30 m wide. Latte zone consists of a stacked set of moderately-to-steeply south-southwest dipping, east-southeast striking brittle-ductile structures. Double Double zone consists of a number of discrete, high-grade strands of mineralization up to several metres wide, trends east-northeast steeply dipping to the north and consists. of a number of discrete, high-grade strands of mineralization up to several metres wide. The Kona zone is hosted in equigranular granite and consists of east-northeast trending, steeply south-dipping stacked structures. The gold structures are associated with narrow, less than 5 m wide, sparsely feldspar phenocrystic to aphanitic andesite to dacite dykes

Kaminak (2015) has prepared a map of all confirmed mineralized structures currently known on the property. 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 hydrogeologic maps provided in subsequent sections of this report.

2.3 Climate Data

2.3.1 Precipitation

A detailed discussion of the precipitation measurements and analyses is presented in Lorax (2016b). The mean average precipitation increases as a function of topographic elevation in the Project area and is shown in Table 2-1. These mean average precipitation values were used as the basis for the simulated recharge distribution in the groundwater model.

Table 2-1:
Average Annual Precipitation as a function of Elevation

Elevation (masl)	Mean Annual Precipitation (mm/y)
400	289.5
500	305.9
600	323.5
700	342.2
800	362.1
900	383.5
1000	406.3
1100	430.7
1200	456.8
1300	484.7
1400	514.6
1500	546.7
1600	581.1
1700	618.0
1800	657.6

2.3.2 Evapotranspiration

Evapotranspiration is an important hydrologic process in the Project area. This process is not explicitly simulated in the groundwater model but is indirectly incorporated into the applied groundwater recharge rates.

2.4 Baseline Hydrology Data

A detailed discussion of the baseline hydrology data is presented in Lorax (2016b). As part of the baseline hydrology, an estimate was made of the stream baseflow derived from groundwater, excluding interflow. This baseflow target was based on direct observations of baseflow during the June 2015 low-flow period. The mean annual baseflow estimates for streams in the Project area are presented in Table 2-2. The baseflow target was computed to range between 0.4 L/s/km^2 to 0.9 L/s/km^2 except for ML-1.0 and CC-1.0, which were lower than the 0.4 L/s/km^2 yield value. For these two catchments, the lower bound baseflow target was set to the measured June 2015 stream flow.

Table 2-2:
Groundwater Baseflow (L/s) to Streams

	Basin Area	Lower Baseflow Target (L/s)	Upper Baseflow Target (L/s)
Mine Area Catchment			
IC-2.5	17.3	6.9	16
IC-3.0	18.3	7.3	16
HC-2.5	14.8	5.9	13
HC-5.0	27.0	11	24
ML-1.0	11.8	3.8	11
CC-6.0	9.6	3.8	8.6
CC-1.0	3.4	0	3.1
CC-1.5	23.1	9.3	21
CC-3.5	69.8	28	63
Other Catchments at Model Edges			
IC-1.5 (SW Boundary)	81.1	32	73
IC-4.5 (W Boundary)	222.3	89	200

The analysis of streamflow in the Project area indicates that for low-flow periods, the streamflow at station CC-1.5 in Latte Creek is often higher than the streamflow at Latte Creek station CC-3.5, located approximately 10 km downstream of CC-1.5. In addition, the vertical head distribution at monitoring well cluster MW15-02, located adjacent to Latte Creek, indicates both vertical gradients favouring upward flow into the stream channel and, at greater depths, gradients favouring downward groundwater flow to a deeper stratum. These two observations strongly suggest that a deep groundwater flow path is present along Latte Creek between CC-1.5 and CC-3.5 that affects stream flows.

2.5 Baseline Hydrogeology

2.5.1 Water Levels

The Project area is characterized by a thin veneer of colluvium underlain by bedrock. As groundwater levels are typically below the colluvium/bedrock interface, the majority of groundwater flow in the Project area occurs through bedrock fractures. The water levels measured in bedrock wells in the Project area indicate higher water tables at higher elevations and low, sometimes artesian, water levels in valley bottoms. Groundwater levels have been monitored since 2013. Continuous logging of groundwater pressures with vibrating wire piezometers at selected wells began in the fall of 2014. Water levels from these measurement points were evaluated for long-term trends. The computed steady state groundwater head targets for the groundwater model are shown in Table 2-3 and are presented and interpreted in the hydrogeology baseline report (Lorax, 2016c).

**Table 2-3:
Computed Average Groundwater Head Target**

Well ID	Target Head (masl)
MW14-02A	1017.7
MW14-02B	1009.6
MW14-03A	959.8
MW14-03B	959.8
MW14-05A	1136.2
MW14-05B	1136.2
MW14-07T	1164.2
MW15-01T-715	766.2
MW15-01T-728	766.6
MW15-01WB-P1	767.4
MW15-01WB-P6	767.4
MW15-02-AZ	731.2
MW15-02T	726.8
MW15-02WB-P1	727.9
MW15-02WB-P4	734.6
MW15-03-AZ	556.3
MW15-03T-461	561.2
MW15-03T-508	557
MW15-03WB-P1	559.9
MW15-03WB-P7	557.5
MW15-04T-619	670.9
MW15-04T-632	670.8
MW15-04WB-P1	672.3
MW15-04WB-P5	672.5
MW15-05T-1012	1042.7
MW15-05T-986	1029.1
MW15-05WB-P1	1044.6
MW15-05WB-P4	1044.7
MW15-06WB-P3	956.8
MW15-06WB-P7	962.7
MW15-07T-915	1046.4
MW15-07T-944	1045
SRK-15D-07T-800	898.4
SRK-15D-07T-845	904.1
SRK-15D-08AT-776	927.3
SRK-15D-08AT-822	934.2
SRK-15D-09T	782.9
CFD318	1092
CFD324	931.6
CFD351	967.8

2.5.2 Hydraulic Conductivity

The measured hydraulic conductivity in the Project area is described in detail in Lorax (2016c). Hydraulic conductivities range over several orders of magnitude from values exceeding $1x10^{-6}$ m/s to others below the resolution of the testing method (less than 10^{-10} m/s). There is no consistent trend of higher or lower bedrock hydraulic conductivity as a function of geologic unit. A consistent reduction in hydraulic conductivity with increasing depth from ground surface was observed in the majority of wells, with the exception of borings designed to target key transmissive geologic structures.

Additional geotechnical testing around the proposed pits indicates that the hydraulic conductivity of key mapped structures is consistently higher than bulk bedrock not associated with these structures. SRK (2015) report a narrow range of hydraulic conductivity values—$1x10^{-7}$ m/s to $3x10^{-6}$ m/s—for the structures with an arithmetic mean value of $7x10^{-7}$ m/s. An arithmetic mean rather than a geometric mean was presented for the tests in highly transmissive fracture zones because the groundwater entering and leaving the borehole test area traveled along planar features rather than converging or diverging radially from the vicinity of the borehole. The arithmetic mean of tests performed in valley locations is $1x10^{-6}$ m/s, which is generally 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 $9x10^{-7}$ m/s.

2.6 Permafrost

The Project area is underlain by discontinuous permafrost. Permafrost is generally present along north-facing slopes and generally absent along south-facing slopes in the Project area. Thermistor measurements indicate permafrost thickness that are often greater than 100 m (Lorax, 2016c). At higher elevations, the bottom of permafrost, as measured with the in situ thermistors, is often above the water table, indicating that the permafrost reduces groundwater recharge. The majority of monitoring wells outfitted with thermistors in the Project area indicate permafrost in the upper layers. Nevertheless, the water table in these wells generally follows area topography, suggesting that some recharge may occur through some permafrost-covered areas. A further discussion of the role of permafrost on the groundwater conceptual model is presented in Section 3.1 Conceptual Model.

2.7 Project Infrastructure

The calibrated, numerical groundwater was used to simulate the interaction between proposed Project facilities and groundwater flow. The numerical model incorporates Project activities that may alter groundwater quantity, namely open pit development and placement of waste rock. The model also simulates potential changes to groundwater recharge beneath the proposed heap leach and event ponds. 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 9) 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 (Year 28).

Development of the baseline model is described in Section 3 below. Integration of Project infrastructure into the groundwater model for end of Operation Phase and Post-Closure is described in greater detail in Section 4.

3. Baseline Model

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3. Baseline Model

3.1 Conceptual Model

The baseline groundwater model prepared for the Project is a steady state model. In other words, it assumes that groundwater flow processes are in a static equilibrium between groundwater recharge and groundwater discharge and that these processes do not change over time. Groundwater in the model discharges to creeks and to the Yukon River.

Modelled groundwater recharge is assumed to occur primarily by infiltration through non-permafrost areas, where the ground surface is not frozen. In accordance with field observations of precipitation, recharge in the groundwater model increases with topographic elevation. At the majority of areas covered in permafrost, no recharge is applied to the model. At the highest elevation band (1200 masl to 1400 masl) of frozen ground, a minimal rate of recharge was applied in order to better match simulated baseflows to streams at upper elevations and to match observed heads in monitoring wells.

Although permafrost is often considered to be an impermeable barrier to groundwater recharge, studies have shown that snowmelt can recharge groundwater through partially frozen soils (Kane *et al.*, 2013). The ice content of soil or bedrock is important in assessing the infiltration capacity of permafrost. Kane and Stein (1983) concluded that "[f]rozen but relatively dry soils behave in a manner similar to unfrozen soils". In addition, streamflow assessments have indicated that although permafrost restricts infiltration and groundwater recharge as measured in small-scale experiments, the presence of frozen soil does not significantly increase runoff on the catchment scale. These studies suggest that recharge can and does occur in some areas of otherwise frozen ground (Niu and Yang, 2006; Bosson *et al.*, 2013). Niu and Yang (2006) also discuss the importance of soil macropores on recharge to frozen soils. The analogue to macropores in bedrock are open fractures, as discussed by Scheidegger (2013) who notes that recharge can occur through fractures even in continuous permafrost. Finally, Gruber and Haeberlie (2007) note in their study of permafrost behavior in bedrock that "[t]he few published freezing characteristic curves for basalt, tuff, sandstone and limestone, and concrete hint at a substantial fraction of pore water that remains liquid even at temperatures around -10°C." Because of the possibility of recharge through ice-poor permafrost of the type encountered in the Project area, a small amount of recharge is permitted through permafrost in some areas of the groundwater model domain.

The groundwater model that was developed for the Project is primarily a bedrock hydrogeological model. The stratigraphic and hydrogeologic units comprise very fine primary rock porosity—that is considered to contain essentially immobile groundwater—

and a network of bedrock fractures that transmit the vast majority of mobile groundwater. It is assumed that to meet the objectives of the groundwater model, bedrock can be modeled as an *equivalent porous medium* that has bulk properties that permit water to flow within it as if it were a porous medium, subject to Darcy's law and the application of a bulk hydraulic conductivity. In the equivalent porous media approach, fractures are assumed to form a sufficiently dense and well connected network such that no small group of fractures controls the flow. The fractured system can be approximated by an equivalent porous media. In a discrete fracture network approach, each fracture and its connections to others are described explicitly. While geologically more realistic, a very substantial effort is required to characterize the fracture network.

Permafrost was also treated as an equivalent porous medium, albeit with a lower hydraulic conductivity than the same rock in an unfrozen state. The value of hydraulic conductivity applied to the permafrost in the groundwater model is $6x10^{-10}$ m/s. This value is higher than values applied in other models of permafrost-impacted groundwater. In a model of subglacial, continuous permafrost in Greenland, Jaquet *et al*., (2012) used a hydraulic conductivity of $1x10^{-15}$ m/s for frozen crystalline rock, or five orders of magnitude lower than unfrozen rock. Long-term simulations of groundwater flow on the time scale of hundreds of thousands of years have used values of $1x10^{-13}$ m/s (Teles *et al.,* 2008) or six orders of magnitude lower than unfrozen rock (Lemieux *et al.,* 2008). It should be noted that all three of these published groundwater models are continental in scale and have as their objective the evaluation of long-term climate change on continuous permafrost, so that it is the *difference* in the hydraulic conductivity of frozen versus non-frozen bedrock which is paramount. Furthermore, the processes described above in which groundwater can infiltrate permafrost, especially at temperatures just below freezing, are not of interest on the spatial and temporal scales of the studies of Jaquet *et al.,* (2012), Teles *et al.,* (2008) and Lemieux *et al.*, (2008). The groundwater model developed for the Project is of a discontinuous, generally ice-poor permafrost area with mean annual temperatures that are near the freezing point. As discussed below, the permafrost hydraulic conductivity in the groundwater model and corresponding recharge were calibrated based on the observed baseflow. More specifically, the recharge assumed to occur through the permafrost in upper portions of the model groundwater flow domain was calibrated to match observed baseflow measured in creeks down-gradient from the Project.

Although the bedrock units as a whole were treated as equivalent porous media, five known structural features that have been observed or inferred to enhance groundwater flow are present in the model. The Latte Structure, which trends roughly east-west through the proposed Latte pit, has been observed to be significantly more permeable than the rock around it. The arithmetic mean hydraulic conductivity measured in packer tests in this structure is $7x10^{-7}$ m/s (SRK, 2015), a value that is higher than packer test results in bedrock not associated with this structure. In the groundwater model, the Latte Structure is represented as a zone of high hydraulic conductivity that extends across the vertical projection of this structure as mapped by exploration geologists.

Similarly, the T3 Structure, which extends through the center of the Supremo pit system, has been documented to have higher packer-tested hydraulic conductivities than bulk bedrock. This structure is also represented in the model as a zone of high hydraulic conductivity defined by the vertical projection of the structure from the mine geological model.

In addition to these packer-tested structures, a known structure trends east-west just upstream of the MW15-03 well cluster and is visible from aerial photographs. Marked changes in groundwater gradients and groundwater quality are observed in the vicinity of this feature. This structure is inferred to be associated with a mapped fault by Grodzicki *et al.,* (2015) and is simulated in the model as the “North Fault”.

Lastly, it is assumed that Project area creeks that follow a relatively unidirectional trajectory are associated with structures. Further and as discussed above, the vertical gradients adjacent to Latte Creek strongly suggest a deep groundwater flow path adjacent to this creek that is not observed in Halfway Creek or YT-24. An extra material zone was introduced to simulate this observation.

3.2 Modeling Setup

3.2.1 Software Code

The numerical groundwater model was created using the finite difference model MODFLOW with the Newton solver (MODFLOW-NWT or MODFLOW). Groundwater Vistas version 6 was used as the pre- and post-processor for MODFLOW. MODFLOW was selected for the simulation because it is a well-documented and well-tested groundwater flow program that has been used for decades. MODFLOW-NWT was used as the specific solver because it is better suited for steep topographies than older options within the MODFLOW suite of solvers. Additional simulation settings are discussed below.

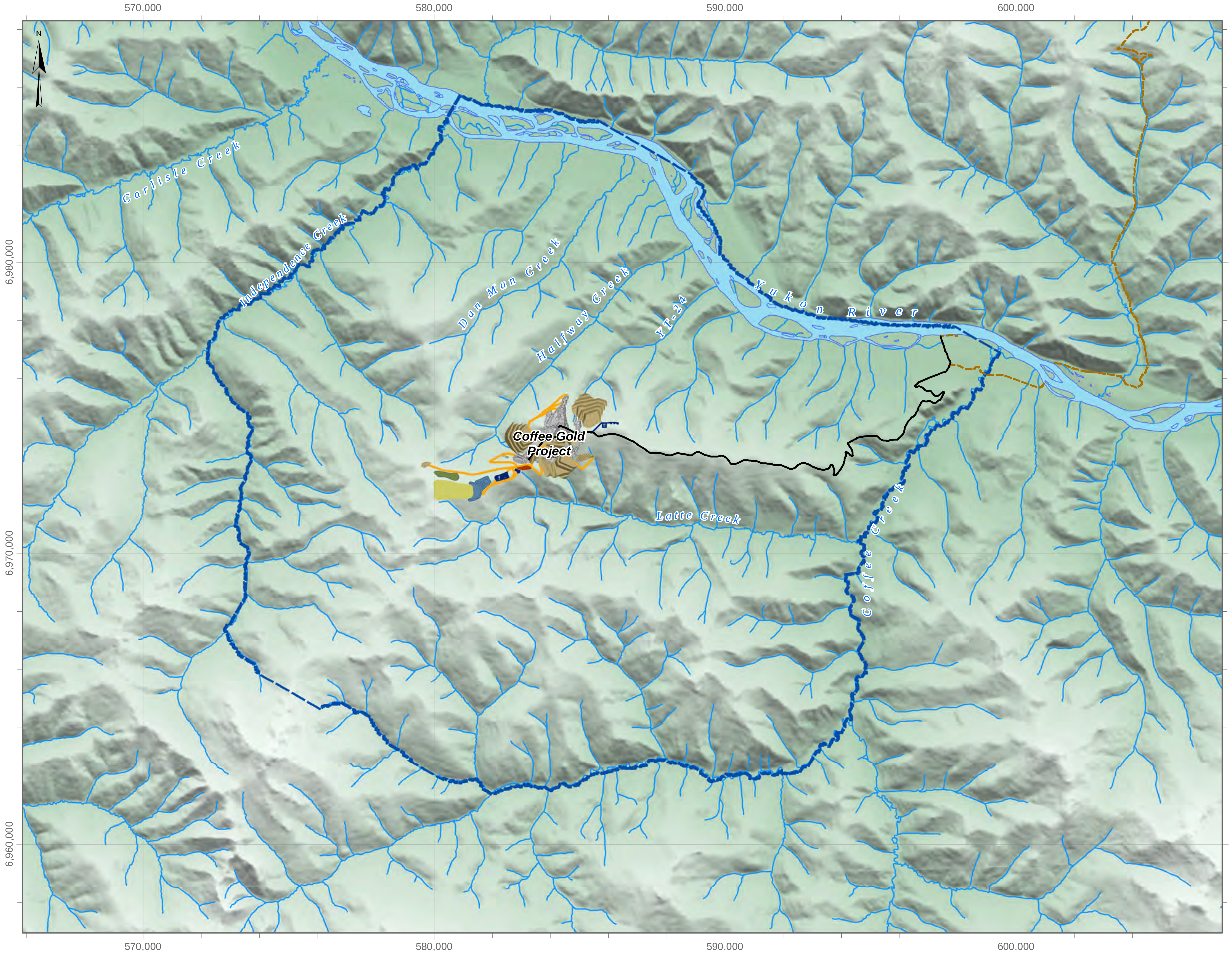
3.2.2 Model domain and Discretization

The model domain is illustrated in Figure 3-1. The groundwater model 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. The model extents are 26 km in a southwest-northeast orientation and 22.3 km in a southeast-northwest orientation. The model grid is rotated 30 degrees east from the north coordinate direction.

The model grid over the entire model extent can be seen in Figure 3-2 while Figure 3-3 shows the grid refinements in the mine area. The model cell sizes were specified with two constraints in mind. In order to retain the ability to simulate the Latte and T3 Structures as enhanced permeability features, the cell width in the immediate vicinity of these fault zones was set to 12-meters. The second constraint on cell spacing was to maintain a horizontal spacing that was small enough that adjacent model cells in areas of steep topography were contiguous in space. To maintain cell contact in all areas of the model, the maximum grid spacing is 70 m at the outer edges of the model domain.

The model was divided vertically into four layers. Representative sections through the model are shown in Figure 3-4 and Figure 3-5. The model contains 450 rows and 520 columns, and a total of 195,252 active finite difference cells.



LEGEND

- Model Domain Boundary
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:125,000

0 2 4 Km

DATE SAVED:	May 03, 2016
DRAWN BY:	GM
REVIEWED:	LF
VERSION:	1

CLIENT:

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LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Model Domain

PROJECT #:	FIGURE:
A362-5	3-1

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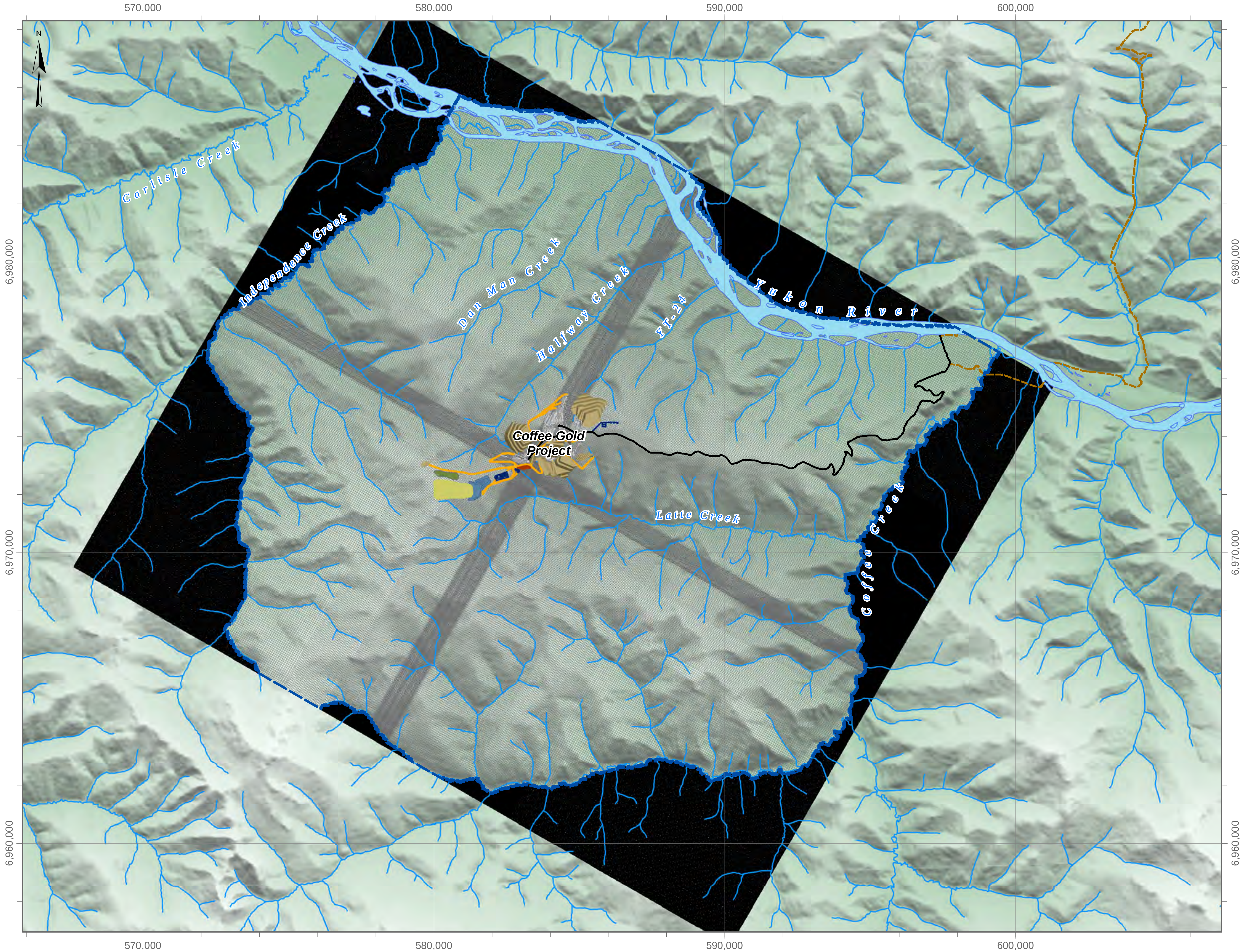

LEGEND

- Model Domain Boundary
- Model Grid Cells
- Inactive Cells
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

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Units: *Meter*

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LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Model-Wide Grid Spacing

PROJECT #: A362-5 *FIGURE:* 3-2

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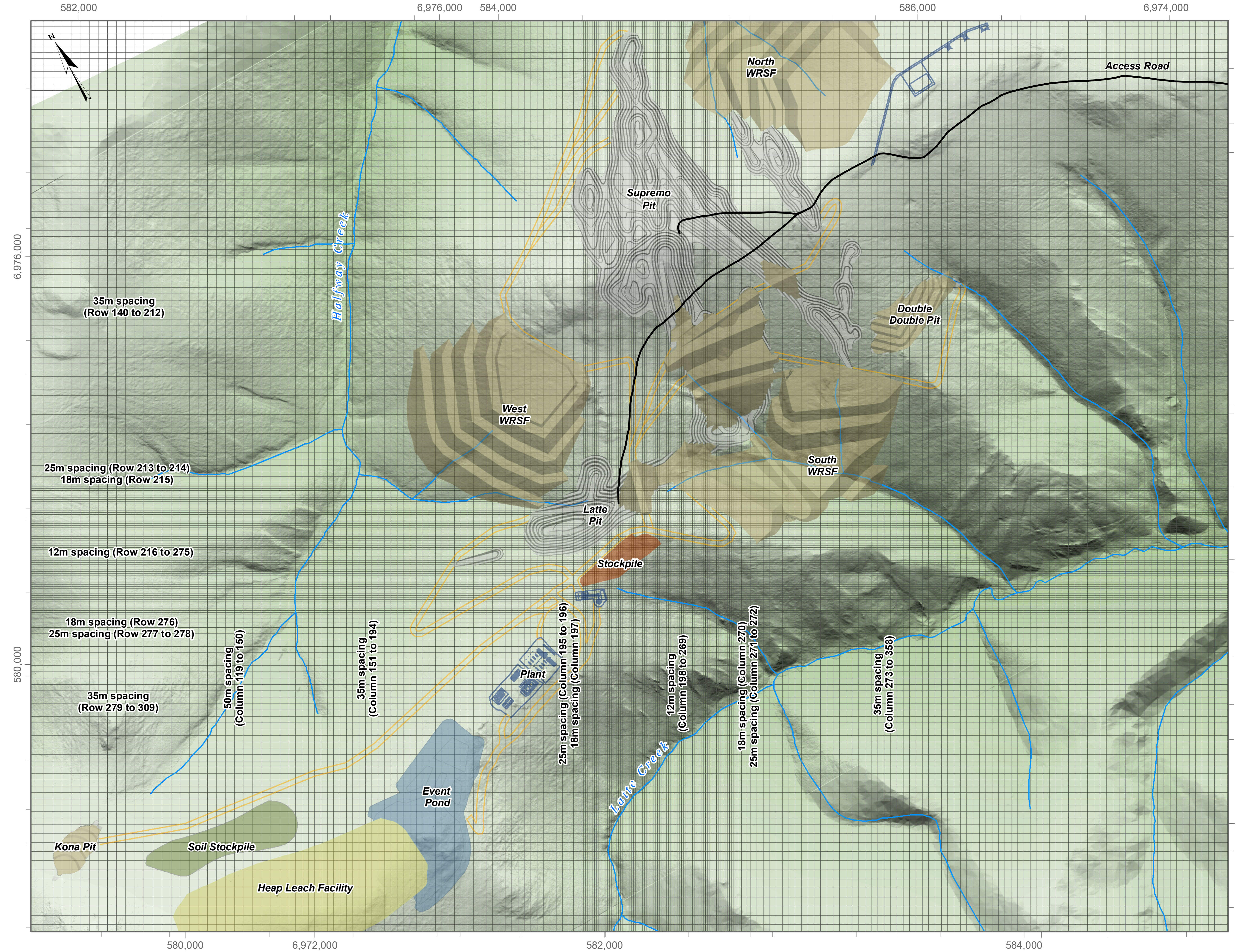

LEGEND

- Model Grid Cells
- Watercourses
- Waterbodies

Proposed Mine Infrastructure

- Pit
- Waste Dump
- Leach pad
- Soil Stockpile
- Stockpile
- Event pond
- Mine Access Road
- Mine Road
- Plant

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:20,000

0 500 1,000 Meters

DATE SAVED:	May 04, 2016
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VERSION:	1

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KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Grid Spacing in Mine Area

PROJECT #: A362-5 *FIGURE:* 3-3

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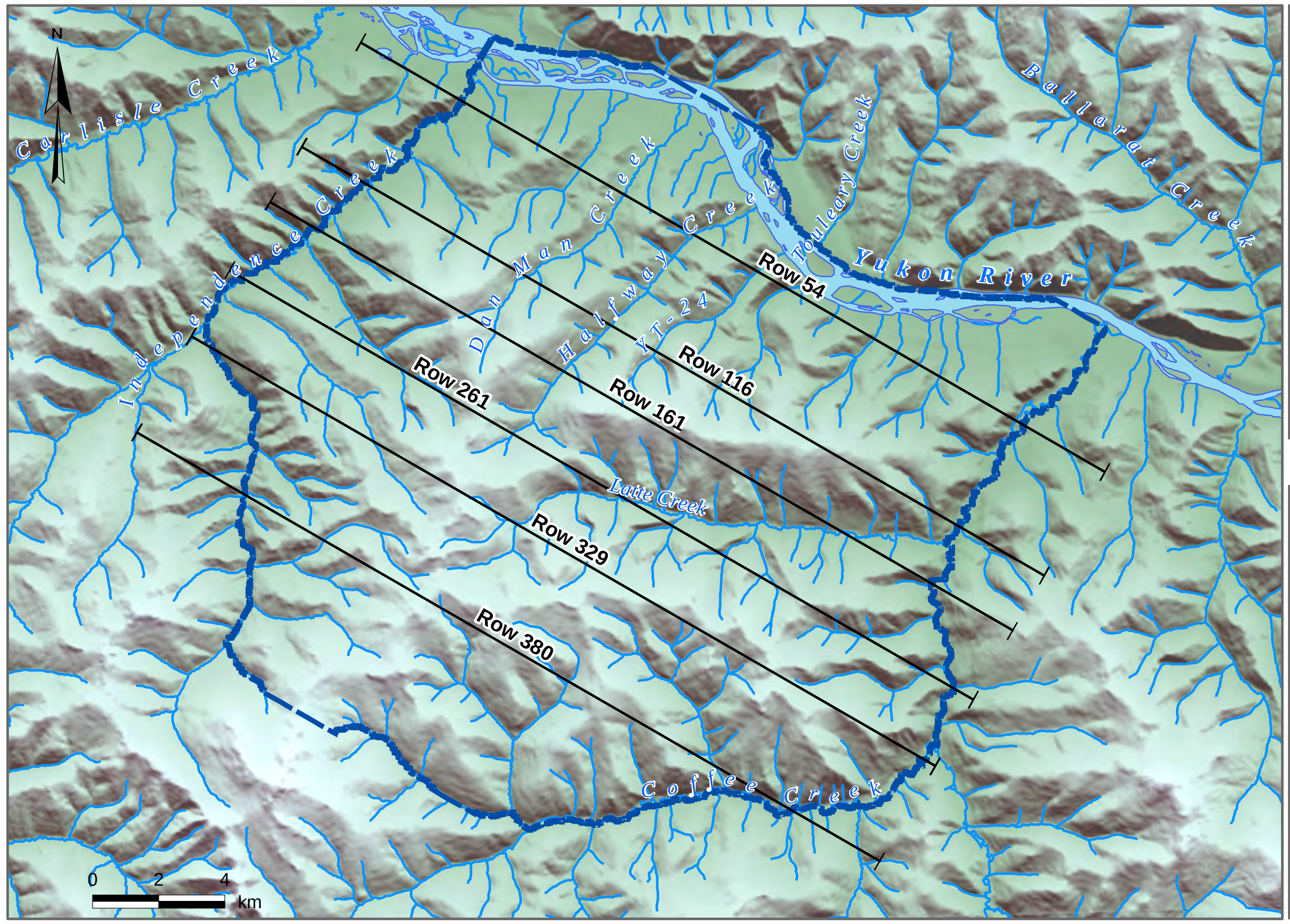

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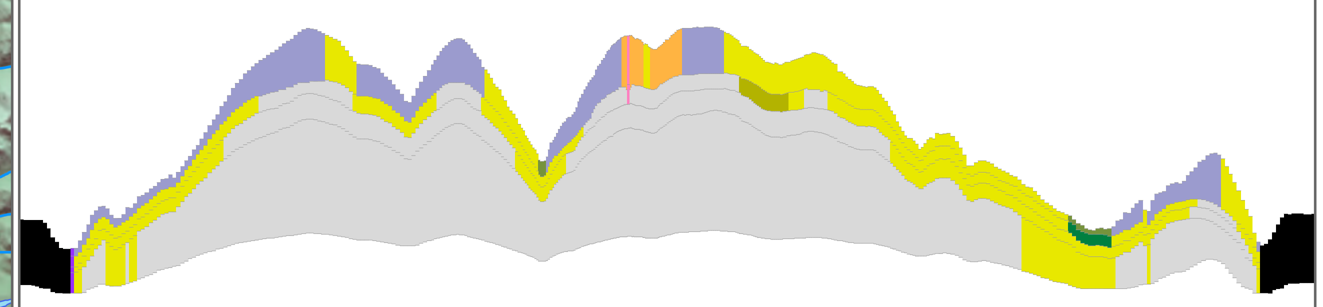

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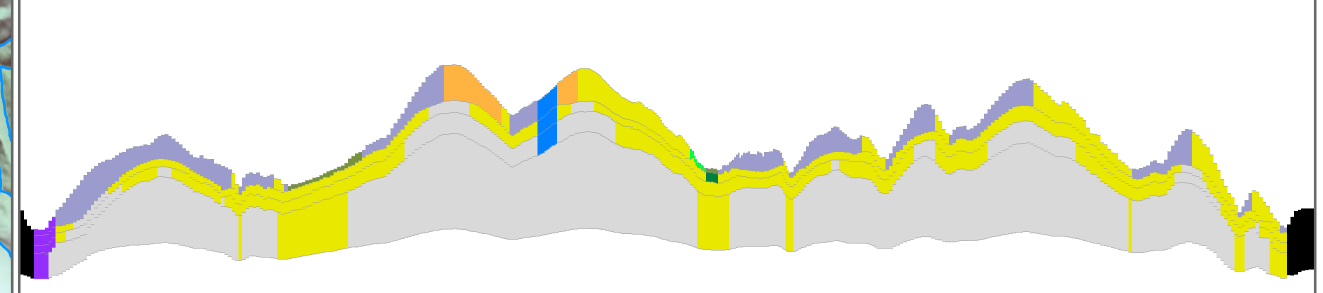

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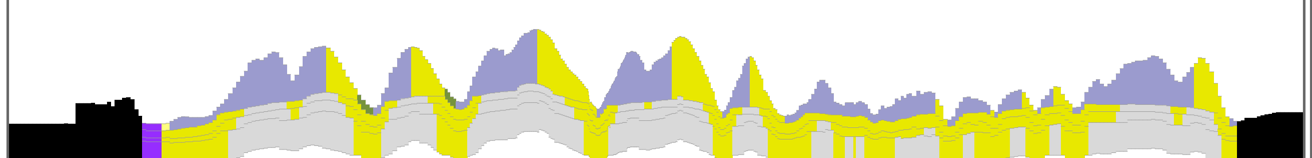

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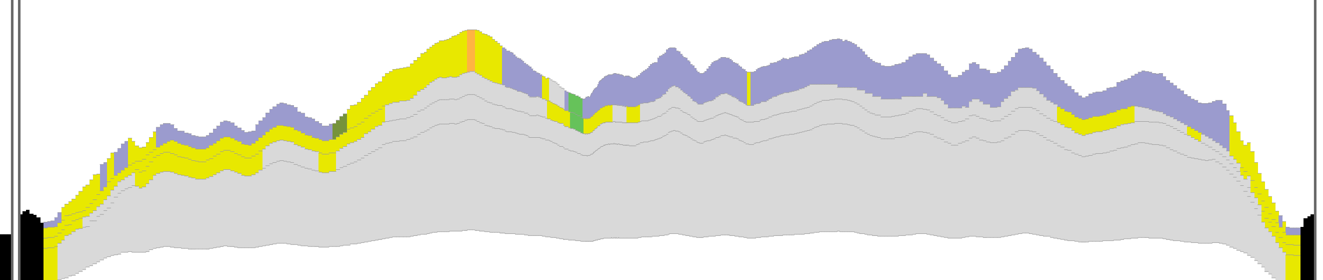

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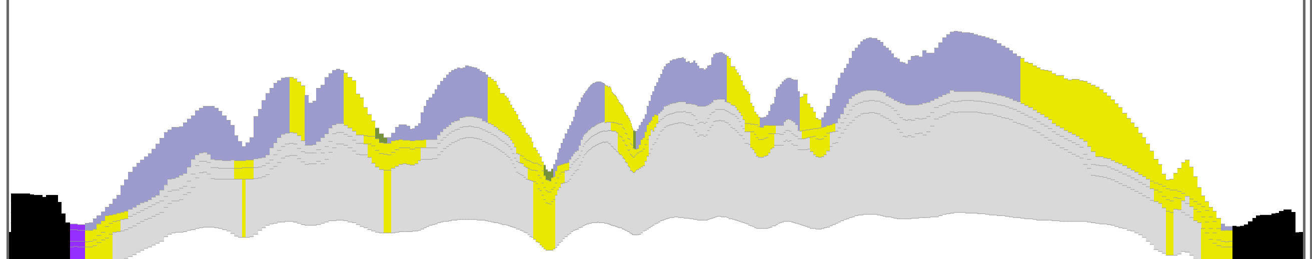

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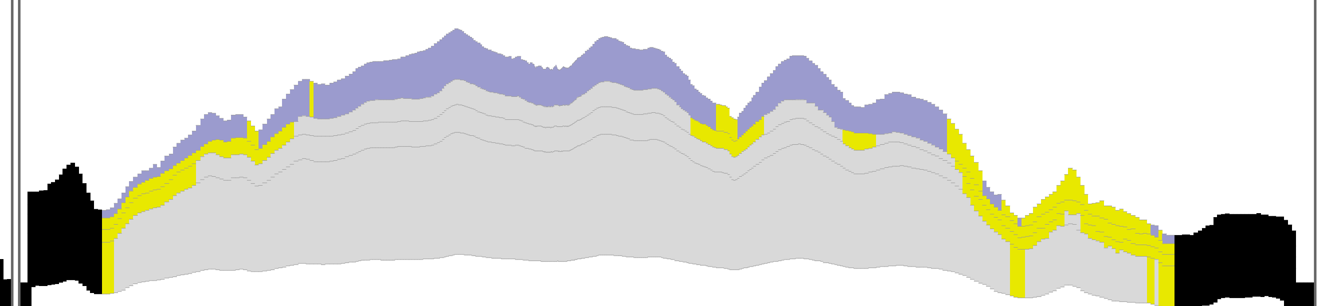

LEGEND

K (m/s)

- Alluvium (1.0E-05)
- Shallow Bedrock (1.2E-07)
- Bedrock w WT PF bottom (1.2E-07)
- Zone @ MW14-02 L2-3b (1.7E-09)
- Deep Bedrock > 120m Depth (1.7E-09)
- Colluvium (3.0E-05)
- T3 Structure (2.0E-06)
- Latte Structure (1.0E-06)
- All Creek hi K zones L1 (6.0E-06)
- N Fault (5.0E-06)
- L2 Upper Latte (4.0E-06)
- L2 Lower Latte (3.0E-05)
- IC Creek Fault (3.0E-05)
- Permafrost (6.0E-10)
- Inactive Cell
- Layer Boundary

Vertical Exaggeration 5x
Horizontal Scale:

1:150,000

0 2 4 km

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LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Cross-Sections along Model Rows

PROJECT #:	*FIGURE:*
A362-5	3-4

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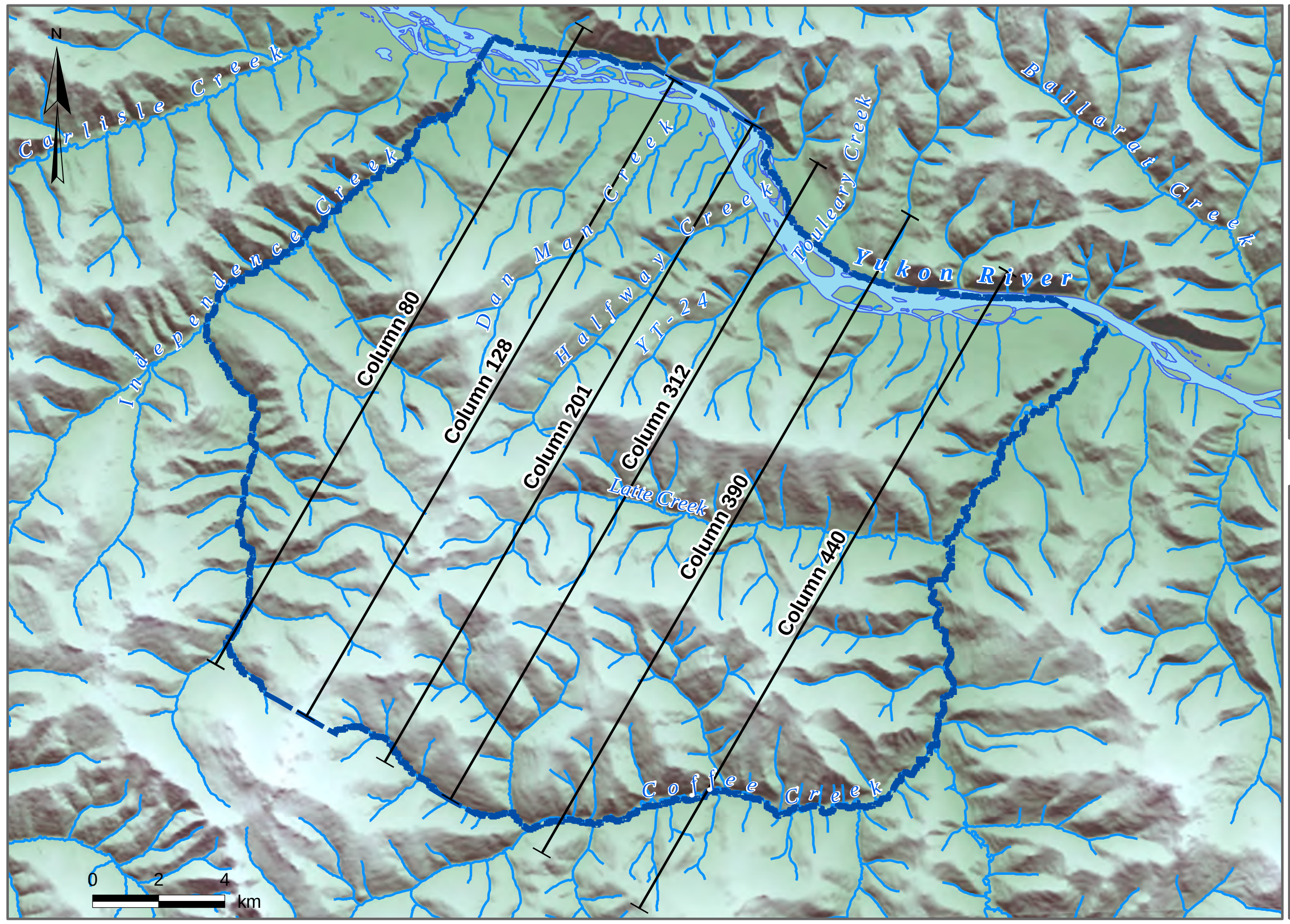

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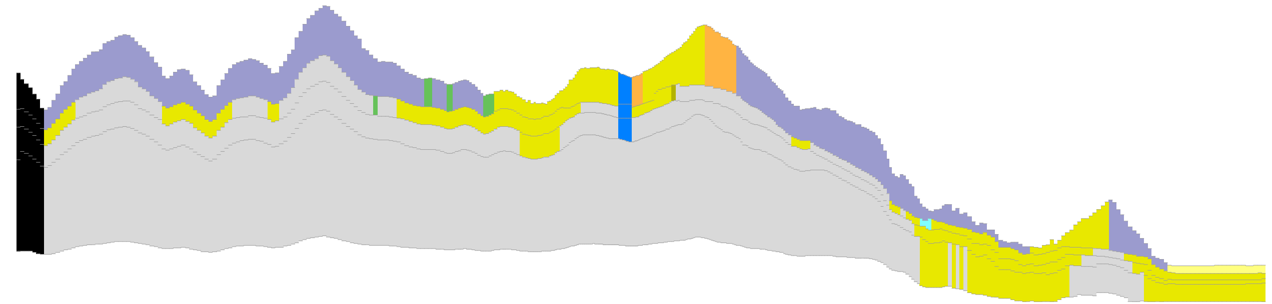

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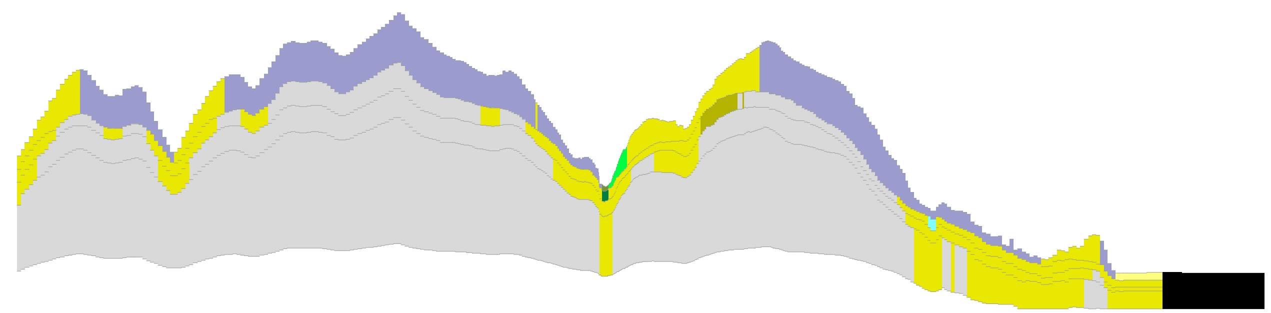

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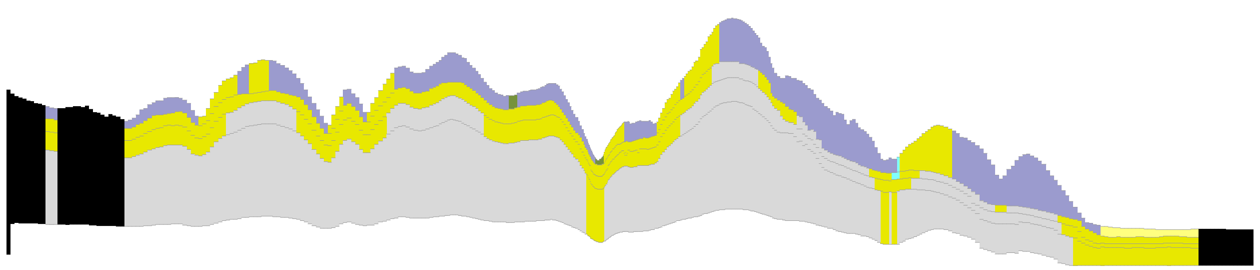

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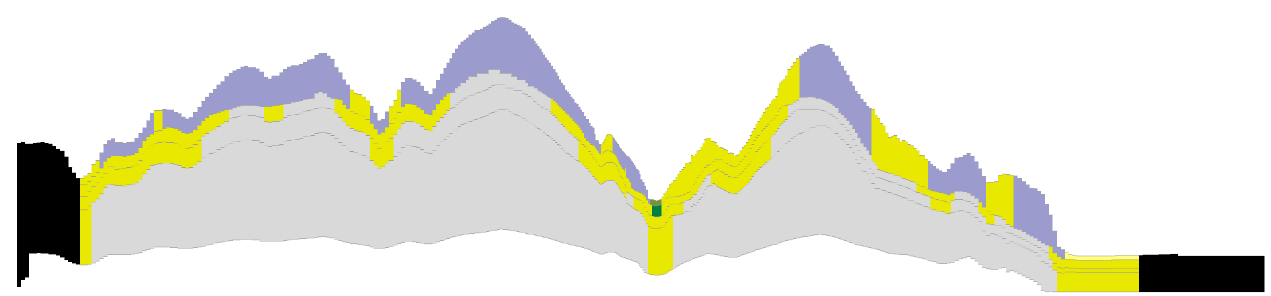
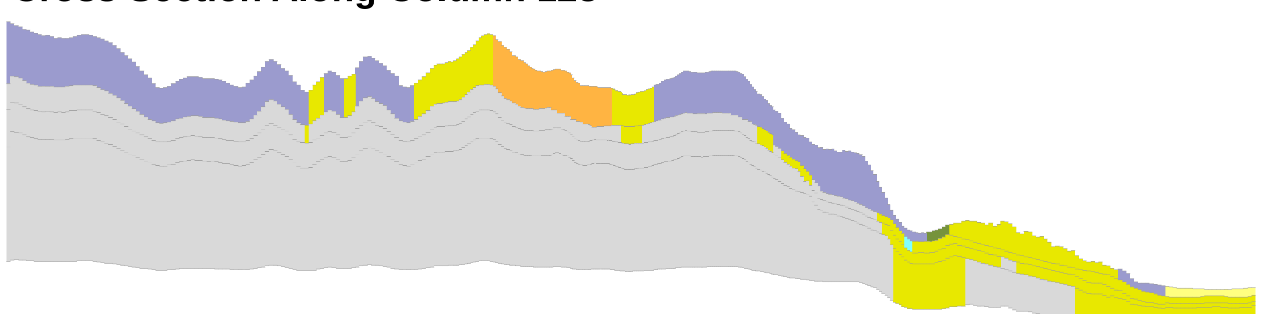
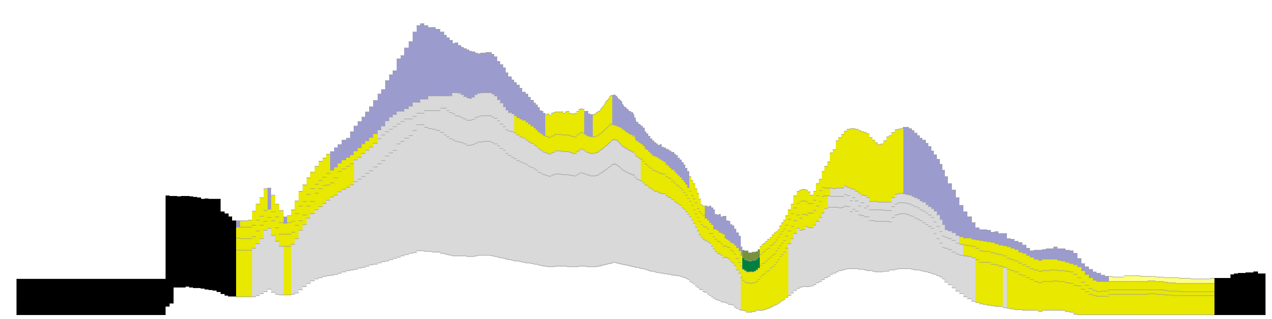


Cross Section Along Column 128



Cross Section Along Column 440



LEGEND

K (m/s)

- Alluvium (1.0E-05)
- Shallow Bedrock (1.2E-07)
- Bedrock w WT PF bottom (1.2E-07)
- Zone @ MW14-02 L2-3b (1.7E-09)
- Deep Bedrock > 120m Depth (1.7E-09)
- Colluvium (3.0E-05)
- T3 Structure (2.0E-06)
- Latte Structure (1.0E-06)
- All Creek hi K zones L1 (6.0E-06)
- N Fault (5.0E-06)
- L2 Upper Latte (4.0E-06)
- L2 Lower Latte (3.0E-05)
- IC Creek Fault (3.0E-05)
- Permafrost (6.0E-10)
- Inactive Cell
- Layer Boundary

Vertical Exaggeration 5x
Horizontal Scale:

1:135,000

0 2 4 km

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PROJECT:

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TITLE:

Cross-Sections along Model Columns

PROJECT #: A362-5	*FIGURE:* 3-5

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3.2.3 Boundary conditions

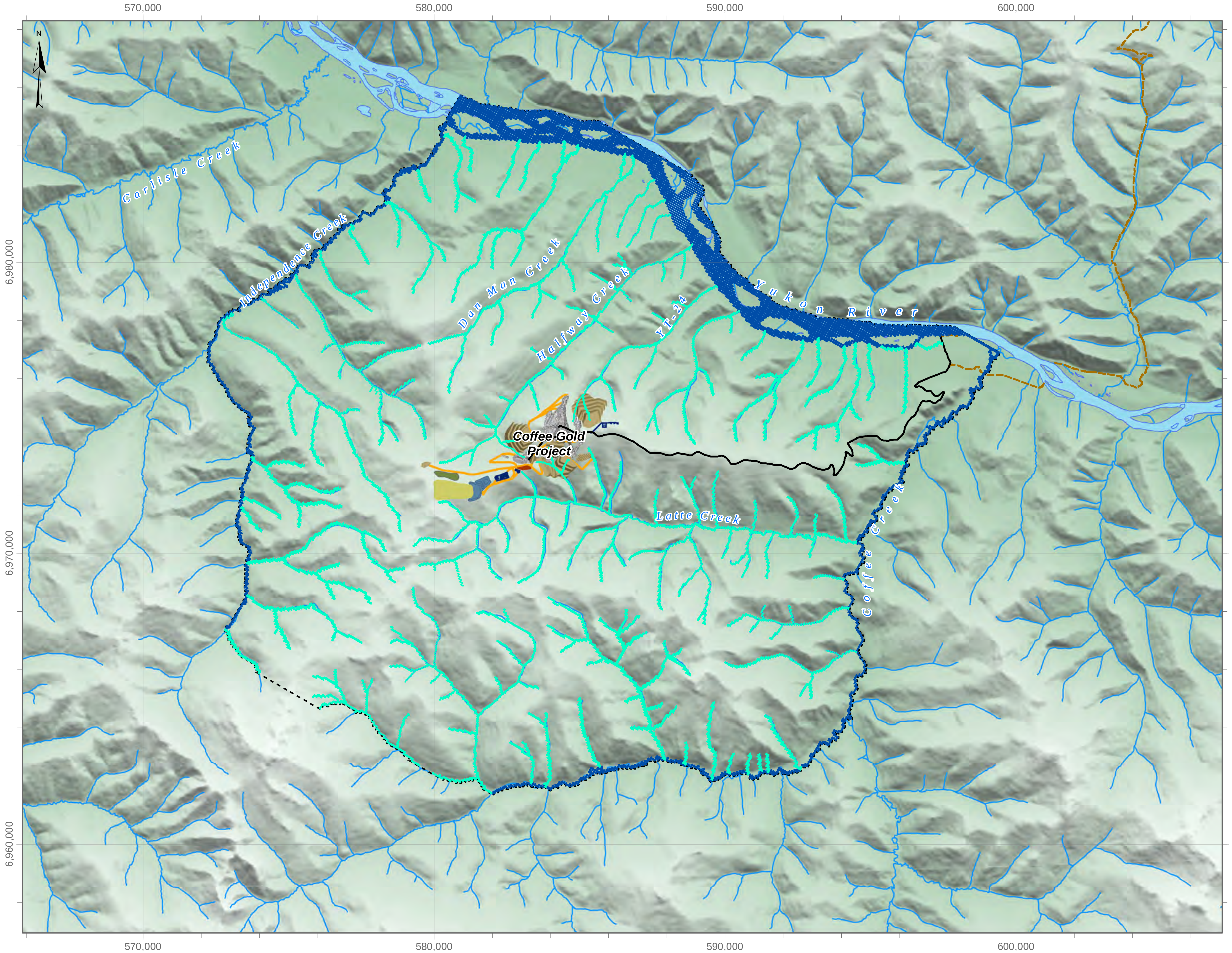
Three classes of boundary conditions exist in the model. At the major streams along the model's outer boundary—*i.e.*, the Yukon River, Independence Creek, and Coffee Creek—constant head conditions were applied based on the stream elevation derived from topographic maps. These constant head boundaries, shown in Figure 3-6, are present in Layers 1 and 2 of the model. The constant head at the Yukon River has a value of 428 masl. The specified boundary condition head along Independence Creek ranges from 858 masl at the upstream end to 428 masl at the Yukon River. The specified boundary head along Coffee Creek ranges from 720 masl at the upstream end to 428 masl at the Yukon River.

At all other surface water bodies, MODFLOW drains were applied, with the drain elevation equal to the topographic elevation of the model cell containing the drain. The drain conductance was computed using the length of the steam within the model cell, a streambed vertical hydraulic conductivity of $5x10^{-5}$ m/s, and streambed widths based on measured values, as shown in

Table 3-1. The length of the stream segments was computed by Groundwater Vistas, and it was assumed that all streambeds were 1 m thick.

Table 3-1:
Streambed Widths used in Drain Conductance Computation

	Model Drain Width (m)	Measured Wetted Stream Width (m)
Mine Area Drainages		
HC-2.5	2.8	2.8
HC-5.0	2.8	2.7
ML-1.0	1.5	1.0
CC-5.0	2.4	2.4
CC-5.5	2.4	
CC-6.0	2.4	2.3
CC-1.0	1.0	0.0
CC-1.5	4.8	4.8
CC-3.5	2.5	2.5
IC-2.5	1.5	1.5
IC-3.0	1.5	1.3
All Other Drainages	1.5	



LEGEND

Boundary Conditions

- Constant Head
- Drain
- No-Flow
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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0 2 4 Km

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PROJECT:

Coffee Gold Hydrogeology

TITLE:

Pre-Mining Boundary Conditions

PROJECT #:	FIGURE:
A362-5	3-6

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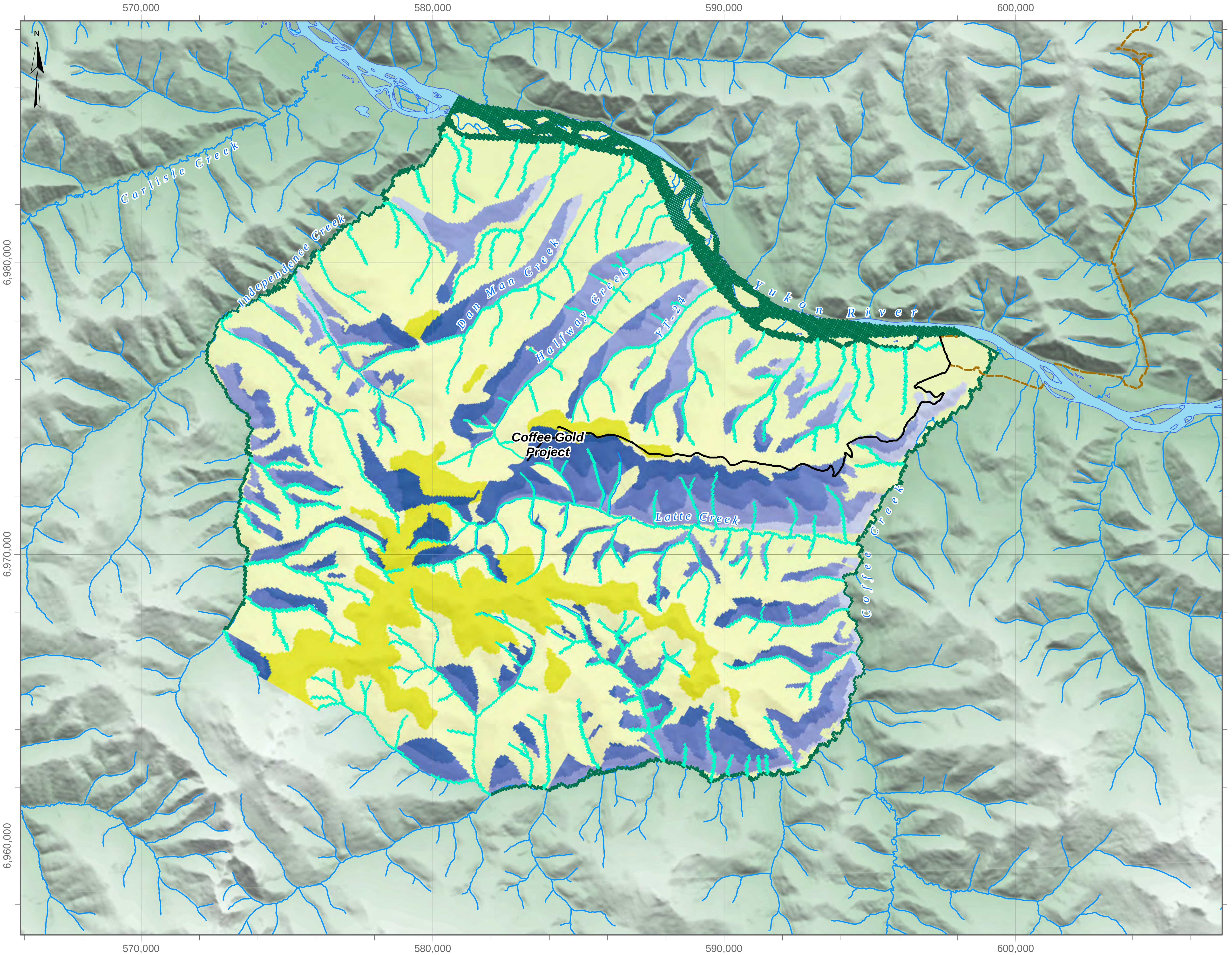
3.2.4 Recharge Distribution

The third type of boundary condition in the model is recharge. Recharge in the model varies according to two criteria: the presence or absence of permafrost and the topographic elevation, as shown in Figure 3-7. At lower elevations, below 600 masl, no recharge is applied in the groundwater model. The reason for this is that these areas correspond to groundwater discharge zones, and net recharge is assumed to be negligible. Unfrozen ground between 600 masl and 1400 masl is divided into 200-m elevation bands, each of which has a recharge rate that equals 15.2% of the mean annual precipitation for that elevation interval. No recharge occurs on permafrost at elevations between 400 and 1200 m. Between 1200 masl and 1400 masl, the model has an applied recharge rate of 5 mm/y to account for low rates of recharge that could occur through a dry permafrost (see discussion above in Section 3.1).

Table 3-2 presents a summary of recharge rates.

Table 3-2:
Pre-Mine Recharge Rates

	Applied Recharge Rate (mm/y)	
Elevation Range (masl)	**Unfrozen Ground**	**Permafrost**
400 to 600	0	0
600 to 800	53.8	0
800 to 1000	59.3	0
1000 to 1200	65.5	0
1200 to 1400	71.1	5.0



LEGEND

Recharge Zones

- 400-600 m Elevation No Permafrost
- 600-800 m Elevation No Permafrost
- 800-1000 m Elevation No Permafrost
- 1000-1200 m Elevation No Permafrost
- 1200-1400 m Elevation No Permafrost
- 400-1200 m Elevation with Permafrost
- 1200-1400 m Elevation with Permafrost
- Constant Head
- Drain
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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0 2 4 Km

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PROJECT:

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TITLE:

Pre-Mining Recharge

PROJECT #:	*FIGURE:*
A362-5	3-7

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3.2.5 Hydraulic Conductivity and Treatment of Permafrost

The hydraulic conductivity zones are shown in Figure 3-8. A total of 15 material zones are shown. These material zones are discussed briefly in this section.

An alluvium zone is defined in Layer 1 of the model in the immediate vicinity of the Yukon River. In the vicinity of stream gauging station CC-1.0, a zone of colluvial overburden is defined, as shown in Figure 3-8. These are the only two overburden units simulated in the groundwater model.

The majority of Layer 1 is composed of permafrost. The permafrost zone is based on the permafrost mapping by EBA and predominates on north-facing slopes within the model domain. The permafrost zone is present only in Layer 1 of the model. At higher elevations, the bottom of the permafrost, as determined through thermistor measurements, is above the water table. In these areas, the hydraulic conductivity of the material below the permafrost—*i.e.*, the unit in which the water table is located—is applied to Layer 1 of the model. A separate colour is used to denote this material zone in the figures. However, the hydraulic conductivity assigned to them is equal to the Shallow Bedrock hydraulic conductivity (see below).

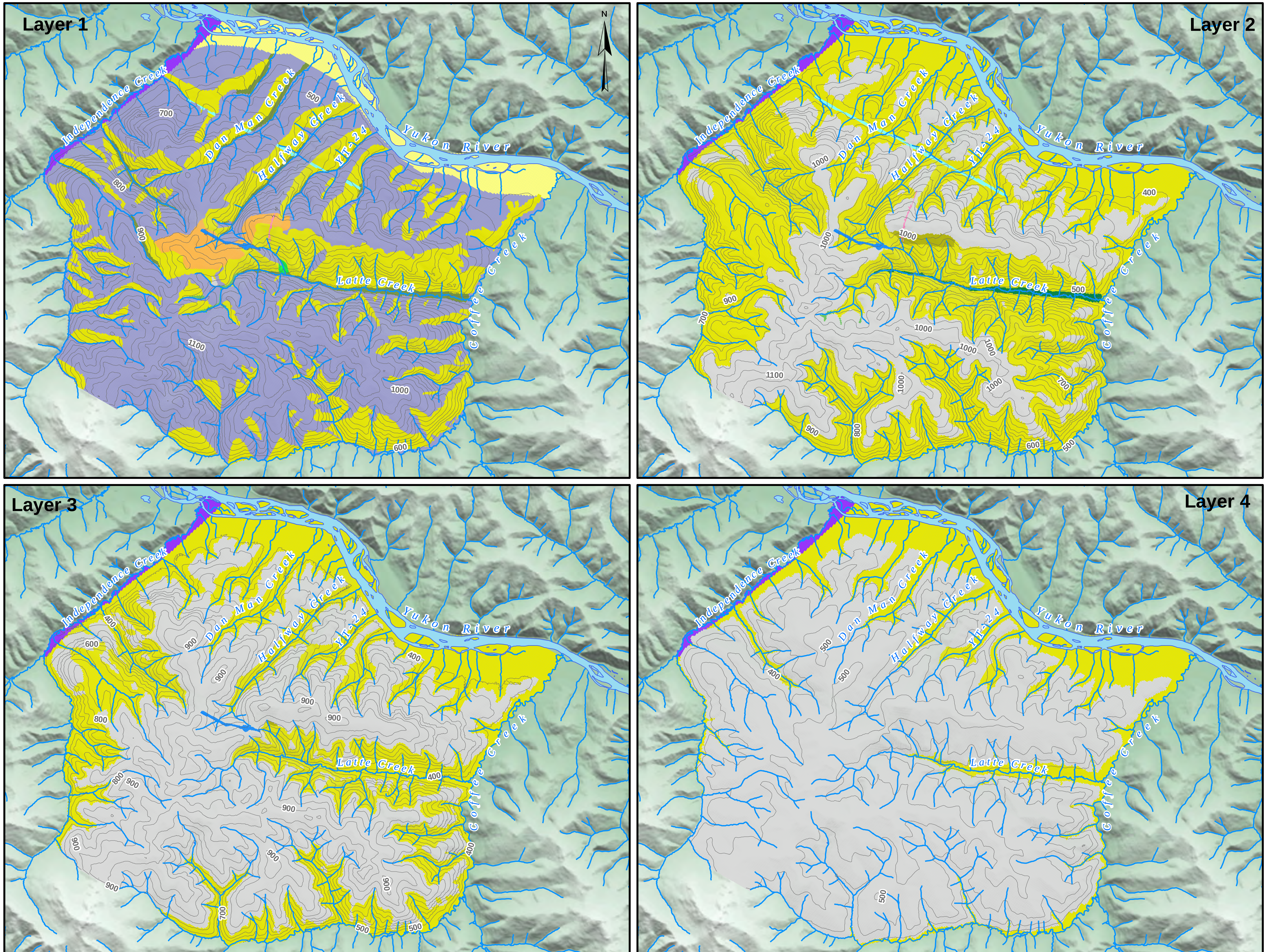
The majority of bedrock in the model is divided into two zones based on the difference between the topographic elevation and the layer bottom elevation. Bedrock model cells whose layer bottom elevation is less than 120 m below ground surface are treated as a single Shallow Bedrock unit. Below the Shallow Bedrock is a Deep Bedrock unit with a lower hydraulic conductivity. This zonation of bedrock is followed in all areas of the model except in:

- The vicinity of MW14-07 in the Upper Latte Creek catchment, where Layers 1 and 2 have Deep Bedrock properties in order to simulate the high observed water tables at MW14-07;l and
- On the ridge to the north of Latte Creek, in the vicinity of the proposed open pits, where the boundary between Shallow and Deep Bedrock was moved south by 600 m to match (raise) the water table observed at MW14-02 and MW15-07.

In addition to the bulk bedrock units, a number of high-permeability structures are present in the model. These are as follows:

- Independence Creek Fault, present in Layers 1 to 4. The Independence Creek Fault is a mapped structure assumed to be transmissive and to be associated with the creek's orientation.

- Latte Structure, present in Layers 2 and 3 and in Layer 1 where permafrost is absent or above the water table. The extent of this structure encompasses the vertical projection of the structure from the mine geological model.
- T3 Structure, present in Layer 2 and in Layer 1 where permafrost is absent or above the water table. The extent of this structure is the vertical projection of the structure from the mine geological model.
- North Fault, an east-west structure that intersects Halfway Creek, is present in Layer 2 and in Layer 1 where permafrost is absent. The transmissive character of this fault is inferred from the observed change in Halfway Creek water quality at this location.
- Finally, a series of transmissive features was introduced along major creek channels in a fashion similar to the structure at Independence Creek. These structures are defined to coincide with areas mapped as containing ice-rich permafrost or where the groundwater model simulated surface groundwater ponding. The reason for including the ice-rich permafrost, which is primarily associated with the Latte Creek channel, is that the presence of ice implies the likelihood of groundwater discharge beneath these areas (Kane *et al*., 2013). Three different hydraulic conductvity zones are applied to these creek-associated structures.
    - At Halfway Creek, YT-24, Latte Creek and other creeks as required, a high hydraulic conductivity zone was introduced in Layer 1, except for:
    - The portion of Latte Creek near the proposed heap leach facility. In this area, a separate hydraulic conductivity zone, in Layer 1 and to some extent in Layer 2 under permafrost, was introduced, and lastly;
    - Layer 2 of the Latte Creek channel was assigned a third hydraulic conductivity zone. The initial purpose of this zone was to permit the development of vertical hydraulic gradients similar to those observed in MW15-02, in which an intermediate measurement point below the creekbed had the lowest head, indicating the highest hydraulic conductivity.



LEGEND

K (m/s)

- Alluvium (1.0E-05)
- Shallow Bedrock (1.2E-07)
- Bedrock w WT PF bottom (1.2E-07)
- Zone @ MW14-02 L2-3b (1.7E-09)
- Deep Bedrock > 120m Depth (1.7E-09)
- Colluvium (3.0E-05)
- T3 Structure (2.0E-06)
- Latte Structure (1.0E-06)
- All Creek hi K zones L1 (6.0E-06)
- N Fault (5.0E-06)
- L2 Upper Latte (4.0E-06)
- L2 Lower Latte (3.0E-05)
- IC Creek Fault (3.0E-05)
- Permafrost (6.0E-10)
- Waterbodies
- Watercourses
- Bottom of Layer Contours (50m)

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:200,000

0 2 4 Km

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PROJECT:

Coffee Gold Hydrogeology

TITLE:

Hydraulic Conductivity Zones - Layers 1-4

PROJECT #:	FIGURE:
A362-5	3-8

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-8_Hydraulic Conductivity_20160518.mxd

3.2.6 Solver Settings

The groundwater flow equations are solved in the model using the Newton (NWT) solver and the Upstream Weighting (UPW) package developed for MODFLOW-2005. Layers 1 to 3 of the model are defined as unconfined layers, and Layer 4 of the model is treated as a confined layer. For the pre-mine simulations, the head convergence criterion is 0.01 m, the flux convergence criterion is 5 m^3/d (0.06 L/s), and the maximum number of outer iterations is 400. All other parameters are set to the default values for a "simple" MODFLOW-NWT model (Niswonger *et al.*, 2011).

3.3 Model Calibration

3.3.1 Hydraulic Heads

Model calibration was completed using the PEST optimization program. The optimization targets are steady state head values in mine area wells and estimated groundwater discharge values to streams within the model domain. The head calibration targets are shown in Table 3-3 along with the weights assigned to them in the optimization runs. The majority of wells was assigned a weight of unity unless the well landed in the same model cell as another well. For example, MW15-04T-632 and MW15-04T-619 are located within the same model cell, and were therefore assigned weights of 0.7.[1] In instances where a thermistor-vibrating wire piezometer installation was adjacent to a Westbay installation, the vibrating wire piezometer data—which are continuous and available over a longer monitoring period—were given precedence over the heads measured in the Westbay installation present in the same model cell; this applies to MW15-01WB-P1, MW15-01WB-P6, MW15-02WB-P4, MW15-03WB-P7, MW15-04WB-P1, MW15-04WB-P5 and MW15-05WB-P4, all of which were given a weight of 0.3. The water level in CFD318 appears to be below the screen, and this well was assigned a weight of 0.4 in the Pest optimization. Finally, the weight at MW14-07 was lowered to 0.125 because during earlier iterations this well had a high residual and skewed some of the calibrated parameters in its favour at the expense of other monitoring wells. The weights in Table 3-3 were for the optimization routine only. When computing model calibration statistics, all wells were given the same weight.

The flow calibration targets are presented in Table 2-2. Two values of the target groundwater discharge to surface water were used bracket a range of acceptable baseflow values. Both are shown in Table 2-2.

[1] Because the objective function is computed to be the square of the residual times the weight, a weight of 0.7 results in a 50% reduction in the importance of a well in the calibration.

**Table 3-3:
Head Calibration Targets**

Well ID	Target Head (masl)	Weight
MW15-03-AZ	556.3	1
MW15-03T-508	557.0	1
MW15-03T-461	561.2	1
MW15-04WB-P1	672.3	1
MW15-04T-632	670.8	0.7
MW15-04T-619	670.9	0.7
MW15-01WB-P1	767.4	1
MW15-01T-715	766.2	1
MW15-01T-728	766.6	1
SRK-15D-07T-800	898.4	1
SRK-15D-07T-845	904.1	1
MW15-06WB-P3	956.8	1
MW15-06WB-P7	962.7	1
MW15-07T-944	1045	1
MW15-07T-915	1046.4	1
SRK-15D-08AT-776	927.3	1
CFD324	931.6	1
SRK-15D-08AT-822	934.2	1
MW14-03A	959.8	1
MW14-03B	959.8	1
CFD351	967.8	1
MW14-02B	1009.6	1
MW14-02A	1017.7	1
CFD318	1092.0	0.4
MW15-02WB-P1	727.9	1
MW15-02-AZ	731.2	1
MW15-02T	726.8	1
SRK-15D-09T	782.9	1
MW15-05T-986	1029.1	1
MW15-05T-1012	1042.7	1
MW14-05A	1136.2	1
MW14-05B	1136.2	1
MW14-07T	1164.2	0.125
MW15-05WB-P1	1044.6	0.3
MW15-05WB-P4	1044.7	0.3
MW15-02WB-P4	734.6	0.3
MW15-03WB-P7	557.5	0.3
MW15-03WB-P1	559.9	0.3
MW15-04WB-P5	672.5	0.3
MW15-01WB-P6	767.4	0.3

The calibrated hydraulic conductivity values are shown in Table 3-4. They are listed from highest to lowest hydraulic conductivity. All materials have isotropic hydraulic conductivities. The most permeable hydraulic conductivity units are the colluvium upstream of stream gauge CC-1.0, the enhanced hydraulic conductivity zones introduced at creek channels, the Independence Creek Fault, the Yukon River alluvium and the east-west trending North Fault that intersects Halfway Creek upstream of MW15-03. The Latte Structure and the T3 Structure have hydraulic conductivities that are eight (8) and 17 times higher than the bulk Shallow Bedrock hydraulic conductivity of $1.2\text{x}10^{-7}$ m/s. The Shallow Bedrock hydraulic conductivity is 70 times higher than the Deep Bedrock hydraulic conductivity of $1.7\text{x}10^{-9}$ m/s and 200 times higher than the permafrost hydraulic conductivity of $6.0\text{x}10^{-10}$ m/s.

Table 3-4:
Calibrated Hydraulic Conductivity

Material Zone	Hydraulic Conductivity (m/s)
Colluvium	3.0×10^{-5}
Independence Creek Fault and Bedrock below Latte Creek, Layer 2	3.0×10^{-5}
Yukon River Alluvium	1.0×10^{-5}
Layer 1 Bedrock at Creeks	6.0×10^{-6}
North fault	5.0×10^{-6}
Layer 1 and 2 Upper Latte Creek	4.0×10^{-6}
T3 Structure	2.0×10^{-6}
Latte Structure	1.0×10^{-6}
Shallow Bedrock, including Bedrock in Layer 1 where water table is below the bottom of permafrost	1.2×10^{-7}
Deep Bedrock (see text) and Bedrock near MW14-02 in Layers 2 and 3	1.7×10^{-9}
Permafrost	6.0×10^{-10}

As discussed below in the sensitivity and prediction analyses, the groundwater model, which was designed to simulate groundwater flow below and adjacent to permafrost areas, does not yield calibration results or environmental impacts that are sensitive to the hydraulic conductivity of the permafrost within the model. The hydraulic conductivity applied to the permafrost was selected based on the zonation of recharge shown in Figure 3-7 and the predicted groundwater discharge rates to surface water (see below). Once the recharge distribution was calibrated, the permafrost hydraulic conductivity was selected to be capable of accepting this amount of recharge. The hydraulic conductivity of the permafrost is 3.8 times higher than the 5 mm/y of recharge applied to the highest elevation band of permafrost recharge (Table 3-2).

Hydraulic head calibration statistics are illustrated in Figure 3-9. The overall model normalized root mean squared error (NRMSE) is 1.67%, with a residual mean of -1.7 m, and an absolute residual mean of 7.7 m. Figure 3-9 shows the normalized root mean squared error and the absolute residual mean for all wells together and with wells grouped by surface water catchment. In the catchment groupings, the wells given a calibration weight of 0.3 in Table 3-3—*i.e.*, Westbay installations located in the same model cell as a continuously monitoring vibrating-wire transducer—are not included in the calculated statistics. Table 3-5 presents a summary of calibration statistics. Table 3-6 lists the computed heads and the residuals—*i.e.*, the differences between the simulated heads and the calibration targets—for all wells included in the calibration.

