

Appendix 4.4-A

SRK, Groundwater Technical Report for the Tenas Coal Project, Telkwa



Groundwater Technical Report for the Tenas Coal Project, Telkwa

Prepared for

Telkwa Coal Ltd



Prepared by



SRK Consulting (Canada) Inc.
1CT027.004
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Executive Summary

Telkwa Coal Ltd (TCL) is proposing to develop the Tenas Coal Project (the Project), a surface coal mine designed to produce metallurgical coal. The proposed mine site is in northwestern British Columbia (BC), approximately 25 kilometres south of Smithers and seven kilometres southwest of Telkwa, within the Wet'suwet'en Nation's traditional territory. This report presents the results of a groundwater study prepared by SRK Consulting (Canada) Inc. (SRK) on behalf of TCL in support of a Joint Application for a Mines Act permit, and an effluent discharge permit. The objectives were to establish baseline conditions and to quantify the potential changes to the groundwater system that could occur as a result of the Project.

Project Background

The climate and hydrological conditions were characterized by SRK (2020). The average total precipitation between 2018 and 2019 was 587 mm/y, with snow comprising 71% and 31% in 2018 and 2019, respectively. The streamflow regime is nival (snowmelt) with the majority of runoff (MAR 367 mm/year) occurring in the spring and early summer.

The deposit is hosted in a coal-bearing sedimentary rock sequence, associated with the Lower Cretaceous age Skeena Group (marine and continental sediments interbedded with coal seams), and overlies unconformably the Jurassic-age Hazelton volcanic group (andesite, trachyte, and basalt with associated tuffs and breccias). The sedimentary sequence in the pit area is folded into a syncline. Faulting is generally near-vertical, and can be subdivided into two main groups, one which strikes approximately northwest/southeast, and the other northeast/southwest.

The surficial geology consists of glacial clay- silt-rich till, and glaciofluvial sand-gravel-rich till. South of the proposed pit, the bedrock outcrops are close to ground surface; North of the proposed pit and towards Tenas Creek and Goathorn Creek, the till deepens and exceed 100 m. Other deposits are present locally; patches of glaciolacustrine deposits scattered throughout the morainal landscape in low ridges and depressions; and fluvial deposits found in the narrow-incised floodplains of Goathorn and Tenas Creek, and the wide floodplains of the Telkwa and Bulkley River.

The estimated total area disturbed by the Project is 840 ha, including the open pit (289 ha), the coal processing plant (10 ha), material storage facilities (137 ha), sediment ponds (40 ha), and management ponds (227 ha). The Projected mine life is approximately 25 years, including construction, operations, and reclamation phases.

In terms of waste, TCL identified several types of material that will need to be managed. The growth media (i.e., top organic soil,) will be stockpiled. The overburden will be placed into the compaction zones and/or buttress components of the dams for the management ponds, or otherwise placed as backfill within the pit. The low sulfur rock will be placed within the buttress region of the dams for the management ponds, or otherwise backfilled within the pit. The high sulfur and processed rocks will be placed into external flooded management ponds or within flooded portions of the pit.

In terms of water management, the facilities will include ditches, sedimentation ponds and management ponds. Three storage management ponds will collect the groundwater pumped from the pit during operation. These ponds are designed for underwater long-term storage of potentially acid generating material. A fourth pond will collect surface runoff from the mine infrastructure and overflows from the management ponds. This pond is designed to ensure that no water discharge occurs during operations between the October 31 and March 31 periods and to control the sedimentation for the overall site. It also provides contingency water to ensure PAG material is submerged, and a location for water displaced during management pond operations. All the ponds will be lined. The storage management will be lined with an engineered soil-bentonite compacted layer, and the Control Pond with a bituminous geomembrane.

Raw water for the coal preparation plant and make-up water for the mine infrastructure complex will be sourced from precipitation and melting snow collected onsite. Potable water for domestic facilities will be sourced from surface runoff and/or groundwater. A potable water treatment plant will be onsite to ensure that drinking water standards are met. Another 1.5 million m³/year of make-up water is assumed for additional contingency and robustness to the water balance. This water would be sourced from Goathorn Creek (i.e., approx. 2.5% of Goathorn's Creek and less than 1% of the Telkwa River's annual flow respectively) via water supply wells located along the edge of Goathorn Creek.

Groundwater Baseline Studies

To assess the potential effects of the Project to groundwater, two spatial boundaries were considered: The Local Study Area (LSA) and the Regional Study Area (RSA). The LSA was defined where the Project may have a direct influence on the groundwater system and/or groundwater users, and the RSA by the fish habitats in the Telkwa River watershed and in the tributaries to the Bulkley River. The time-steps considered for the evaluation included 2020 (construction), 2023 (End-of-Year 1), 2029 (End-of-Year 7), and post-closure (post-2043).

SRK consulted the BC regulations and guidelines relevant to groundwater and reviewed the Project desktop information and the groundwater site data collected between 1983 and 2016. The level of details, methods, and quality of the information were considered adequate for a Joint Application for a Mines Act permit, and for an effluent discharge permit.

Groundwater Baseline Data

The bedrock is characterized by a low to moderate hydraulic conductivity (i.e., K geomean of 2×10^{-7} m/s). K geomean values sorted by lithological types, from the least permeable to the most permeable, are conglomerate (2×10^{-8} m/s), mudstone/siltstone (7×10^{-8} m/s), volcanic rock (1×10^{-7} m/s), sandstone (2×10^{-7} m/s), and coal (5×10^{-7} m/s). For the overburden, K in the clay-silt-rich till is relatively low (9×10^{-9} m/s), and in the sand-gravel-rich till moderately high (1×10^{-6} m/s). There is no site measurement for specific storage or specific yield.

The groundwater in both systems flows towards the valleys, moving away from the Tenas pit towards Tenas Creek, the Telkwa River, and Goathorn Creek. Static water levels are generally less than 2 mbgs (meters below ground surface) in the south Tenas area, to more than 20 mbgs

in the north, where overburden changes to a thick sequence of sand-gravel-rich till deposits. The overburden well showed water level highs in spring following freshet and lows in winter. The seasonal observations in bedrock wells were divided in two groups. One group showed seasonal variations similar to overburden, with highs in spring, lows in fall/winter, suggesting it has a connection with overburden. The other group showed highs in winter, lows in summer/fall, implying recharge is delayed by several months, potentially by the low permeability of the silt-clay-rich till.

The groundwater chemistry in overburden wells is classified as a calcium-magnesium-bicarbonate type; while groundwater in bedrock wells is sodium-bicarbonate type. The groundwater quality statistics, the exceedances, and the baseline average groundwater quality are presented in the report. Exceedances above the BC water quality guidelines for freshwater aquatic life (approved or working) were observed for fluoride, ammonia, total arsenic, total copper, total chromium, total and dissolved iron, total zinc, and selenium. The differences observed in historical wells over time, and the correlations between turbidity and total/dissolved metals concentrations suggest exceedances of total metals were likely caused by suspended particles generated by disturbances (i.e., drilling and well installation). Exceedances above the BC water quality guidelines for drinking water sources were observed for fluoride, and dissolved metals (i.e., arsenic, iron, cobalt, manganese, antimony, mercury, lead, and uranium – the last four parameters exceeded the guideline values only once).

The aquifer database of the ministry of Environment reports six aquifers of limited extent with low to moderate productivity, all located near the town of Telkwa, where the Telkwa River joins the Bulkley River, about 8 to 10 km north east from the Project. The closest private wells, located along the expected flow paths between the Project and the Telkwa River, are about 3.8 km north of the Project. In terms of human activities, small-scale underground and surface mining occurred sporadically about 3.6 km north and northwest from the Project between 1918 and 1985; nowadays there are no significant human activities other than mining exploration and forestry.

Conceptual Groundwater Model

Conceptually, the groundwater system is divided into two sub-systems: deep bedrock and shallow overburden. The deep bedrock is composed of the Skeena sedimentary rock group, the volcanic group, fractures and faults. At the scale of the Telkwa watershed, the fractured rock is assumed to act as an equivalent porous medium. The hydrogeology of the bedrock is assumed to be represented as a single unit characterized by an anisotropy ratio perpendicular to sedimentary bedding planes (i.e. K parallel to beddings higher than K perpendicular to beddings). Data do not indicate influences from known faults (i.e., preferential flow pathways and/or barriers), and there is no mapped structure directly connecting the Project and the private well locations.

The lateral extent of bedrock is characterized by confined flow, relatively long residence times in the subsurface, and higher concentrations of dissolved solids. Groundwater levels indicate generally north-oriented flow lines, from upland areas to streams, namely the Telkwa River and its tributaries, Tenas Creek and Goathorn Creek.

Shallow overburden is composed of two units: silt-clay-rich glacial till and glaciofluvial sand-gravel-rich till. Its hydraulic characteristics are controlled by the distribution of fine materials, with silt-clay-rich till acting as an aquitard, and impeding flow between the higher permeability sand-gravel-rich layers. The 3D geometries of the hydrostratigraphic units were generated from the analyses of drillhole intercepts (TCL's database), geological maps (surface and bedrock geology, regional and local maps, 2D cross sections; Clague 1984, MEMPR 1993, BCGS 2005, TCL 2018), and considerations on the ability of a unit to convey groundwater.

The shallow overburden is characterized as a local unconfined system with relatively short residence times and low concentrations of dissolved solids. Groundwater flows in a north-easterly direction towards Four Creek and in a north-westerly direction towards Tenas Creek, moving from topographic highs to adjacent lows. Discharge from overburden is expected to occur in the valleys of Tenas, Four and Goathorn Creeks.

Groundwater Effect Predictions

Numerical groundwater modeling was completed to predict pit inflows, potential changes to baseflows, and contributions/travel times of mine-affected groundwater to creeks and private wells. Two models, a base and high case, were developed to evaluate the potential groundwater effects from the Project:

Base Case: The base case corresponded to the model that achieved the best fit to field data, with a final Normalized Root Mean Square Error (NRMSE) of 3.2% for hydraulic heads and 3.6% for baseflows.

High Case: The high case corresponded to a model where the hydraulic conductivities were maximized, while still maintaining calibration near the minimum generally accepted in BC (10% NRMSE).

Modeling was based on steady-state conditions for both calibration and forward predictions. Model uncertainties were assessed through a sensitivity analysis. Details on the modeling assumptions, model designs, and calibration are included in the report.

The model may be classified as moderate complexity (Wels et al., 2012), defined as follows: "These (...) are based on a reasonable, though limited, dataset and having limited calibration. These models may be used to determine the potential range of change or to "bracket" potential effects that may occur due to a given stress." The model is based on a unique conceptualisation of the 3D geology; detailed characterization of aquitards or aquicludes are not well characterized; baseflows are estimated from historical stream flow records; the model was calibrated to steady state conditions, and the results have highest confidence in the vicinity of the mine area where there are relatively more data.

The key conclusions for EOM conditions were as follows:

- The pit inflows ranged between 310 and 850 m³/d for the base case, and 400 and 1,110 m³/d for the high case. Under groundwater conditions alone, inflows of these magnitudes are typically managed with pit sumps and do not require active dewatering systems.
- The seepage rate underneath the control pond was 140 m³/d for the base case and 290 m³/d for the high case.
- The total seepage rate underneath the management ponds at end-of mine was 1,110 m³/d for the base case and 2,330 m³/d for the high case.
- Neither the drawdown cone nor groundwater mound are predicted to reach private well locations.
 - The drawdown induced by dewatering extended up to a maximum of 23 and 28 km² for the base case and high case respectively.
 - The management ponds and the control pond influence the progression of the drawdown to the north; in this area the model predicted a groundwater mound of about 10 to 14 km² for the base case and high case respectively.
 - Sensitivity analysis evaluated the worst-case drawdown extents (i.e., pit fully excavated, dewatering active, but no pond). The predicted drawdown extended to a surface of approximately 34 and 44 km² for the base case and high case respectively but did not reach private well locations.
- The maximum reductions of baseflows are predicted to occur prior to construction of the waste and water management facilities. A reduction of about 7% at Tenas Creek, 14% at Four Creek, 3% at the Goathorn Creek, and less than 1% at the Telkwa River is expected.
- The first particle of mine-affected groundwater was predicted to discharge into Tenas Creek after 16 years for the base case, and 8 years for the high case. No particles were predicted to discharge in the first 25 years into Four Creek, Goathorn Creek, Telkwa River, or near private wells.
- The base case forecasts of potential contributions of mine affected groundwater to baseflows, after 25 years of operations, were 0.3% for Tenas Creek, 0.1% for Goathorn Creek, and less than 0.1% for the Telkwa River. The high case forecasts are 10% for Tenas Creek, 4.3% for Goathorn Creek, and 0.5% for the Telkwa River.

The key conclusions based on the modeling of post-closure conditions were as follows:

- The seepage rate (i.e., outflow) underneath the saturated waste rock and pit lake was 10 m³/d for the base case and 260 m³/d for the high case; these features predominantly act as a sink, with an inflow of 370 and 350 m³/d for the base case and high case respectively.
- The total seepage rate underneath the management ponds was 1,080 m³/d for the base case and 2,170 m³/d for the high case.

- The long-term drawdown induced by the Project is projected to extend up to a maximum of 16 and 23 km² and the mound to about 8 to 16 km², for the base case and high case respectively. Neither the drawdown nor mounding is predicted to reach the private wells.
- Modeling suggests that baseflows will slightly decrease by 0.7% in Tenas Creek, 7% in Four Creek, 0.1% in Goathorn Creek, and less than 0.1% in the Telkwa River predicted for the base case model; and increase by 24% in Tenas Creek, 70% in Four Creek, 7% in Goathorn Creek, and 5% in the Telkwa River for the high case model.
- In terms of effect to private groundwater users, the model predicted particles would travel for more than 400 years in the base case, and 300 years in the high case, before reaching the private wells.
- The predicted long-term contributions of mine affected groundwater to baseflows were 7.7% for Tenas Creek, 3.4% for Goathorn Creek, and less than 0.6% for the Telkwa River for the base case. The high case estimates were 15% for Tenas Creek, 6.5% for Goathorn Creek, and 1.3% for the Telkwa River.
- The average time for a particle to reach the creeks in the base case was predicted to be 65 years for Tenas creek, 320 years for Goathorn Creek, and over 400 year for Telkwa. The high case was 23 years for Tenas, 45 years for Goathorn, and 400 for Telkwa.
 - The WBLM assumed conservatively that 100% of the potential waste and water management pond loads discharged into creeks via groundwater paths after 25 years.
- Three private wells (Goalder, Mapletoft, and Baker) located in the Telkwa River valley are potentially within the paths of mine affected groundwater. No constituent is predicted to exceed the BC-DWG in the base case scenario, and only cobalt exceeds the BC-DWG in the high case scenario (max. predicted 2.3 µg/L, BC-DWG for cobalt 1 µg/L). The processes of diffusion, dispersion, or natural attenuation and the predicted travel times (i.e., > 400 years) between the Project and the Telkwa alluvial floodplain were not considered in the analysis.
- The sensitivity analysis showed that the model was most sensitive to recharge and the hydraulic conductivity of the tills and Skeena group units. The parameters impacted the predictions as follow:
 - The highest sensitivity pit inflow was 1,550 m³/d.
 - None of the sensitivity models predicted drawdown or mounding to reach the private wells.
 - The maximum sensitivity reduction to baseflows was about 14% for the Tenas Creek, and 3% for the Goathorn Creek.
 - The travel time in all sensitivity runs to private wells was in excess of 170 years.
 - The maximum sensitivity contribution of mine affected groundwater to baseflows was 11% in Tenas Creek, and 1% in the Goathorn Creek.

The modeling presented herein provides forecasts of the expected Project behavior, derived from the available hydrogeological information. Upgrades to the model should be considered as additional information becomes available. Additional modeling should be completed if changes are made to the design basis or any new information found that changes the parameters considered in the modeling.