Table 3-5:
Summary of Calibration Statistics

Well Group	NRMSE	Residual Mean (m)	Absolute Residual Mean (m)	Number of Wells
All Wells	1.67%	-1.69	7.69	40
Halfway Creek Catchment	1.04%	-1.94	8.85	15
Latte Creek Catchment	2.50%	-1.94	8.67	12
YT-24 Catchment	3.24%	-0.10	8.13	6
Duplicate Westbay Points	0.80%	-2.06	3.17	7

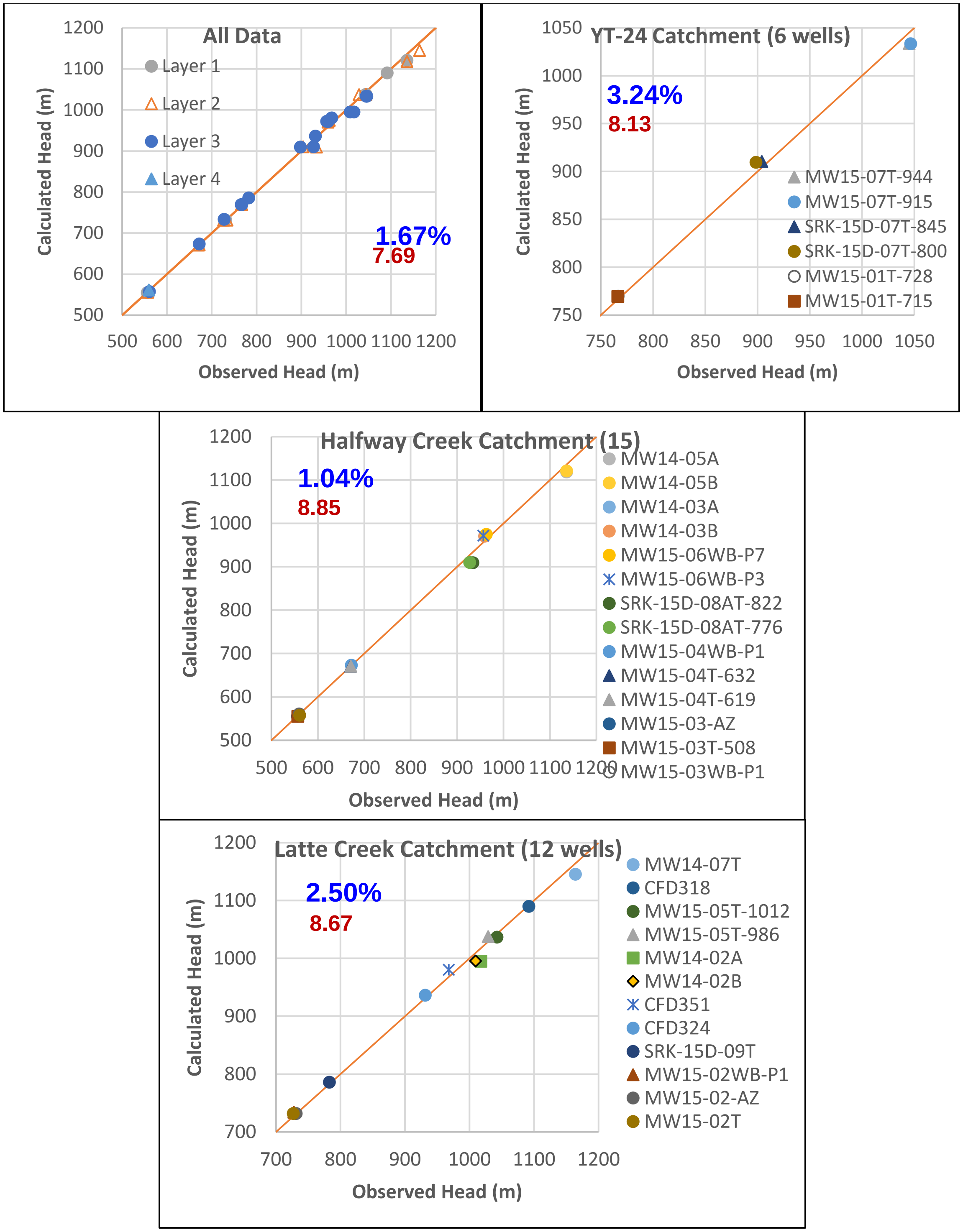


Figure 3-9: Head Calibration Results, showing NRMSE in blue (%) and Absolute Residual Mean (m) in red.

Table 3-6:
Head Residuals

Name	Computed Head (m)	Observed Minus Computed Head (m)
MW15-03-AZ	555.05	1.25
MW15-03T-508	555.30	1.70
MW15-03T-461	561.09	-1.19
MW15-04WB-P1	557.58	3.62
MW15-04T-632	670.88	-0.08
MW15-04T-619	670.88	0.02
MW15-01WB-P1	673.28	-0.98
MW15-01T-715	769.55	-3.35
MW15-01T-728	769.76	-3.16
SRK-15D-07T-800	909.73	-11.33
SRK-15D-07T-845	910.37	-6.27
MW15-06WB-P3	972.01	-15.21
MW15-06WB-P7	974.83	-12.13
MW15-07T-944	1033.35	11.65
MW15-07T-915	1033.35	13.05
SRK-15D-08AT-776	910.19	17.11
CFD324	936.27	-4.67
SRK-15D-08AT-822	909.79	24.41
MW14-03A	971.49	-11.69
MW14-03B	970.33	-10.53
CFD351	980.40	-12.60
MW14-02B	995.34	14.26
MW14-02A	995.05	22.65
CFD318	1090.01	1.99
MW15-02WB-P1	733.84	-5.94
MW15-02-AZ	731.87	-0.67
MW15-02T	731.84	-5.04
SRK-15D-09T	785.91	-3.01
MW15-05T-986	1037.51	-8.41
MW15-05T-1012	1036.87	5.83
MW14-05A	1118.41	17.79
MW14-05B	1121.14	15.06
MW14-07T	1145.30	18.90
MW15-05WB-P1	556.15	1.35
MW15-05WB-P4	671.56	0.94
MW15-02WB-P4	731.75	2.85
MW15-03WB-P7	769.25	-1.85
MW15-03WB-P1	769.46	-2.06
MW15-04WB-P5	1038.08	6.52
MW15-01WB-P6	1038.06	6.64

Figure 3-10 presents a chart of all the calibration residuals as a function of screen elevation. The residuals are significantly lower below an elevation of 750 masl than above 750 masl. This is due to the proximity of the lower-elevation monitoring wells to creek channels, where the hydraulic head is more constrained than at higher elevations. In general, there is no significant consistent bias above or below the calibration target for wells at elevations between 750 masl and 1000 masl. For the four wells located at the highest elevations, the head is generally underpredicted, but a consistent trend cannot be clearly observed. Figure 3-11 shows the calibration residuals by catchment, with well labels shown. The blue points in Figure 3-11 are the Westbay points which were underweighted in the calibration because only a handful of head measurements were available at these locations. The Westbay data points are not labeled, but they are adjacent to the wells nearest to them on the graphs.

Figure 3-12 presents histograms of residuals for all head measurement points and for well groupings by catchment.

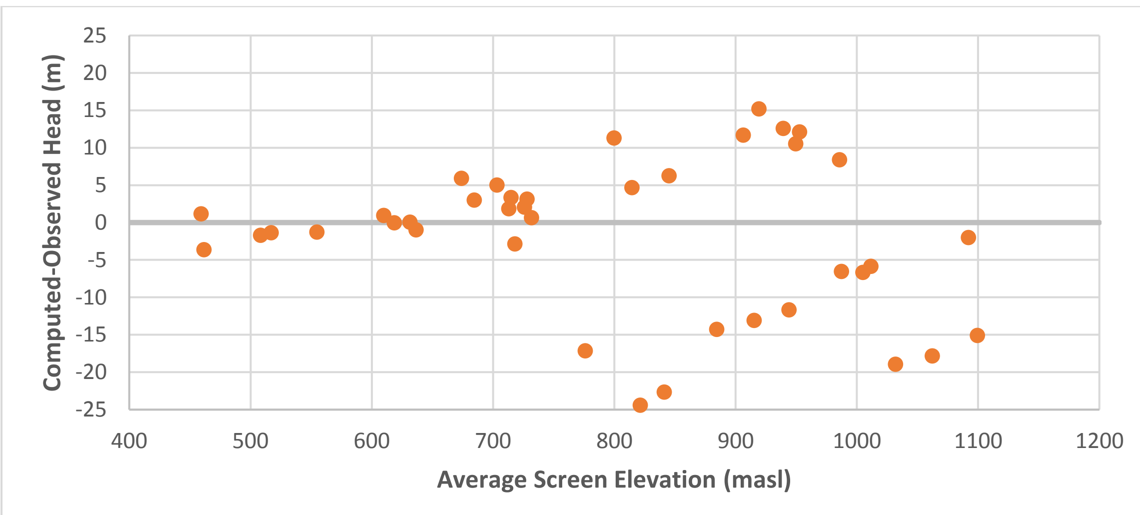


Figure 3-10: Calibration Residual versus Well Screen Elevation, All Wells

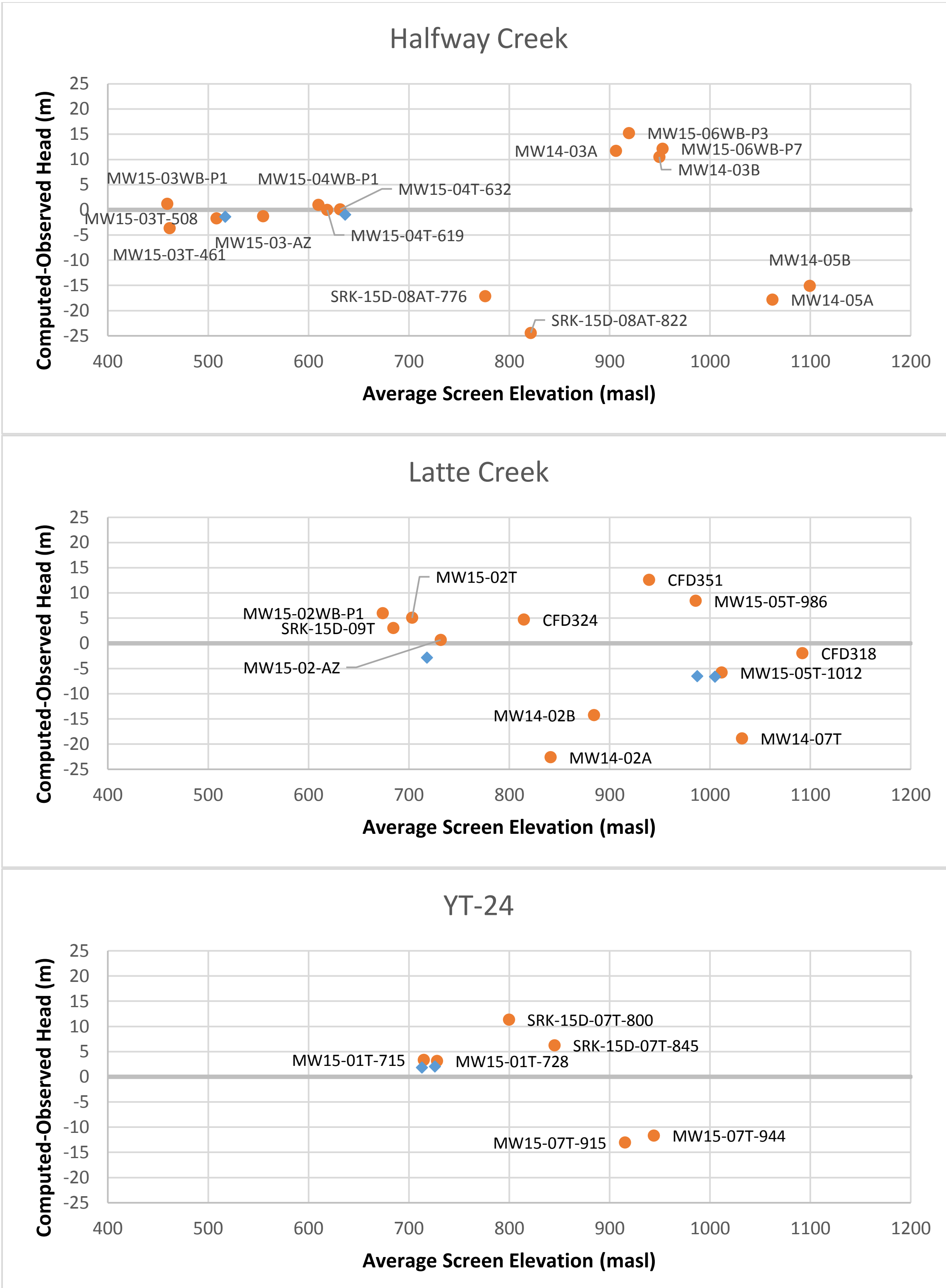


Figure 3-11: Calibration Residual versus Well Screen Elevation, By Catchment

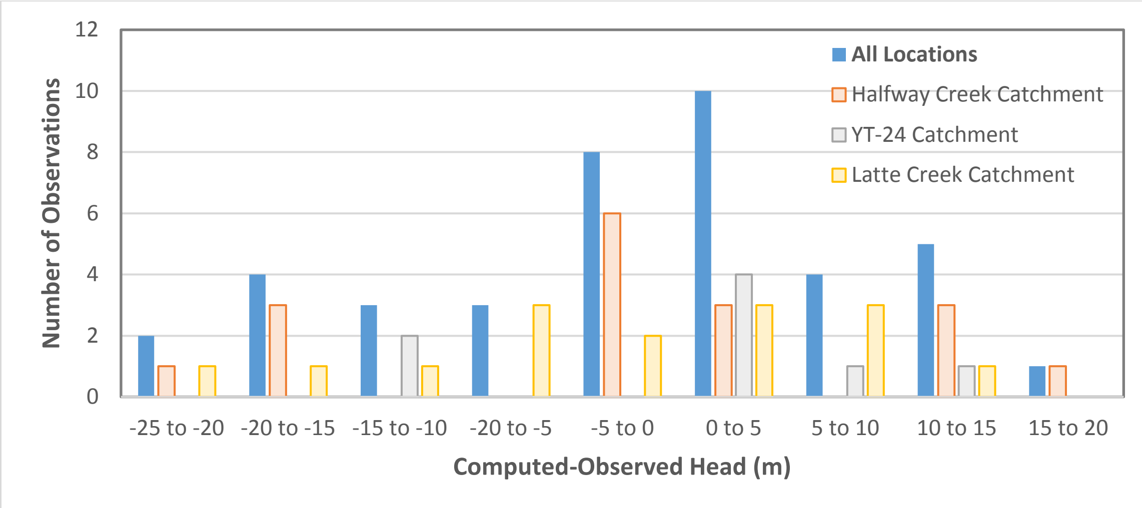


Figure 3-12: Histogram of Residuals

3.3.2 Water Balance and Base Flow Predictions

Table 3-7 presents the model-wide mass balance under baseline conditions. The model mass balance is good, and the specified convergence criteria are reasonable for the problem. Table 3-8 presents the results of the flow calibration, in which simulated groundwater discharge to surface water was compared with measured values. The majority of simulated groundwater discharge values fall within the upper and lower bound calibration targets. At IC-2.5, the groundwater model underpredicts the groundwater discharge to the creek; however, for this catchment, the water quality signature suggests that the measured low-flow stream discharge is not primarily derived from bedrock groundwater. Overall, the flow calibration is adequate.

Table 3-7:
Model-Wide MassBalance

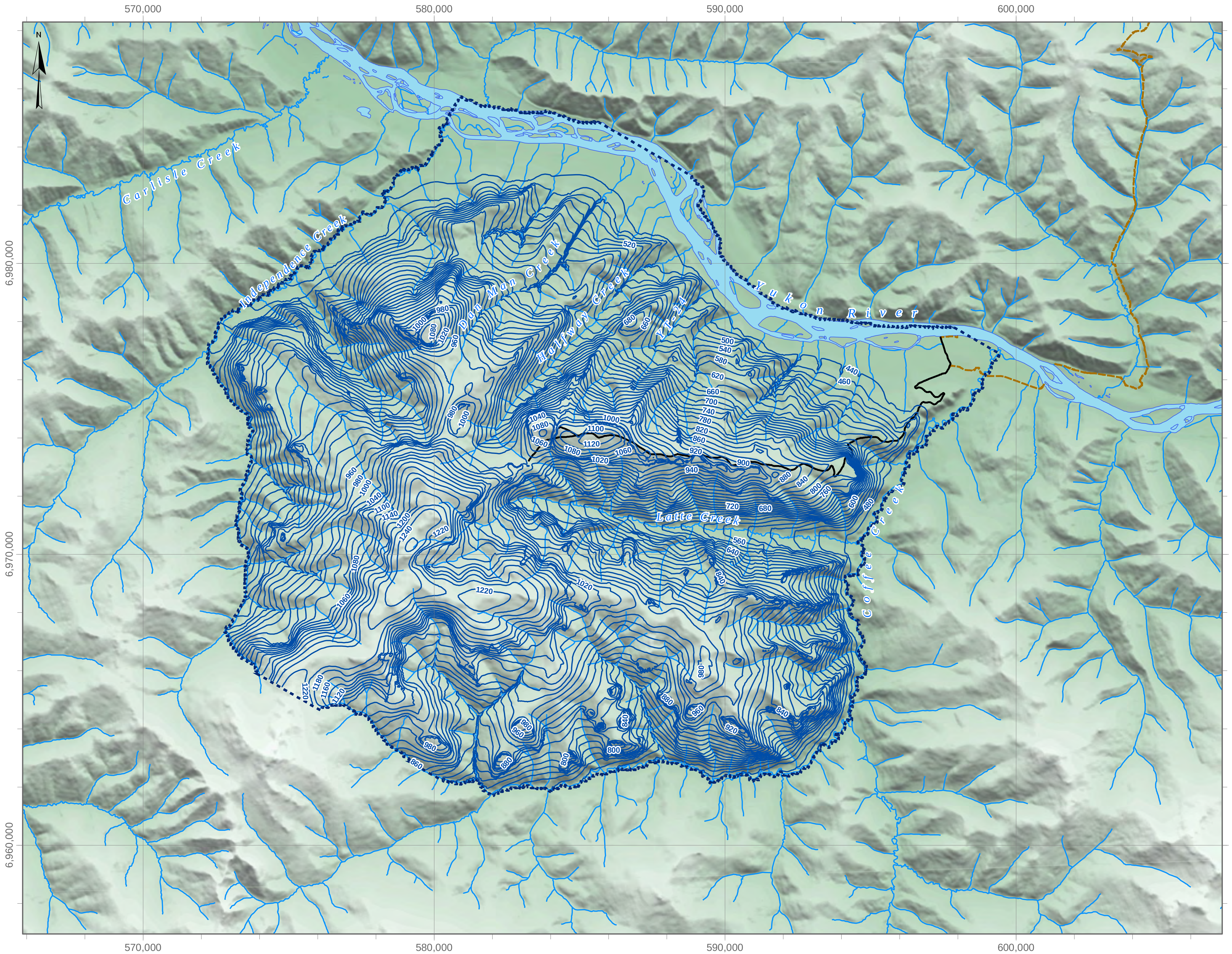
	Inflow (L/s)	Outflow (L/s)	Discrepancy (L/s)	Percent Discrepancy
Constant Head	192.0	242.5		
Recharge	202.1			
Drains		151.8		
Total	**394.1**	**394.2**	**-0.15**	**-0.04%**

Table 3-8:
Simulated Groundwater Discharge

	Target (L/s)	Simulated (L/s)	Comment
Mine Area Catchment			
IC-2.5	6.9/16	3.1	Lower than target
IC-3.0	7.3/16	11	Within range
HC-2.5	5.9/13	8.5	Within range
HC-5.0	11/24	18	Within range
ML-1.0	3.8/11	7.2	Within range
CC-6.0	3.8/8.6	4.4	Within range
CC-1.0	0.0/3.1	1.8	Within range
CC-1.5	9.3/21	13	Within range
CC-3.5	28/63	48	Within range
Other Catchments at Model Edges			
IC-1.5 (SW Boundary)	32/73	22	Simulated value should be approx. half target
IC-4.5 (W Boundary)	89/200	42	Simulated value should be approx. half target

3.3.3 Flow Directions and Potentiometric Map

The calibrated water table is shown in Figure 3-13 to Figure 3-15. The steepest hydraulic gradients are associated with changes in the recharge rate applied to permafrost areas in the southern portion of the model (compare with Figure 3-7) and with the boundary between Shallow and Deep Bedrock zones in Layer 2. The importance of the hydraulic conductivities in Layer 2 is due to the fact that in some of the higher elevation model grid cells, the water table occurs in Layer 2, as illustrated in the sections in Figure 3-14 and Figure 3-15. The model is able to predict the observed shape of the water table, including instances where the water table was observed to be below the bottom of the permafrost zone. For instance, this is evident in the eastern portion of Row 116 in Figure 3-14. At other areas, the much higher recharge through unfrozen bedrock leads to confined water tables beneath permafrost, even at relatively high elevations, such as in the central portions of Row 312. More commonly, confined or artesian heads occur at or near creek channels. The model is able to simulate strong vertical gradients favouring downward flow at higher elevations. However, given that the model contains only four layers, vertical gradients are generally not pronounced in the sections except where permafrost is present at higher elevations.



LEGEND

- Pre-Mine Water Table Contours (20m)
- Model Domain Boundary
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:125,000

0 2 4 Km

DATE SAVED:	May 13, 2016
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PROJECT:

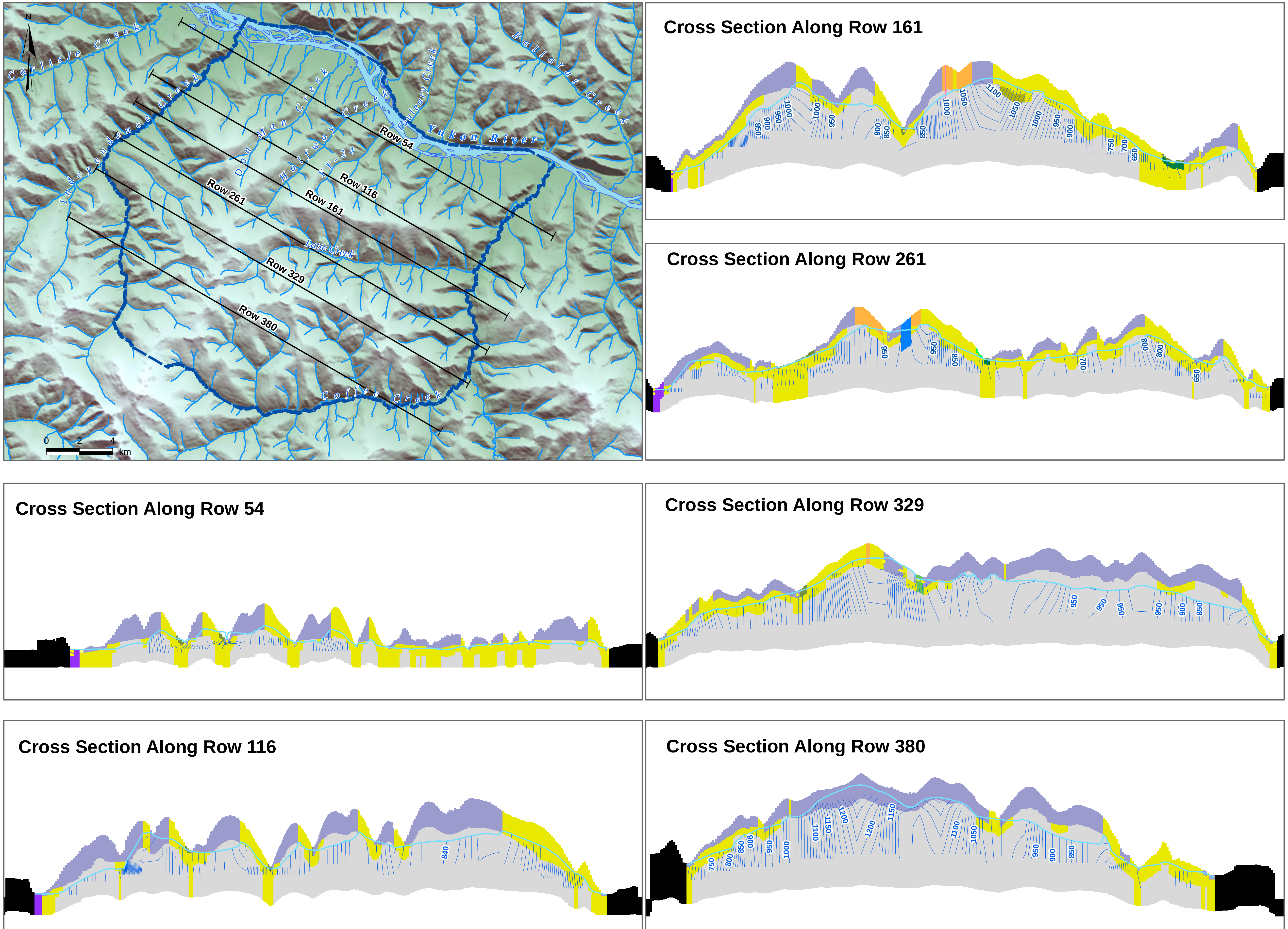
Coffee Gold Hydrogeology

TITLE:

Calibrated Water Table

PROJECT #:	*FIGURE:*
A362-5	3-13

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-13_Calibrated Water Table_20160513.mxd



LEGEND

- Head Contours (10m)
- Water Table
- Inactive Cell

K (m/s)

- Alluvium (1.0E-05)
- Shallow Bedrock (1.2E-07)
- Bedrock w WT PF bottom (1.2E-07)
- Zone @ MW14-02 L2-3b (1.7E-09)
- Deep Bedrock > 120m Depth (1.7E-09)
- Colluvium (3.0E-05)
- T3 Structure (2.0E-06)
- Latte Structure (1.0E-06)
- All Creek hi K zones L1 (6.0E-06)
- N Fault (5.0E-06)
- L2 Upper Latte (4.0E-06)
- L2 Lower Latte (3.0E-05)
- IC Creek Fault (3.0E-05)
- Permafrost (6.0E-10)

Vertical Exaggeration 5x
Horizontal Scale:

1:150,000

0 2 4 km

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TITLE:

Cross-Sections along Model Rows, Showing Calibrated Head Solution

PROJECT #:	*FIGURE:*
A362-5	3-14

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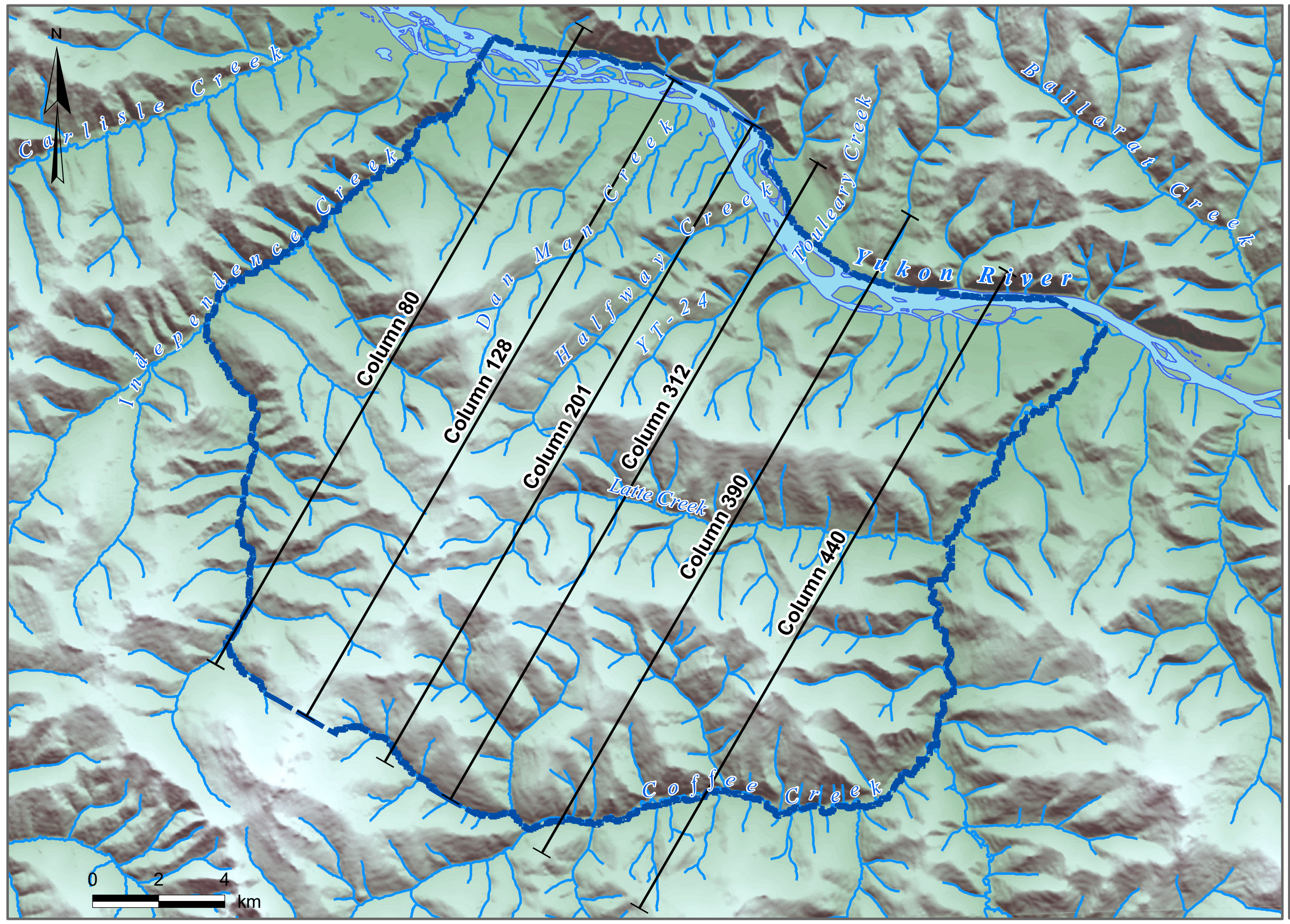
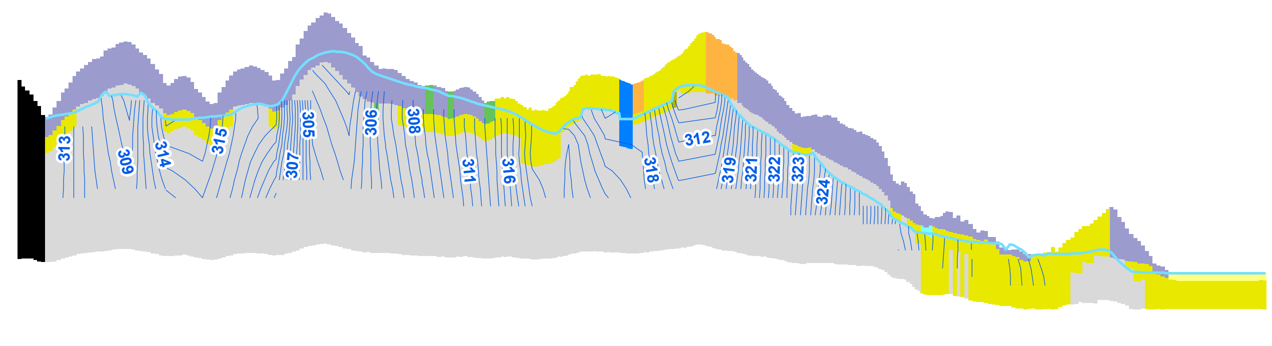
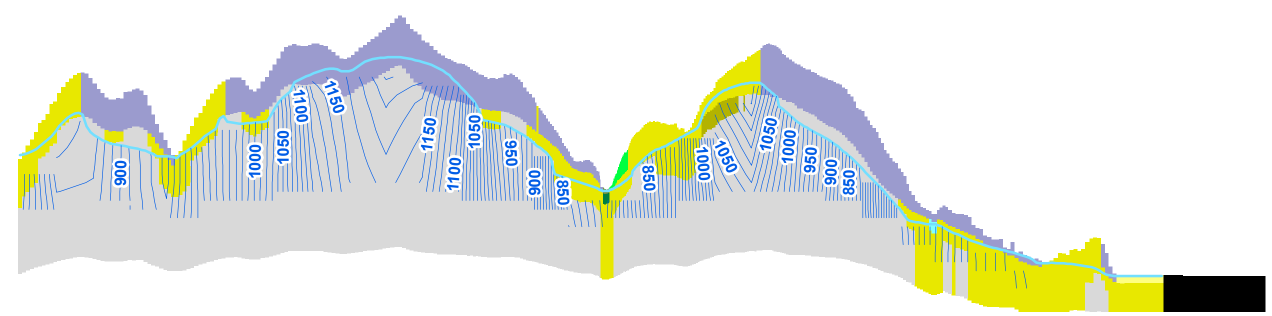


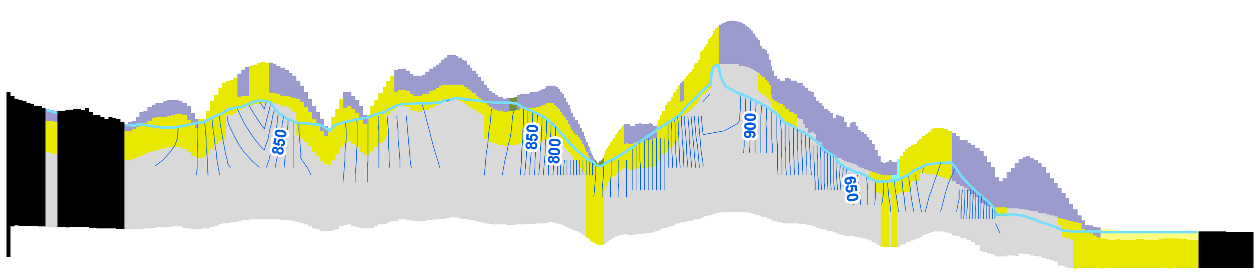
Cross Section Along Column 201



Cross Section Along Column 312



Cross Section Along Column 80



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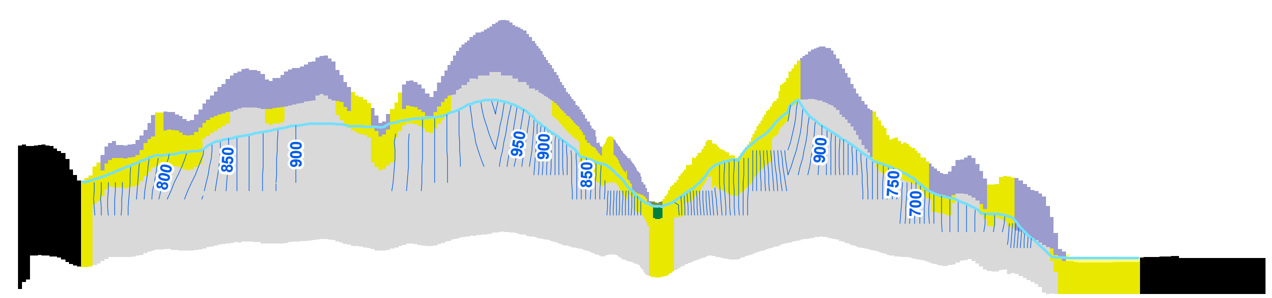

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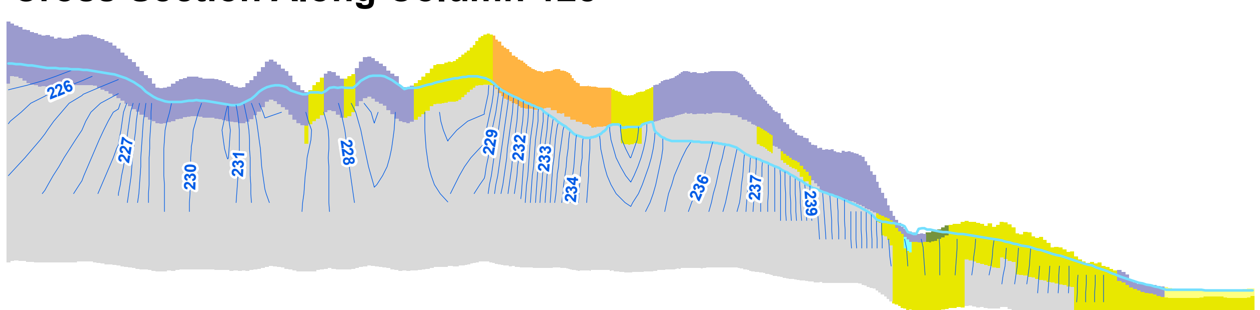
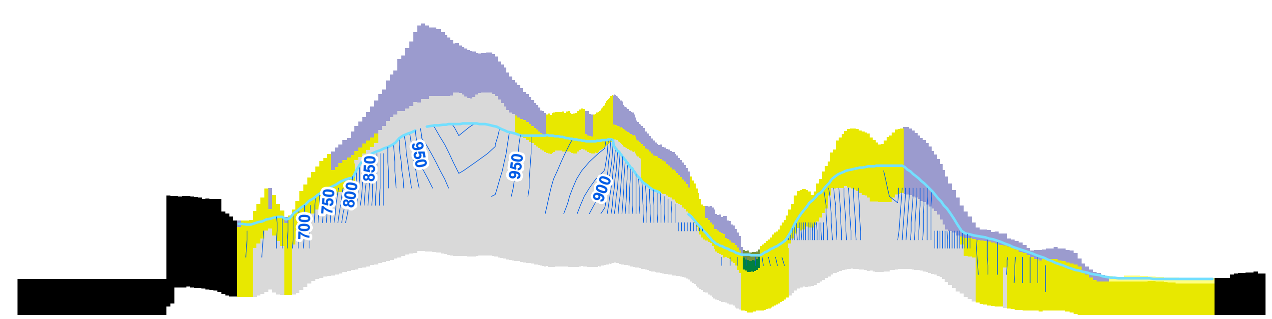


Cross Section Along Column 440



LEGEND

- Head Contours
- Water Table
- Inactive Cell

K (m/s)

- Alluvium (1.0E-05)
- Shallow Bedrock (1.2E-07)
- Bedrock w WT PF bottom (1.2E-07)
- Zone @ MW14-02 L2-3b (1.7E-09)
- Deep Bedrock > 120m Depth (1.7E-09)
- Colluvium (3.0E-05)
- T3 Structure (2.0E-06)
- Latte Structure (1.0E-06)
- All Creek hi K zones L1 (6.0E-06)
- N Fault (5.0E-06)
- L2 Upper Latte (4.0E-06)
- L2 Lower Latte (3.0E-05)
- IC Creek Fault (3.0E-05)
- Permafrost (6.0E-10)

Vertical Exaggeration 5x
Horizontal Scale:

1:135,000

0 2 4 km

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Coffee Gold Hydrogeology

TITLE:

Cross-Sections along Model Columns, Showing Calibrated Head Solution

PROJECT #:	*FIGURE:*
A362-5	3-15

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3.4 Sensitivity Analysis

As in all groundwater models, uncertainties remain in the model calibration. To address these uncertainties, a series of sensitivity runs were completed in which a single parameter was adjusted upward or downward to evaluate the importance of this parameter in the calibration result and in the model predictions. The discussion below focuses on the head and flux calibrations and the predicted steady state inflows to the pit lakes.

3.4.1 Sensitivity to Shallow Bedrock Hydraulic Conductivity

The hydraulic conductivity of the Shallow Bedrock zone has a significant impact on the head and flow calibration, as shown in Table 3-9, Table 3-10 and Figure 3-16 to Figure 3-18. Because of the large areal extent of this parameter zone, it has the greatest impact on simulated flows and head. Therefore, this parameter was varied by the smallest factor, as shown in Table 3-9 and Table 3-10. The parameter was increased by factors of five and two and decreased by a factor of two. An increase in the hydraulic conductivity by a factor of five depressed the water table by more than 120 m in areas within the model domain and as much as 60 m in parts of the Project area. Increasing the value of the Shallow Bedrock hydraulic conductivity by a factor of two reduced the water table by more than 80 m in parts of the model domain and as much as 30 m in the Project area. The residual mean changed from -1.7 m to -11.6 m, and the NRMSE rose from 1.7% to 3.1%. Reducing the hydraulic conductivity by a factor of two raises the water table by as much as 70 m in parts of the model domain and by as much as 30 m in the Project area. The residual mean rose from -1.7 m to 7.4 m and the NRSME rose to 2.5%. A further reduction in the Shallow Bedrock hydraulic conductivity led to excessive ponding at higher elevations, including the heap leach area and the southern portions of the Supremo pit system; therefore, the results of a run with the Shallow Bedrock hydraulic conductivity divided by five are not presented.

The Shallow Bedrock hydraulic conductivity also significantly affects groundwater discharge rates to CC-1.0, CC-6.0, and HC-2.5. This parameter has a similarly pronounced effect on the predicted pit inflows (see Section 4.3.1). However, the goodness of fit of the calibration is highly sensitive to small changes in this parameter, and the uncertainty around the calibrated value of 1.2×10^{-7} m/s is low compared to other model parameters due to the extreme changes in water level brought on by changes in this parameter.

Table 3-9:
Summary of Mass Balance from Shallow Bedrock K Sensitivity Runs

	Shallow Rx K x 5 ($6.0x10^{-7}$ m/s)	Shallow Rx K x 2 ($2.4x10^{-7}$ m/s)	Base Case ($1.2x10^{-7}$ m/s)	Shallow Rx K/2 ($6.0x10^{-8}$ m/s)
Model-Wide Inflow (L/s):				
Constant Head	192.4	192.3	192.0	192.7
Recharge	202.1	202.1	202.1	202.1
Total	394.5	394.4	394.1	394.9
Model-Wide Outflow (L/s)				
Constant Head	254.5	233.8	242.5	225.1
Drain	140.1	160.8	151.8	169.9
Total	394.6	394.5	394.2	395.0
Inflow-Outflow (L/s)	-0.07	-0.10	-0.15	-0.13
Inflow-Outflow (%)	-0.02	-0.02	-0.04	-0.03
Discharge to Streams (L/s)				
IC-2.5	0.0	2.0	3.1	4.3
IC-3.0	11	11	11	10
HC-2.5	6.2	7.9	8.5	8.9
HC-5.0	17	17	18	18
ML-1.0	7.1	7.1	7.2	7.3
CC-6.0	2.8	4.0	4.4	4.7
CC-1.0	0.0	1.0	1.8	2.2
CC-1.5	12	13	13	13
CC-3.5	45	47	48	48
IC-1.5	22	22	22	22
IC-4.5	41	41	42	42

**Table 3-10:
Head Calibration Statistics for Shallow Bedrock K Sensitivity**

Well Group	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All - Shallow Rx Kx5 ($6.0x10^{-7}$ m/s)	5.55%	-24.43	25.06
All - Shallow Rx Kx2($2.4x10^{-7}$ m/s)	3.06%	-11.65	13.06
All - Base Case ($1.2x10^{-7}$ m/s)	1.67%	-1.69	7.69
All - Shallow Rx K/2 ($6.0x10^{-8}$ m/s)	2.51%	7.44	11.01
HC - Shallow Rx Kx5	2.48%	-18.58	18.79
HC - Shallow Rx Kx2	1.61%	-10.90	12.37
HC - Base Case	1.04%	-1.94	8.85
HC - Shallow Rx K/2	1.43%	7.11	12.17
LC - Shallow Rx Kx5	8.73%	-25.36	27.21
LC - Shallow Rx Kx2	5.02%	-12.53	15.41
LC - Base Case	2.50%	-1.94	8.67
LC - Shallow Rx K/2	2.64%	5.56	8.31
YT-24 - Shallow Rx Kx5	15.62%	-43.69	43.69
YT-24 - Shallow Rx Kx2	7.58%	-18.38	18.38
YT-24 - Base Case	3.24%	-0.10	8.13
YT-24 - Shallow Rx K/2	8.65%	20.43	20.43
Duplicate - Shallow Rx Kx5	5.27%	-18.86	18.86
Duplicate - Shallow Rx Kx2	1.42%	-5.96	5.96
Duplicate - Base Case	0.80%	-2.06	3.17
Duplicate - Shallow Rx K/2	1.24%	0.25	5.06

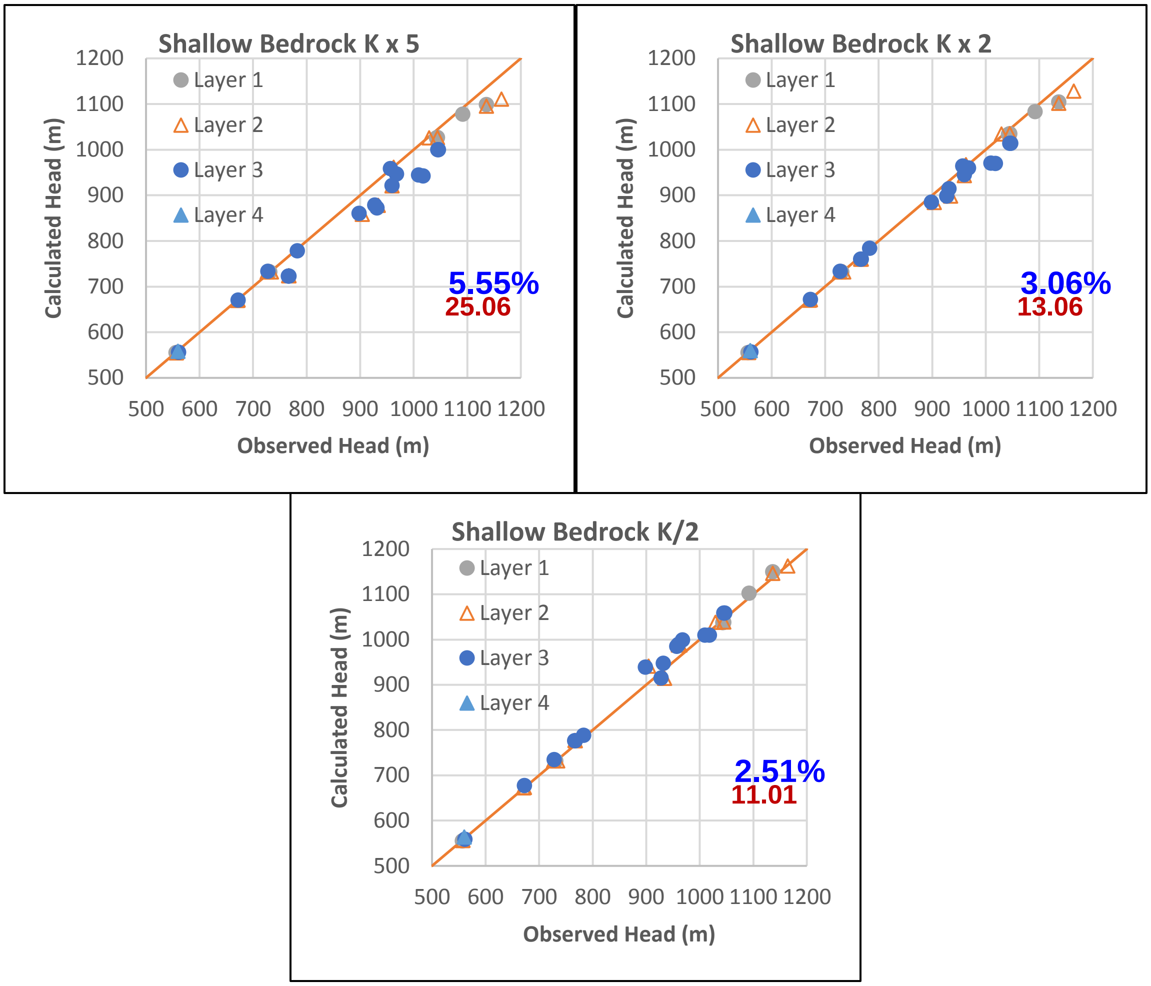
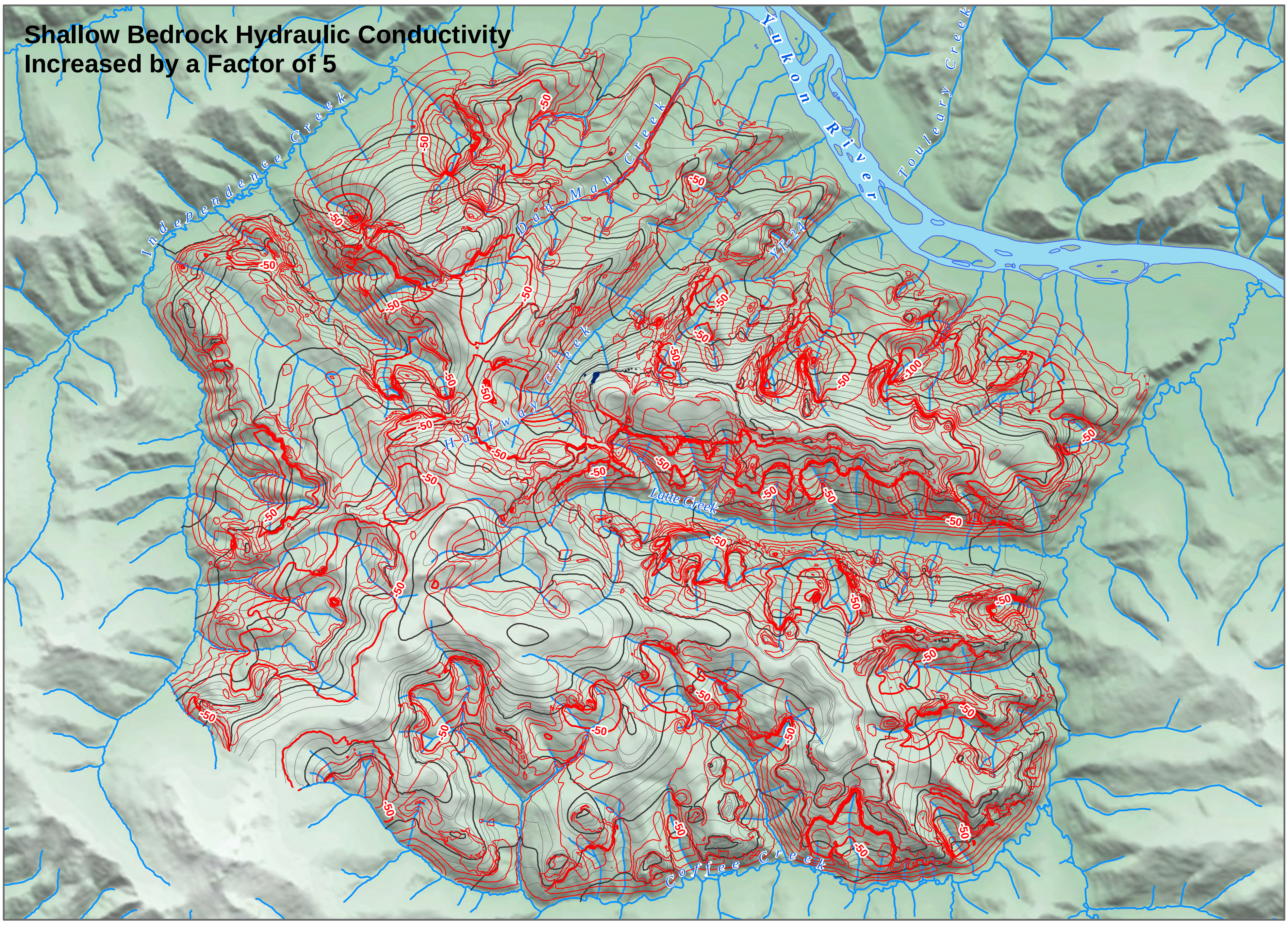
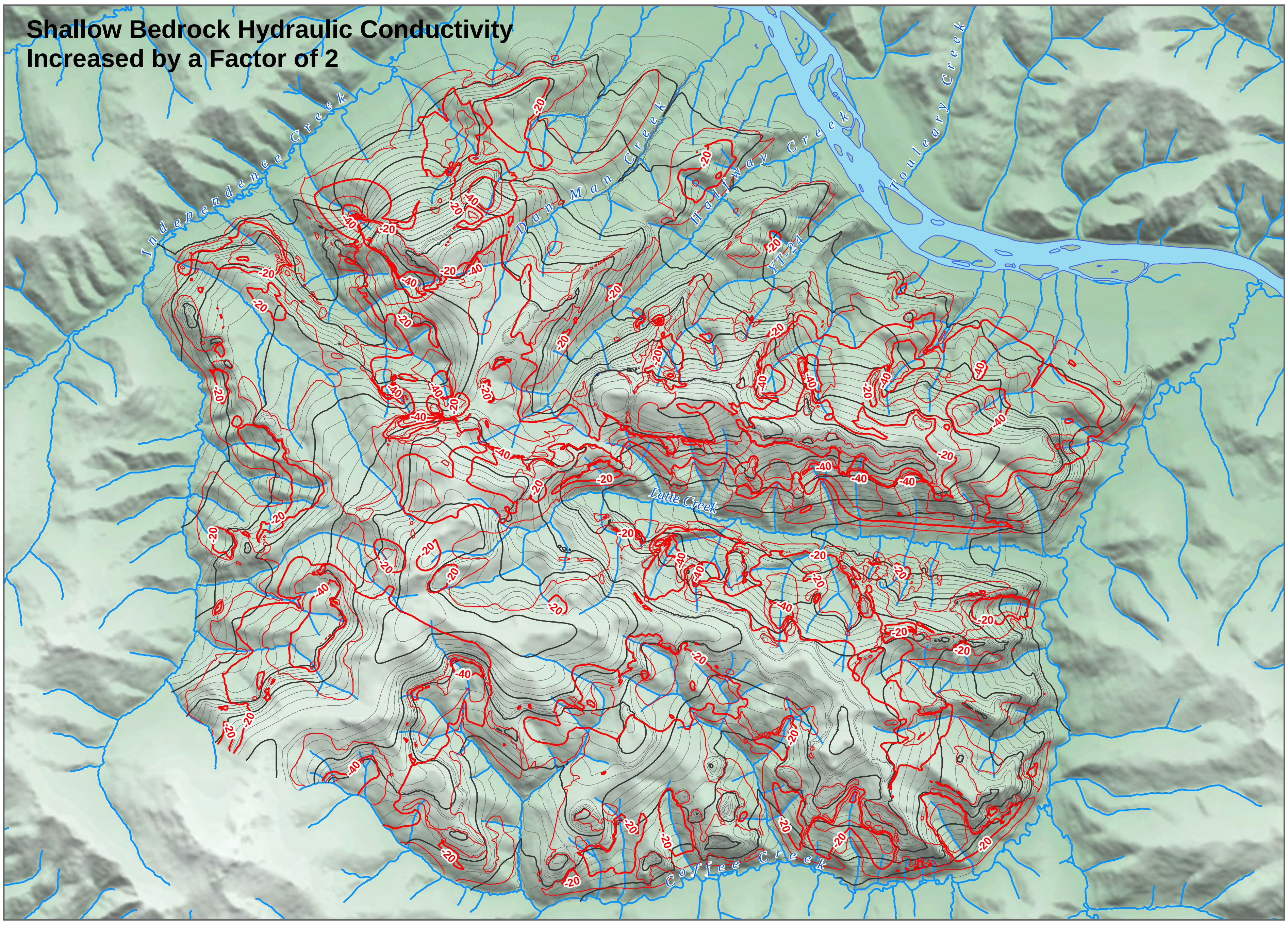


Figure 3-16: Head Calibration Results, Sensitivity of Shallow Bedrock Hydraulic Conductivity Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

Change in Head (m) from Base Case Model

- 10m Interval (>=10)
- 10m Interval (<=-10)

Simulated Premining Water Table for Sensitivity Run

- 100m
- 20m

DATE SAVED:	May 12, 2016
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Coordinate System: NAD 1983 UTM Zone 7N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

1:125,000

0 2 4 Kilometers

CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Change in Water Table Elevation with Increase in Shallow Bedrock Hydraulic Conductivity

PROJECT #: A362-5

FIGURE: 3-17

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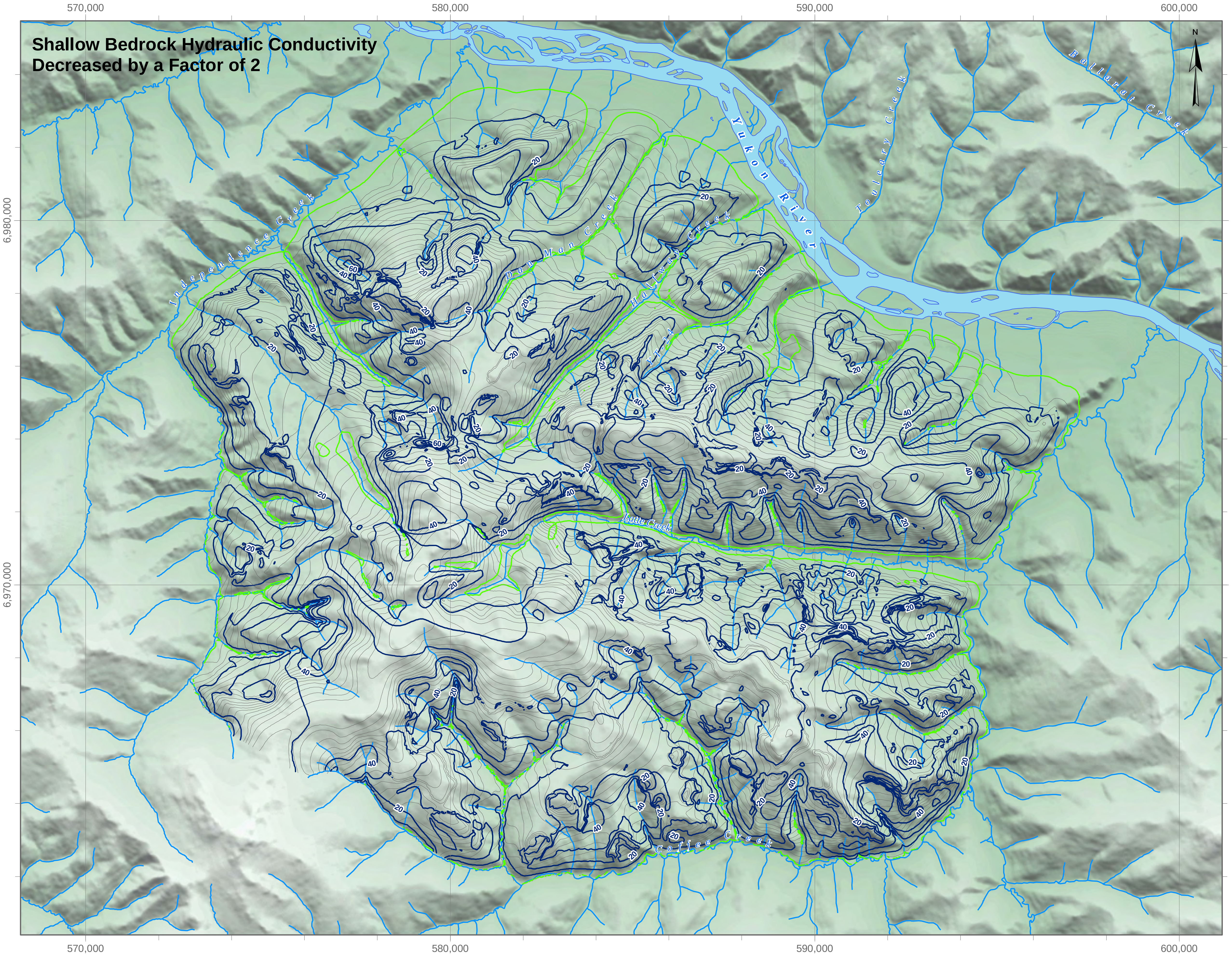

LEGEND

Change in Head (m) from Base Case Model

- 10m Interval (>=10)
- 10m Interval (<=-10)
- 1m
- -1m
- Simulated Premining Water Table for Sensitivity Run (20m)

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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TITLE:

Change in Water Table Elevation with Decrease in Shallow Bedrock Hydraulic Conductivity

PROJECT #:	*FIGURE:*
A362-5	3-18

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-18_Change in WT Elevation Shallow Bedrock decrease_20160512.mxd

3.4.2 Sensitivity to Deep Bedrock Hydraulic Conductivity

The results of the sensitivity analysis on the Deep Bedrock hydraulic conductivity are summarized in Table 3-11, Table 3-12, Figure 3-19, and Figure 3-20. This parameter has a significant effect on the head solution, and increasing or decreasing it by a factor of five has a noticeable impact on the model's goodness-of-fit to observed head values. Raising the Deep Bedrock hydraulic conductivity by a factor of five from 1.7×10^{-9} m/s to 8.5×10^{-9} m/s lowers the water table by as much as 160 m within the model domain and as much as 120 m in the mine area. At well locations, raising the Deep Bedrock hydraulic conductivity causes the residual mean to drop to -16.9 m from -1.7 m. Because the Deep Bedrock zone does not extend all the way to the major discharge zones—Independence Creek, Coffee Creek and the Yukon River—the head gradient becomes relatively steeper along major stream channels compared to the calibrated model, resulting in an increase in head in these areas. When the Deep Bedrock hydraulic conductivity was reduced by a factor of two to 8.5×10^{-10} m/s, the water table in the model domain rises by as much as 100 m and as much as 60 m in the mine area. A further reduction in the hydraulic conductivity of Deep Bedrock yielded water table elevations that significantly exceeded ground elevations in the southern portions of the model, south of the heap leach area. For this reason, the minimum value of this parameter presented here is a reduction by a factor of two.

This parameter affects the predicted groundwater discharge rates to CC-6.0 and CC-1.0. A higher Deep Bedrock hydraulic conductivity results in lower water tables and consequently lower discharge rates of groundwater to surface water. Reducing the hydraulic conductivity of this parameter by a factor of five raises the water table and results in increases in baseflow in some locations. As for the Shallow Bedrock hydraulic conductivity, the degree of uncertainty around the calibrated value is relatively low compared to other model parameters due to its significant impact on simulated groundwater elevations.

Table 3-11:
Summary of Mass Balance from Deep Bedrock K Sensitivity Runs

	Deep Rx K x 5 (8.5x10^{-9} m/s)	**Base Case (1.7x10^{-9} m/s)**	**Deep Rx K/2 \(8.5x10^{-10} m/s)**
Model-Wide Inflow (L/s):			
Constant Head	192.1	192.0	192.0
Recharge	202.1	202.1	202.1
Total	394.2	394.1	394.1
Model-Wide Outflow (L/s)			
Constant Head	241.4	242.5	241.8
Drain	153.2	151.8	152.9
Total	394.7	394.2	394.8
Inflow-Outflow (L/s)	-0.49	-0.15	-0.60
Inflow-Outflow (%)	-0.12	-0.04	-0.15
Discharge to Streams (L/s)			
IC-2.5	1.9	3.1	3.4
IC-3.0	12	11	10
HC-2.5	8.3	8.5	8.7
HC-5.0	18	18	18
ML-1.0	7.0	7.2	7.3
CC-6.0	2.1	4.4	4.7
CC-1.0	1.1	1.8	1.8
CC-1.5	12	13	13
CC-3.5	45	48	48
IC-1.5	23	22	22
IC-4.5	43	42	42

Table 3-12:
Head Calibration Statistics for Deep Bedrock K Sensitivity

Well Group	**Normalized Root mean squared**	**Residual Mean (m)**	**Absolute Residual Mean (m)**
All - Deep Rx Kx5 (8.5x10^{-9} m/s)	4.93%	-16.89	18.38
All - Base Case (1.7x10^{-9} m/s)	1.67%	-1.69	7.69
All - Deep Rx K/5 (3.4x10^{-10} m/s)	2.51%	3.25	9.90
HC - Deep Rx Kx5	2.88%	-20.46	21.05
HC - Base Case	1.04%	-1.94	8.85
HC - Deep Rx K/5	1.87%	4.49	13.40
LC - Deep Rx Kx5	5.63%	-13.03	17.28
LC - Base Case	2.50%	-1.94	8.67
LC - Deep Rx K/5	2.11%	-0.02	7.56
YT-24 - Deep Rx Kx5	16.29%	-31.93	31.93
YT-24 - Base Case	3.24%	-0.10	8.13
YT-24 - Deep Rx K/5	5.42%	13.20	13.20
Duplicate - Deep Rx Kx5	0.69%	-2.95	2.95
Duplicate - Base Case	0.80%	-2.06	3.17
Duplicate - Deep Rx K/5	0.92%	-2.32	3.57

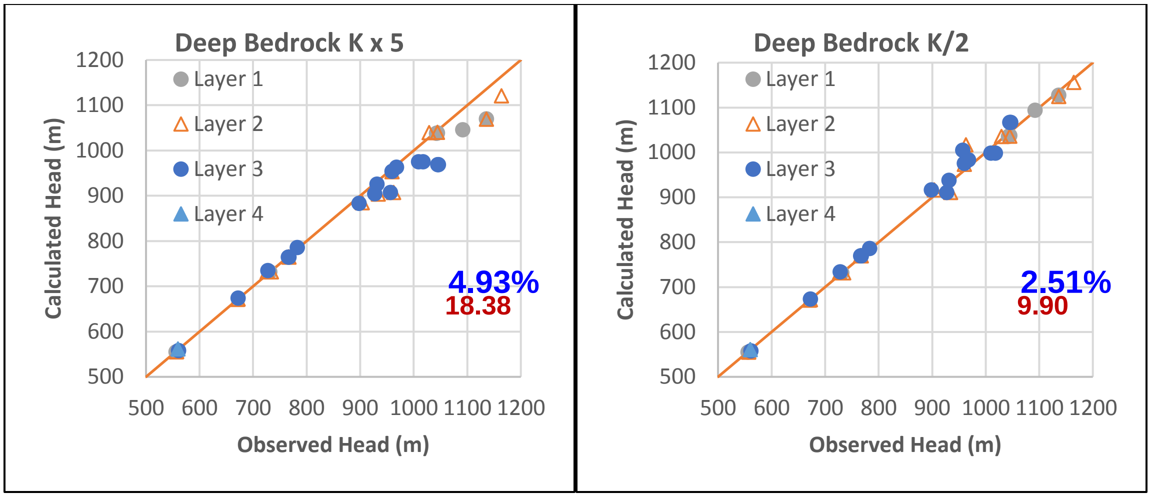
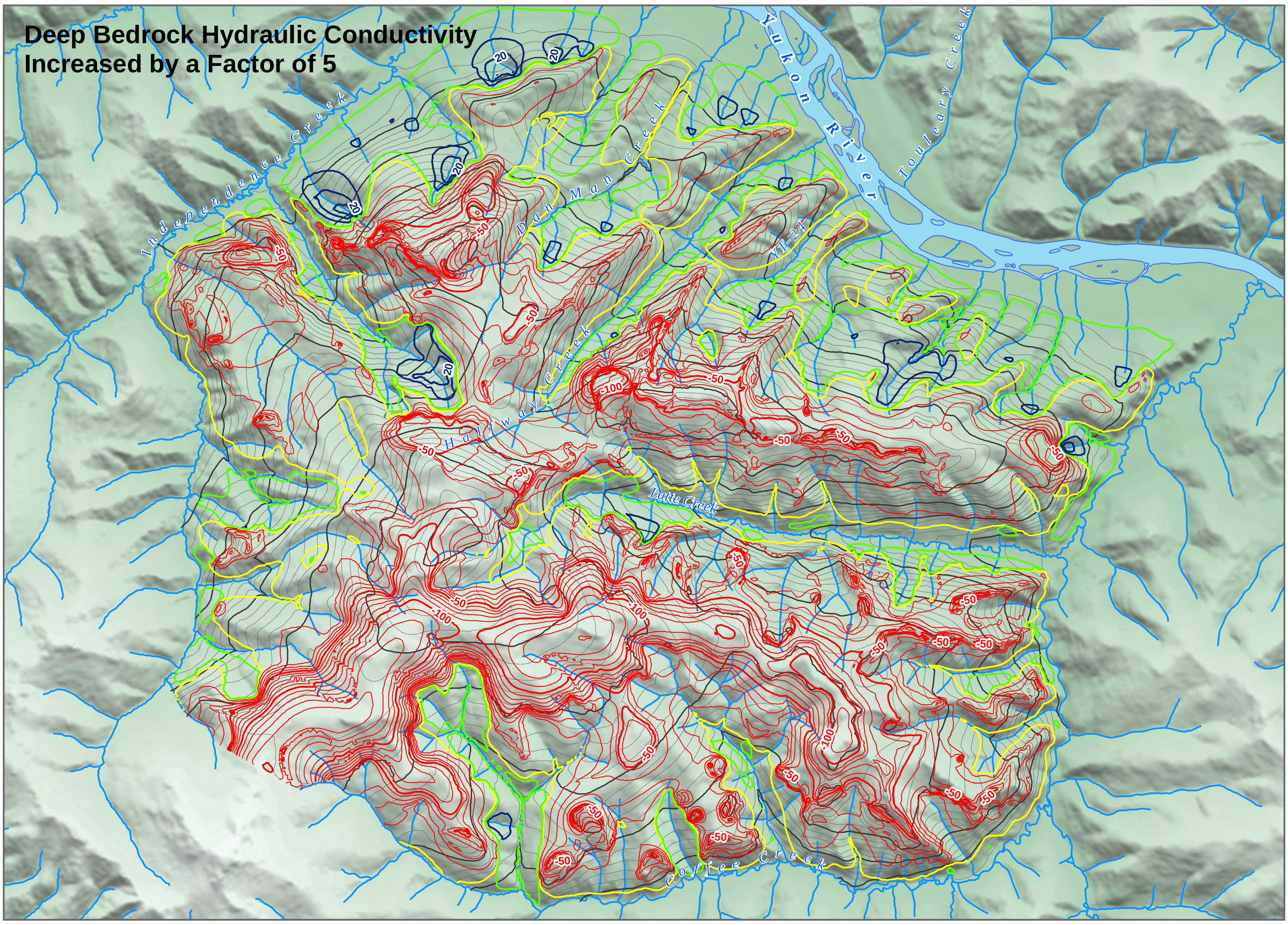
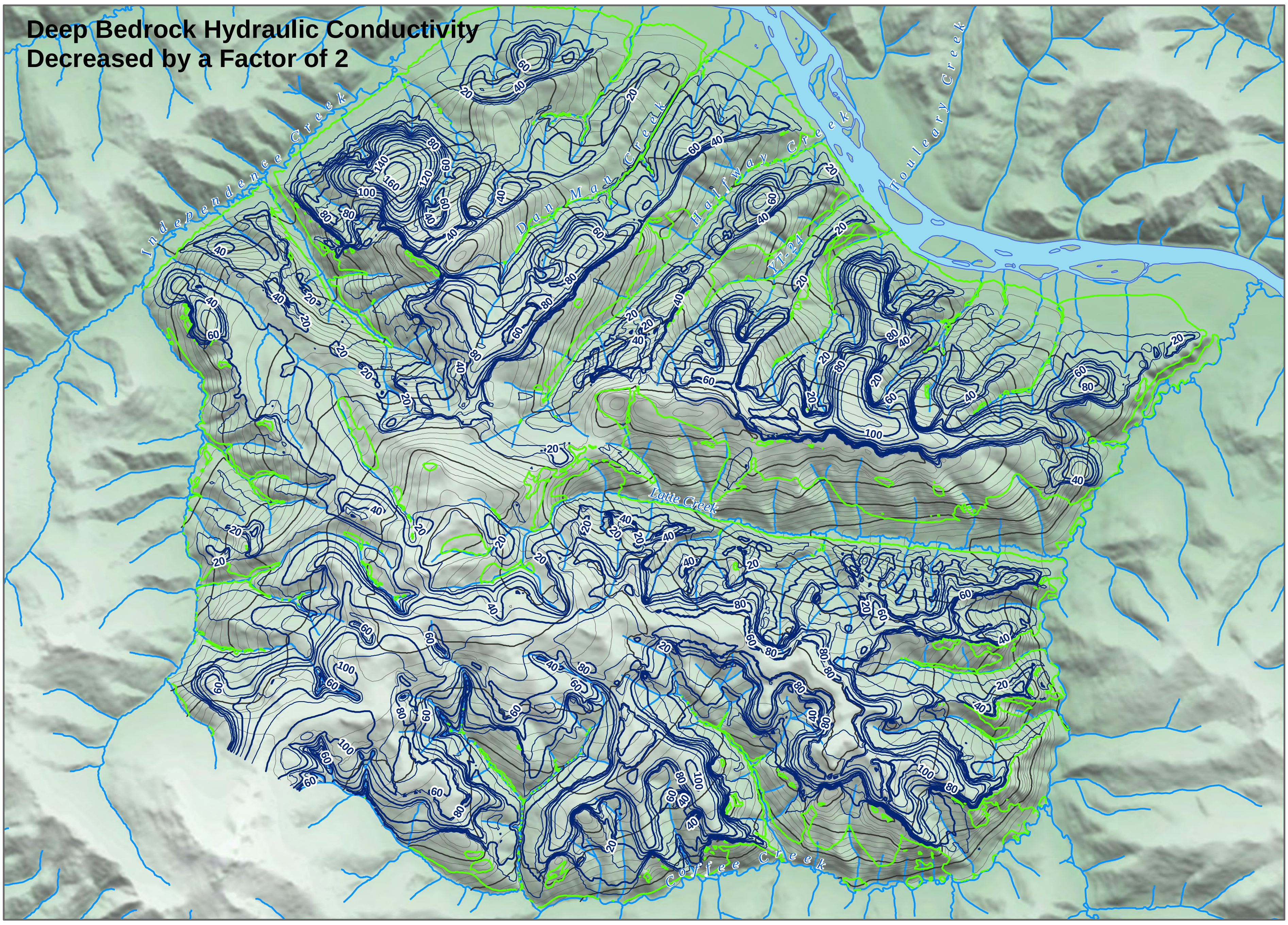


Figure 3-19: Head Calibration Results, Sensitivity of Deep Bedrock Hydraulic Conductivity Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

Change in Head (m) from Base Case Model
- 10m Interval (>=10)
- 10m Interval (<=-10)
- 1m
- -1m

Simulated Premining Water Table for Sensitivity Run
- 100m
- 20m

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Units: *Meter*

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TITLE:

Change in Water Table Elevation with Change in Deep Bedrock Hydraulic Conductivity

PROJECT #: A362-5 *FIGURE:* 3-20

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-20_Change in WT Elevation Deep Bedrock_20160513.mxd

3.4.3 Sensitivity to T3 Structure Hydraulic Conductivity

The hydraulic conductivity of the T3 Structure has a relatively minor effect on both the head and flow calibration, as shown in Table 3-13, Table 3-14 and Figure 3-21. The hydraulic conductivity of this material was selected to be at least as high as the arithmetic mean hydraulic conductivity of $7x10^{-7}$ m/s reported by SRK (2015). The best fit value using this constraint was $2x10^{-6}$ m/s. Raising the T3 Structure hydraulic conductivity from $2.0x10^{-6}$ m/s to $2.0x10^{-5}$ m/s reduces the water table elevation along most of the trace of this fault zone except at the northern and southern ends, where it slightly raises the water table elevation. Enhanced-permeability linear features tend to behave this way because of their tendency to flatten the water table along their linear extent. The maximum reduction in predicted water level elevation as a result of increasing the T3 Structure hydraulic conductivity is 46 m, within the simulated fault zone. However, this drop in head does not significantly affect any of the predicted heads at monitoring wells and hence does not noticeably affect the calibration.

There is a much wider range of head change due to a reduction in the T3 Structure hydraulic conductivity, with a maximum increase in head of approximately 55 m within the center of the simulated structure and a drop in head of as much as a 55 m at the northern end of the T3 Structure. Another zone of head decrease is observed at the southern end of the structure. The reduction in head is due to the fact that at a lower hydraulic conductivity, this structure is not able to transmit a high water table to its extremities, especially the northern, lower elevation portion of its trace. It can be seen in both Figure 3-22 and Table 3-14 that lowering the T3 Structure hydraulic conductivity has a more pronounced negative impact on both the calibration statistics and the predicted water table than raising the T3 Structure hydraulic conductivity. The hydraulic conductivity of this parameter does not significantly affect groundwater discharge rates to Project area creeks (Table 3-13).

The T3 Structure runs through the proposed Supremo 1, 2 and 3 pits. As a consequence, the hydraulic conductivity of this parameter zone has a significant influence on predicted flows into and out of the proposed pits (see Section 4.3).

Table 3-13:
Summary of Mass Balance from T3 Structure K Sensitivity Runs

	T3 Structure K x 10 ($2.0x10^{-5}$ m/s)	Base Case ($2.0x10^{-6}$ m/s)	T3 StructureK/10 ($2.0x10^{-7}$ m/s)
Model-Wide Inflow (L/s):			
Constant Head	192.0	192.0	192.0
Recharge	202.1	202.1	202.1
Total	394.1	394.1	394.1
Model-Wide Outflow (L/s)			
Constant Head	242.5	242.5	242.5
Drain	152.0	151.8	151.8
Total	394.5	394.2	394.2
Inflow-Outflow (L/s)	-0.39	-0.15	-0.13
Inflow-Outflow (%)	-0.10	-0.04	-0.03
Discharge to Streams (L/s)			
IC-2.5	3.1	3.1	3.1
IC-3.0	11	11	11
HC-2.5	8.5	8.5	8.6
HC-5.0	18	18	18
ML-1.0	7.2	7.2	7.3
CC-6.0	4.4	4.4	4.4
CC-1.0	1.9	1.8	1.7
CC-1.5	13	13	13
CC-3.5	48	48	48
IC-1.5	22	22	22
IC-4.5	42	42	42

Table 3-14:
Head Calibration Statistics for T3 Structure K Sensitivity

Well Group	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All - T3 Structure Kx10 ($2.0x10^{-5}$ m/s)	1.71%	-2.75	7.45
All - Base Case ($2.0x10^{-6}$ m/s)	1.67%	-1.69	7.69
All - T3 Structure K/10 ($2.0x10^{-7}$ m/s)	2.18%	0.98	8.70
HC - T3 Structure Kx10	0.95%	-3.32	7.50
HC - Base Case	1.04%	-1.94	8.85
HC - T3 Structure K/10	1.68%	2.12	12.86
LC - T3 Structure Kx10	2.95%	-2.99	9.78
LC - Base Case	2.50%	-1.94	8.67
LC - T3 Structure K/10	1.97%	-0.03	6.81
YT-24 - T3 Structure Kx10	3.29%	-1.50	7.83
YT-24 - Base Case	3.24%	-0.10	8.13
YT-24 - T3 Structure K/10	3.24%	3.44	8.15
Duplicate - T3 Structure Kx10	0.78%	-2.21	3.05
Duplicate - Base Case	0.80%	-2.06	3.17
Duplicate - T3 Structure K/10	0.83%	-1.82	3.47

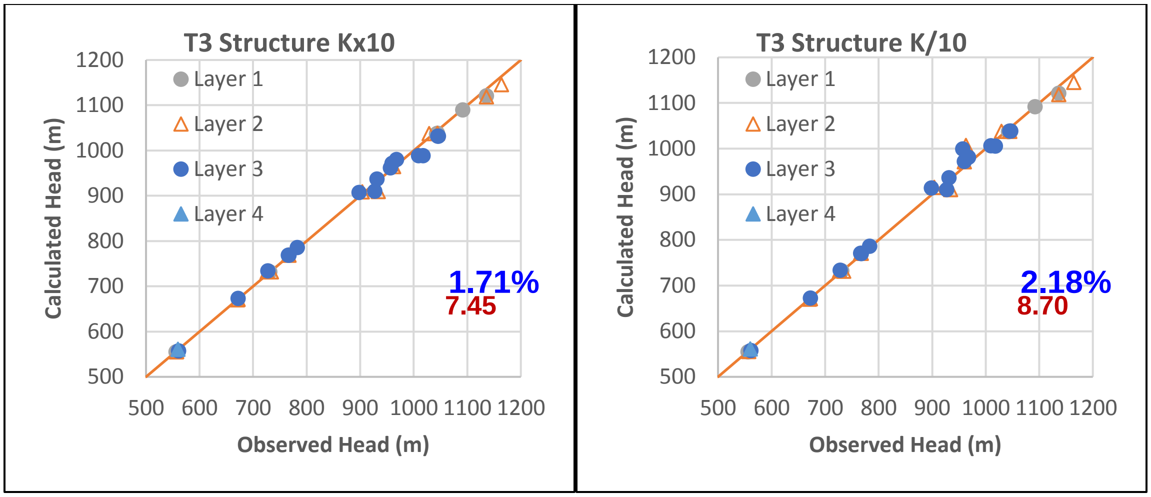
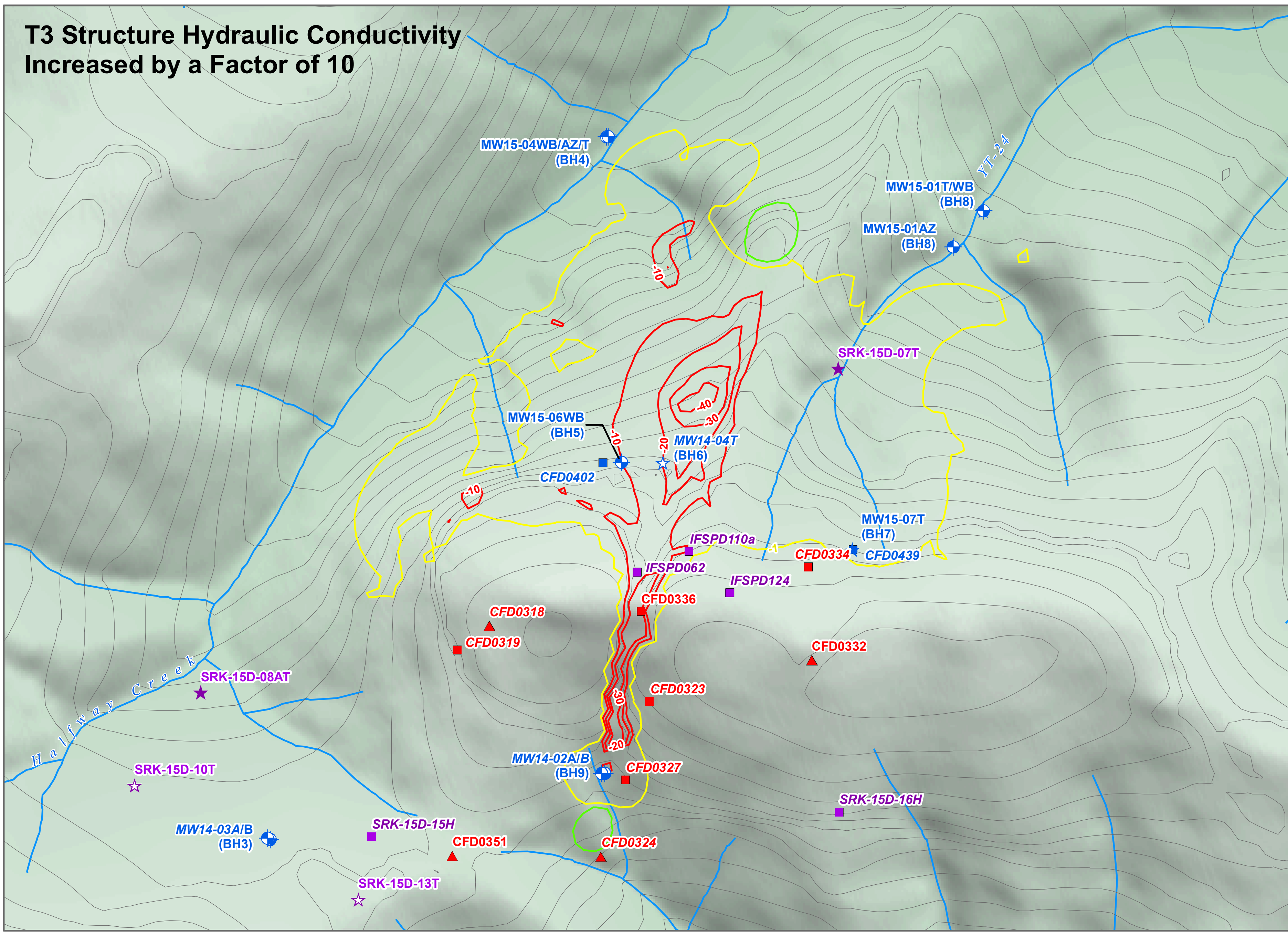
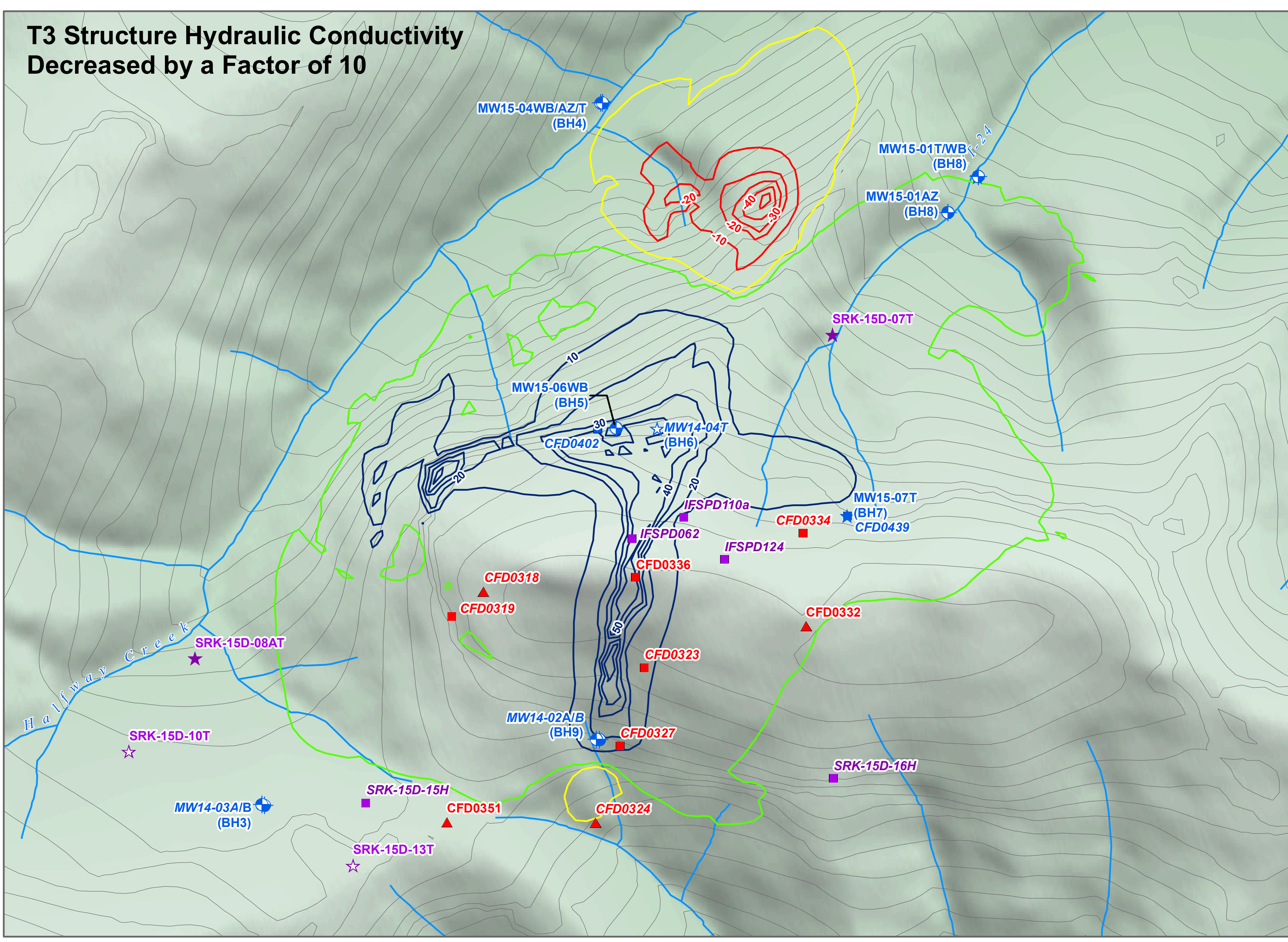


Figure 3-21: Head Calibration Results, Sensitivity of T3 Structure Hydraulic Conductivity Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

- Monitoring Well
- 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)

Change in Head (m) from Base Case Model

- 10m Interval (>=10)
- 10m Interval (<=-10)
- 1m
- -1m
- Simulated Premining Water Table for Sensitivity Run

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Coffee Gold Hydrogeology

TITLE:

Change in Water Table Elevation with Change in T3 Hydraulic Conductivity

PROJECT #: A362-5

FIGURE: 3-22

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-22_Change in WT Elevation T3_20160512.mxd

3.4.4 Sensitivity to Latte Structure Hydraulic Conductivity

As with the T3 Structure, the hydraulic conductivity of the Latte Structure was constrained in the calibration to be at least as high as the arithmetic mean hydraulic conductivity of $7x10^{-7}$ m/s measured for this structure. A calibrated hydraulic conductivity of $1x10^{-6}$ m/s was selected for this parameter. Although the zone of impact of this parameter is minor (see Figure 3-24), the sensitivity analysis on the Latte Structure hydraulic conductivity indicates that an order of magnitude increase in the hydraulic conductivity of this structure to $1x10^{-5}$ m/s leads to a slight reduction in the NRMSE, indicating a better overall calibration. This improvement in model goodness of fit is primarily due to a better prediction of head at monitoring wells CFD351, MW14-03A, MW14-03B and CFD324, at which the hydraulic head is overestimated in the base case model (see Table 3-6). However, a Latte Structure hydraulic conductivity of $1x10^{-5}$ m/s is higher than the field data suggest (SRK, 2015).

Figure 3-24 shows that the magnitude of the water table change due to an increase in the Latte Structure hydraulic conductivity is lower than any of the parameters tested in Sections 3.4.1 to 3.4.3. A maximum drop in head of 14 m is observed in the immediate vicinity of the Latte structure when its hydraulic conductivity is raised to $1x10^{-5}$ m/s. A maximum water table rise of 24 m is observed in the Latte structure when its hydraulic conductivity is lowered to $1x10^{-7}$ m/s. These changes lead to minor effects on the baseflow estimates and on the overall head calibration statistics. Like the T3 Structure, the Latte Structure has an important impact on the pit predictions (see Section 4.3).

Table 3-15:
Summary of Mass Balance from Latte Structure K Sensitivity Runs

	Latte Structure K x 10 (1.0x10^{-5} m/s)	Base Case (1.0x10^{-6} m/s)	Latte Structure K/10 (1.0x10^{-7} m/s)
Model-Wide Inflow (L/s):			
Constant Head	192.0	192.0	192.0
Recharge	202.1	202.1	202.1
Total	394.1	394.1	394.1
Model-Wide Outflow (L/s)			
Constant Head	242.5	242.5	242.5
Drain	151.7	151.8	151.8
Total	394.2	394.2	394.2
Inflow-Outflow (L/s)	-0.10	-0.15	-0.14
Inflow-Outflow (%)	-0.03	-0.04	-0.04
Discharge to Streams (L/s)			
IC-2.5	3.1	3.1	3.1
IC-3.0	11	11	11
HC-2.5	8.7	8.5	8.4
HC-5.0	18	18	18
ML-1.0	7.2	7.2	7.2
CC-6.0	4.4	4.4	4.4
CC-1.0	1.7	1.8	1.8
CC-1.5	13	13	13
CC-3.5	48	48	48
IC-1.5	22	22	22
IC-4.5	42	42	42

Table 3-16:
Head Calibration Statistics forLatte Structure K Sensitivity

Well Group	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All - Latte Structure Kx10 (1x10^{-5} m/s)	1.64%	-2.42	7.26
All - Base Case (1x10^{-6} m/s)	1.67%	-1.69	7.69
All - Latte Structure K/10 (1x10^{-7} m/s)	1.75%	-1.35	7.96
HC - Latte Structure Kx10	1.02%	-2.93	8.34
HC - Base Case	1.04%	-1.94	8.85
HC - Latte Structure K/10	1.04%	-2.02	8.81
LC - Latte Structure Kx10	2.43%	-3.14	7.86
LC - Base Case	2.50%	-1.94	8.67
LC - Latte Structure K/10	2.83%	-0.74	9.59
YT-24 - Latte Structure Kx10	3.24%	-0.13	8.13
YT-24 - Base Case	3.24%	-0.10	8.13
YT-24 - Latte Structure K/10	3.24%	-0.08	8.13
Duplicate - Latte Structure Kx10	0.80%	-2.06	3.17
Duplicate - Base Case	0.80%	-2.06	3.17
Duplicate - Latte Structure K/10	0.79%	-2.05	3.17

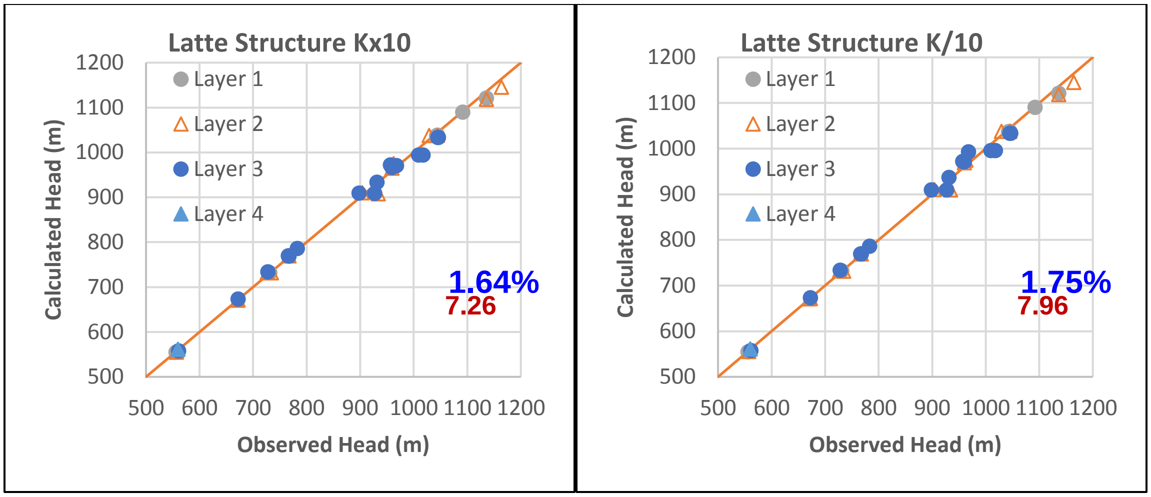
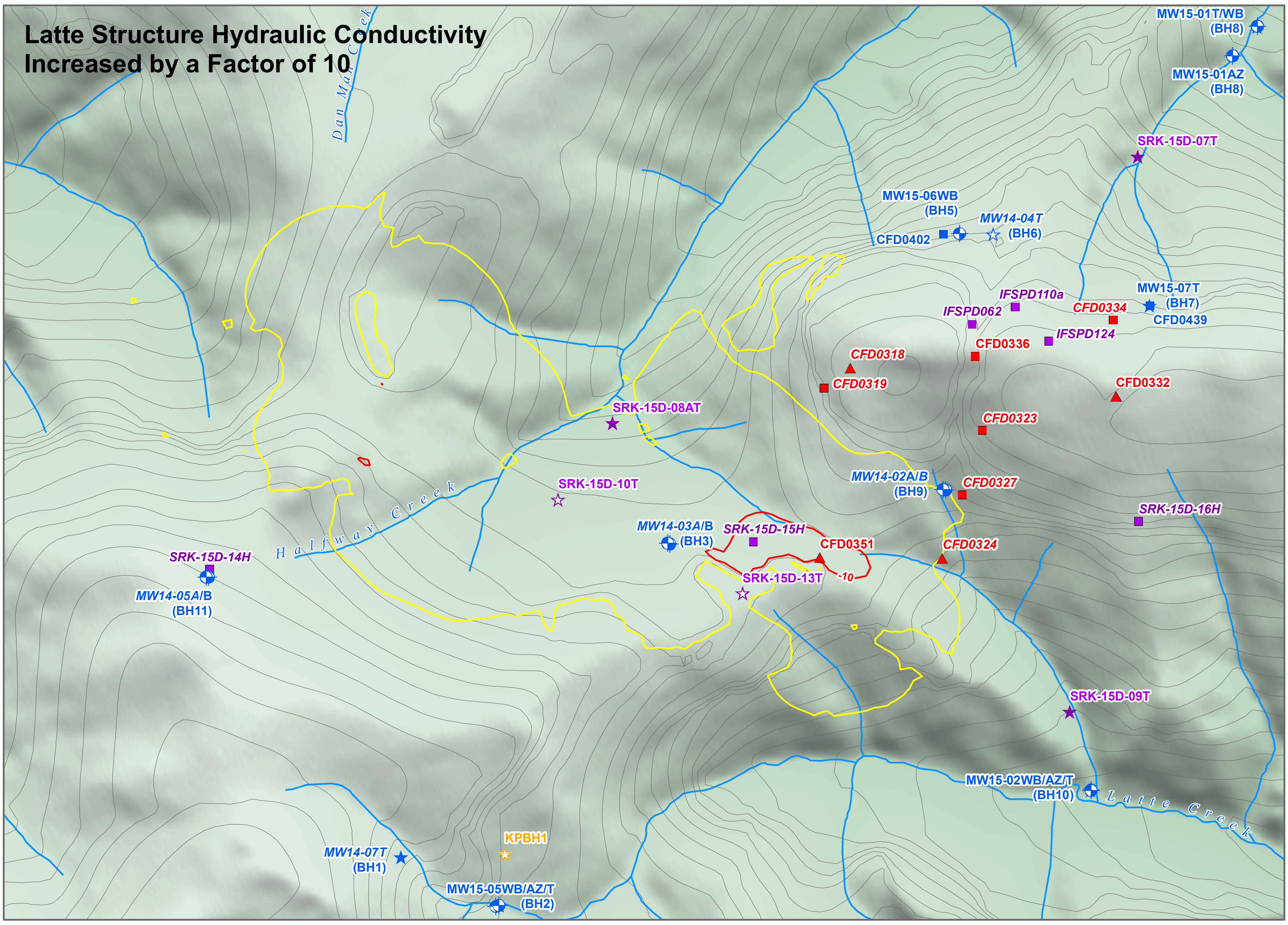
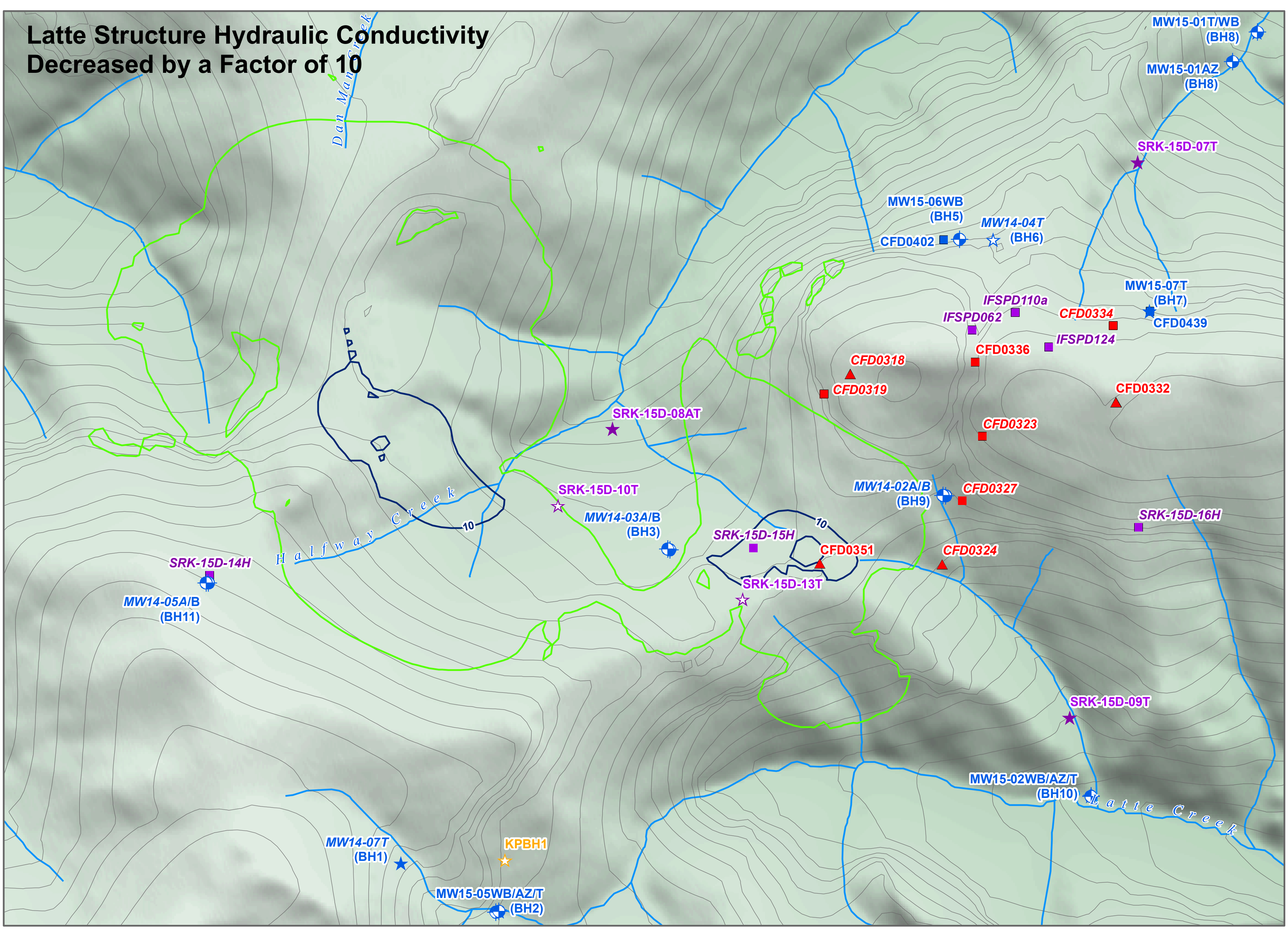


Figure 3-23: Head Calibration Results, Sensitivity of Latte Structure Hydraulic Conductivity Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

- Monitoring Well
- 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)

Change in Head (m) from Base Case Model

- 10m Interval (>=10)
- 10m Interval (<=-10)
- 1m
- -1m
- Simulated Premining Water Table for Sensitivity Run

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TITLE:

Change in Water Table Elevation with Change in Latte Structure Hydraulic Conductivity

PROJECT #: A362-5

FIGURE: 3-24

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-24_Change in WT Elevation Latte_20160513.mxd

3.4.5 Sensitivity to Non-Permafrost Recharge

Recharge rates on non-permafrost areas were raised and lowered by 30% to evaluate the importance of this parameter in the calibration and predictions. The upper bound recharge corresponds to 19.8% of mean annual precipitation (MAP) as a function of elevation. The lower bound recharge corresponds to 10.6% of MAP. Recharge has an easily observable influence on all aspects of the calibration and prediction, as shown in Table 3-17, Table 3-18, Figure 3-25, and Figure 3-26. When the recharge rate was increased to 19.8% of MAP, the water table rose by up to 55 m in the model domain and rose by a typical value of 10 m in the Project area. This increase in recharge results in a 30% to 60% increase in baseflows, with the highest percentage increase observed at CC-1.0. When the recharge rate was decreased to 10.6% of MAP, the water table in the Project area dropped on average by 10 m, and the baseflows to creeks dropped 30% to 60%, again with the greatest impact observed at CC-1.0. In both cases, the calibration statistics are poorer than for the base case. The optimal value of this parameter is relatively well-constrained by the calibration targets due to its strong impact on both groundwater heads and baseflows.

The value of recharge applied to the model also impacts the pit lake inflow predictions (see Section 4.3), but to a lower degree than the T3 and Latte Structures and the Shallow and Deep Bedrock units.

Table 3-17:
Summary of Mass Balance from Non-Permafrost Recharge Sensitivity Runs

	Non-Permafrost Recharge +30% (19.8% MAP)	**Base Case (15.2% MAP)**	**Non-Permafrost Recharge +30% (10.6% MAP)**
Model-Wide Inflow (L/s):			
Constant Head	191.7	192.0	192.4
Recharge	260.9	202.1	143.3
Total	452.6	394.1	335.7
Model-Wide Outflow (L/s)			
Constant Head	251.9	242.5	232.5
Drain	200.8	151.8	103.3
Total	452.7	394.2	335.8
Inflow-Outflow (L/s)	-0.10	-0.15	-0.09
Inflow-Outflow (%)	-0.02	-0.04	-0.03
Discharge to Streams (L/s)			
IC-2.5	4.6	3.1	1.7
IC-3.0	14	11	8
HC-2.5	11.5	8.5	5.6
HC-5.0	23	18	12
ML-1.0	9.5	7.2	5.0
CC-6.0	5.9	4.4	2.9
CC-1.0	2.8	1.8	0.8
CC-1.5	18	13	8
CC-3.5	65	48	31
IC-1.5	28	22	16
IC-4.5	54	42	30

Table 3-18:
Head Calibration Statistics for Non-Permafrost Recharge Sensitivity

Well Group	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All - Non-PF Recharge+30%	2.01%	3.98	8.84
All - Base Case	1.67%	-1.69	7.69
All - Non-PF Recharge-30%	2.49%	-9.34	10.10
HC - Non-PF Recharge+30%	1.30%	3.75	10.48
HC - Base Case	1.04%	-1.94	8.85
HC - Non-PF Recharge-30%	1.30%	-8.88	8.94
LC - Non-PF Recharge+30%	2.25%	2.71	8.02
LC - Base Case	2.50%	-1.94	8.67
LC - Non-PF Recharge-30%	4.01%	-9.34	11.82
YT-24 - Non-PF Recharge+30%	5.29%	10.84	11.62
YT-24 - Base Case	3.24%	-0.10	8.13
YT-24 - Non-PF Recharge-30%	6.31%	-14.22	14.22
Duplicate - Non-PF Recharge+30%	1.11%	0.76	4.36
Duplicate - Base Case	0.80%	-2.06	3.17
Duplicate - Non-PF Recharge-30%	1.50%	-6.14	6.14

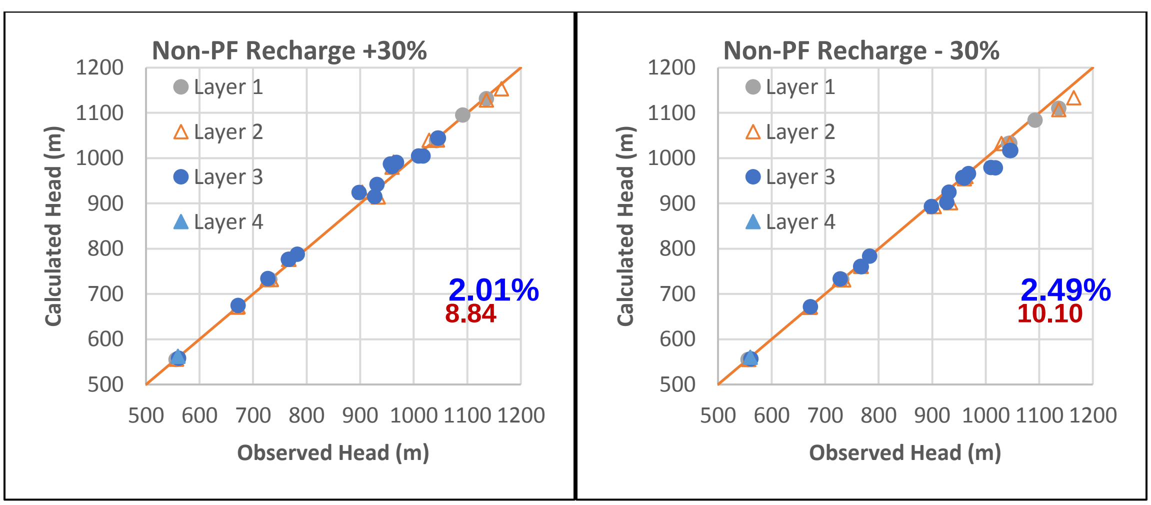
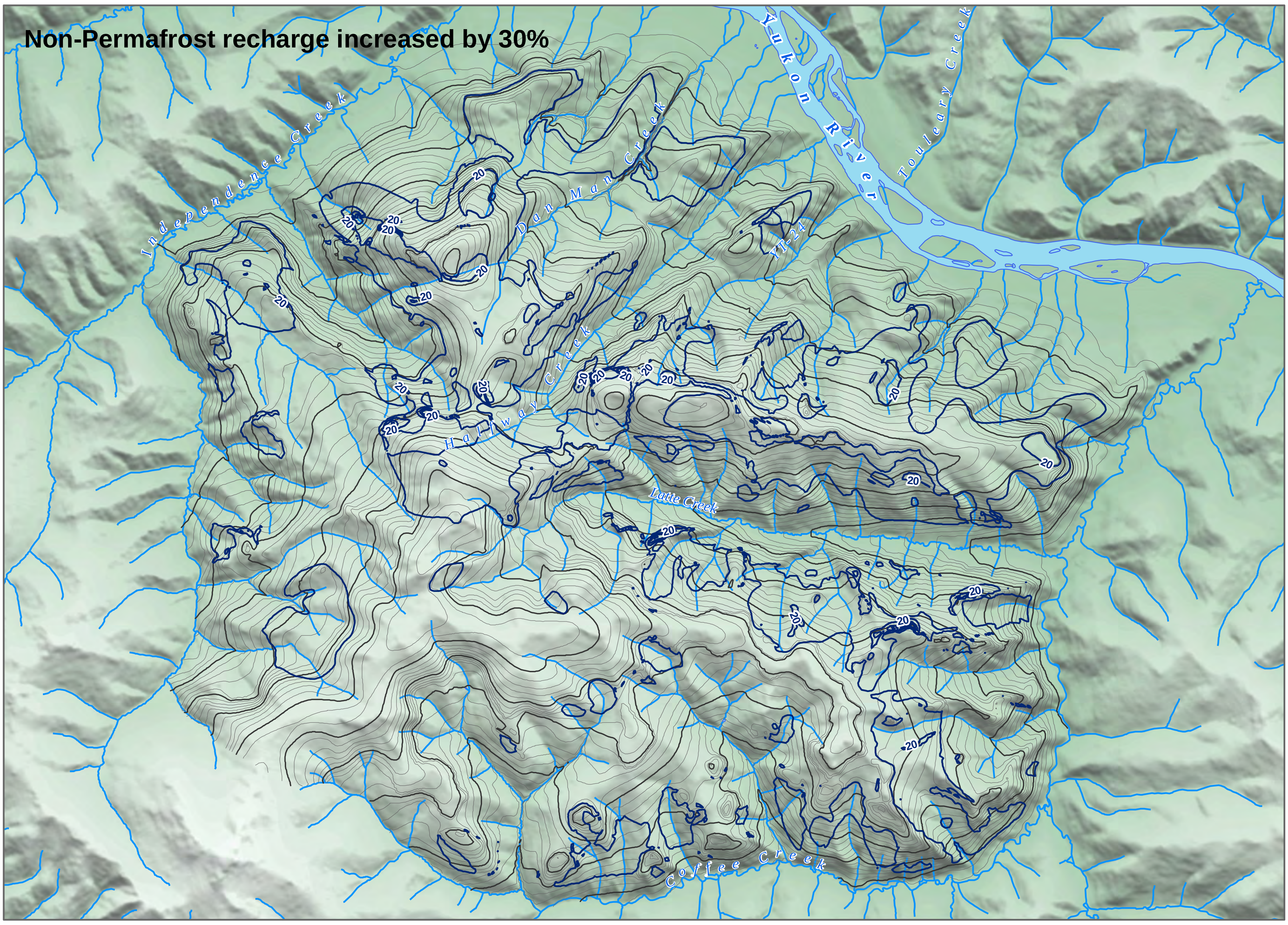
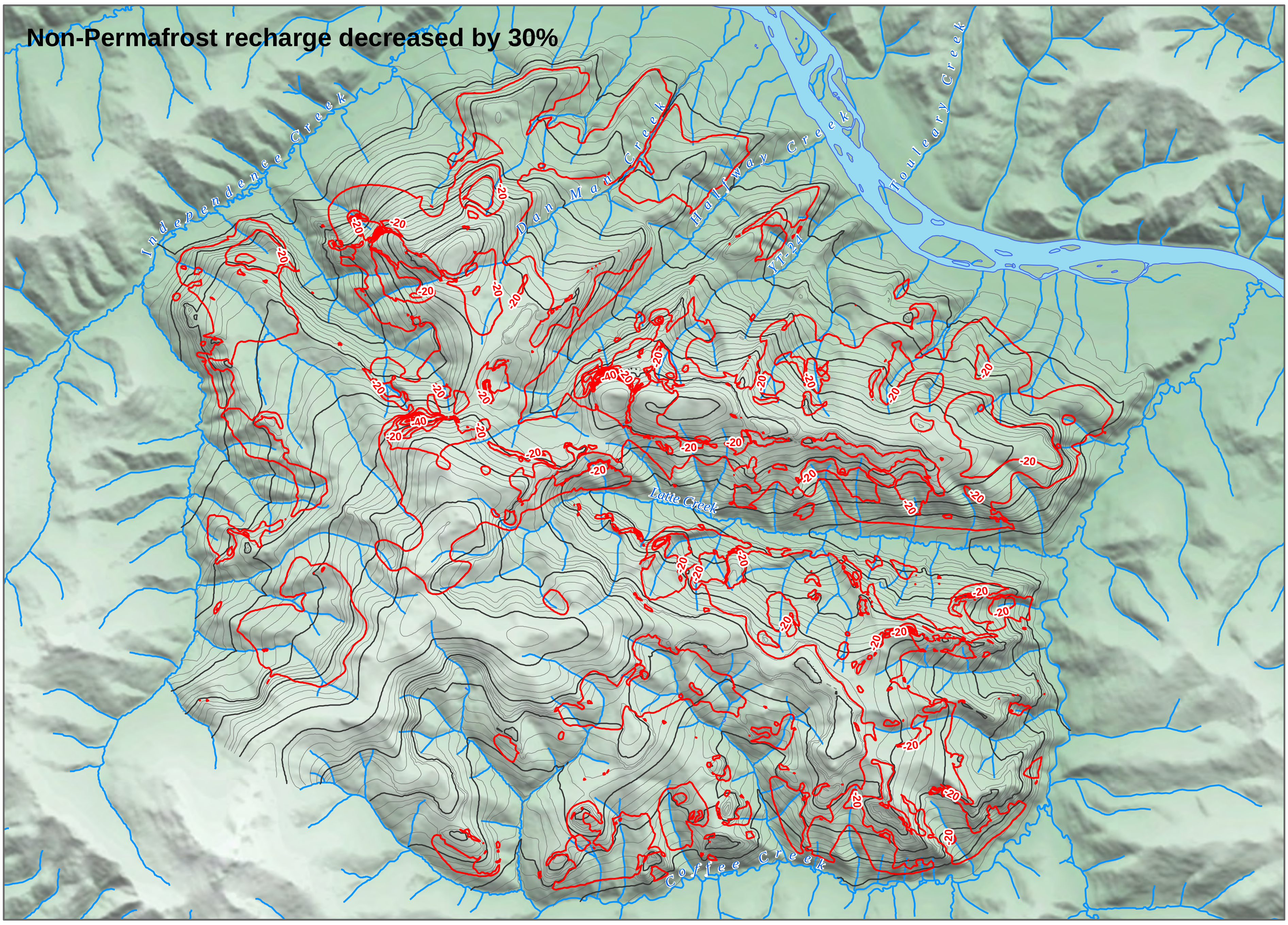


Figure 3-25: Head Calibration Results, Sensitivity of Non-Permafrost Recharge Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

Change in Head (m) from Base Case Model
- 10m Interval (>=10)
- 10m Interval (<=-10)

Simulated Premining Water Table for Sensitivity Run
- 100m
- 20m

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PROJECT:

Coffee Gold Hydrogeology

TITLE:

Change in Water Table Elevation with Change in Non-Permafrost Recharge

PROJECT #: A362-5

FIGURE: 3-26

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-26_Change in WT Elevation Non-Permfrost Recharge_20160512.mxd

3.4.6 Sensitivity to Recharge through Permafrost

As indicated in Table 3-2, zero recharge was applied to permafrost at elevations between 400 masl and 1200 masl. Between 1200 masl and 1400 masl, 5 mm/y of recharge was allowed to occur through fractures in the ice-poor permafrost above the water table at these elevations. In the first run in this sensitivity analysis, the recharge rate was increased to 5 mm/y on permafrost at elevations between 400 masl and 1200 masl and to 7 mm/y at elevations between 1200 masl and 1400 masl. As a result of these increased recharge rates, the model predicts increases in head of up to 160 m in the model domain and a rise in head of up to 60 m in the Project area. The increase in recharge through permafrost increased baseflow estimates in the Project area by between 6% at CC-1.0 to 17% at HC-2.5 and CC-6.0.

In the second run, no recharge was introduced to any permafrost areas. Removing all recharge through permafrost areas lowered the water table by up to 240 m in the southern portion of the model and as much as 60 m in the Project area. Lowering the recharge reduced simulated baseflow to CC-6.0 by 21% but generally had a minor impact on groundwater discharge rates to other creeks of interest.

Both sensitivity runs yielded poorer head calibration statistics than the base case model, as shown in Table 3-20. The calibrated values of permafrost recharge are relatively well constrained by the calibration targets. As discussed below, the recharge on permafrost had only a minor impact on the predictive runs.

Table 3-19:
Summary of Mass Balance from Permafrost Recharge Sensitivity Runs

	Permafrost Recharge +2-5 mm/y	Base Case	No Permafrost Recharge
Model-Wide Inflow (L/s):			
Constant Head	190.9	192.0	192.0
Recharge	244.1	202.1	196.0
Total	435.0	394.1	388.0
Model-Wide Outflow (L/s)			
Constant Head	252.7	242.5	242.3
Drain	182.4	151.8	145.8
Total	435.1	394.2	388.1
Inflow-Outflow (L/s)	-0.09	-0.15	-0.09
Inflow-Outflow (%)	-0.02	-0.04	-0.02
Discharge to Streams (L/s)			
IC-2.5	4.0	3.1	2.9
IC-3.0	13	11	10
HC-2.5	10.0	8.5	8.2
HC-5.0	21	18	17
ML-1.0	8.3	7.2	7.1
CC-6.0	5.1	4.4	3.5
CC-1.0	1.9	1.8	1.7
CC-1.5	15	13	12
CC-3.5	53	48	46
IC-1.5	26	22	21
IC-4.5	53	42	40

Table 3-20:
Head Calibration Statistics for Permafrost Recharge Sensitivity

Well Group	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All - PF Recharge+2-5 mm/y	2.24%	3.33	9.72
All - Base Case	1.67%	-1.69	7.69
All - PF Recharge-5 mm/y	2.14%	-4.86	8.50
HC - PF Recharge+2-5 mm/y	1.58%	3.83	12.45
HC - Base Case	1.04%	-1.94	8.85
HC - PF Recharge-5 mm/y	1.10%	-5.59	8.36
LC - PF Recharge+2-5 mm/y	2.33%	-0.22	8.19
LC - Base Case	2.50%	-1.94	8.67
LC - PF Recharge-5 mm/y	2.73%	-2.75	9.18
YT-24 - PF Recharge+2-5 mm/y	4.78%	12.06	12.06
YT-24 - Base Case	3.24%	-0.10	8.13
YT-24 - PF Recharge-5 mm/y	7.47%	-9.87	14.01
Duplicate - PF Recharge+2-5 mm/y	1.15%	0.84	4.51
Duplicate - Base Case	0.80%	-2.06	3.17
Duplicate - PF Recharge-5 mm/y	0.82%	-2.62	2.92

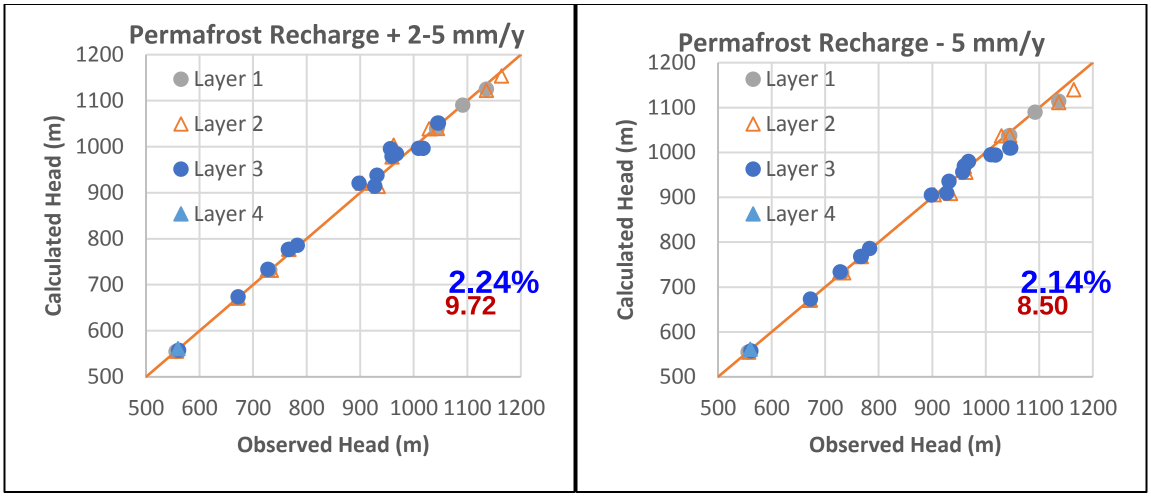
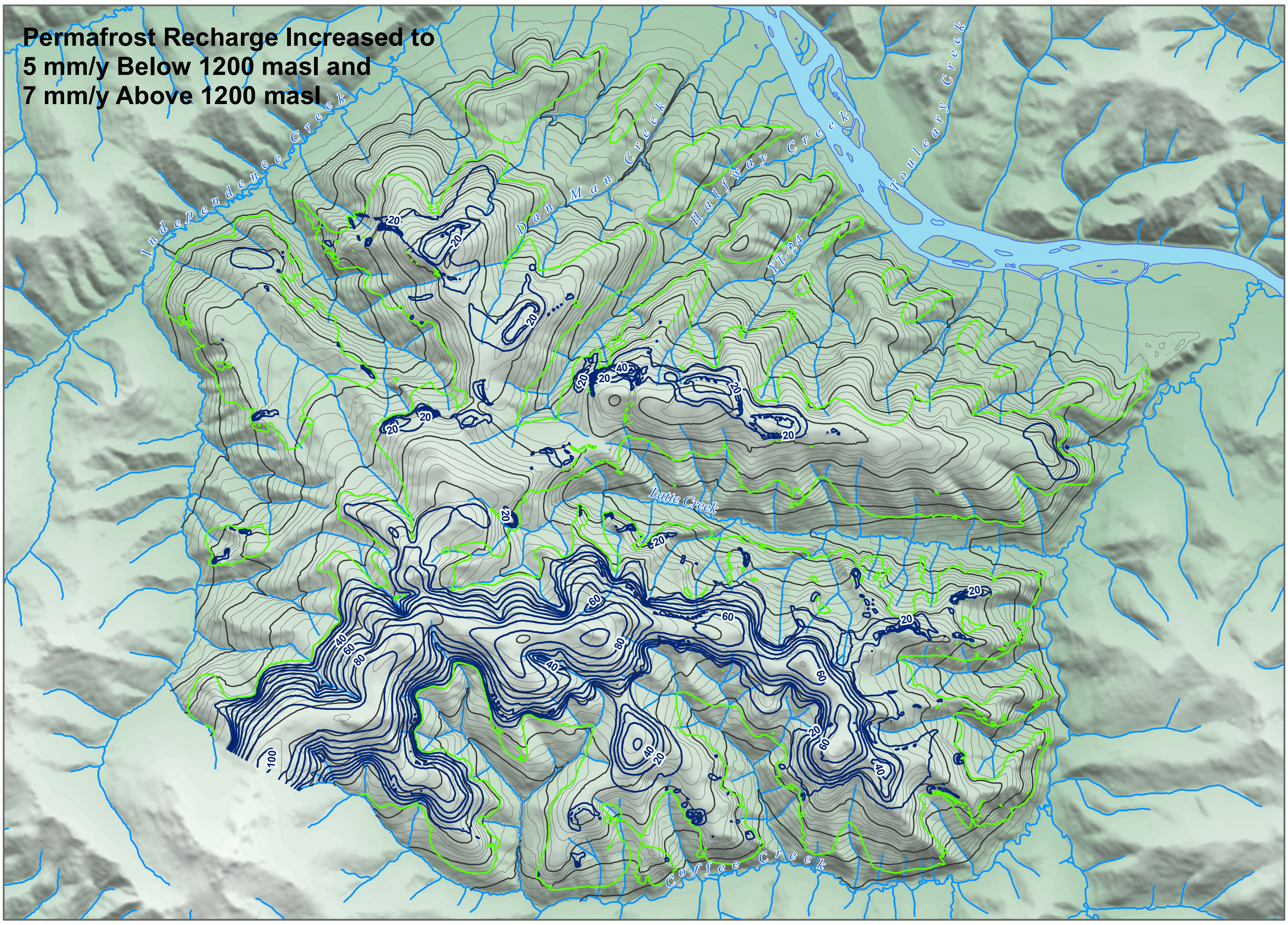
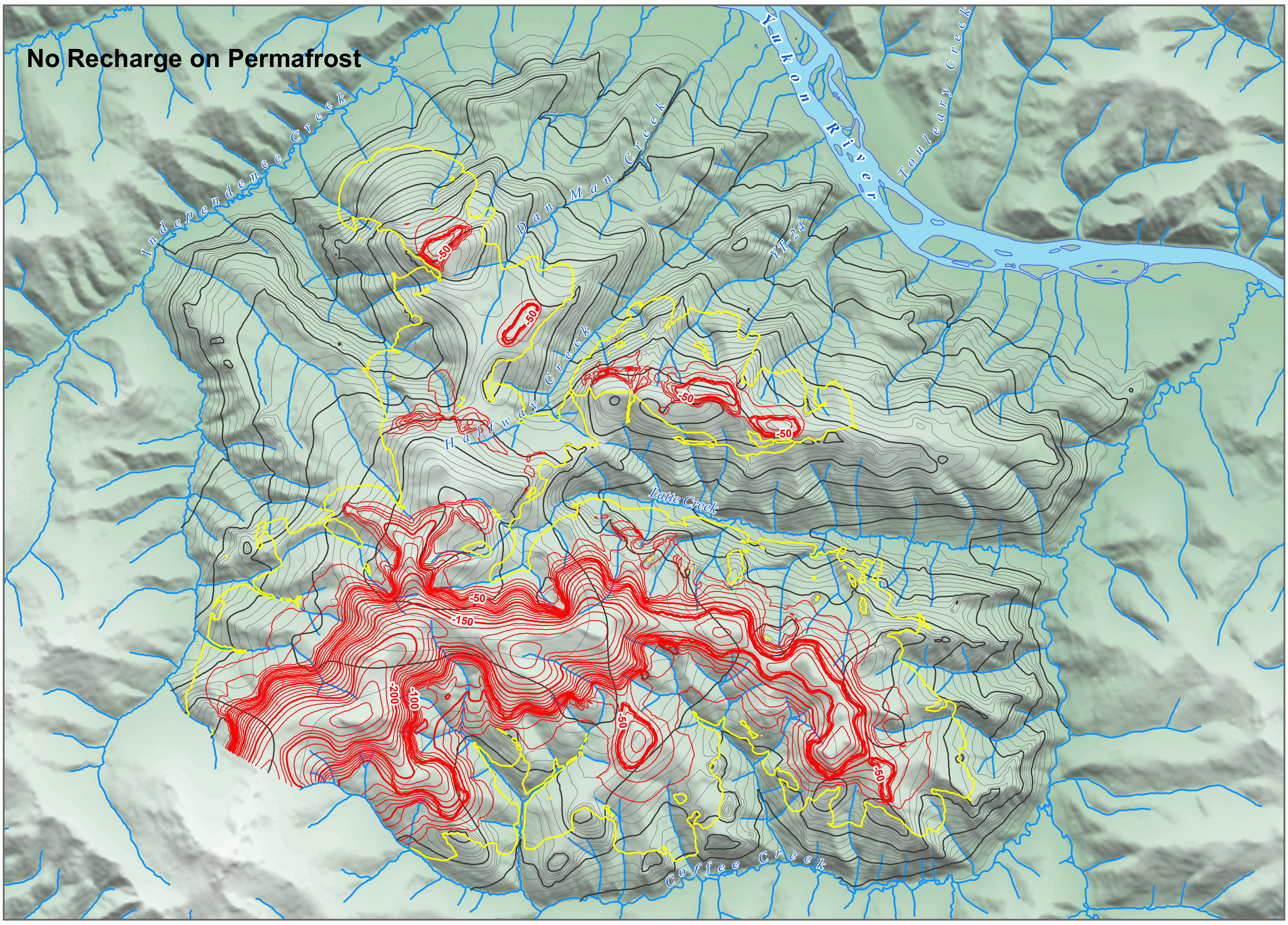


Figure 3-27: Head Calibration Results, Sensitivity of Permafrost Recharge Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

Change in Head (m) from Base Case Model
- 10m Interval (>=10)
- 10m Interval (<=-10)
- -1m
- 1m

Simulated Premining Water Table for Sensitivity Run
- 100m
- 20m

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TITLE:

Change in Water Table Elevation with Change in Permafrost Recharge

PROJECT #: A362-5 *FIGURE:* 3-28

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3.4.7 Sensitivity to General Creek Structures Hydraulic Conductivity

In the calibrated model, the hydraulic conductivity in Layer 1 along the banks of Halfway Creek, YT-24, Dan Man Creek, Latte Creek and other tributaries was increased in order to simulate the hydraulic heads in wells near creek channels. This material zone is shown in Figure 3-8 and has a calibrated hydraulic conductivity of $6x10^{-6}$ m/s. In addition, hydraulic conductivities were increased along the upper reaches of Latte Creek in Layer 1 where permafrost was not present and, in some areas, in Layer 2 below permafrost. These areas are shown in Figure 3-8 and have a calibrated hydraulic conductivity of $4x10^{-6}$ m/s. The hydraulic conductivity of these two material zones was increased and decreased by an order of magnitude in this sensitivity analysis.

This parameter has a noticeable impact on the simulated heads, particularly in the vicinity of Dan Man Creek (see Figure 3-30). In the mine area, raising the hydraulic conductivity of these units by a factor of ten lowered the water table in the vicinity of Halfway Creek, the upper portions of Latte Creek and YT-24 by between 30 m and 40 m. As a result of the drop in water table along the creek banks, the groundwater discharge rates to some of the creeks drop in spite of the increase in the simulated creek-structure hydraulic conductivity. The reason for this is that groundwater is able to flow parallel to and beneath the creek in cases where the hydraulic conductivity of the underground conduit is higher. Reducing the hydraulic conductivity of the structures associated with these drainages leads to a rise in the water table in the vicinity of the creeks and an increase in the baseflow to key streams due to the lower strength of the groundwater conduit beneath the creeks.

To the extent that this group of stream-related structures can be treated together, there is moderate confidence in the calibrated hydraulic conductivity value. These parameters have a moderate impact on the simulations; however, their impact is lower than that of the T3 and Latte Structure hydraulic conductivity.

Table 3-21:
Summary of Mass Balance from General Creek-K Zone Sensitivity Runs

	General Creek K x 10 (4-6x10^{-5} m/s)	Base Case (4-6x10^{-6} m/s)	General Creek K/10 (4-6x10^{-7} m/s)
Model-Wide Inflow (L/s):			
Constant Head	192.0	192.0	192.0
Recharge	202.1	202.1	202.1
Total	394.1	394.1	394.1
Model-Wide Outflow (L/s)			
Constant Head	244.3	242.5	242.1
Drain	149.9	151.8	152.2
Total	394.2	394.2	394.2
Inflow-Outflow (L/s)	-0.10	-0.15	-0.14
Inflow-Outflow (%)	-0.03	-0.04	-0.03
Discharge to Streams (L/s)			
IC-2.5	3.4	3.1	3.5
IC-3.0	11	11	10
HC-2.5	1.4	8.5	9.2
HC-5.0	18	18	18
ML-1.0	7.3	7.2	7.5
CC-6.0	1.9	4.4	4.9
CC-1.0	0.8	1.8	3.0
CC-1.5	13	13	14
CC-3.5	42	48	52
IC-1.5	21	22	22
IC-4.5	41	42	42

Table 3-22:
Head Calibration Statistics General Creek-K Zone Sensitivity

Well Group	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All - General Creek Kx10	3.34%	-11.41	14.11
All - Base Case	1.67%	-1.69	7.69
All - General Creek K/10	2.17%	5.02	10.33
HC - General Creek Kx10	1.83%	-9.06	12.20
HC - Base Case	1.04%	-1.94	8.85
HC - General Creek K/10	0.89%	2.21	7.41
LC - General Creek Kx10	4.11%	-9.12	13.17
LC - Base Case	2.50%	-1.94	8.67
LC - General Creek K/10	3.03%	2.71	10.72
YT-24 - General Creek Kx10	5.93%	-11.83	13.93
YT-24 - Base Case	3.24%	-0.10	8.13
YT-24 - General Creek K/10	7.03%	12.30	18.29
Duplicate - General Creek Kx10	5.18%	-19.99	19.99
Duplicate - Base Case	0.80%	-2.06	3.17
Duplicate - General Creek K/10	2.43%	8.74	9.08

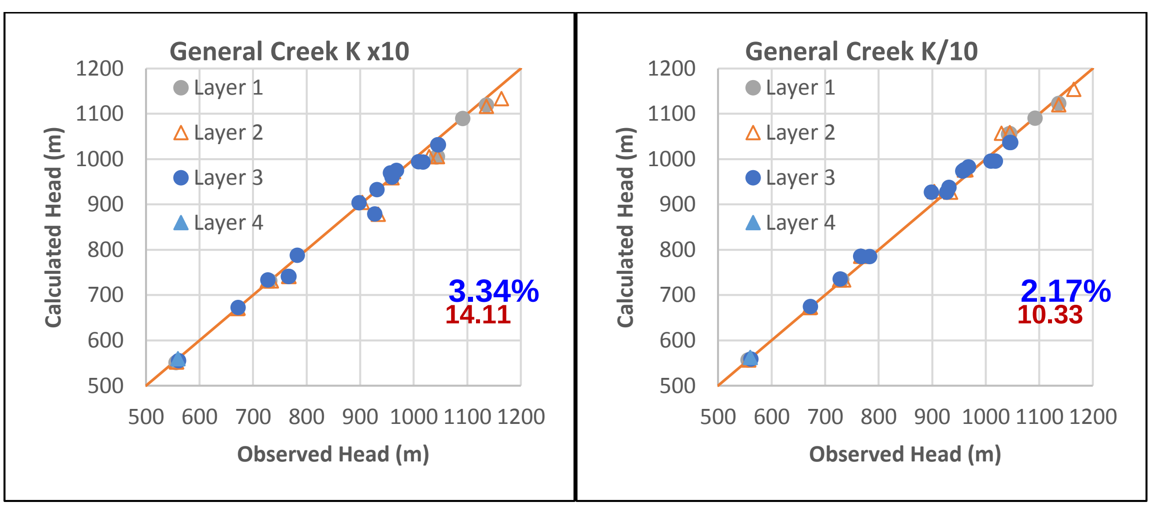
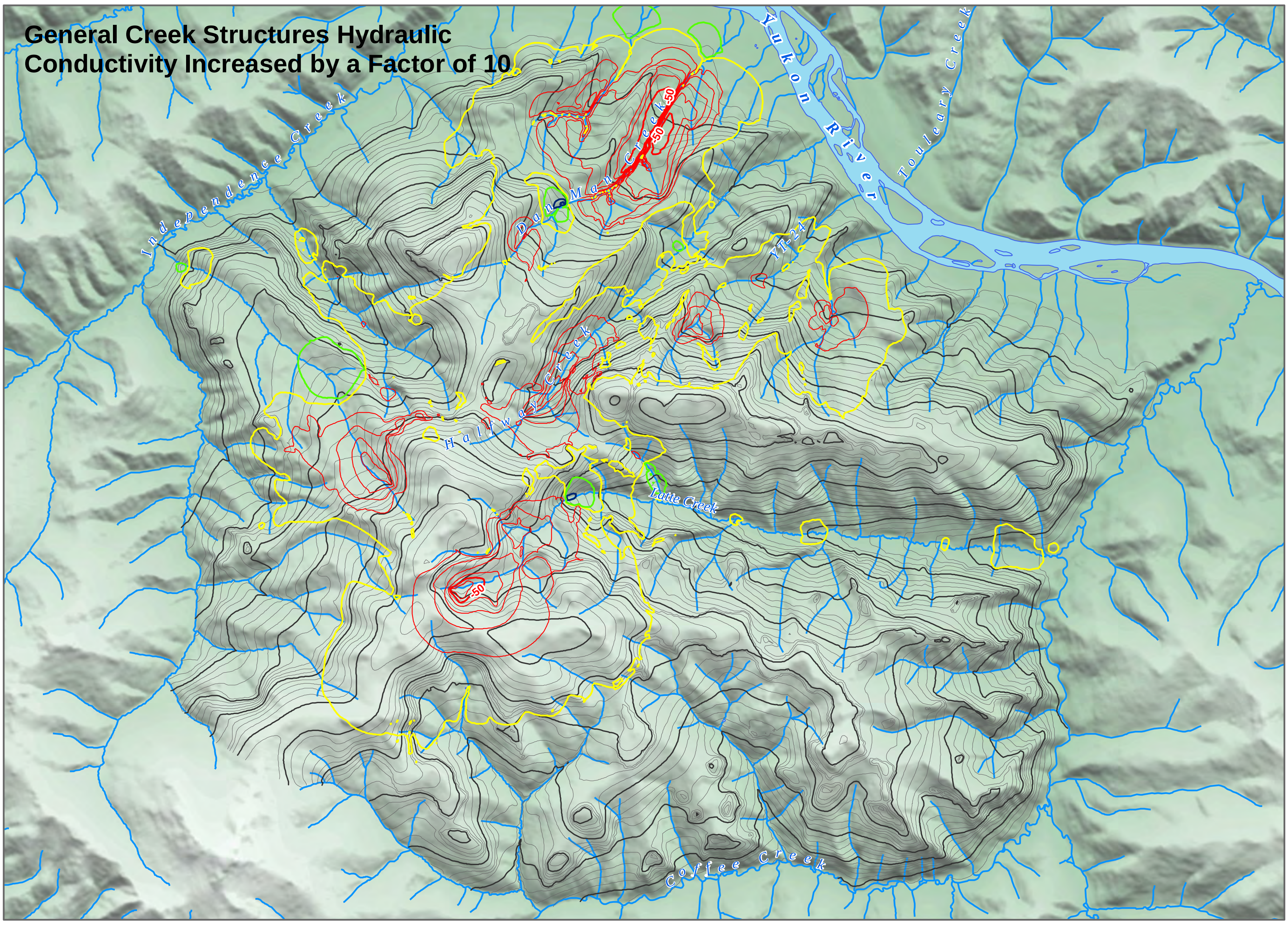
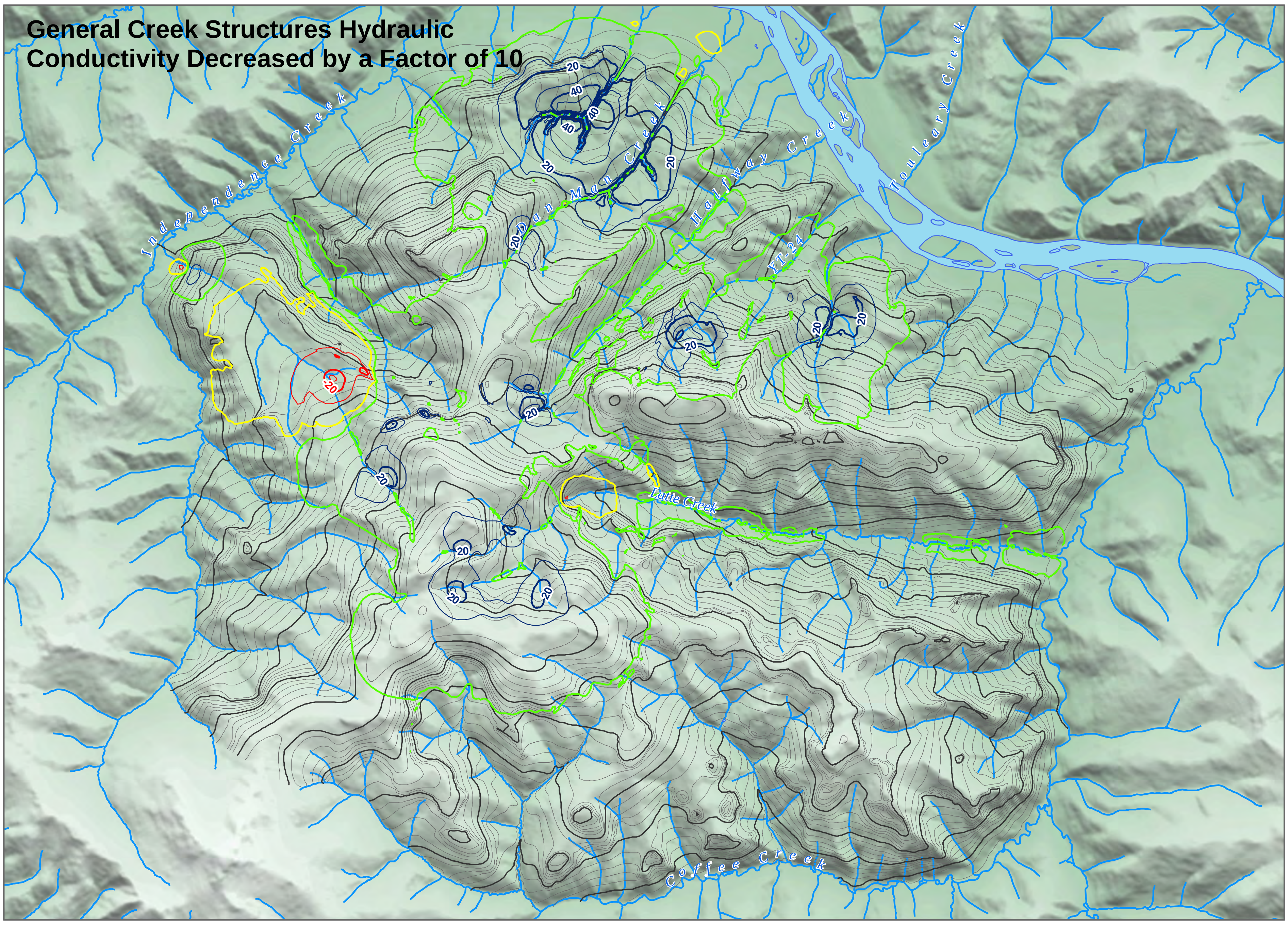


Figure 3-29: Head Calibration Results, Sensitivity of General Creek Hydraulic Conductivity Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

Change in Head (m) from Base Case Model

- 10m Interval (>=10)
- 10m Interval (<=-10)
- 1m
- -1m

Simulated Premining Water Table for Sensitivity Run

- 100m
- 20m

DATE SAVED:	May 12, 2016
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Coordinate System: *NAD 1983 UTM Zone 7N*
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Units: *Meter*

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LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Change in Water Table Elevation with Change in General Creek K

PROJECT #: A362-5

FIGURE: 3-30

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-30_Change in WT Elevation Creek K_20160512.mxd

3.4.8 Sensitivity to Highest Hydraulic Conductivity Materials

The hydraulic conductivity in Layer 2 of the model at Latte Creek is among the highest in the model, along with the colluvium in the CC-1.0 catchment and the Independence Creek Fault. The hydraulic conductivity of all three of these materials was varied together in this set of sensitivity runs. These three parameters together have a moderate impact on the head calibration, as shown in Table 3-24 and Figure 3-31. The main impact can be seen in the groundwater-surface water interaction, particularly in Latte Creek (see Table 3-23).

Streamflow changes along Latte Creek between CC-1.5 and CC-3.5 suggest that there is a deep groundwater flow path associated with Latte Creek. When the hydraulic conductivity in Layer 2 at Latte Creek is increased by an order of magnitude, the simulated water table drops by as much as 50 m along the banks of Latte Creek, leading to a reduction in groundwater discharge to Latte Creek CC-3.5 from 27 L/s to 48 L/s for the base case model. As for the Halfway Creek structure described above, the reason for the reduced baseflow at CC-3.5 is that groundwater can continue to flow beneath and parallel to Latte Creek and discharge to surface water at a point farther downstream directly into Coffee Creek.

Lowering the hydraulic conductivity of these units by an order of magnitude results in a water table rise along the portion of Latte Creek between the heap leach and CC-1.0. This increase in water table elevation results in an increase in creek baseflows to Latte Creek to 55 L/s. A small part of the changes in baseflow can be attributed to the change in hydraulic conductivity of the colluvium. However, the influence on overall hydrologic processes of the small CC-1.0 catchment is small relative to the groundwater-surface water interactions along Latte Creek.

The hydraulic conductivity of these permeable units does not significantly change pit inflow rates, but does have an impact on pathline trajectories (see Section 4.3).

Table 3-23:
Summary of Mass Balance from Colluvium, Layer 2 of Latte Creek and Independence Creek Fault K Sensitivity Runs

	High-K Materials K x 10 ($3.0x10^{-4}$ m/s)	Base Case ($3.0x10^{-5}$ m/s)	High-K Materials K/10 ($3.0x10^{-6}$ m/s)
Model-Wide Inflow (L/s):			
Constant Head	1927.2	192.0	18.5
Recharge	202.1	202.1	202.1
Total	2129.4	394.1	220.7
Model-Wide Outflow (L/s)			
Constant Head	1977.4	242.5	69.2
Drain	152.0	151.8	151.6
Total	2129.5	394.2	220.8
Inflow-Outflow (L/s)	-0.12	-0.15	-0.10
Inflow-Outflow (%)	-0.01	-0.04	-0.05
Discharge to Streams (L/s)			
IC-2.5	3.1	3.1	3.1
IC-3.0	11	11	11
HC-2.5	8.5	8.5	8.6
HC-5.0	18	18	18
ML-1.0	7.2	7.2	7.2
CC-6.0	4.4	4.4	4.4
CC-1.0	1.5	1.8	3.6
CC-1.5	6	13	17
CC-3.5	27	48	55
IC-1.5	21	22	22
IC-4.5	40	42	42

Table 3-24:
Head Calibration Statistics for Colluvium, Layer 2 of Latte Creek and Independence Creek Fault K Sensitivity

Well Group	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All - Layer 2 LC and IC Kx10	2.18%	-4.85	10.05
All - Base Case	1.67%	-1.69	7.69
All - Layer 2 LC and IC K/10	1.69%	-1.38	7.92
HC - Layer 2 LC and IC Kx10	1.03%	-1.99	8.82
HC - Base Case	1.04%	-1.94	8.85
HC - Layer 2 LC and IC K/10	1.04%	-1.89	8.88
LC and IC - Layer 2 LC and IC Kx10	3.79%	-9.93	14.06
LC and IC - Base Case	2.50%	-1.94	8.67
LC and IC - Layer 2 LC and IC K/10	2.60%	-1.05	9.44
YT-24 - Layer 2 LC and IC Kx10	3.24%	-0.11	8.14
YT-24 - Base Case	3.24%	-0.10	8.13
YT-24 - Layer 2 LC and IC K/10	3.24%	-0.08	8.13
Duplicate - Layer 2 LC and IC Kx10	2.65%	-6.33	7.45
Duplicate - Base Case	0.80%	-2.06	3.17
Duplicate - Layer 2 LC and IC K/10	0.77%	-1.95	3.07

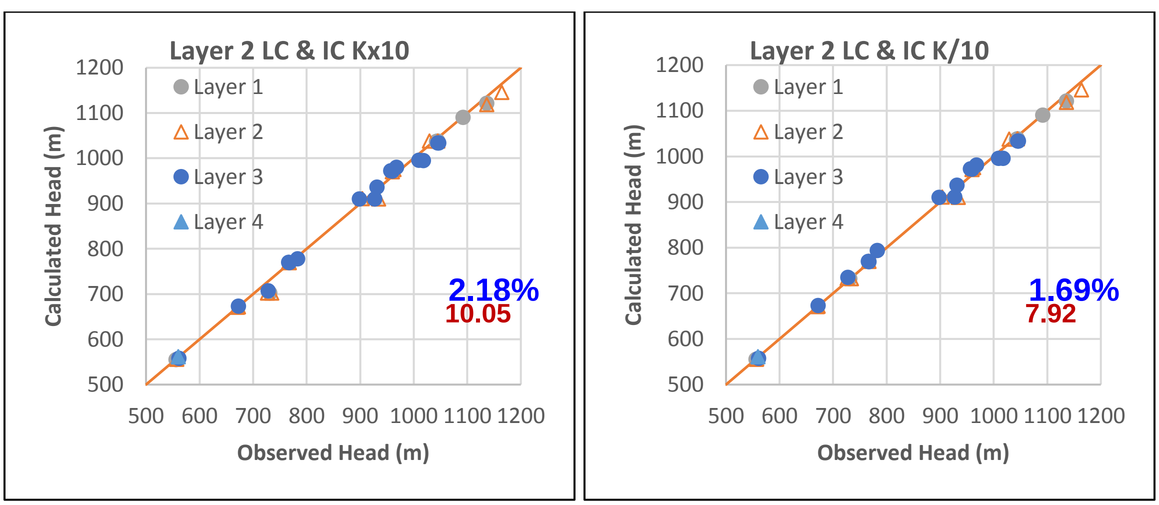
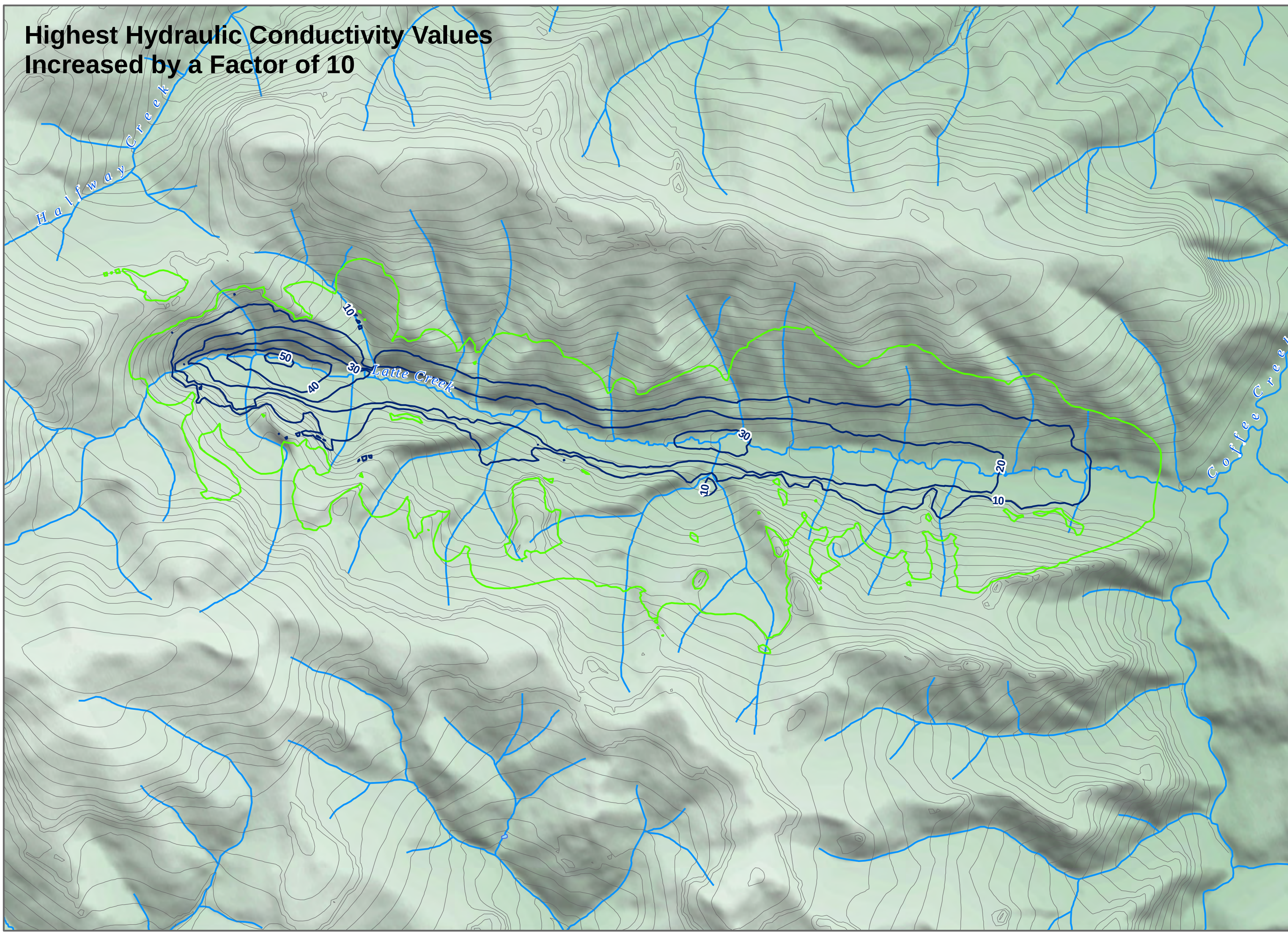
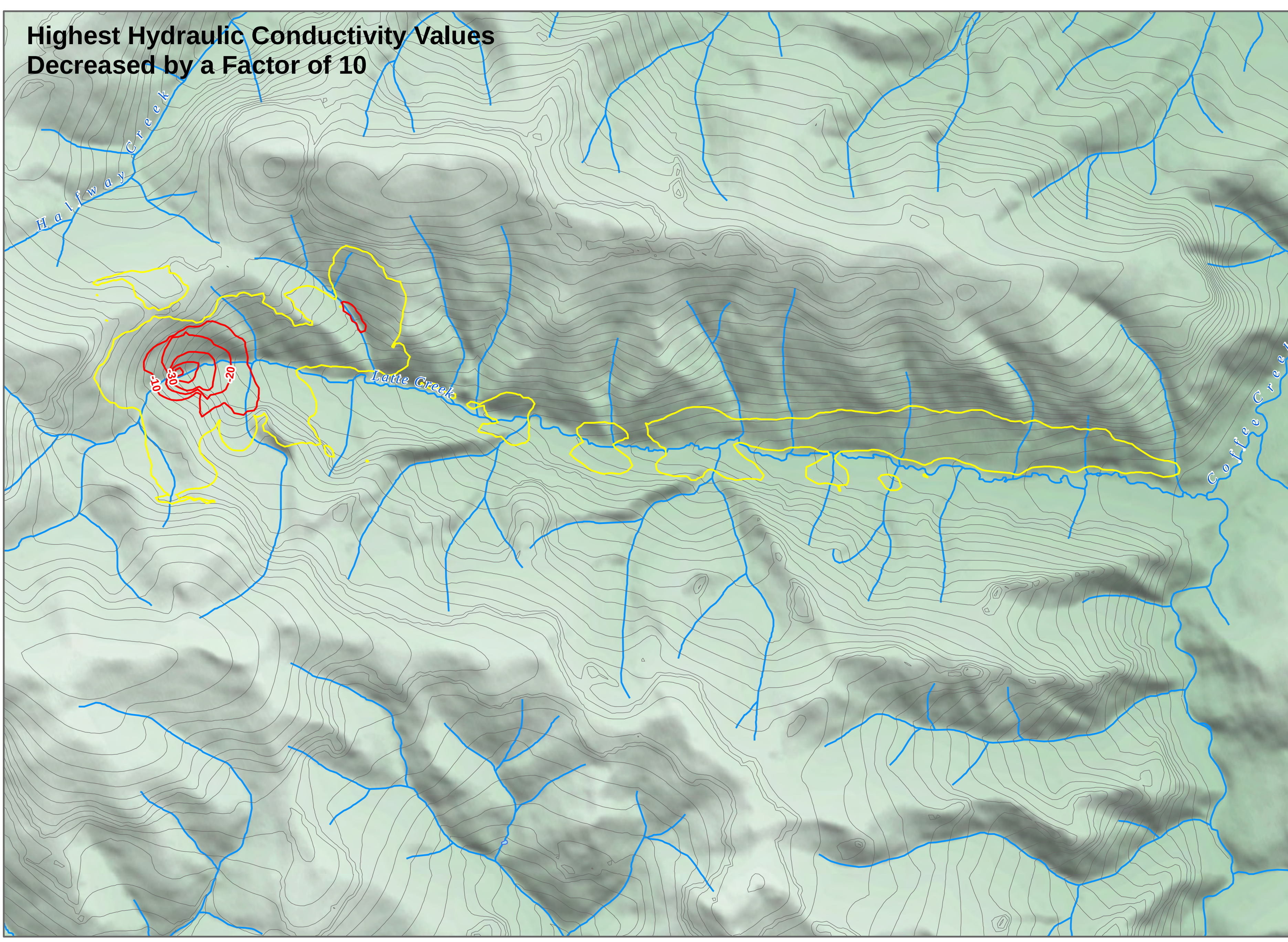


Figure 3-31: Head Calibration Results, Sensitivity of Hydraulic Conductivity at Colluvium, Layer 2 of Latte Creek and Independence Creek Fault K Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

Change in Head (m) from Base Case Model

- 10m Interval (>=10)
- 10m Interval (<=-10)
- 1m
- -1m
- Simulated Premining Water Table for Sensitivity Run (20m)

DATE SAVED:	May 12, 2016
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Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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0 500 1,000 Meters

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KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Change in Water Table Elevation with Change in Hydraulic Conductivity at Colluvium, Layer 2 of Latte Creek and Independence Creek Fault K

PROJECT #: A362-5

FIGURE: 3-32

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3.4.9 Sensitivity to Permafrost Hydraulic Conductivity

The results of the sensitivity analysis on the hydraulic conductivity of the permafrost zone is shown in Table 3-25 and Table 3-26. The impact of this parameter on the overall head calibration statistics and groundwater discharge rates is generally low, and the majority of changes to the model results are outside the Project area (see Figure 3-34). The parameter was raised by an order of magnitude and lowered by a factor of two. When the hydraulic conductivity was raised by a factor of ten, the water table change in the Project area was minor; however, a reduction in head of as much as 10 m can be observed in the YT-24 catchment. This parameter had minimal impacts on the head and flow calibration statistics.