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List of Abbreviations

°	Degree		
°C	Degree Celsius	MEMPR	Ministry of Energy, Mines and Petroleum Resources
3D	Three dimensional		
ARD	Acid Rock Drainage	mg/l	milligram per litre
BC	British Columbia	ML/ARD	Metal leaching / acid rock drainage
BDR	Bedrock	mm/yr	Millimetre per year
CPP	Coal preparation plant	Mt	Million tons
CUB	Calibrated unit baseflow	MW	Monitoring well
d	Day	Non-PAG	Non-Potentially acid generating
DEM	Digital Elevation Model	NMP	North management pond
DWS	Drinking water sources	NRMSE	Normalized root mean square error
EA	Environmental Assessment	NTU	Nephelometric turbidity unit
EMP	East management pond	OVb	Overburden
EOM	End-of-mine	PAG	Potentially Acid-Generating
EoY	End-of-year	Project	Tenas Project
FAL	Freshwater aquatic life	PSD	Particle size distribution
Ha	Hectare	QA	Quality assurance
K	Hydraulic conductivity	QC	Quality control
km	Kilometer	R	Recharge
km ²	Kilometer square	ROM	Run-of-mine
kV	Kilovolt	RPD	Relative Percent Difference
LIDAR	Light detection and ranging	RSA	Regional study area
LSA	Local study area	s	Second
L/s	Litre per second	SRK	SRK Consulting (Canada) Inc.
m	Meter	S _s	Specific storage
m ²	meter square	S _y	Specific yield
m ³ /day	meter cube per day	TCL	Telkwa Coal Ltd
m/s	meter per second	TDS	Total dissolved solids
MAP	Mean annual precipitation	TSS	Total suspended solids
MAR	Mean annual runoff	WBLM	Water balance and load model
masl	Meters above sea level	WMP	West management pond
mbgs	Meters below ground surface	WQG	Water quality guidelines
		WSC	Water survey of Canada

1 Introduction

Telkwa Coal Ltd (TCL) is proposing to develop the Tenas Coal Project (the Project), a surface coal mine designed to produce metallurgical coal at a planned annual production rate of between 775,000 and 825,000 tonnes. The mine life of the Project will be approximately 25 years, including construction, operations, decommissioning, and reclamation phases.

This report presents the results of hydrogeological studies in support of a Joint Application for a Mines Act permit issued by the Ministry of Energy, Mines and Petroleum Resources, and an effluent discharge permit issued under the Environmental Management Act by the Ministry of Environment. It was prepared by SRK Consulting (Canada) Inc. (SRK), on behalf of TCL.

1.1 Objectives

The objectives of the work presented here are to establish the baseline groundwater conditions and to quantify the potential changes to the groundwater system that could occur as a result of the Project. The baseline information was used to construct and calibrate a three-dimensional (3D) numerical model, which was then utilized to predict the Project's potential effect on groundwater during mining and long-term closure (post-closure) phases, and to inform the waste and water management system designs (Part A, Section 1 of the EAC Application) and the surface water and load balance model (WBLM, Section 4, Chapter 3 of the EAC Application). The WBLM was used to evaluate the overall effects of the Project on the hydrology and surface water quality at both local and regional scales.

1.2 Report Layout

The report is organized as follows:

- Section 2 presents background information relevant to hydrogeological studies.
- Section 3 defines the groundwater assessment boundaries, and presents the regulatory guidelines relevant to the study, the sources of desktop and field information, and the methodologies for the field data collection, data management, and QA/QC methods.
- Section 4 reviews the hydrogeological data supporting the characterization of the groundwater flow system and groundwater quality.
- Section 5 presents the groundwater conceptual model of the Project area for baseline, mining, and post-closure conditions.
- Section 6 describes a numerical groundwater modelling assessment and presents the predictions of the potential changes to the groundwater system.
- Section 7 presents the conclusions of the study.

2 Project Background

2.1 Location

The proposed mine site is in the Regional District of Bulkley-Nechako in northwestern British Columbia (BC), approximately 25 kilometres south of Smithers and seven kilometres southwest of Telkwa, within the Wet'suwet'en Nation's traditional territory, which includes the majority of the Bulkley River drainage. The Telkwa River, the Tenas Creek and the Goathorn Creek run through the coalfield, dissecting it into three coal exploration areas known locally as Tenas, Goathorn, and North. The proposed pit and the waste and water management facilities are in the Tenas area, approximately 54°36'48" north latitude and 127°09'32" west longitude. Figure 1 and Figure 2 shows the Project locations.

2.2 Topography

The Project is located within the Coast Mountains (Bulkley Ranges) of the Cordillera Region. The Project is centered on a remnant glacial terrace; upland areas are characterized by moderate to steeply incised valleys separated by moderately undulating terrain; and lowland areas are characterized by relatively flat to moderately rolling topography.

2.3 Climate

The climate conditions were characterized in the Hydrometeorological Baseline and Model Development Report (SRK 2020). Observations for years 2017, 2018, and 2019 are compiled in Table 2-1 and shown in Figure 3. The average total precipitation was 587 mm/y between 2018 and 2019, with snow comprising 71% and 31% in 2018 and 2019, respectively.

Table 2-1: Mean and Annual Precipitation, and Temperature at the Telkwa Project

Year	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
2017	Total Precipitation [mm]										147	134	10	-
	Rainfall [mm]										114	0	0	-
	Snowfall [mm SWE]										33	134	10	-
	Average Snow Depth [cm]										4	28	47	-
	Mean temperature [°C]										1.9	-5.6	-8.9	-
2018	Total Precipitation [mm]	50	150	81	14	14	42	50	2	50	54	51	113	672
	Rainfall [mm]	0	0	1	3	14	42	50	2	30	42	9	0	195
	Snowfall [mm SWE]	50	150	80	10	0	0	0	0	20	11	42	113	477
	Average Snow Depth [cm]	63	101	119	110	12	0	0	0	1	0	9	38	-
	Mean temperature [°C]	-7.6	-9.8	-3.3	1.1	9.4	10.6	15.5	15.3	5.9	3.0	-1.0	-6.1	-
2019	Total Precipitation [mm]	60	19	8	13	26	57	83	21	47	93	73	2	502
	Rainfall [mm]	5	0	0	7	26	57	83	21	46.5	69	32	0	346
	Snowfall [mm SWE]	55	19	8	6	0	0	0	0	0.5	24	41	2	156
	Average Snow Depth [cm]	66	75	74	32	0	0	0	0	0	5	5	14	-
	Mean temperature [°C]	-3.8	-12.7	-1.3	2.4	10.5	10.9	12.9	12.9	8.2	0.7	-1.9	-7.9	-

Source: SRK report Oct 2020: Tenas Project – Hydrometeorological Baseline and Model Development Report.

Note:

Na, not available

2.4 Hydrology

The main drainages in the Project area are the Bulkley River, the Telkwa River, Goathorn Creek, Tenas Creek, Cabinet Creek, and Four Creek. Figure 4 shows a map of the drainages, surface water monitoring stations, and watershed boundaries. Table 2-2 provides a short description of the main drainages.

The streamflow regime in the Project area is nival (snowmelt) with the majority of runoff (MAR 367 mm/year) occurring in the spring and early summer due to the melting winter snowpack. After the snowmelt-driven high flow, there is typically a period of low flow throughout the late summer and early fall, although high intensity rain during the fall period can produce substantial peak events. Annual low flows occur during the winter when the air temperatures remain below freezing; precipitations fall as snow and are stored in the snowpack. During the winter low flow period, the streams are mostly supplied by groundwater discharge; some streams in the region have glacial inputs but this is less prominent in the Project area.

Table 2-2: Description of the Main Rivers and Creeks

River/Creek Name	Description
Bulkley River	The Bulkley River is a tributary of the Skeena River. It originates southeast of the project and flows in a north-south trending valley approximately 6 km east of the Project area. Discharge into the Skeena is approximately 100 km downstream from its confluence with the Telkwa River. The size of the watershed is about 12,400 km ² . The Bulkley River is a known fish-bearing stream.
Telkwa River	The Telkwa River is a substantial tributary to the Bulkley River. It originates west of the Project and flows east, discharging into the Bulkley River approximately 6 km east of the confluence with Goathorn Creek. The size of the watershed is about 830 km ² . The Telkwa River is a known fish-bearing stream.
Goathorn Creek	Goathorn Creek is a tributary to the Telkwa River. It is a moderately wide and extensively braided creek, with a floodplain approximately 20 to 100 m wide. It flows north along the east side of the Project then discharges into the Telkwa River approximately 8 km downstream of the proposed pit. The size of the watershed is about 130 km ² . The Goathorn Creek is a known fish-bearing stream.
Tenas Creek	Tenas Creek is a tributary to Goathorn Creek. It is a small watercourse that flows north and northwest, along the northwest side of the Project, then discharges into Goathorn Creek approximately 8 km downstream of the proposed pit. The size of the watershed is about 60 km ² . The Tenas Creek is a known fish-bearing stream.
Cabinet Creek	Cabinet Creek is a small tributary to Goathorn Creek. It is a small watercourse that flows north of the Project, then discharges into Goathorn Creek approximately 6 km east of the proposed pit. The size of the watershed is about 54 km ² .
Four Creek	Four Creek is a very small tributary to Goathorn Creek. It drains northeast, bordering the Project to the east before discharging into Goathorn Creek in the immediate vicinity of the Project. The size of the watershed is about 14 km ² .

Baseflow is defined as the groundwater discharges into surface streams (i.e., water seeping into the creeks and rivers from groundwater). The rate at which groundwater discharges into surface streams was characterized based on the historical data recorded at the WSC Goathorn station using a recursive digital filter to separate baseflow from surface runoff (SRK 2020). A single filter parameter, typically ranging from 0.90 to 0.99, is used to separate total streamflow into a baseflow and surface runoff component (Nathan and McMahon 1990). The filter parameter was selected based on parsing flow records from 2000 to 2019. A filter parameter of 0.99 was found to best fit the data after three passes (n=3). The unit baseflows and monthly baseflows estimated are provided Table 2-3 and plotted in Figure 5.

Table 2-3: Estimated average unit and monthly baseflows

Month	Unit Baseflow (L/s/km ²)	Baseflows (L/s)					
		Cabinet Ck at Goathorn (54 km ²)	Four Ck at Goathorn (14.2 km ²)	Goathorn Ck at Cabinet (50.3 km ²)	Goathorn Ck at Four (116.7 km ²)	Goathorn Ck at 08EE008 (133.5 km ²)	Tenas Ck at Goathorn (58.6 km ²)
Jan	2.03	109.9	28.7	102.2	237	271	119
Feb	1.96	106	27.7	98.6	228.6	261	114.8
Mar	1.93	104.3	27.3	97.1	225	257	113
Apr	1.98	106.9	28	99.5	230.6	264	115.8
May	2.60	140.5	36.7	130.7	303	347	152.1
Jun	4.05	219.1	57.3	203.9	472.7	541	237.3
Jul	4.91	265.5	69.4	247	572.7	655	287.5
Aug	4.49	243.2	63.6	226.2	524.5	600	263.4
Sep	3.76	203.3	53.2	189.1	438.5	502	220.2
Oct	3.17	171.7	44.9	159.7	370.3	424	185.9
Nov	2.51	135.8	35.5	126.3	292.9	335	147.1
Dec	2.09	113	29.5	105.1	243.6	279	122.3

Source: SRK report Oct 2020: Tenas Project – Hydrometeorological Baseline and Model Development Report.

Note:

Calibrated Unit Baseflow (CUB) = 1.81 L/s/km²,

2.5 Bedrock Geology

The project is located within the northeast/southwest trending Skeena Arch, which separates Jurassic-age sedimentary rocks of the Bowser Basin in the north from the Jurassic to Cretaceous-age sedimentary rocks of the Nechako Basin to the south. The coal-bearing sedimentary rock sequence is associated with the Lower Cretaceous age Skeena Group, and overlies unconformably the Jurassic-age Hazelton volcanic group. Figure 6 presents a simplified stratigraphic column of the Tenas, Goathorn, and North regions.

Figure 7 shows the geological map of the Telkwa Coal field based on the MEMPR geological map (B.D. Ryan, 1993-21) and modified by TCL (2018), and Figure 8 three cross-sections associated with the MEMPR geological map. Figure 9 presents the local geological map of the Tenas area from TCL, and Figure 10 to 13 four cross sections associated with the local geology map.

2.5.1 Jurassic Hazelton Volcanic Group

The volcanic rocks (i.e., Figure 7: Telkwa formation - volcanic rocks) include andesite, trachyte, and basalt with associated tuffs and breccias. Figure 14 shows samples of the volcanic rock collected from a diamond core drilling rig in the Tenas area.

2.5.2 Lower Cretaceous Skeena Group

The Lower Cretaceous Skeena Group includes marine and continental sediments interbedded with coal seams, often correlated over long lateral distances. It is subdivided into four units (Units I through IV) and a unit of undivided sediments overlying the four units (Figure 6). The economic coal seams in the Tenas area (coal zone 1, Lower and Upper) are located within Unit I; Unit III is absent from the Tenas area but present in the Goathorn and North areas.

- Unit I consist of more than 100 m of fine to coarse-grained cross-bedded sandstone, conglomerate, siltstone, mudstone and coal (coal zone 1). Overall, Unit I fines upward, from primarily conglomerate and sandstone to almost entirely carbonaceous mudstone, seatearth and coal (1A to 1G). The conglomerate and sandstone were deposited in braided channels and bars, and mudstone accumulated in floodplains. Thin coal seams formed in poorly drained, peat-forming backswamps, and seatearths formed under leaching conditions in less submerged areas. With denudation of the volcanic source area, braid plains were abandoned and extensive low-energy, peat-forming swamps were established, resulting in the formation of thick coal seams in the upper part of the Unit.
- Unit II separates coal zone 1 and coal zone 2. It consists of up to 140 m of primarily of a monotonous silty mudstone, occasionally interbedded with beds of chert-rich, micaceous, bioturbated or cross-bedded sandstone. The sediments were deposited in a deltaic/shallow marine environment following a regional marine transgression. The mudstone accumulated in bays, and the sandstones in distributary channels and mouthbars. Locally, thin discontinuous peat beds formed in salt marshes.
- Unit III comprises about 90 m of chert-rich, micaceous sandstone, siltstone and mudstone, and up to nine coal zones (coal zones 2 through 10). The sandstone and mudstone were deposited and biogenically reworked in a tidal flat environment; siltstone accumulated in a restricted, nearshore marine environment. Peat accumulated in freshwater coastal marshes which periodically prograded over tidal flats.
- Unit IV consists of approximately 150 m of a laterally extensive, bright green, chert-rich, chloritic sandstone or siltstone bed at the base, overlain by massive grey silty mudstone similar to that of Unit II. The basal sandstone is a transgressive lag deposit, and silty mudstone, the predominant lithofacies, was deposited in a quiet, nearshore, shallow marine environment.

Figure 15 shows samples of the Skeena Group sediment rocks collected from a diamond core drilling rig in the Tenas area.

2.5.3 Intrusions

Tertiary and Cretaceous-age porphyritic dykes and sills (i.e., Figure 7: Bulkley plutonic suite – intrusive rocks) are present, the most notable of which includes a large Tertiary granodiorite plug located on the north side of the Telkwa River.

2.5.4 Geological Structures

Figure 7 and Figure 9 show the geological structures at the scale of the Telkwa coal field and Tenas area respectively.

The sedimentary sequence in the Tenas area is folded into an upright syncline in which the gently (typically 10 to 20°) northeast-dipping western limb of the syncline subcrops on the western side of the pit area, while the moderately (40 to 45°) southwest-dipping eastern limb subcrops on the eastern side of the pit. Faulting is generally near-vertical, and can be subdivided into two main groups, one which strikes approximately northwest/southeast and the other northeast/southwest. A few east/west striking faults have also been interpreted.

The Goathorn area is located within an outlier of the Lower Cretaceous Skeena Group. The structural geology is somewhat more complex than the Tenas area and is characterized by a complex series of sub-parallel north-south trending reverse faults, and to a lesser extent east-west, trending normal faults.

Northeast striking faults are related to emplacement of the Bulkley intrusions in the Late Cretaceous.

2.6 Surficial Geology

The surficial geology consists primarily of glacial clay- silt-rich till, and glaciofluvial sand-gravel-rich till (Figure 16). The 2018 and 2019 drilling investigations showed the till was generally a sandy lean clay with gravel. The clay-silt-rich till typically contained silt and fine sand with some gravel, was commonly very-stiff to hard in consistency with low to medium plasticity, and well graded. Sand, silt and gravel lenses were commonly encountered within the till at depth across the north of the project site. The sand-gravel rich till was dense to very dense as assessed by standard penetration testing during the sonic drilling. Figure 17 shows typical samples of overburden collected with a diamond core or a sonic core drilling rig, and Figure 18 shows particle distribution curves (PSD) of samples classified as clay-silt-rich tills, and sand-gravel-rich tills. At upper elevations and south of the proposed pit, the bedrock outcrops are close to ground surface, with mantles of clay-silt-rich tills between 3 m and 10 m thick. North of the proposed pit and towards Tenas Creek and Goathorn Creek, drillholes report thin mantles of clay- silt-rich tills deposits, between 3 m and 10 m thick, underlain by a thick sand-gravel-rich till that can exceed 100 m.

Other deposits are present locally. Patches of glaciolacustrine deposits are scattered throughout the morainal landscape in low ridges and in depressions, comprising bedded and laminated mud, and minor sand and gravel (Clague 1984). Recent fluvial deposits are present in the narrow floodplains of Goathorn Creek and Tenas Creek, which are 40 m to 80 m deep incised into the

subdued morainal landscape, and the wide floodplains of the two-wandering gravel-bed rivers, the Telkwa River and the Bulkley River. The fluvial deposits range from extremely coarse, poorly sorted gravel on steep alluvial fans to moderately to well-sorted sand and mud on low-gradient floodplains (Clague 1984).