Lowering the permafrost hydraulic conductivity by a factor of two also had minimal impacts on the water table in the majority of the Project area, except for the upper reaches of YT-24 southeast of the proposed South Waste Rock Storage Facility (WRSF). The hydraulic conductivity of the permafrost could not be reduced further while keeping the recharge on high-elevation permafrost at 5 mm/y.

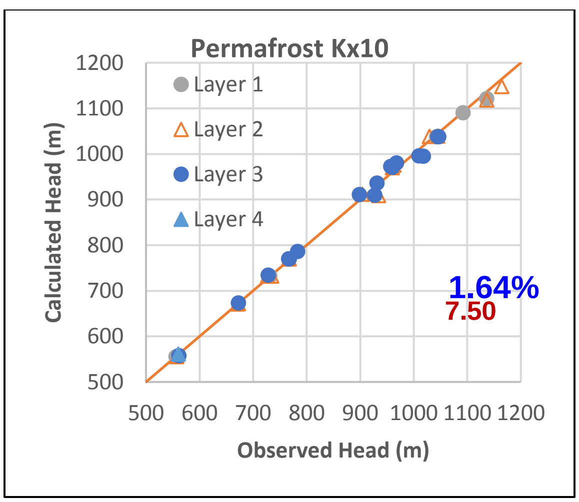
The hydraulic conductivity of the permafrost, whose main role was to restrict recharge at upper elevations and confine groundwater at lower elevations, did not affect the predictions (see Section 4.3).

Table 3-25:
Summary of Mass Balance from Permafrost K Sensitivity Runs

	Permafrost K x 10 ($6.0x10^{-9}$ m/s)	**Base Case ($6.0x10^{-10}$ m/s)**	**Permafrost K/2 ($3.0x10^{-10}$ m/s)**
Model-Wide Inflow (L/s):			
Constant Head	192.0	192.0	192.0
Recharge	202.1	202.1	202.1
Total	394.1	394.1	394.1
Model-Wide Outflow (L/s)			
Constant Head	241.1	242.5	242.6
Drain	153.1	151.8	152.5
Total	394.1	394.2	395.2
Inflow-Outflow (L/s)	0.00	-0.15	-1.05
Inflow-Outflow (%)	0.00	-0.04	-0.27
Discharge to Streams (L/s)			
IC-2.5	3.1	3.1	3.1
IC-3.0	11	11	11
HC-2.5	8.5	8.5	8.9
HC-5.0	18	18	18
ML-1.0	7.2	7.2	7.2
CC-6.0	4.2	4.4	4.4
CC-1.0	1.8	1.8	1.8
CC-1.5	13	13	13
CC-3.5	47	48	48
IC-1.5	22	22	22
IC-4.5	42	42	42

Table 3-26:
Head Calibration Statistics Permafrost K Sensitivity

Well Group	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All - Permafrost Kx10	1.64%	-1.42	7.50
All - Base Case	1.67%	-1.69	7.69
All - Permafrost K/2	1.68%	-1.72	7.72
HC - Permafrost Kx10	1.05%	-2.22	8.87
HC - Base Case	1.04%	-1.94	8.85
HC - Permafrost K/2	1.04%	-1.92	8.85
LC and IC - Permafrost Kx10	2.43%	-1.72	8.47
LC and IC - Base Case	2.50%	-1.94	8.67
LC and IC - Permafrost K/2	2.52%	-2.00	8.72
YT-24 - Permafrost Kx10	2.80%	1.61	7.23
YT-24 - Base Case	3.24%	-0.10	8.13
YT-24 - Permafrost K/2	3.31%	-0.29	8.26
Duplicate - Permafrost Kx10	0.76%	-1.82	3.13
Duplicate - Base Case	0.80%	-2.06	3.17
Duplicate - Permafrost K/2	0.79%	-2.04	3.14



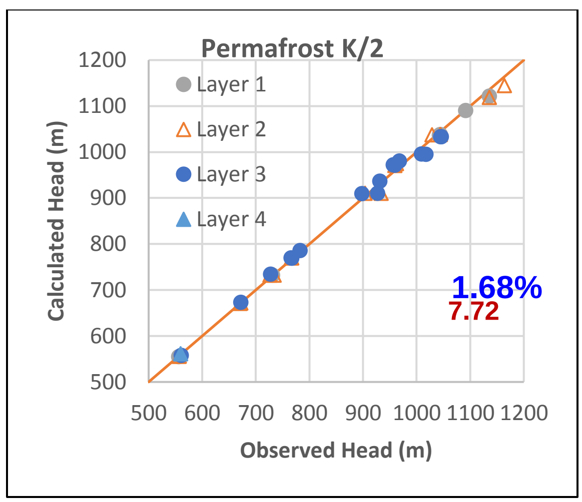
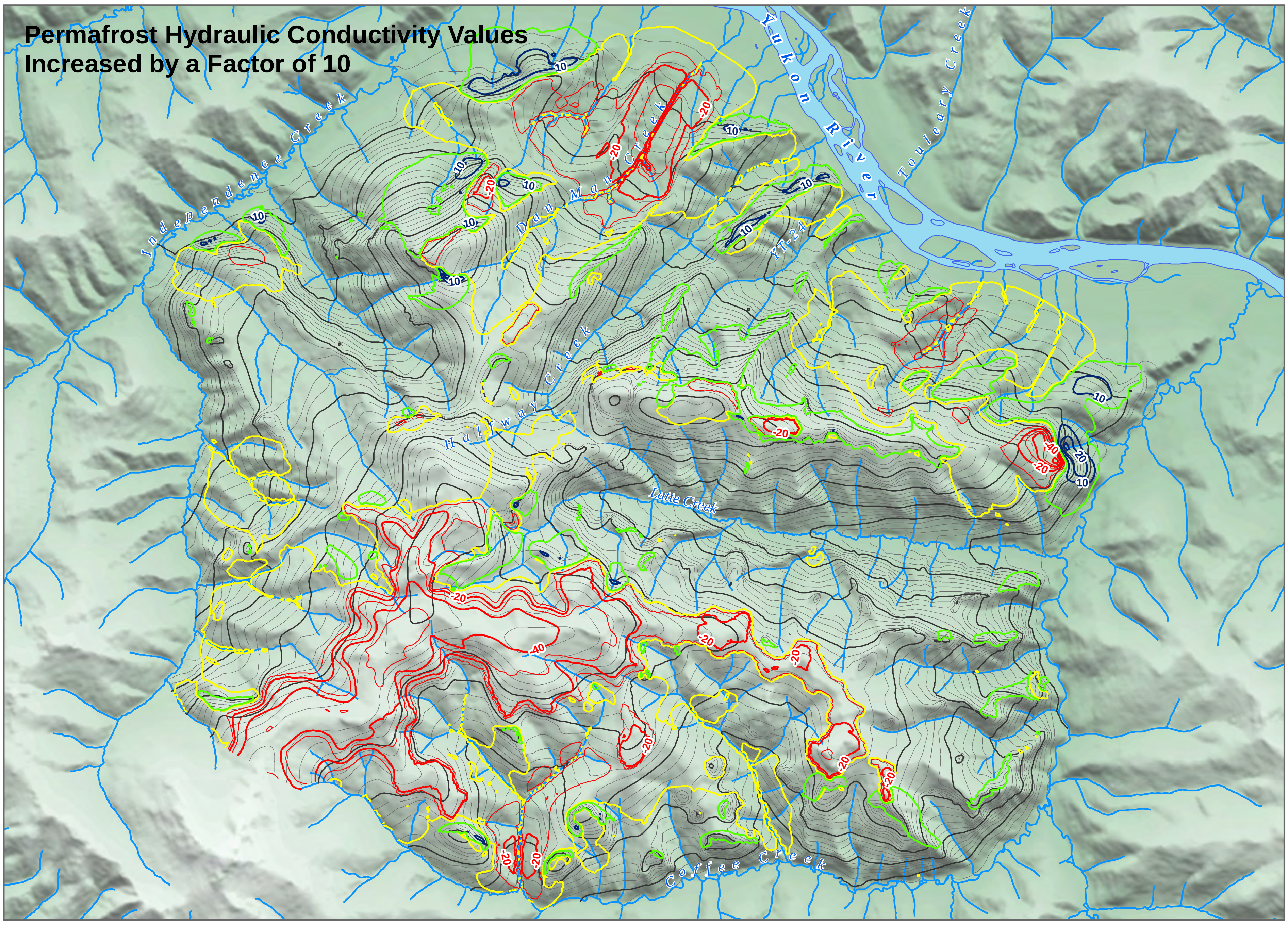
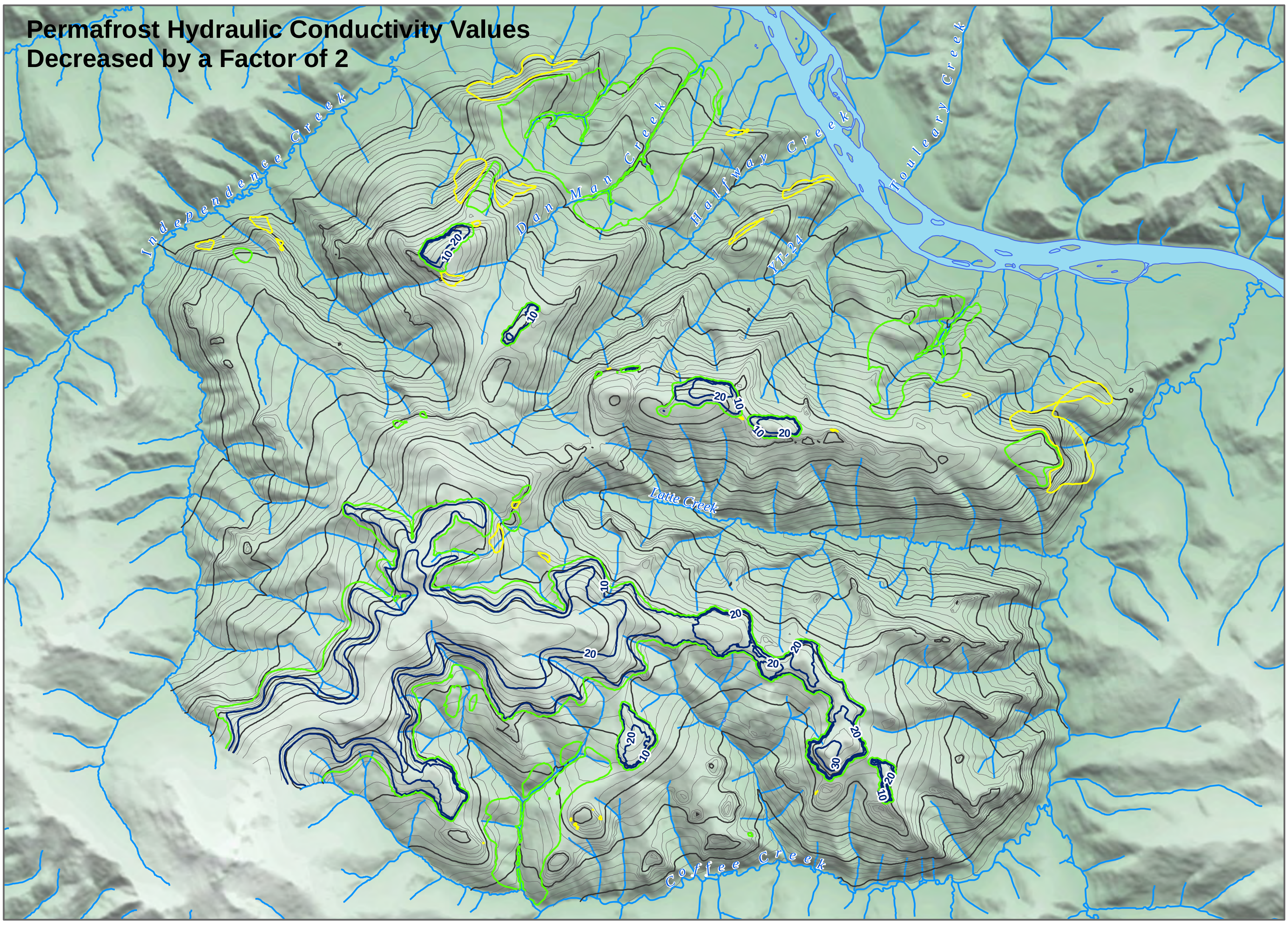


Figure 3-33: Head Calibration Results, Sensitivity of Permafrost Hydraulic Conductivity Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

Change in Head (m) from Base Case Model

- 10m Interval (>=10)
- 10m Interval (<=-10)
- 1m
- -1m

Simulated Premining Water Table for Sensitivity Run

- 100m
- 20m

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VERSION:	1

Coordinate System: NAD 1983 UTM Zone 7N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

1:125,000

0 2 4 Kilometers

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LORAX ENVIRONMENTAL

PROJECT: **Coffee Gold Hydrogeology**

TITLE: Change in Water Table Elevation with Change in Permafrost Hydraulic Conductivity

PROJECT #: A362-5

FIGURE: 3-34

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-34_Change in WT Permafrost K_20160512.mxd

3.5 Summary

A steady state groundwater baseline model was developed and calibrated to observed monitoring well heads and observed stream baseflows in the Project area. The model was able to fit the groundwater heads in monitoring wells to a residual mean of -1.7 m and a normalized root mean squared error of 1.7%. The model was able to predict groundwater discharge targets in eight of nine Project area streams to within calibration targets. It was not able to simulate the baseflow target at the IC-2.5 catchment; however, the water quality signature of this stream suggests that the majority of baseflow is not associated with deep, bedrock-derived groundwater that is simulated in this model. Model results are therefore consistent with and calibrated to observations.

A sensitivity analysis was completed on the majority of model parameters. The parameters that were not included in the sensitivity analysis are the hydraulic conductivity of the Yukon River alluvium and the conductance of the creek drains. These parameters were evaluated in a previous sensitivity analysis and were found to have minor impacts on both the calibration and the predictions (Lorax, 2016a).

Parameters that have a significant impact on the calibration and a significant impact on model predictions (discussed in the next section) include:

- Shallow Bedrock hydraulic conducitvity and
- Deep Bedrock hydraulic conductivity

Parameters that have an insignificant impact on the calibration but a significant impact on model predictions include:

- T3 Structure hydraulic conductivity and
- Latte Structure hydraulic conductivity

Parameters that have a moderate impact on the calibration and a moderate impact on the model predictions include:

- Recharge on unfrozen areas,
- General Creek Structure hydraulic conductivity, and
- Highest Hydraulic Conductivity units

Finally, the following parameters have a low or moderately low impact on the calibration and a minor impact on the model predictions:

- Recharge on permafrost and
- Permafrost hydraulic conductivity

4. Mine Model

4. Mine Model

4.1 Model Setup

4.1.1 Conceptual Approach

Groundwater flow and particle-tracking models were developed for two stages of mine development. In the first model, called the end-of-mine (EOM) or end of Operation Phase model, the open pits and waste dumps at the end of operations (end of Year 9) were simulated under steady state conditions. This model simulation includes pit lakes at the following mined-out pits:

- Lake R2.2 Supremo of R2.3.3 located in the Supremo 1 pit, called SU1 in this report;
- Lake R1.2 on R2.3.3 located in the Supremo 2 pit, called SU2 in this report;
- Lake R1.2.1 in the Latte pit; and
- Lake R1.2 in the western portion of the Supremo 3 pit, called SU3W in this report.

At the end of Year 9, mining will have just finished at the Supremo 4 and Supremo 5 pits and these pits are therefore assumed to be dewatered. The northeastern portion of Supremo 3, whose lake at Post-Closure will be linked with a pit lake in Supremo 4, is also assumed to be dewatered in the EOM model.

In addition to these pits, zero recharge to bedrock groundwater was applied beneath waste rock at the North Waste Rock Storage Facility (WRSF), the South WRSF, the West WRSF, the Kona WRSF, the SU1 backfill, the SU4 backfill, and waste rock used to backfill the Kona pit. The treatment of the waste storage facilities as zero-recharge features is consistent with the surface water balance and water quality model assumptions. An exception to this case, the recharge rate on the Double Double pit backfill was increased relative to base case conditions to simulate a possible increase in recharge to bedrock groundwater from waste rock at this location.

In the steady state model for Post-Closure (Year 28), all mining is assumed to have ceased, and pit lakes are simulated at all the pit lakes simulated in the EOM model plus:

- Lake R2.2.1 in the northeastern portion of the Supremo 3 pit, called SU3N in this report;
- Lake R2.2.2 in the northern portion of the Supremo 4 pit, called SU4N in this report;

- Lake R3.3 of R3.2.1 in the southern portion of the Supremo 4 pit, called SU4S in this report;
- Lake R3.2 in the northern portion of the Supremo 5 pit, called SU5N in this report; and
- Lake R3.3 in the southern portion of the Supremo 5 pit, called SU5S in this report.

The waste rock recharge assumptions remained unchanged between EOM and Post-Closure simulations.

4.1.2 Model Boundary Conditions – End-of-Mine-Conditions

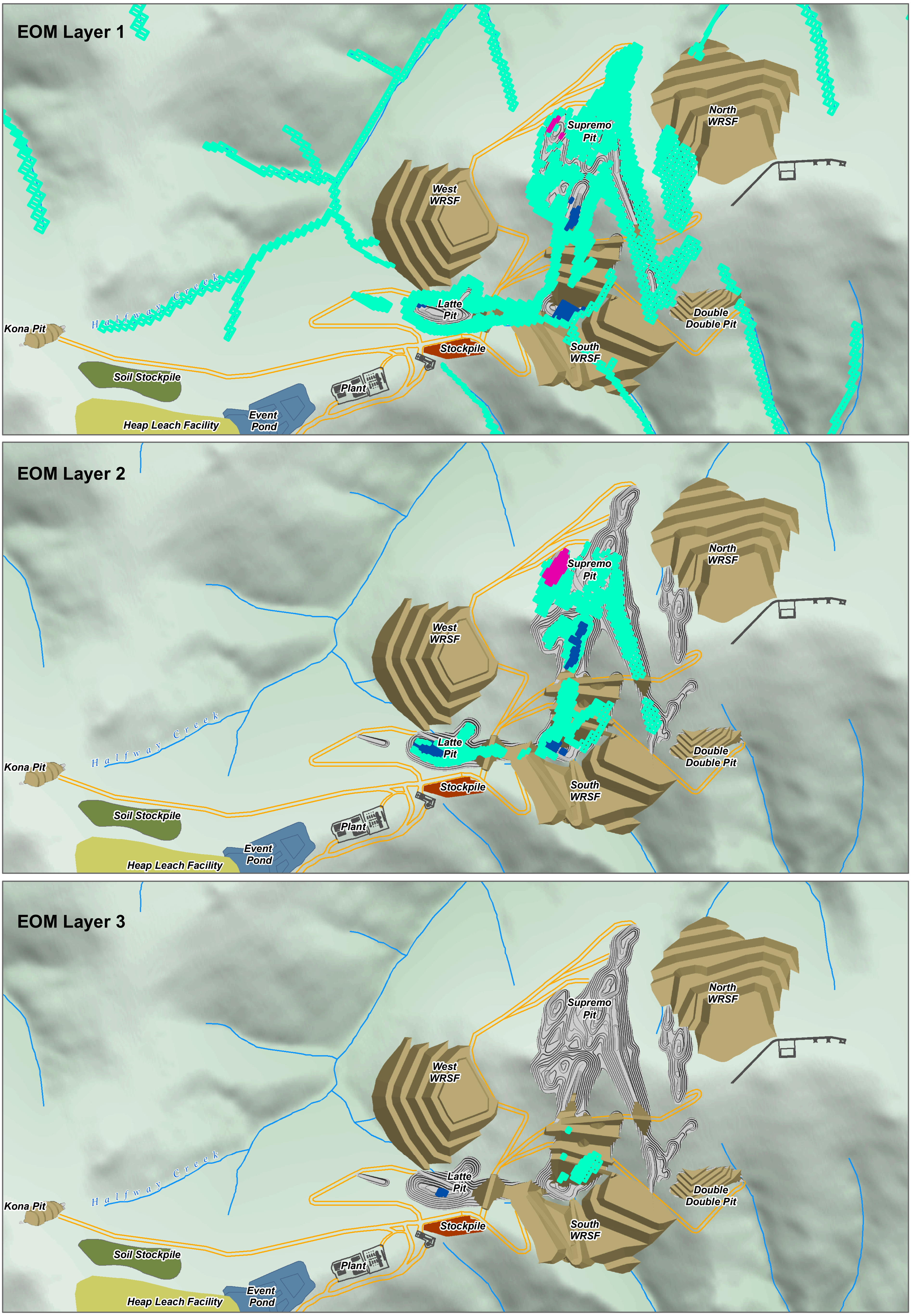
For the EOM model, the majority of drain boundary conditions present within the footprint of the open pits and waste rock storage facilities (WRSFs) were removed. The exception is the central portion of the CC-1.0 stream, which will coincide with a portion of the South WRSF rockfill underdrain system. These Layer 1 drains are retained, as shown in Figure 4-1. Within the open pit footprint, new MODFLOW drains were introduced to simulate potential seepage faces along pit walls above a pit lake. Pit drain conductances were computed using the length and width of the cell containing the pit drain, a drain thickness of 1 m, and a drain hydraulic conductivity of $1x10^{-5}$ m/s. The location of these drains is shown in Figure 4-1.

The pit lakes were simulated with constant head and general head boundary cells. The pit lake elevations at EOM were based on an iterative solution between the numerical groundwater model and the surface water balance model and are listed in Table 4-1. Pit lakes that are located on unfrozen ground—Supremo 1, Supremo 2, Supremo 4S—were treated as constant head boundaries. Pits whose bottom elevations intersect the simulated pre-mine water table—Supremo 4N, Latte—were also treated as constant head boundaries. Finally, pits located on permafrost with lake levels and pit bottom elevations at least 30 m above the pre-mine water table were treated as general head boundary cells, with the general head specified to be the pit lake elevation and the general head thickness computed to equal the distance between the pit bottom elevation in the model and the water table. The hydraulic conductivity of permafrost was used to compute the general head conductance.

The treatment of the back-filled Kona and Double Double pits is discussed below.

Table 4-1:
EOM and Post-Closure Pit Lake Elevations

Pit Lake	Elevation at EOM (masl)	Elevation at Post-Closure (masl)	Boundary Type
Supremo 1	939	939	Constant Head
Supremo 2	1078	1085	Constant Head
Supremo 3W	1172	1196	General Head
Supremo 3N	n/a	1090	General Head
Supremo 4N	n/a	1090	Constant Head
Supremo 4S	n/a	1036	Constant Head
Supremo 5N	n/a	1123	General Head
Supremo 5S	n/a	1177	General Head
Latte	989	1017	Constant Head



LEGEND

- Constant Head
- Drain
- General Head

Proposed Infrastructure

- Waste Dump
- Pit
- Leach pad
- Soil Stockpile
- Stockpile
- Plant
- Mine Road
- Event pond

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VERSION:	1

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0 400 800 Meters

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LORAX ENVIRONMENTAL

PROJECT: **Coffee Gold Hydrogeology**

TITLE: Pit Boundary Conditions at EOM

PROJECT #: A362-5

FIGURE: 4-1

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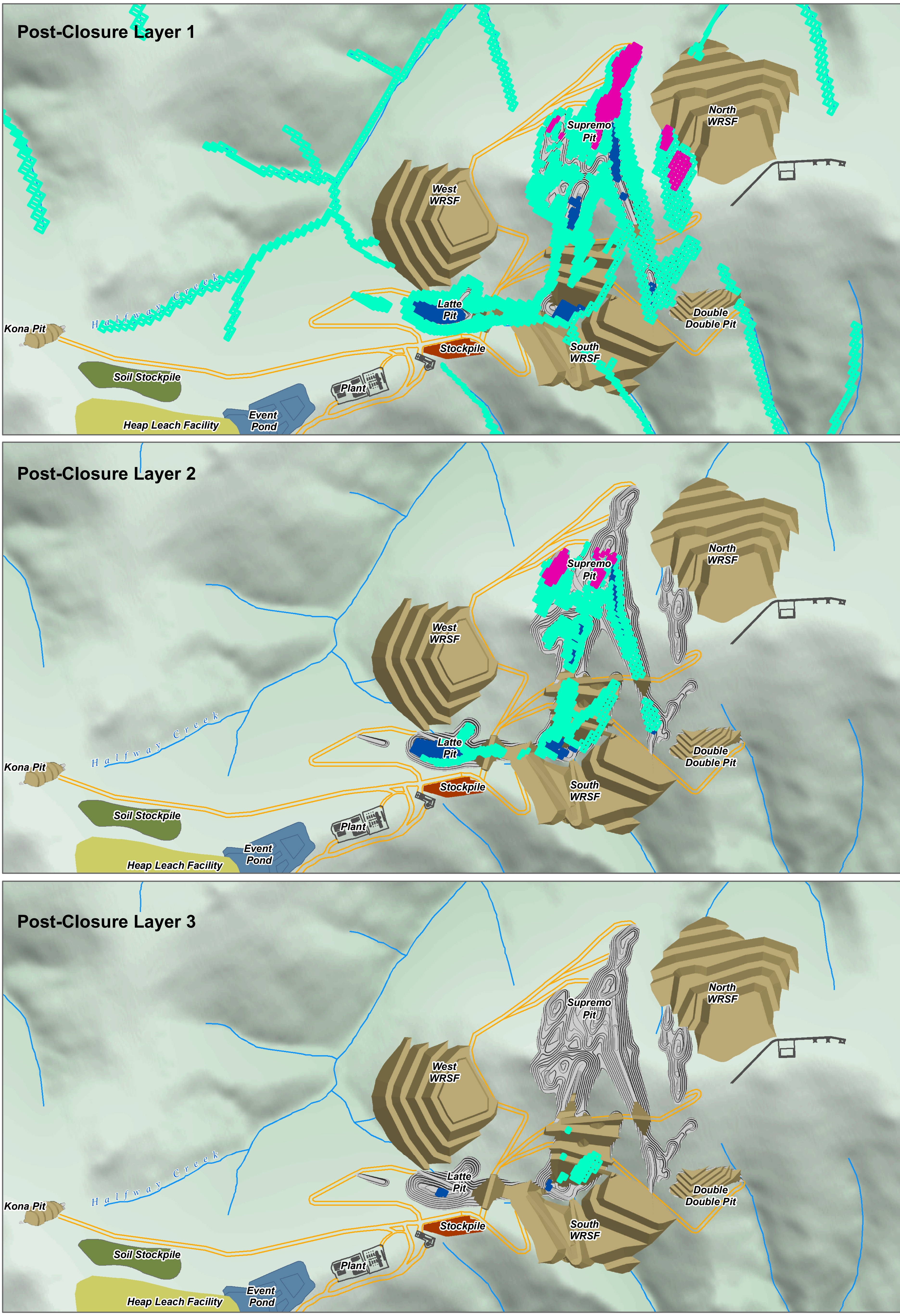
4.1.3 Model Boundary Conditions at Post-Closure

Figure 4-2 shows the drain, constant head, and general head boundaries applied at Post-Closure. The boundary conditions differ slightly from EOM because of the change in pit lake elevations and because Supremo 4 and Supremo 5 pits will no longer be actively dewatered from Closure onward. The general head boundary properties are the same as for the EOM model, but there are more general head boundary cells because Supremo 4 and 5 have pit lakes, as summarized in Table 4-1.



LEGEND

- Constant Head
- Drain
- General Head

Proposed Infrastructure

- Waste Dump
- Pit
- Leach pad
- Soil Stockpile
- Stockpile
- Plant
- Mine Road
- Event pond

DATE SAVED:	Aug 03, 2016
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VERSION:	1

Coordinate System: NAD 1983 UTM Zone 7N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

1:30,000

0 400 800 Meters

CLIENT: KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT: **Coffee Gold Hydrogeology**

TITLE: Pit Boundary Conditions at Post-Closure

PROJECT #: A362-5

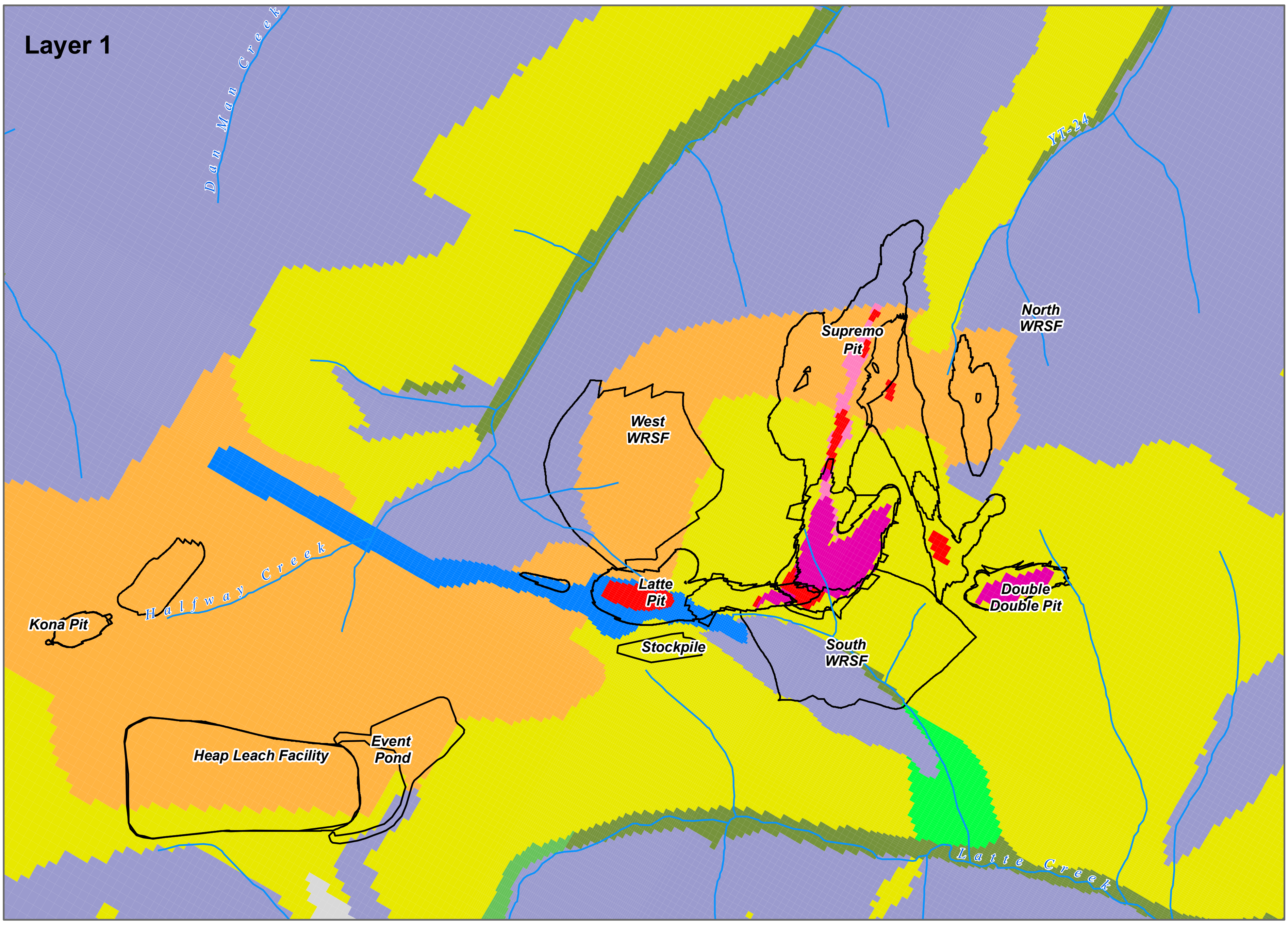
FIGURE: 4-2

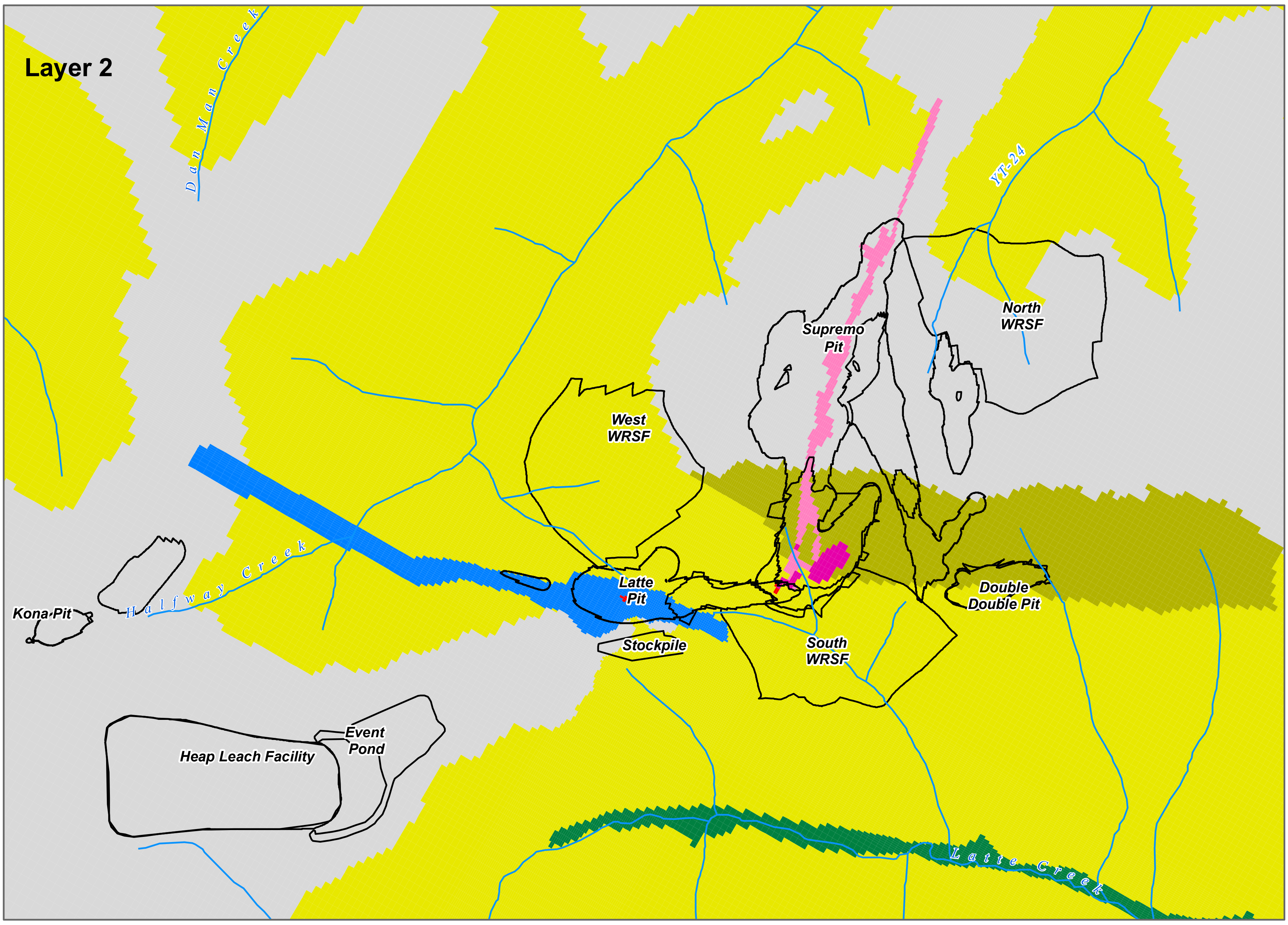
P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-2_Pit Boundary Conditions Closure_20160803.mxd

4.1.4 Hydraulic Conductivity

Minor adjustments were made to the hydraulic conductivity distribution in Supremo 1, Supremo 2, Supremo 4, Latte and Double Double pits. In areas where waste rock is deposited into open pits and where the bottom of the backfill is at or below the model layer bottom, waste rock properties were applied to the cell. These waste rock cells are present in the Supremo 1 pit, the southern portion of the Supremo 2 pit, the eastern portion of the Latte pit, and the Double Double pit. The Kona pit is also backfilled, but this higher-elevation pit is located in a portion of the model with thicker model layers, and no separate waste rock material is simulated. A hydraulic conductivity of $5x10^{-5}$ m/s was applied to waste rock cells.

In areas where the pit extends below the layer bottom, a hydraulic conductivity of $2x10^{-4}$ m/s was specified to simulate the void. These cells are present in the Latte, Supremo 1, Supremo 2, Supremo 3, and Supremo 4 pits, as shown in Figure 4-3.





LEGEND

K (m/s)

- Alluvium (1.0E-05)
- Shallow Bedrock (1.2E-07)
- Bedrock w WT PF bottom (1.2E-07)
- Zone @ MW14-02 L2-3b (1.7E-09)
- Deep Bedrock > 120m Depth (1.7E-09)
- Colluvium (3.0E-05)
- T3 Structure (2.0E-06)
- Latte Structure (1.0E-06)
- All Creek hi K zones L1 (6.0E-06)
- N Fault (5.0E-06)
- L2 Upper Latte (4.0E-06)
- L2 Lower Latte (3.0E-05)
- IC Creek Fault (3.0E-05)
- Permafrost (6.0E-10)
- Pit Void (2.0E-04)
- Backfilled Waste Rock (5.0E-05)

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Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Changes to Hydraulic Conductivity in Layers 1 and 2 for EOM and Post-Closure

PROJECT #: A362-5 *FIGURE:* 4-3

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-3_Conductivity Changes for EOM and Closure_20160803.mxd

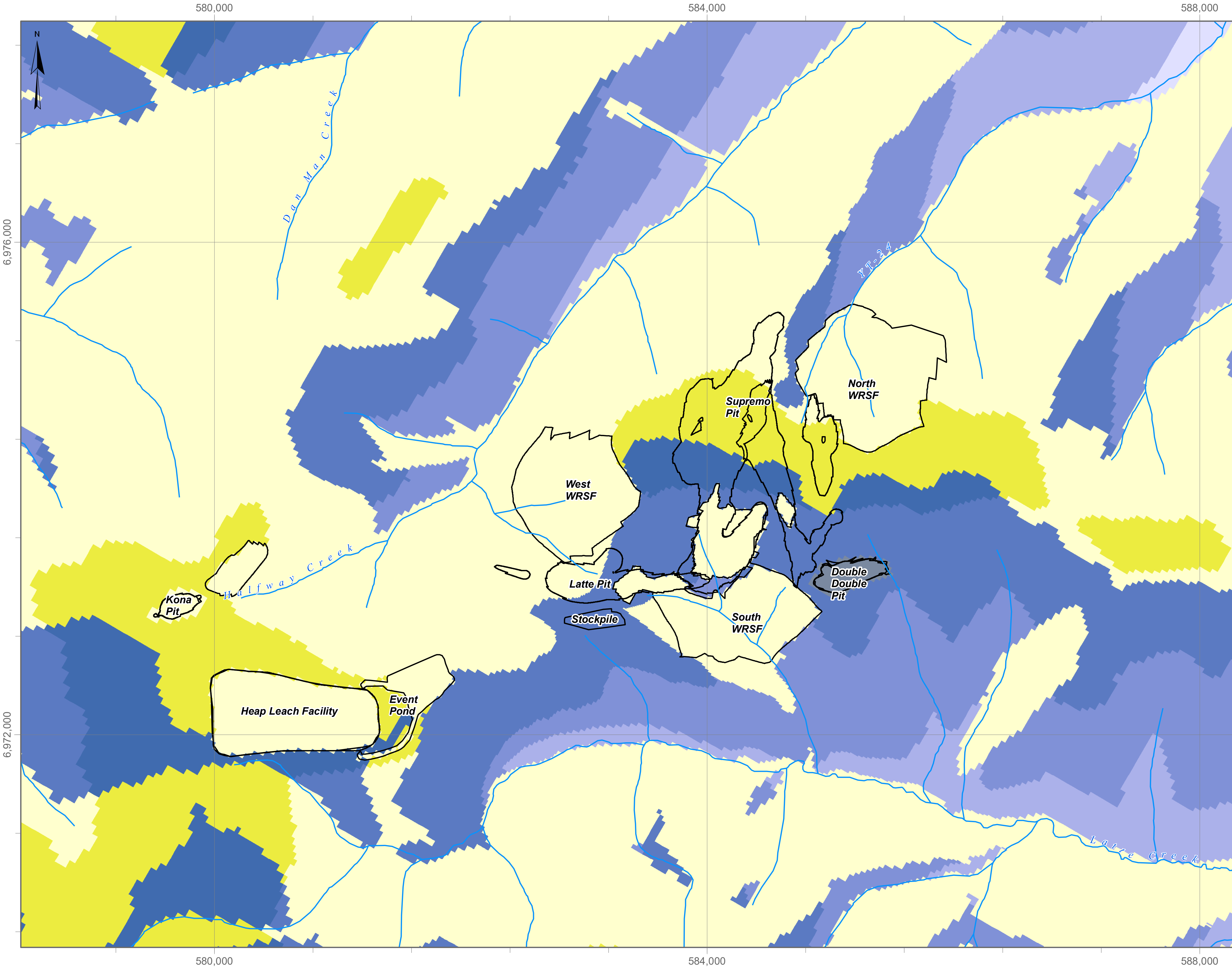
4.1.5 Recharge

The recharge rates utilized in the predictive models are listed in Table 4-2 and shown in Figure 4 4. For the EOM and Post-Closure runs, the recharge rate on the majority of waste dumps was reduced to zero, with the exception being the Double Double backfilled pit. The following assumptions underpin the recharge distribution used in the 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 footprint areas each ex-pit WRSF (North, South, West) to simulate the effect of French drains, which allow water to flow through the base of the waste rock pile and report to the associated sediment pond. Given the topographic relief of the WRSF sites and prevalence of permafrost, it is believed that the French 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 Kona pits. 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 advanced 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 4-2:
EOM and Post-Closure Recharge on Waste Dumps

Waste Rock Storage Facility	Recharge (mm/y)	Total Simulated Recharge (L/s)
Double Double Backfill	151	0.69
All others	n/a	n/a



LEGEND

Recharge Zones

- 400-600 m Elevation No Permafrost
- 600-800 m Elevation No Permafrost
- 800-1000 m Elevation No Permafrost
- 1000-1200 m Elevation No Permafrost
- 1200-1400 m Elevation No Permafrost
- Zero Recharge
- 1200-1400 m Elevation with Permafrost
- Double Double Backfill

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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0 400 800 Meters

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CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

EOM and Post-Closure Recharge with Recharge on Pits

PROJECT #:	*FIGURE:*
A362-5	4-4

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-4_EOM and Closure Recharge_20160803.mxd

4.1.6 Particle Tracking

Particle tracking was simulated using MODPATH 5. One starting particle was set at the center of every model grid cell that was simulated as a constant head boundary or a general head boundary to simulate a pit lake. In addition, one starting particle was set at the first saturated layer under every cell for which a waste rock recharge was applied. Pathlines were permitted to bypass "weak sinks" in which the flux into a boundary condition was less than half of the flow in the cell containing the boundary condition.

For EOM, 50-year travel times were simulated over the steady state head solution. For Post-Closure, 200-year travel times were simulated.

The porosity values used to compute groundwater velocities are listed in Table 4-3.

Table 4-3:
Porosity Values for Particle Tracking

Material Type	Porosity
Yukon River Alluvium	0.1
CC-1.0 Colluvium and Waste Rock	0.2
Bedrock and Permafrost	0.01
Pit Void	1

4.1.7 Solver Settings

As in the pre-mine simulations, the head convergence criterion is 0.01 m. The flux convergence criterion was increased to 100 m^3/d (1.2 L/s) from the 5 m^3/d used in the baseline model, and the maximum number of outer iterations was increased to 600 from 400. For selected sensitivity runs, in which the parameters pushed the water table in some areas above the top of Layer 1, the number of outer iterations for the predictive runs was increased to 1200. All other parameters are set to the default values for a "complex" MODFLOW-NWT model (Niswonger *et al.,* 2011). The solver parameters were changed from the "simple" settings used for the baseline model in order to improve the model-wide mass balance for the predictive runs. No obvious changes in the predicted heads or fluxes in the mine area were evident between the "simple" and "complex" settings. For particle tracking simulations, the inactive flag HDRY within MODFLOW-NWT was set to 1.

4.2 Model Predictions

4.2.1 End of Operation Phase

Figure 4-5 shows the water table simulated at the end of operations, and Figure 4-6 shows the change in head relative to the pre-mine calibration model. The steady state EOM model predicts that the water table will rise beneath the Latte pit, Supremo 3W pit and the Supremo 2 pit; at these locations, the pit lake elevation at EOM is higher than the pre-mine water table elevation. The water table also rises beneath the Double Double backfilled pit, where the simulated recharge rate was increased from 65.5 mm/y to 151 mm/y.

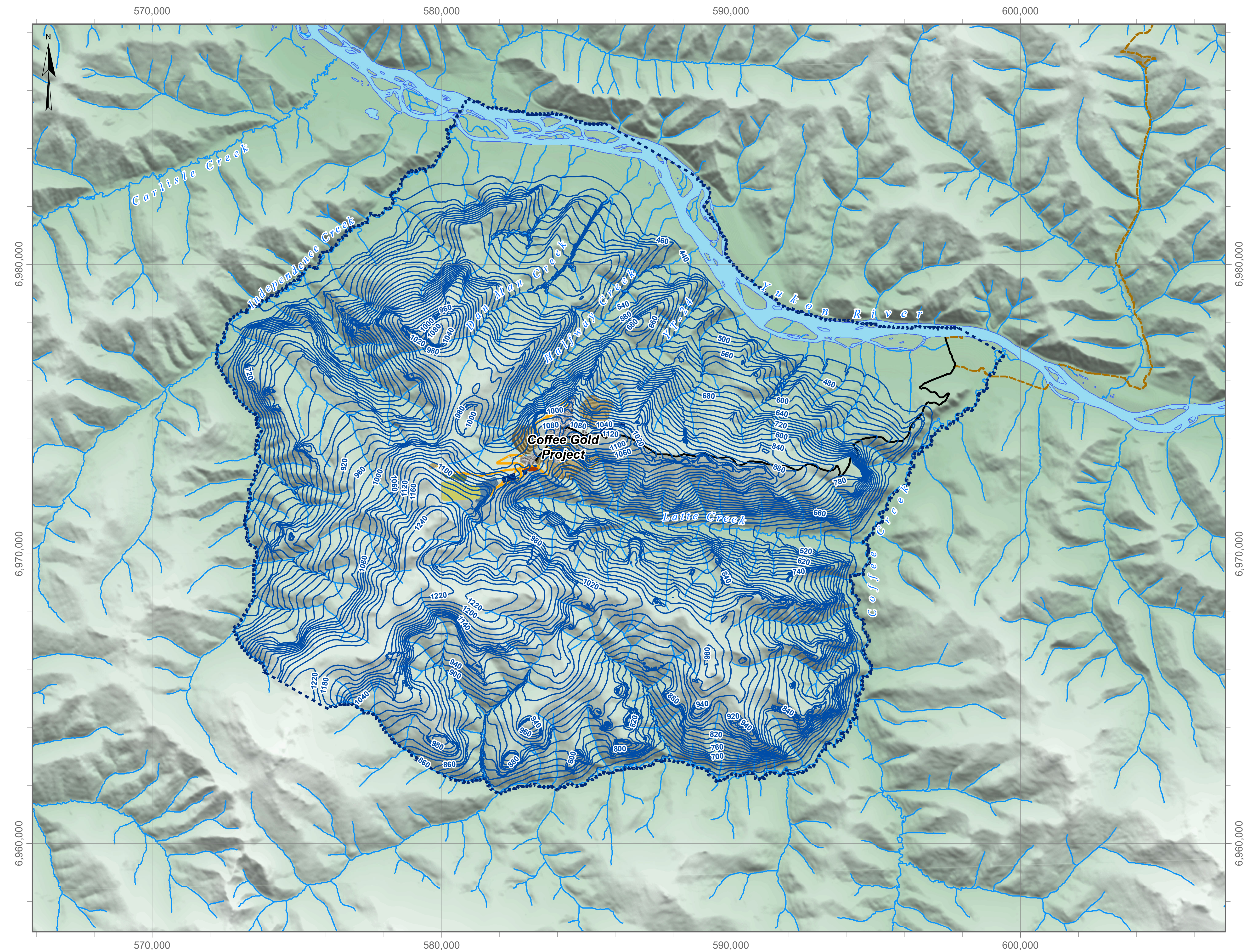
The water table is predicted to drop beneath the waste dumps because the recharge rate was reduced to zero under these dumps as well as beneath the backfilled Kona pit and the heap leach facility and event ponds. Beneath the North WRSF, the water table is predicted to drop as much as 40 m; beneath the West WRSF, the water table is predicted to drop by up to 10 m. Beneath the South WRSF, where the water table reduction is caused by both the reduction in recharge on the South WRSF and the Supremo 1 pit lake elevation, the maximum drop in head is approximately 25 m. The greatest reduction in water table elevation is beneath the Supremo 1 Backfill, where the water table is expected to drop as much as 80 m. For the most part, the zone of head change due to the mine facilities is constrained by Halfway Creek in the west and Latte Creek in the southeast.

The second area of notable Project changes to the water table is in the vicinity of the Kona pit and the Heap Leach Facility. In this southwestern area, the reduction in recharge causes the water table to drop on the order of 6 m and 15 m, respectively for the Kona area and the Heap Leach Facility and associated Event ponds. Although the maximum drawdown is lower than in the main mine area, the greater distance of the Kona and Heap Leach facilities from major stream channels results in the comparably large area of water table decline.

Finally, there is a small area of water table decline in the northern portion of the Double Double pit. The reason for this reduction in head is the change in hydraulic properties to reflect the backfilled waste rock (see Figure 4-3), which leads to a flattening of the hydraulic gradient within the backfill.

In spite of the relatively large aerial extent of water table decline due to the reduction in waste rock recharge, the majority of catchments are not predicted to experience a significant change in baseflow, as discussed below.

The model-wide mass balance is shown in Table 4-4. The recharge rate has increased relative to pre-mine conditions due to the enhanced recharge simulated for the waste dumps. The inflow and outflow via constant heads has also increased, due to a combination of the increased overall recharge and the specified heads at pit lakes.



LEGEND

- EOM Water Table Contours (20m)
- Model Domain Boundary
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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0 2 4 Km

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VERSION:	1

CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

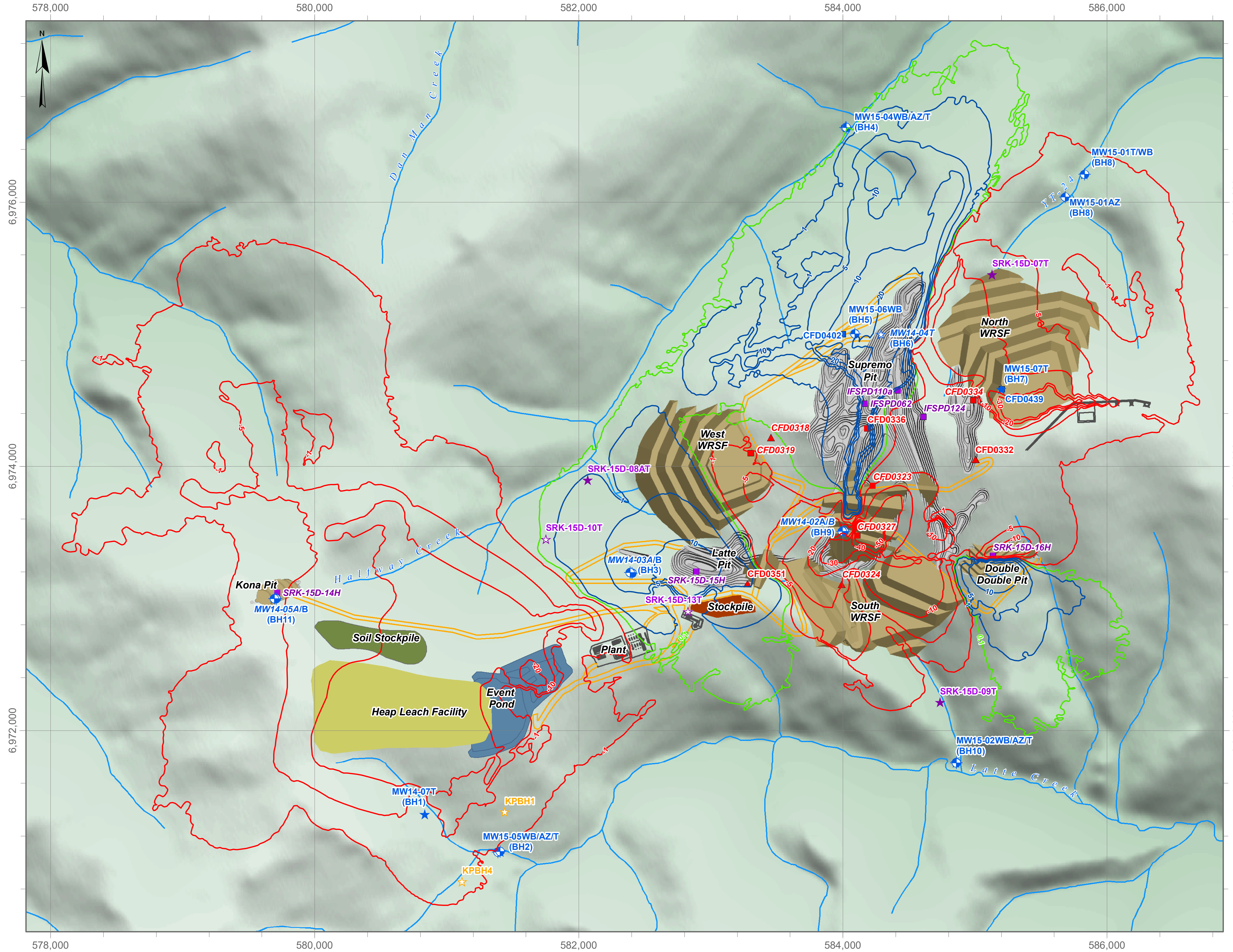
Coffee Gold Hydrogeology

TITLE:

Water Table at End of Operations

PROJECT #:	*FIGURE:*
A362-5	4-5

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-5_Water Table EOM_20160531.mxd



LEGEND

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

- Monitoring Well
- 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)

EOM Drawdown Contours (10m)

- <0m
- >0.1m
- 0.1m

Proposed Infrastructure

- Waste Dump
- Pit
- Leach pad
- Soil Stockpile
- Stockpile
- Plant
- Mine Road
- Event pond

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:27,500

0 400 800 Meters

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LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Change in Water Table Elevation from Pre-Mining Conditions to End of Operations

PROJECT #:	FIGURE:
A362-5	4-6

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-6_Change in WT EOM_20160601.mxd

**Table 4-4:
Model-Wide MassBalance, EOM**

	Inflow (L/s)	Outflow (L/s)	Discrepancy (L/s)	Percent Discrepancy
Constant Head	194.8	243.9		
Recharge	200.0			
General Head	0.0	0.0		
Drains		150.9		
Total	394.8	394.8	-0.01	0%

Table 4-5 lists the steady state groundwater inflow rates to the pit lakes. The seepage rates were determined with a combination of the water balance output and pathline trajectories. Only groundwater fluxes associated with constant head or general head boundary cells are included in the seepage rate estimates, while pit lake inflows also include groundwater flow that reports to the pit drains. The Supremo 1 pit lake is predicted to receive a net groundwater inflow of 1.28 L/s. As noted in the table, 1.34 L/s of the groundwater inflow that enters the Supremo 1 pit comes from the Supremo 2 pit lake through the T3 Structure. An additional 0.35 L/s of groundwater not associated with the Supremo 2 pit flows into the Supremo 2 pit lake. At the downgradient end of the Supremo 1 pit lake, 0.33 L/s pit lake water is predicted to seep into groundwater and discharge to Latte Creek, and 0.08 L/s pit lake water reports to the South WRSF underdrain and will be collected at the sediment pond.

At EOM, the Supremo 2 pit lake is predicted to have a lake elevation of 1078 masl (Table 4-1). Under steady state groundwater flow conditions, this lake is net "losing" to groundwater. Groundwater inflow into the pit is predicted by the model to be 0.24 L/s. Groundwater outflow is predicted to be 1.67 L/s, for a net groundwater outflow of 1.43 L/s. Of the groundwater recharged by the Supremo 2 pit lake, 1.34 L/s discharges to the Supremo 1 pit lake, and the balance discharges to Halfway Creek. The Latte pit lake and recharge on its pit walls are predicted to contribute a net flow of 0.71 L/s to groundwater. Of this, 0.58 L/s will discharge to Halfway Creek, and 0.12 L/s will discharge to Latte Creek. A negligible amount of less than 0.01 L/s seepage is predicted for SU3W lake, due to its proximity to MW14-04T, where 168 m of permafrost is present and assumed to restrict recharge from the pit lake to the water table, which is simulated to be at least 95 m below the base of the pit.

Table 4-5:
Groundwater Discharge to Pit Lakes, EOM

Pit Lake	Groundwater Flow (L/s)					
	Net Groundwater Inflow	Groundwater Flow into Pit	Seepage to Latte Creek	Seepage to Halfway Creek	Seepage to SWRSF Drain	Seepage to Supremo 1
Supremo 1	1.28	1.69	-0.33	-	-0.08	-
Supremo 2	-1.43	0.24	-0.00	-0.32	-	-1.34
Latte	-0.71	-	-0.12	-0.58	-	-
Supremo 3W	-0.0	-	-	-0.004	-	-
Supremo 4S	-0.1	Still being dewatered				
Supremo 5N	0.0	Still being dewatered				

Note: Negative values indicate flow out of pit lake

Table 4-6 lists the predicted groundwater discharge rates to area creeks at EOM. The model predicts slight changes to groundwater baseflows to Halfway Creek and YT-24, due to the presence of several pit lake elevations above current groundwater elevations. The groundwater baseflow directly to Latte Creek stream channel is predicted to drop due to the reduced water table in the Supremo 1 pit area and reduced recharge in the South WRSF area (compare Figure 4-5 with Figure 4-1). However, when the 1.28 L/s of groundwater-derived pit lake outflow is added to the groundwater-derived Latte Creek streamflow, the change in baseflow to Latte Creek is also minimal, and a net 12% increase in baseflow to CC-1.0 is predicted.

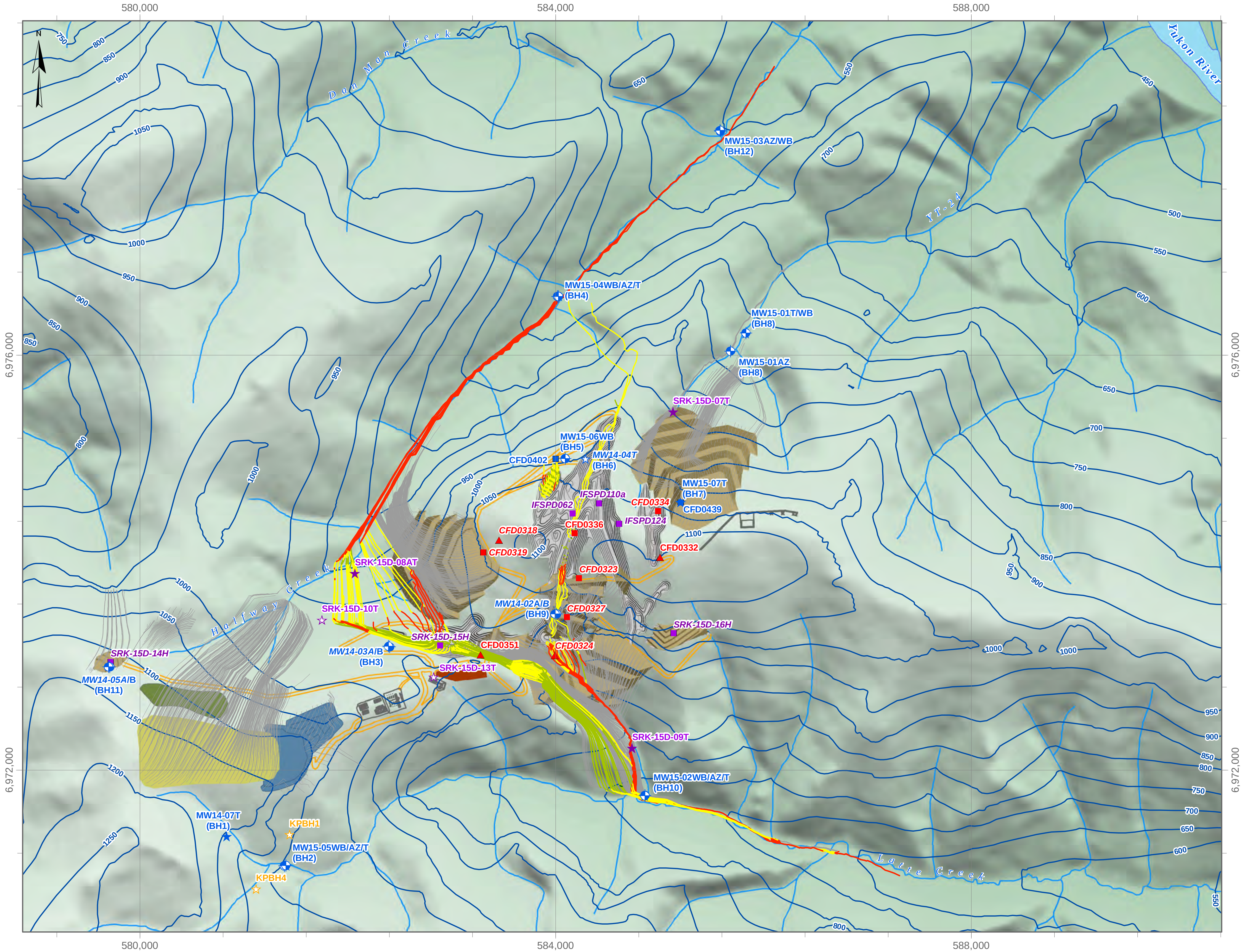
Table 4-6:
Simulated Groundwater Discharge to Surface Water, EOM

	EOM (L/s)	Pre-Mine (L/s)	Change (%)
Mine Area Catchment			
IC-2.5	3.1	3.1	-1.5
IC-3.0	11	11	-0.1
HC-2.5	8.6	8.5	1.1
HC-5.0	18	18	1.0
ML-1.0	7.1	7.2	-1.3
CC-6.0	4.4	4.4	-0.6
CC-1.0*	0.7	1.8	-61
CC-1.5**	12	13	-10
CC-3.5***	48	48	-3.7
Other Catchments at Model Edges			
IC-1.5 (SW Boundary)	22	22	0.4
IC-4.5 (W Boundary)	42	42	-0.1

Notes: *In addition to 0.7 L/s of groundwater discharge to the CC-1.0 stream channel, an additional 1.28 L/s of CC-1.0 streamflow will derive from Supremo 1 pit lake outflow associated with groundwater (see Table 4-5), for a groundwater discharge rate of 2.0 L/s, or a 12% increase in baseflow.
** With the addition of pit lake spill rates from groundwater, the EOM groundwater discharge to CC-1.5 is 13 L/s, corresponding to a -0.7% change in baseflow.
*** With the addition of pit lake spill rates from groundwater, the EOM groundwater discharge to CC-3.5 is 47 L/s, corresponding to a -1.0% change in baseflow.

Figure 4-7 shows particle tracks for a travel time of 50 years from mine facilities using the EOM steady state head distribution. A summary of early travel times to surface water receptors is presented in Table 4-7. Note that the reported travel times do not take into account the time required for seepage to travel through frozen and/or unsaturated ground between the facility and the water table. The largest volume of seepage inflow, 0.9 L/s, is predicted to discharge to Halfway Creek (see Table 4-5). From the particle tracking results on the steady state flow model, pathlines are predicted to arrive at Halfway creek in approximately 5.5 years. Approximately 0.5 L/s of seepage is predicted to report to Latte Creek; the steady state flow model predicts this seepage will take around seven (7) years to flow to Latte Creek from the Supremo 1 pit. The EOM model predicts no pit lake seepage losses to YT-24.

Figure 4-7 also shows the particle tracks from the North WRSF, West WRSF, South WRSF, Supremo 1 Backfill, Supremo 2 Backfill, Kona backfill, Kona WRSF, and Heap Leach and event ponds. These facilities are treated in the groundwater model as zero-recharge features. The reason for this is that the chemical load from these facilities is predicted to report to surface water features and not recharge groundwater in the water quality model. The assumption of no-recharge is conservative for the water quality model, and is also applied to the groundwater model. Therefore, the pathlines presented are to demonstrate the likely discharge points for groundwater originating from these facilities in the event that the assumption of zero recharge is not achieved in the future. Recharge from the North WRSF is predicted to discharge to YT-24. The West WRSF, Heap Leach and Kona WRSF are predicted to direct seepage to Halfway Creek. The Supremo 1 Backfill and Supremo 4 Backfill would impact Latte Creek if recharge into them rises above zero. The South WRSF and the Heap Leach Event Ponds would impact both Halfway Creek and Latte Creek if recharge was from them were greater than zero. The Kona pit backfill is predicted to impact IC-3.0. Additional simulations will be required if significantly higher recharge is anticipated from these facilities.



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)

EOM 50 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities
- EOM Water Table Contours (50m)

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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0 400 800 Meters

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VERSION:	1

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KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE: 50-Year Travel Time Particle Traces From Proposed Facilities with End of Operations Head Solution

PROJECT #:	FIGURE:
A362-5	4-7

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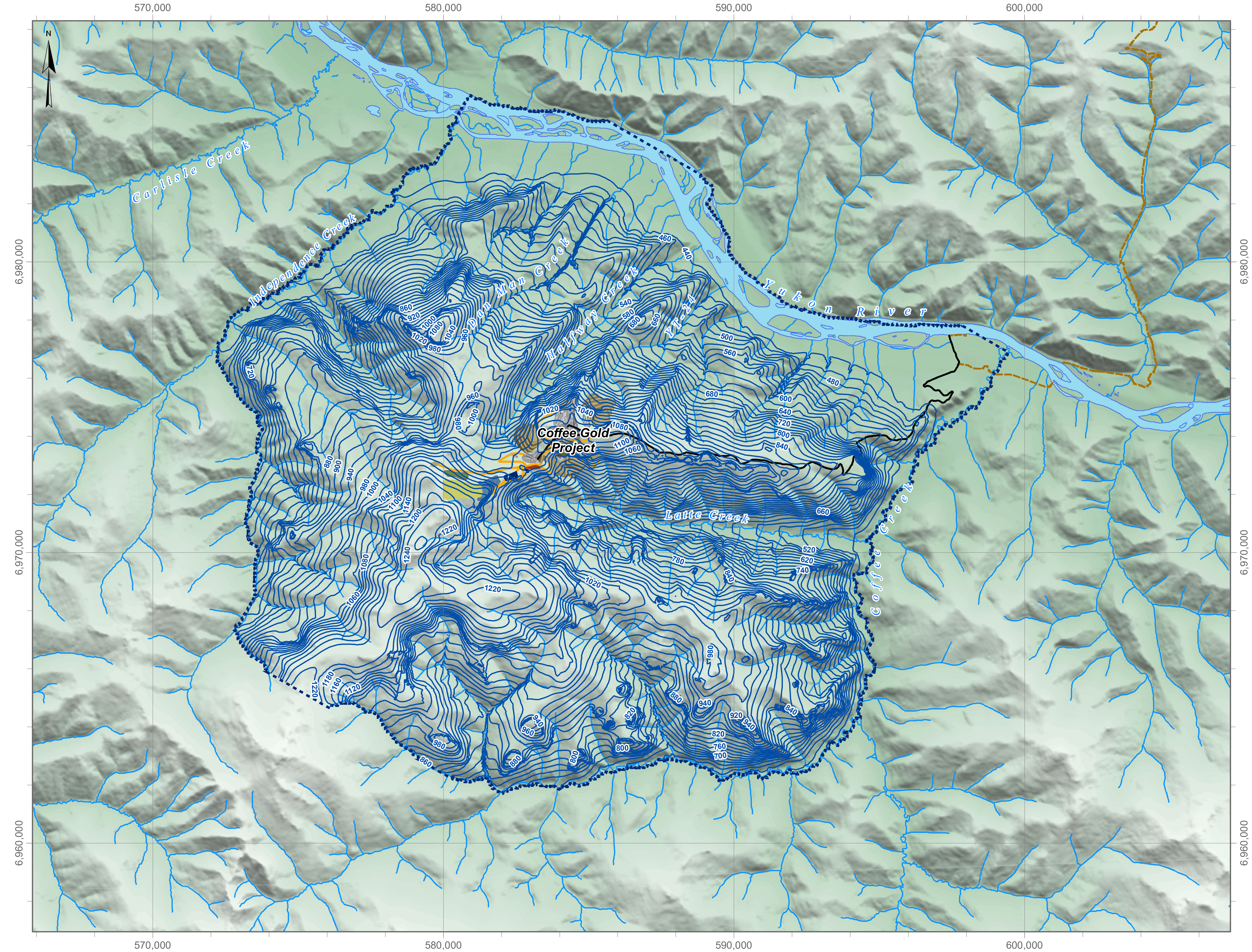
**Table 4-7:
Travel Time Estimate to Mine-Area Streams**

Source of Pathlines	Travel Time (years) of First Pathline to Surface Water Receptor					
	S WRSF	Latte Creek tributary (E of CC-1.0)	Latte Creek	Halfway Creek	YT-24	IC-3.0
Supremo 1	<1		7			
Supremo 2			>200	14		
Latte @ EOM			47	5.5		
Latte @ Post-Closure			18	2		
Double Double		<1	10			
Supremo 3W				>200		

4.2.2 Post-Closure

Figure 4-8 shows the water table simulated at closure, and Figure 4-9 shows the change in head relative to the pre-mine calibration model. The differences between Figure 4-6 and Figure 4-9 are due to the change in pit lake elevation at closure compared to EOM (see Table 4-1). The magnitude of head increase around the Supremo pits and the Latte pit is evident. The extent of water table rise due to the Latte Pit has also increased. In other areas of the model, the zone of water table impact has not increased.

The model-wide mass balance is shown in Table 4-8. The inflow and outflow via constant heads has increased relative to the EOM, due to an increase in the specified heads at some pit lakes.



LEGEND

- Post-Closure Water Table Contours (20m)
- Model Domain Boundary
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:125,000

0 2 4 Km

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VERSION:	1

CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

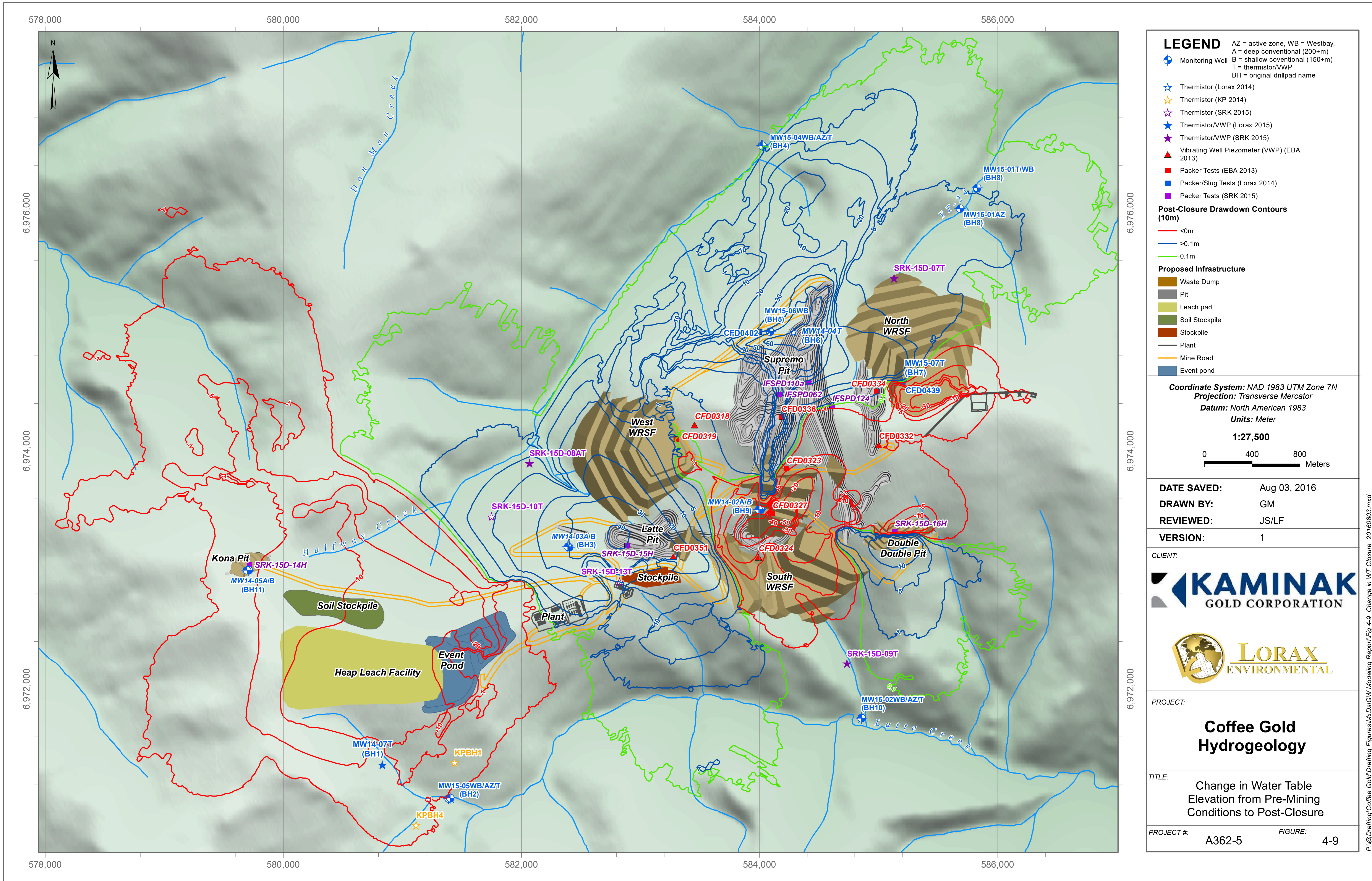
Coffee Gold Hydrogeology

TITLE:

Water Table at Post-Closure

PROJECT #:	*FIGURE:*
A362-5	4-8

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-8_Water Table Closure_20160803.mxd



LEGEND
AZ = active zone, WB = Westbay, A = deep conventional (200+m) B = shallow coventional (150+m) T = thermistor/VWP BH = original drillpad name
Monitoring Well
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 (10m)
<0m
>0.1m
0.1m
Proposed Infrastructure
Waste Dump
Pit
Leach pad
Soil Stockpile
Stockpile
Plant
Mine Road
Event pond
Coordinate System: NAD 1983 UTM Zone 7N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
1:27,500
0 400 800 Meters
DATE SAVED: Aug 03, 2016
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REVIEWED: JS/LF
VERSION: 1
CLIENT:
KAMINAK GOLD CORPORATION
LORAX ENVIRONMENTAL
PROJECT:
Coffee Gold Hydrogeology
TITLE:
Change in Water Table Elevation from Pre-Mining Conditions to Post-Closure
PROJECT #: A362-5
FIGURE: 4-9
P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-9_Change in WT Closure_20160803.mxd
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580,000
582,000
584,000
586,000
6,976,000
6,974,000
6,972,000
N
Dan Man Creek
Halfway Creek
Latte Creek
YT-24
MW15-04WB/AZ/T (BH4)
MW15-01T/WB (BH8)
MW15-01AZ (BH8)
SRK-15D-07T
North WRSF
MW15-06WB (BH5)
CFD0402
MW14-04T (BH6)
Supremo Pit
MW15-07T (BH7)
IFSPD110a
IFSPD062
IFSPD124
CFD0334
CFD0439
CFD0336
CFD0318
CFD0319
West WRSF
CFD0332
SRK-15D-08AT
CFD0323
SRK-15D-10T
MW14-02A/B (BH9)
CFD0327
SRK-15D-16H
MW14-03A/B (BH3)
Latte Pit
SRK-15D-15H
CFD0351
CFD0324
Double Double Pit
Kona Pit
SRK-15D-14H
MW14-05A/B (BH11)
SRK-15D-13T
Stockpile
South WRSF
Soil Stockpile
Plant
Event Pond
Heap Leach Facility
SRK-15D-09T
MW15-02WB/AZ/T (BH10)
MW14-07T (BH1)
KPBH1
MW15-05WB/AZ/T (BH2)
KPBH4

Table 4-8:
Model-Wide MassBalance, Post-Closure

	Inflow (L/s)	Outflow (L/s)	Discrepancy (L/s)	Percent Discrepancy
Constant Head	197.9	244.6		
Recharge	199.9			
General Head	0.0	0.0		
Drains		153.2		
Total	397.8	397.8	-0.003	0%

Table 4-9 lists the steady state groundwater inflow rates to the pit lakes at Post-Closure. The net groundwater inflow to Supremo 1 pit lake is predicted to increase to 2.0 L/s from 1.3 L/s at EOM. The total groundwater inflow to the pit is 2.4 L/s, 1.7 L/s of which derives from the Supremo 2 pit lake. At the downgradient end of the Supremo 1 pit lake, 0.37 L/s is predicted to discharge to Latte Creek, and 0.03 L/s is predicted to be captured by the South WRSF sediment pond. The reason for the increased inflow to the pit lake is largely a function of catchment area and associated water balance (precipitation and runoff) which results in the rise in the overall water table. The resulting increase in pit lake elevation from 1078 masl at EOM to 1085 at Post-Closure results in a higher flow out of the Supremo 2 pit lake.