2.7 Project Description

The following description consists of an overview of the proposed mine components, adapted from Section 1 of the main EA document.

2.7.1 Mine Plan

The Project configuration is shown on Figure 19. It will consist of a conventional shovel and truck coal extraction operation, similar to other rock quarry and surface mine operations in the region. The estimated total area disturbed by the Project is 840 ha, including the open pit (289 ha), the coal processing plant (10 ha), material storage facilities (137 ha), sediment ponds (40 ha), and management ponds (227 ha).

The Project will include the following major components:

- Open pit.
- Coal Processing Plant (CPP).
- Coal handling systems for run-of-mine (ROM) coal, processed rock, and processed coal (including plant conveyors, storage bins, and stockpiles).
- Storage piles and stockpiles for rock (non-PAG), overburden, growth media, and processed coal.
- Three management ponds for storage of potentially acid generating (PAG) rock: the North (NMP), the East (EMP), and the West Management Ponds (WMP).
- One control pond.
- Four sedimentation ponds: The Plant Sedimentation Pond, Rail Infrastructure Sedimentation Pond, Explosives Site Sedimentation Pond, and Explosives Magazine Sedimentation Pond.
- Surface water ditches.
- Water supply wells, storage, and distribution network.
- Fuel and lubricant storage facilities and distribution network.
- Explosive's magazine, storage silos, and vehicle wash and maintenance facilities.
- Propane storage facilities and distribution network (no longer required).
- Solid waste management systems including landfill, recycling and composting facilities.

- Administration, first aid, maintenance/warehouse, mine dry, laboratory, light vehicle, mine rescue, and warehouse buildings.
- Haul roads and access roads within the minesite.
- Tenas Access Corridor which encompasses a 11 km newly constructed Bypass Road and improvements to approximately 5.0 km of an existing forestry service road.
- A 3.5 km long 25 kV powerline and a 25 to 600 kV substation adjacent to the CPP.
- A rail infrastructure consisting of processed coal stockpiles, scales, dust control facilities and a 2.5 km rail loop connected to the Canadian National Railway track.
- A permanent bridge over Goathorn Creek.

2.7.2 Waste Management

TCL has identified several types of material associated with coal extraction that will need to be managed:

- **Growth Media (Non-PAG)** is the top 0.20 to 0.50 m of material and contains the bulk of organic material and material acceptable for the growth of vegetation. There is approximately 1.75 million m³ of this material. This material will be stockpiled in designated locations for reclamation activities or direct placed on areas available for growth media placement.
- **Overburden (Non-PAG)** is the non-rock material between growth media material unit and the rock unit that consists of primarily till material with almost no organic material. There is approximately 24 million m³ of this material. This material will be placed into the critical compaction zones and/or buttress components of the dams required for the management ponds, otherwise it will be placed as backfill within the pit.
- **Low sulfur rock (Non-PAG)** is the rock present in the Project's pit area that has sulfur levels with little potential to cause ARD. This material is also known as non-acid-generating (Non-PAG) rock. There is approximately 29 million m³ of this material. This material will be placed within the buttress region of the dams for the management ponds otherwise it will be backfilled within the pit.
- **High sulfur rock (PAG)** is the rock present in the Project's pit area that has sulfur levels that are elevated and will have the potential to cause ARD. This material is also known as PAG rock. There is approximately 31 million m³ of this material. All PAG material will be placed into external flooded management ponds or within flooded portions of the pit.
- **Processed rock (PAG)** is the rock produced during coal processing to produce a processed coal suitable for the marketplace that will be separated from the coal through gravity separation methods, such as cyclones. This material is classified as PAG material. There is approximately 3.3 million m³ of this material. All PAG material will be placed into external flooded management ponds or within flooded portions of the pit.
- **Run-of-mine (ROM) coal** is the coal that is recovered in the open pit from mining operations and then hauled to the CPP to be placed into one of two stockpiles. These stockpiles are

expected to be constantly changing in response to pit production sequence, marketing requirements, and plant production requirements. There is approximately 22.0 Mt of ROM coal recovered during the life of this Project.

- **Processed coal** is the coal after it has been washed in the CPP removing unwanted rock from the coal so that it is suitable for the marketplace. Based on the work completed, there is approximately 16.0 Mt of processed coal.

2.7.3 Water Management

Surface water management features (i.e., ditches, sedimentation ponds and management ponds) are illustrated in Figure 19.

Upslope diversion ditches will divert non-contact water away from the material storage piles and surface mine areas into existing natural watercourses. Downslope collection ditches will collect runoff from the material storage areas and divert it into sedimentation ponds for treatment with approved flocculants to reduce total suspended solid levels.

The storage management ponds (i.e., NMP, EMP, and WMP) will collect the groundwater pumped from the pit during operation. These ponds are designed for underwater long-term storage of potentially acid generating (PAG) material to limit its potential exposure to oxygen. The Control Pond will collect surface runoff from the mine infrastructure and overflows from the management ponds. It is designed to ensure that no water discharge will occur during operations between the October 31 and March 31 period and to control the sedimentation for the overall site. It provides also contingency water to ensure PAG material is submerged, and a location for water displaced during management pond operations. The storage management will be lined with engineered soil-bentonite compacted layers (i.e., 0.56 m thick for EMP and NMP, and 0.45 m thick for WMP), and the Control Pond with a bituminous geomembrane. The design details of the management ponds and Control Pond are documented in Part A, Section 1 of the EAC Application.

Raw water is required for CPP make-up water and for the mine infrastructure complex, i.e., heavy vehicle and explosive facility wash bays, workshop hoses, and non-potable water requirements. Raw water is estimated at approximately 14,000 m³ per month (about 15 m³/h) and will be sourced from precipitation and melting snow collected onsite. Potable water for domestic facilities will be sourced from surface runoff and/or groundwater; a potable water treatment plant will be onsite to ensure that drinking water standards are met.

Another 1.5 million m³/year of make-up water is assumed for additional contingency and robustness to the water balance. This water would be sourced from Goathorn Creek (i.e., approx. 2.5% of Goathorn's Creek and less than 1% of the Telkwa River's annual flow respectively) via water supply wells located along the edge of Goathorn Creek.

2.7.4 Project Phases and Scheduling

The Projected mine life is approximately 25 years, including approximately 1.5 years of construction, 21 years of operations (2022 to 2043), and 4 years of decommission and reclamation (2044 to 2047).

Major activities during construction will include site clearing, pre-stripping, building construction, road development, rail loop construction, bridge construction, and development of onsite utilities and services.

Mining operations are scheduled to commence in the north portion of the pit to excavate overburden, and to construct the initial embankment structures for the Control Pond and the NMP. The Control Pond will be constructed first along with the Plant Sedimentation Pond, then NMP will follow. Once the NMP reaches approximately 50% of its planned capacity, excavation of PAG rock will start to expose the first coal. Between 2023 and 2025 mining will continue west to produce overburden for the management ponds while for coal release, mining will move towards the south. In 2025 and continuing through to 2031 mining will start and the initial phases of the pit will be available for backfill. Mining will also continue working west producing overburden for the embankments associated with the management ponds. In 2032, mining will move to the far southern tip of the pit and proceed towards the central area of the pit through to the completion of mining in 2043.

Once mining is complete, decommissioning and reclamation activities will commence with the removal of all buildings and structures. Any pile or pit walls that have not been sloped will be sloped and have topsoil placed on them. Vegetation and monitoring activities will then complete the reclamation phase. Once water coming into contact with the mine and flowing through the Control Pond meets acceptable turbidity values for a number of years, this structure will be allowed to drain, and a wetland will be established in the former bottom of this pond.

3 Groundwater Baseline Studies

This section summarizes important information for understanding how the baseline groundwater conditions were evaluated.

3.1 Spatial Boundaries

The spatial boundaries define the limits within which changes to the groundwater system will be evaluated. Two spatial boundaries were considered for the groundwater assessment: the Local Study Area (LSA) and the Regional Study Area (RSA).

The LSA is defined as where the Project may have a direct influence on the groundwater system and/or groundwater users. The area was delimited based on watersheds and to include the project footprint, and the private domestic wells located downgradient of the Project. The RSA is a larger area defined by the fish habitats in the Telkwa River watershed and in the tributaries to the Bulkley River crossed by the haul road; it is used to provide context for the assessment of potential Project effects and represents the cumulative effects assessment study area. The extent of the LSA and RSA are shown on Figure 20.

3.2 Temporal Boundaries

The temporal boundaries encompass the periods during which the Project is expected to have potential effects on the Hydrogeology. The relevant time-steps used for the assessment are presented in Table 3-1.

Table 3-1: Temporal Boundaries for Hydrogeology

Phase	Project Year	Description of Activities
Construction	2020	Site clearing, pre-stripping, construction of the buildings, roads, rail loop, bridge, and onsite utilities and services
End-of-Year 1 (EoY1)	2023	Excavation of the pit and development of material storage piles. Coal processing. Dewatering of the pit. The Control Pond and NMP are constructed.
End-of-Year 7 (EoY7)	2029	Excavation of the pit and development of material storage piles. Coal processing. Dewatering of the pit. The Control Pond, NMP, and EMP are constructed.
End-of-Mine (EOM)	2043	The mine is fully excavated. Dewatering of the pit. The Control Pond and all the management ponds are constructed, and water levels are at their maximum.
Post-closure	To be determined from monitoring	No activities. All infrastructures removed and reclaimed except the storage ponds.

3.3 Regulations and Guidelines

The groundwater baseline studies for the Project were designed to meet the requirements of a Joint Application for *Mines Act and Environmental Management Act Permits* (BC MEM & BC MOE, 2016). Groundwater is a valued component of the biological and physical environment and is protected under the Groundwater Protection Regulation of the British Columbia (BC) *Water Sustainability Act* (2016).

The environmental guidelines listed below were consulted to help with the characterization of the groundwater baseline conditions and the assessment of potential Project influences on the groundwater system:

- *Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities*, prepared by BC MOE (2012).
- *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators*, prepared by the BC MOE (Version 2, 2016).
- *Draft Guidelines for the Preparation of an Environmental Impact Statement, December 2015*. Prepared by the Canadian Environmental Assessment Agency.

- Framework for a Hydrogeologic Study in support of an Application for an Environmental Assessment Certificate under the Environmental Assessment Act and Regulations (BC Ministry of Environment, Water Stewardship Division 2019).
- Information Sources
- SRK reviewed the information listed in the next two sections. The level of details, methods, and quality of the information were considered to be adequate for a Joint Application for a Mines Act permit, and for an effluent discharge permit.

3.3.1 Desktop Information

- TCL 2018 drillhole database (dated 27 Nov. 2018)
- Technical reports from Klohn Leonoff Consulting Engineers (Klohn, 1985), Piteau Engineering Ltd (Piteau 1990, 1994, 1995, 1996a, 1996b, 1997a, 1997b, 1998), Stantec (Stantec 2016) and field and technical baseline memo/reports produced ERM (2017, 2020), Cassiar (2020ab), or SRK (2018, 2019) between 2018 and 2020.
- Groundwater baseline data – Hydrogeology and groundwater quality (ERM 2020).
- Digital Elevation Model (DEM) from a LIDAR survey conducted in August 2017 on behalf of TCL.
- Geological publications and maps (Clague 1984, Plasgrove 1991, Massey 2005, BC Gov 2018).
- Digital maps and databases of aquifers, domestic and private wells, and water licences (BC Government 2018, BC MOE 2018abc).
- Monthly precipitation grids for Alaska, British Columbia, and Yukon (Stavros 2016).
- Raster grid of a global estimation of groundwater recharge (Jasechko 2014).

3.3.2 Field Investigations

Baseline studies were initiated between 1983 and 1998 by the former owners of the Project property, Crowsnest Resources and Manalta Coal Ltd. TCL continued and expanded on these studies since 2016, after acquiring the property. Table 3-2 lists all the field programs related to groundwater and Table 3-3 compiles a summary of the available groundwater field data.

Table 3-2: List of the hydrogeological field investigation conducted for the project

Author	Date	Area	Description
Klohn Leonoff ⁽¹⁾	1982-1984	Pit 3 ⁽⁴⁾	Borehole drilling and installation of 20 piezometers within bedrock. Falling head permeability tests and packer tests in selected coal horizons. Groundwater sampling.
Piteau ⁽²⁾	1989	Pit 7&8 ⁽⁴⁾	Borehole drilling and installation of 5 piezometers within bedrock. Rising head permeability tests. Measurements of groundwater levels in piezometers and open boreholes. Groundwater sampling.
	1993	Pit 7&8 ⁽⁴⁾	Borehole drilling and installation of 5 monitoring wells within bedrock and 1 within surficial till. Rising head permeability tests. Groundwater sampling.
	1995	Tenas Pit	Borehole drilling and installation of 5 monitoring wells within bedrock. Rising head permeability tests. Groundwater sampling.
	1996	Tenas Pit	Preliminary assessment of potential groundwater inflows and dewatering requirements for the Tenas Pit. Borehole drilling and installation of 5 monitoring wells within bedrock and 6 within surficial sediments. Rising head permeability tests. Groundwater sampling.
	1996	Pit 3 ⁽⁴⁾	Borehole drilling and installation of 5 monitoring wells within bedrock and 6 within surficial sediments. Rising head permeability tests. Groundwater sampling.
	1996	Former Tailings Pond	Borehole drilling and installation of 6 monitoring wells within surficial sediments. Rising head permeability tests. Groundwater sampling. Mapping of the surficial geology based on air-photo interpretations.
	1997	Pit 3, Tenas Pit, Pit 7 & 8 ⁽⁴⁾	A 7h aquifer test in the northern portion of Pit 3. Domestic well survey in area extending three to five km north of Pit 3. Borehole drilling and installation of 27 piezometers in Reclamation Pit (test pit originally excavated in 1983). Groundwater sampling from nearby domestic wells and from all piezometers, where possible
Stantec ⁽³⁾	2016	Tenas Area	Inspection of 6 monitoring wells around the northern portion of the Tenas Pit. Of the 6 wells inspected, only 1 was not dry or damaged. Groundwater samples were taken from 3 wells.
ERM, Cassiar Geoscience, and SRK	2017-2019	Tenas Area, Access Road, Rail loadout	Hydrogeology baseline monitoring program: Inspection of 22 existing monitoring wells to determine their usability for the baseline program on July 25 and 26, 2017; Field reconnaissance of seeps along Tenas and Four Creek; Drilling of 26 boreholes, and installation of 1 pumping test well, 18 single screen and 2 nested monitoring wells (8 screens in bedrock and 15 in surficial sediments), and three vibrating wire piezometers. Development of all the new wells; 1 pumping test, 13 packer injection tests performed in 3 boreholes, 12 rising or falling head permeability tests completed in 11 monitoring wells, and 19 K values inferred from PSD analyses in overburden at 17 locations; Automatic measurements of continuous groundwater levels at 5 monitoring wells since Sep.2017, and 16 campaigns of manual measurements at the monitoring wells between Jul.2017 and Nov. 2019. Quarterly groundwater quality monitoring at 13 monitoring wells initiated in July 2017.

Notes:

1. Klohn Leonoff Consulting Engineers (1985).
This original report could not be found, but the associated data is included in Piteau's technical report (1998).

2. Piteau (1990, 1994, 1995a, 1996a, 1996b, 1997a, 1997b).

3. Stantec (2016).

4. Pit names have changed compared to the EA mine plan described by Manalta Coal Ltd. in 1998. The Tenas Area englobes the Tenas North Pit and the Tenas West Pit, the Goathorn Area englobes the Pit 3 and Pit 6, and the North Area englobes the Pit 7 and Pit 8.

Table 3-3: Summary of the available groundwater data

Parameter	Method/Type	Tenas Area ⁽¹⁾	Goathorn Area	North Area
Hydraulic conductivity tests (K)	Grain size analyses	19 (ovb)	-	-
	Rising head tests	10 (ovb), 19 (bdr)	2 (ovb), 19 (bdr)	8 (bdr)
	Packer injection tests	13 (bdr)	-	-
	Pumping tests	1 (bdr)	1 (bdr)	-
Monitoring wells (MW)	Screen within ovb.	26	6	1
	Screen within bdr.	19	22	7
	Multiple screen MW	6	7	2
Groundwater level observations	Manual	Up to 28 levels measured in ovb in a single event and 26 in bdr (i.e., Mar/Apr 2019). Period of records: Aug.94 to Nov.19.	6 levels measured in ovb, and 28 in bdr. Period of records: Sep.96 to Sep.97.	2 levels measured in ovb, and 22 in bdr. Period of records: Nov.89 to Sep.97.
	Automated	5 loggers (2 in ovb, 3 in bdr). Period of records: Sep.17 to Aug.20.	-	-
Groundwater samples ⁽²⁾	3 in Oct.1995 (bedrock). 7 in Sep./Oct.1996 (4 bedrock / 3 overburden). 8 in Aug./Sep.1997 (4 bedrock / 4 overburden). 99 between Nov.2016 to Nov.2019 (50 from bedrock and 49 from overburden).			