Similarly, the flows out of Latte Pit are predicted to increase due to the increase in the lake elevation to 1017 masl at Post-Closure from 989 masl at EOM. The seepage loss from

Table 4-9:
Groundwater Discharge to Pit Lakes, Post-Closure

Pit Lake	Groundwater Flow (L/s)					
	Net Groundwater Inflow	Groundwater Flow into Pit	Seepage to Latte Creek	Seepage to Halfway Creek	Seepage to YT-24	Seepage to Supremo 1
Supremo 1	1.97	2.36	-0.37	-	-	-
Supremo 2	-1.70	0.22	-	-0.20	-	-1.72
Latte	-2.01	0.72	-0.81	-1.92	-	-
Supremo 3W	-0.00	-	-	-0.005	-	-
Supremo 3N	-0.01	-		-0.01	-0.002	
Supremo 4N	-0.42	0.06		-0.31	-0.17	
Supremo 4S	-0.22	0.14	-0.36			
Supremo 5S	-0.01	-			-0.007	
Supremo 5N	-0.00	-			-0.002	

Note: Negative values indicate flow out of pit lake

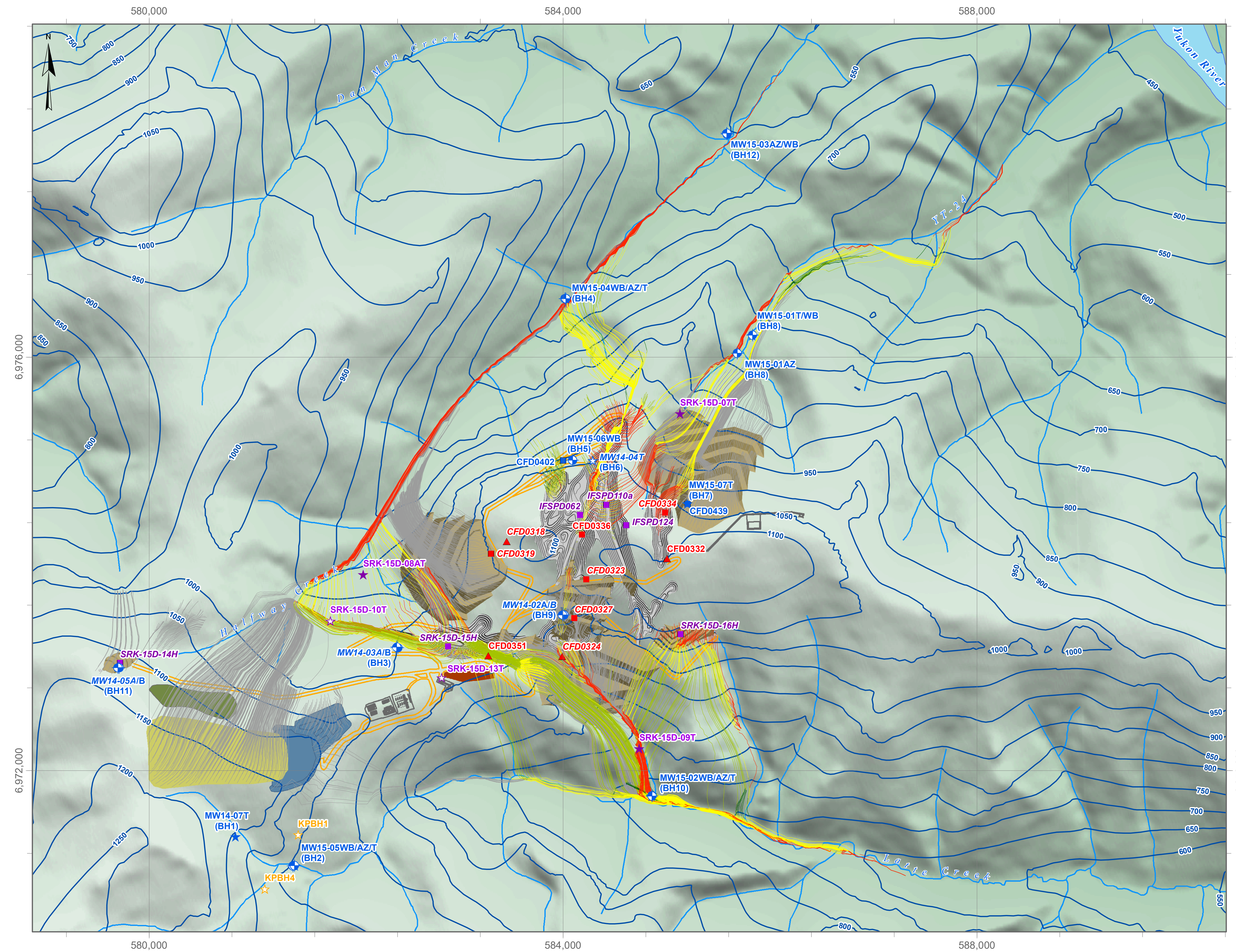
SU4N is predicted to be 0.4 L/s. The seepage losses from SU3W remains less than 0.01 L/s due to effects from the underlying permafrost. A less-than-0.01 L/s seepage loss is predicted for SU5S and SU5N pit lakes which are also assumed to be perched on permafrost. At SU5N, the model estimates that the water table is at least 75 m below the base of the pit, and at SU5S, the estimated distance between the base of the pit and the water table is greater than 50 m. MW15-07, located in the vicinity of the Supremo 5 pit has 140 m of permafrost.

Table 4-10 lists the predicted groundwater discharge rates to area creeks at Post-Closure. As for the EOM condition, minor changes to the baseflow to IC-2.5, IC-3.0 and CC-6.0 are predicted. Baseflows to Latte Creek are predicted to decline due to the reduced water table around the Supremo 1 pit and the South WRSF. When the groundwater-derived pit lake outflow is included, the groundwater-derived Latte Creek discharge is predicted to increase, as shown in the table. The primary difference in groundwater baseflows for EOM and Post-Closure occur at Halfway Creek, where the 1017 m Latte pit lake results in a predicted increase in baseflows to Halfway Creek.

Table 4-10:
Simulated Groundwater Discharge to Surface Water, Post-Closure

	Post-Closure (L/s)	Pre-Mining (L/s)	Change (%)
Mine Area Catchment			
IC-2.5	3.1	3.1	-1.5
IC-3.0	11	11	-0.4
HC-2.5	9.3	8.5	9.1
HC-5.0	19	18	5.1
ML-1.0	7.3	7.2	0.8
CC-6.0	4.4	4.4	-0.6
CC-1.0*	0.9	1.8	-50
CC-1.5**	12	13	-6.4
CC-3.5***	47	48	-2.5
Other Catchments at Model Edges			
IC-1.5 (SW Boundary)	22	22	0.4
IC-4.5 (W Boundary)	42	42	-0.1

Notes: *In addition to 0.7 L/s of groundwater discharge to the CC-1.0 stream channel, an additional 1.97 L/s of CC-1.0 streamflow will derive from Supremo 1 pit lake outflow associated with groundwater (see Table 4-9), for a groundwater discharge rate of 2.9 L/s, or a 62% increase in baseflow.
** With the addition of pit lake spill rates from groundwater, the EOM groundwater discharge to CC-1.5 is 14 L/s, corresponding to an 8.4% increase in baseflow.
*** With the addition of pit lake spill rates from groundwater, the EOM groundwater discharge to CC-3.5 is 49 L/s, corresponding to a 1.6% increase in baseflow



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)
- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities
- Post-Closure Water Table Contours (50m)

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:35,000

0 400 800 Meters

DATE SAVED:	Aug 03, 2016
DRAWN BY:	GM
REVIEWED:	LF
VERSION:	1

CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE: 200-Year Travel Time Particle Traces From Proposed Facilities with Post-Closure Head Solution

PROJECT #: A362-5 FIGURE: 4-10

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-10_200 Yr Particle Traces Closure_20160803.mxd

Figure 4-10 shows particle tracks for a travel time of 200 years from mine facilities using the Post-Closure steady state head distribution. A summary of leading-particle travel times to surface water receptors from pits that are dewatered in the EOM run but have pit lakes at Post-Closure is presented in

Table 4-11. At closure, Latte Creek and Halfway Creek are both expected to receive approximately 2 L/s of seepage from the pit lakes. Approximately one tenth of that amount of seepage is predicted to report to YT-24.

Like Figure 4-7, Figure 4-10 shows the particle tracks zero-recharge mine facilities. The receptors for potential recharge from these facilities is the same at Post-Closure as at EOM.

Table 4-11:
Travel Time Estimate to Mine-Area Streams, Pits that are Dewatered at EOM

	Travel Time (years) of First Pathline to Surface Water Receptor			
Source of Pathlines	**CC-1.0**	**Latte Creek**	**Halfway Creek**	**YT-24**
Supremo 3N			8	160
Supremo 4N			25	23
Supremo 4S		4		
Supremo 5S				>200
Supremo 5N				>200

4.3 Sensitivity Analysis on Predictions

Model runs were completed with EOM and Post-Closure boundary conditions for all sensitivity runs described in Section 3 for the baseline model. In addition, a sensitivity analysis was completed on the recharge applied to the Double Double backfilled waste rock. A summary of the mass balance, baseflow estimates and pit inflow numbers from these runs are presented in Table 4-12 and Table 4-13. Note that in these tables, the baseflows to CC-1.0, CC-1.5 and CC-3.5 do not include groundwater-derived pit lake outflow from the Supremo 1 pit.

Table 4-12:
Mass Balance, Baseflows, and Pit Inflows, EOM Sensitivity Runs

	Base Case	Shallow Bedrock K x 5	Shallow Bedrock K x 2	Shallow Bedrock K/2	Deep Bedrock K x 5	Deep Bedrock K/2	T3 Structure K x 10	T3 Structure K/10	Latte Structure K x 10	Latte Structure K/10	non-PF Recharge +30%	non-PF Recharge -30%	Permafrost Recharge +2-5 mm/y	Permafrost Recharge 0 mm/y	General Creek Structure K x 10	General Creek Structure K/ 10	Highest Ks x 10	Highest Ks / 10	Permafrost K x10	Permafrost K/2	Waste Rock Recharge +25%	Waste Rock Recharge +50%
Model-Wide Inflow (L/s):																						
Constant Head	194.8	206.3	197.0	194.3	195.6	194.7	208.9	193.3	197.7	194.3	194.2	195.6	193.4	194.8	195.1	194.6	1930.1	21.3	194.8	194.8	194.8	194.8
General Head	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Recharge	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	257.6	142.3	242.2	194.1	200.0	200.0	200.0	200.0	200.0	200.0	200.1	200.3
Total	394.8	406.3	397.0	394.3	395.5	394.7	408.9	393.3	397.7	394.3	451.8	337.9	435.6	389.0	395.1	394.6	2130.1	221.3	394.8	394.8	394.9	395.1
Model-Wide Outflow (L/s)																						
Constant Head	243.9	278.6	255.6	235.6	248.5	243.3	252.1	242.8	243.9	243.9	253.5	233.8	254.1	243.7	245.7	243.5	1977.3	70.9	242.5	244.0	243.9	243.9
General Head	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drain	150.9	127.7	141.4	158.8	147.0	151.4	156.8	150.4	153.9	150.4	198.3	104.1	181.6	145.3	149.5	151.1	152.8	150.4	152.4	150.7	151.1	151.2
Total	394.8	406.3	397.0	394.5	395.5	394.7	408.9	393.3	397.8	394.3	451.8	337.9	435.6	389.0	395.2	394.6	2130.1	221.3	394.9	394.8	394.9	395.1
In-Out (L/s)	0.0	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
In-Out (%)	0.00	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	-0.03	0.00	0.00	0.00	0.00	-0.02	-0.03	0.00	0.00	0.00	-0.04	-0.01	0.00	-0.01
Discharge to Streams (L/s)																						
IC-2.5	3.1	0.0	1.9	4.2	1.8	3.2	3.1	3.1	3.1	3.1	4.6	1.7	4.0	2.9	3.4	3.4	3.1	3.1	3.1	3.1	3.1	3.1
IC-3.0	11	11	11	10	12	10	11	11	11	11	13	8	13	10	10	10	11	11	11	11	11	11
HC-2.5	8.6	8.7	8.6	8.6	8.8	8.6	8.8	8.4	11.4	8.2	11.1	6.0	10.0	8.3	1.4	9.1	8.5	8.5	8.6	8.5	8.5	8.5
HC-5.0	18	19	18	18	19	18	18	18	21	17	23	13	21	18	18	18	18	18	18	18	18	18
ML-1.0	7.1	7.0	7.0	7.2	7.0	7.1	7.2	7.1	7.1	7.1	9.3	5.0	8.2	7.1	7.2	7.4	7.1	7.1	7.1	7.1	7.1	7.1
CC-6.0	1.5	1.5	1.5	1.6	0.3	1.7	1.5	1.5	1.5	1.5	2.1	1.0	1.7	1.4	1.5	1.5	1.5	1.5	1.1	1.6	1.5	1.5
CC-1.0	0.7	2.1	1.1	0.4	0.7	0.7	0.7	0.7	0.7	0.6	0.8	0.5	0.8	0.7	0.1	1.9	0.4	2.4	0.7	0.7	0.7	0.8
CC-1.5	12	16	13	11	11	12	12	12	12	12	16	8	14	11	11	12	5	16	12	12	12	12
CC-3.5	46	49	47	46	44	46	46	46	46	46	62	30	52	44	41	50	23	53	45	46	46	46
IC-1.5	22	22	22	22	23	22	22	22	22	22	28	16	26	21	21	22	21	22	22	22	22	22
IC-4.5	42	41	41	42	43	41	42	42	42	42	54	30	53	40	41	42	40	41	42	42	42	42
GW Inflow to Pits (L/s)																						
SU1 Lake 939	1.3	-3.7	0.1	1.8	1.1	1.3	12.5	0.1	1.4	1.2	1.5	1.1	1.4	1.3	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3
SU2 1078	-1.4	-1.6	-1.5	-1.4	-2.1	-1.3	-15.6	0.1	-1.4	-1.4	-1.4	-1.5	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4
Latte 989	-0.7	-3.7	-1.7	-0.1	-1.3	-0.6	-0.7	-0.7	-3.7	-0.1	-0.5	-1.0	-0.5	-0.7	-1.0	-0.6	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
SU3W GHB 1171	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SU4S	0.1	0.0	0.0	0.2	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
SU4N	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4-13: Mass Balance, Baseflows, and Pit Inflows, Post-Closure Sensitivity Runs

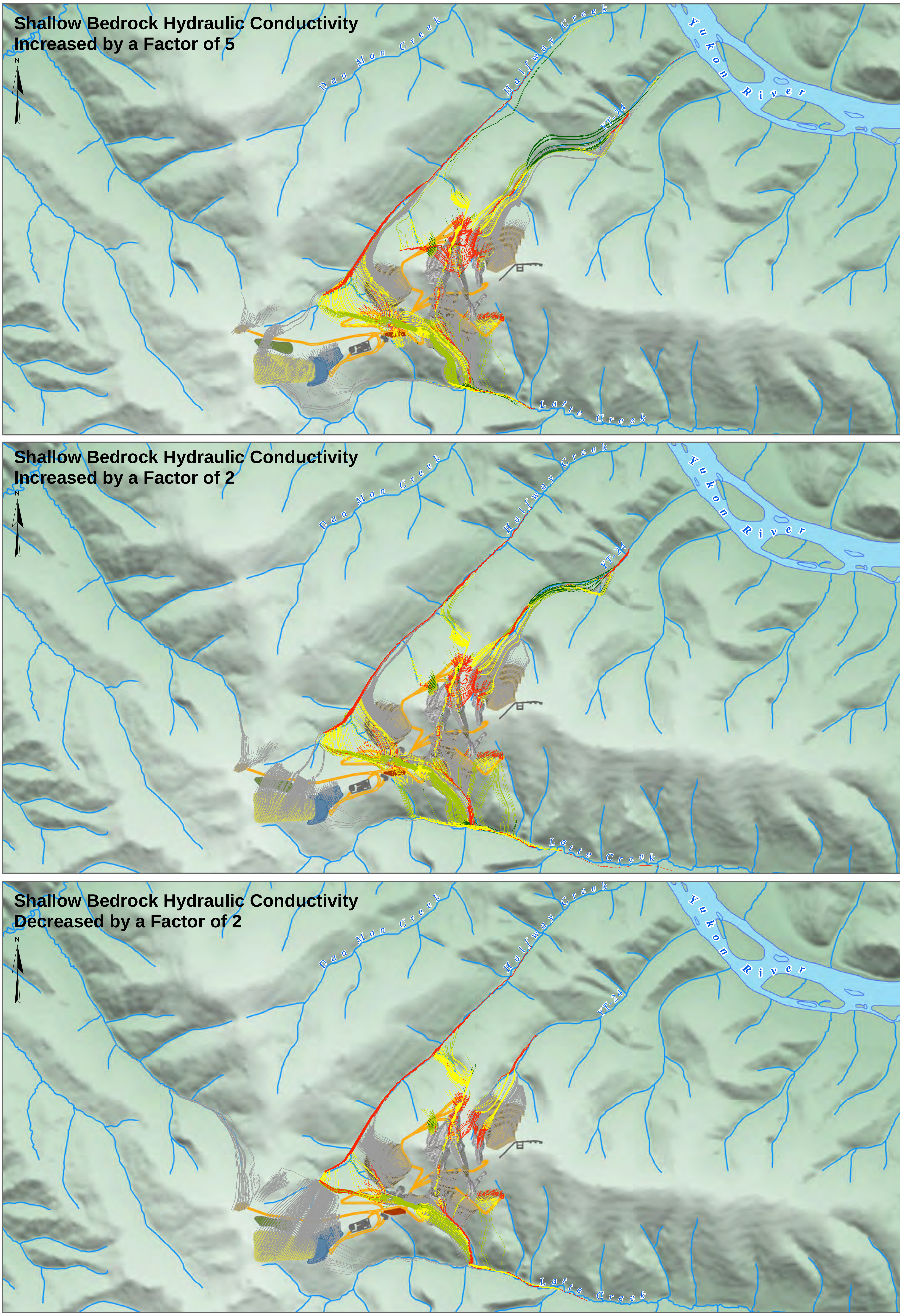
	Base Case	Shallow Bedrock K x 5	Shallow Bedrock K x 2	Shallow Bedrock K/2	Deep Bedrock K x 5	Deep Bedrock K/5	T3 Structure K x 10	T3 Structure K /10	Latte Structure K x 10	Latte Structure K /10	non-PF Recharge +30%	non-PF Recharge -30%	Permafrost Recharge +2-5 mm/y	Permafrost Recharge 0 mm/y	General Creek Structure K x 10	General Creek Structure K / 10	Highest Ks x 10	Highest Ks / 10	Permafrost K x10	Permafrost K /2	Waste Rock Recharge +25%	Waste Rock Recharge +50%
Model-Wide Inflow (L/s):																						
Constant Head	197.9	214.0	201.2	196.6	199.3	197.7	212.1	196.1	209.0	196.1	197.3	198.7	196.5	197.9	198.2	197.7	1933.2	24.4	198.0	197.9	197.9	197.9
General Head	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Recharge	199.9	199.9	199.9	199.9	199.9	199.9	199.9	199.9	199.9	199.9	257.5	142.3	242.1	194.1	199.9	199.9	199.9	199.9	199.9	199.9	200.1	200.2
Total	397.8	413.9	401.2	396.6	399.3	397.6	412.0	396.0	409.0	396.0	454.8	341.0	438.7	392.0	398.1	397.7	2133.1	224.4	397.9	397.8	398.0	398.1
Model-Wide Outflow (L/s)																						
Constant Head	244.6	279.6	256.4	236.2	249.2	244.1	256.9	243.3	244.7	244.5	254.3	234.5	254.8	244.5	246.4	244.3	1978.0	71.6	243.3	244.8	244.6	244.6
General Head	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Drain	153.2	134.3	144.7	160.4	150.1	153.6	155.1	152.7	164.2	151.5	200.6	106.5	183.8	147.6	151.8	153.4	155.1	152.8	154.8	153.0	153.4	153.5
Total	397.8	413.9	401.2	396.6	399.3	397.7	412.0	396.0	409.0	396.0	454.9	341.0	438.7	392.1	398.3	397.7	2133.2	224.4	398.0	397.8	398.0	398.2
In-Out (L/s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
In-Out (%)	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.04	0.00	0.00	-0.01	-0.02	0.00	0.00	0.00
Discharge to Streams (L/s)																						
IC-2.5	3.1	0.0	1.9	4.2	1.8	3.2	3.1	3.1	3.1	3.1	4.6	1.7	4.0	2.9	3.4	3.4	3.1	3.1	3.1	3.1	3.1	3.1
IC-3.0	11	11	11	10	12	10	11	11	11	11	13	8	13	10	10	10	11	11	11	11	11	11
HC-2.5	9.3	10.7	9.6	9.1	9.8	9.3	9.7	9.2	15.6	8.6	11.9	6.8	10.8	9.1	2.0	9.9	9.3	9.3	9.4	9.3	9.3	9.3
HC-5.0	19	21	19	18	20	19	19	18	25	18	24	14	21	19	19	19	19	19	19	19	19	19
ML-1.0	7.3	8.0	7.4	7.2	7.3	7.2	7.4	7.2	7.3	7.3	9.4	5.2	8.3	7.2	7.3	7.6	7.3	7.3	7.3	7.3	7.3	7.3
CC-6.0	4.4	2.8	4.0	4.6	2.1	4.6	4.4	4.4	4.4	4.4	5.9	2.8	5.1	3.5	1.9	4.9	4.4	4.4	4.1	4.4	4.4	4.4
CC-1.0	0.9	3.5	1.5	0.5	1.0	0.9	0.9	0.9	0.9	0.8	1.0	0.7	1.0	0.9	0.1	2.2	0.6	2.7	0.9	0.9	0.9	1.0
CC-1.5	12	18	14	11	12	12	12	12	13	12	16	9	14	11	12	13	5	16	12	12	13	13
CC-3.5	47	52	48	46	45	47	47	47	47	46	62	31	52	45	41	51	23	54	46	47	47	47
IC-1.5	22	22	22	22	23	22	22	22	22	22	28	16	26	21	21	22	21	22	22	22	22	22
IC-4.5	42	41	41	42	43	41	42	42	42	42	54	30	53	40	41	42	40	41	42	42	42	42
GW Inflow to Pits (L/s)																						
SU1 Lake 939	2.0	-2.0	1.1	2.4	1.8	2.0	15.4	0.5	2.2	1.7	2.2	1.7	2.1	2.0	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0
SU2 1082	-1.7	-1.9	-1.7	-1.7	-2.3	-1.6	-16.1	0.0	-1.7	-1.7	-1.7	-1.8	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7
SU4N CHB 1090	-0.4	-1.8	-0.8	-0.1	-1.0	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.5	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Latte 1017	-2.0	-7.2	-3.6	-1.1	-2.8	-1.9	-2.0	-2.0	-8.7	-0.7	-1.8	-2.3	-1.8	-2.0	-2.2	-1.9	-2.0	-2.0	-2.1	-2.0	-2.0	-2.0
SU3N GHB 1090	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SU4S CHB 1036	-0.2	-2.1	-0.7	0.1	-0.5	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
SU3W GHB 1194	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SU5N GHB 1123	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SU5S GHB 1180	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

4.3.1 Sensitivity to Shallow Bedrock Hydraulic Conductivity

As discussed in Section 3.4.1, the model calibration is highly sensitive to the hydraulic conductivity assigned to the Shallow Bedrock unit in the model. Not surprisingly, the hydraulic conductivity of the Shallow Bedrock also plays a large role in the predictions of Project changes to groundwater due to mining, as shown in Table 4-12 and Table 4-13. The net inflow to all of the pit lakes is strongly influenced by this parameter. For the Supremo 1 pit lake, the net inflow at Post-Closure can vary from -2.0 L/s, a net outflow, for a Shallow Bedrock hydraulic conductivity of $6.0x10^{-7}$ m/s to a 2.4 L/s, a net inflow, for a Shallow Bedrock hydraulic conductivity of $6.0x10^{-8}$ m/s. The effect on the seepage losses from the Latte pit lake is more pronounced, with loss rates ranging from 1.1 L/s for a low hydraulic conductivity to 7.2 L/s for the highest hydraulic conductivity.

Figure 4-11 illustrates the changes in pit lake seepage losses on the pathlines of water from the pit lakes. The highest hydraulic conductivity yields the greatest density of pathlines to the creeks and the longest travel distance over 200 years. This is due to a combination of the higher hydraulic conductivity and the lower water table, which results in longer travel times within bedrock groundwater before discharge to surface water. Furthermore, for the higher hydraulic conductivity simulation a greater number of pathlines travels in deeper layers, particularly in the YT-24 catchment. For the lowest hydraulic conductivity value, the pathlines that escape the mine are fewer, travel less far and less deep in the time period simulated, as shown in Figure 4-11.

Predicted baseflows to Halfway Creek, Latte Creek and IC-2.5 are also influenced by this parameter. In Halfway Creek, YT-24 and Latte Creek downstream of CC-6.0, an increase in the Shallow Bedrock hydraulic conductivity results in higher baseflows. The most pronounced increase in baseflow is predicted for CC-1.0, where a more than doubling of groundwater discharge is predicted for a five-times increase in Shallow Bedrock hydraulic conductivity. At other locations, such as Latte Creek at CC-6.0 and at IC-2.5, a higher shallow bedrock hydraulic conductivity reduces the water table to below the creek bottom, leading to a reduction in baseflow. In the most extreme case, IC-2.5 is expected to receive no groundwater discharge when the Shallow Bedrock hydraulic conductivity is increased by a factor of five. For CC-6.0 and IC-2.5, a lowering of the Shallow Bedrock hydraulic conductivity results in higher groundwater discharge rates due to a higher water table around the creek.



LEGEND

Post-Closure 200 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities

DATE SAVED:	Aug 03, 2016
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REVIEWED:	JS/LF
VERSION:	1

Coordinate System: NAD 1983 UTM Zone 7N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

1:80,000

0 1 2 Kilometers

CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

200 Year Post-Closure Particle Traces from Sensitivity Analysis of Shallow Bedrock Hydraulic Conductivity

PROJECT #: A362-5

FIGURE: 4-11

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-11_200 Yr Particle Traces SA Shallow Bedrock_20160803.mxd

4.3.2 Sensitivity to Deep Bedrock Hydraulic Conductivity

The hydraulic conductivity of the Deep Bedrock has a notable influence on model results as the Deep Bedrock unit is present over a large proportion of the model domain. Table 4-12 and Table 4-13 show that this parameter has a less pronounced impact on the pit inflows than the Shallow Bedrock. The maximum change in the net flow to the pits is 0.8 L/s, for the Latte pit, compared to a more than 5 L/s change for the Shallow Bedrock sensitivity analysis (Section 4.3.1).

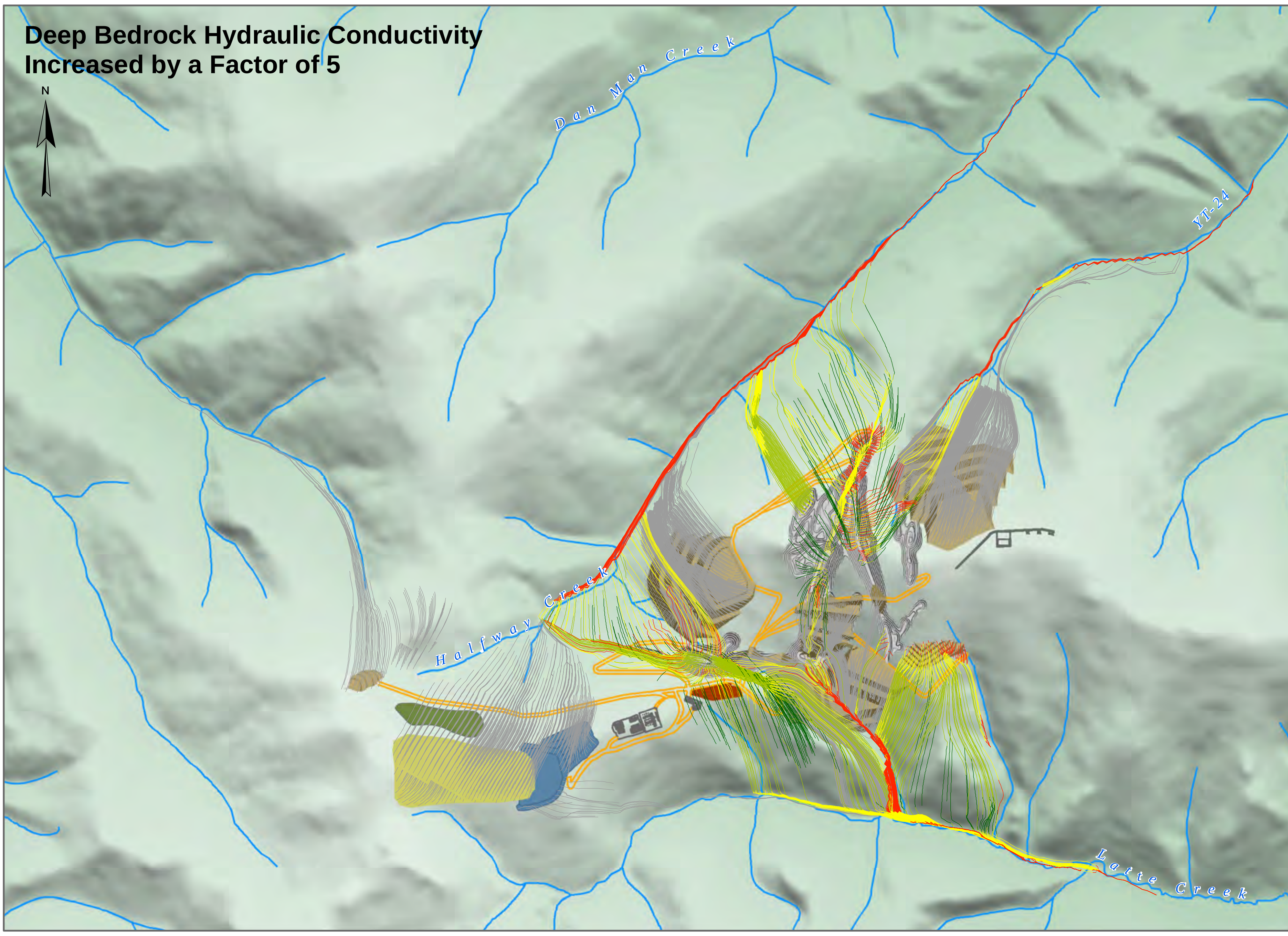
Figure 4-12 shows a greater pathline density and deeper pathline trajectory for the higher deep bedrock hydraulic conductivity than the lower deep bedrock hydraulic conductivity, but a similar overall travel distance in 200 years.

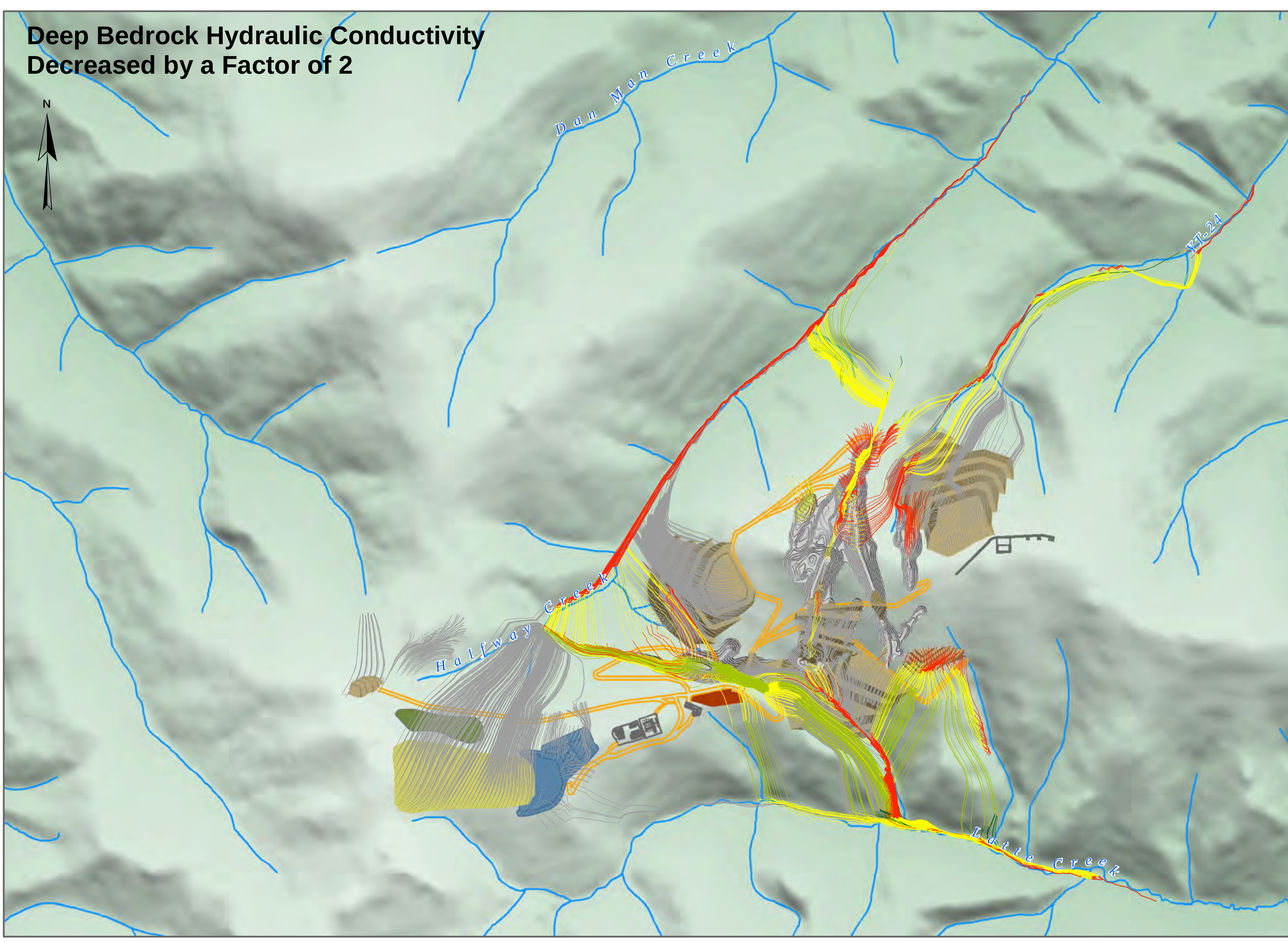
This parameter has a pronounced impact on the baseflows to a few streams, especially the baseflow to CC-6.0. When the deep bedrock hydraulic conductivity is increased by a factor of five, the simulated baseflow to CC-6.0 is reduced by more than a factor of two, from 4.4 L/s to 2.1 L/s. The baseflow to IC-2.5 at Post-Closure also decreases—from 3.1 L/s to 1.8 L/s—when the deep bedrock hydraulic conductivity is increased by a factor of five.

4.3.3 Sensitivity to T3 Structure Hydraulic Conductivity

As discussed in Section 3.4.3, the hydraulic conductivity of the T3 Structure has a relatively minor influence on the model calibration. Table 4-12 and Table 4-13 show that this parameter has a minor effect on baseflows to streams or on pit inflows to the Latte pit lake. The T3 Structure hydraulic conductivity has a profound effect on the pit lake-groundwater interactions at the Supremo 1 and Supremo 2 lakes, which are underlain by the T3 Structure. For a T3 Structure hydraulic conductivity of 2×10^{-5} m/s, there is significant flow from the 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. For the higher hydraulic conductivity tested, the computed pit lake elevation in the Supremo 2 pit lake would be lower, resulting in a different flow regime than the base case model. On the other hand, the majority of pathlines shown in Figure 4-13 indicate that the flow regime outside the pit area, assuming no change in pit lake elevations, is not strongly influenced by this parameter. The exception are the flowlines from the Supremo 3N pit lake, which for the low-hydraulic conductivity T3 Structure simulation recharge deeper into bedrock and therefore take a longer time to discharge to Halfway Creek than the base case simulation or the high-hydraulic conductivity T3 Structure simulation.





LEGEND

Post-Closure 200 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities

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***Coordinate System:** NAD 1983 UTM Zone 7N*
***Projection:** Transverse Mercator*
***Datum:** North American 1983*
***Units:** Meter*

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CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

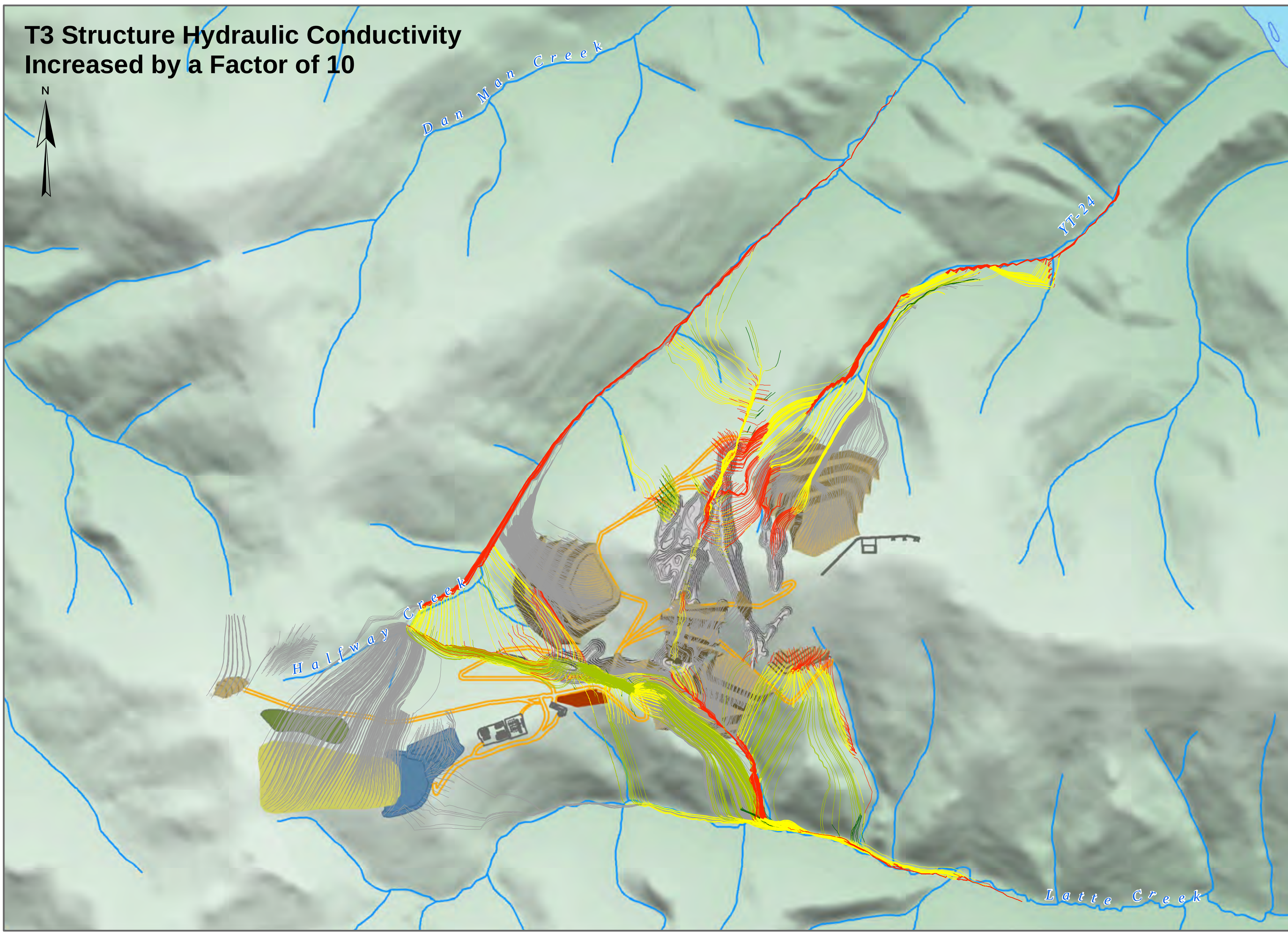
TITLE:

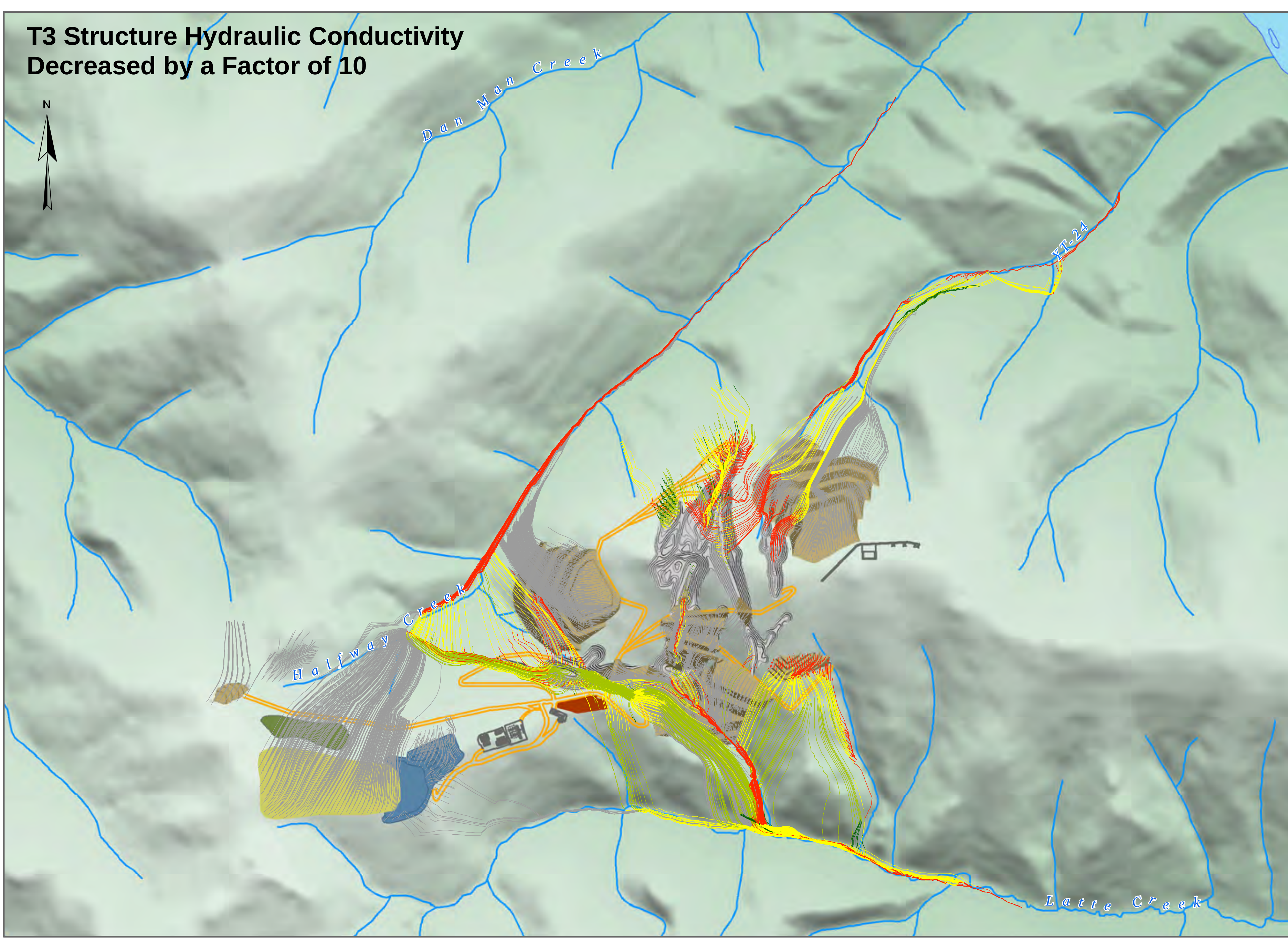
200 Year Post-Closure Particle Traces from Sensitivity Analysis of Deep Bedrock Hydraulic Conductivity

PROJECT #: A362-5

FIGURE: 4-12

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-12_200 Yr Particle Traces SA Deep Bedrock_20160803.mxd





LEGEND

Post-Closure 200 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities

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Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
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Units: *Meter*

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CLIENT:

KAMINAK GOLD CORPORATION

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PROJECT:

Coffee Gold Hydrogeology

TITLE:

200 Year Post-Closure Particle Traces from Sensitivity Analysis of T3 Hydraulic Conductivity

PROJECT #: A362-5 *FIGURE:* 4-13

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-13_200 Yr Particle Traces SA T3_20160803.mxd

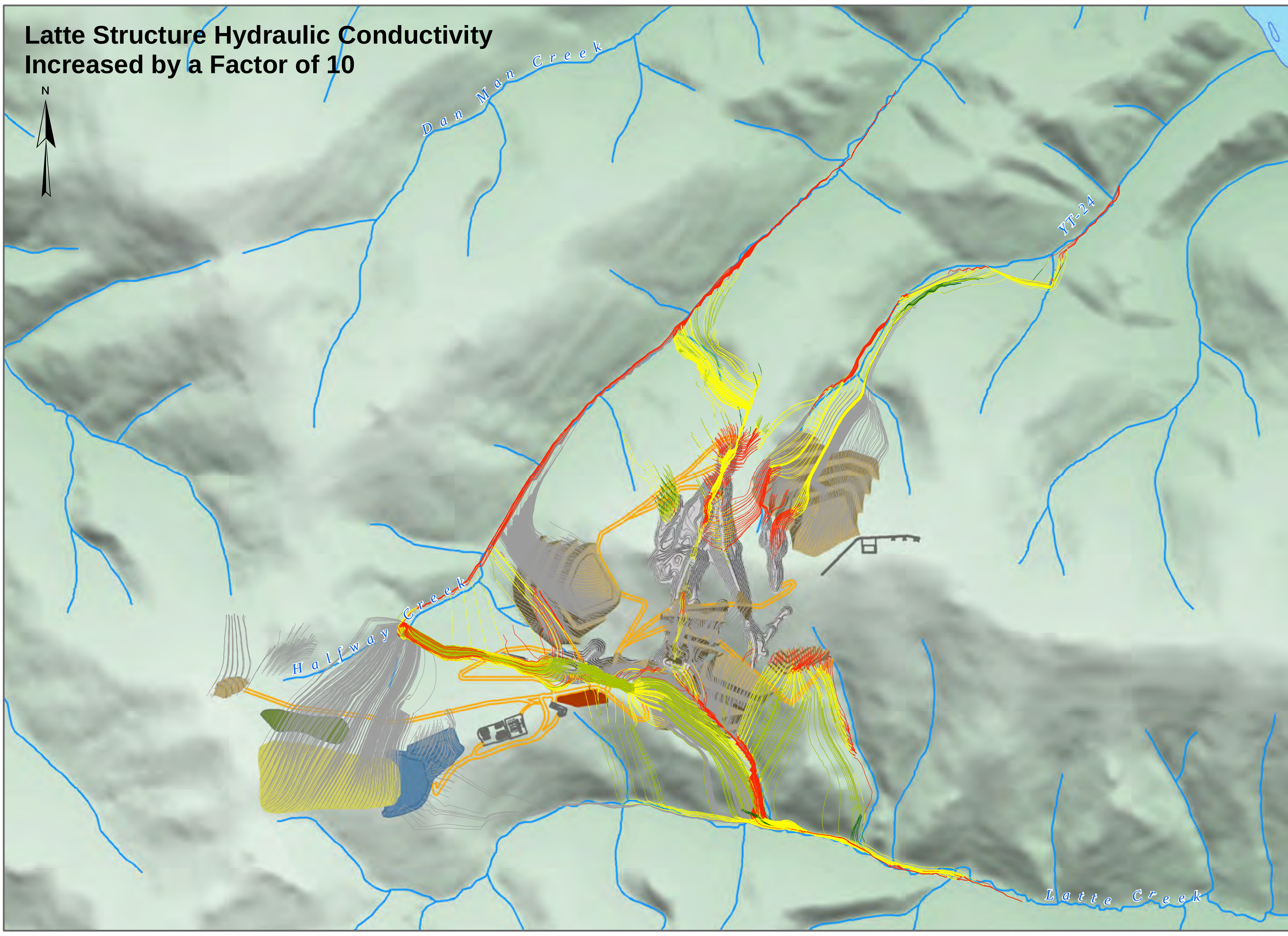
4.3.4 Sensitivity to Latte Structure Hydraulic Conductivity

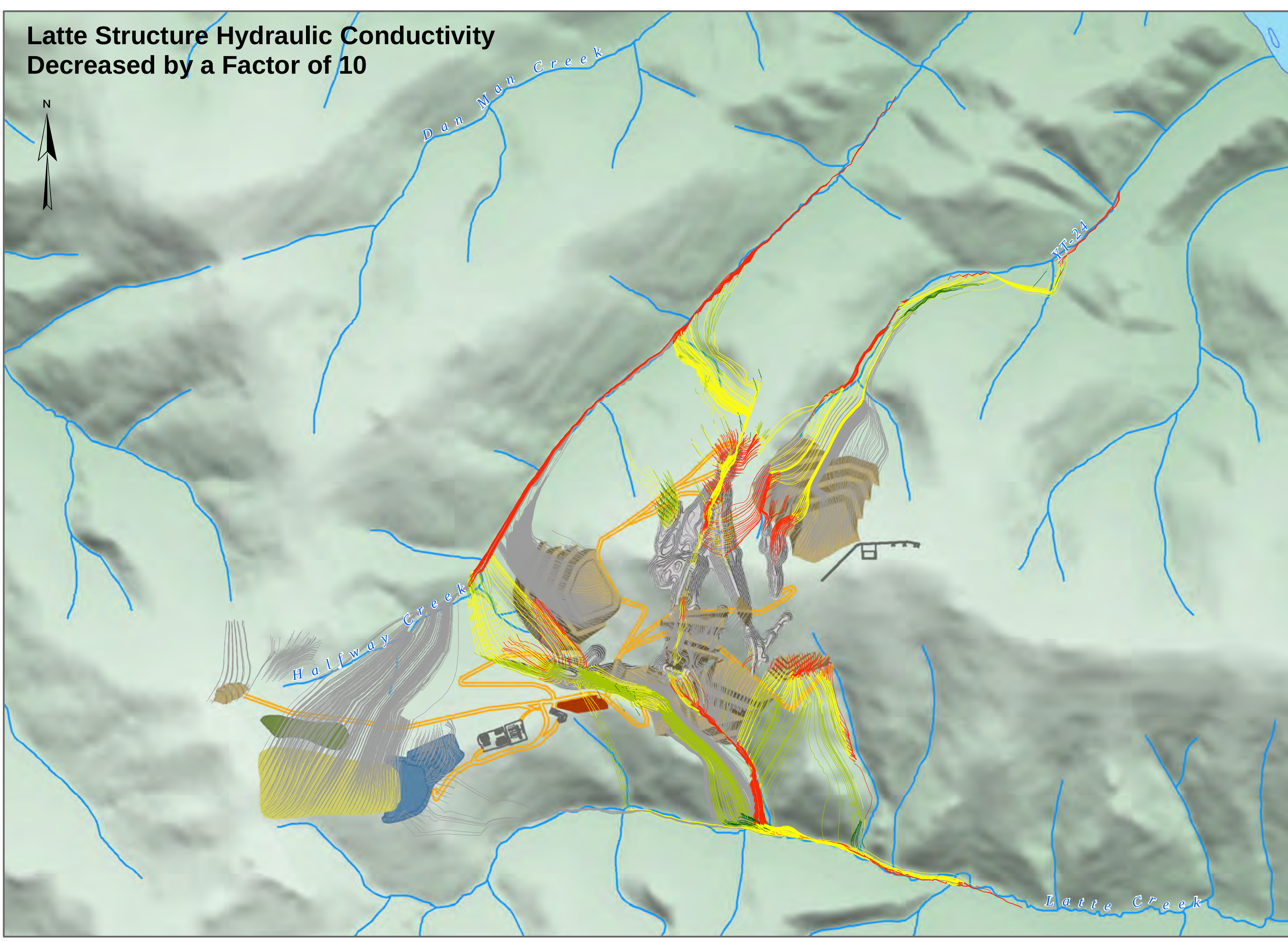
Like the T3 Structure, the Latte Structure has a relatively minor influence on the calibration. However, this structure has a pronounced effect on the flows into and out of the Latte pit and the baseflows to Halfway Creek, as shown in Table 4-13. When the Latte Structure hydraulic conductivity is increased by a factor of 10, the predicted Post-Closure baseflow to HC-2.5 increases 60% from 9.3 L/s to 16 L/s. A reduction in the hydraulic conductivity of the Latte Structure has lower effect on the simulated HC-2.5 baseflow, which drops from 9.3 L/s to 8.6 L/s.

At Post-Closure, this parameter also affects pit inflows to the Supremo 1 and Supremo 2 pit lakes because of its influence on the shape of the water table between the Latte and Supremo pits. Because the Latte Structure is located near the center of the model domain within the main mine facilities, the length of the particle tracks is generally unaffected by this parameter, as shown in Figure 4-14. The exceptions are the pathlines from the Latte Pit. For the higher Latte Structure hydraulic conductivity, a greater proportion of the particles from the Latte pit flow along the structure before discharging to Halfway Creek than for the lower hydraulic conductivity.

4.3.5 Sensitivity to Non-Permafrost Recharge

The recharge on unfrozen ground plays a role in the head and flow calibration, as discussed in Section 3.4.5. This set of recharge values has a minor influence on the EOM and Post-Closure flows into and out of the Supremo pit lakes, as shown in Table 4-13. The recharge rate has an effect on the net seepage loss from the Latte pit, due to its influence on the water table around the pit. Lowering recharge increases the net pit outflow by13%, and raising recharge reduces the net outflow from the Latte pit by 12%. The recharge rate has a much more pronounced influence on the EOM and Post-Closure baseflows, due to the strong link between groundwater recharge and groundwater discharge. Recharge on non-permafrost areas also affects the travel distance of particle tracks from the mine facilities, as shown Figure 4-15. With lower recharge outside of the mine area, the particle tracks travel farther in groundwater before discharging to surface water.





LEGEND

Post-Closure 200 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities

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Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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CLIENT:

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LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

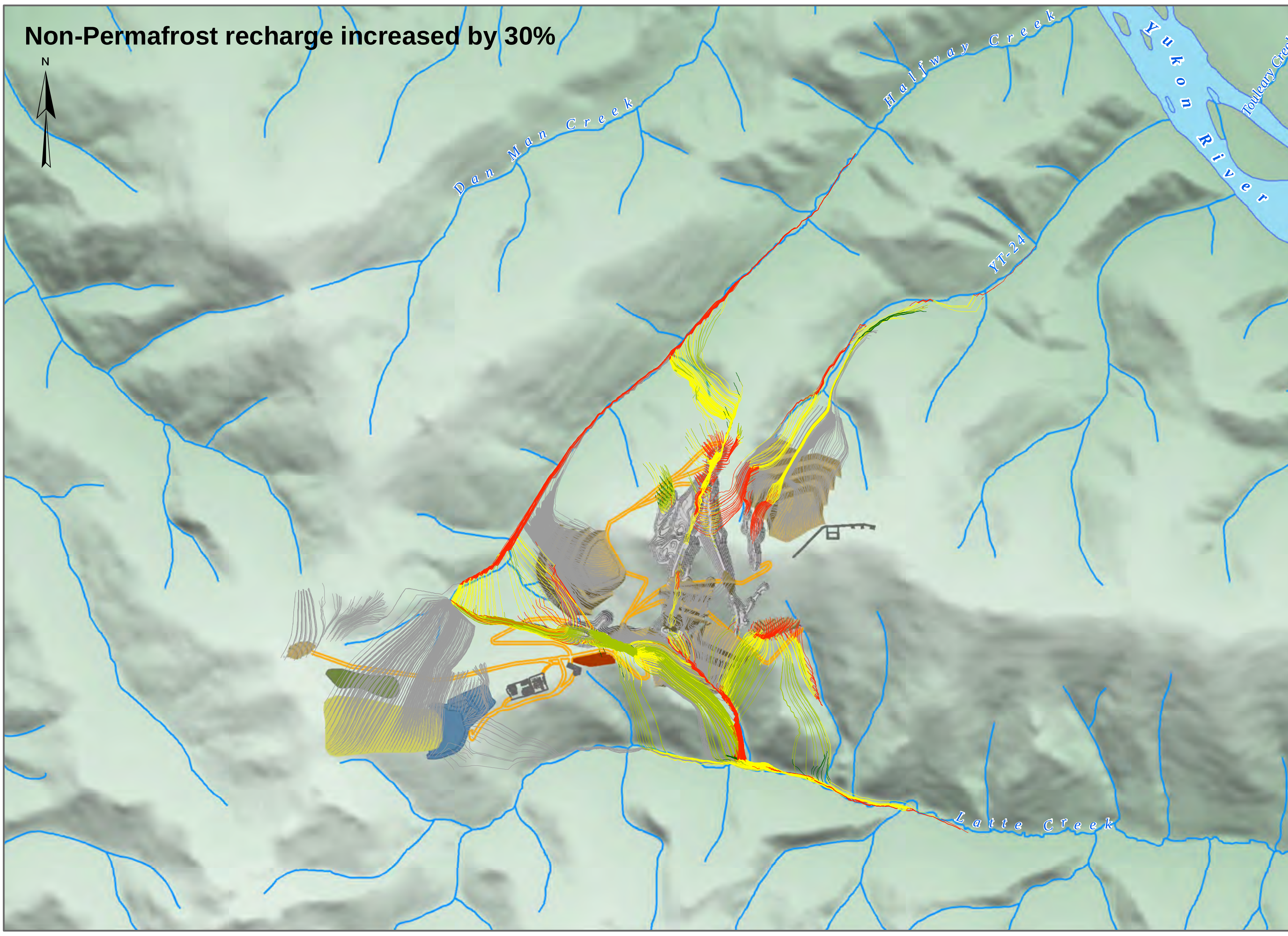
TITLE:

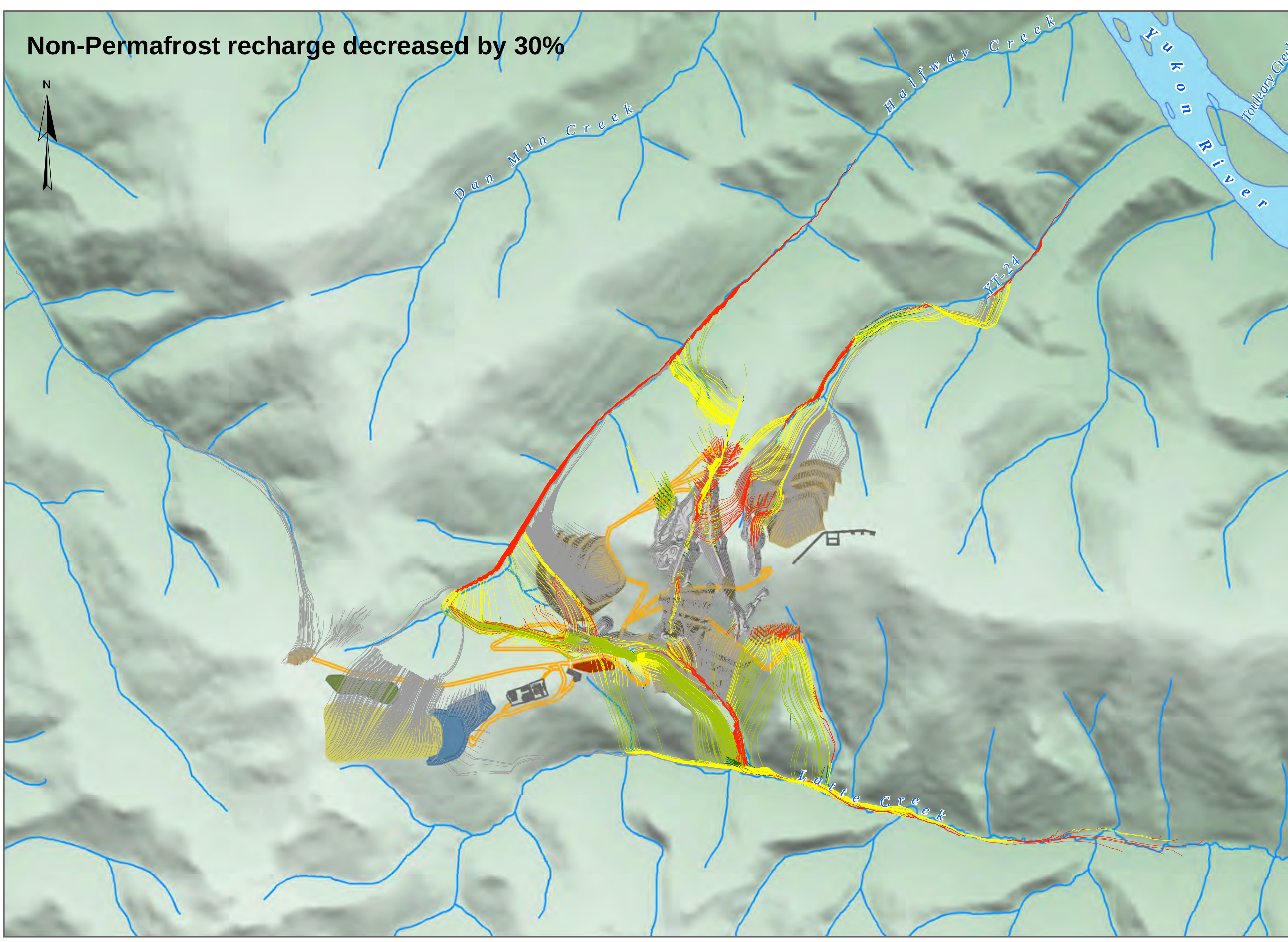
200 Year Post-Closure Particle Traces from Sensitivity Analysis of Latte Structure Hydraulic Conductivity

PROJECT #: A362-5

FIGURE: 4-14

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-14_200 Yr Particle Traces SA Latte_20160803.mxd





LEGEND

Post-Closure 200 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities

DATE SAVED:	Aug 03, 2016
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Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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0 0.5 1 Kilometers

CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

200 Year Post-Closure Particle Traces from Sensitivity Analysis of Non-Permafrost Recharge

PROJECT #: A362-5 *FIGURE:* 4-15

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-15_200 Yr Particle Traces SA Non-Permafrost_20160803.mxd

4.3.6 Sensitivity to Permafrost Recharge

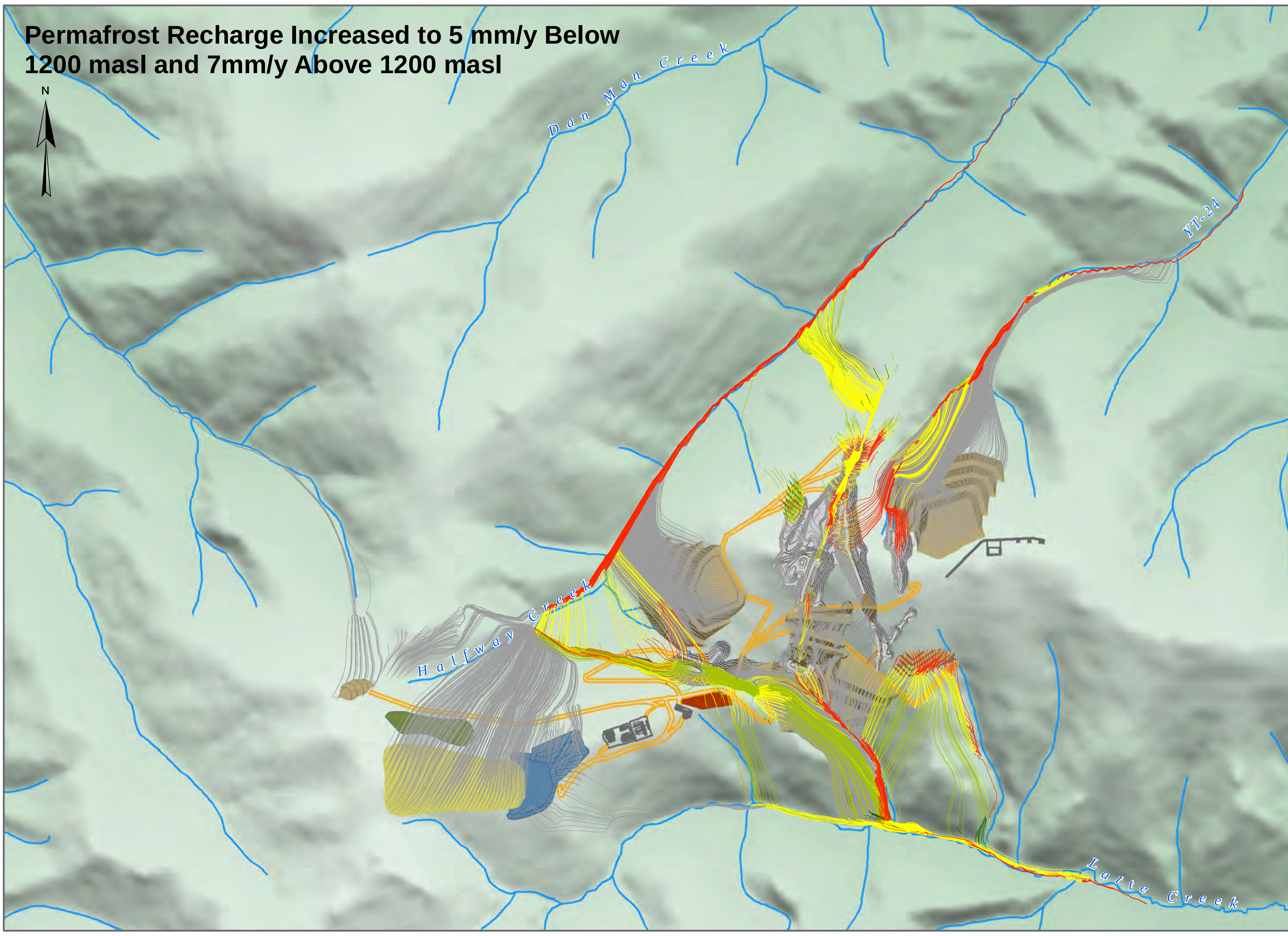
The specified recharge on permafrost areas has a minor effect on pit inflows of particle trajectories, as shown in, Table 4-13 and Figure 4-16. As for the recharge onto non-permafrost areas, the primary influence of the parameter is on the stream baseflows. The effect on baseflows due to recharge on permafrost is muted relative to the effect of changes in the much higher recharge on unfrozen areas; in the mine area, the increase or decrease in baseflow is up to 20%, compared to the 60% change in baseflow predicted due to changes in the recharge rate on unfrozen areas.

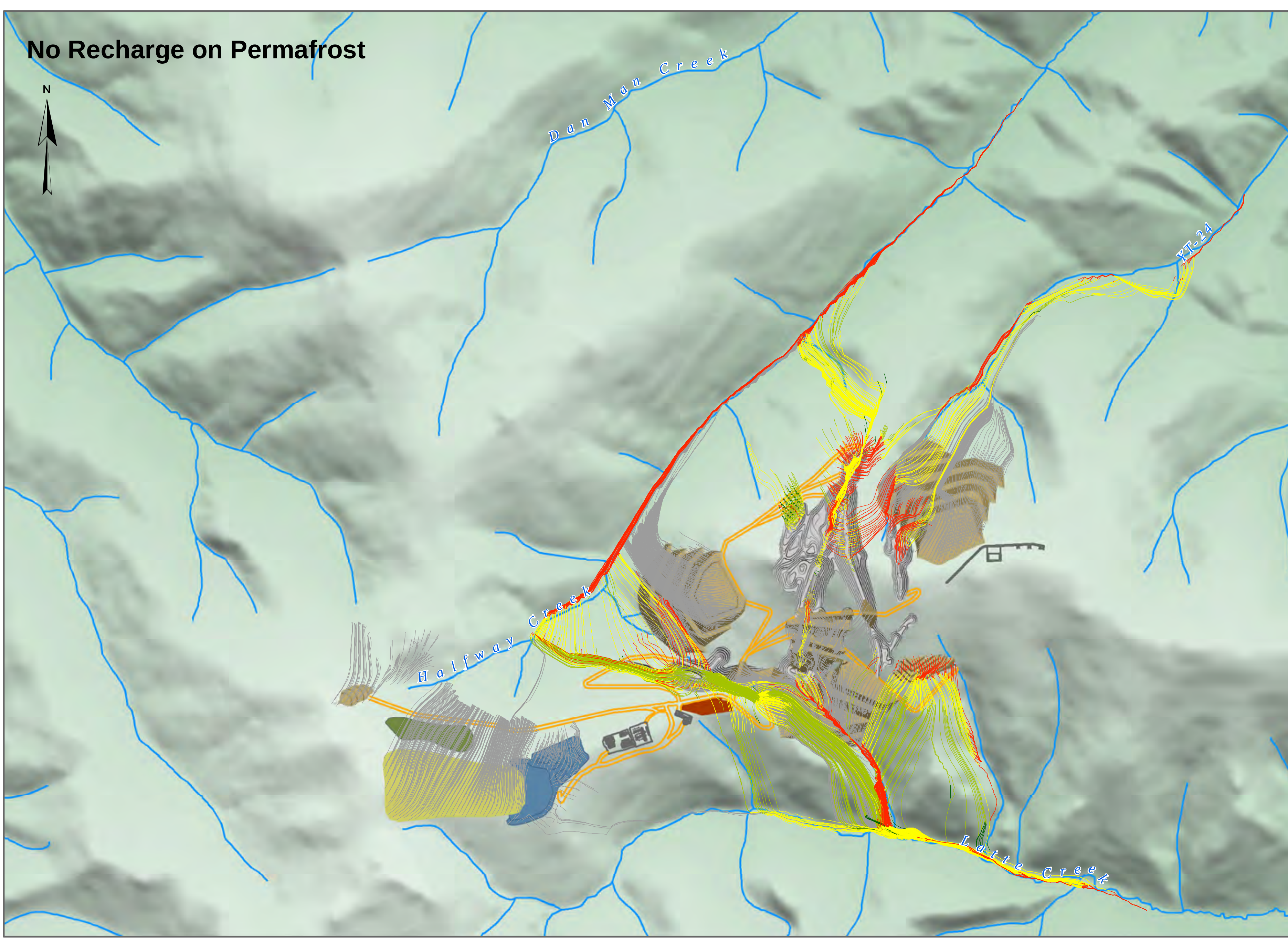
A higher value for permafrost recharge reduces the net outflow from the Latte pit by 11% and increases the net inflow to the Supremo 1 pit by 5%.

4.3.7 Sensitivity to General Creek Structures Hydraulic Conductivity

As discussed in Section 3.4.7, the hydraulic conductivity along the creek channels has a significant effect on the simulated heads along the creeks. Table 4-13 shows that the value of this material property has an effect on the inflows to the Supremo 1 and Latte pit lakes and baseflows at the majority of creeks in the model domain. In general, a higher creek channel hydraulic conductivity depresses the water table in the model, leading to lower groundwater discharge rates to stream channels. The reason for the reduced channel inflow is that the gradient between the head in the streams and the groundwater around them is low. In association with the lower groundwater discharge to streams, pathlines from the mine facilities spend a longer time in groundwater adjacent to the streams before discharging to surface water, as illustrated in Figure 4-17.

When the hydraulic conductivity of the creek channels is reduced, the baseflow to the creeks increases. As a consequence, pathlines travel shorter distances in groundwater before discharging to streams, as shown in Figure 4-17.





LEGEND

Post-Closure 200 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities

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Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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PROJECT:

Coffee Gold Hydrogeology

TITLE:

200 Year Post-Closure Particle Traces from Sensitivity Analysis of Permafrost Recharge

PROJECT #: A362-5

FIGURE: 4-16

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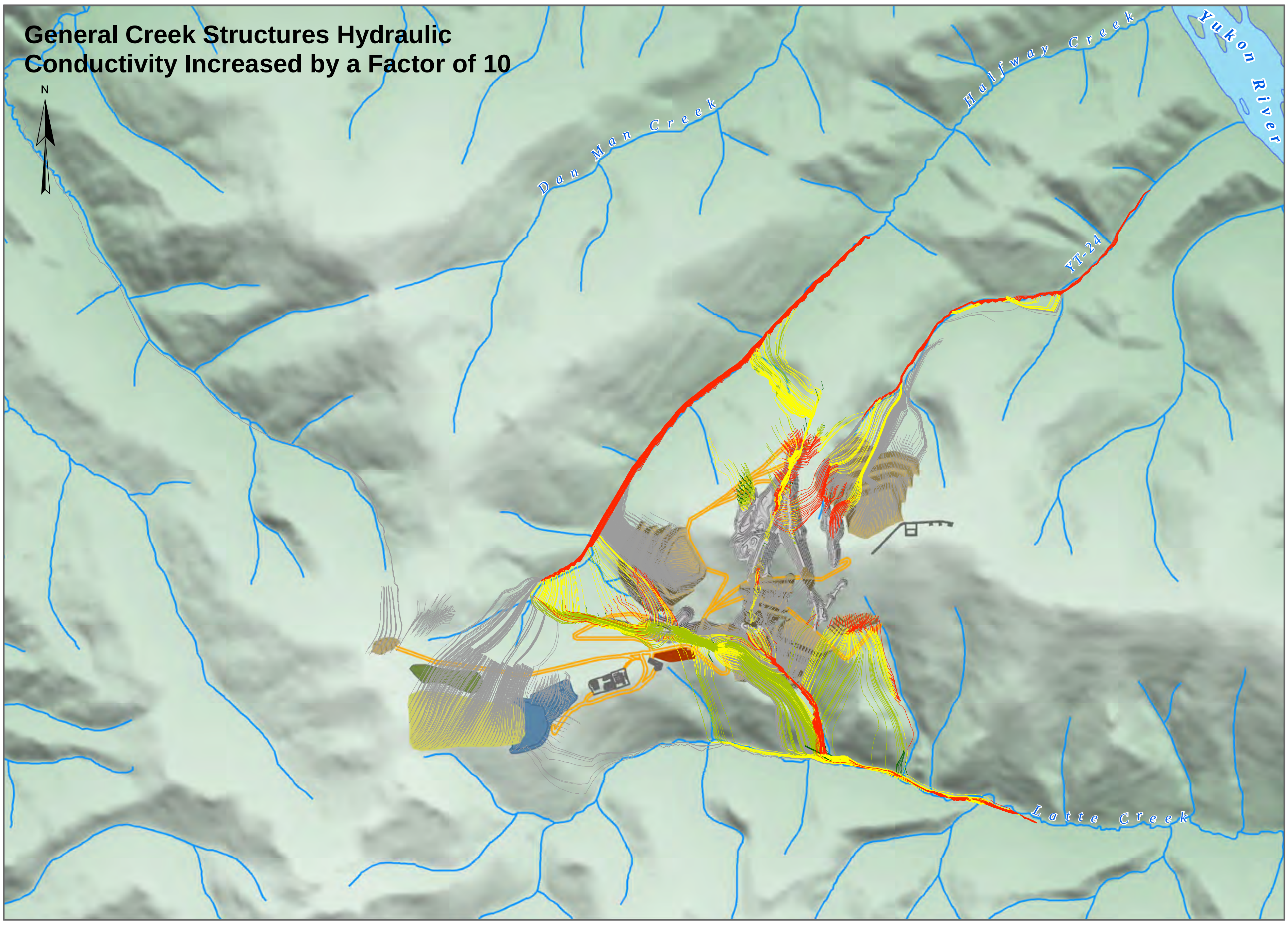

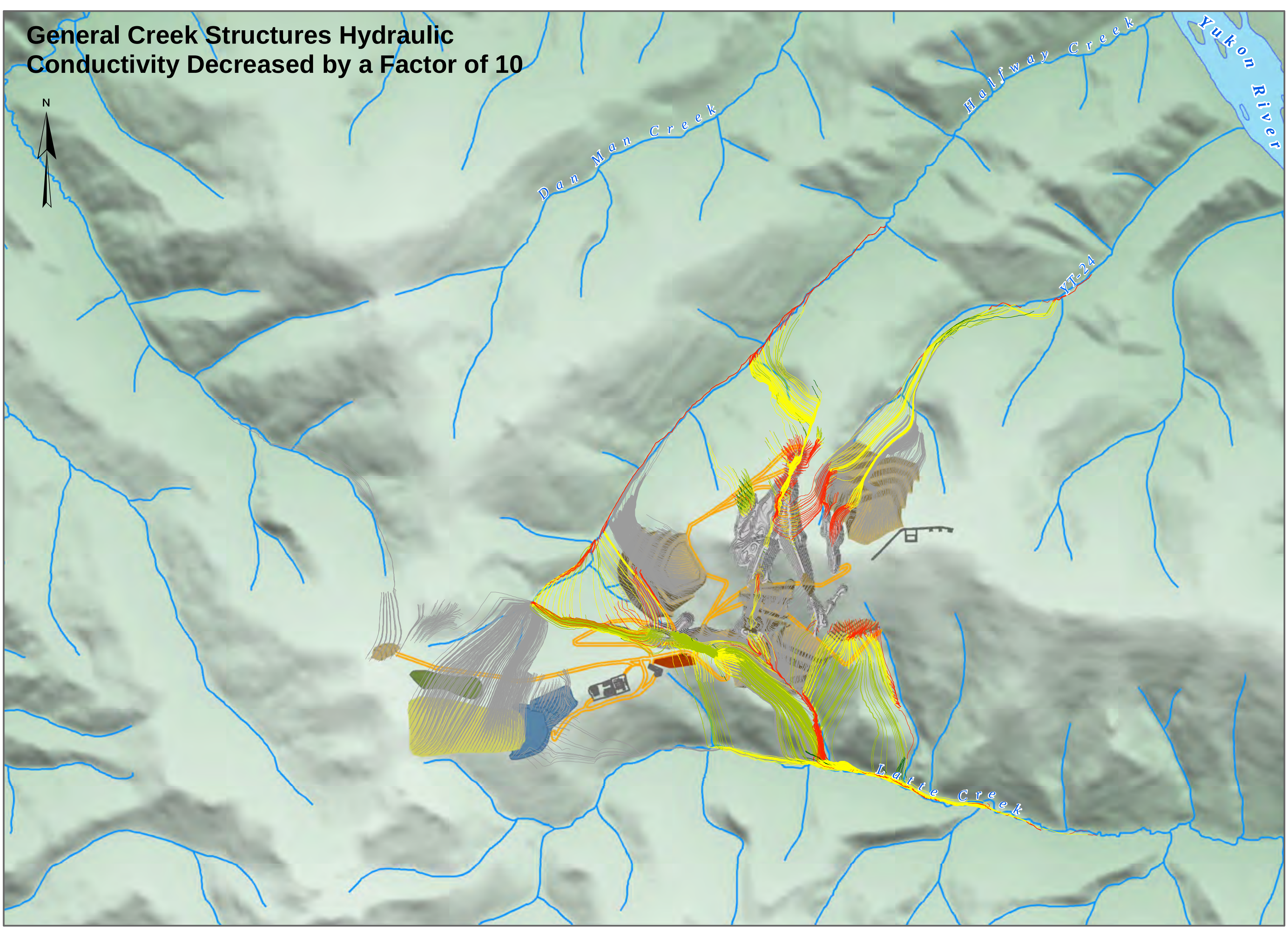

LEGEND

Post-Closure 200 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities

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Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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0 0.5 1 Kilometers

CLIENT:

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PROJECT:

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TITLE:

200 Year Post-Closure Particle Traces from Sensitivity Analysis of General Creek Structures Hydraulic Conductivity

PROJECT #: A362-5

FIGURE: 4-17

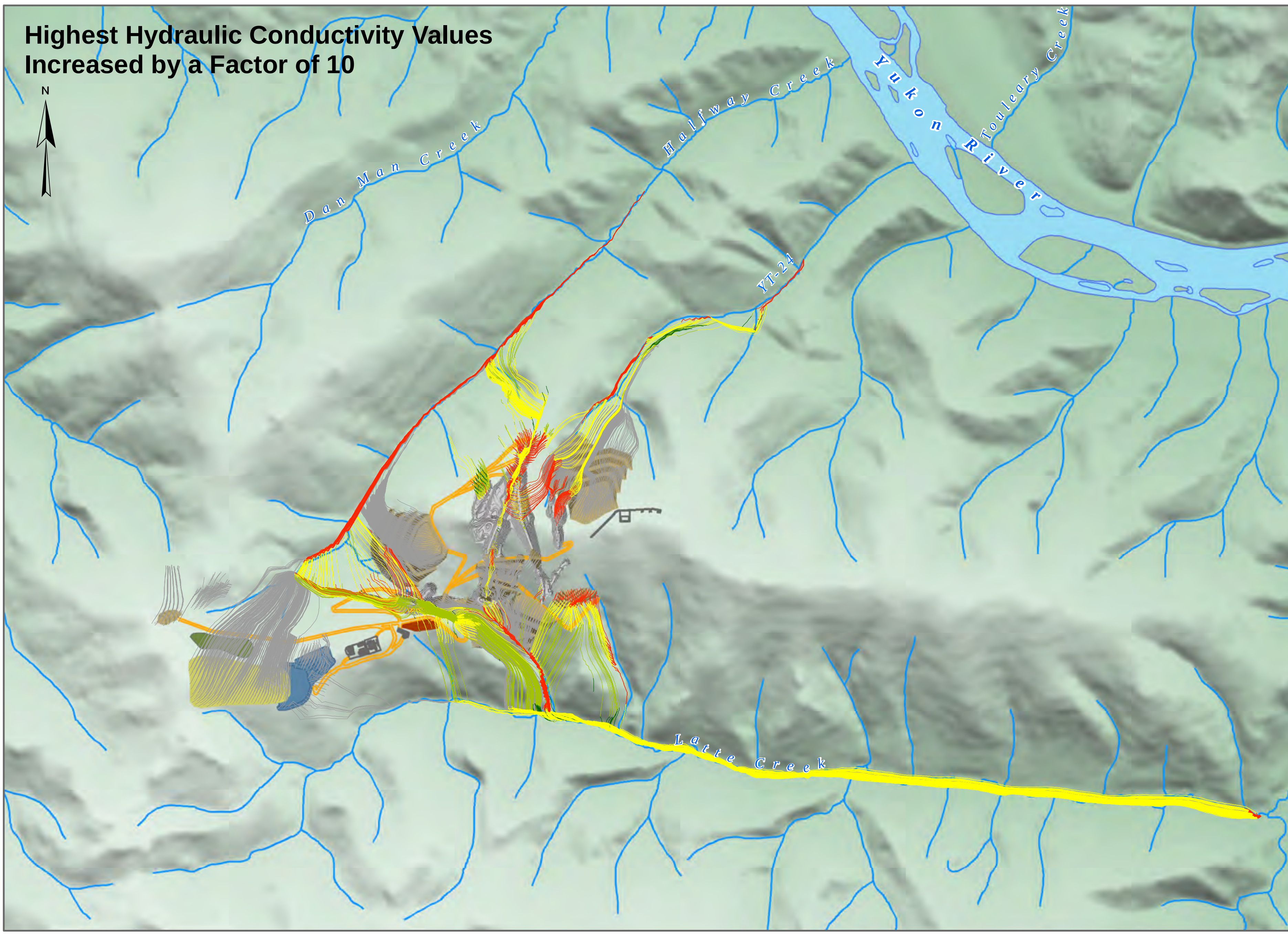
P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-17_200 Yr Particle Traces SA General Creek_20160803.mxd

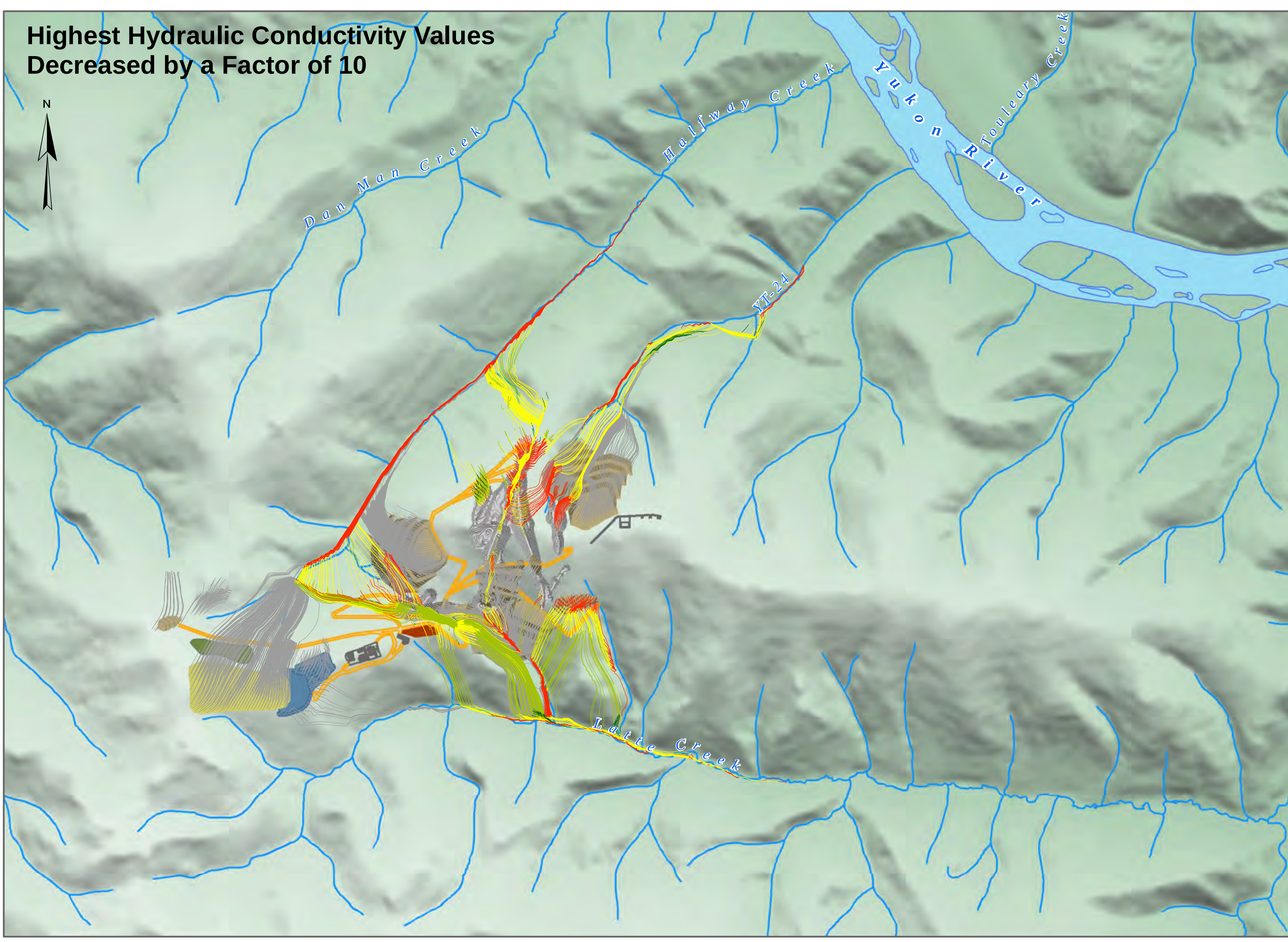
4.3.8 Sensitivity to Highest Hydraulic Conductivity Materials

As discussed in Section 3.4.8, the three hydraulic conductivity zones with the highest value of hydraulic conductivity—colluvium in CC-1.0, Layer 2 under Latte Creek, and the Independence Creek Fault zone—were treated together in the sensitivity analysis. Table 4-12 and Table 4-13 show the results of these runs for EOM and Post-Closure, respectively. The influence of this parameter on the pit lake flows is negligible.