Notes:

Ovb, Overburden; Bdr, Bedrock

1. Tenas area includes the Tenas, access road, and rail loadout areas.

2. Samples collected in the Tena area.

3.4 Field Data Collection Methodology, QAQC, and Data Management

The methodologies, QA/QC procedures, and observations of the groundwater baseline monitoring program are detailed in Section 17 of the EAC Application. SRK reviewed the information and compiled the data into excel spreadsheets, and GIS databases (ArcMap and Leapfrog) for analyses and mapping. All monitoring locations (hydraulic conductivity (K) tests intervals, groundwater levels, and seep locations) were plotted in 3D space based on the high-resolution LIDAR or surveyed collar elevation, and Telkwa database of drillhole surveys.

4 Groundwater Baseline Data

This section summarizes the groundwater data collected to date, as of August 2020, that supports the characterization and understanding of the groundwater system at the Project.

4.1 Monitoring Network

Figures 21 to 23 shows the monitoring well locations. Table 1A in Appendix A provides detailed information on each well.

4.2 Hydraulic Conductivity

A total of 92 values of hydraulic conductivity (K) values were obtained since the exploration of the Telkwa coal field started. Table 4-1 compiles a statistical summary of the test results. Figure 25 shows a 3D perspective views of the K tests, Figure 26 and Figure 27 box plots and histograms of K frequencies by lithological unit, Figure 28 a plot of K values versus elevation, and Figure 29 a plot of K values versus depth. Additional details are provided for the individual tests in Table 1B, Appendix B.

Table 4-1: K statistics

SUB-CLASS		TENAS AREA						GOATHORN AREA						NORTH AREA					
		n	K min	K harm	K geo	K arith	K max	n	K min	K harm	K geo	K arith	K max	n	K min	K harm	K geo	K arith	K max
		#	m/s	m/s	m/s	m/s	m/s	#	m/s	m/s	m/s	m/s	m/s	#	m/s	m/s	m/s	m/s	m/s
ALL TESTS		62	7x10 ⁻¹¹	2x10 ⁻⁹	1x10 ⁻⁷	2x10 ⁻⁶	5x10 ⁻⁵	22	8x10 ⁻¹²	2x10 ⁻¹⁰	1x10 ⁻⁸	3x10 ⁻⁷	4x10 ⁻⁶	8	3x10 ⁻⁹	1x10 ⁻⁸	4x10 ⁻⁸	1x10 ⁻⁷	4x10 ⁻⁷
BEDROCK		33	3x10 ⁻⁹	3x10 ⁻⁸	2x10 ⁻⁷	7x10 ⁻⁷	6x10 ⁻⁶	20	8x10 ⁻¹²	1x10 ⁻¹⁰	1x10 ⁻⁸	3x10 ⁻⁷	4x10 ⁻⁶	8	3x10 ⁻⁹	1x10 ⁻⁸	4x10 ⁻⁸	1x10 ⁻⁷	4x10 ⁻⁷
Bedrock Lithologies	Coal seams	12	2x10 ⁻⁸	1x10 ⁻⁷	5x10 ⁻⁷	1x10 ⁻⁶	6x10 ⁻⁶	16	2x10 ⁻¹⁰	1x10 ⁻⁹	2x10 ⁻⁸	4x10 ⁻⁷	4x10 ⁻⁶	8	3x10 ⁻⁹	1x10 ⁻⁸	4x10 ⁻⁸	1x10 ⁻⁷	4x10 ⁻⁷
	Sandstone	3	4x10 ⁻⁸	9x10 ⁻⁸	2x10 ⁻⁷	3x10 ⁻⁷	5x10 ⁻⁷	1	1x10 ⁻⁶					0	n/a				
	Mudstone, Siltstone	9	8x10 ⁻⁹	3x10 ⁻⁸	7x10 ⁻⁸	7x10 ⁻⁷	5x10 ⁻⁶	2	8x10 ⁻¹²	2x10 ⁻¹¹	1x10 ⁻¹⁰	1x10 ⁻⁹	3x10 ⁻⁹	0	n/a				
	Conglomerate	2	7x10 ⁻⁹	2x10 ⁻⁸	2x10 ⁻⁸	3x10 ⁻⁷	6x10 ⁻⁸	0	n/a					0	n/a				
	Volcanic rock	7	3x10 ⁻⁹	1x10 ⁻⁸	1x10 ⁻⁷	4x10 ⁻⁸	9x10 ⁻⁷	0	n/a					0	n/a				
	Not defined	0	n/a					1	2x10 ⁻⁹					0	n/a				
OVERBURDEN		29	7x10 ⁻¹¹	1x10 ⁻⁹	6x10 ⁻⁸	3x10 ⁻⁶	5x10 ⁻⁵	2	8x10 ⁻⁹	1x10 ⁻⁸	1x10 ⁻⁸	1x10 ⁻⁸	1x10 ⁻⁸	0	n/a				
Overburden Lithologies	Clay/Silt	17	7x10 ⁻¹¹	7x10 ⁻¹⁰	9x10 ⁻⁹	1x10 ⁻⁷	7x10 ⁻⁷	2	8x10 ⁻⁹	1x10 ⁻⁸	1x10 ⁻⁸	1x10 ⁻⁸	1x10 ⁻⁸	0	n/a				
	Sand/Gravel	5	6x10 ⁻⁸	2x10 ⁻⁷	1x10 ⁻⁶	3x10 ⁻⁶	1x10 ⁻⁵	0	n/a					0	n/a				
	Mixed grains	7	7x10 ⁻⁹	4x10 ⁻⁸	7x10 ⁻⁷	8x10 ⁻⁶	5x10 ⁻⁵	0	n/a					0	n/a				

Note:

n Number of tests.
K min Minimum K value.
K harm Harmonic mean
K geo K geomean.
K arith Arithmetic mean
K max Maximum K value.
n/a Not applicable.

4.2.1 Bedrock

- Bedrock has a low to moderate hydraulic conductivity. K values in the Tenas area are generally higher than in the Goathorn and North areas, with a geomean of 2×10^{-7} m/s, 1×10^{-8} m/s and 4×10^{-8} m/s respectively. The differences between Tenas, Goathorn, and North may result from the heterogeneity of the overall sedimentary sequence; the tested unit in the Tenas area is the Unit I of the Skeena group, and in the Goathorn and North areas it is the Unit III.
- Geomean K values sorted by lithology for the Tenas area, from the least permeable to the most permeable, are conglomerate (2×10^{-8} m/s), mudstone/siltstone (7×10^{-8} m/s), volcanic rock (1×10^{-7} m/s), sandstone (2×10^{-7} m/s), and coal (5×10^{-7} m/s).
- A progressive reduction of K values with depth (Figure 29) is interpreted to occur due to a reduction of fracture apertures with depth as lithostatic load increases.
- Piteau (1998) conducted a pump test in the Goathorn area as a mean to assess the potential role of faults. Pumping lasted seven hours at a constant rate of $15.8 \text{ m}^3/\text{day}$. The test did not conclusively confirm the hydraulic role of the faults in that area. The transmissivity of the bedrock (interval between coal seam #2 and top of bedrock) was determined to be relatively low, in the range of 0.02 and $0.24 \text{ m}^2/\text{day}$. The observations in nearby wells suggested limited lateral hydraulic connection within the coal seam #2, and between the seam and underlying mudstone. No measurable drawdown occurred in observations wells completed in coal, the closest of which was approximately 170 m away, nor in a well installed in the underlying mudstone, less than 10 m away from the pumping well.
- In March 2019, Cassiar Geoscience and SRK conducted a pump test in T18-01D (ARD2), in the Tenas area, to estimate the physical properties of the sandstone aquifer and test if there was a hydraulic connection between the sandstone and the overlying coal seam units. Pumping lasted 20 hours at a constant average rate of $7.5 \text{ m}^3/\text{day}$. There was no drawdown observed in T95R-64, the closest well available, approximately 440 m away; therefore, the test did not confirm the hydraulic connection with the overlying coal seams. The interpretation of the drawdown and recovery curves indicated hydraulic conductivity of the sandstone was consistent with the other K measurements; Theis Recovery Analysis – 4×10^{-7} m/sec, and Theis Step Test (Drawdown and Recovery) – 1×10^{-7} m/sec. The test also showed a boundary started to influence drawdown after about five and half hours of pumping; the interpretation of the derivative drawdown curve indicated test was potentially influenced by a leaky aquifer (Cassiar 2020a).

4.2.2 Overburden

K in overburden varies according to lithologies. K in the clay-silt-rich till is relatively low, with a geomean of 9×10^{-9} m/s, and K in the sand-gravel-rich till is moderately high, with a geomean of 1×10^{-6} m/s.

4.3 Storage Properties

The specific storage (S_x) and specific yield (S_y) influence the volumetric water release in an aquifer induced per unit change of hydraulic head under saturated conditions, and the pressure response of the material. A specific storage value of 1.2×10^{-4} in bedrock was estimated from the pump test analysis in T18-01D (Cassiar 2020a); however, this analysis was based on groundwater level observations from the pumping well, which are less reliable than analysis based on observation wells. According to lithology, scientific literature (Domenico 1990, Singhal 2010), and professional experience (Piteau 1997, SRK 2018), the expected ranges are:

- In Bedrock, S_x between 1×10^{-7} and $1 \times 10^{-4} \text{ m}^{-1}$ and S_y between 0.01 and 0.2.
- In clay/silt deposits, S_x between 1×10^{-5} and $1 \times 10^{-2} \text{ m}^{-1}$ and S_y between 0.05 and 0.15.
- In sand/gravel deposits, S_x between 5×10^{-5} and $1 \times 10^{-3} \text{ m}^{-1}$ and S_y between 0.1 and 0.3.

4.4 Groundwater Levels

Table 1C in Appendix C reports the number of available monitored wells by area and dates; Table 2C the groundwater level statistics for each location; Table 3C vertical gradients estimated from dual/nested wells; and Table 4C the raw manual level data.

Figure 30 shows a map of the Tenas area with the inferred water tables associated with the overburden and bedrock units. The groundwater in both systems is interpreted to flow under an average horizontal hydraulic gradient of approximately 0.04 m/m in the overburden and 0.09 m/m in the bedrock, towards the valleys, moving away from the Tenas pit towards Tenas Creek, the Telkwa River, and Goathorn Creek. Static water levels are generally less than 2 mbgs (meters below ground surface) in the south part of the Tenas area, to more than 20 mbgs in the north part of the Tenas area, where overburden changes to thick sequence of sand-gravel-rich till deposits. Six wells¹ screened in bedrock indicated flowing artesian conditions, at least on a seasonal basis, and are interpreted to be controlled by topography. Six wells² showed small upward gradients from bedrock to overburden: and four wells³ downward gradients from overburden to bedrock or from bedrock upper layer to lower layers.

Figure 31 shows continuous groundwater level measurements recorded from Sep. 2018 to Aug. 2019, in TOB96-02-06 and TOB96-02-20 (screened in till, and sand and gravel respectively), and T95R64, T95R-15C, and T96R-16-19 (all screened in Coal unit 1). TOB96-02-20 is dry, the water levels dropped below the well screen bottom. The records at T95R-15C have a data gap between April and June.

The overburden well (TOB96-02-06) shows highs occur in spring with freshet and lows in winter; amplitude between highs and lows is about 3 m. The 2018 and 2019 records have differences; the peaks associated with freshet are offset (i.e., mid-May 2018 and mid-July 2019), and an increase of 1 m is observed between November 2017 and January 2018 but not in 2019. These

¹ T18-04D#2 (W01#D), T95R-15C, T95R-39C, T96R-34-67, T96R-34-87, T96R-56C-83

² 18-04D, 96R-16 (0.001 to 0.03)

³ 18-08D, 96R-34, OB96-02, OB96-11 (0.006 to 0.7, and >1 where groundwater perched in overburden)

differences correlate with the differences in precipitations (i.e., high rainfall in Oct. 2017, high snowfall in Feb. 2018, and a total precipitation of 672 and 502 mm/yr in 2018 and 2019 respectively with the snow equivalent to 70% of total precipitation in 2018 versus 30% in 2019).

The bedrock wells can be divided in two groups: one with T96R-16-19, the other with T95R-64 and T95R 15C. T96R-16-19 shows highs in spring with freshet, and lows in fall and winter; amplitude between highs and lows is about 1 m. The variations are similar to those observed in TOB96-02-06 which suggest the well is connected with overburden. Differences with overburden wells are noted but difficult to interpret: The winter 2017-2018 peak occurs earlier (Nov.17 versus Jan.18); level is low in August 2018 then increases gradually by a small amplitude, and contrary to the overburden well the 2018 and 2019 peak have similar magnitudes. T95R-64 and T95R 15C show a different trend: the highs are observed in winter and lows in summer and fall; amplitude is about 0.4 m. This implies recharge from precipitation is delayed by several months, potentially by the low permeability of the silt-clay-rich till. Differences between the two wells are noted but difficult to interpret: the highs and lows are offsets by about 1 to 2 months; and in the last three months of records the trends diverge (i.e., levels decline in T95R-15C, and increase in T95R-64).

4.5 Groundwater Seepages

In November and December 2018, ERM searched for seeps along the Tenas and Four creeks. The survey was completed via helicopter and during winter conditions to aid visual identification of seeps from the air. One seep was located and photographed on Tenas Creek. (Easting 617555 Northing, 6055416; Plate 17). The survey line, seep location and photo of the seep are shown on Figure 32. The geological control of this resurgence is uncertain. It could be linked to a perched system on top of clay. There is no mapped geological structure aligned with the seep.

4.6 Groundwater Quality

The baseline groundwater quality program and data (i.e., TCL's MW and residential wells) are detailed in EA Chapter 6; the locations of the monitoring well screens are shown in Figure 33.

Statistics for groundwater quality constituents in the overburden and bedrock units are provided in Table 4-2, exceedances compared the British Columbia water quality guidelines – freshwater aquatic life (BC WQG FAL, MOE 2020d) and drinking water sources (BC WQG DWS, MOE 2020e) are mapped in Figure 34, and a summary of the groundwater quality is presented in Appendix D. Piper plots of the observed groundwater quality are shown in Figure 35. The analysis of the groundwater quality shows:

- The pH value for the bedrock and the overburden wells ranges from 7 to 9 with the exception of T18-04 (W1D, W1S) and T18-08D (W3S). This is within the range of the British Columbia water quality guidelines – freshwater aquatic life (BC WQG FAL,) for pH of 6.5 to 9.0. The pH above 9 were observed in two opposite areas, to the west and south sides of the deposit respectively in W1D (9.1 to 9.6, seven out of eight events), W1S (9.1 to 9.6, three out of eight events), and W3S (7.8 to 9.2, one out eight events). They correlated with high turbidity values, which may indicate incomplete development within the holes.

- Turbidity was below the BC WQG – FAL value of 50 NTU (Nephelometric Turbidity Unit), with the exception of 19 samples in 8 monitoring wells (T95R-40, T95R-15C, T96R-34-87, T18-04, TOB96-02-20, TOB96-01-05, and T18-06 D). Turbidity values were generally slightly higher in the overburden wells in comparison to the bedrock wells due to the fine-grained nature of the glacially deposited material.
- Hardness (CaCO_3) - The bedrock groundwater is 'considered soft' and overburden groundwater 'hard'. Hardness in the bedrock wells ranged from 3.9 to 138.0 mg/L, with an average concentration of 51.3 mg/L, and in the overburden wells from 57.9 to 423.0 mg/L, with an average concentration of 222.8 mg/L.
- Anions and nutrients - Fluoride exceeded the BC WQG – FAL guideline of 0.4 to 2.0 mg/L (hardness dependent). In bedrock wells, fluoride ranged from 0.32 to 5.55 mg/L, with an average concentration of 1.68 mg/L; in the overburden wells from 0.086 to 0.383 mg/L, with an average concentration of 0.18 mg/L. Fluoride also exceeded the BC WQG - DWS guideline of 1.5 mg/L at T95R-64, T96R-34-87, T95R-15C, and T18-04D (W1D). Nitrate concentrations were below detection limits, except for two bedrock wells (T18-04D, T18-08D) and three overburden wells (TOB96-01-05, TOB96-02-06 and TOB-11-04). Low concentrations of nitrite were detected in one bedrock well (T18-08D) and four overburden wells (TOB96-02-06, TOB96-11-04, TOB96-02-20, and T18-08S). Ammonia concentrations exceeded the BC FWQ-FAL guidelines in two overburden wells (T18-08S March 2019, T18-06D September 2018, and April, June, August and November 2019).
- Exceedances of dissolved and total metals above BC WQG – FAL approved or working guidelines are summarized below; the complete dataset is provided in Section 17 of the EAC Application:
 - Exceedances of total arsenic (>0.005 mg/L): T95R-15C, T95R-40, T96R-34-87, TOB96-02-20, T18-08S (W3S) and T18-06D (W2).
 - Exceedances of total copper (>0.002 - 0.026 mg/L [hardness dependent]): T18-04D (W1D), and -04S (W1S), T18-08D (W3D), T95R-40, T95R-64, TOB96-02-20, TOB96-01-05, and T18-06D (W2).
 - Exceedances of total chromium (Cr^{III} >0.0089 mg/L; Cr^{IV} >0.001 mg/L): T95R-15C, T95R-40, T95R-64, T96R-34-87, TOB96-02-20, and T18-06D (W2).
 - Exceedances of total iron (>1 mg/L): T95R-15C, T95R-40, T96R-34-87, T18-04D (W1D), and -04S (W1S), TOB96-02-20, TOB96-11-04, TOB96-01-05, and T18-06D (W2).
 - Exceedances of dissolved iron (>0.35 mg/L): T95R-40, T95R-64, and T96R-34-87.
 - Exceedances of selenium (>0.002 mg/L): TOB96-02-20.
 - Exceedances of total zinc (>0.033 - 0.265 mg/L, [hardness dependent]): T95R-15C, T95R-40, T95R-64, T96R-34-87, T18-08D (W3D), and T18-06D (W2).

The wells installed before 2017 reported more exceedances for total and dissolved metals before 2017 than between 2017 to 2019, which suggest the historical exceedances where

caused by suspended particles derived from the formation (i.e., drilling and well installation disturbances) rather than natural dissolved metals in groundwater. This is also likely the case for the wells recently installed (i.e., 2017 to 2019) that reported exceedances of total metals; for the same metals and during the same sampling event, dissolved metal concentrations were below guideline values and generally below detection limits.

- Exceedances of dissolved and total metals above BC WQG DWS guidelines are summarized below:
 - Exceedances of dissolved antimony (>0.006 mg/L): T95R-64, T95R-40, T95R-15C (noted in only one sampling event at each location).
 - Exceedances of dissolved arsenic (>0.01 mg/L): T18-06D (W2).
 - Exceedances of dissolved iron (>0.3 mg/L): T95R-64, T95R-40, T96R-34-87, and T95R-15C.
 - Exceedances of dissolved cobalt (>0.001 mg/L): T95R-64, T95R-40, T95R-15C, T0B96-02-06, T0B96-02-20, T0B96-11-04, and T0B96-01-05.
 - Exceedances of dissolved mercury (>0.001 mg/L): T95R-64, T95R-40, T96R-34-87, T95R-15C, T0B96-01-05 (noted in only one sampling event at each location).
 - Exceedances of dissolved lead (>0.005 mg/L): T95R-64, T95R-40, T95R-15C, and T0B96-02-20 (noted in only one sampling event at each location).
 - Exceedances of dissolved manganese (>0.12 mg/L): T0B96-01-05, T18-06D (W2), and T18-08D (W3D), and noted in only one sampling event at T95R-64, T95R-40, T96R-34-87, T95R-15C, and T0B96-11-04.
 - Exceedances of dissolved uranium (>0.02 mg/L): T95R-64, T95R-40 and T95R-15C (noted in only one sampling event at each location).
- The piper plots show there are distinct hydrochemical differences between the shallow overburden wells (T0B96-11-04, T0B96-01-05, and T0B96-02-06), the deep confined overburden wells (T18-06D and T18-08D#1), the bedrock wells (T95R-15C, T95R-40, T95R-64, T94R-34-87, T18-04D#1 and #2, T18-08D#2) These differences are indicative of different residence time.
 - Groundwater from shallow overburden wells is classified as a calcium-magnesium-bicarbonate (Ca-Mg-HCO₃) type. TDS range: 167 to 427 mg/L. T0B96-02-20 and T0B96-01-05 show minor cation variability between sampling events/seasons, while T0B96-11-04 and T0B96-02-06 have very consistent hydrochemistry between sampling events/seasons.
 - Groundwater from the bedrock wells, and from one of the new deeper overburden wells (T18-06D), is classified as sodium-bicarbonate type with minor calcium, magnesium, sulphate and chloride. TDS range: 365 to 1,910 mg/L. There are minor ionic differences between the Skeena Group coal seam bedrock wells and the Hazelton Group volcanic bedrock wells, with the volcanic rocks having a slightly higher percentage of sulfate than

the coal seam bedrock wells. All the coal seam bedrock wells have similar chemistry. The groundwater from deep overburden is interpreted to have interactions with the underlying volcanic rock unit.

- Groundwater in the newly installed nested well T18-08 is also classified as a sodium-bicarbonate (Na-HCO_3) water type, although percentage of calcium + magnesium and sulfate are higher. The similar chemistry between upper and lower well screen may imply a hydraulic connection between the two lithologic units; a strong downward vertical hydraulic gradient is observed between the two wells.

Table 4-2: Average groundwater quality in overburden and in bedrock

Parameter	Units	Overburden Water Quality				Bedrock Water Quality			
		Avg.	P50	P95	Count	Avg.	P50	P95	Count
TSS	mg/L	840	15	2000	48	55	13	230	69
TDS	mg/L	330	340	410	48	920	820	1800	69
pH (Field)	-	7.9	7.7	8.8	46	8	7.7	9.2	68
Alkalinity, total	mg CaCO3/L	290	290	400	48	800	760	1700	69
Hardness, total	mg CaCO3/L	220	190	390	48	51	44	120	69
Specific Conductance	µS/cm	530	540	700	48	1400	1300	2800	69
Bromide	mg/L	0.061	0.05	0.1	39	0.35	0.25	1	57
Chloride	mg/L	1.5	0.52	3.3	48	4.2	2.5	10	69
Fluoride	mg/L	0.17	0.13	0.35	41	1.7	1.5	5.1	61
Sulfate	mg/L	18	11	42	48	24	6	75	69
Ammonia, total	mg-N/L	0.15	0.025	0.61	44	0.32	0.32	0.69	69
Nitrate	mg-N/L	0.04	0.005	0.17	41	0.07	0.025	0.16	58
Nitrite	mg-N/L	0.0016	0.001	0.005	41	0.0072	0.005	0.02	58
Nitrogen, total	mg/L	1.3	0.54	5.9	40	0.81	0.38	2.2	64
Aluminum, dissolved	mg/L	0.032	0.005	0.034	44	0.033	0.0086	0.1	69
Antimony, dissolved	mg/L	0.00052	0.0005	0.00054	37	0.022	0.0005	0.00097	61
Arsenic, dissolved	mg/L	0.0034	0.00081	0.011	44	0.0011	0.0006	0.002	69
Barium, dissolved	mg/L	0.12	0.093	0.25	45	0.85	0.33	3.6	69
Beryllium, dissolved	mg/L	0.00034	0.0001	0.0002	44	0.00079	0.0001	0.005	69
Boron, dissolved	mg/L	0.084	0.10	0.10	44	0.19	0.16	0.34	69
Cadmium, dissolved	mg/L	0.00012	0.000021	0.00027	45	0.00022	0.000012	0.0016	69
Calcium, dissolved	mg/L	51	50	86	46	16	14	35	68
Chromium, dissolved	mg/L	0.0015	0.001	0.001	44	0.0011	0.001	0.002	69
Cobalt, dissolved	mg/L	0.0009	0.0003	0.0041	44	0.00057	0.0003	0.0026	69
Copper, dissolved	mg/L	0.0016	0.001	0.005	45	0.0019	0.001	0.0039	69
Iron, dissolved	mg/L	0.043	0.03	0.099	44	0.2	0.065	0.59	69
Lead, dissolved	mg/L	0.0021	0.0005	0.00093	44	0.0014	0.0005	0.001	69
Lithium, dissolved	mg/L	0.0048	0.0028	0.0067	45	0.054	0.05	0.1	66
Magnesium, dissolved	mg/L	21	14	51	46	3	1.9	8.6	68
Manganese, dissolved	mg/L	0.13	0.052	0.57	45	0.061	0.017	0.25	69
Mercury, dissolved	mg/L	0.0012	0.000005	0.00018	44	0.0029	0.000005	0.03	69
Molybdenum, dissolved	mg/L	0.0053	0.001	0.015	45	0.0044	0.001	0.015	69
Nickel, dissolved	mg/L	0.0027	0.001	0.017	44	0.0021	0.001	0.005	69
Phosphorus, dissolved	mg/L	0.18	0.012	0.89	40	0.023	0.016	0.06	61
Potassium, dissolved	mg/L	1.8	2	2	44	2.2	2	3.5	68
Selenium, dissolved	mg/L	0.00032	0.0002	0.00096	45	0.00026	0.00014	0.001	69
Sodium, dissolved	mg/L	46	20	110	45	350	320	720	68

Parameter	Units	Overburden Water Quality				Bedrock Water Quality			
		Avg.	P50	P95	Count	Avg.	P50	P95	Count
Silver, dissolved	mg/L	0.0001	0.00002	0.00027	44	0.059	0.00002	0.0001	68
Thallium, dissolved	mg/L	0.00019	0.0002	0.0002	37	0.0002	0.0002	0.0002	58
Tin, dissolved	mg/L	0.001	0.0005	0.0049	36	0.00061	0.0005	0.00053	51
Titanium, dissolved	mg/L	0.012	0.01	0.024	44	0.013	0.01	0.05	66
Uranium, dissolved	mg/L	0.0017	0.0011	0.0032	45	0.023	0.0004	0.0071	69
Vanadium, dissolved	mg/L	0.0027	0.001	0.005	45	0.0039	0.00053	0.03	69
Zinc, dissolved	mg/L	0.011	0.005	0.012	44	0.0067	0.005	0.011	69

Source: GWQuality_Summary_Stats_rev08_smh.xlsx, (2020/11/19)

Note:
Avg., average
P50, 50th percentile
P95, 95th percentile

4.7 Groundwater Resources

The MOE Aquifer Classification Database (BC MOE 2020a) reports six aquifers located near the town of Telkwa, where the Telkwa River joins the Bulkley River, about 8 to 10 km north east from the Project. Each aquifer is described in Table 4-3. Their outlines are mapped in Figure 36.

Table 4-3: Description of the minor aquifers (BC MOE Well database)

Ref. Number	Class (1)	Rank (2)	Size (km ²)	Description	Productivity
569	IIC	7	2.4	Confined sand and gravel aquifers within undifferentiated sediment, overlain by fluvial and glaciomarine sediments (silt and clay).	Moderate. Well yields reported range between 0.23 and 3.0 L/s, median 0.95 L/s.
576	IIC	11	5	Confined sand and gravel aquifers within undifferentiated sediment, overlain by fluvial and glaciomarine sediments (silt and clay).	High. Well yields reported range between 0.30 and 1.5 L/s, median 0.83 L/s.
578	IIC	8	159.8	Confined bedrock aquifer. Predominately Middle Jurassic extrusive igneous rock. Minor sedimentary rocks are also noted (i.e., sandstone, conglomerate, and shale).	Low. Well yields reported range between 0.005 and 1.5 L/s, median 0.15 L/s.
581	IIIC	9	26.7	Confined sand and gravel aquifers within undifferentiated sediment, overlain by fluvial and glaciomarine sediments (silt and clay).	Moderate. Well yields reported range between 0.15 and 8.18 L/s, median 0.76 L/s.
582	IIB	9	0.83	Unconfined sand and gravel aquifer.	Moderate. Well yields reported range between 0.38 and 3.8 L/s, median 1.1 L/s.
583	IIA	10	2.47	Unconfined sand and gravel aquifer.	Moderate. Well yields reported range between 0.23 and 1.9 L/s, median 0.91 L/s.

Note:

- ¹ Development subclass: the level of development of an aquifer is determined by assessing demand verses the aquifer's yield or productivity - high (I), moderate (II), or low (III); Vulnerability subclass: the vulnerability of an aquifer to contamination from surface sources is assessed based on: type, thickness and extent of geologic materials overlying the aquifer, depth to water (or top of confined aquifers), and the type of aquifer materials - high (A), moderate (B), or low (C)
- ² A numerical measure of an aquifer's priority is provided by the aquifer's ranking value. The ranking value is determined by summing the point values for each of the following hydrogeologic and water use criteria: productivity, size, vulnerability, demand, type of use, quality concerns (that have health risk implications), and quantity concerns. Possible ranking scores range from a low of 5 to a high of 21; the higher the ranking score, the greater the aquifer's priority.

4.8 Groundwater Users

Figure 36 shows known locations of private wells within the LSA (Sources: BC MOE 2020b, and TCL March and July 2020). The closest private domestic wells are located:

- About 3.8 km (i.e., Goalder, Baker, and Mapletoft wells) north of the Project, to the west of Goathorn Creek, along the expected groundwater flow paths towards the Telkwa River.
- About 3.1 km (i.e., Alain's well), and 4.5 to 5.4 km (i.e., Kerr, Schmike, Shearer, Beukema wells, etc.) north west of the Project, to the east of Goathorn Creek; there are located downgradient of the Project but not along the expected groundwater flow paths towards the Goathorn Creek or the Telkwa River.

As part of the baseline program, one residential well (Kerr well) was sampled quarterly during the groundwater sampling events from June 2018 to April 2019. Four additional residential wells (Schmike, Shearer, Ragula, and Beukema) were each sampled once during winter 2019.

The groundwater type for each of the residential wells (Figure 35) is categorized as a Ca+Mg bicarbonate type with the Schmike well containing a higher relative abundance of sulfate in relation to the other tested residential wells. Total arsenic, iron, manganese, and dissolved iron exceeded BC WQG FAL and the maximum acceptable concentration for drinking water sources in the Kerr well. Total phosphorus and TOC also exceeded the BC WQG DWS guidelines. Total copper exceeded the BC WQG FAL approved guideline in both the Schmike and Shearer wells. The Shearer well also had an exceedance of BC WQG DWS for total organic carbon. Total iron and manganese exceed the BC WQG DWS in the Ragula well. There were no exceedances in the Beukema well.

4.9 Past and Current Human Activities

Coal was reportedly discovered in the Telkwa area around 1900. Small-scale underground and surface mining began in 1918 and continued sporadically until 1985, resulting in the recovery of over 400,000 tonnes of coal at about 3.6 km north and northwest from the Project (Figure 36). Modern exploration of the Project to delineate further exploitable coal reserves started in 1978. Nowadays there are no significant human activities other than mining exploration and forestry; current human activities (i.e., mostly agriculture and forestry) are concentrated in the village of Telkwa and along roads, trails, and rail tracks.

5 Conceptual Groundwater Model

Groundwater is a key component of the biophysical environment, based on linkages to other ecosystem components, including surface water quantity, surface water quality, human health, aquatic resources, and wetlands.

This section presents conceptual models of the groundwater system for baseline, mining, and post-closure conditions. These models are simplified representations of the essential features of the groundwater system.

The development of conceptual models is an iterative process; therefore, it should be updated as new data becomes available, as the understanding of the system is improved, or as questions and modelling objectives evolve (Wels 2012).

The baseline conceptual model was developed from the data presented in Section 3. The mining, and post-closure conceptual models were developed from a scoping exercise that identified the Project components and activities having a potential to interact with the groundwater flow system; the identification was based on professional experience with other mining projects in British Columbia and through multi-disciplinary consultation with TCL and external consultants working on behalf of TCL.

5.1 Baseline Conditions

5.1.1 Hydrostratigraphic Units

The groundwater system is divided into two sub-systems: a deep bedrock system, and a shallow overburden system. Figure 37 shows how the Project K data generally compares to published K values.

Deep Bedrock System

The deep bedrock groundwater system is interpreted to be controlled by the hydraulic properties of the Skeena sedimentary rock group, the volcanic group, fractures and faults. At the scale of the Telkwa watershed the fractured rock system is assumed to be equivalent to a porous medium.

Table 5-1 presents the two conceptualized hydrostratigraphic units in bedrock.