The higher hydraulic conductivity zone in Layer 2 under Latte Creek has an important effect on baseflows to Latte Creek, with a lower hydraulic conductivity leading to higher baseflows and shorter flowlines within groundwater (see Figure 4-18). Conversely, a higher hydraulic conductivity in Layer 2 under Latte Creek leads to lower baseflows and longer flowlines in groundwater beneath the creek.

Finally, the hydraulic conductivity in the Independence Creek fault zone yields small changes in the baseflow to IC-2.5, but much higher flows to the constant head boundary cells along Independence Creek.





LEGEND

Post-Closure 200 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities

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0 1 2 Kilometers

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TITLE:

200 Year Post-Closure Particle Traces from Sensitivity Analysis of Highest Hydraulic Conductivity Materials

PROJECT #: A362-5

FIGURE: 4-18

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-18_200 Yr Particle Traces SA Highest HC_20160803.mxd

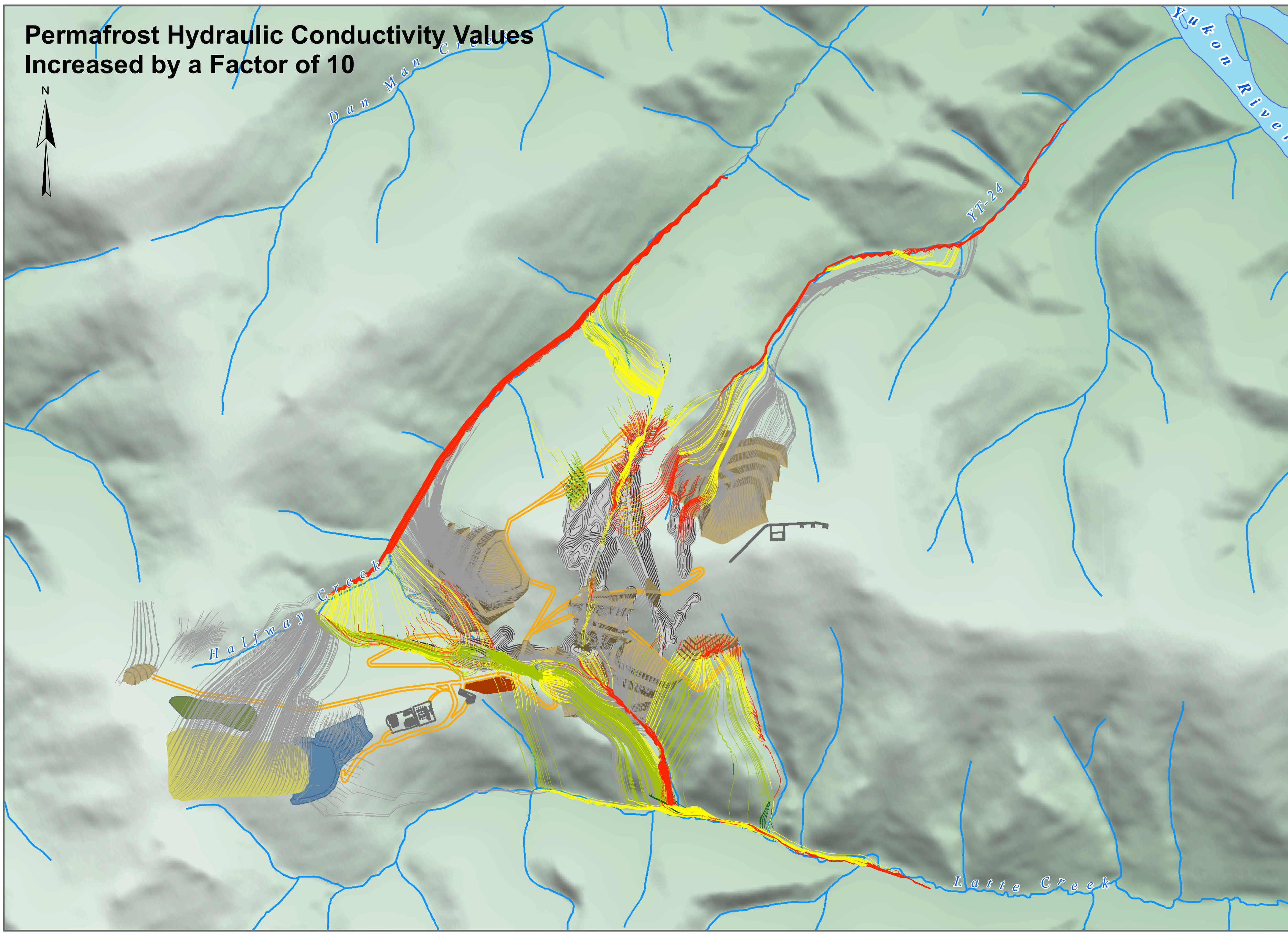
4.3.9 Sensitivity to Permafrost Hydraulic Conductivity

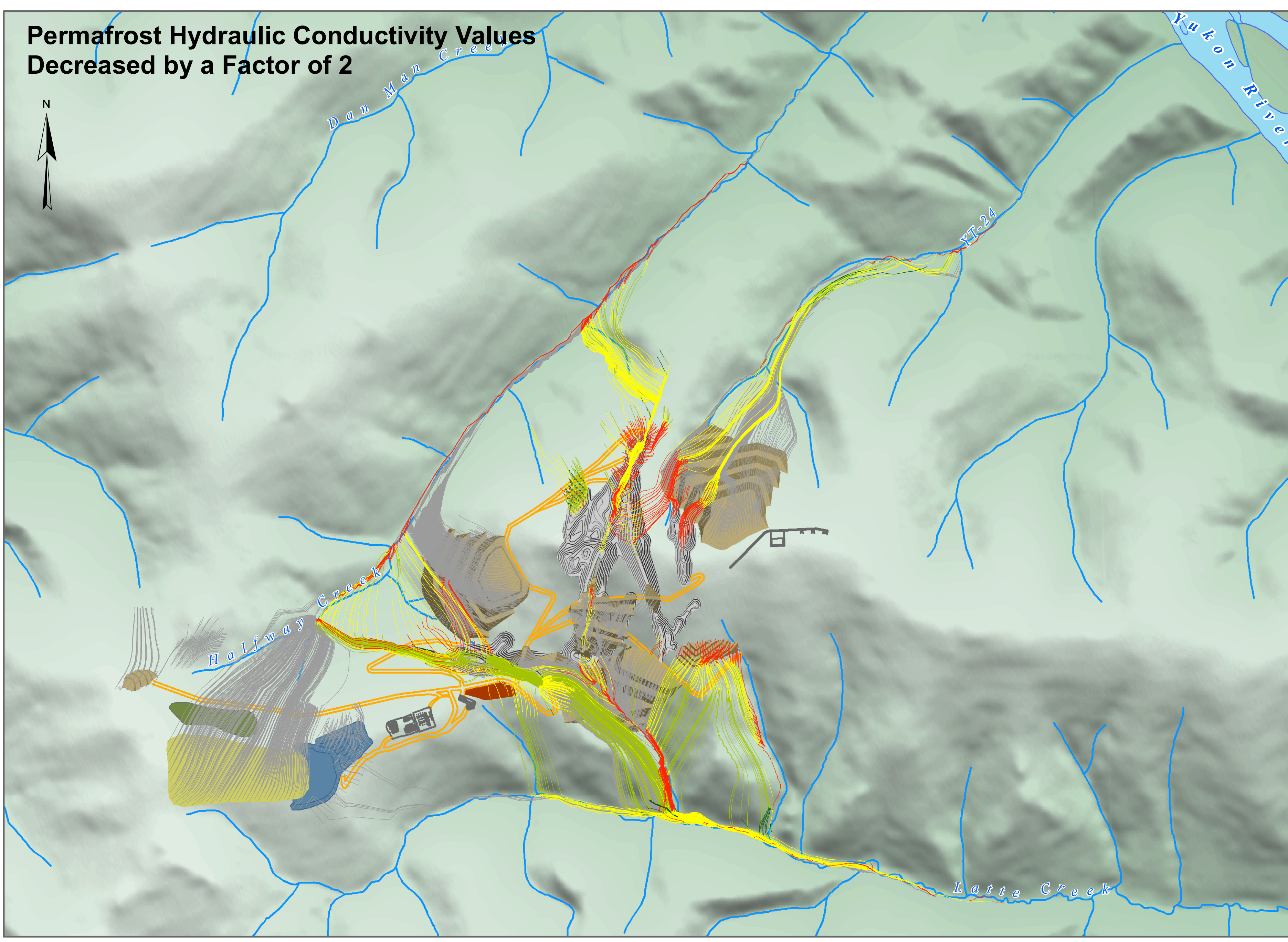
As discussed above in Section 3.2.5, the value of the permafrost hydraulic conductivity was selected to be consistent with the recharge applied to the permafrost. Therefore, as mentioned in Section 3.4.9, the value of this parameter could be reduced only by a small factor.

Increasing or decreasing the permafrost hydraulic conductivity by an order of magnitude does not influence pit inflow rates. It also has no noticeable effect on the pathline trajectories shown in Figure 4-19. Further, the hydraulic conductivity of the permafrost has no influence on the baseflows to the majority of the streams, with the exception of the upper reaches of Latte Creek at CC-6.0.

4.3.10 Sensitivity to Double Double Backfill Recharge

The recharge onto the Double Double backfilled pit was increased by 25% and 50% to 43.8% of MAP and 52.5% of MAP, respectively, to evaluate the importance of waste rock recharge on model results. As seen in Table 4-12 and Table 4-13, the total recharge into the model is negligible and increases from 199.9 L/s to 200.1 L/s and 200.2 L/s, respectively, for these two runs. Because the Double Double pit is at the far western portion of the Project area, the recharge onto this backfilled pit has a negligible effect on pit lake flows. The effect of this parameter on groundwater discharge rates is also minimal. Further, differences in pathline trajectories are also minimal, as shown in Figure 4-20.





LEGEND

Post-Closure 200 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities

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Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

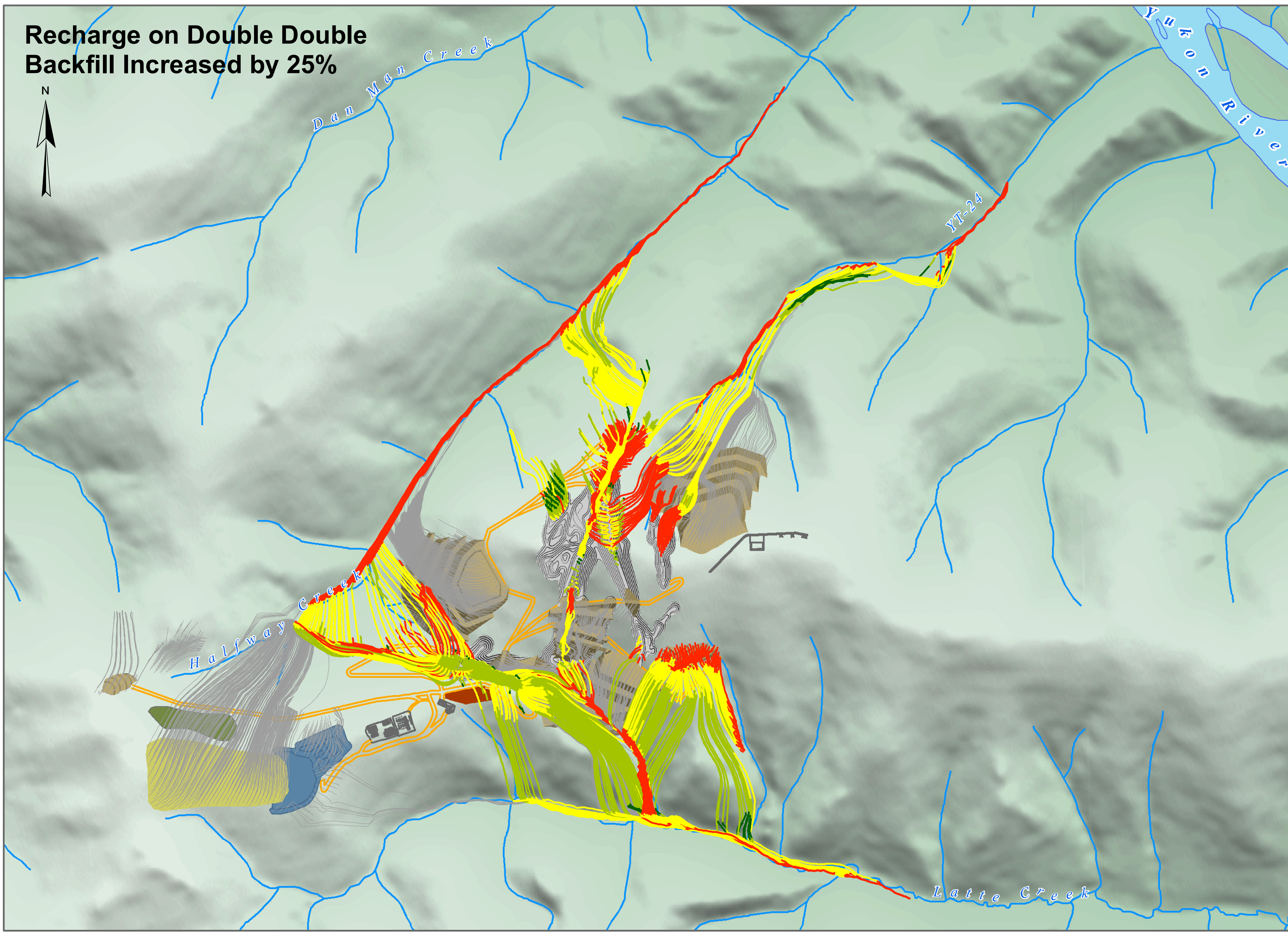
TITLE:

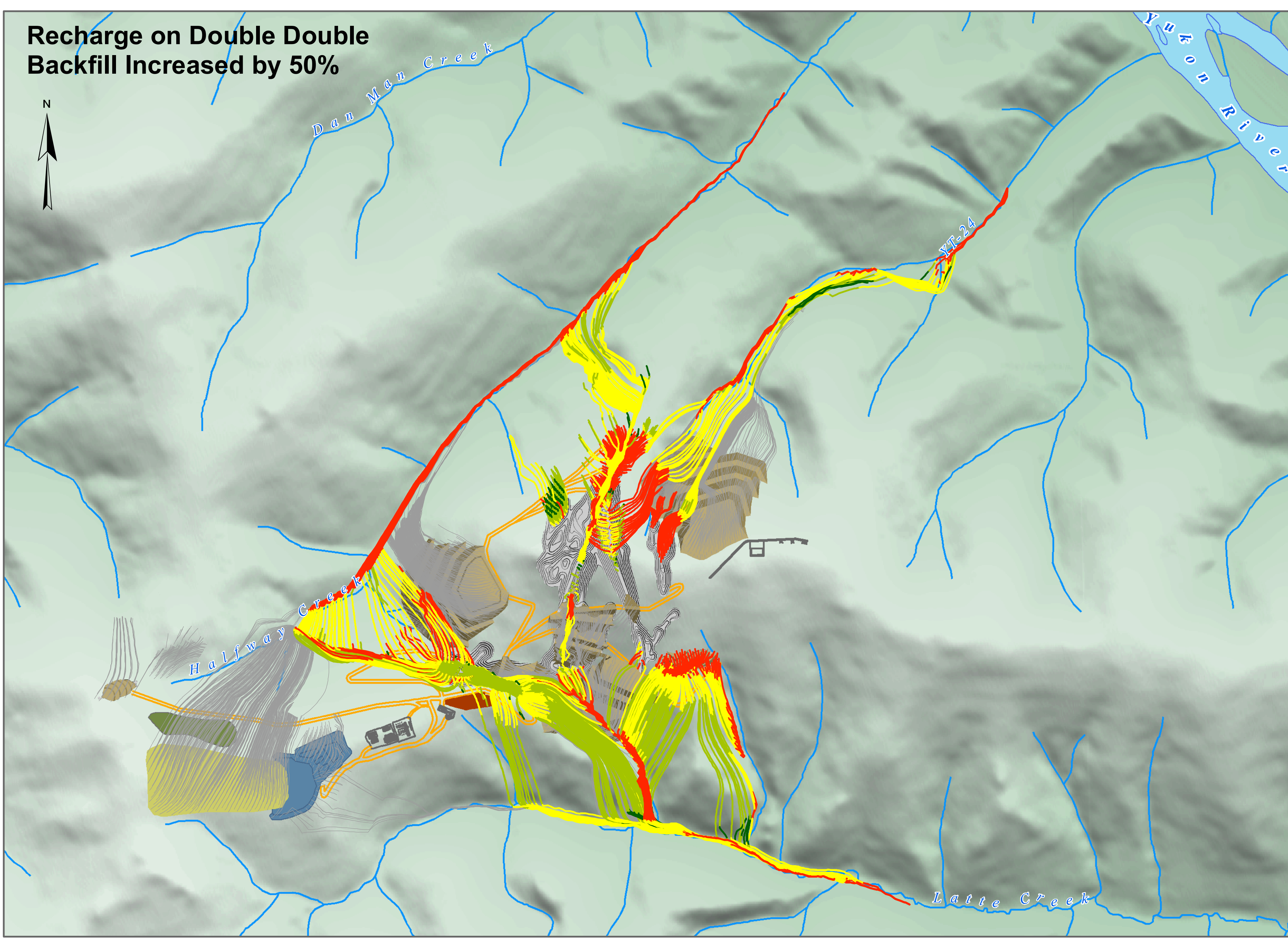
200 Year Post-Closure Particle Traces from Sensitivity Analysis of Permafrost Hydraulic Conductivity

PROJECT #: A362-5

FIGURE: 4-19

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-19_200 Yr Particle Traces SA PermafrostHC_20160803.mxd





LEGEND

Post-Closure 200 Year Pathlines

- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- Particle Trace from Zero Recharge Mine Facilities

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0 0.5 1 Kilometers

CLIENT:

KAMINAK GOLD CORPORATION

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

200 Year Post-Closure Particle Traces from Sensitivity Analysis of Waste Rock Recharge

PROJECT #: A362-5 *FIGURE:* 4-20

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 4-20_200 Yr Particle Traces SA Waste Rock_20160803.mxd

4.4 Summary

Steady state simulations were completed for the proposed Project at EOM and Post-Closure using pit lake elevations derived iteratively with the site-wide water balance model. At EOM, the Supremo 1 pit lake elevation is predicted to have reached its spill elevation. An estimated 1.3 L/s of groundwater inflow to the Supremo 1 pit is predicted to spill under steady state conditions for the EOM condition. In addition, the Supremo 1 pit lake is predicted to recharge groundwater at a rate of 0.4 L/s, 0.1 L/s of which is captured by the South WRSF underdrain; the remaining 0.3 L/s is predicted to discharge to Latte Creek. The Supremo 2 pit lake is predicted to reach a lake elevation of 1078 m, well below its spill point elevation. The Supremo 2 pit lake is predicted to recharge groundwater, with 0.3 L/s of pit lake water recharging groundwater and discharging to Halfway Creek. The Latte pit, with a lake elevation of 989 m, is predicted to be net losing, with 0.6 L/s of seepage from the Latte pit reporting to Halfway Creek, and 0.1 L/s reporting to Latte Creek. The Supremo 3W pit, located on permafrost, is predicted to lose less than 0.01 L/s of pit lake water to groundwater.

At Post-Closure, the Supremo 1 and Latte pit lakes continue to experience the greatest interactions with groundwater. The Supremo 1 pit lake is predicted to discharge 2 L/s of groundwater as surface water and 0.4 L/s as groundwater which ultimately discharges to Latte Creek. Water from the Latte pit is predicted to recharge groundwater, with 1.9 L/s ultimately discharging to Halfway Creek, and 0.8 L/s of pit-derived groundwater discharging to Latte Creek. Seepage from the Supremo 4S, Supremo 4N and Supremo 2 pit lakes are predicted to discharge to Latte, Halfway and/or YT-24 Creeks at rates less than 0.4 L/s. The pit lake at Supremo 3N is predicted to recharge groundwater at a rate of 0.01 L/s, most of which discharges to Halfway Creek. Pit lakes at Supremo 3W, Supremo 5S, and Supremo 5N are predicted to recharge groundwater at rates of less than 0.01 L/s.

Parameters that have a significant influence on model predictions include:

- Shallow Bedrock hydraulic conducitvity;
- Deep Bedrock hydraulic conductivity;
- T3 Structure hydraulic conductivity; and
- Latte Structure hydraulic conductivity.

Of these, the Shallow Bedrock and Deep Bedrock hydraulic conductivity values are well-constrained by the calibration targets. The sensitivity analyses on the T3 Structure and Latte Structure hydraulic conductivities are responsible for the upper bound pit inflow estimates for the Supremo 1 and Latte pits (see Table 4-12 and Table 4-13).

Parameters that have a moderate influence on the model predictions include:

- Recharge on unfrozen areas;
- General Creek Structure hydraulic conductivity; and
- Highest Hydraulic Conductivity units.

Finally, the following parameters have a minor influence on the model predictions:

- Recharge on permafrost; and
- Permafrost hydraulic conductivity.

5. Conclusions and Limitations

KAMINAK
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5. Conclusions and Limitations

5.1 Conclusions

A three-dimensional, numerical, steady-state, groundwater model was developed for the Coffee Creek Gold Mine. The model was calibrated to site-specific, field-based observations of hydraulic head and groundwater discharge data. The model was able to fit the groundwater heads in monitoring wells to a residual mean of -1.7 m and a normalized root mean squared error of 1.7%. The model was able to predict groundwater discharge targets in eight of nine Project area streams to within calibration targets. It was not able to simulate the baseflow to the IC-2.5 catchment; however, the water quality signature of this stream suggests that the majority of baseflow is not the deep, bedrock-derived groundwater that is simulated in this model. Model results are therefore consistent with and calibrated to observations.

The calibrated model was used to predict steady state pit inflows to the pit lakes at end of operations and at Post-Closure and the receptors for seepage losses from the proposed mine facilities.

At EOM, the Supremo 1 pit lake elevation is predicted to have reached its spill elevation, and 1.3 L/s of groundwater inflow to the pit is predicted to spill. In addition, the Supremo 1 pit lake is predicted to recharge groundwater at a rate of 0.4 L/s, 0.1 L/s of which is captured by the South WRSF underdrain; the remaining 0.3 L/s is predicted to discharge to Latte Creek. The Latte pit, with a lake elevation of 989 m, is predicted to be net losing, with 0.6 L/s of seepage from the Latte pit reporting to Halfway Creek, and 0.1 L/s reporting to Latte Creek. The Supremo 2 pit lake interacts closely with the Supremo 1 pit lake via the T3 Structure and is predicted to lose 0.3 L/s to Halfway Creek. The Supremo 3W pit, located on permafrost, is predicted to lose less than 0.01 L/s of pit lake water to groundwater.

At Post-Closure, the Supremo 1 and Latte pit lakes continue to experience the greatest interactions with groundwater. The Supremo 1 pit lake is predicted to discharge 2 L/s of groundwater as surface water and 0.4 L/s as groundwater which ultimately discharges to Latte Creek. Water from the Latte pit is predicted to recharge groundwater, with 1.9 L/s ultimately discharging to Halfway Creek, and 0.8 L/s of pit-derived groundwater discharging to Latte Creek. Seepage from the Supremo 4S, Supremo 4N and Supremo 2 pit lakes are predicted to discharge to Latte, Halfway and/or YT-24 Creeks at rates less than 0.4 L/s. The pit lake at Supremo 3N is predicted to recharge groundwater at a rate of 0.01 L/s, most of which discharges to Halfway Creek. Pit lakes at Supremo 3W, Supremo 5S, and Supremo 5N are predicted to recharge groundwater at rates of less than 0.01 L/s.

A sensitivity analysis was completed for both baseline and predictive scenarios. The parameters that have a significant impact on model predictions include:

- Shallow Bedrock hydraulic conducitvity;
- Deep Bedrock hydraulic conductivity;
- T3 Structure hydraulic conductivity; and
- Latte Structure hydraulic conductivity.

Of these, Shallow Bedrock and Deep Bedrock hydraulic conductivity values are well-constrained by the calibration targets. The sensitivity analyses on the T3 Structure and Latte Structure hydraulic conductivities are responsible for the upper bound pit inflow estimates for the Supremo 1 and Latte pits.

5.2 Limitations

The assessment presented herein is based on an idealized, three-dimensional, steady state, numerical groundwater model in an area of discontinuous permafrost. There are a number of uncertainties inherent to this type of analysis. One important area of uncertainty is in the conceptual model of how permafrost interacts with underlying groundwater. As discussed in Section 3.1, the key issue of how much, if any, recharge infiltrates through an ice-poor but fractured bedrock is not fully resolved. The assumption that bedrock permafrost in the Project area is generally impermeable to infiltrating water except at the highest elevations is supported by field data, recent technical literature, and the modeling to date; however, future field information may result in a refinement of this assumption. Bulk bedrock within the model domain is assumed to be generally homogeneous and divisible into two depth-based hydraulic conductivity zones. Therefore, significant zones of enhanced bedrock transmissivity that are present in the field but not incorporated into the model will affect the accuracy of these predictions. The accuracy of the model will depend on the quality and quantity of data used to calibrate the model and the time frame over which the data were collected. Future revisions of the model as more information comes available are recommended.

A sensitivity analysis was completed on 10 parameters or parameter groups to evaluate the importance of these parameters on the baseline model. It is possible that this analysis has not been exhaustive and that there exist other viable parameter combinations that were not considered. Finally, model calibration is non-unique, meaning that more than one set of parameters can lead to a model solution that meets the calibration targets. While uncertainty is inherent to any numerical groundwater model, the variability of results from the sensitivity analyses conducted are relatively small and provide confidence in the overall assessment.

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Appendix P-1:
Coffee Gold Mine Numerical Groundwater Model 2017 Update:

GOLDCORP

Coffee Gold Mine
Numerical Groundwater Model 2017 Update

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Project No. A362-5
March 29, 2017

FINAL

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GOLDCORP

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1. Introduction

GOLDCORP

1. Introduction

1.1 Background

Kaminak Gold Corporation, a subsidiary of Goldcorp, Inc., is in the process of developing and permitting the Coffee Gold Mine (Project), a proposed heap leach operation located in west-central Yukon, approximately 180 km south of Dawson City.

A three-dimensional groundwater model was developed for the Project in 2016, based on the original mine plan developed by Kaminak. The results of the 2016 modeling effort are contained in the 2016 Lorax report titled "Coffee Gold Mine: Numerical Groundwater Model Report." Upon acquisition of Kaminak by Goldcorp, the 2016 mine plan was re-evaluated and modified. The main modifications associated with the mine plan, as they relate to groundwater, include slightly deeper open pits and consolidation of all ex-pit mine waste rock facilities (WRSFs) (formerly the North, South and West WRSFs) into a single facility – the Alpha WRSF, located in the Halfway Creek drainage.

The development of the new mine plan under Goldcorp has necessitated an update to the 2016 groundwater model so as to enable quantification of Project effects on groundwater. This report comprises the results of the groundwater model update, and should be reviewed in tandem with the 2016 Lorax report.

1.2 Objectives

A three-dimensional numerical groundwater model has been developed for the Project to satisfy licensing and permitting requirements. The model is described in detail in Lorax (2016). The current document presents an updated model calibration completed to accommodate new information from the 2016 field programs and predictions of potential groundwater impacts from the 2017 Goldcorp mine plan.

The calibrated, numerical groundwater was used to simulate the interaction between proposed Project facilities and groundwater flow. The numerical model incorporates Project activities that may alter groundwater quantity, namely open pit development and placement of waste rock. The model also simulates potential changes to groundwater recharge beneath the proposed heap leach and event ponds. 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. This last model includes the simulation of through taliks under pit lakes located on permafrost.

Development of the baseline model is described in Section 2 below. Integration of Project infrastructure into the groundwater model for end of Operation Phase and Post-Closure is described in greater detail in Section 3. An abridged sensitivity analysis is presented for both the pre-mine and the post-closure simulations. A more extensive sensitivity analysis can be found in Lorax (2016).

1.3 Data Sources

For the most part, the data sources used in model calibration are the same as those presented in Lorax (2016). The two exceptions are that the new model includes information from two nested vibrating wire piezometers (VWPs) installed in 2016 in borehole MW16-01T, located along the northeast margin of the Heap Leach Facility (HLF) (Lorax, 2017). In addition, Tetra Tech Canada has revised permafrost mapping in the headwaters of Halfway Creek (Tetra Tech, 2017).

1.4 Project Infrastructure

The 2017 mine plan proposes deeper open pit depths for several of the Project pits and a single mine waste rock storage facility (Alpha WRSF) to replace the three contained in the previous mine design (North, West and South WRSFs). In addition, adjustments have been made to the in-pit backfill configuration. Other changes to the mine plan do not affect the bedrock groundwater system and were not included in the simulations presented in this report.

2. Baseline Model

GOLDCORP

2. Baseline Model

2.1 Conceptual Model

The mine conceptual model is presented in Lorax (2016). The groundwater model that was developed for the Project is a bedrock hydrogeological model that includes permafrost as a hydrogeological unit and includes several structural features that have been observed to be more permeable than the rock around it.

2.2 Modeling Setup

The model computer code, solver settings, domain, discretization, and pre-mine constant head and drain boundaries are described in Lorax (2016).

2.2.1 Recharge Distribution

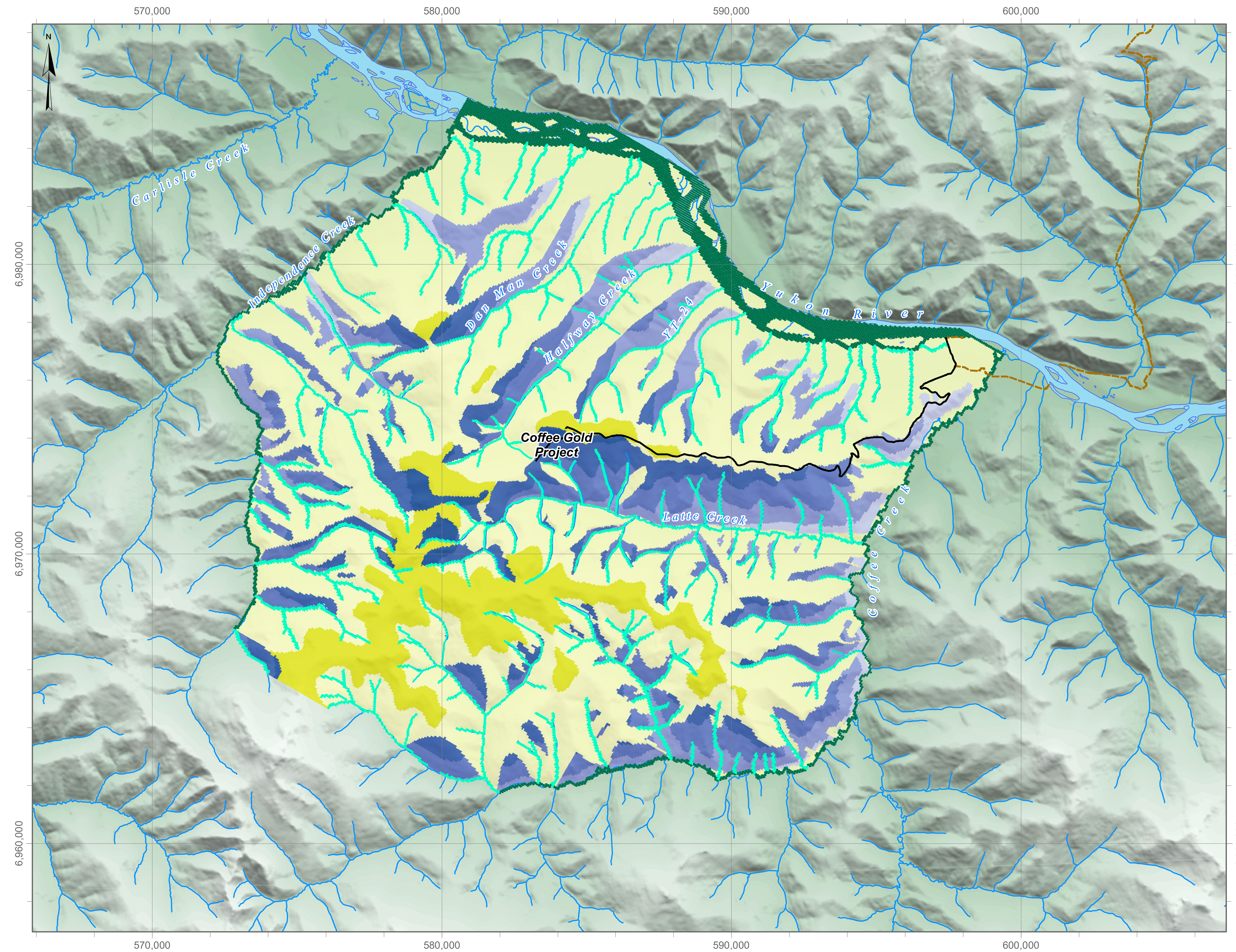
Recharge in the model varies according to two criteria: the presence or absence of permafrost and the topographic elevation. The recharge rates as a function of elevation and the presence of permafrost are presented in Lorax (2016).

In the current model, minor adjustments were made in the distribution of frozen and unfrozen ground to reflect additional field information analyzed by Tetra Tech Canada (Tetra Tech, 2017). The new information identifies an additional area of unfrozen ground west of the proposed Latte pit and minor changes in the frozen/unfrozen ground boundary east of this area. The updated recharge distribution within the groundwater model is shown in Figure 2-1.

2.2.2 Hydraulic Conductivity and Treatment of Permafrost

The hydraulic conductivity zones of the updated model are shown in Figure 2-2. A total of 16 material zones are shown. The material zones that are different from the model presented in Lorax (2016) are discussed briefly in this section.

An alluvium zone in the immediate vicinity of the Yukon River and the colluvium near stream gauging station CC-1.0 are the same as before (Lorax, 2016). The high-permeability structures are defined as in the previous model (Lorax, 2016), except that the structure that follows Halfway Creek north of the mine was shortened by 500 m in order to allow the simulated head at the SRK-15D-08 VWP couplet to rise to its calibration targets. The hydraulic conductivity value applied to the alluvium, colluvium, Independence Creek Fault zone, the North Fault zone, all creek-related structures, and the Latte Structure remain unchanged from the previous model.



LEGEND

Recharge Zones

- 400-600 m Elevation No Permafrost
- 600-800 m Elevation No Permafrost
- 800-1000 m Elevation No Permafrost
- 1000-1200 m Elevation No Permafrost
- 1200-1400 m Elevation No Permafrost
- 400-1200 m Elevation with Permafrost
- 1200-1400 m Elevation with Permafrost
- Constant Head
- Drain
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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0 2 4 Km

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GOLDCORP

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Recharge Distribution used in the Baseline Groundwater Model

PROJECT #:	*FIGURE:*
A362-5	2-1

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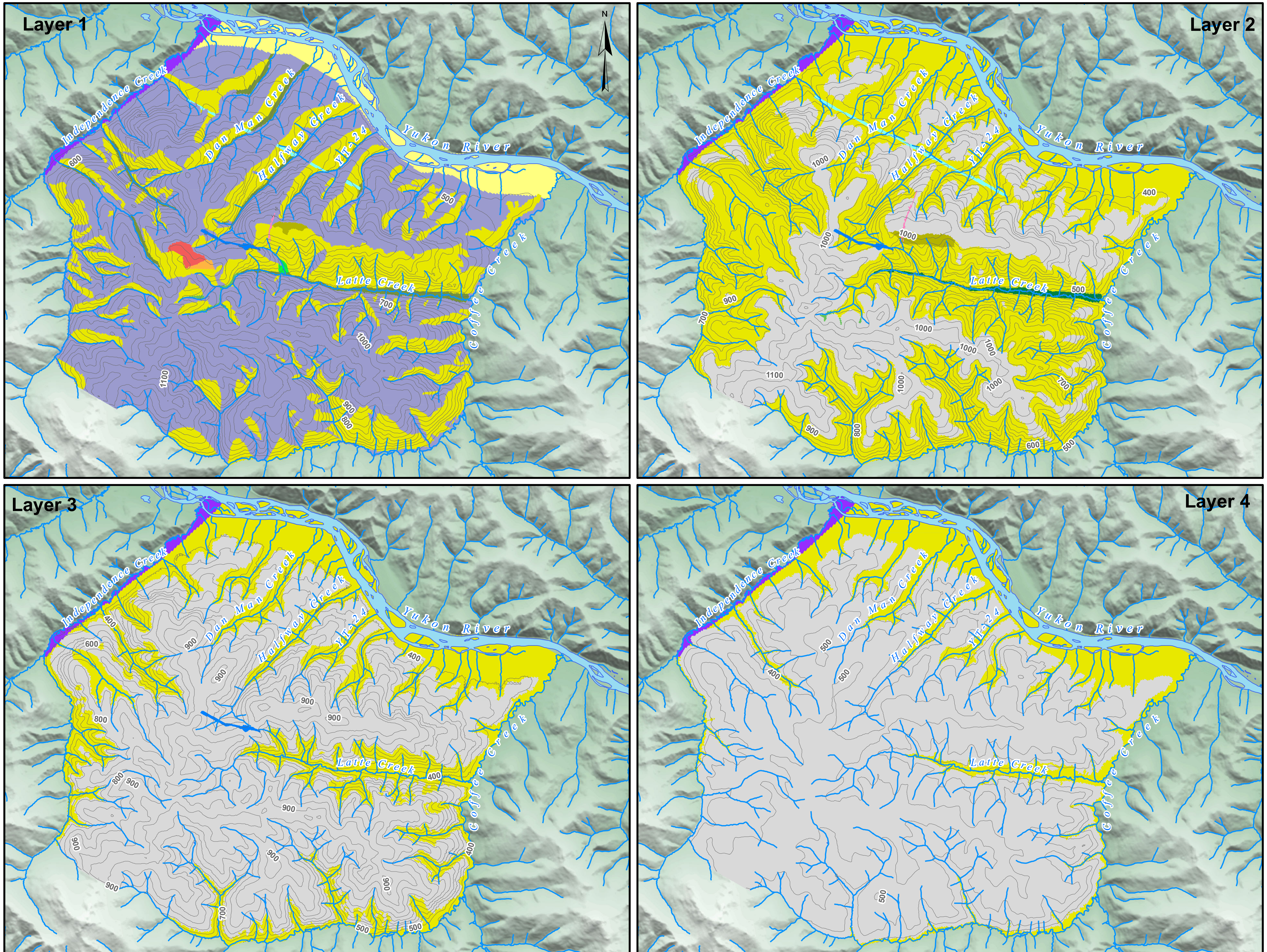

LEGEND

K (m/s)

- Alluvium (1.0E-05)
- Shallow Bedrock (1.3E-07)
- L1 Bedrock below PF (MW16-01) (1.0E-06)
- L1 Bedrock below PF (MW15-07) (1.0E-06)
- L1 Bedrock below PF (MW14-05) (2.6E-09)
- K Deep Bedrock > 100m Depth (2.6E-09)
- Colluvium (3.0E-05)
- T3 Structure (1.0E-06)
- Latte Structure (1.0E-06)
- All Creek hi K zones L1 (6.0E-06)
- N Fault (5.0E-06)
- Layer 1 and 2 Upper Latte Creek (4.0E-06)
- L2 Lower Latte (3.0E-05)
- IC Creek Fault (3.0E-05)
- Permafrost (6.0E-10)
- Waterbodies
- Watercourses
- Bottom of Layer Contours (50m)

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:200,000

0 2 4 Km

DATE SAVED:	Mar 29, 2017
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VERSION:	1

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GOLDCORP

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Hydraulic Conductivity Zones - Layers 1-4

PROJECT #: A362-5

FIGURE: 2-2

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 2-2_Hydraulic Conductivity_20170327.mxd

The hydraulic conductivity of the T3 Structure, which was $2x10^{-6}$ m/s in the previous model, was reduced to $1x10^{-6}$ m/s in the current model. The reason for this is two-fold. First, the value of hydraulic conductivity previously applied along the entire length of the T3 Structure was three times the arithmetic mean value of hydraulic conductivities measured in any high-permeability structure in the Project area. It is common practice to apply the geometric mean value of measured hydraulic conductivities, given the typically lognormal distribution of these measurements. Even a value of $1x10^{-6}$ m/s is higher than the arithmetic mean, $7x10^{-7}$ m/s, measured for all structures. The second reason for reducing the hydraulic conductivity of the T3 Structure is that the band of lower hydraulic conductivity that flanked the southern part of this structure in Layer 2 of the previous model had been removed, as discussed later in this section. With the removal of this zone, the simulated water table became sensitive to the hydraulic conductivity of the T3 Structure, and the automated optimization of parameters sought to reduce the T3 Structure hydraulic conductivity to below the field-measured hydraulic conductivity range. To remain consistent with the conceptual model and maintain this feature as a potentially important groundwater conduit, its hydraulic conductivity was not permitted to drop below that of the Latte Structure.

The majority of Layer 1 is composed of permafrost. The permafrost distribution is based on the permafrost maps produced by EBA Tetra Tech in 2016 (EBA TT, 2016) which have been revised slightly in 2017 (Tetra Tech, 2017). Permafrost predominates on north-facing slopes within the groundwater model domain and is simulated in Layer 1 only. At higher elevations, the bottom of the permafrost, as determined through thermistor measurements, is above the water table. In these areas, the hydraulic conductivity of the bedrock below the permafrost—*i.e.,* the unit in which the water table is located—is applied to Layer 1 of the model. Three different sub-permafrost zones are defined in the model (see below).

The majority of bedrock in the model is divided into two zones based on the difference between the topographic elevation and the layer bottom elevation. Bedrock model cells whose layer top elevation is less than 100 m below ground surface are treated as a single Shallow Bedrock unit. Below the Shallow Bedrock is a Deep Bedrock unit with a lower hydraulic conductivity. The location of the division between Shallow and Deep Bedrock in the model has been raised from 120 m below ground surface in the previous model calibration (Lorax, 2016) to 100 m in the updated model. This depth-zonation of bedrock is followed in all areas of the model. By comparison, some exceptions were permitted in the previous model, as described in the next paragraph.

Previously, some deviation between the shallow and deep bedrock zonations were applied in areas near the boundary between north- and south-facing slopes. The primary rationale for introducing these hydrogeological units was that the water table on the north-facing side of major ridgelines were higher than could be simulated using bedrock hydraulic conductivities that were simply based on depth from ground surface. In these areas—particularly in the vicinity of MW15-07 and the new VWP couplet MW16-01—a mechanism was required to draw recharge from south-facing slopes to the north-facing, permafrost-covered slopes. This conceptualization of groundwater flow is consistent with observations made in other areas of permafrost, where groundwater on north-facing slopes is recharged on the south side of a ridgeline (*e.g.*, Kane *et al.*, 2013). Previously, the water table in the vicinity of MW15-07 was raised by lowering the hydraulic conductivity of an east-west band of the shallow bedrock in Layer 2 on the south-facing slope immediately south of MW15-07. A similar reduction in the shallow bedrock hydraulic conductivity in the vicinity of MW16-01 was ineffective at achieving the requisite increase in head in the MW16-01 area.

Therefore, rather than reduce the hydraulic conductivity of shallow bedrock in Layer 2, the hydraulic conductivity of the bedrock immediately beneath the permafrost in Layer 1 was raised in the vicinity of both MW15-07 and MW16-01, as shown in in Figure 2-2. In these two areas, the water table is assumed to be present below the bottom of permafrost, as observed on other locations where a well is placed near the top of a ridgeline. The water table inferred from piezometric measurements is located at or below the bottom of permafrost at three locations: MW14-03B, MW14-05B and MW15-06WB-P7 (Lorax, 2017). All three of these wells are located on the upper portion of a north-facing slope. There are two other head measurement points located in the upper elevation portion of a north-facing slope: MW15-07T-944 and MW16-01T-1072. At MW15-07T-944, the piezometric head is just 2 m above the bottom of permafrost as measured by the VWPs at this location, and it is assumed that the water table is below the bottom of permafrost farther up the north-facing slope at this location. At MW16-01T, both VWPs indicate flowing artesian pressures with a piezometric head 70 m above that measured at nearby MW14-05B. It is assumed that here, too, the water table farther up the slope is below the bottom of permafrost. The water table at MW14-03 and MW15-06 is strongly controlled by the Latte and T3 Structures, respectively. For this reason, no adjustments were made to the hydraulic conductivity in the upper part of the unfrozen subsurface at these locations. At the other three locations, the hydraulic conductivity in Layer 1 in the uppermost (i.e., southernmost) portion of the north-facing slopes was increased to indicate the presence of unfrozen groundwater below permafrost in these areas.

Because the model layers are a muted image of the topography, with thicker layers along ridgelines and thinner layers at creek beds, these three areas are associated with substantial Layer 1 thicknesses. South of MW16-01, the Layer 1 thickness ranges from 118 m to 173 m in the separate hydraulic conductivity zone defined here (see Figure 2-2). Since MW16-01 has artesian heads and is not in the zone associated with water tables below the bottom of permafrost, this zone does not include MW16-01. At the zone south of MW15-07 where the water table is inferred to exist below the bottom of permafrost, Layer 1 ranges in thickness from 137 m to 189 m. At the zone around MW14-05, the thickness of model Layer 1 ranges from 120 to 201 m. MW14-05 is located within this third zone because this well has a water table that is below the bottom of permafrost. To simulate the presence of a high-permeability layer at the bottom of Layer 1 available for groundwater flow below the bottom of permafrost, Layer 1 cells in the areas around MW16-01 and MW15-07 were assigned a hydraulic conductivity of $1x10^{-6}$ m/s. This value of the hydraulic conductivity was selected to yield a flat enough hydraulic gradient that the relatively elevated water levels at MW15-07 and MW16-01 could be simulated.

At the third sub-permafrost shallow bedrock zone around MW14-05, the measured piezometric head is lower than around MW16-01. Because the piezometric head at MW14-05 appears to be less closely integrated with the higher piezometric heads on the south-facing slope south of it, the hydraulic conductivity of the fractured bedrock below permafrost at MW14-05 was set to be equal to the hydraulic conductivity of the bedrock below the permafrost at this location in Layer 2, or, because of the thickness of the layer, this area was assigned the hydraulic conductivity of Deep Bedrock.

At all three locations, the sub-permafrost hydraulic conductivity zone abuts the Shallow Bedrock zone and extends the area of elevated hydraulic conductivity under a ridgeline. The alignment of the sub-permafrost zone south of MW15-07 is similar to the orientation of the reduced-hydraulic conductivity band applied in Layer 2 of the previous model (Lorax, 2016).

In summary, in Project areas at the top of a major ridgeline, the hydraulic conductivity was raised above the permafrost value in Layer 1. In the case of MW14-05 and its vicinity, the hydraulic conductivity of the rock beneath it, the Deep Bedrock unit, was applied to Layer 1. At this location, the water table is known to exist below the bottom of permafrost. South of MW15-07 and MW16-01, also located near the top of a north-facing ridgeline, the hydraulic conductivity was further increased to $1x10^{-6}$ m/s. Two other locations where the water table is observed to be below the bottom of permafrost, MW14-03 and MW15-06, have piezometric surfaces controlled primarily by major transmissive structures in their vicinity, and no adjustments to the Layer 1 hydraulic conductivity were made at these locations.

2.3 Model Calibration

2.3.1 Hydraulic Heads

Model calibration was completed using the PEST optimization program. The optimization targets are steady state head values in mine area wells and estimated groundwater discharge values to streams within the model domain. The head calibration targets, including the two new calibration points at MW16-01, are shown in Table 2-1 along with the weights assigned to them in the optimization runs. The head data were assigned weights in PEST as described in Lorax (2016). The weights in Table 2-1 were for the optimization routine only. When computing model calibration statistics, all wells were given the same weight.

The flow calibration targets are presented in Lorax (2016).

The calibrated hydraulic conductivity values are shown in Table 2-2. They are listed from highest to lowest hydraulic conductivity. All materials have isotropic hydraulic conductivities. The most permeable hydraulic conductivity units are the colluvium upstream of stream gauge CC-1.0, the enhanced hydraulic conductivity zones introduced at creek channels, the Independence Creek Fault, the Yukon River alluvium and the east-west trending North Fault that intersects Halfway Creek upstream of MW15-03. The Latte Structure and the T3 Structure have a hydraulic conductivity that is eight (8) times higher than the bulk Shallow Bedrock hydraulic conductivity of 1.3×10^{-7} m/s. The permeable sub-permafrost zones in Layer 1 south of MW16-01 and MW15-07 are assigned the same hydraulic conductivity as the T3 and Latte Structures. The Shallow Bedrock hydraulic conductivity is 50 times higher than the Deep Bedrock hydraulic conductivity of 2.6×10^{-9} m/s and 200 times higher than the permafrost hydraulic conductivity of 6.0×10^{-10} m/s. As noted above, sub-permafrost bedrock in Layer 1 in the vicinity of MW14-05 is assigned a hydraulic conductivity of 2.6×10^{-9} m/s, the same value as applied to Deep Bedrock.

Hydraulic head calibration statistics are illustrated in Figure 2-3. The overall model normalized root mean squared error (NRMSE) is 1.13%, with a residual mean of 0.22 m, and an absolute residual mean of 5.5 m. Figure 2-3 shows the normalized root mean squared error and the absolute residual mean for all wells together and with wells grouped by surface water catchment. In the catchment groupings, the wells given a calibration weight of 0.3 in Table 2-1—*i.e.*, Westbay installations located in the same model cell as a continuously monitoring vibrating-wire transducer (see Lorax, 2016)—are not included in the calculated statistics. Table 2-3 presents a summary of calibration statistics. Table 2-4 lists the computed heads and the residuals—*i.e.*, the differences between the simulated heads and the calibration targets—for all wells included in the calibration.

2.3 Model Calibration

2.3.1 Hydraulic Heads

Model calibration was completed using the PEST optimization program. The optimization targets are steady state head values in mine area wells and estimated groundwater discharge values to streams within the model domain. The head calibration targets, including the two new calibration points at MW16-01, are shown in Table 2-1 along with the weights assigned to them in the optimization runs. The head data were assigned weights in PEST as described in Lorax (2016). The weights in Table 2-1 were for the optimization routine only. When computing model calibration statistics, all wells were given the same weight.

The flow calibration targets are presented in Lorax (2016).

The calibrated hydraulic conductivity values are shown in Table 2-2. They are listed from highest to lowest hydraulic conductivity. All materials have isotropic hydraulic conductivities. The most permeable hydraulic conductivity units are the colluvium upstream of stream gauge CC-1.0, the enhanced hydraulic conductivity zones introduced at creek channels, the Independence Creek Fault, the Yukon River alluvium and the east-west trending North Fault that intersects Halfway Creek upstream of MW15-03. The Latte Structure and the T3 Structure have a hydraulic conductivity that is eight (8) times higher than the bulk Shallow Bedrock hydraulic conductivity of 1.3×10^{-7} m/s. The permeable sub-permafrost zones in Layer 1 south of MW16-01 and MW15-07 are assigned the same hydraulic conductivity as the T3 and Latte Structures. The Shallow Bedrock hydraulic conductivity is 50 times higher than the Deep Bedrock hydraulic conductivity of 2.6×10^{-9} m/s and 200 times higher than the permafrost hydraulic conductivity of 6.0×10^{-10} m/s. As noted above, sub-permafrost bedrock in Layer 1 in the vicinity of MW14-05 is assigned a hydraulic conductivity of 2.6×10^{-9} m/s, the same value as applied to Deep Bedrock.

Hydraulic head calibration statistics are illustrated in Figure 2-3. The overall model normalized root mean squared error (NRMSE) is 1.13%, with a residual mean of 0.22 m, and an absolute residual mean of 5.5 m. Figure 2-3 shows the normalized root mean squared error and the absolute residual mean for all wells together and with wells grouped by surface water catchment. In the catchment groupings, the wells given a calibration weight of 0.3 in Table 2-1—*i.e.*, Westbay installations located in the same model cell as a continuously monitoring vibrating-wire transducer (see Lorax, 2016)—are not included in the calculated statistics. Table 2-3 presents a summary of calibration statistics. Table 2-4 lists the computed heads and the residuals—*i.e.*, the differences between the simulated heads and the calibration targets—for all wells included in the calibration.

Table 2-2: Calibrated Hydraulic Conductivity

Material Zone	Hydraulic Conductivity (m/s)
Colluvium	3.0×10^{-5}
Independence Creek Fault and Bedrock below Latte Creek, Layer 2	3.0×10^{-5}
Yukon River Alluvium	1.0×10^{-5}
Layer 1 Bedrock at Creeks	6.0×10^{-6}
North fault	5.0×10^{-6}
Layer 1 and 2 Upper Latte Creek	4.0×10^{-6}
T3 Structure	1.0×10^{-6}
Latte Structure	1.0×10^{-6}
Sub-permafrost Bedrock in vicinity of MW15-07 and MW16-01	1.0×10^{-6}
Shallow Bedrock	1.3×10^{-7}
Deep Bedrock (top of model layer more than 100 m below ground surface) and Sub-permafrost Bedrock in vicinity of MW14-05	2.6×10^{-9}
Permafrost	6.0×10^{-10}

Table 2-3: Summary of Calibration Statistics

Well Group	NRMSE	Residual Mean (m)	Absolute Residual Mean (m)	Number of Wells
All Wells	1.13%	0.22	5.50	42
Halfway Creek Catchment	0.63%	-0.70	5.35	17
Latte Creek Catchment	2.08%	2.45	8.46	12
YT-24 Catchment	1.97%	-0.35	4.65	6
Duplicate Westbay Points	0.36%	-0.90	1.49	7

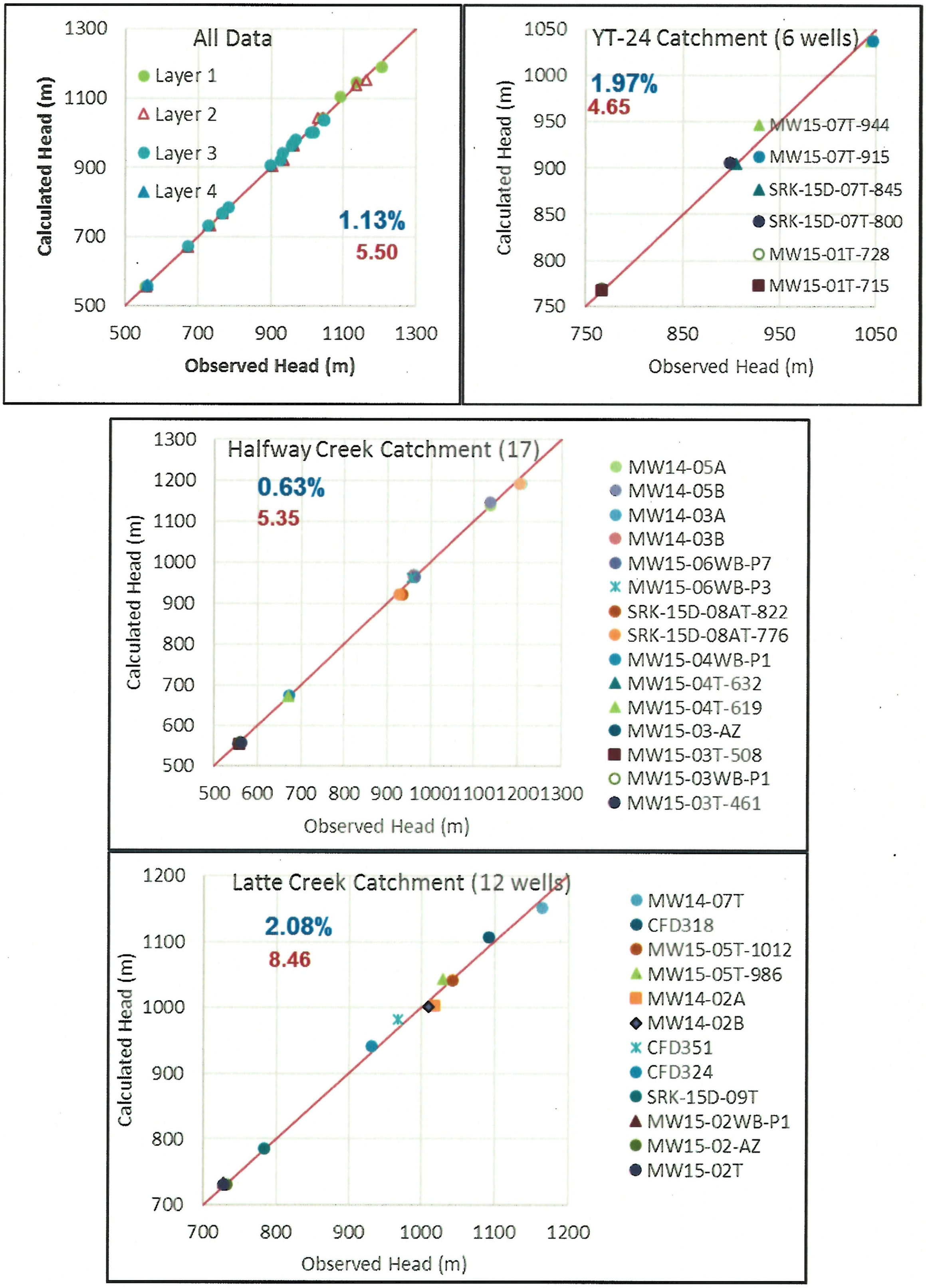


Figure 2-3: Head Calibration Results, showing NRMSE in blue (%) and Absolute Residual Mean (m) in red.

Table 2-4:
Head Residuals

Name	Computed Head (m)	Observed Minus Computed Head (m)
MW15-03-AZ	555.05	1.25
MW15-03T-508	555.23	1.77
MW15-03WB-P1	560.77	-0.87
MW15-03T-461	557.40	3.80
MW15-04T-632	670.86	-0.06
MW15-04T-619	670.86	0.04
MW15-04WB-P1	673.32	-1.02
MW15-01T-715	767.64	-1.44
MW15-01T-728	769.82	-3.22
SRK-15D-07T-800	905.84	-7.44
SRK-15D-07T-845	904.92	-0.82
MW15-06WB-P3	962.41	-5.61
MW15-06WB-P7	963.93	-1.23
MW15-07T-944	1038.20	6.80
MW15-07T-915	1038.20	8.20
SRK-15D-08AT-776	922.28	5.02
CFD324	941.15	-9.55
SRK-15D-08AT-822	920.61	13.59
MW14-03A	969.17	-9.37
MW14-03B	967.69	-7.89
CFD351	981.58	-13.78
MW14-02B	1002.45	7.15
MW14-02A	1002.79	14.91
CFD318	1106.54	-14.54
MW15-02WB-P1	733.81	-5.91
MW15-02-AZ	731.83	-0.63
MW15-02T	731.80	-5.00
SRK-15D-09T	784.97	-2.07
MW15-05T-986	1043.10	-14.00
MW15-05T-1012	1041.29	1.41
MW14-05A	1138.87	-2.67
MW14-05B	1147.03	-10.83
MW14-07T	1151.59	12.61
MW16-01T-1106	1192.19	13.71
MW16-01T-1072	1192.09	12.21
MW15-03WB-P7	556.09	1.41
MW15-04WB-P5	671.54	0.96
MW15-02WB-P4	731.71	2.89
MW15-01WB-P1	767.27	0.13
MW15-01WB-P6	769.46	-2.06
MW15-05WB-P1	1044.08	0.52
MW15-05WB-P4	1042.25	2.45

Figure 2-4 presents a chart of all the calibration residuals as a function of screen elevation. The residuals are significantly lower below an elevation of 750 masl than above 750 masl. This is due to the proximity of the lower-elevation monitoring wells to creek channels, where the hydraulic head is more constrained than at higher elevations. In general, there is no significant consistent bias above or below the calibration target for wells at elevations above 750 masl. Figure 2-5 shows the calibration residuals by catchment, with well labels shown. The blue points in Figure 2-5 are the Westbay points which were underweighted in the calibration because only a handful of head measurements were available at these locations. The Westbay data points are not labeled, but they are adjacent to the wells nearest to them on the graphs.

Figure 2-6 presents histograms of residuals for all head measurement points and for well groupings by catchment.

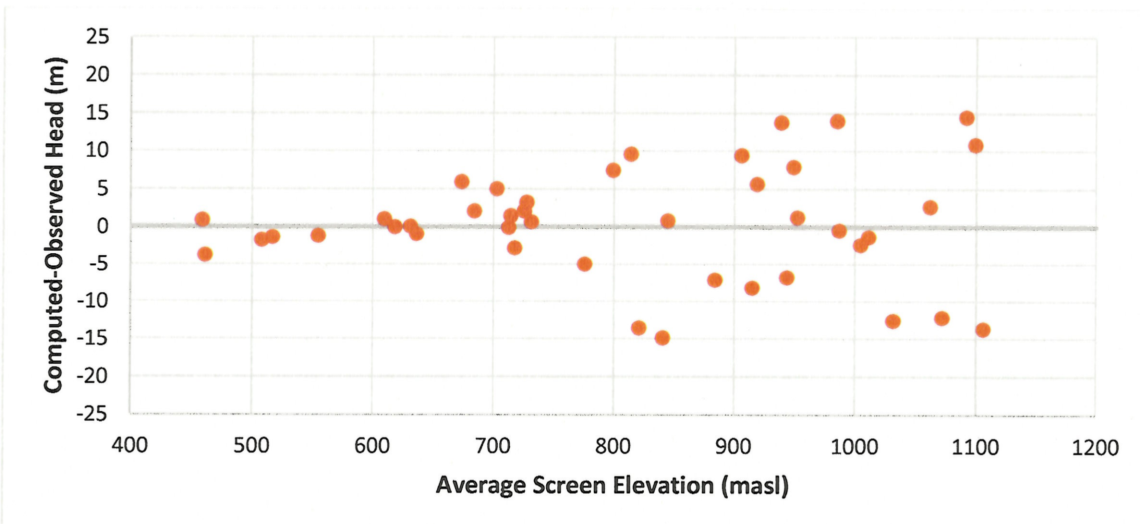


Figure 2-4: Calibration Residual versus Well Screen Elevation, All Wells

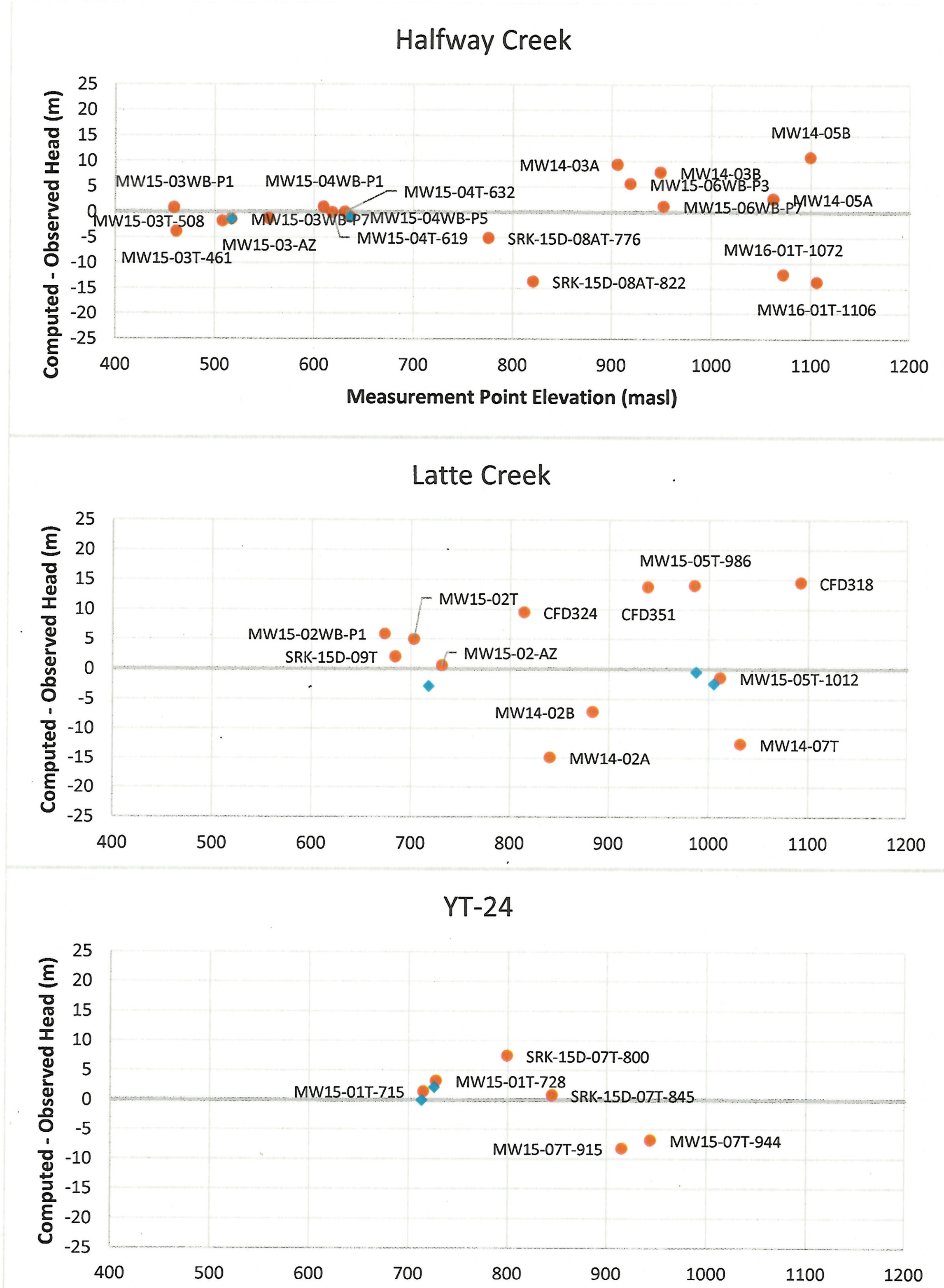


Figure 2-5: Calibration Residual versus Well Screen Elevation, By Catchment

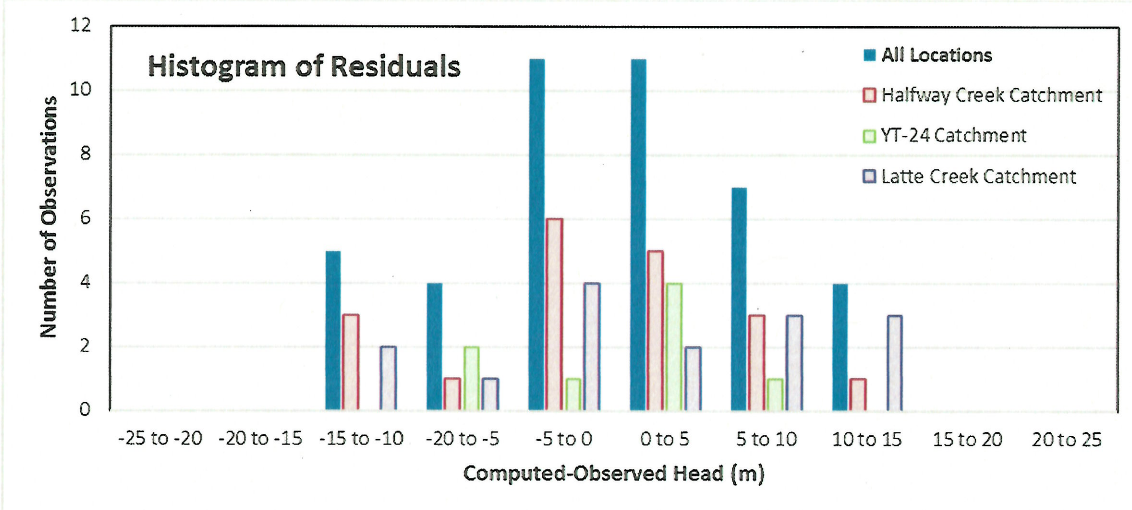


Figure 2-6: Histogram of Residuals

2.3.2 Water Balance and Base Flow Predictions

Table 2-5 presents the model-wide mass balance under baseline conditions. The model mass balance is good, and the specified convergence criteria are reasonable for the problem. Table 2-6 presents the results of the flow calibration, in which simulated groundwater discharge to surface water was compared with measured values. The majority of simulated groundwater discharge values fall within the upper and lower bound calibration targets. At IC-2.5, the groundwater model underpredicts the groundwater discharge to the creek; however, for this catchment, the water quality signature suggests that the measured low-flow stream discharge is not primarily derived from bedrock groundwater. Overall, the flow calibration is adequate.