Table 5-1: Hydrostratigraphic units conceptualized for the bedrock system

Unit	Type	Expected Permeability	K_{xy} range (m/s)	Extent
Skeena Group	Confined aquifer interbedded with aquitards/aquicludes	Moderate $K_{xy} > K_z$ ⁽¹⁾	K_{xy} 10^{-8} to 10^{-6} Anisotropy Ratio 2 to 4	Tenas and Goathorn synclines
Volcanic Group	Confined aquifer	Moderate $K_{xy} \approx K_z$	K_{xyz} 10^{-8} to 10^{-6}	Entire Project area

Note:

¹ K_{xy} , hydraulic conductivity parallel to beddings, and K_z , hydraulic conductivity perpendicular to beddings

The complex sedimentary sequence of the Skeena group is simplified and represented as a single unit characterized by an anisotropy ratio perpendicular to bedding planes (i.e., K parallel to beddings higher than K perpendicular to beddings). The rationale for this simplification and the approach to estimate the ratio are described below:

- The hydraulic tests show that coal seams and sandstones tend to be characterized by a moderate K and mudstone and siltstones by a lower K ; as a result, the coal seams and sandstone beds should act as preferential pathways to groundwater, and the mudstone and

siltstone beds as aquitards or aquicludes. This behavior is equivalent to a bedding-aligned anisotropy⁴, with K perpendicular to bedding (K_z) lower than K parallel to bedding (K_x , K_y);

- The anisotropic ratio can be estimated based on TCL drillhole logs and K measurements. The analysis is summarized in Table 5-2; the details of the analysis are provided in Table 2B in Appendix B.

It is also noted that the drillhole logs and the TCL geological model generally indicate relatively thick layers of mudstone between the open pit floor and the top of the volcanic group, which could limit the transmission of groundwater to and from the open pit. This complexity is not accounted in the conceptual models because the current dataset does not guarantee the absence of connections between upper and lower sub-units separated by mudstone, for example along faults where displacements may have created connections between layers previously separated.

Table 5-2: Assumptions and summary of the Skeena group equivalent K analysis

Lithology	K_i (m/s)	B_i (m)	K_{xy} (m/s)	K_z (m/s)	K_{xy}/K_z ratio
Coal seams	5×10^{-7} m/s	Drillhole logs	Min= 3×10^{-8} Max= 4×10^{-7} Geomean= 1×10^{-7}	Min= 3×10^{-8} Max= 2×10^{-7} Geomean= 5×10^{-8}	Min=1.0 Max=4.7 Average=3.0
Sandstone	3×10^{-7} m/s				
Mudstone/Siltstone	3×10^{-8} m/s				

Note:

The equivalent K parallel to bedding (K_{xy}) and equivalent K perpendicular to bedding (K_z) are calculated for each drillhole using the formula:

$$K_{xy} = (\sum_{i=1}^n B_i \times K_i) / (\sum_{i=1}^n B_i) \text{ and } K_z = (\sum_{i=1}^n B_i) / (\sum_{i=1}^n \frac{B_i}{K_i}). \text{ (Freeze and Cherry, 1979)}$$

Where B_i and K_i are respectively the thickness and hydraulic conductivity of the layer i , and K_i corresponds to the K geomean of each lithology calculated from the TCL K database (Section 4.2).

Two other conceptual simplifications are assumed:

1. No major geological structure is represented as preferential flow pathway or barrier. Data collected to date do not indicate influences on the flow system from known faults mapped in the Project area. There is no groundwater spring or seep identified along the projected interpreted fault lines; there is no significant change of hydraulic conductivity associated with fractures or faults, and there is no apparent change in water levels or hydraulic gradients caused by faults; and there is no structure linking directly the Project and the private well locations.
2. The intrusions located at about 5 km east and 7 km northwest from the open pit are merged with the Volcanic Group. The intrusive rocks are located away from the potential flow paths where groundwater originating from the Project would potentially discharge at surface. They are not expected to influence the groundwater predictions during mining and post-closure phases.

⁴ Based on the nature of the testing performed to date, the K data is interpreted as representative of the hydraulic conductivity parallel to bedding.

Shallow Overburden System

The shallow overburden system is influenced by the distribution of fine material within the till, which is conceptualized and simplified to have two main units: the silt- or clay-rich glacial till, and the glaciofluvial sand-gravel-rich till or outwash. Where present, the silt-clay-rich till act as an aquitard that limits the infiltration of precipitation and promotes runoff, whereas the sand-gravel-rich till act as an aquifer that connects the groundwater system to the stream valleys. The sand-gravel-rich till unit contains fines (Figure 17) and is characterized by moderate K (1×10^{-6} m/s); it is not a clean sand and gravel unit with homogeneously high K . Lenses of sand and/or gravels interbedded in silt-clay-rich till may be present locally; these are expected to have limited influence on the system because of the low permeability material surrounding them. Table 5-3 presents the three conceptualized hydrostratigraphic units in overburden.

Table 5-3: Hydrostratigraphic units conceptualized for the overburden system

Unit	Type	Expected Permeability	K_{xy} range (m/s)	Extent
Fluvial sand/gravel	Unconfined aquifer	High $K_{xy} \approx K_z$	K_{xyz} 10^{-4} to 10^{-2}	Stream beds and alluvial valleys
Glaciofluvial sand-gravel rich till	Unconfined aquifer	High $K_{xy} \approx K_z$	K_{xyz} 10^{-7} to 10^{-3}	Bedrock depressions north of the open pit
Glaciofluvial silt-clay-rich till	Aquitard or aquiclude	Low $K_{xy} \approx K_z$	K_{xyz} 10^{-9} to 10^{-7}	Cover almost all the Project area

3D Geometries of the Hydrostratigraphic Units

The 3D geometries of the hydrostratigraphic units were generated with the software Leapfrog Geo v4.4.2 (i.e., a 3D geological modelling tool) from the analyses of drillhole intercepts (TCL's database), geological maps (surface and bedrock geology, regional and local maps, 2D cross sections; Clague 1984, MEMPR 1993, BCGS 2005, TCL 2018), and considerations on the ability of a unit to convey groundwater (i.e., permeability or hydraulic conductivity).

SRK generated the initial 3D solids of the sand-gravel-rich till and extended the 3D surface of the top Hazelton volcanic group contact based on the regional geology map (Figure 7). The fluvial sand/gravel deposits present in the creek/river valleys were not explicitly represented; they were merged with the sand-gravel-rich till on the basis that site data was not available and that groundwater flow to creeks is controlled by the lower K units (i.e., bedrock or fine-grained overburden) surrounding the fluvial deposits.

To control the quality of the interpolation, surfaces were verified visually in cross sections with respect to the reported borehole lithologies. Corrections and further interpretations of the hydrostratigraphic contacts were based on professional judgement, for example where density of borehole data is low. The extrapolation of the overburden geometries outside the Tenas area, where drillhole information is limited or absent, was constrained by the following assumptions:

- In areas located downstream of the Project and flow paths expected to connect to the creeks, the potential connections between the mine area and the streams through thick permeable sand and gravel deposits are emphasized.
- Elsewhere overburden consists of fine textured glacial deposits with a relatively low thickness of about 5 to 10 m (i.e., based on TCL drillhole database the median thickness is 7 m).

TCL's chief geologist, Ron Parent, reviewed the initial SRK 3D solids and used TCL's drillhole database (as of May 2019) to refine the distribution of silt-clay-rich till and sand-gravel-rich. The update was provided to SRK as 3D surfaces (i.e., bedrock/overburden contact, upper silt-clay-rich till/sand-gravel-rich till contact, and sand-gravel-rich till/lower silt-clay-rich till contact). The distinction between upper and lower silt-clay-rich till is predicated on the presence of an intervening sand (or gravel) layer; so, although both sub-units are comprised of similar material, they are given this distinction to facilitate modeling. Figure 38 isopach thickness for the overburden, Figure 39 for the sand-gravel outwash deposits, and Figure 40 for the silt-clay-rich till cover. Figure 41 shows the isopach thickness (i.e., total thickness) map for the Skeena group.

5.1.2 Groundwater Flow

Conceptual cross-sections of the baseline groundwater flow system are presented in Figure 42 to 46. The deep bedrock groundwater system has a large lateral extent and is characterized by confined flow, relatively long residence times in the subsurface, and higher concentrations of dissolved solids. The bulk of recharge to the bedrock system occurs from the infiltration of precipitation and runoff in the upland area of the Tenas Creek and Goathorn Creek watersheds, where the silt-clay-rich till coverage is limited. Groundwater level measurements indicate that hydraulic gradients (and inferred groundwater flow) are from the upland areas in a northerly direction towards the major drainage features of the area, namely the Telkwa River and its tributaries, Tenas Creek and Goathorn Creek. Discharge from the bedrock system is expected to be dominant in these three drainages because of the difference of elevation between the valleys and the terraces. Infiltration from the creeks to the bedrock or overburden system may occur locally in floodplains but will be likely limited to shallow flow paths (i.e., water from the streams getting into bedrock, flowing subsurface superficially, and daylighting further downstream).

The shallow overburden system is characterized by local unconfined groundwater systems with relatively short residence times and lower concentrations of dissolved solids. Groundwater flows in a north-easterly direction towards Four Creek and in a north-westerly direction towards Tenas Creek, from topographic highs to adjacent topographic lows (Figure 30). A downward vertical gradient is observed between the upper and lower water-bearing surficial deposits, and between overburden units and bedrock units. Locally the groundwater can be disconnected (i.e., perched) above the bedrock groundwater system. Groundwater discharge from overburden is expected to occur in the valleys of Tenas Creek, in Four Creek and in Goathorn Creek, at least those portions known to be connected to the water table, as well as marshes and swamps.

Recharge from precipitation to groundwater is expected to range between 5 and 30% of MAP (Table 5-4).

Table 5-4: Estimated annual recharge rates for the Tenas Creek, Goathorn Creek, and Telkwa River

Creek/River name	Estimated annual recharge rate (m ³ /d)		Estimated baseflow (m ³ /d)
	Recharge = 5% MAP ⁽¹⁾	Recharge = 30% MAP ⁽¹⁾	
Tenas Creek (watershed 60 km ²)	5,823	34,940	9,383
Goathorn Creek (watershed 130 km ²)	19,049	114,294	20,330
Telkwa River (watershed 830 km ²)	82,315	493,892	129,799

Note:

¹ MAP = 721 mm/y (SRK 2020)

5.2 Mining and Post-closure Conditions

During the pre-construction and construction phases, activities will modify the characteristics of the subsurface but their influence on the groundwater system is anticipated to be minor and localized to the immediate footprints of the respective infrastructures.

During mining and until closure, the development and dewatering of the open pit, and the construction and operation of the waste and water management facilities will change the physical properties of the ground and subsurface, site drainage patterns, and groundwater flows at and around the mine (i.e., pore pressures behind slopes, drawdown cone). Dewatering activities will result in a drawdown of the water table that will gradually expand over time, and possibly induce a seasonal reduction of baseflow to the Tenas Creek and Goathorn Creek. Mining activities may impact the groundwater quality; mine-affected water (i.e., from PAG rocks, blasting, dust, potential spillage of chemicals and fuels, etc.) will infiltrate into the ground and migrate through the groundwater system into the valleys (i.e., Tenas River, Goathorn Creek, Telkwa River) or private domestic wells. The NMP, EMP, WMP, and Control Pond are designed with low permeability liners and ditches along their peripheries to minimize the infiltration of mine-affected water and intercept water discharges downgradient of the dams. The whole footprints of the NMP, EMP, and Control Pond, and 57% of the WMP's footprint will be lined (i.e., the natural ground located outside the pit, and the pit walls intercepting overburden; the pit walls and pit floors intercepting bedrock will not be lined). The storage management will be lined with engineered soil-bentonite compacted layers (i.e., 0.56 m thick for EMP and NMP, and 0.45 m thick for WMP), and the Control Pond with a bituminous geomembrane. The design details of the management ponds and Control Pond are documented in Part A, Section 1 of the EAC Application.

At closure, the total footprint of the project will correspond respectively to about 5.5% and 2.2% of the Tenas Creek and Goathorn Creek watersheds; dewatering of the open pit will stop and the groundwater system will progressively return to steady post-closure conditions. The management ponds will remain, and the Control Pond will be decommissioned. The mine affected water that entered the groundwater system during operation will continue migrating while new mine-affected water from weathering of open pit walls, pit lakes and management ponds will enter and migrate through the groundwater system. Conceptual cross-sections of the groundwater flow system at post-closure are presented in Figure 47 to 51.

Table 5-5 summarizes the potential effects of the Project to the groundwater system. The key potential issues are the effects on groundwater discharges into nearby creeks, and the migration of mine-affected water to private domestic wells located immediately downstream of the Project.

Table 5-5: Potential Project Interactions with the Groundwater System

Project Component or Activity	Potential Effect / Pathway of Interaction with Hydrogeology
Construction Phase	
Site clearing, pre-stripping, building construction, road development, rail loop construction, bridge construction, and development of onsite utilities and services.	Changes to site drainage patterns and subsurface characteristics due to construction works. Changes to groundwater quality resulting from dust deposition or accidental spillage.
Mining Phase	
Excavate the open pit.	Changes to watercourses, site drainage patterns, subsurface characteristics and groundwater flow caused by mining and dewatering. Changes to groundwater quality as a result of metal leaching and acid rock drainage.
Establish and operate waste management facilities.	Changes to watercourses, site drainage patterns, subsurface characteristics and groundwater flow caused by construction, diversions, and infiltration underneath stockpiles or storage management ponds (NMP, EMP, and WMP). Changes to groundwater quality caused by infiltration of mine-affected water underneath waste management facilities.
Establish and operate water management facilities.	Changes to watercourses, site drainage patterns, subsurface characteristics and groundwater flow caused by construction, diversions, and infiltration underneath the Control Pond, sedimentation ponds, and ditches. Changes to groundwater quality caused by infiltration of mine-affected water underneath water management facilities.
Pump groundwater for domestic facilities.	Changes to groundwater flow at the vicinity of the well caused by pumping.
Temporarily store hazardous substances including fuel, explosives, and mine supplies	Changes to groundwater quality from the use of chemicals and fuel and the potential for spills
Contingency pumping of water from water supply wells along the edge of Goathorn Creek.	Changes to groundwater flows in the alluvial bed of Goathorn Creek caused by pumping.
Closure and Reclamation Phase	
Decommission and reclaim of all buildings and structures. Re-contour slopes and re-vegetate.	Changes to site drainage patterns due to decommissioning activities; changes to groundwater flow through changes to local scale flow or drainage pathways. Changes to groundwater quality as a result of erosion, sedimentation, and changes to infiltration rates.
Stop dewatering, open pit reflood, and formation of pit lakes.	Changes to groundwater flows. Changes to groundwater quality caused by infiltration of mine-affected water underneath the pit lakes.
Maintenance of the waste management facilities.	Changes to groundwater quality caused by infiltration of mine-affected water underneath waste management facilities.

6 Groundwater Effects Predictions

This section presents the 3D-numerical model developed for the EA Application to assess the effects of the Project on the groundwater. The predictions include estimates of groundwater quantities intercepted by the mine, potential changes to groundwater baseflows in creeks, and potential contributions and average travel times of mine-affected groundwater to creeks and private wells.

6.1 Model Software

Numerical groundwater modeling was completed using the software, FEFLOW 7.4 (DHI, 2020). FEFLOW is a professional software package for modeling fluid flow and transport of dissolved constituents and/or heat transport processes in the subsurface. This program is used extensively for groundwater mining projects around the world. The code is based on a finite element solution of the partial differential equations for flow and transport.

6.2 Model Assumptions

The numerical model required several simplifying assumptions. These include:

- The groundwater system can be simulated using unconfined saturated flow equations.
- Groundwater flow can be approximated by an equivalent porous media model.
- Heterogeneity in the stratigraphic layering can be approximated using anisotropic conditions.
- Faulting does not have a significant influence on the regional scale flow system, with no major structures identified that act as significant conduits and/or barriers.
- Groundwater flow states can be approximated based on steady-state flow conditions.
- Waste rock storage piles do not significantly alter the sub-surface flow conditions.

6.3 Groundwater Model Setup

6.3.1 Model Domain

The model domain (Figure 52) covers an area of approximately 20 x 15 km, with a total area of 280 km². The domain is set to encompass the Goathorn Creek watershed, and to be bounded by the Telkwa River and the Bulkley River.

The upper surface of the model is defined based on the DEM provided by TCL (Email dated May 2019). The base of the model is set at a fixed depth of 400 mbgs projected downward from the surface topography, which is 3.3x times deeper than the proposed pit (120 mbgs).

6.3.2 Model Mesh

The finite element mesh (Figure 52) is constructed with 30 layers. Each model layer has a constant thickness (Table 6-1) and comprises 85,595 prismatic elements. The top elevation

corresponds to the topographical surface. Horizontal spacing is refined in the Project area and along the creeks (i.e., an element length of approximately 30 m at the Project and along creeks and increasing to a maximum of 500 m).

Table 6-1: Thicknesses of the model layers

Layer #	Thickness (m)
1 and 2	0.5
4	3
5 to 23	5
24 and 25	25
26 to 30	50

6.3.3 Boundary Conditions

The boundary conditions are described below and illustrated in Figure 53.

In-Situ Boundaries

- No flow (i.e., zero-flux) boundaries are assigned to:
 - Model edges which correspond to the upper reaches of the surface water catchment divides,
 - The top surface of the model, except where creeks/rivers or mine workings are present,
 - The base of the model.
- Constant head (i.e., Dirichlet) boundaries are assigned to:
 - Lower reaches of the creeks/rivers.
Head values were assigned based on ground surface elevations.
- Seepage (i.e., flux constrained Dirichlet) boundaries are assigned to:
 - Upper reaches of the creeks/rivers.
Head values were assigned based on ground surface elevations and are constrained to only allow flow out of the model. For example, flow can discharge into the creeks when heads exceed the creek levels, but the reverse is not allowed (i.e., ingress into the model if heads drop below creek levels). This represents the fact that small streams have limited capacity and do not significantly contribute to the recharge when dry.
- Source/sink (i.e., modified Neuman) boundaries are assigned to:
 - Top layer of model to simulate vertical recharge into the model.

Mine Working Boundaries

- Seepage (i.e., flux constrained Dirichlet) boundaries are assigned to:
 - Pit walls (e., EoY1, EoY7, EOM, and post-closure conditions).
Head values were assigned based on pit wall elevations.
- Constant head (i.e., Dirichlet) boundaries are assigned to:
 - Unlined portions of the WMP, saturated waste rock, and pit lake during post-closure.
Assigned head values correspond to maximum water level at the WMP and spill point elevations (Table 6-2).

Table 6-2: Head levels at WMP saturated waste rock, and pit lake

Feature	Period	Head Elevation (masl)
Pit lake	Post-closure	909
Saturated waste rock	Post-closure	901
WMP (not lined)	Operation, Post-closure	851

- Well (point-source fluid-flux) boundaries were assigned to lined water management facilities (i.e., management ponds and Control Pond). Seepage rates for the facilities were calculated using:
 - NMP, EMP, and WMP.
Seepage rates were calculated from 2D Seep W modelling documented in Appendix E. Results are presented in Table 6-3.
 - Control Pond.
Seepage rates were calculated using the analytical solution presented in Giroud (1997) for the migration of liquid through composite liners with geomembrane defects. The analysis is documented in Appendix F; results are presented in Table 6-3.

Table 6-3: Estimated seepage rates through designed liners (Control Pond, MPs)

Case	Total seepage rate under liners (m ³ /d)				
	Control Pond	EMP	NMP	WMP Expit	WMP Inpit ⁽¹⁾
Base Case	140	277	87	267	155
High Case	290	296	90	277	377

Sources: Appendix F, and surface areas from TCL 2020.

Note:

⁽¹⁾ WMP inpit lined surface = 145,762 m²

6.3.4 Model Properties

Each model element was assigned with the property of one of the conceptual hydrostratigraphical units (i.e., sand-gravel rich till, silt-clay-rich till, Skeena group, or volcanic Group) based on the 3D geometries illustrated in Figure 40 to 41 (Section 5.1.1). Table 6-4 compiles the properties of the base case and high case numerical models (i.e., the base and high case terminologies are defined in Section 6.4).

Table 6-4: Groundwater model properties

Hydrostratigraphic Unit	Parameter	Unit	Base Case	High Case ⁽²⁾
Sand-Gravel-rich till - Homogeneous and isotropic.	K_{xyz}	m/s	2.9×10^{-6}	7.8×10^{-6}
	S_y	-	0.23	0.23
	S_x	1/m	4×10^{-4}	4×10^{-4}
Silt- clay-rich Till - Homogeneous and isotropic.	K_{xyz}	m/s	2.4×10^{-7}	6.4×10^{-7}
	S_y	-	0.11	0.11
	S_x	-	2×10^{-5}	2×10^{-5}
Sedimentary rocks - Homogeneous and anisotropic. The highest conductivity (K_{xy}) is parallel to bedding dip and the lowest (K_z) is perpendicular; the bedding orientation matches the 3D surfaces of the Hazelton Volcanic Group contact (Section 5.1.1)	K_{xy}	m/s	3.6×10^{-7}	9.8×10^{-7}
	K_z	m/s	1.8×10^{-8}	4.9×10^{-8}
	S_y	-	0.09	0.09
	S_x	-	5×10^{-6}	5×10^{-6}
Volcanic & Intrusive rocks - Homogeneous and isotropic.	K_{xyz}	m/s	2.1×10^{-8}	5.6×10^{-8}
	S_y	-	0.05	0.05
	S_x	-	5×10^{-6}	5×10^{-6}
Recharge ⁽¹⁾ - Uniform and constant.	R	mm/yr	57.62	57.62

Note:

1 The modeled annual recharge is equivalent to about 8% of MAP.

6.4 Model Calibration

Two cases, a base case and a high case, were defined for evaluating the range of potential effects from the Project to the groundwater system. Calibration was conducted manually and based on steady-state conditions.

Base Case: The base case model corresponds to the best fit to head observations between the 6th and 15th of September 2018 and average annual baseflows estimated from the historical WSC Goathorn station data. The fit was adjusted by varying the hydraulic conductivities (K_{xyz}), and the recharge I. Calibration plots and a map of the residual errors are presented in Figure 55; full details on the calibration dataset provided in Table 1F of Appendix G.

The overall base case fit is considered reasonable for both heads and baseflows, with a Normalized Root Mean Square Error (NRMSE) of 3.2% for hydraulic heads and 3.6% for baseflows (Figure 55). A minor north-south trend is observed in the residual error structure,

which may reflect a minor unaccounted-for geological control. The sensitivity of the model to the calibration is addressed in Section 6.7.

High Case: The high case model corresponds to an outlier condition where the hydraulic conductivities are maximized (i.e., increased by a factor of 2.7 compared to base case), while the calibration target is held near the minimum generally accepted in BC (10% NRMSE). This was done to emphasize potential groundwater flows into the pit, underneath the waste and water management facilities, and into the creeks. Model fits are presented in Figure 56.

The high case predicted lower heads compared to the base case, because the increased capacity of the overburden and bedrock to transmit water (i.e., higher hydraulic conductivities). Compared to the base case, this improved the head residual errors in the northwest, but emphasized the underestimation in the southeast. The lower water levels also reduced baseflows in the upper reaches of Tenas and Four Creek.

6.5 Model Scenarios and Applications

The modeling scenarios are presented in Table 6-5. The steady state groundwater predictions are used to support the evaluation of Project effects to groundwater users, for both quantity and quality. Particle tracks are used to estimate the flow paths of mine affected groundwater and their potential contribution to creeks, rivers, and private wells. The Water Balance and Load Model (WBLM, Section 4, Chapter 3 of the EAC Application) combines the groundwater predictions (flow rates, changes to baseflows, contributions of mine affected groundwater to creeks), the direct precipitation, the runoff, the surface flows of the waste and water management systems, and the loads to evaluate the effects of the Project to surface water, for both quantity and quality.

Table 6-5: Summary of the Model Simulations

Temporal Boundary	Assumptions	Objectives
<u>Current conditions:</u>	No mining activities. The system is driven by the recharge I at surface, and the discharges at drainages (rivers, creeks, swamps).	To estimate the calibrated properties of the base case and high case models and simulate the baseline conditions of the groundwater system.
<u>Pre-construction and construction phases</u>	These periods are not considered. The influences from site clearing; pre-stripping; construction of the buildings, road, rail loop, bridge, and onsite utilities and services are expected to be minimal.	
<u>Mining</u> EoY1	The mine has been excavated for one year. Pit dewatering is active ⁽¹⁾ . The Control Pond and NMP are constructed and water levels are at their maximum.	To estimate pit inflow rates, changes to groundwater baseflow in creeks, mine-affected infiltration rates, pathways, travel times, and potential contributions to creeks and domestic wells.
<u>Mining</u> EoY7	The mine has been excavated for seven years ⁽¹⁾ . Pit dewatering is active. Rock storage piles are not explicitly modelled ⁽²⁾ . The Control Pond, NMP, and EMP are constructed and water levels are at their maximum.	

Temporal Boundary	Assumptions	Objectives
<u>Mining</u> EOM	The mine is fully excavated ⁽¹⁾ (i.e., 22 years). Pit dewatering is active. Rock storage piles are not explicitly modelled ⁽²⁾ . The Control Pond and all the management ponds are constructed, and water levels are at their maximum.	
<u>Mining</u> EOM hypothetical worst-case drawdown	The mine is fully excavated ⁽¹⁾ . The pit dewatering is active. Rock storage piles are not explicitly modelled ⁽²⁾ . There is no Control Pond or management ponds impeding the progression of groundwater drawdown.	To estimate worst case drawdown extent.
<u>Post-closure:</u> EoY ∞	The mine is fully excavated ⁽¹⁾ . Dewatering pumps are shut off and open pit is allowed to re-flood; the groundwater systems return to equilibrium. Rock storage piles are not explicitly modelled ⁽²⁾ . The Control Pond has been decommissioned. The NMP, and EMP are constructed and water levels are at their maximum.	To estimate the changes to groundwater baseflow in creeks, mine-affected infiltration rates, pathways, travel times, and potential contributions to creeks and domestic wells.

Note:

- ¹ The progressive incremental excavation of the pit is not simulated. At the start of a simulation (time, $t = 0$), the predictive scenarios assume excavations correspond to the pit shell of the simulated year (EoY1, EoY7, EOM, and Post-closure). This is considered acceptable because the predictions of the effects of the Project to the groundwater flow system are expected to be overestimated as a result of bigger stresses.
- ² The waste rock storage piles are expected to be characterized by hydraulic conductivities several magnitudes higher than overburden and bedrock due to high porosities between the rocks. The recharge over the rock storage piles are assumed to remain unaffected (i.e., reduced or increased compared to baseline) and transmitted quickly to the base of the piles.

6.6 Model Results

6.6.1 Current Conditions

The predictions of hydraulic heads are mapped in Figure 57 and 58.

6.6.2 Mining Conditions

Pit inflows and seepages underneath the mine facilities

Table 6-6 (base case) and Table 6-7 (high case) compile the groundwater inflow and outflow rates predicted at the pit, the Control Pond, and the management ponds. These predictions served as inputs to the WBLM (Section 4, Chapter 3 of the EAC Application) to design the water management system and evaluate the overall effects of the Project to surface water.

The pit inflows range between 310 and 850 m³/d for the base case, and 400 and 1,110 m³/d for the high case. Under groundwater conditions alone, inflows of these magnitudes are typically managed with pit sumps and do not require active dewatering systems. The seepage rate underneath the control pond is 140 m³/d for the base case and 290 m³/d for the high case. The

total seepage rate underneath the management ponds at end-of mine is 1,110 m³/d for the base case and 2,230 m³/d for the high case.

Table 6-6: Base case forecasts of pit inflows and seepages underneath the management ponds

Feature		Groundwater flow rate (m ³ /d)			
		EoY1	EoY7	EOM	Worst case drawdown, no MPs
Pit inflows	IN	0	0	0	0
	OUT	314	854	537	846
Control Pond	IN	140	140	140	na
	OUT	0	0	0	na
NMP	IN	87	87	87	na
	OUT	0	0	0	na
EMP	IN	0	277	277	na
	OUT	0	0	0	na
WMP	IN	0	0	742	na
	OUT	0	0	624	na
Total: Management ponds (NMP, EMP, WMP)	IN	87	364	1106	na
	OUT	0	0	117	na

Source: Telkwa_EIA_Mdl list-mdls setup&calib_20211101.xlsx

Notes:

IN = flow into the model (i.e., seepage or infiltration)
OUT = flow out of the model (i.e., discharges into surface)
na, not applicable

Table 6-7: High case forecasts of pit inflows and seepages underneath the management ponds

Feature		Groundwater flow rate (m ³ /d)			
		EoY1	EoY7	EOM	Worst case drawdown, no MPs
Pit inflows	IN	0	0	0	0
	OUT	403	1106	663	1106
Control Pond	IN	290	290	290	na
	OUT	0	0	0	na
NMP	IN	90	90	90	na
	OUT	0	0	0	na
EMP	IN	0	296	296	na
	OUT	0	0	0	na
WMP	IN	0	0	1944	na
	OUT	0	0	87	na
Total: Management ponds (NMP, EMP, WMP)	IN	90	386	2330	na
	OUT	0	0	87	na

Source: Telkwa_EIA_Mdl list-mdls setup&calib_20211101.xlsx

Notes:

IN = flow into the model (i.e., seepage or infiltration)
OUT = flow out of the model (i.e., discharges into surface)
na, not applicable

Predicted levels and changes compared to baseline conditions

Figures 59 to 66 presents the predicted hydraulic heads and changes to heads compared to baseline conditions for EoY1, EoY7, and EOM. The model predicts the drawdown induced by the pit dewatering (i.e., long term, EOM conditions) could extend up to a maximum of 23 and 28 km² for the base case and high case respectively. The influence of the management ponds and the control pond stop the progression of the drawdown to the north; in this area the model predicts a groundwater mound of about 10 to 14 km² for the base case and high case respectively. Neither the drawdown cone nor the groundwater reaches private well locations.

Figure 62 and Figure 66 show the hypothetical worst-case drawdown extent, when the pit is assumed to be fully excavated, pit dewatering active, but no Control Pond or management ponds impede the progression of groundwater drawdown. These hypothetical models predicted a drawdown area of approximately 34 and 44 km² for the base case and high case respectively; but did not reach private well locations.

Predicted changes to surface water baseflows

Table 6-8 and Table 6-9 compile the predicted differences of groundwater baseflow between baseline and operations at surface water stations; Figure 4, and Figure 57 to 64 show the locations of the WQS stations. The results are expressed in relative percent differences (RPD). These predictions served as inputs to the WBLM (Section 4, Chapter 3 of the EAC Application) to evaluate the overall effects of the Project to surface water.

Table 6-8: Base case forecasts of changes to creek baseflows during operations

Stations	Changes to net baseflows compared to baseline (%)			
	EoY1	EoY7	EOM	Worst case EOM drawdown, no MPs
Tenas Creek stations				
WQS01	-0.1%	-0.1%	-0.3%	-0.4%
WQS02	-1.5%	-4.3%	0.9%	-5.2%
WQS22	-2.1%	-7.2%	1.1%	-9.2%
WQS04	-2.0%	-6.8%	1.1%	-8.7%
Tenas Creek U/S Goathorn Creek	-2.0%	-6.7%	1.1%	-8.6%
Four Creek stations				
WQS03	-0.7%	-20.5%	-29.3%	-29.7%
WQS21	-1.6%	-23.1%	-35.0%	-37.6%
WQS20	-2.6%	-23.9%	-35.7%	-38.3%
WQS03DS	-5.6%	-14.7%	-11.0%	-33.7%
Four Creek U/S Goathorn Creek	-5.4%	-14.3%	-10.7%	-33.0%
Goathorn Creek stations				
WQS13	0.0%	0.0%	0.0%	0.0%
WQS06US	0.0%	0.0%	0.0%	-0.1%
WQS06	-0.4%	-1.0%	-0.7%	-2.6%

Stations	Changes to net baseflows compared to baseline (%)			
	EoY1	EoY7	EOM	Worst case EOM drawdown, no MPs
WQS05	-0.8%	-2.7%	-0.2%	-4.3%
Goathorn Creek U/S Telkwa River	-0.8%	-2.6%	-0.2%	-4.2%
Telkwa River stations				
WQS09	-0.7%	-2.3%	-0.2%	-3.7%
Telkwa River U/S Bulkley River	-0.7%	-2.2%	-0.2%	-3.5%
Bulkley River stations				
WQS11	0.01%	0.01%	0.01%	0.01%
WQS12	-0.01%	-0.03%	0.00%	-0.05%

Source: Telkwa_EIA_Mdl list-mdls setup&calib_20211101.xlsx

Table 6-9: High case forecasts of changes to creek baseflows during operations

Stations	Changes to net baseflows compared to baseline (%)			
	EoY1	EoY7	EOM	Worst case EOM drawdown, no MPs
Tenas Creek stations				
WQS01	-0.1%	-0.4%	-0.5%	-0.8%
WQS02	-2.0%	-7.1%	9.4%	-8.9%
WQS22	-2.5%	-15.7%	29.8%	-24.0%
WQS04	-2.1%	-13.6%	26.1%	-21.1%
Tenas Creek U/S Goathorn Creek	-2.0%	-13.1%	25.2%	-20.4%
Four Creek stations				
WQS03	0.0%	0.0%	0.0%	0.0%
WQS21	-20.4%	-100.0%	-100.0%	-100.0%
WQS20	-20.4%	-100.0%	-100.0%	-100.0%
WQS03DS	-22.2%	-54.3%	42.6%	-97.1%
Four Creek U/S Goathorn Creek	-20.4%	-50.4%	40.6%	-91.4%
Goathorn Creek stations				
WQS13	0.1%	-0.1%	-0.4%	-0.4%
WQS06US	0.0%	-0.3%	-0.3%	-0.9%
WQS06	-0.3%	-1.3%	0.7%	-2.9%
WQS05	-0.7%	-3.4%	5.1%	-6.0%
Goathorn Creek U/S Telkwa River	-0.6%	-3.3%	5.0%	-5.9%
Telkwa River stations				
WQS09	-0.5%	-2.5%	3.8%	-4.5%
Telkwa River U/S Bulkley River	-0.5%	-2.4%	3.6%	-4.3%
Bulkley River stations				
WQS11	0.0%	0.0%	0.0%	0.0%
WQS12	-0.01%	-0.04%	0.06%	-0.07%

Source: Telkwa_EIA_Mdl list-mdls setup&calib_20211101.xlsx

Potential Migration of mine-affected water

Figures 59 to 66 show the predicted particle paths for EoY1 (one year of travel time), EoY7 (seven years of travel time), and EOM (25 years of travel time). No particles are predicted to discharge into creeks by EoY1 or EoY7. The models predict mine-affected groundwater could potentially start discharging into Tenas Creek after about 16 years for the base case, and 8 years for the high case respectively. In the first 25 years, no particle is predicted to discharge into Four Creek, Goathorn Creek, Telkwa River, or near private wells downstream of the projects.