Table 2-5:
Model-Wide MassBalance

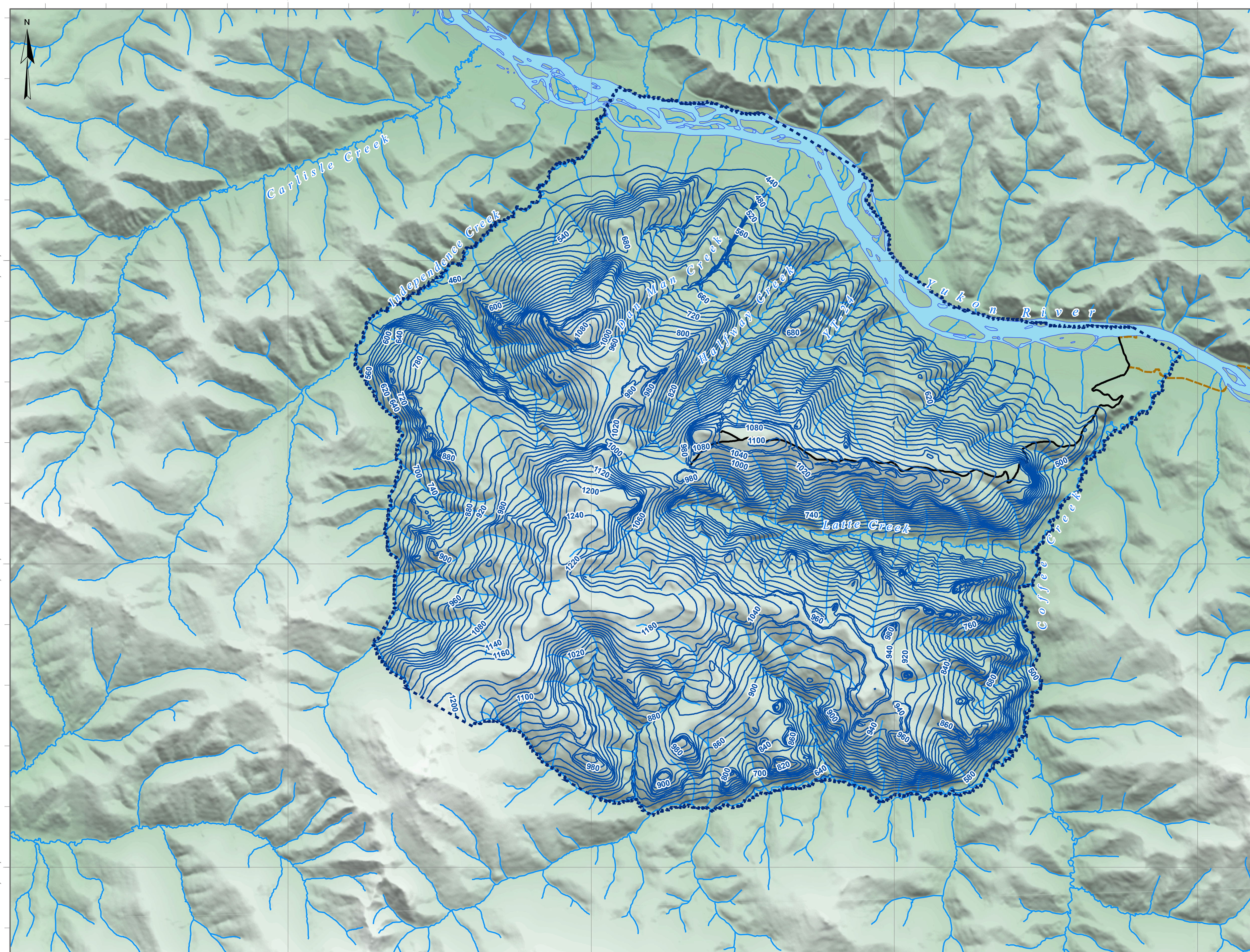
	Inflow (L/s)	Outflow (L/s)	Discrepancy (L/s)	Percent Discrepancy
Constant Head	192.1	241.0		
Recharge	202.7			
Drains		153.7		
Total	**394.8**	**394.8**	**0.00**	**0.00%**

Table 2-6:
Simulated Groundwater Discharge

	Target (L/s)	Simulated (L/s)	Comment
Mine Area Catchment			
IC-2.5	6.9/16	4.7	Lower than target
IC-3.0	7.3/16	10	Within range
HC-2.5	5.9/13	8.2	Within range
HC-5.0	11/24	17	Within range
ML-1.0	3.8/11	7.3	Within range
CC-6.0	3.8/8.6	4.4	Within range
CC-1.0	0.0/3.1	2.1	Within range
CC-1.5	9.3/21	14	Within range
CC-3.5	28/63	48	Within range
Other Catchments at Model Edges			
IC-1.5 (SW Boundary)	32/73	22	Simulated value should be approx. half target
IC-4.5 (W Boundary)	89/200	42	Simulated value should be approx. half target

2.3.3 Flow Directions and Potentiometric Map

The calibrated water table is shown in Figure 2-7 to Figure 2-9. The steepest hydraulic gradients are associated with changes in the recharge rate applied to permafrost areas in the southern portion of the model (compare with Figure 2-1) and with the boundary between Shallow and Deep Bedrock zones in Layer 2. The importance of the hydraulic conductivities in Layer 2 is due to the fact that in some of the higher elevation model grid cells, the water table occurs in Layer 2, as illustrated in the sections in Figure 2-8 and Figure 2-9. The model is able to predict the observed shape of the water table, including instances where the water table was observed to be below the bottom of the permafrost zone. For instance, this is evident in the eastern portion of Row 116 in Figure 2-8. At other areas, the much higher recharge through unfrozen bedrock leads to confined water tables beneath permafrost, even at relatively high elevations, such as in the central portions of Column 312. More commonly, confined or artesian heads occur at or near creek channels. The model is able to simulate strong vertical gradients favouring downward flow at higher elevations. However, given that the model contains only four layers, vertical gradients are generally not pronounced in the sections except where permafrost is present at higher elevations.



LEGEND

- Pre-Mine Water Table Contours (20m)
- Model Domain Boundary
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:125,000

0 2 4 Km

DATE SAVED:	Mar 29, 2017
DRAWN BY:	GM
REVIEWED:	LF
VERSION:	1

CLIENT:

GOLDCORP

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Calibrated Baseline Water Table

PROJECT #:	A362-5	*FIGURE:*	2-7

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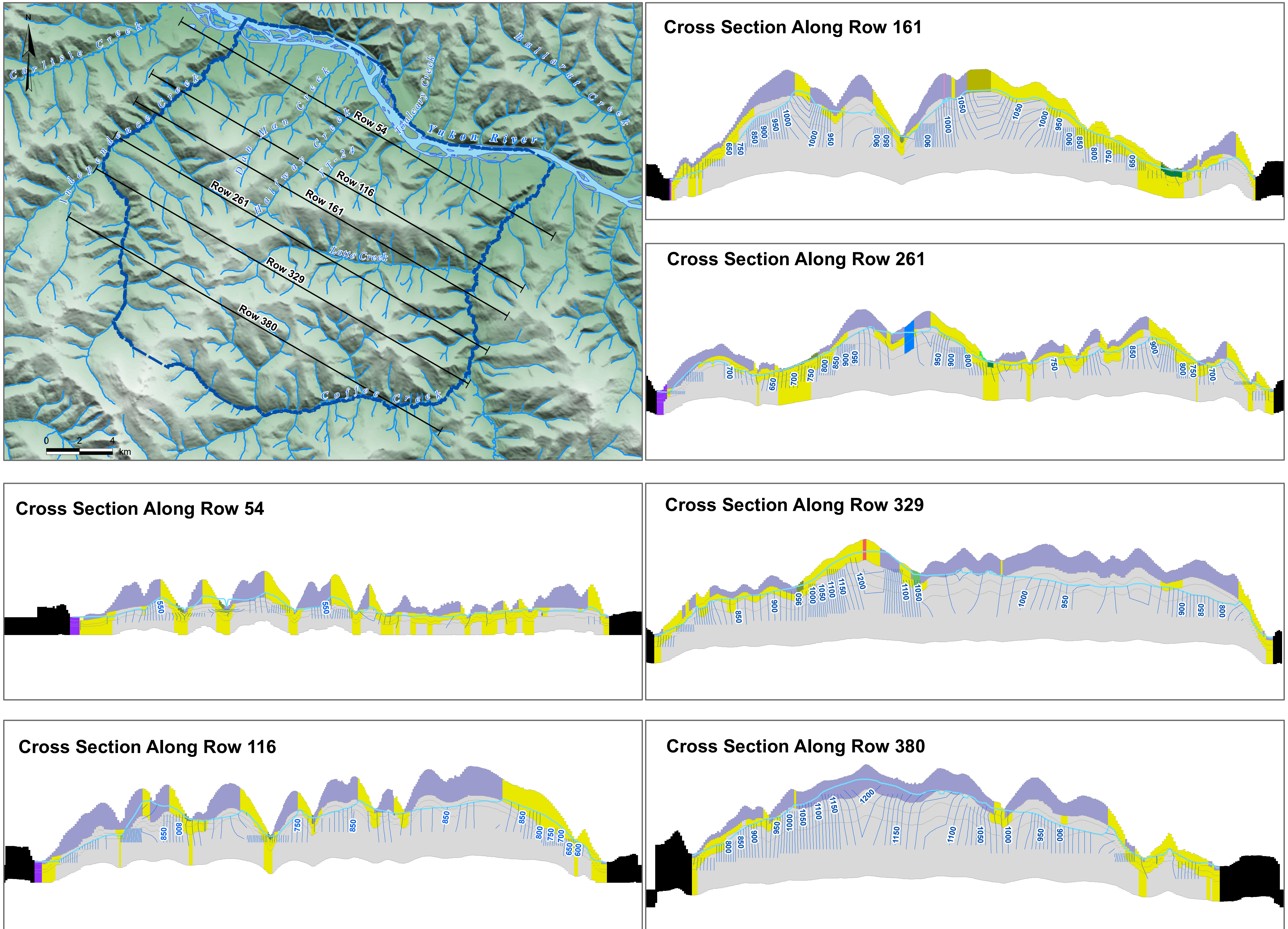

LEGEND

K (m/s)

- Alluvium (1.0E-05)
- Shallow Bedrock (1.3E-07)
- L1 Bedrock below PF (MW16-01) (1.0E-06)
- L1 Bedrock below PF (MW15-07) (1.0E-06)
- L1 Bedrock below PF (MW14-05) (2.6E-09)
- K Deep Bedrock > 100m Depth (2.6E-09)
- Colluvium (3.0E-05)
- T3 Structure (1.0E-06)
- Latte Structure (1.0E-06)
- All Creek hi K zones L1 (6.0E-06)
- N Fault (5.0E-06)
- Layer 1 and 2 Upper Latte Creek (4.0E-06)
- L2 Lower Latte (3.0E-05)
- IC Creek Fault (3.0E-05)
- Permafrost (6.0E-10)
- Inactive Cell
- Head Contours (10m)
- Water Table
- Layer Boundary

Vertical Exaggeration 5x
Horizontal Scale:

1:150,000

0 2 4 km

DATE SAVED:	Mar 29, 2017
DRAWN BY:	GM
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VERSION:	1

CLIENT:

GOLDCORP

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Cross-Sections along Model Rows, Showing Calibrated Head Solution

PROJECT #: A362-5

FIGURE: 2-8

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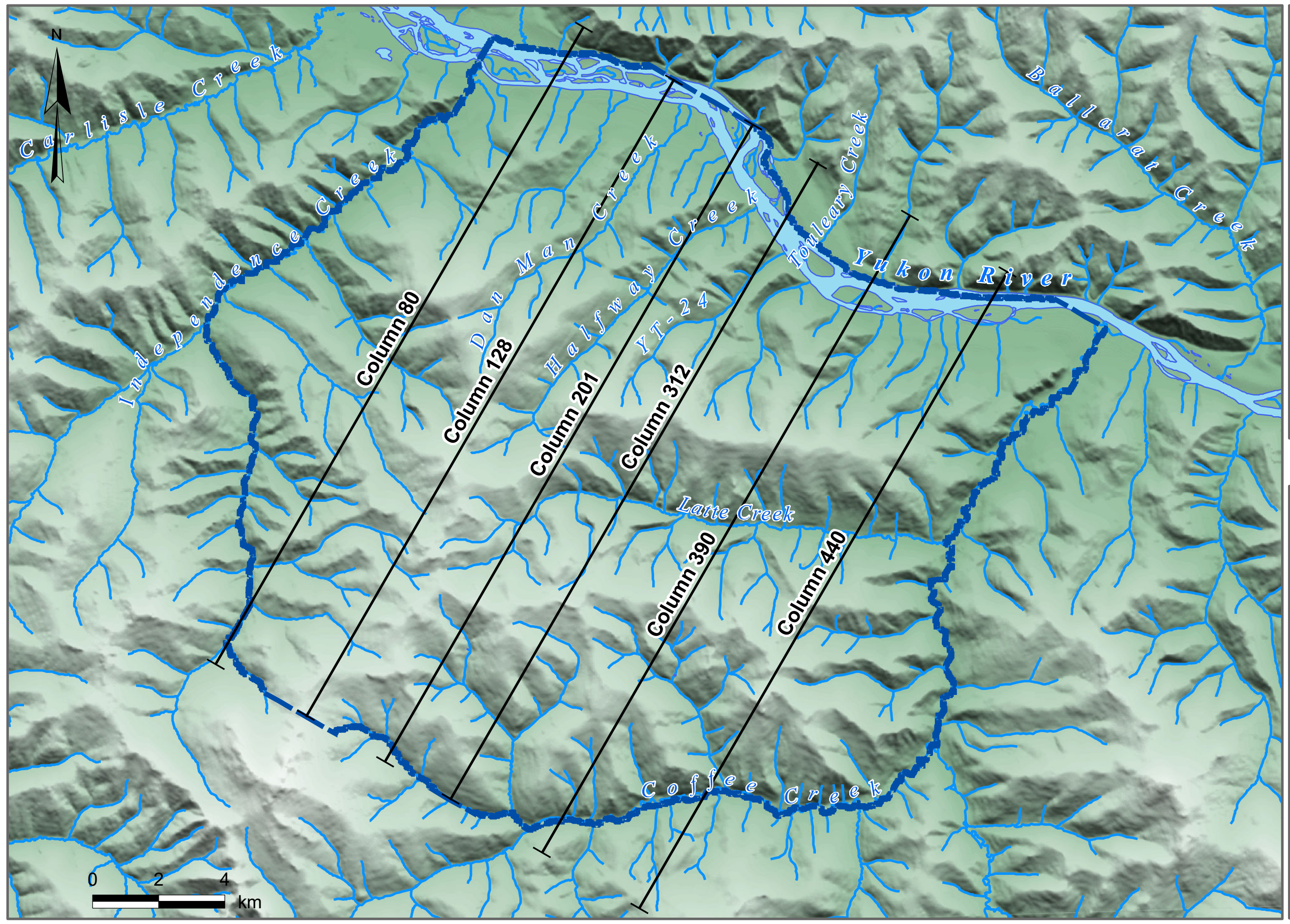
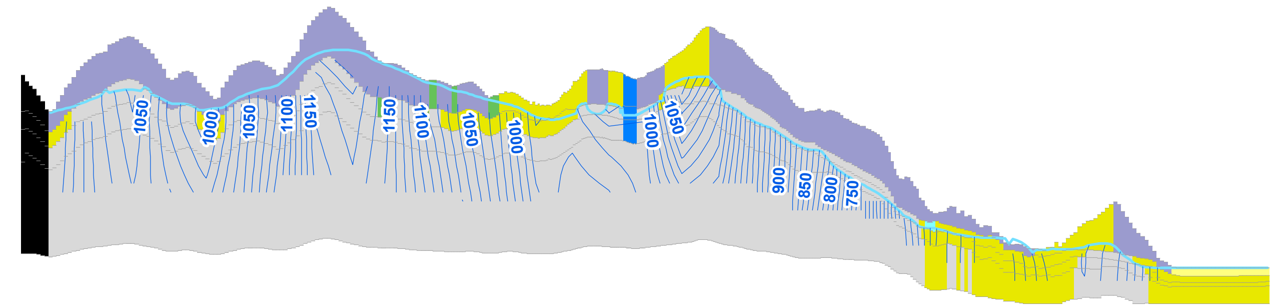
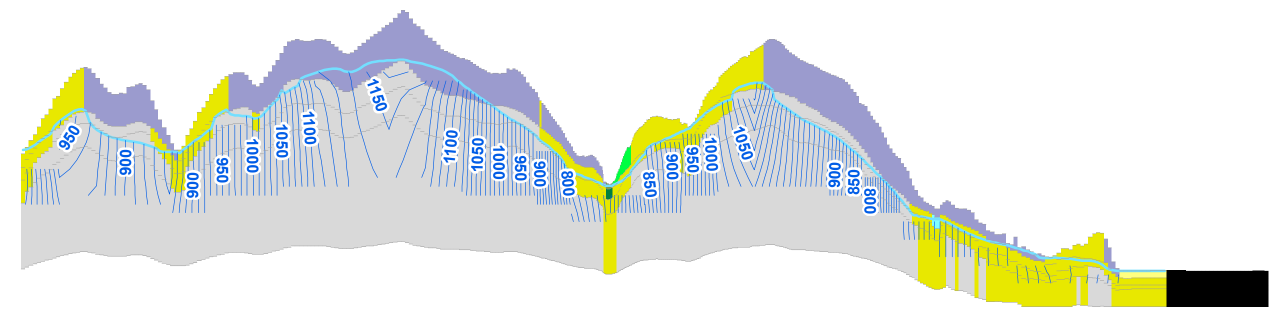


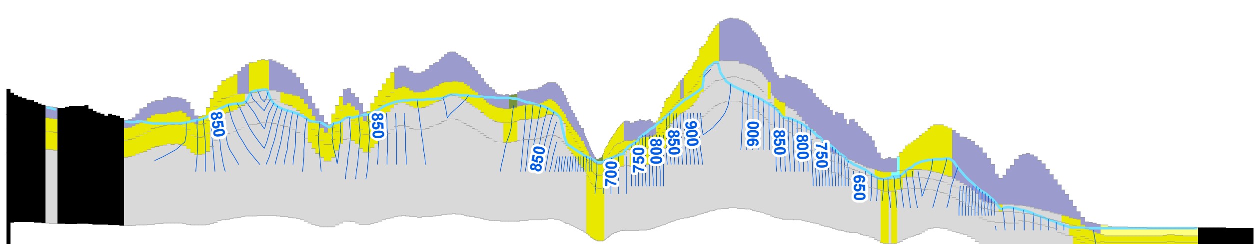
Cross Section Along Column 201



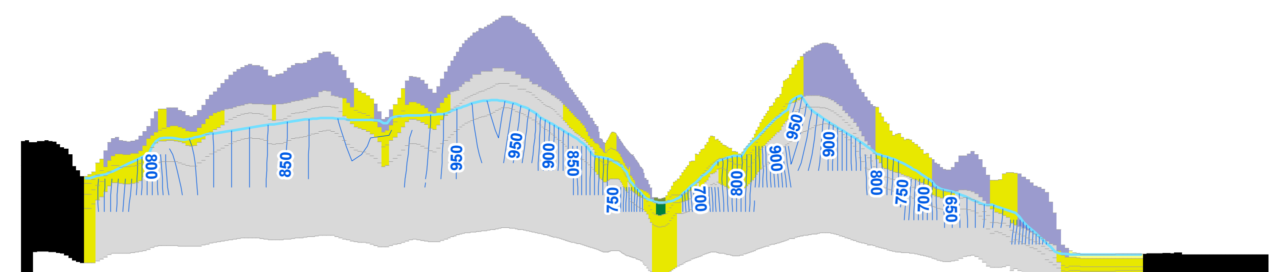
Cross Section Along Column 312



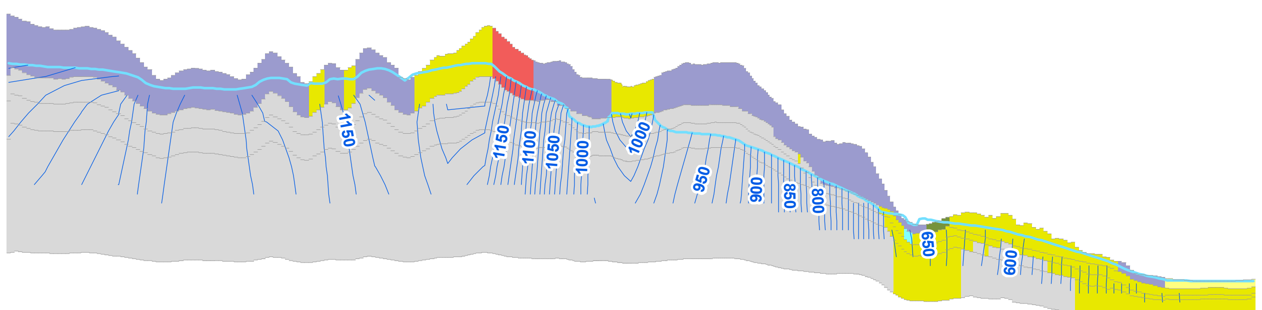
Cross Section Along Column 80



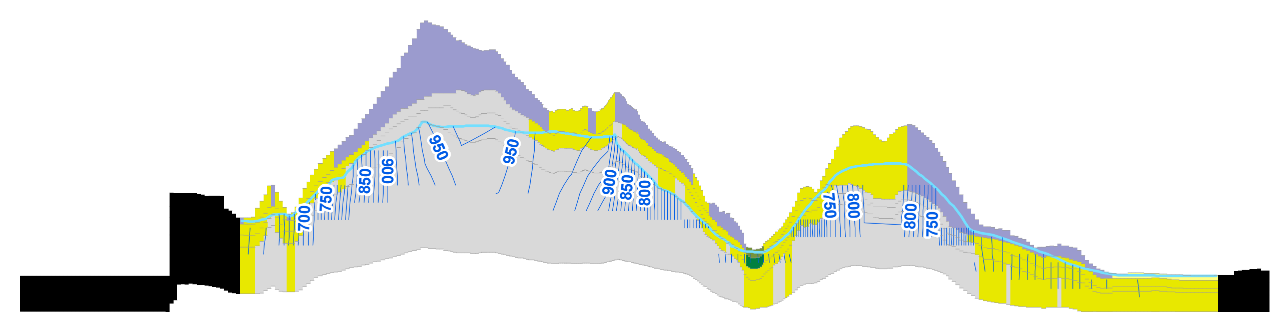
Cross Section Along Column 390



Cross Section Along Column 128



Cross Section Along Column 440



LEGEND

K (m/s)

- Alluvium (1.0E-05)
- Shallow Bedrock (1.3E-07)
- L1 Bedrock below PF (MW16-01) (1.0E-06)
- L1 Bedrock below PF (MW15-07) (1.0E-06)
- L1 Bedrock below PF (MW14-05) (2.6E-09)
- K Deep Bedrock > 100m Depth (2.6E-09)
- Colluvium (3.0E-05)
- T3 Structure (1.0E-06)
- Latte Structure (1.0E-06)
- All Creek hi K zones L1 (6.0E-06)
- N Fault (5.0E-06)
- Layer 1 and 2 Upper Latte Creek (4.0E-06)
- L2 Lower Latte (3.0E-05)
- IC Creek Fault (3.0E-05)
- Permafrost (6.0E-10)
- Inactive Cell
- Head Contours (10m)
- Water Table
- Layer Boundary

Vertical Exaggeration 5x
Horizontal Scale:
1:135,000

0 2 4 km

DATE SAVED:	Mar 29, 2017
DRAWN BY:	GM
REVIEWED:	JS/LF
VERSION:	1

CLIENT:

GOLDCORP

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Cross-Sections along Model Columns, Showing Calibrated Head Solution

PROJECT #:	*FIGURE:*
A362-5	2-9

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2.4 Sensitivity Analysis

The sensitivity analysis on the model parameters is presented in Lorax (2016). The abridged sensitivity analysis below presents an analysis of the three new parameter zones in the updated model.

2.4.1 Sensitivity to Sub-Permafrost Bedrock near MW16-01

Increasing or decreasing the hydraulic conductivity of the sub-permafrost bedrock just upgradient of MW16-01 has a minor impact on the head and flow calibration, as shown in Table 2-7, Table 2-8 and Figure 2-10. Increasing the value of the MW16-01 area sub-permafrost bedrock hydraulic conductivity by a factor of 10 reduces the water table by up to 7 m under the southwestern corner of the proposed heap leach facility and increases the water table by up to 5.5 m under the southeastern corner of the proposed heap leach facility, as shown in the upper pane of Figure 2-11. The residual mean changed from 0.22 m to 0.38 m, and the NRMSE dropped from 1.13% to 1.09%. Reducing the hydraulic conductivity by a factor of ten raises the water table by as much as 12 m under the southwestern corner of the proposed heap leach facility and reduces the water table by up to 14 m under the southeastern corner of the heap facility. The residual mean dropped from 0.22 m to -0.40 m and the NRSME rose to 1.35%. The primary reason for a change in the calibration statistics is due to the simulated baseline head at MW16-01, as indicated for the Halfway Creek area in Table 2-8 and shown in the lower pane of Figure 2-11.

The hydraulic conductivity of the sub-permafrost area near MW16-01 has a negligible effect on groundwater discharge rates to streams as well as the predicted impacts to groundwater (see Section 3.3.1). It can be noted that the calibration statistics are improved if the sub-permafrost bedrock south of MW16-01 is increased from 1×10^{-6} m/s to 1×10^{-5} m/s. However, as noted below in Section 3.3.1, increasing the value of this parameter does not significantly change the effects assessment. Therefore, the hydraulic conductivity of this zone was kept at 1×10^{-6} m/s, which is within the range of measured hydraulic conductivities in the Project area in highly-fractured bedrock.

Table 2-7:
Summary of Mass Balance from MW16-01 Area Sub-Permafrost K Sensitivity Runs

	MW16-01 Area Sub-Permafrost K x 10 ($1.0x10^{-5}$ m/s)	Base Case ($1.0x10^{-6}$ m/s)	MW16-01 Area Sub-Permafrost K/10 ($1.0x10^{-7}$ m/s)
Model-Wide Inflow (L/s):			
Constant Head	192.1	192.1	192.1
Recharge	202.7	202.7	202.7
Total	394.8	394.8	394.8
Model-Wide Outflow (L/s)			
Constant Head	241.0	241.0	241.0
Drain	153.7	153.7	153.7
Total	394.8	394.8	394.8
Inflow-Outflow (L/s)	0.00	0.00	0.00
Inflow-Outflow (%)	0.00	0.00	0.00
Discharge to Streams (L/s)			
IC-2.5	4.7	4.7	4.8
IC-3.0	10	10	10
HC-2.5	8.2	8.2	8.2
HC-5.0	17	17	17
ML-1.0	7.3	7.3	7.3
CC-6.0	4.4	4.4	4.4
CC-1.0	2.1	2.1	2.1
CC-1.5	14	14	14
CC-3.5	48	48	48
IC-1.5	22	22	22
IC-4.5	42	42	42

**Table 2-8:
Head Calibration Statistics for MW16-01 Area Sub-Permafrost K Sensitivity**

Well Group	MW16-01 Area K	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All	Kx10 ($1.0x10^{-5}$ m/s)	1.09%	0.38	5.29
All	Base ($1.0x10^{-6}$ m/s)	1.13%	0.22	5.55
All	K/10 ($1.0x10^{-7}$ m/s)	1.35%	-0.40	6.18
Halfway Creek	Kx10 ($1.0x10^{-5}$ m/s)	0.57%	-0.40	4.91
Halfway Creek	Base ($1.0x10^{-6}$ m/s)	0.63%	-0.70	5.35
Halfway Creek	K/10 ($1.0x10^{-7}$ m/s)	0.91%	-2.02	6.91
Latte Creek	Kx10 ($1.0x10^{-5}$ m/s)	2.08%	2.56	8.40
Latte Creek	Base ($1.0x10^{-6}$ m/s)	2.07%	2.45	8.46
Latte Creek	K/10 ($1.0x10^{-7}$ m/s)	2.10%	2.24	8.57
YT-24	Kx10 ($1.0x10^{-5}$ m/s)	1.97%	-0.35	4.65
YT-24	Base ($1.0x10^{-6}$ m/s)	1.97%	-0.35	4.65
YT-24	K/10 ($1.0x10^{-7}$ m/s)	1.97%	-0.35	4.65

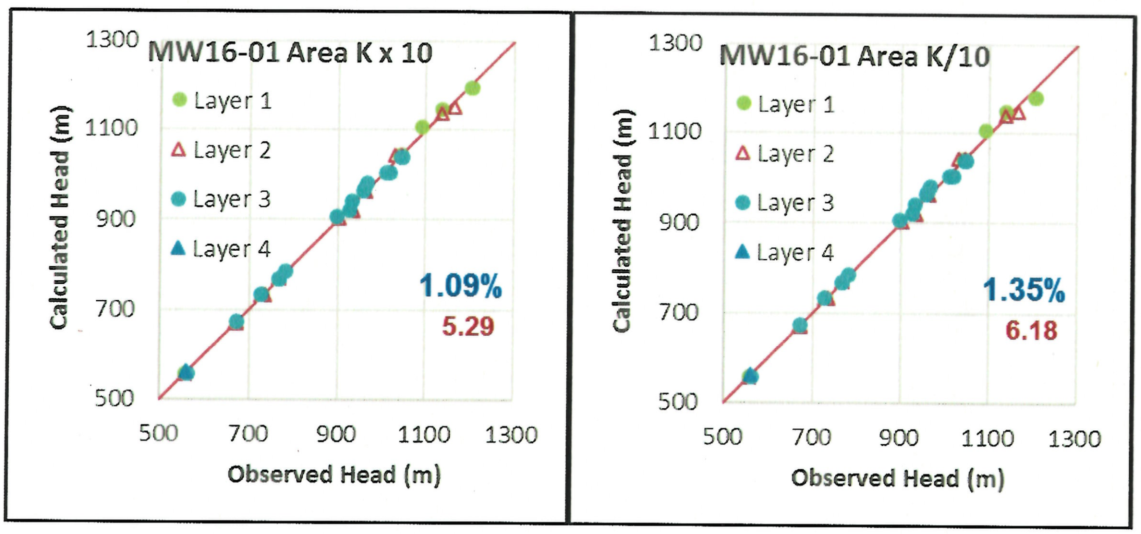
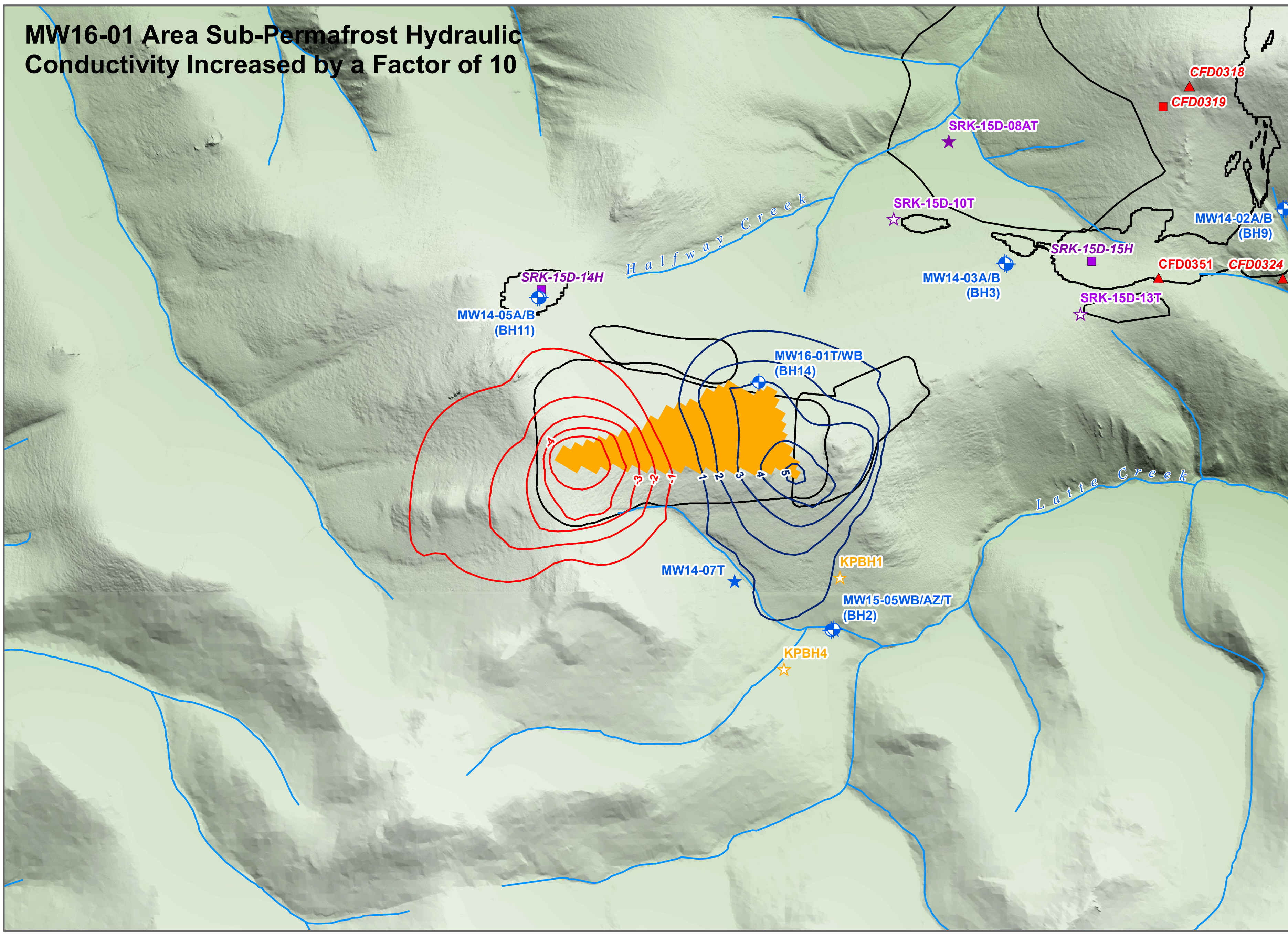
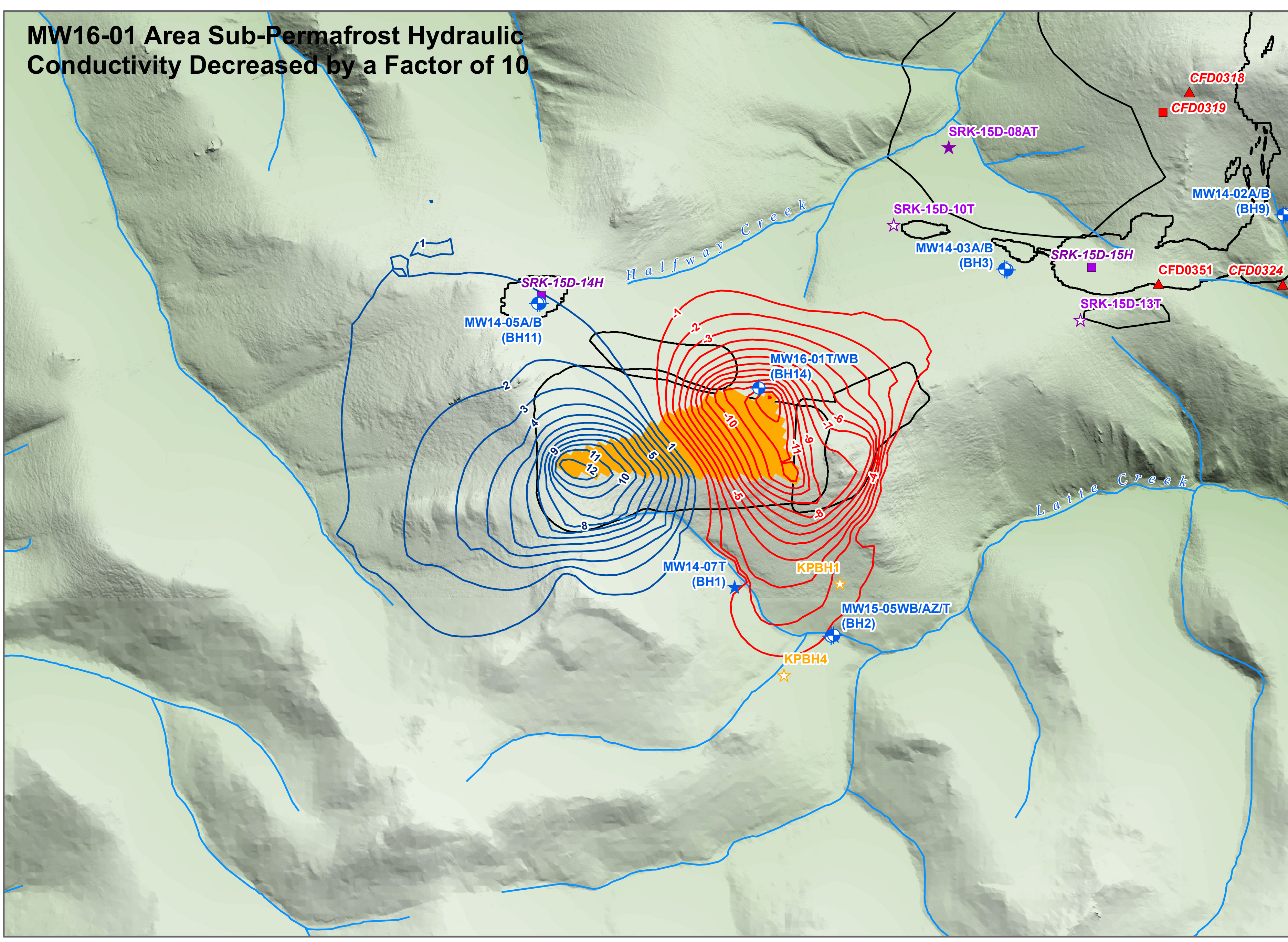


Figure 2-10: Head Calibration Results, Sensitivity of MW16-01 Area Sub-Permafrost Hydraulic Conductivity Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

Change in Head (m) from Base Case Model
- <0m
- >0m
- Bedrock PF Zone (MW16-01)
- Mine Infrastructure
- Monitoring Well
- 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)

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LORAX ENVIRONMENTAL

PROJECT: **Coffee Gold Hydrogeology**

TITLE: Change in Water Table Elevation with Changes in MW16-01 Area Sub-Permafrost Hydraulic Conductivity

PROJECT #: A362-5

FIGURE: 2-11

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 2-11_Change in WT Elevation MW16-01_20170328.mxd

2.4.2 Sensitivity to Sub-Permafrost Bedrock near MW15-07

The results of the sensitivity analysis on the sub-permafrost hydraulic conductivity upgradient of MW15-07 hydraulic conductivity are summarized in Table 2-9, Table 2-10, and Figure 2-12. This parameter has a minor effect on the head solution. Raising the MW15-07 area sub-permafrost hydraulic conductivity by a factor of ten from 1.0×10^{-6} m/s to 1.0×10^{-5} m/s lowers the water table by as much as 4 m in the area south and upgradient of MW15-07 (see Figure 2-13, upper pane). Because this hydraulic conductivity zone is near the T3 Structure to the west, the water table in the northern part of the T3 Structure is raised by as much as 4 m. When the MW15-07 area sub-permafrost hydraulic conductivity was reduced by a factor of ten to 1.0×10^{-7} m/s, or 79% of the Shallow Bedrock hydraulic conductivity, the water table in the northern part of the Project area drops by as much as 29 m. This is because this transmissive sub-permafrost bedrock is not sufficiently permeable to allow significant recharge from the south face of the ridge to the frozen area to the north (see Figure 2-13, lower pane). Consequently, this parameter has an impact on the head calibration, primarily in the YT-24 catchment wells (see Table 2-10).

This parameter does not affect the predicted groundwater discharge rates to streams as shown in Table 2-9.

Table 2-9:
Summary of Mass Balance from MW15-07 Area Sub-Permafrost K Sensitivity Runs

	MW15-07 Area Sub-Permafrost K x 10 (1.0×10^{-5} m/s)	**Base Case (1.0×10^{-6} m/s)**	**MW15-07 Area Sub-Permafrost K/10 (1.0×10^{-7} m/s)**
Model-Wide Inflow (L/s):			
Constant Head	192.1	192.1	192.1
Recharge	202.7	202.7	202.7
Total	394.8	394.8	394.8
Model-Wide Outflow (L/s)			
Constant Head	241.0	241.0	241.0
Drain	153.7	153.7	153.7
Total	394.8	394.8	394.8
Inflow-Outflow (L/s)	0.00	0.00	0.00
Inflow-Outflow (%)	0.00	0.00	0.00
Discharge to Streams (L/s)			
IC-2.5	4.7	4.7	4.8
IC-3.0	10	10	10
HC-2.5	8.2	8.2	8.2
HC-5.0	17	17	17
ML-1.0	7.3	7.3	7.3
CC-6.0	4.4	4.4	4.4
CC-1.0	2.1	2.1	2.1
CC-1.5	14	14	14
CC-3.5	48	48	48
IC-1.5	22	22	22
IC-4.5	42	42	42

Table 2-10:
Head Calibration Statistics for MW15-07 Area Sub-Permafrost K Sensitivity

Well Group	MW15-07 Area K	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All	Kx10 ($1.0x10^{-5}$ m/s)	1.13%	0.30	5.55
All	Base ($1.0x10^{-6}$ m/s)	1.13%	0.22	5.55
All	K/10 ($1.0x10^{-7}$ m/s)	1.20%	-0.28	5.74
Halfway Creek	Kx10 ($1.0x10^{-5}$ m/s)	0.64%	-0.57	5.47
Halfway Creek	Base ($1.0x10^{-6}$ m/s)	0.63%	-0.70	5.35
Halfway Creek	K/10 ($1.0x10^{-7}$ m/s)	0.63%	-0.88	5.21
Latte Creek	Kx10 ($1.0x10^{-5}$ m/s)	2.07%	2.51	8.43
Latte Creek	Base ($1.0x10^{-6}$ m/s)	2.07%	2.45	8.46
Latte Creek	K/10 ($1.0x10^{-7}$ m/s)	2.08%	2.41	8.48
YT-24	Kx10 ($1.0x10^{-5}$ m/s)	1.99%	-0.27	4.74
YT-24	Base ($1.0x10^{-6}$ m/s)	1.97%	-0.35	4.65
YT-24	K/10 ($1.0x10^{-7}$ m/s)	3.25%	-3.18	6.76

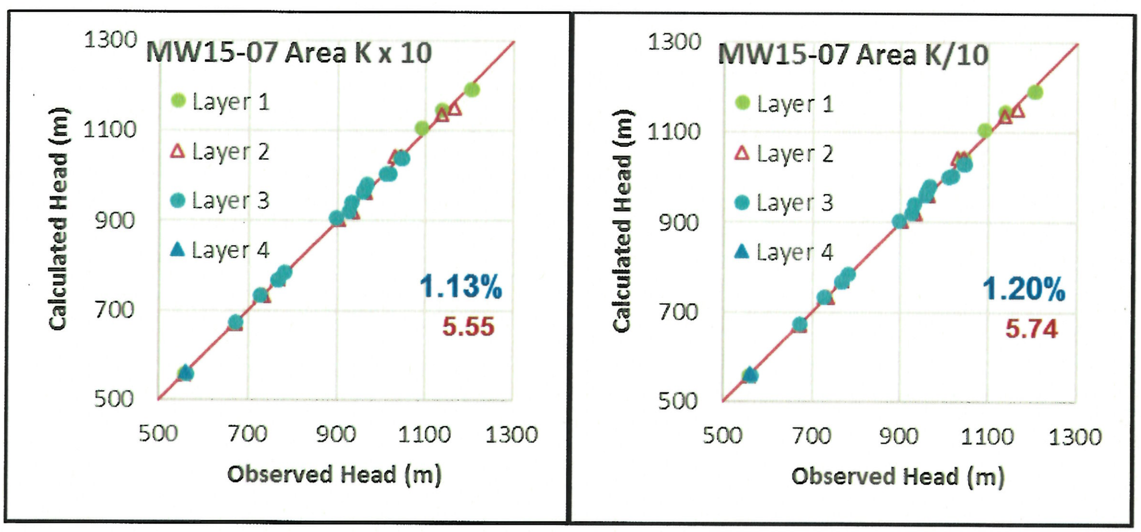
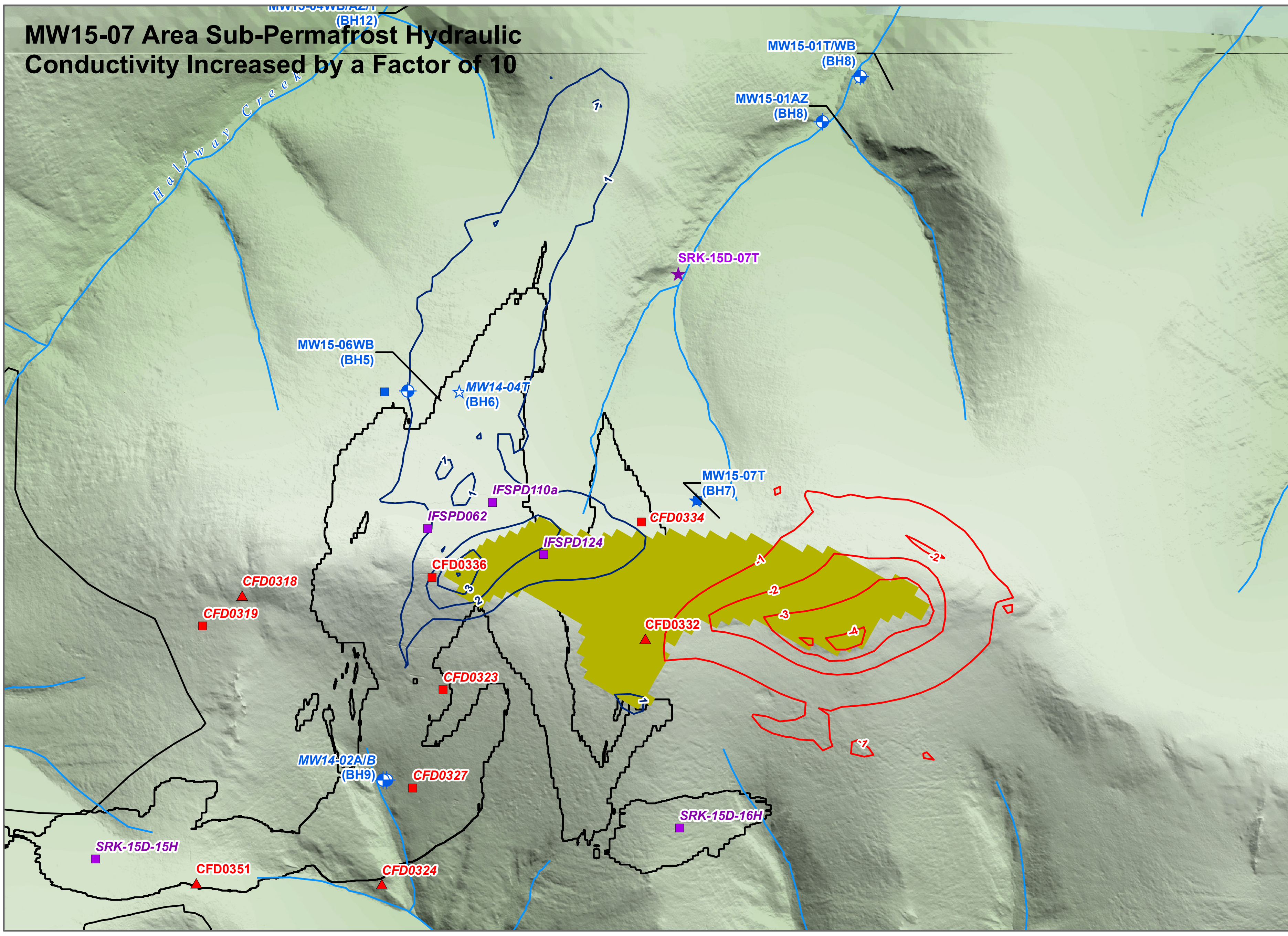
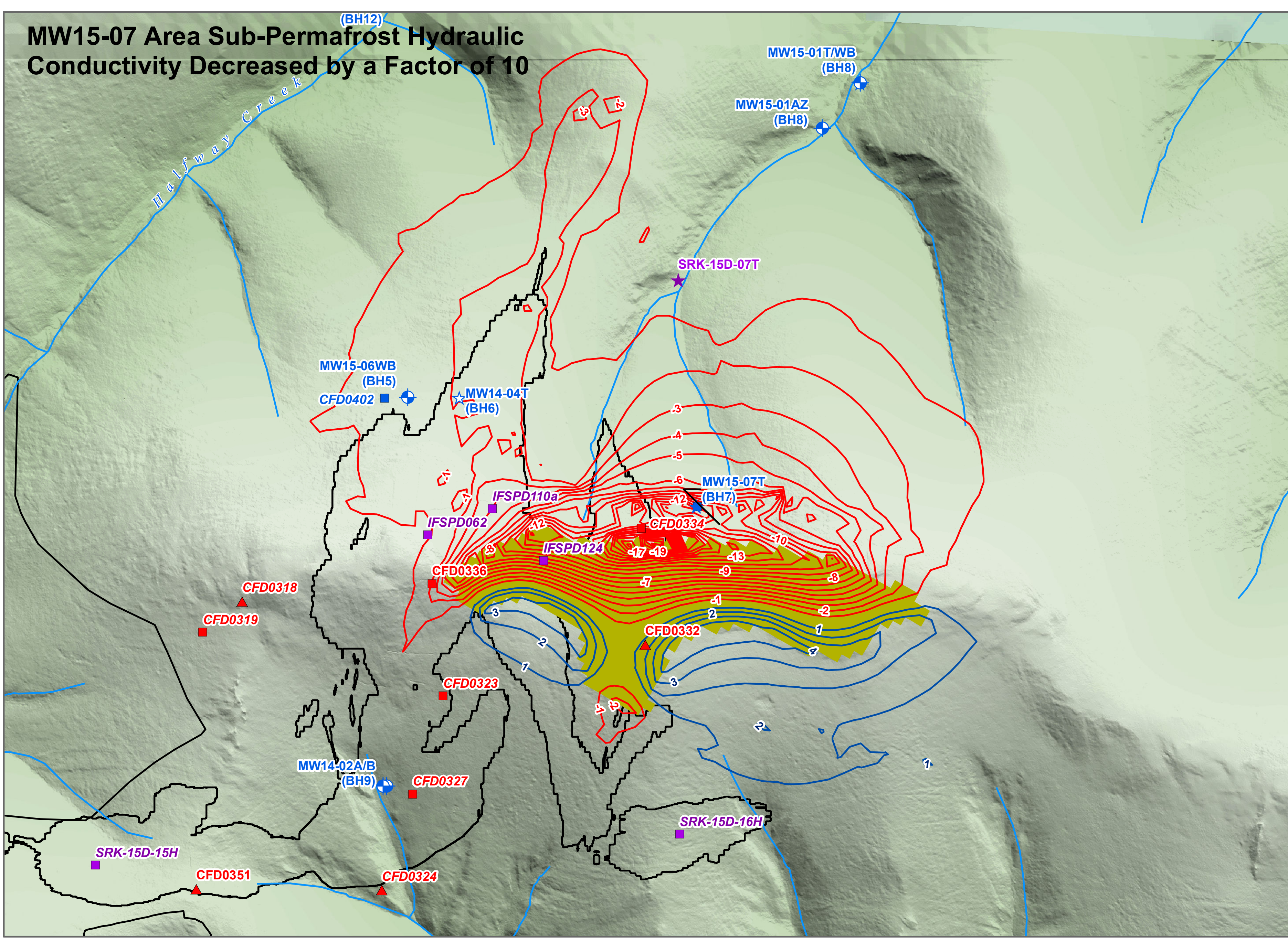


Figure 2-12: Head Calibration Results, Sensitivity of Deep Bedrock Hydraulic Conductivity Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.





LEGEND

Change in Head (m) from Base Case Model

- <0m
- >0m
- Bedrock PF Zone (MW15-07)
- Mine Infrastructure
- Monitoring Well
- 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)

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Coffee Gold Hydrogeology

TITLE:

Change in Water Table Elevation with Changes in MW15-07 Area Sub-Permafrost Hydraulic Conductivity

PROJECT #: A362-5 FIGURE: 2-13

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 2-13_Change in WT Elevation MW15-07_20170328.mxd

2.4.3 Sensitivity to Sub-Permafrost Bedrock near MW14-05

The hydraulic conductivity of the sub-permafrost bedrock around MW14-05 has a relatively minor effect on both the head and flow calibration, as shown in Table 2-11, Table 2-12 and Figure 2-14. Increasing the hydraulic conductivity of this unit leads to a flatter water table in the sub-permafrost zone. As a consequence, the hydraulic head at lower elevations increases, and the hydraulic conductivity at higher elevations drops, as shown in the upper pane of Figure 2-15. The maximum increase in predicted water level elevation as a result of increasing the MW14-05 zone hydraulic conductivity is 45 m, at the western edge of this zone. In the north center of the proposed heap leach facility, at the eastern edge of this hydraulic conductivity zone, the water table is predicted to increase by as much as 25 m (see Figure 2-15, upper pane). The head in the area south of this sub-permafrost zone is reduced by a smaller amount.

Reducing the hydraulic conductivity of this area to equal the hydraulic conductivity of permafrost results in the formation of a groundwater mound in the upgradient portion of the MW14-05 sub-permafrost zone, with an increase in head west of the heap leach facility of as much as 14 m, as shown in Figure 2-15 (lower pane).

Because this parameter affects the predicted heads at MW14-05, the calibration statistics in the Halfway Creek catchment are affected, as shown in Table 2-12.

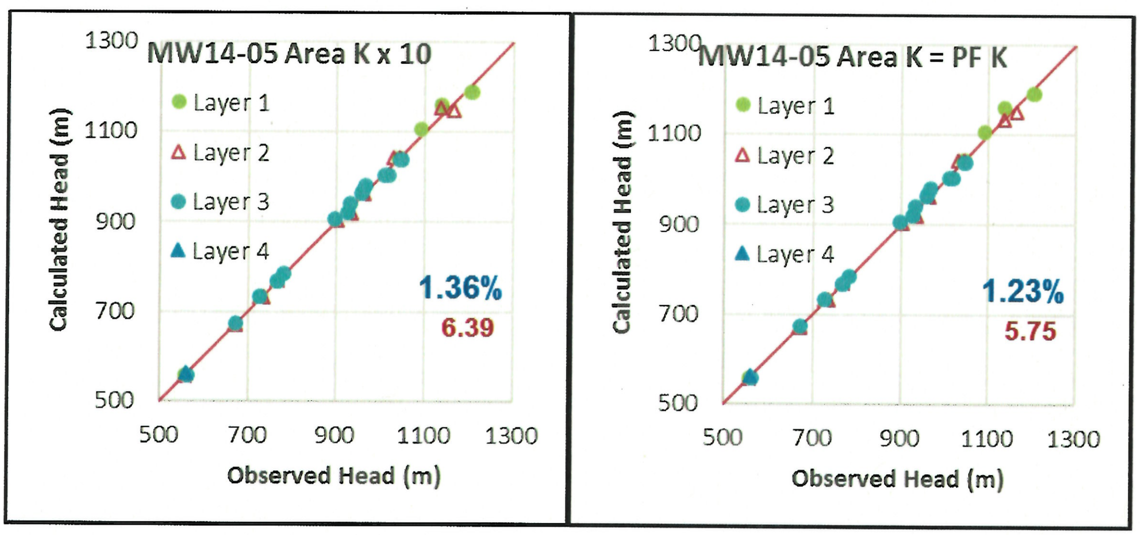


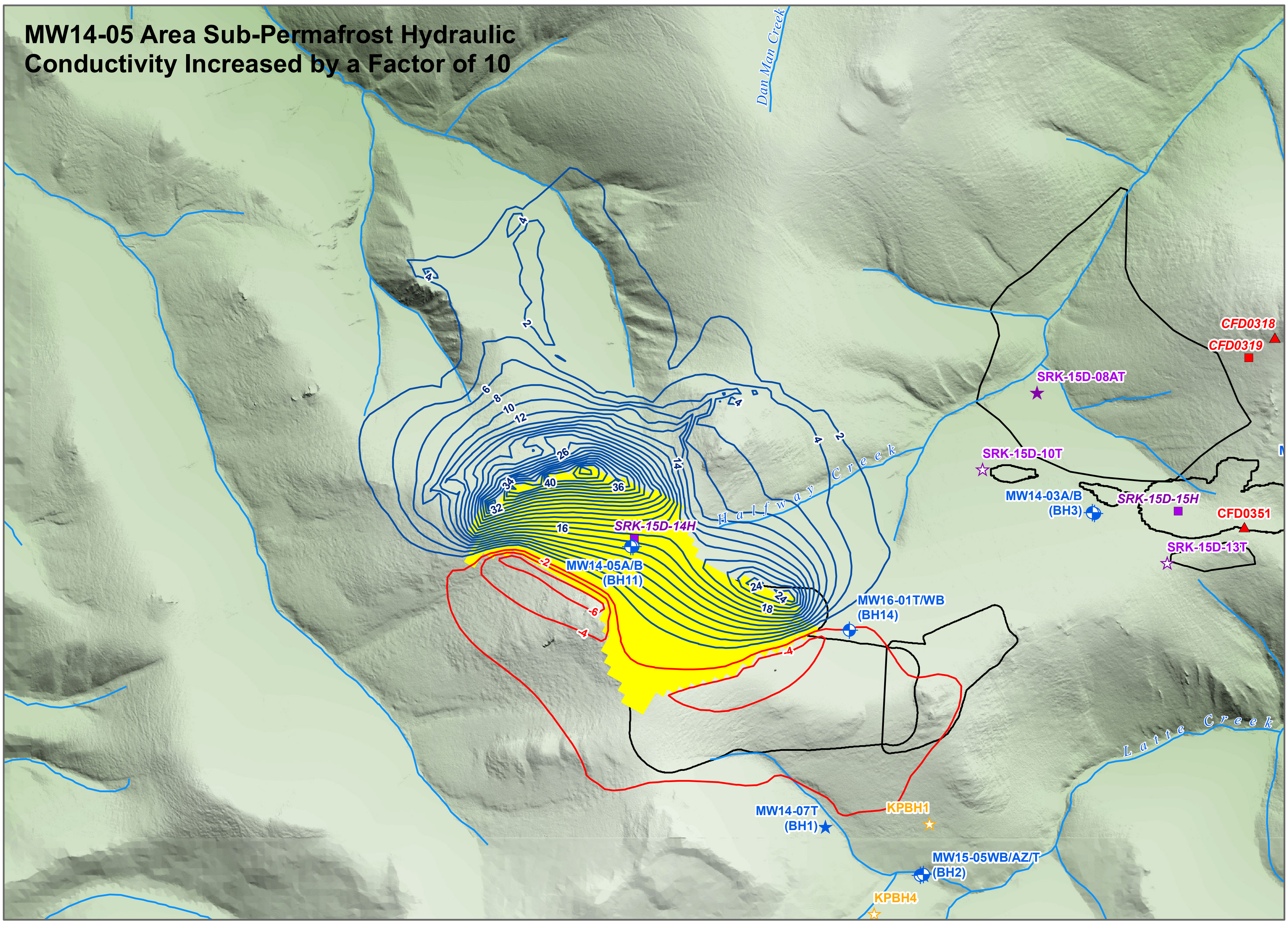
Figure 2-14: Head Calibration Results, Sensitivity of MW14-05 Area Sub-Permafrost Hydraulic Conductivity Showing NRMSE in Blue (%) and Absolute Residual Mean (m) in Red.

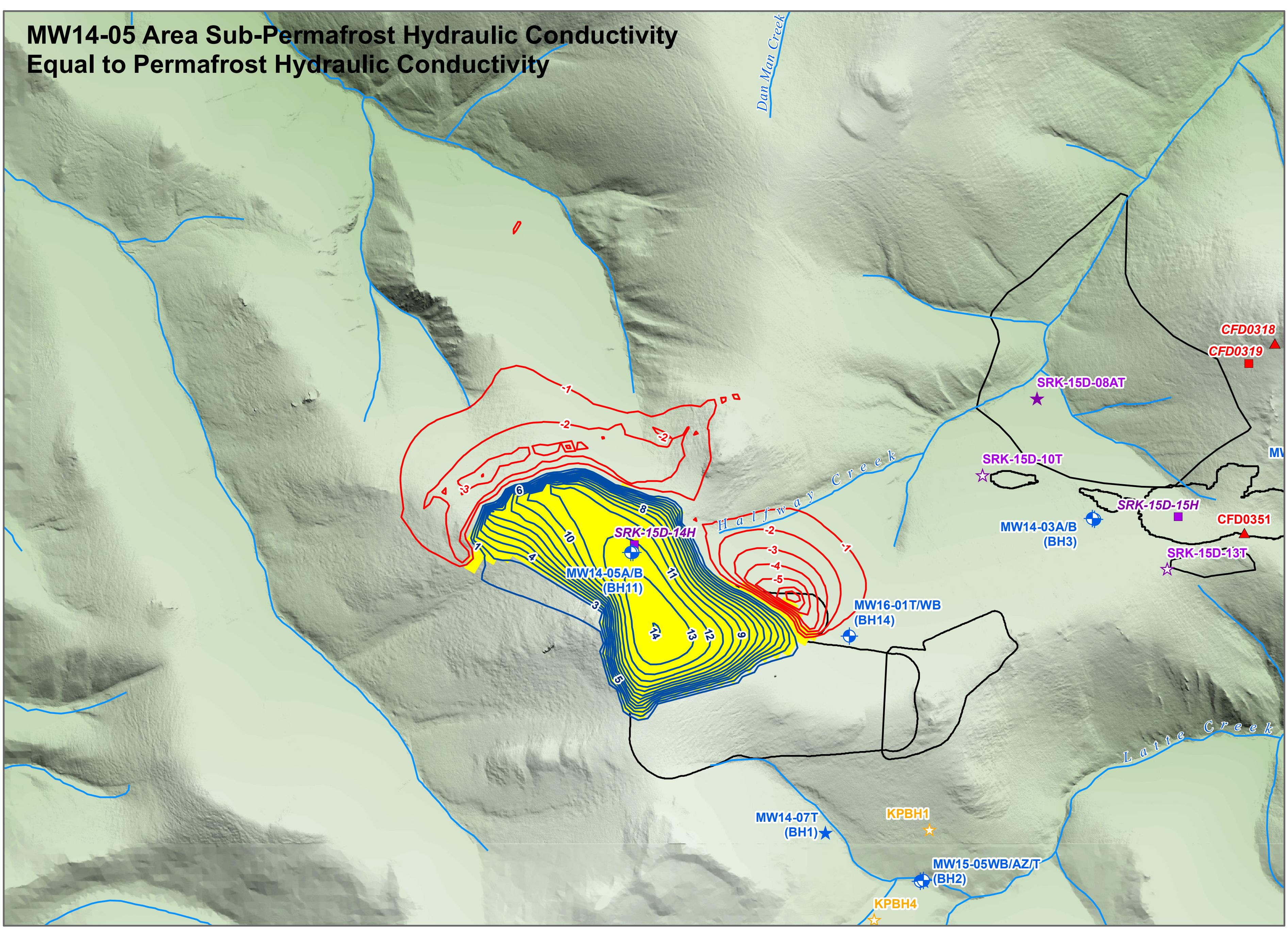
Table 2-11: Summary of Mass Balance from MW14-05 Area Sub-Permafrost K Sensitivity Runs

	MW14-05 Area Sub-Permafrost K x 10 (2.6x10^{-8} m/s)	Base Case (2.6x10^{-9} m/s)	MW14-05 Area Sub-Permafrost K=Permafrost K (6.0x10^{-10} m/s)
Model-Wide Inflow (L/s):			
Constant Head	192.1	192.1	192.1
Recharge	202.7	202.7	202.7
Total	394.8	394.8	394.8
Model-Wide Outflow (L/s)			
Constant Head	241.0	241.0	241.0
Drain	153.7	153.7	153.7
Total	394.8	394.8	394.8
Inflow-Outflow (L/s)	0.00	0.00	0.00
Inflow-Outflow (%)	0.00	0.00	0.00
Discharge to Streams (L/s)			
IC-2.5	4.7	4.7	4.7
IC-3.0	10	10	10
HC-2.5	8.2	8.2	8.2
HC-5.0	17	17	17
ML-1.0	7.3	7.3	7.3
CC-6.0	4.4	4.4	4.4
CC-1.0	2.1	2.1	2.1
CC-1.5	14	14	14
CC-3.5	48	48	48
IC-1.5	22	22	22
IC-4.5	42	42	42

Table 2-12:
Head Calibration Statistics for MW14-05 Area Sub-Permafrost K Sensitivity

Well Group	MW14-05 Area K	Normalized Root mean squared	Residual Mean (m)	Absolute Residual Mean (m)
All	Kx10 ($2.6x10^{-8}$ m/s)	1.36%	0.77	6.39
All	Base ($2.6x10^{-9}$ m/s)	1.13%	0.22	5.55
All	PF K ($6.0x10^{-10}$ m/s)	1.23%	0.43	5.75
Halfway Creek	Kx10 ($2.6x10^{-8}$ m/s)	0.92%	0.81	7.44
Halfway Creek	Base ($2.6x10^{-9}$ m/s)	0.63%	-0.70	5.35
Halfway Creek	PF K ($6.0x10^{-10}$ m/s)	0.76%	-0.21	6.00
Latte Creek	Kx10 ($2.6x10^{-8}$ m/s)	2.10%	2.31	8.57
Latte Creek	Base ($2.6x10^{-9}$ m/s)	2.07%	2.45	8.46
Latte Creek	PF K ($6.0x10^{-10}$ m/s)	2.07%	2.48	8.45
YT-24	Kx10 ($2.6x10^{-8}$ m/s)	1.97%	-0.25	4.65
YT-24	Base ($2.6x10^{-9}$ m/s)	1.97%	-0.35	4.65
YT-24	PF K ($6.0x10^{-10}$ m/s)	1.97%	-0.35	4.65





LEGEND

Change in Head (m) from Base Case Model
- <0m
- >0m
- Bedrock w WT below PF (MW14-05)
- Mine Infrastructure
- Monitoring Well
- 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)

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PROJECT:

Coffee Gold Hydrogeology

TITLE:

Change in Water Table Elevation with Changes in MW14-05 Area Sub-Permafrost Hydraulic Conductivity

PROJECT #: A362-5 FIGURE: 2-15

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2.5 Summary

A steady state groundwater baseline model was developed and calibrated to observed monitoring well heads and observed stream baseflows in the Project area. The model was able to fit the groundwater heads in monitoring wells to a residual mean of less than 1 meter and a normalized root mean squared error of 1.13%. The model was able to predict groundwater discharge targets in eight of nine Project area streams to within calibration targets. It was not able to simulate the baseflow target at the IC-2.5 catchment; however, the water quality signature of this stream suggests that the majority of baseflow is not associated with deep, bedrock-derived groundwater that is simulated in this model. Model results are therefore consistent with and calibrated to observations.

The adjustment of hydraulic conductivity zones near the MW14-05, MW16-01 and MW15-07 installations neither had a significant impact on the model-wide calibration nor predicted baseflows. All three zones were introduced to improve the head calibration at specific areas within the model and as such, all of the sensitivity runs resulted in some variation in the head calibration statistics. In the case of the high-permeability sub-permafrost zone upgradient of MW16-01, increasing the hydraulic conductivity by a factor of ten from $1x10^{-6}$ m/s to $1x10^{-5}$ m/s improved the calibration. However, the predictions are not affected by an increase in this parameter (see Section 3.3.1 below), and the value was retained at the specified value, which is consistent with field data for permeable structures in the Project area (see Section 2.2.2).

3. Mine Model

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3.1 Model Setup

3.1.1 Model Boundary Conditions – End-of-Mine-Conditions

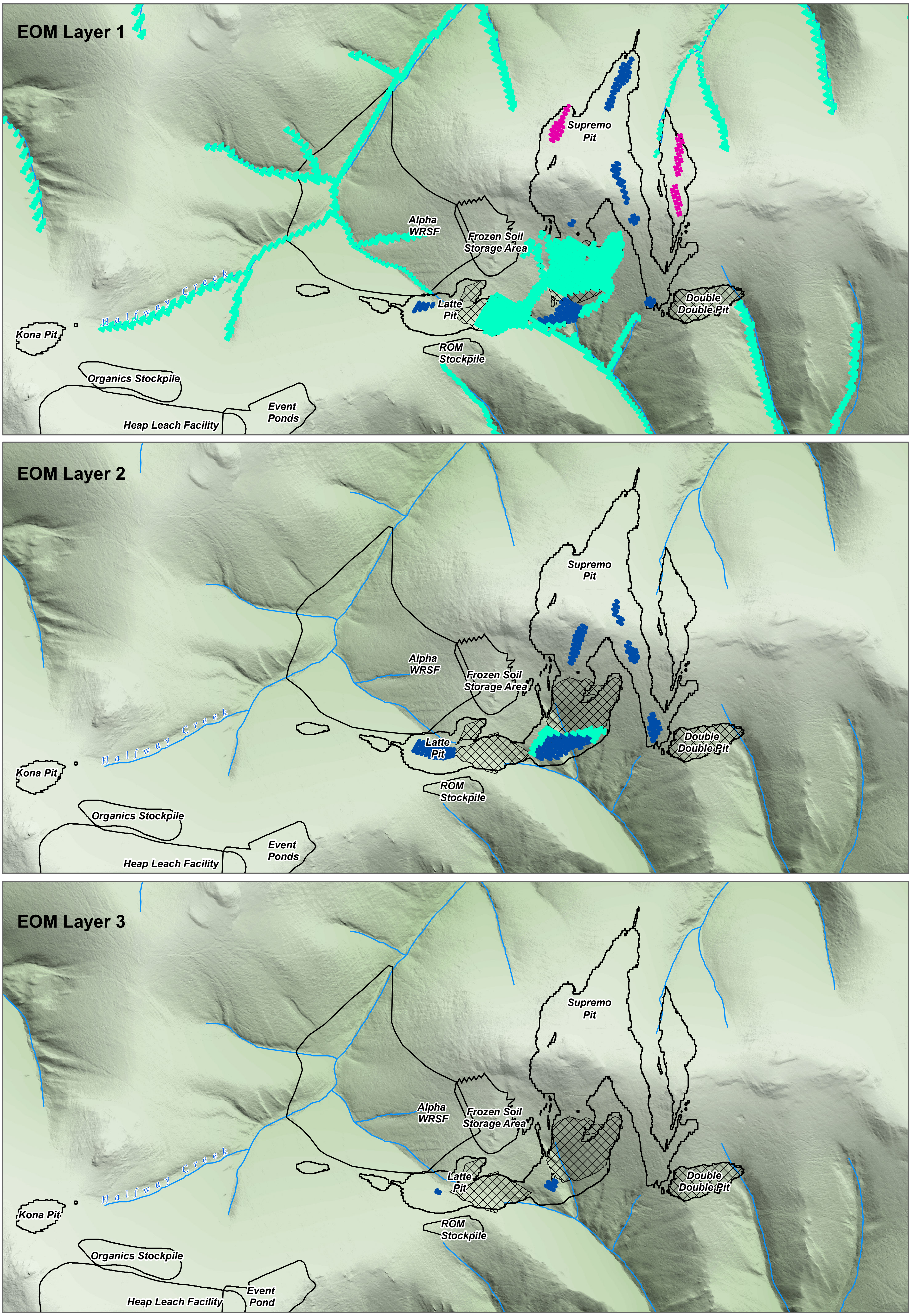
The configuration of the 2017 mine plan that is relevant to the groundwater model is presented in Figure 3-1. For the End-of-Mine (EOM) model, the majority of drain boundary conditions present within the footprint of the open pits were removed. The drain cells used to simulate the upper portions of Halfway Creek are retained. Within the open pit footprint, new MODFLOW drains were introduced to simulate potential seepage faces along the pit walls above a pit lake. Pit drain conductances were computed using the length and width of the cell containing the pit drain, a drain thickness of 1 m, and a drain hydraulic conductivity of $1x10^{-5}$ m/s. The location of these drains is shown in Figure 3-1.

The pit lakes were simulated with constant head and general head boundary cells. The pit lake elevations at EOM were based on the surface water balance model and are listed in Table 3-1. Pit lakes that are located on unfrozen ground—Supremo 1, Supremo 2, Supremo 4S—were treated as constant head boundaries. Pits whose bottom elevations intersect the simulated baseline water table—Supremo 4N, Latte—or the mounded water table below the pit—Supremo 3N—were also treated as constant head boundaries. Finally, pits located on permafrost with lake levels and pit bottom elevations at least 28 m above the pre-mine water table were treated as general head boundary cells, with the general head specified to be the pit lake elevation, and the general head thickness computed to equal the distance between the pit bottom elevation in the model and the water table. The hydraulic conductivity of permafrost, $6x10^{-10}$ m/s, was used to compute the general head conductance.

The treatment of the backfilled Kona and Double Double pits is the same as in the previous model (Lorax, 2016). The recharge on the Double Double pit was increased to 35% of the mean annual precipitation to simulate potential increases in recharge as a result of the backfilled waste rock in this pit, which is located on unfrozen ground. The recharge on the Kona backfilled pit and the Alpha WRSF was set to zero because these facilities are located mostly or wholly on permafrost, and the reduction in recharge increased the water quality impacts to surface water. Recharge on the Supremo-Latte in-pit backfill was also set to zero to be conservative with respect to water quality impacts.

Table 3-1:
EOM and Post-Closure Pit Lake Elevations

Pit Lake	Elevation at EOM (masl)	Elevation at Post-Closure (masl)	EOM Boundary Type
Supremo 1	942	942	Constant Head
Supremo 2	1061	1081	Constant Head
Supremo 3W	1176	1200	General Head
Supremo 3N	1050	1090	Constant Head
Supremo 4N	1083	1090	Constant Head
Supremo 4S	1013	1048	Constant Head
Supremo 5N	1140	1140	General Head
Supremo 5S	1165	1165	General Head
Latte	998	1040	Constant Head



LEGEND

- Constant Head
- Drain
- General Head
- Backfill
- Mine Infrastructure

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PROJECT:

Coffee Gold Hydrogeology

TITLE:

Pit Boundary Conditions at EOM

PROJECT #: A362-5 FIGURE: 3-1

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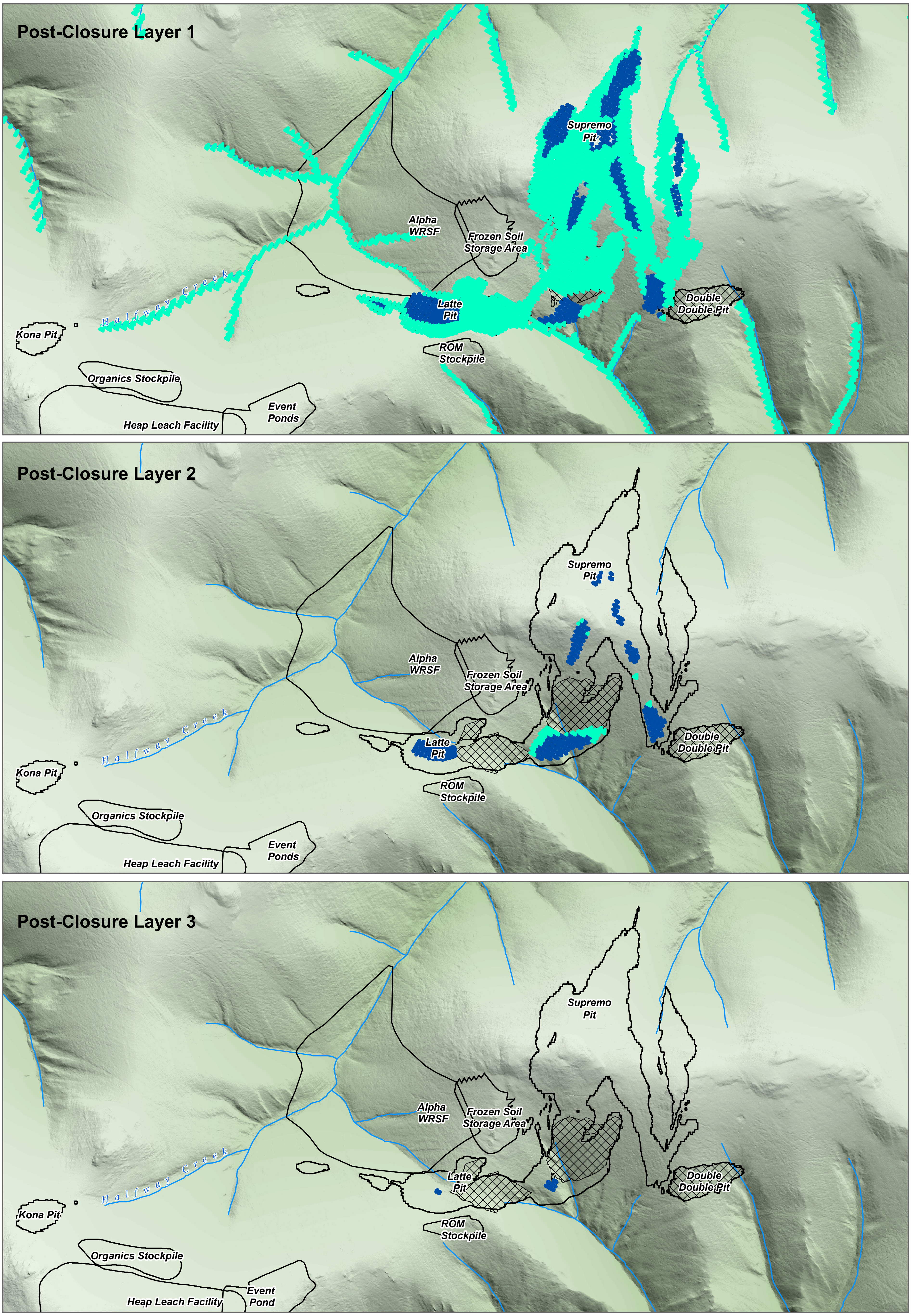
3.1.2 Model Boundary Conditions at Post-Closure

Figure 3-2 shows the drain, and constant head boundaries applied in the post-closure simulation. The boundary conditions differ from EOM because of the change in pit lake elevations, as summarized in Table 3-1. In addition, all pit lakes present on frozen ground—Supremo 3N, Supremo 3W, Supremo 5N and Supremo 5S—are assumed to form through taliks beneath them, putting them in direct contact with the underyling groundwater system. The model cells containing the constant head boundary conditions that simulate these post-closure talik lakes were assigned the hydraulic conductivity of shallow bedrock, except for the cells at the Supremo 5S pit lake, which were already assigned a hydraulic conductivity of 1×10^{-6} m/s in the calibration, since it is located in the high permeability zone around MW15-07 (see Section 2.2.2).



LEGEND

- Constant Head
- Drain
- General Head
- Backfill
- Mine Infrastructure

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PROJECT:

Coffee Gold Hydrogeology

TITLE:

Pit Boundary Conditions at Post-Closure

PROJECT #: A362-5

FIGURE: 3-2

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3.1.3 Hydraulic Conductivity

Hydraulic conductivity adjustments for backfilled waste rock (5x10^{-5} m/s) and mined out cells (2x10^{-4} m/s) were applied as described in Lorax (2016). Because of the different pit configuration, the specific locations of the waste rock and pit void cells are different from the previous calibration and are shown in Figure 3-3.

3.1.4 Recharge

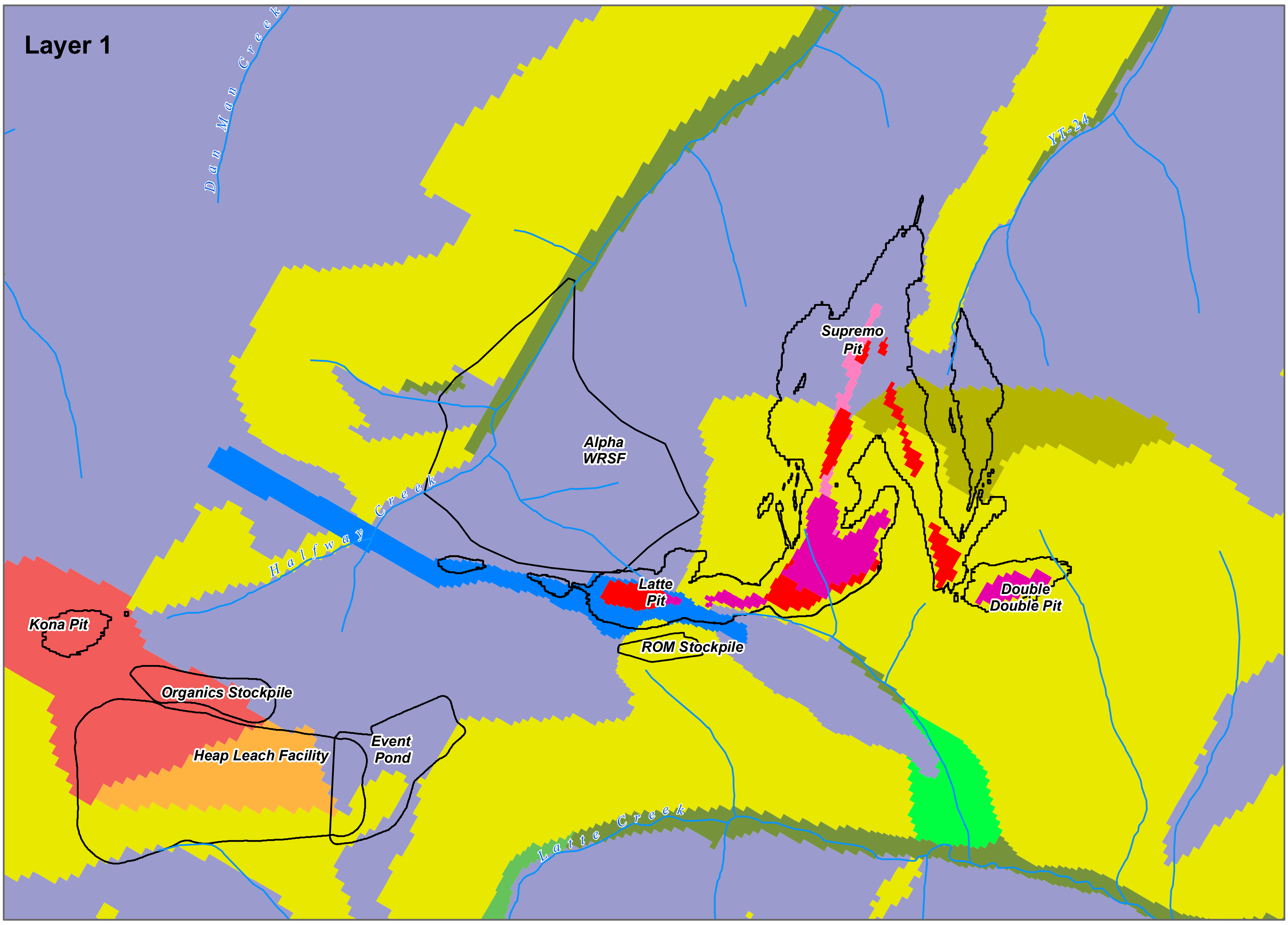
The methodology for assigning recharge rates in the predictive models is described in Lorax (2016) and shown in Figure 3-4 for the updated permafrost distribution and 2017 mine plan configuration.

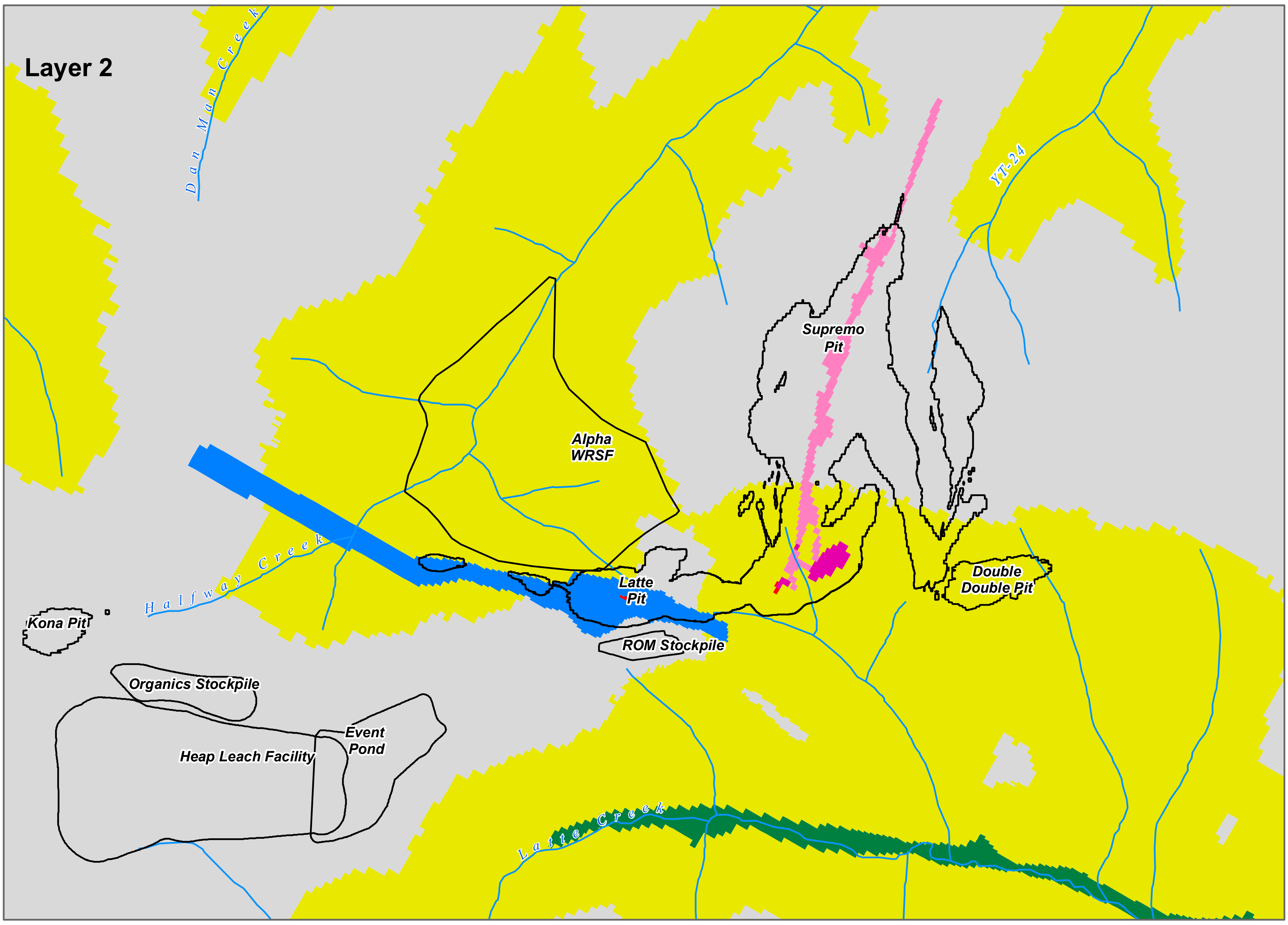
3.1.5 Particle Tracking

Particle tracking was simulated using MODPATH 5 as described in Lorax (2016).

3.1.6 Solver Settings

As in the pre-mine simulations, the head convergence criterion is 0.01 m. The flux convergence criterion was kept at 5 m^3/d (0.06 L/s), and the maximum number of outer iterations was increased to 600 from 400. Previously, the convergence criterion was relaxed for the predictive simulation (Lorax, 2016). All other parameters are set to the default values for a "complex" MODFLOW-NWT model. The solver parameters were changed from the "simple" settings used for the baseline model in order to improve the model-wide mass balance for the predictive runs. No obvious changes in the predicted heads or fluxes in the mine area were evident between the "simple" and "complex" settings. For particle tracking simulations, the inactive flag HDRY within MODFLOW-NWT was set to 1.





LEGEND

K (m/s)

- Alluvium (1.0E-05)
- Shallow Bedrock (1.3E-07)
- L1 Bedrock below PF (MW16-01) (1.0E-06)
- L1 Bedrock below PF (MW15-07) (1.0E-06)
- L1 Bedrock below PF (MW14-05) (2.6E-09)
- K Deep Bedrock > 100m Depth (2.6E-09)
- Colluvium (3.0E-05)
- T3 Structure (1.0E-06)
- Latte Structure (1.0E-06)
- All Creek hi K zones L1 (6.0E-06)
- N Fault (5.0E-06)
- L1 Upper Latte (4.0E-06)
- L2 Lower Latte (3.0E-05)
- IC Creek Fault (3.0E-05)
- Permafrost (6.0E-10)
- Pit Void (2.0E-04)
- Backfilled Waste Rock (5.0E-05)

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LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

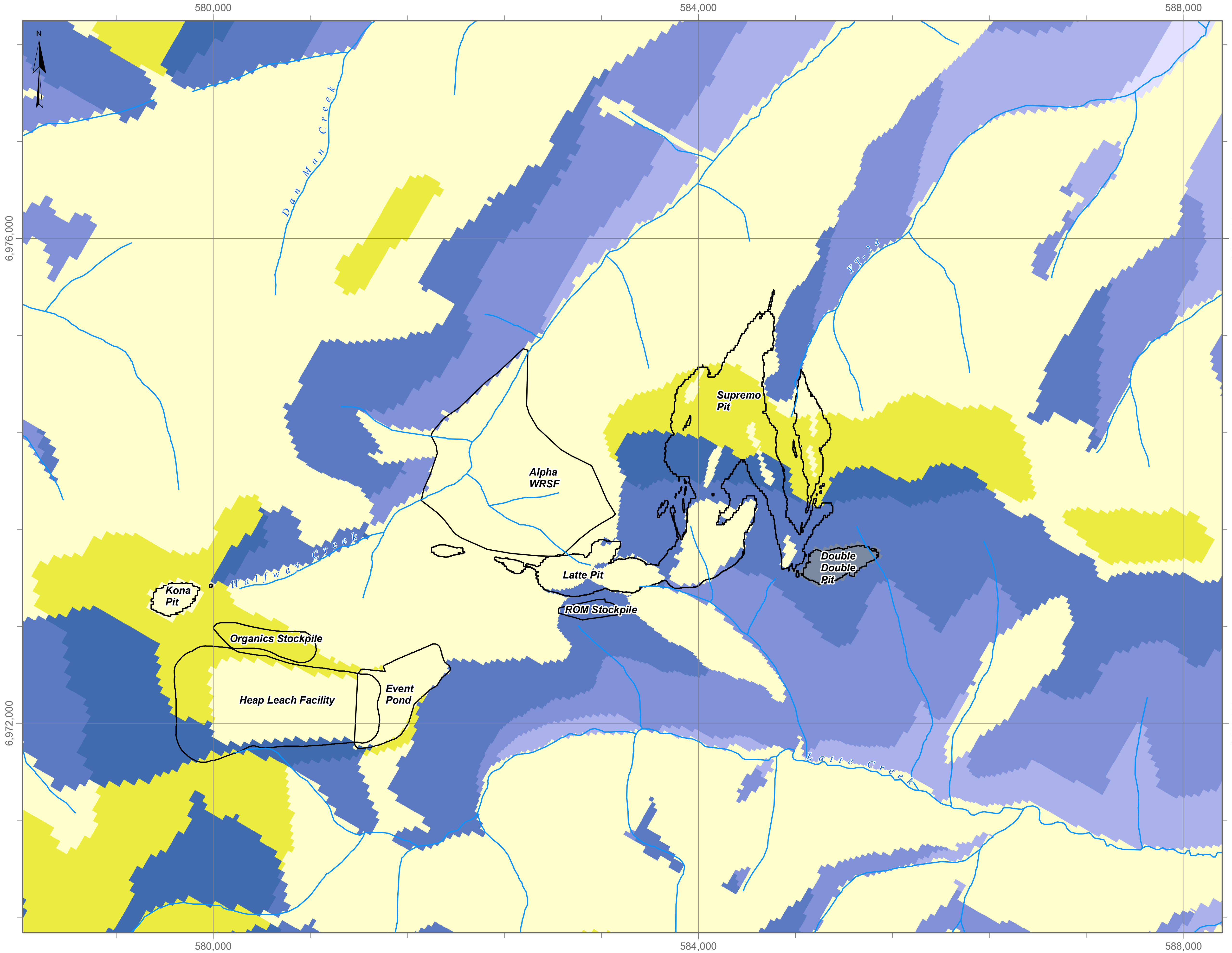
TITLE:

Changes to Hydraulic Conductivity in Layers 1 and 2 for EOM and Post-Closure

PROJECT #: A362-5

FIGURE: 3-3

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-3_Conductivity Changes for EOM and Closure_20170327.mxd



LEGEND

Recharge Zones

- 400-600 m Elevation No Permafrost
- 600-800 m Elevation No Permafrost
- 800-1000 m Elevation No Permafrost
- 1000-1200 m Elevation No Permafrost
- 1200-1400 m Elevation No Permafrost
- Zero Recharge
- 1200-1400 m Elevation with Permafrost
- Double Double Backfill

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PROJECT:

Coffee Gold Hydrogeology

TITLE:

EOM and Post-Closure Recharge

PROJECT #:	*FIGURE:*
A362-5	3-4

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3.2 Model Predictions

3.2.1 End of Mine

Figure 3-5 shows the water table simulated at the end of operations, and Figure 3-6 shows the change in head relative to the baseline calibration model. The steady state EOM model predicts that the water table will rise beneath the Latte pit, the Supremo 3N pit, the Supremo 3W pit, the Supremo 5N pit, the northern part of the Supremo 4N pit, the northern part of the Supremo 2 pit, and the southern part of the Supremo 4S pit; at these locations, the pit lake elevation at EOM is higher than the pre-mine water table elevation. The water table also rises beneath the Double Double backfilled pit, where the simulated recharge rate was increased from 65.5 mm/y to 151 mm/y.

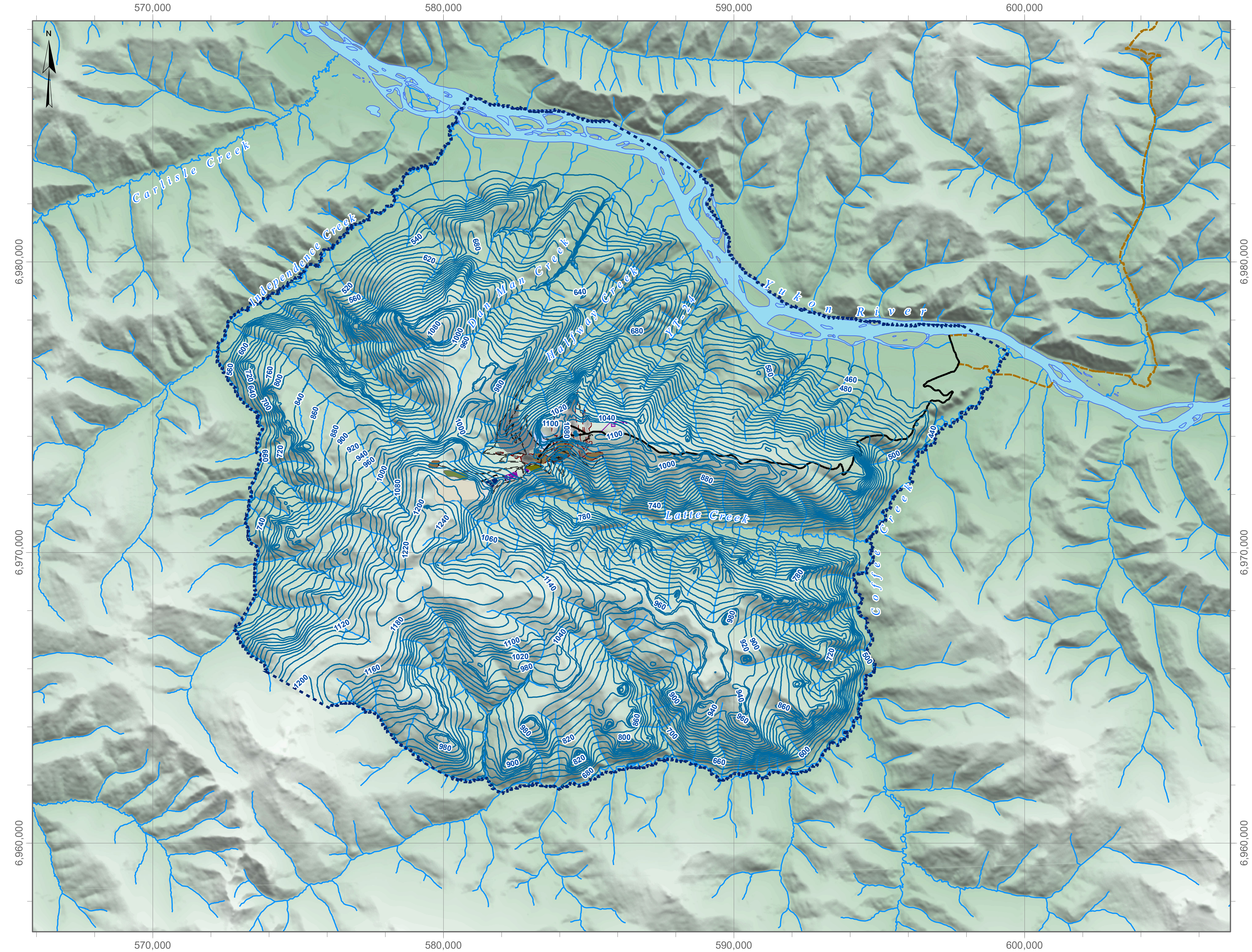
The water table is predicted to drop beneath the backfilled Kona pit and the HLF and event ponds because the recharge rate was reduced to zero at these locations. Beneath the HLF, the water table is predicted to drop as much as 50 m. Beneath the Supremo 1 pit lake elevation, the maximum drop in head is approximately 25 m. The water table is also predicted to drop below the bottom of the southern portion of the Supremo 2 pit lake. For the most part, the zone of head change due to the mine facilities is constrained by Halfway Creek in the northwest and Latte Creek in the south.

In spite of the relatively large areal extent of water table decline due to the reduction in recharge, at the heap leach and Kona pit areas, the majority of catchments are not predicted to experience a significant change in baseflow, as discussed below.

The model-wide mass balance is shown in Table 3-2. The recharge rate has decreased relative to pre-mine conditions due to the reduction in recharge on pit lakes, the heap leach the WRSF, and the backfilled portions of the pits. The inflow and outflow via constant heads has increased, due to the introduction of specified heads at pit lakes.

Table 3-2:
Model-Wide MassBalance, EOM

	Inflow (L/s)	Outflow (L/s)	Discrepancy (L/s)	Percent Discrepancy
Constant Head	195.2	243.4		
Recharge	201.0			
General Head	0.0	0.0		
Drains		152.9		
Total	396.3	396.3	0.00	0.00%



LEGEND

- EOM Water Table Contours (20m)
- Model Domain Boundary
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:125,000

0 2 4 Km

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LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Water Table at End of Mine

PROJECT #:	*FIGURE:*
A362-5	3-5

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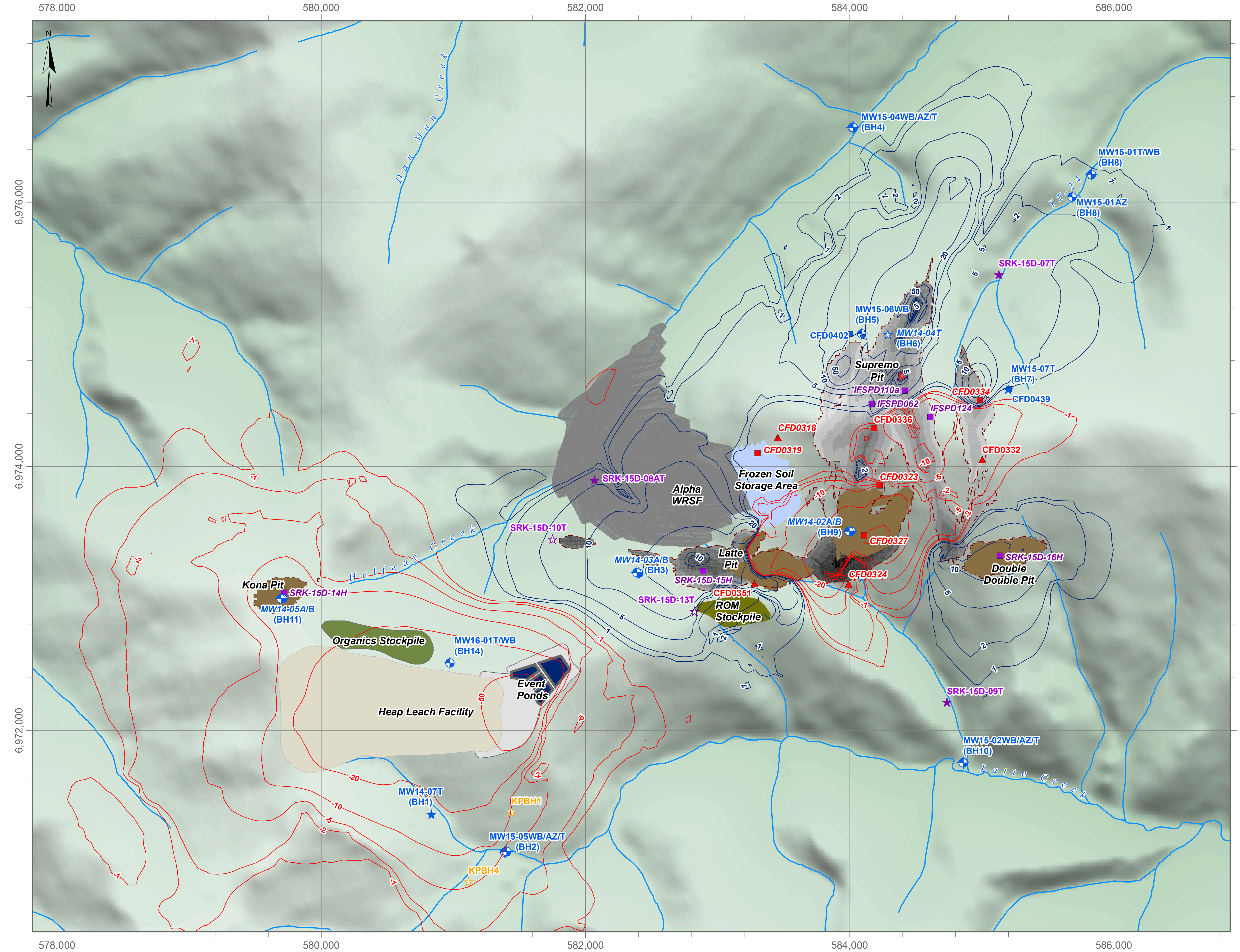

LEGEND

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

- Monitoring Well
- 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

Proposed Infrastructure

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

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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CLIENT:

GOLDCORP

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Change in Water Table Elevation from Pre-Mining Conditions to End of Mine

PROJECT #: A362-5

FIGURE: 3-6

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-6_Change in WT EOM_20170327.mxd

Table 3-3 lists the steady state groundwater inflow rates to the pit lakes. The seepage rates were determined with a combination of the model water balance output and pathline trajectories. Only groundwater fluxes associated with constant head or general head boundary cells are included in the seepage rate estimates, while pit lake inflows also include groundwater flow that reports to the drains along the pit walls. The Supremo 1 pit lake is predicted to receive a net groundwater inflow of 1.23 L/s. As noted in the table, 0.50 L/s of the groundwater inflow that enters the Supremo 1 pit comes from the Supremo 2 pit lake through the T3 Structure. An additional 1.38 L/s of groundwater not associated with the Supremo 2 pit flows into the Supremo 1 pit lake. At the downgradient end of the Supremo 1 pit lake, 0.32 L/s pit lake water is predicted to seep into groundwater and discharge to Latte Creek, and 0.33 L/s pit lake water reports to the CC-1.0 tributary to Latte Creek.

At EOM, the Supremo 2 pit lake is predicted to have a lake elevation of 1061 masl (Table 3-1). Under steady state groundwater flow conditions, this lake is net "losing" to groundwater. Groundwater inflow into the pit is predicted by the model to be 0.21 L/s. Groundwater outflow is predicted to be 0.53 L/s, for a net groundwater outflow of 0.32 L/s. Of the groundwater recharged by the Supremo 2 pit lake, 0.50 L/s discharges to the Supremo 1 pit lake, and the majority of the balance discharges to Halfway Creek. A trickle (<0.01 L/s) is predicted to report to Latte Creek. The Latte pit lake and recharge on its pit walls are predicted to contribute a net flow of 1.15 L/s to groundwater. Of this, 0.85 L/s will discharge to Halfway Creek, 0.21 L/s will discharge to Latte Creek, and 0.09 L/s is predicted to flow into the Supremo 1 pit lake. The Supremo 4S is also a net losing pit lake, with 0.20 L/s of groundwater inflow and 0.47 L/s groundwater loss to the Latte Creek catchment. The Supremo 4N pit lake is predicted to gain 0.11 L/s of groundwater and lose 0.02 L/s to the Halfway Creek catchment; this lake therefore is predicted to have a net groundwater inflow at EOM.

A negligible amount of less than 0.01 L/s seepage is predicted for the three pit lakes that are treated as general head boundaries: Supremo 3W, Supremo 5S and Supremo 5N. The Supremo 3W pit lake, due to its proximity to MW14-04T, where 168 m of permafrost is present and assumed to restrict recharge from the pit lake to groundwater, has a simulated water table that is at least 50 m below the base of the pit. The water level below the Supremo 5N pit is predicted to be at least 61 m below the base of the pit. At Supremo 5N, the minimum distance between the pit base and the water table is 29 m.

Recharge through the Double Double backfill is predicted to discharge to Latte Creek.

Table 3-3:
Groundwater Discharge to and from Pit Lakes, EOM

Pit Lake	Groundwater Flow (L/s)[1]						
	Net Groundwater Inflow	**Groundwater Flow into Pit**	**Seepage to Latte Creek**	**Seepage to Halfway Creek**	**Seepage to Latte Tributary**	**Seepage to YT-24**	**Seepage to Supremo 1**
Supremo 1	1.23	1.88	-0.32	-	-0.33	-	-
Supremo 2	-0.32	0.21	-0.00	-0.03	-	-	-0.50
Latte	-1.15	-	-0.21	-0.85	-	-	-0.09
Supremo 3W	-0.01	-	-	-0.01	-	-	-
Supremo 3N	-0.24	-	-	-0.24	-	-	-
Supremo 4N	0.08	0.11	-0.00	-0.02	-	-	-0.00
Supremo 4S	-0.27	0.20	-0.47	-	-	-	-
Supremo 5S	-0.01	-	-	-0.01	-	-	-
Supremo 5N	-0.01	-	-0.00	-0.00	-0.00	-0.01	-
Double Double[2]	-0.76		-0.76				
Total	**-0.70**	**2.40**	**-1.76**	**-1.16**	**-0.33**	**-0.01**	**-0.59**

Notes: [1]Negative values indicate flow out of pit lake.
[2]Double Double is a backfilled pit with a specified recharge rate of 151 mm/y.

Table 3-4 lists the predicted groundwater discharge rates to area creeks at EOM. The model predicts slight increases in groundwater baseflows to Halfway Creek and YT-24, due to the presence of several pit lake elevations above current groundwater elevations. The groundwater baseflow directly to the Latte Creek stream channel is predicted to drop due to the reduced water table in the Supremo 1 pit area (see Figure 3-5). However, when the 1.23 L/s of groundwater-derived pit lake outflow is added to the groundwater-derived Latte Creek streamflow, the baseflow to Latte Creek is also minimal, and a net 19% increase in baseflow to the CC-1.0 tributary is predicted, and a 0.2% decrease in baseflow to Latte Creek at CC-1.5.

The reduction in recharge at the heap leach area is predicted to reduce baseflows to the CC-6.0 tributary to Latte Creek by 2.2% and baseflows to the IC-2.5 and IC-3.5 tributaries to Independence Creek by 3.1% and 0.1%, respectively.

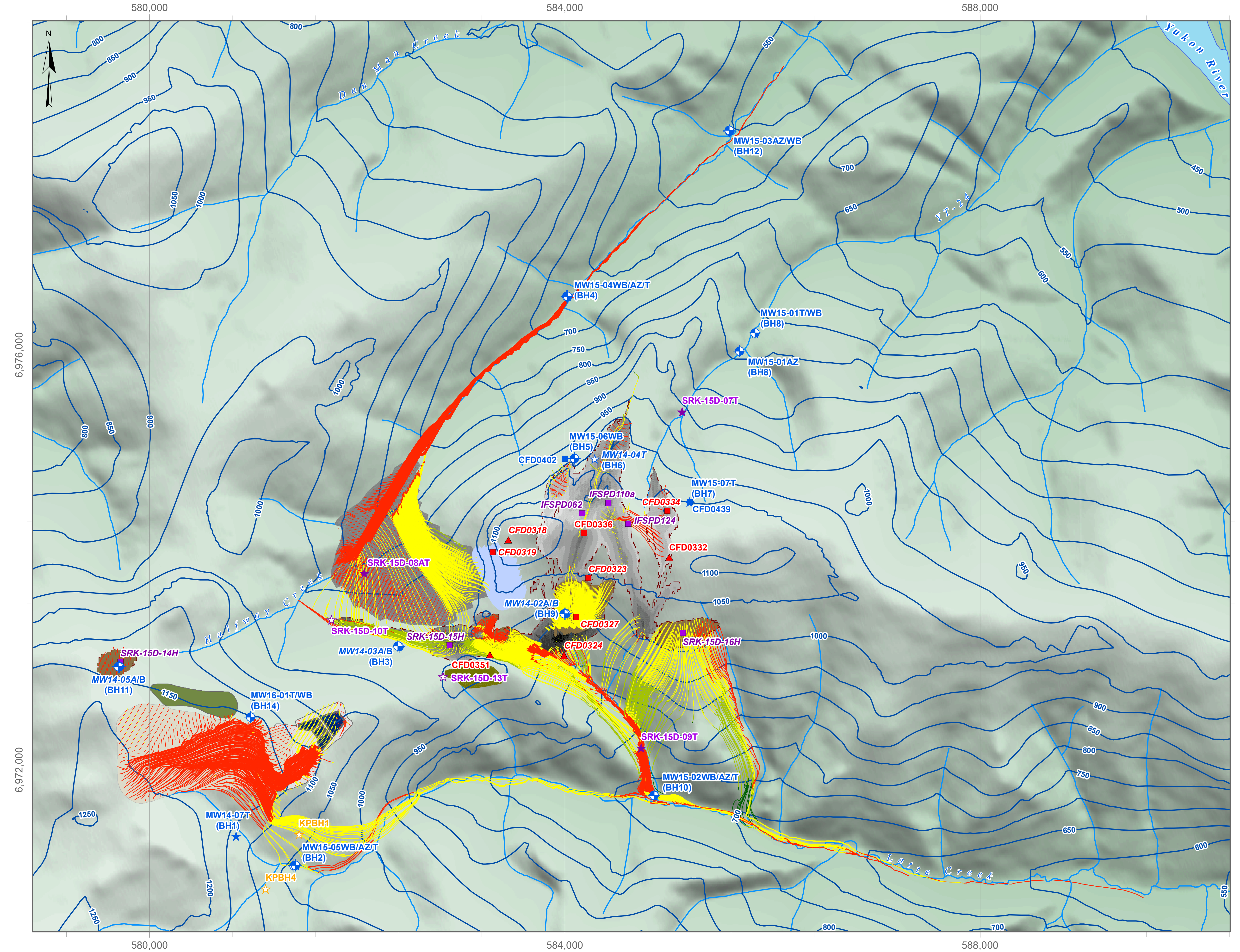
Table 3-4:
Simulated Groundwater Discharge to Surface Water, EOM

	EOM (L/s)	Pre-Mine (L/s)	Change (%)
Mine Area Catchment			
IC-2.5	4.6	4.7	-3.1
IC-3.0	9.8	9.8	-0.1
HC-2.5	8.4	8.2	2.7
HC-5.0	18	17	1.4
ML-1.0	7.4	7.3	1.0
CC-6.0	4.3	4.4	-2.2
CC-1.0*	1.2	2.1	-40
CC-1.5**	12	14	-9.1
CC-3.5***	47	48	-2.2
Other Catchments at Model Edges			
IC-1.5 (SW Boundary)	22	22	-0.0
IC-4.5 (W Boundary)	42	42	-0.4

Notes: *In addition to 1.2 L/s of groundwater discharge to the CC-1.0 stream channel, an additional 1.2 L/s of CC-1.0 streamflow will derive from Supremo 1 pit lake outflow associated with groundwater (see Table 3-3), for a groundwater discharge rate of 2.5 L/s, or a 19% increase in baseflow.
** With the addition of pit lake spill rates from groundwater, the EOM groundwater discharge to CC-1.5 is 14 L/s, corresponding to a --0.2% change in baseflow.
*** With the addition of pit lake spill rates from groundwater, the EOM groundwater discharge to CC-3.5 is 48 L/s, corresponding to a 0.3% change in baseflow.

Figure 3-7 shows particle tracks for a travel time of 50 years from mine facilities using the EOM steady state head distribution. A summary of early travel times to surface water receptors is presented in Table 3-5. Note that the reported travel times do not take into account the time required for seepage to travel through frozen and/or unsaturated ground between the heap facility and the WRSF. The largest volume of seepage inflow, 1.16 L/s, is predicted to discharge to Halfway Creek (see Table 3-3). From the particle tracking results on the steady state flow model, pathlines are predicted to arrive at Halfway Creek from the Latte pit in approximately seven (7) years. Approximately 1.0 L/s of seepage from the Supremo 1 pit is predicted to report to Latte Creek in around eight (8) years. The EOM model predicts 0.01 L/s of pit lake seepage losses to YT-24 from Supremo 5N; this seepage is predicted to discharge to YT-24 after 1000 years.

Figure 3-7 also shows the particle tracks from the Alpha WRSF, the Supremo-Latte pit backfill, the Kona backfill, and Heap Leach and event ponds. These facilities are treated in the groundwater model as zero-recharge features. Therefore, the pathlines presented are to demonstrate the likely discharge points for groundwater originating from these facilities in the event that the assumption of zero recharge is not achieved in the future. Groundwater draining the Alpha WRSF footprint is predicted to discharge to Halfway Creek. The majority of groundwater draining the heap leach footprint is predicted to report to Halfway Creek. Groundwater draining the southern edge of the heap leach is predicted to report to Latte Creek. Seepage from the Supremo pit backfill is expected to discharge to the Supremo 1 pit lake. The portion of backfill located between the Latte and Supremo 1 pits show pathlines both to Latte Creek and Halfway Creek, depending on where the seepage originates. Groundwater draining the Kona pit footprint area is predicted to report to IC-3.0. Additional simulations will be required if significantly higher recharge is anticipated from any of these facilities.



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)
- Particle Trace in Model Layer 1
- Particle Trace in Model Layer 2
- Particle Trace in Model Layer 3
- Particle Trace in Model Layer 4
- EOM Water Table Contours (50m)

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:35,000

0 400 800 Meters

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LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE: 50-Year Travel Time Particle Traces From Proposed Facilities with End of Mine Head Solution

PROJECT #:	*FIGURE:*
A362-5	3-7

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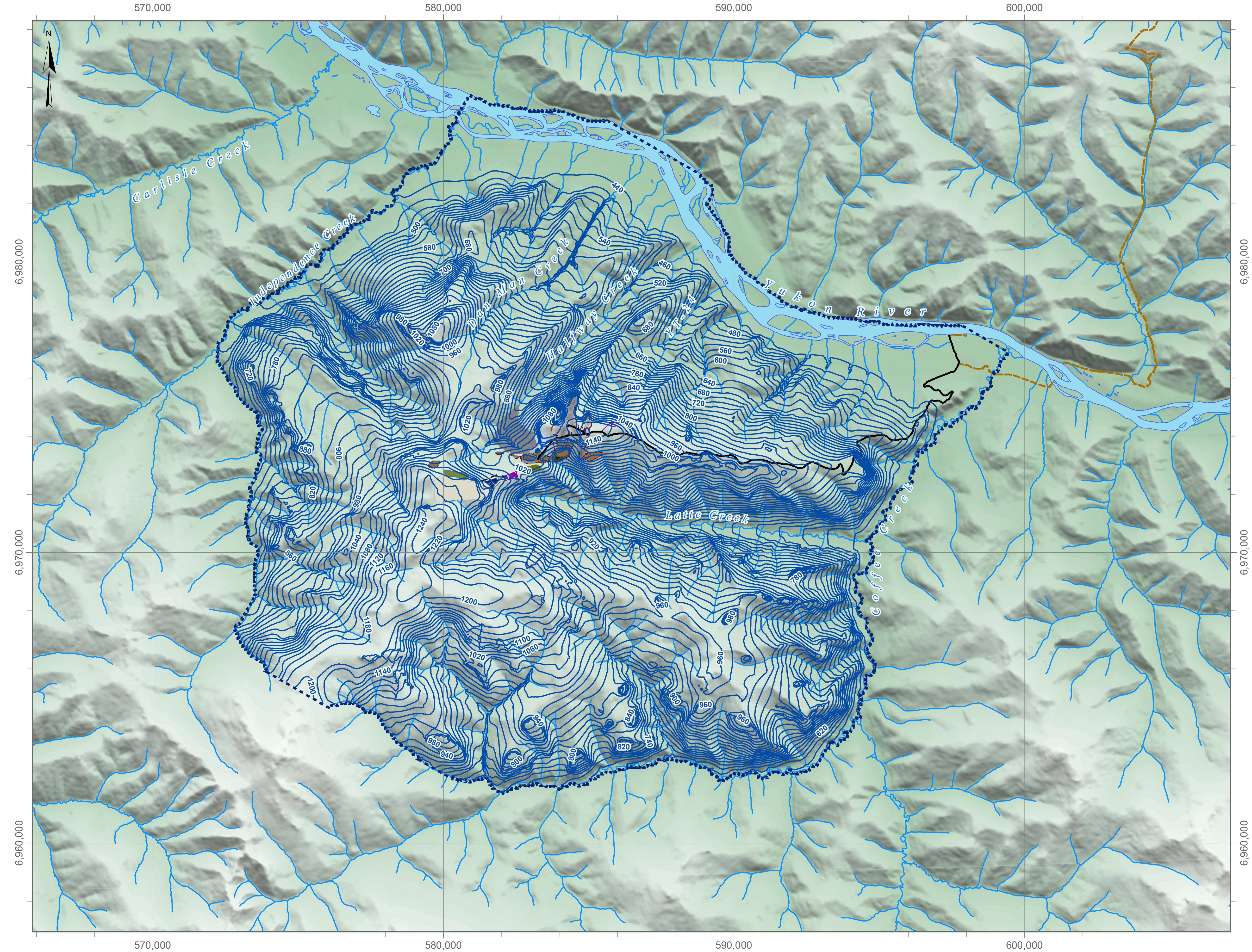
Table 3-5:
Travel Time Estimate to Mine-Area Streams, EOM Water Table Configuration

Source of Pathlines	Travel Time (years) of First Pathline to Surface Water Receptor				
	Latte Creek tributary (E of CC-1.0)	Latte Creek	Halfway Creek	YT-24	IC-3.0
Supremo 1	<2	8			
Supremo 2		>200	>200		
Latte		23	7		
Supremo 3W			10		
Supremo 3N			6.5		
Supremo 4N		>200	>200		
Supremo 4S		12			
Supremo 5S			>200		
Supremo 5N		>200	>200	>200	

3.2.2 Post-Closure

Figure 3-8 shows the water table simulated at Post-Closure, and Figure 3-9 shows the change in head relative to the pre-mine calibration model. The differences between Figure 3-6 and Figure 3-9 are due to the change in pit lake elevation at closure compared to EOM (see Table 3-1). The magnitude of head increase around the Supremo pits and the Latte pit is evident. In the case of the Latte Pit, the increase in head extends as far as the Kona pit. The water table beneath the heap leach area remains unchanged.

The model-wide mass balance is shown in Table 3-6. The inflow and outflow via constant heads has increased relative to the EOM, due to an increase in the specified heads at some pit lakes. There is a slight reduction in recharge because the footprint of the pit lakes has increased, and no recharge is applied to the constant head cells used to simulate the pit lakes.



LEGEND

- Post-Closure Water Table Contours (20m)
- Model Domain Boundary
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

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LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Water Table at Post-Closure

PROJECT #: A362-5

FIGURE: 3-8

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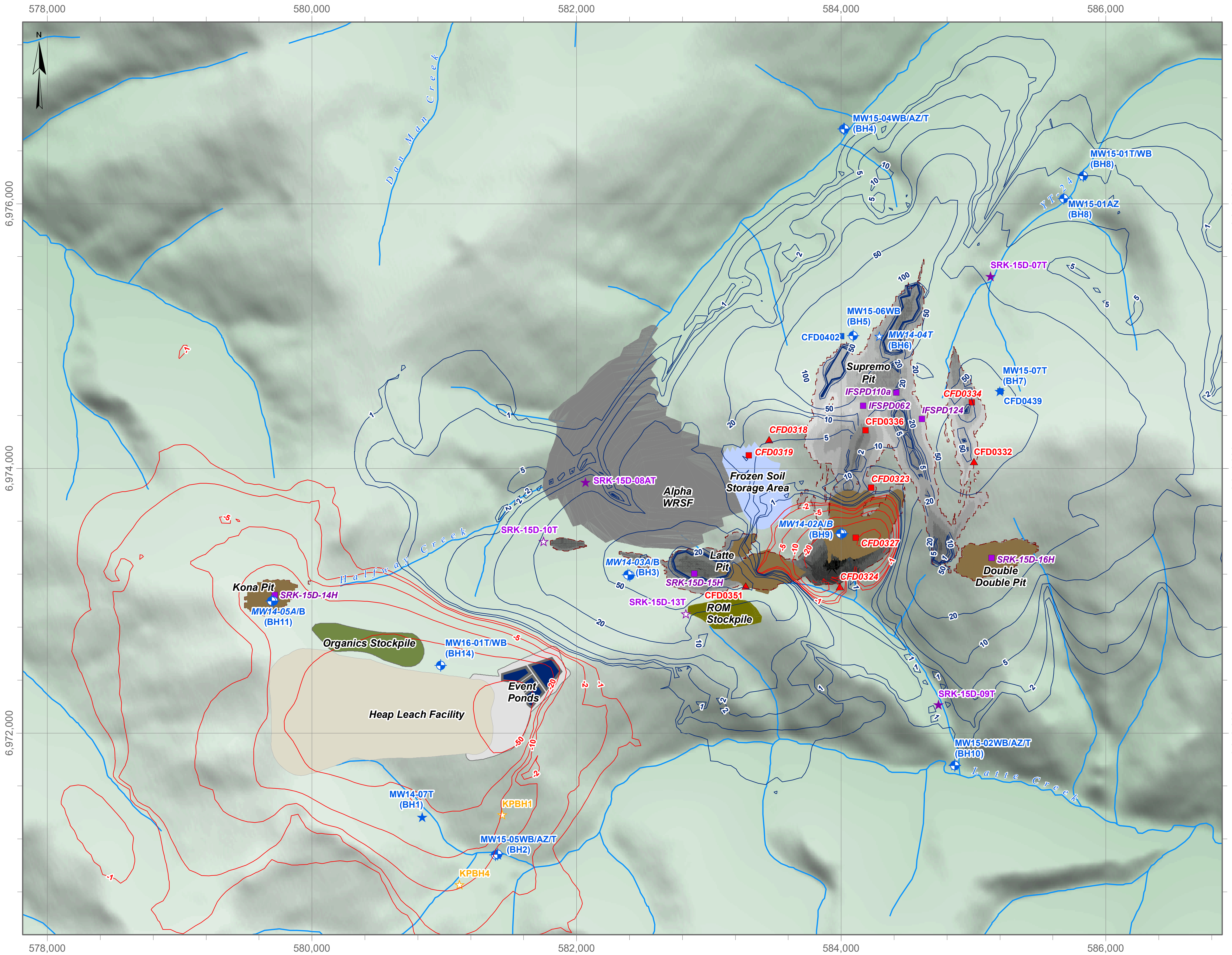

LEGEND

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

- Monitoring Well
- 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

Proposed Infrastructure

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

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:27,500

0 400 800 Meters

DATE SAVED:	Mar 29, 2017
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REVIEWED:	JS/LF
VERSION:	1

CLIENT:

GOLDCORP

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Change in Water Table Elevation from Baseline Conditions to Post-Closure

PROJECT #: A362-5

FIGURE: 3-9

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Table 3-6:
Model-Wide MassBalance, Post-Closure

	Inflow (L/s)	Outflow (L/s)	Discrepancy (L/s)	Percent Discrepancy
Constant Head	206.7	249.0		
Recharge	200.9			
Drains		158.6		
Total	407.6	407.6	-0.08	-0.02%

Table 3-7 lists the steady state groundwater inflow rates to the pit lakes in the post-closure simulation. The net groundwater inflow to the Supremo 1 pit lake is predicted to increase to 3.18 L/s from 1.23 L/s at EOM. The total groundwater inflow to the pit is 3.68 L/s, 1.10 L/s of which derives from the Supremo 2 pit lake, and 0.77 L/s of which comes from the Latte pit lake. At the downgradient end of the Supremo 1 pit lake, 0.19 L/s is predicted to discharge to Latte Creek, and 0.30 L/s is predicted to discharge to the CC-1.0 tributary of Latte Creek. The reason for the increased inflow to the pit lake compared to the EOM simulation is largely a function of the rise in the overall water table resulting from increased pit lake elevations at the other pits. The increase in pit lake elevation from 1061 masl at EOM to 1081 masl in the post-closure period results in a higher flow out of the Supremo 2 pit lake. The gradient is also predicted to change, and in the post-closure run, no pathlines are predicted to report to Halfway Creek from the Supremo 2 pit lake; this is primarily due to the increase in head in the Supremo 3W and 3N pit lakes, located between Supremo 2 and Halfway Creek.

The flows out of Latte Pit are predicted to increase due to the increase in the lake elevation to 1040 masl in the post-closure period from 998 masl at EOM. The surface water receptors of the seepage loss from Latte pit remain the same as at EOM, namely the majority reports to Halfway Creek, with smaller flows to Latte Creek and the CC-1.0 tributary to Latte Creek.

The seepage loss from Supremo 4S increases from EOM to closure from 0.47 L/s to 1.67 L/s. The increase in seepage loss is partly due to the 1.17 L/s of inflow to Supremo 4S from the talik-lake combination at Supremo 5S (see Table 3-8). The seepage is predicted to report to Latte Creek, as before, with a minor flow component to the Supremo 1 pit lake. The seepage loss from Supremo 3N increases from 0.24 L/s at EOM to 0.63 L/s in the post-closure period. With the higher pit lake level at Supremo 3N, some of the seepage, 0.11 L/s, is predicted to report to YT-24.

The seepage losses from Supremo 3W increases to 0.29 L/s from 0.01 L/s at EOM because of the simulated talik below this pit lake. Although the pit lake is treated as a talik with bedrock beneath it assigned the hydraulic conductivity of Shallow Bedrock, the Supremo 3W pit lake talik is surrounded by permafrost, and the zone of influence of the groundwater mound in the talik is limited.

Table 3-7:
Groundwater Discharge to Pit and from Lakes, Post-Closure

Pit Lake	Groundwater Flow (L/s)					
	Net Groundwater Inflow	Groundwater Flow into Pit	Seepage to Latte Creek	Seepage to Halfway Creek	Seepage to YT-24	Seepage to Latte Tributary
Supremo 1	3.18	3.68	-0.19	-	-	-0.30
Supremo 2	-0.65	0.45	-0.00	-	-	-
Latte	-3.80	0.00	-0.71	-2.31	-	-0.00
Supremo 3W	-0.29	-	-	-0.28	-	-
Supremo 3N	-0.59	0.40	-	-0.43	-0.11	-
Supremo 4N	2.35	2.50	-0.00	-0.01	-0.00	-
Supremo 4S	-0.84	0.93	-1.67	-	-	-
Supremo 5S	-6.24	-	-0.37		-0.33	
Supremo 5N	1.80	1.85	-	-	-0.06	
Double Double[2]	-0.76		-0.76			
Total	**-5.08**	**9.81**	**-3.70**	**-3.03**	**-0.50**	**-0.31**

Notes: [1]Negative values indicate flow out of pit lake.
[2]Double Double is a backfilled pit with a specified recharge rate of 151 mm/y.

The seepage loss at Supremo 5S is predicted to increase significantly from 0.01 L/s at EOM to 6.2 L/s in the post-closure period due to the creation of a talik beneath this pit lake. In addition, the Supremo 5S pit lake is located in an area of high hydraulic conductivity (see Section 2.2.2), and the hydraulic conductivity associated with this talik is therefore higher than the taliks under the other Supremo pit lakes that will be on permafrost. In addition to the 0.37 L/s predicted to flow from the Supremo 5S into groundwater to ultimately discharge to Latte Creek, and the 0.33 L/s predicted to discharge to YT-24, a far larger flow rate is predicted to flow to other pit lakes with lower lake elevations, as shown in Table 3-8. More than 2 L/s is predicted to flow from the Supremo 5S pit lake to each of the

Supremo 4N and Supremo 5S pit lakes, and another 1.17 L/s is predicted to discharge to the Supremo 4S pit lake.

The increase in groundwater discharge to Supremo 4N and Supremo 5S results in these two pit lakes becoming net inflow lakes. The seepage loss from Supremo 4N to creek discharge zones decreases from 0.02 L/s at EOM to 0.01 L/s in the post-closure period. The Supremo 4N pit lake is predicted to lose some seepage to the Supremo 1 and Supremo 2 pit lakes in the post-closure period (see Table 3-8).

Supremo 5N is also predicted to be a net-groundwater-inflow pit lake. In the post-closure period, 0.06 L/s of pit lake water from Supremo 5N is predicted to flow via groundwater to the YT-24 catchment.

Table 3-8:
Groundwater Discharge to Between Pit Lakes, Post-Closure

From	Groundwater Flow (L/s) to					
	Supremo 1	**Supremo 2**	**Supremo 3N**	**Supremo 4N**	**Supremo 4S**	**Supremo 5S**
Supremo 2	1.10	-	-	-	-	-
Latte	0.77	-	-	-	-	-
Supremo 3W	-	0.01	0.00		-	-
Supremo 3N	-	0.09		-	-	-
Supremo 4N	0.06	0.08		-	-	-
Supremo 4S	0.10	-	-	-	-	-
Supremo 5S	-	-	-	2.33	1.17	2.04
Supremo 1	No Flow from Supremo 1 to other pit lakes					
Supremo 5N	No Flow from Supremo 5N to other pit lakes					

Table 3-9 lists the predicted groundwater discharge rates to area creeks after closure. As for the EOM condition, changes to the baseflow of less than or equal to 3% are predicted for IC-2.5, IC-3.0 and CC-6.0. Baseflows to Latte Creek are predicted to decline due to the reduced water table around the Supremo 1 pit. When the groundwater-derived pit lake outflow is included, the groundwater-derived Latte Creek discharge is predicted to increase, as shown in the table. The primary difference in groundwater baseflows for EOM and post-closure occur at Halfway Creek, where the 1040 m Latte pit lake results in a predicted increase in baseflows to Halfway Creek of 22% and 11% at HC-2.5 and HC-5.0, respectively.

Table 3-9:
Simulated Groundwater Discharge to Surface Water, Post-Closure

	Post-Closure (L/s)	Pre-Mine (L/s)	Change (%)
Mine Area Catchment			
IC-2.5	4.6	4.7	-3.0
IC-3.0	9.8	9.8	-0.1
HC-2.5	10	8.2	22
HC-5.0	19	17	11
YT-24	7.6	7.3	4.5
CC-6.0	4.4	4.4	-2.1
CC-1.0*	1.9	2.1	-5.5
CC-1.5	14	14	1.3
CC-3.5	50	48	2.8
Other Catchments at Model Edges			
IC-1.5 (SW Boundary)	22	22	0.0
IC-4.5 (W Boundary)	42	42	-0.3

Notes: *In addition to 1.9 L/s of groundwater discharge to the CC-1.0 stream channel, an additional 3.2 L/s of CC-1.0 streamflow will derive from Supremo 1 pit lake outflow associated with groundwater (see Table 3-7), for a groundwater discharge rate of 5.1 L/s, or a 150% increase in baseflow.
** With the addition of pit lake spill rates from groundwater, the EOM groundwater discharge to CC-1.5 is 17 L/s, corresponding to an 25% increase in baseflow.
*** With the addition of pit lake spill rates from groundwater, the EOM groundwater discharge to CC-3.5 is 53 L/s, corresponding to a 9.4% increase in baseflow

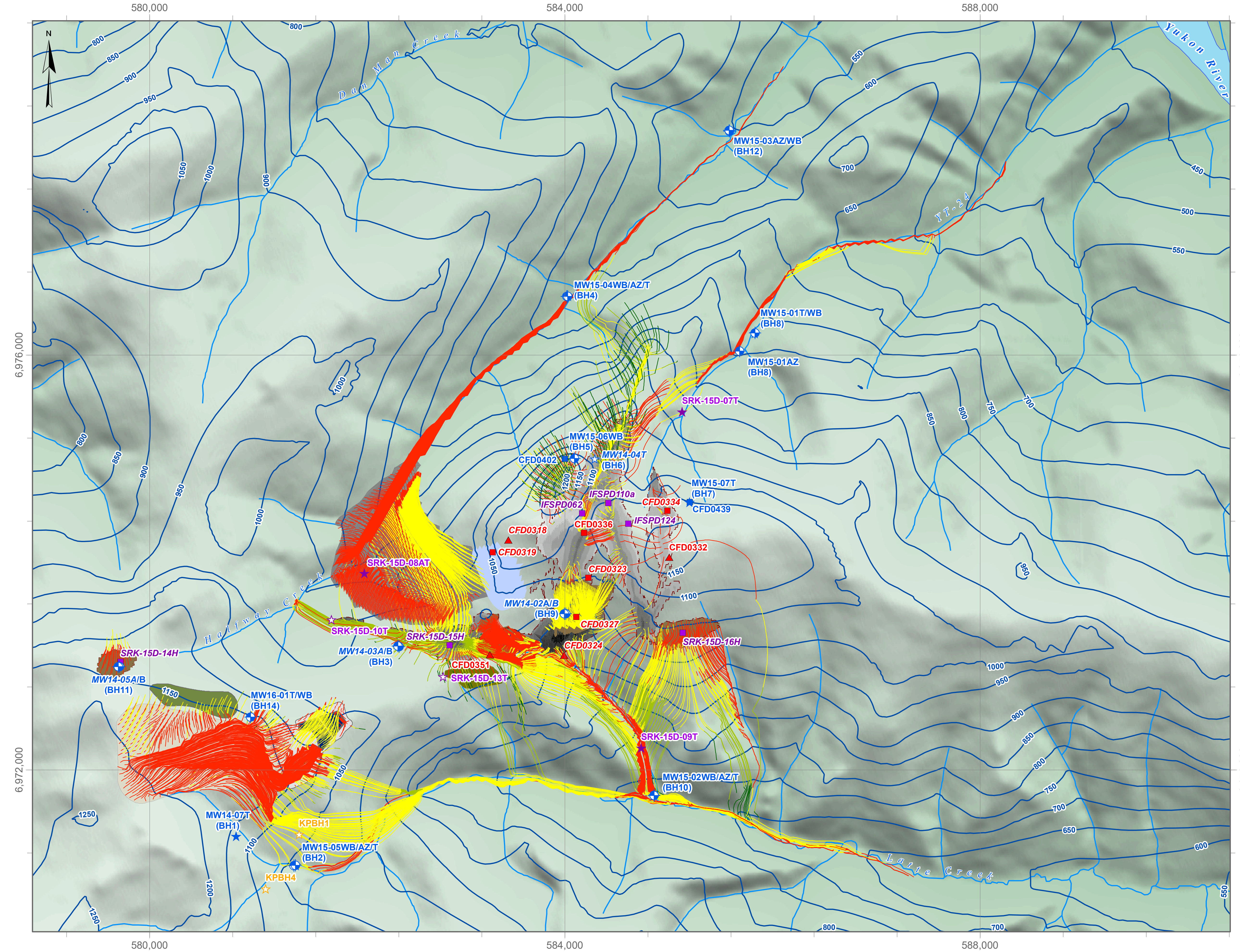
Figure 3-10 shows particle tracks for a travel time of 200 years from mine facilities using the post-closure steady state head distribution. A summary of leading-particle travel times to surface water receptors is presented in Table 3-10. At closure, Latte Creek and Halfway Creek are both expected to receive approximately 3 L/s of seepage from the pit lakes. Latte Creek is predicted to receive an additional 0.8 L/s from recharge through the backfilled Double Double pit. Approximately 0.50 L/s of seepage is predicted to report to YT-24.

Like Figure 3-7, Figure 3-10 shows the particle tracks from zero-recharge mine facilities. Groundwater draining the Alpha WRSF is predicted to discharge to Halfway Creek. The majority of groundwater draining the heap leach is predicted to report to Halfway Creek. Groundwater draining the southern edge of the heap leach is predicted to report to Latte Creek. Most of the seepage that escapes the Supremo pit backfill is expected to discharge to the Supremo 1 pit lake. The portion of backfill located between the Latte and Supremo 1 pit lakes show pathlines both to Latte Creek and Halfway Creek, depending on where the seepage originates. Groundwater draining the Kona pit footprint is predicted to report to

IC-3.0. Additional simulations will be required if significantly higher recharge is anticipated from any of these facilities.

Table 3-10:
Travel Time Estimate to Mine-Area Streams, Post-Closure Water Table Configuration

Source of Pathlines	Travel Time (years) of First Pathline to Surface Water Receptor				
	Latte Creek tributary (E of CC-1.0)	Latte Creek	Halfway Creek	YT-24	IC-3.0
Supremo 1	2	8			
Supremo 2		>200			
Latte	16	17	6		
Supremo 3W			26		
Supremo 3N			73	32	
Supremo 4N		>200	>200	>200	
Supremo 4S		7			
Supremo 5S		90		>200	
Supremo 5N				>200	
Double Double		10			



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)	
Particle Trace in Model Layer 1	
Particle Trace in Model Layer 2	
Particle Trace in Model Layer 3	
Particle Trace in Model Layer 4	
Post-Closure Water Table Contours (50m)	

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:35,000

0 400 800 Meters

DATE SAVED:	Mar 29, 2017
DRAWN BY:	GM
REVIEWED:	LF
VERSION:	1

CLIENT:

GOLDCORP

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE: 200-Year Travel Time Particle Traces From Proposed Facilities with Post-Closure Head Solution

PROJECT #: A362-5

FIGURE: 3-10

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\GW Modeling Report\Fig 3-10_200 Yr Particle Traces Closure_20170327.mxd

3.3 Sensitivity Analysis on Predictions

Model runs were completed with EOM and post-closure boundary conditions for all sensitivity runs described in Section 2.4 for the baseline model.

3.3.1 Sensitivity to Sub-Permafrost Bedrock near MW16-01

As discussed in Section 2.4.1, the model calibration is only sensitive to the hydraulic conductivity assigned to the sub-permafrost bedrock upgradient of MW16-01 in the immediate vicinity of this well. As a consequence, the hydraulic conductivity of the sub-permafrost bedrock upgradient of MW16-01 plays a minor role in the predictions of Project effects to groundwater, as shown in Table 3-11 and Table 3-12. The predicted post-closure baseflows to creeks is essentially unchanged when this parameter is increased or decreased by an order of magnitude. Similarly, the flows into and out of the pits remain unchanged.

Table 3-11:
Mass Balance, Baseflows, Post-Closure MW16-01 Area Sub-Permafrost K Sensitivity Runs

	MW16-01 Area Sub-Permafrost K x 10 ($1.0x10^{-5}$ m/s)	Base Case ($1.0x10^{-6}$ m/s)	MW16-01 Area Sub-Permafrost K/10 ($1.0x10^{-7}$ m/s)
Model-Wide Inflow (L/s):			
Constant Head	206.6	206.7	206.7
Recharge	200.9	200.9	200.9
Total	407.6	407.6	407.6
Model-Wide Outflow (L/s)			
Constant Head	249.0	249.0	249.0
Drain	158.6	158.6	158.6
Total	407.6	407.6	407.6
Inflow-Outflow (L/s)	-0.01	-0.08	-0.01
Inflow-Outflow (%)	-0.00	-0.02%	-0.00%
Total Groundwater Discharge to Streams (L/s)			
IC-2.5	4.5	4.6	4.7
IC-3.0	9.8	9.8	9.8
HC-2.5	10	10	10
HC-5.0	19	19	19
ML-1.0	7.6	7.6	7.6
CC-6.0	4.4	4.4	4.4
CC-1.0	1.9	1.9	1.9
CC-1.5	14	14	14
CC-3.5	50	50	49
IC-1.5	22	22	22
IC-4.5	42	42	42

Table 3-12:
Pit Inflows and Outflows, Post-Closure MW16-01 Area Sub-Permafrost K Sensitivity Runs

	MW16-01 Area Sub-Permafrost K x 10 ($1.0x10^{-5}$ m/s)	**Base Case ($1.0x10^{-6}$ m/s)**	**MW16-01 Area Sub-Permafrost K/10 ($1.0x10^{-7}$ m/s)**
Net Groundwater Inflow to Pits (L/s):			
Supremo 1	3.2	3.2	3.2
Supremo 2	-0.7	-0.7	-0.7
Latte	-3.8	-3.8	-3.8
Supremo 3W	-0.3	-0.3	-0.3
Supremo 3N	-0.6	-0.6	-0.6
Supremo 4N	2.3	2.3	2.3
Supremo 4S	-0.8	-0.8	-0.8
Supremo 5S	-6.2	-6.2	-6.2
Supremo 5N	1.8	1.8	1.8
Double Double	-0.8	-0.8	-0.8
Groundwater Flow from All Pit Lakes to Streams (L/s)			
Halfway Creek	3.0	3.0	3.0
CC-1.0	0.3	0.3	0.3
Latte Creek	3.7	3.7	3.7
YT-24	0.5	0.5	0.5

3.3.2 Sensitivity to Sub-Permafrost Bedrock near MW15-07

The hydraulic conductivity of the sub-permafrost bedrock upgradient of MW15-07 has a notable influence on pit lake-to-pit-lake fluxes, as shown in Table 3-14. In particular, the taliks associated the Supremo 5S pit and the southern part of the Supremo 5S pit are simulated to come in direct contact with this high-hydraulic conductivity sub-permafrost zone during the post-closure period, with the result that the flow out of the Supremo 5S pit lake rises from 6 L/s for the calibrated model to 45 L/s for the simulation in which the hydraulic conductivity of the sub-permafrost zone upgradient of MW15-07 is increased by a factor of ten. Conversely, when the hydraulic conductivity of this zone is reduced to be approximately equal to the Shallow Bedrock unit, the flux out of the Supremo 5S pit lake drops from 6 L/s to 1 L/s.

On the other hand, Table 3-14 and Table 3-13 show that the majority of the increased seepage loss from the Supremo 5S pit lake reports to either the Supremo 5N pit lake or the Supremo 4N pit lake. As a consequence, the pathline analysis yields relatively minor changes in the predictions from a groundwater perspective. The total flow from the pit lakes via groundwater to CC-1.0 and Halfway Creek remain the same as for the base case model. The total pit-derived groundwater flow to Latte Creek is lower for both runs than for the base case model. When the hydraulic conductivity of the sub-permafrost zone upgradient of MW15-07 is increased by an order of magnitude, the pit seepage that reports to Latte Creek drops because seepage losses from the Supremo 5S pit lake, which are 0.4 L/s for the base case model, drop to zero, as the higher hydraulic conductivity of the MW15-07 sub-permafrost area favours groundwater flow northward toward the Supremo 5N pit lake and YT-24. When the hydraulic conductivity of the sub-permafrost zone upgradient of MW15-07 is reduced by an order of magnitude, the water table at the top of the ridge drops, reducing hydraulic gradients and leading to lower flows to Latte Creek.

Similarly, the flow of pit lake water that recharges groundwater and ultimately discharges to YT-24 is lower for both runs than for the base case model. When the hydraulic conductivity of the sub-permafrost zone upgradient of MW15-07 is increased by an order of magnitude, seepage losses from the Supremo 5S pit lake (0.3 L/s in the base case model) no longer report to YT-24, located north of the zone of high permeability and instead discharge to the Supremo 4N pit lake. When the hydraulic conductivity of the sub-permafrost zone upgradient of MW15-07 is reduced by an order of magnitude, there continues to be seepage losses from the Supremo 5S pit lake that reports to YT-24, but the volume of flow is lower because of the lower hydraulic conductivity in the MW15-07 area.

This parameter has a minor impact on the baseflows to CC-1.0, as shown in Table 3-13.

Finally, it should be noted that the flows out of the Supremo 5S pit lake are substantially higher than baseflows to mine-area catchments. In all likelihood, if the hydraulic conductivity associated with a talik under this lake is as high as $1x10^{-5}$ m/s, then the pit lake will not reach its spillpoint elevation, and the flows predicted by this sensitivity solution are therefore likely to be over-estimated.

Table 3-13:
Mass Balance, Baseflows, Post-Closure MW15-07 Area Sub-Permafrost K Sensitivity Runs

	MW15-07 Area Sub-Permafrost K x 10 ($1.0x10^{-5}$ m/s)	Base Case ($1.0x10^{-6}$ m/s)	MW15-07 Area Sub-Permafrost K/10 ($1.0x10^{-7}$ m/s)
Model-Wide Inflow (L/s):			
Constant Head	245.4	206.7	201.5
Recharge	200.9	200.9	200.9
Total	446.3	407.6	402.5
Model-Wide Outflow (L/s)			
Constant Head	284.6	249.0	245.1
Drain	161.7	158.6	157.4
Total	446.3	407.6	402.5
Inflow-Outflow (L/s)	-0.01	-0.08	-0.05
Inflow-Outflow (%)	-0.00%	-0.02%	-0.01%
Total Groundwater Discharge to Streams (L/s)			
IC-2.5	4.6	4.6	4.6
IC-3.0	9.8	9.8	9.8
HC-2.5	10	10	10
HC-5.0	19	19	19
ML-1.0	7.6	7.6	7.6
CC-6.0	4.4	4.4	4.4
CC-1.0	2.0	1.9	1.9
CC-1.5	14	14	14
CC-3.5	50	50	49
IC-1.5	22	22	22
IC-4.5	42	42	42

**Table 3-14:
Pit Inflows and Outflows, Post-Closure MW15-07 Area Sub-Permafrost K Sensitivity Runs**

	MW15-07 Area Sub-Permafrost K x 10 ($1.0x10^{-5}$ m/s)	Base Case ($1.0x10^{-6}$ m/s)	MW15-07 Area Sub-Permafrost K/10 ($1.0x10^{-7}$ m/s)
Net Groundwater Inflow to Pits (L/s):			
Supremo 1	3.2	3.2	3.2
Supremo 2	-0.6	-0.7	-0.7
Latte	-3.8	-3.8	-3.8
Supremo 3W	-0.3	-0.3	-0.3
Supremo 3N	-0.6	-0.6	-0.6
Supremo 4N	20.9	2.33	0.3
Supremo 4S	-0.2	-0.8	-1.5
Supremo 5S	-45.0	-6.2	-1.1
Supremo 5N	21.0	1.8	0.1
Double Double	-0.8	-0.8	-0.8
Groundwater Flow from All Pit Lakes to Streams (L/s)			
Halfway Creek	3.0	3.0	3.0
CC-1.0	0.3	0.3	0.3
Latte Creek	3.3	3.7	3.5
YT-24	0.2	0.5	0.3

3.3.3 Sensitivity to Sub-Permafrost Bedrock near MW14-05

The hydraulic conductivity of the sub-permafrost zone around MW14-05 has a minor influence on the model calibration. Table 3-15 shows that reducing the value of this parameter has no significant effect on baseflows to streams or on pit inflows to the Latte pit lake. Increasing the hydraulic conductivity in the MW14-05 area has the no appreciable effect on baseflows, and the predicted impacts from the proposed mine facilities are unchanged.

Table 3-15:
Mass Balance, Baseflows, Post-Closure MW14-05 Area Sub-Permafrost K Sensitivity Runs

	MW14-05 Area Sub-Permafrost K x 10 ($2.6x10^{-8}$ m/s)	**Base Case ($2.6x10^{-9}$ m/s)**	**MW14-05 Area Sub-Permafrost K/10 ($6.0x10^{-10}$ m/s)**
Model-Wide Inflow (L/s):			
Constant Head	206.6	206.7	206.7
Recharge	200.9	200.9	200.9
Total	407.6	407.6	407.6
Model-Wide Outflow (L/s)			
Constant Head	249.0	249.0	249.0
Drain	158.6	158.6	158.6
Total	407.6	407.6	407.6
Inflow-Outflow (L/s)	0.00	-0.08	-0.01
Inflow-Outflow (%)	0.00%	-0.02%	-0.00%
Total Groundwater Discharge to Streams (L/s)			
IC-2.5	4.7	4.6	4.6
IC-3.0	9.9	9.8	9.8
HC-2.5	10	10	10
HC-5.0	17	19	19
ML-1.0	7.6	7.6	7.6
CC-6.0	4.4	4.4	4.4
CC-1.0	19	1.9	1.9
CC-1.5	14	14	14
CC-3.5	49	50	50
IC-1.5	22	22	22
IC-4.5	42	42	42

Table 3-16: Pit Inflows and Outflows, Post-Closure MW14-05 Area Sub-Permafrost K Sensitivity Runs

	MW14-05 Area Sub-Permafrost K x 10 ($2.6x10^{-5}$ m/s)	Base Case ($2.6x10^{-6}$ m/s)	MW14-05 Area Sub-Permafrost K/10 ($6.0x10^{-7}$ m/s)
Net Groundwater Inflow to Pits (L/s):			
Supremo 1	3.2	3.2	3.2
Supremo 2	-0.7	-0.7	-0.7
Latte	-3.8	-3.8	-3.8
Supremo 3W	-0.3	-0.3	-0.3
Supremo 3N	-0.6	-0.6	-0.6
Supremo 4N	2.3	2.3	2.3
Supremo 4S	-0.8	-0.8	-0.8
Supremo 5S	-6.2	-6.2	-6.2
Supremo 5N	1.8	1.8	1.8
Double Double	-0.8	-0.8	-0.8
Groundwater Flow from All Pit Lakes to Streams (L/s)			
Halfway Creek	3.0	3.0	3.0
CC-1.0	0.3	0.3	0.3
Latte Creek	3.7	3.7	3.7
YT-24	0.5	0.5	0.5

3.3.4 Effect of Talik

A simulation was completed for the post-closure period in which no taliks are simulated under the pit lakes present on permafrost—Supremo 3W, Supremo 3N, Supremo 5S and Supremo 5N. The predicted baseflows with and without talik formation are similar, as shown in Table 3-17.

Table 3-17:
Mass Balance, Baseflows, Post-Closure Run without Talik Formation

	Base Case With Talik Formations	Without Talik Formation
Model-Wide Inflow (L/s):		
Constant Head	206.7	201.8
General Head	n/a	0.0
Recharge	200.9	200.9
Total	407.6	402.7
Model-Wide Outflow (L/s)		
Constant Head	249.0	245.5
Drain	158.6	157.2
Total	407.6	402.7
Inflow-Outflow (L/s)	-0.08	-0.00
Inflow-Outflow (%)	-0.02%	-0.00%
Total Groundwater Discharge to Streams (L/s)		
IC-2.5	4.6	4.6
IC-3.0	9.8	9.8
HC-2.5	10	10
HC-5.0	19	19
ML-1.0	7.6	7.5
CC-6.0	4.4	4.4
CC-1.0	1.9	1.9
CC-1.5	14	14
CC-3.5	50	49
IC-1.5	22	22
IC-4.5	42	42

Table 3-18 presents the flows to and from the pit lakes with and without the formation of taliks. The inter-pit flows, particularly from Supremo 5S, are significantly lower when no taliks are assumed to form. The pit lake groundwater recharge rates are similar with and without talik formation. However, the pit-derived groundwater flow to YT-24 is lower when no taliks are assumed.

Table 3-18:
Pit Inflows and Outflows, Post-Closure without Talik Formation

	Base Case With Talik Formations	**Without Talik Formation**
Net Groundwater Inflow to Pits (L/s):		
Supremo 1	3.2	3.1
Supremo 2	-0.7	-0.7
Latte	-3.8	-3.8
Supremo 3W	-0.3	-0.1
Supremo 3N	-0.6	-0.6
Supremo 4N	2.3	0.7
Supremo 4S	-0.8	-1.5
Supremo 5S	-6.2	0.0
Supremo 5N	1.8	-1.5
Double Double	-0.8	-0.8
Groundwater Flow from All Pit Lakes to Streams (L/s)		
Halfway Creek	3.0	3.0
CC-1.0	0.3	0.3
Latte Creek	3.7	3.8
YT-24	0.5	0.1

3.3.5 Summary

Steady state simulations were completed for the proposed Project at EOM and post-closure using pit lake elevations derived iteratively with the site-wide water balance model. At EOM, the Supremo 1 pit lake elevation is predicted to have reached its spill elevation. An estimated 1.2 L/s of groundwater inflow to the Supremo 1 pit is predicted to spill under steady state conditions for the EOM condition. In addition, the Supremo 1 pit lake is predicted to recharge groundwater at a rate of 0.6 L/s, which ultimately discharges to CC-1.0 or to Latte Creek. The Supremo 2 pit lake is predicted to reach a lake elevation of 1061 m, below its spill point elevation. The Latte pit, with a lake elevation of 998 m, is predicted to be net losing, with 0.9 L/s of seepage from the Latte pit reporting to Halfway Creek, and 0.2 L/s reporting to Latte Creek. The Supremo 3W pit, located on permafrost, is predicted to lose less than 0.01 L/s of pit lake water to groundwater.

The post-closure model incorporates the development of through taliks under pit lakes residing in permafrost. Overall, this, in combination with higher pit lake elevations, causes significant mounding of the groundwater table and more communication between pit facilities than simulated in the EOM model. Total pit seepage losses to receiving creeks are about double EOM values. During the post-closure period, the Supremo 1 and Latte pit lakes continue to experience the greatest interactions with groundwater. The Supremo 1 pit lake is predicted to discharge 3.2 L/s of groundwater as surface water and 0.5 L/s as groundwater which ultimately discharges to CC-1.0 or Latte Creek. Water from the Latte pit is predicted to recharge groundwater, with 2.3 L/s ultimately discharging to Halfway Creek, and 0.8 L/s of pit-derived groundwater discharging to Latte Creek. Seepage from the Supremo 4S is predicted to discharge to Latte Creek in the amount of 1.7 L/s. Supremo 4N is predicted to receive a net inflow of groundwater of 2.3 L/s. Supremo 2 pit lakes is sandwiched between Supremo 3N and Supremo 1, and most of the groundwater that flows out of this lake reports to either Supremo 3N or Supremo 1.

The formation of a talik beneath Supremo 5S is predicted to allow a large volume of water to seep into groundwater from this pit lake. The majority of the recharge from Supremo 5S flows into Supremo 4N, Supremo 4S, and Supremo 5N. The development of taliks beneath Supremo 5N, Supremo 3N and Supremo 3W increase flows out of these lakes in the post-closure period.

4. Conclusions and Limitations

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4. Conclusions and Limitations

4.1 Conclusions

A three-dimensional, numerical, steady-state, groundwater model was developed for the Coffee Creek Gold Mine. The model was calibrated to site-specific, field-based observations of hydraulic head and groundwater discharge data. The model was able to fit the groundwater heads in monitoring wells to a residual mean of 0.22 m and a normalized root mean squared error of 1.12%. The model was able to predict groundwater discharge targets in eight of nine Project area streams to within calibration targets. It was not able to simulate the baseflow to the IC-2.5 catchment; however, the water quality signature of this stream suggests that the majority of baseflow is not the deep, bedrock-derived groundwater that is simulated in this model. Model results are therefore consistent with and calibrated to observations.

The calibrated model was used to predict steady state pit inflows to the pit lakes at end of operations and during the post-closure period and the receptors for seepage losses from the proposed mine facilities. A summary of fluxes and travel times to creeks is presented in Table 4-1. Detailed fluxes and travel times are presented in Section 3. The majority of pit lake water that recharges groundwater will discharge to Latte and Halfway Creeks. Smaller groundwater flows from the pit lakes to CC-1.0 and YT-24 are predicted.

Table 4-1:
Summary of Groundwater-Pit Lake Interactions

Discharge Zone	EOM Groundwater Flow (L/s) from Pits to Discharge Zone	Time of Arrival to Discharge Zone (years) from EOM model	Post-Closure Groundwater Flow (L/s) from Pits to Discharge Zone	Time of Arrival to Discharge Zone (years) from Post-Closure model
CC-1.0	0.33	1.6	0.31	1.6
Latte Creek	1.76	7.6	3.70	7.3
Halfway Creek	1.16	6.5	3.03	5.6
YT-24	0.01	>200	0.50	32
Total to Creeks	**2.50**		**6.78**	
Inter-Pit Flow	0.59		7.75	

The most significant difference between the EOM and post-closure simulations is the 7.8 L/s that recharges groundwater at one pit lake and discharges at another in the post-closure simulation. By comparison, at the end of operations, less than 1 L/s of groundwater recharges at a pit and discharges at Supremo 1 pit lake.

A sensitivity analysis was completed for both baseline and predictive scenarios for the parameters were introduced in this updated model calibration. The new parameters improve the model calibration statistics but, for the most part, do not have a significant impact on the predicted mine impacts. The exception is the hydraulic conductivity zone associated with MW15-07. The magnitude of this hydraulic parameter had a large impact on the pit-lake-to-pit-lake groundwater interactions. However, both increasing and decreasing the hydraulic conductivity of the sub-permafrost shallow bedrock associated with MW15-07 reduced the pit seepage flow rates to Latte Creek and YT-24.

4.2 Limitations

The assessment presented herein is based on an idealized, three-dimensional, steady state, numerical groundwater model in an area of discontinuous permafrost. There are a number of uncertainties inherent to this type of analysis. One important area of uncertainty is in the conceptual model of how permafrost interacts with underlying groundwater. As discussed in Section 2.1, the key issue of how much, if any, recharge infiltrates through an ice-poor but fractured bedrock is not fully resolved. The assumption that bedrock permafrost in the Project area is generally impermeable to infiltrating water except at the highest elevations is supported by field data, recent technical literature, and the modeling to date; however, future field information may result in a refinement of this assumption. Bulk bedrock within the model domain is assumed to be generally homogeneous and divisible into two depth-based hydraulic conductivity zones. Therefore, significant zones of enhanced bedrock transmissivity that are present in the field but not incorporated into the model will affect the accuracy of these predictions. The accuracy of the model will depend on the quality and quantity of data used to calibrate the model and the time frame over which the data were collected. Future revisions of the model as more information comes available are recommended.

A sensitivity analysis was completed on three parameters to evaluate their importance on the baseline model. This sensitivity analysis supplements the sensitivity runs completed previously (Lorax, 2016).

Model calibration is non-unique, meaning that more than one set of parameters can lead to a model solution that meets the calibration targets. While uncertainty is inherent to any numerical groundwater model, the variability of results from the sensitivity analyses conducted are relatively small and provide confidence in the overall assessment.

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