Table 6-10 compiles the EOM forecasts of the potential contributions of mine affected baseflows by sources after 25 years. These predictions served as inputs to the WBLM (Section 4, Chapter 3 of the EAC Application) to evaluate the overall effects of the Project to surface water.

Table 6-10: Base case and high case predictions of mine affected baseflow at EOM

ID	Potential contributions of mine affected groundwater after 25 years in % of baseflow under base case and EOM conditions				Potential contributions of mine affected groundwater after 25 years in % of baseflow under high case EOM conditions			
	NMP	EMP	WMP	Control Pond	NMP	EMP	WMP	Control Pond
Tenas Creek								
WQS02	-	-	0.1%	-	-	-	3.0%	-
WQS22	-	-	0.4%	-	-	-	10.1%	-
WQS04	-	-	0.3%	-	-	-	9.6%	-
Four Creek								
WQS03	-	-	-	-	-	-	-	-
WQS21	-	-	-	-	-	-	-	-
WQS20	-	-	-	-	-	-	-	-
WQS03DS	-	-	-	-	-	-	-	-
Goathorn Creek								
WQS06US	-	-	-	-	-	-	-	-
WQS06	-	-	-	-	-	-	-	-
WQS05	-	-	0.1%	-	-	-	4.3%	-
Telkwa River								
WQS09	-	-	<0.1%	-	-	-	0.5%	-

Source: Telkwa_EIA_Mdl list-mdls setup&calib_20211101.xlsx

Note:

-, no discharge predicted

6.6.3 Post-Closure

Seepages underneath the mine facilities

Table 6-11 compiles the groundwater inflow and outflow rates predicted at the pit and the management ponds, for the base case and high case respectively. These predictions served as inputs to the Water Balance and Load Model (WBLM) to design the water management system and evaluate the overall effects of the Project to surface water.

Table 6-11: Post-closure forecasts of pit inflows and seepages underneath the management ponds

Feature		Groundwater flow rate (m ³ /d)	
		Base Case	High Case
Pit walls	IN	0	0
	OUT	114	101
Pit Lake (909 mas)	IN	0	72
	OUT	210	244
Saturated waste rock (901 masl)	IN	10	193
	OUT	47	5
Total: pit walls, pit lake, and saturated waste rock	IN	10	371
	OUT	371	350
NMP	IN	87	90
	OUT	0	0
EMP	IN	277	296
	OUT	0	0
WMP	IN	720	1786
	OUT	112	75
Total: Management ponds	IN	1084	2172
	OUT	112	75

Source: Telkwa_EIA_Mdl list-mdls setup&calib_20211101.xlsx

Notes:

IN = flow into the model (i.e., seepage or infiltration)

OUT = flow out of the model (i.e., discharges into surface)

Predicted levels and changes compared to baseline conditions

Figure 67 and Figure 68 show the predicted hydraulic heads and changes to heads compared to baseline conditions for post-closure. The model predicts a drawdown extending up to a maximum of 16 and 23 km² and a mound of about 8 to 16 km², for the base case and high case respectively. The models predict neither the drawdown cone nor the groundwater mound reach private well locations.

Predicted changes to surface water baseflows

Table 6-12 compiles the predicted differences of groundwater baseflow between baseline conditions and post-closure conditions. The results are expressed in RPD. These predictions served as inputs to the WBLM (Section 4, Chapter 3 of the EAC Application) to evaluate the overall effects of the Project to surface water.

Table 6-12: Post-closure forecasts of changes to creek baseflows

Station	Changes to net baseflows compared to baseline (%)	
	Base Case	High Case
Tenas Creek stations		
WQS01	-0.3%	-0.3%
WQS02	0.9%	9.9%
WQS22	0.7%	28.5%
WQS04	0.7%	24.9%
Tenas Creek U/S Goathorn Creek	0.7%	24.0%
Four Creek stations		
WQS03	-22.8%	no flow
WQS21	-25.9%	-100.0%
WQS20	-26.0%	-100.0%
WQS03DS	-6.8%	71.1%
Four Creek U/S Goathorn Creek	-6.6%	66.8%
Goathorn Creek stations		
WQS13	0.0%	-0.6%
WQS06US	0.0%	-0.4%
WQS06	-0.4%	1.1%
WQS05	-0.1%	5.2%
Goathorn Creek U/S Telkwa River	-0.1%	5.1%
Telkwa River stations		
WQS09	-0.1%	3.9%
Telkwa River U/S Bulkley River	-0.1%	3.7%
Bulkley River stations		
WQS11	-0.01%	-0.2%
WQS12	<0.1%	<0.1%

Source: Telkwa_EIA_Mdl list-mdls setup&calib_20211101.xlsx

Potential Migration of mine-affected water

Figure 67 to 78 show the predicted post-closure particle paths at different times including long term paths; Table 6-13 and Figure 79 summarize the predicted travel times before particles discharge into creeks; and Table 6-14 compiles the predicted long term contribution of mine affected baseflows by sources. These predictions served as inputs to the WBLM (Section 4, Chapter 3 of the EAC Application) to evaluate the overall effects of the Project to surface water.

Three private wells (Goalder, Mapletoft, and Baker) are located in the Telkwa River valley are shown to be potentially within the paths of mine affected groundwater. These wells pump groundwater from a fluvial aquifer at a relatively shallow depth (i.e., 15 to 30m deep according to MOE's database) in the Telkwa River valley bottom. The potential maximum effects from the Project on quality of the pumped well water was calculated using the following loading equation:

$$Q_w \times C_w = Q_b \times C_b + \sum (Q_i \times C_i)$$

Q_w , groundwater flow into the Telkwa River valley.

C_w , concentration of the groundwater into the Telkwa River valley.

Q_b , flow contribution from background groundwater.

C_b , concentration of background groundwater (baseline).

Q_i , flow contribution from mine feature i.

C_i , concentration of from mine feature i (source terms).

For a unit volume of Q_w , C_w can be expressed using percentage contributions relative to each source, as predicted by the particle path analyses.

$$C_w = P_b \times C_b + P_m \times \sum (P_i \times C_i)$$

P_b , percentage contribution of background groundwater into the Telkwa River valley.

P_m , percentage contribution of mine affected groundwater into the Telkwa River valley.

P_i , percentage contribution of from a mine feature i to the total mine affected groundwater.

Calculations assumed:

- The loads from the mine are permanent, and constituents migrated to the Telkwa River and constantly discharging into the fluvial aquifer (i.e., post-closure, pseudo -steady state conditions). The predicted travel times (i.e., > 400 years) are not considered in the analysis.
- The private wells pumps groundwater exclusively from the southern side of the Telkwa River valley, upstream of WQS09. The potential contributions from the northern side of the Telkwa River catchment, and from upstream of the project influence (i.e., western limit of the model domain) are not accounted.
- The mass of constituents in groundwater is conserved. The mine affected groundwater is transported by advection (i.e., no diffusion, dispersion, nor natural attenuation mechanisms).
- The parameter's concentrations can be calculated based on the post-closure predictions of mine affected baseflow contributions from the southern side of the Telkwa River valley, upstream of WQS09 (i.e., groundwater numerical model predictions), the average baseline groundwater quality (see Section 4.6), and the water quality at the pit lake, pit backfill, NMP, EMP, WMP, and Control Pond (average winter concentrations predicted by the WBLM).

The analysis is provided in Appendix H. The results show that no constituents are predicted to exceed the BC-DWG for the base case, and that only cobalt exceeds the BC-DWG for the high case (max. predicted 2.3 µg/L, BC-DWG for cobalt 1 µg/L).

Table 6-13: Predicted travel times before discharges into creeks

	Base Case	High Case
Tenas Creek	First particle discharged into Tenas Creek after 15 years. 50% of particles discharged after 65 years, 72% after 400 years	First particle discharged into Tenas Creek after 8 years. 50% of particles discharged after 23 years, 92% after 400 years
Four Creek	First particle discharged into Four Creek after 38 years. 50% of particles discharged after 95 years, all particles discharged after 180 years.	First particle discharged into Four Creek after 29 years. 50% of particles discharged after 45 years, all particles discharged after 170 years.
Goathorn Creek	First particle discharged into Goathorn Creek after 184 years. 50% of particles discharged after 320 years, 62% after 400 years	First particle discharged into Goathorn Creek after 90 years. 50% of particles discharged after 170 years, 89% after 400 years
Telkwa River	First particle discharged into Telkwa River after 400 years.	First particle discharged into Telkwa River after 308 years. 50% of particles discharged after 400 years

Table 6-14: Base case and high case predictions of mine affected baseflow at post-closure

ID	Potential long-term contributions of mine affected groundwater under base case and post-closure conditions					Potential long-term contributions of mine affected groundwater under high case and post-closure conditions				
	NMP	EMP	WMP	PL	SWr	NMP	EMP	WMP	PL	SWr
Tenas Creek										
WQS02	-	-	1.1%	-	-	-	-	2.6%	-	<0.1%
WQS22	0.5%	-	6.9%	-	<0.1%	0.1%	-	13.6%	-	0.1%
WQS04	0.5%	<0.1%	7.2%	-	<0.1%	0.1%	<0.1%	14.6%	-	0.2%
Four Creek										
WQS03	-	-	-	-	-	-	-	-	-	-
WQS21	-	-	-	-	-	-	-	-	-	-
WQS20	-	-	-	-	-	-	-	-	-	-
WQS03DS	-	7.3%	-	-	-	-	3.3%	-	2.4%	-
Goathorn Creek										
WQS06US	-	-	-	-	-	-	-	-	-	-
WQS06	-	1.2%	<0.1%	-	<0.1%	-	0.9%	<0.1%	0.4%	0.5%
WQS05	0.1%	0.9%	2.3%	-	<0.1%	-	1.0%	4.8%	0.2%	0.5%
Telkwa River										
WQS09	<0.1%	0.12%	0.4%	-	<0.1%	<0.1%	0.2%	0.9%	<0.1%	0.1%

Source: Telkwa_EIA_Mdl list-mdls setup&calib_20211101.xlsx

Note:

PL, post-closure pit lake (909 masl)

SWr, post-closure saturated waste rock (901 masl)

-, no discharge predicted

6.7 Model Sensitivity

The sensitivity analysis consisted of a comparison between the model outputs of the base case models and the sensitivity models listed in Table 6-15. The outputs included, for baseline conditions, the NRMSE of observed versus predicted heads and estimated versus predicted baseflows, and for EOM and post-closure conditions, the predictions of drawdown extent, changes to creek baseflows, travel times from Project to creeks, and contributions of mine affected water to creeks. The sensitivity models corresponded to scenarios where properties were varied without recalibration of the model (i.e., sensitivity simulations do not represent alternative conceptualisations of the site). They included variations to hydraulic conductivities and specific yields; storage compressibility was excluded because this parameter influences the release of groundwater from storage, which is negligible under steady state conditions. Alike storage compressibility, specific yield controls the release of storage hence has negligible influence on steady state heads and baseflows; it influences however the predicted travel times of mine affected groundwater to creeks. Feflow uses specific yield as a proxy for the effective porosity (i.e., drainable porosity) to calculate the groundwater velocity (i.e., $q = K/n_e$ with q , velocity of groundwater, K , hydraulic conductivity, and n_e effective porosity).

Table 6-15: Sensitivity scenarios

Parameter	Description	ID
Recharge	R= 30% MAP (R baseline x3.50)	R+
	R= 5% MAP (R baseline x0.58)	R-
K sand-gravel-rich till	plus one standard deviation (Kxyz baseline x11.5)	Kst+
	minus one standard deviation (Kxyz baseline x0.09)	Kst-
	Lower effective porosity value of 0.3	Nst+
	Higher effective porosity of 0.1	Nst-
K silt-clay-rich till	plus one standard deviation (Kxyz baseline x10.71)	Kct+
	minus one standard deviation (Kxyz baseline x0.09)	Kct-
	Lower effective porosity value of 0.2	Nct+
	Higher effective porosity of 0.05	Nct-
K Skeena group	plus one standard deviation (Kxyz baseline x17.26)	Ksk+
	minus one standard deviation (Kxyz baseline x0.06)	Ksk-
	Ratio Kxy/Kz=10	Anisk+
	Ratio Kxy=Kz (no anisotropy)	Anisk-
	Lower effective porosity value of 0.25	Nsk+
	Higher effective porosity of 0.05	Nsk-
K Volcanic rocks	plus one standard deviation (Kxyz baseline x7.1)	Kvl+
	minus one standard deviation (Kxyz baseline x0.14)	Kvl-
	Lower effective porosity value of 0.1	Nvl+
	Higher effective porosity of 0.02	Nvl-

Note:

The standard deviations of K respective to each hydrostratigraphic unit were calculated using the site-specific K measurements distributed on a log scale (i.e., Figure 27).

The specific yield values correspond to the lower and higher ranges for sand, silt, sandstone, and basalt, as reported in *Singhal BBS, and RP Gupta. 2010. Applied hydrogeology of fractured rocks: second edition. Springer, New York, USA. 408 p.*

'xyx' refers to the principal directions of the hydraulic conductivity tensor; x and y correspond to the horizontal plane or directions parallel to beddings, and z corresponds to the vertical plane or directions perpendicular to the bedding planes.

The relative percent differences (RPD) between the base case and the sensitivity scenarios were rated according to the definitions listed in Table 6-16. The ratings of the calibration outputs took into consideration that a difference of about less than 6% with the calibrated heads or baseflows NRMSE implied the calibration target would remain close to the minimum 10% threshold generally accepted in BC. The ratings for prediction outputs were based on differences of less than 10% with predicted base case values. A ten percent difference compared to base case EOM or post-closure predictions corresponds to a maximum pit inflow of 605 m³/d, a maximum drawdown and mound extent of 34 km², a maximum of 13% change to baseflow at Tenas Creek upstream of Goathorn Creek and 11% at Goathorn Creek upstream of Telkwa River, a minimum travel time of 14 years before the first particle discharges at Tenas Creek upstream of WQS04,

and a maximum contribution of mine affected groundwater of 15% at Tenas Creek upstream of WQS04m and 10% at Goathorn Creek at WQS06).

Table 6-16: Ratings of calibration and prediction sensitivity models

Significance	Calibration	Prediction
Null	<1% difference with base case NRMS.	<5% RPD of predicted value.
Low	1 to 3% difference with base case NRMS.	5–10% RPD of the predicted value.
Medium	3 to 6% difference with base case NRMS.	10–30% RPD to the predicted value.
High	>6% difference with base case NRMS.	>30% RPD of the predicted value.

Parameters were classified into sensitivity types as defined by Brown (1996):

- **Type I:** There are insignificant effects for both model calibration residuals and predictive model results (relative to modelling objectives). In other words, within a reasonable range of parameter values, the model outcomes are not significantly affected. This parameter type does not need further data collection or monitoring. Type I sensitivities are of little concern because the impact on predictions is insignificant.
- **Type II:** There is a significant effect on model calibration, but an insignificant effect on predictive model results (relative to modelling objectives). The model calibration is affected (residuals increase for some part of the parameter range being tested) so the parameter has an effect on the calibration goodness of fit. However, the results of the predictive model are still insensitive to this parameter. Type II sensitivities are of little concern because the impact on predictions is insignificant.
- **Type III:** There are significant effects on both model calibration and model prediction results (relative to modelling objectives). The parameter has an effect on the calibration goodness of fit and a corresponding effect on the predictive model results. Type III sensitivity is of concern only for an uncalibrated model, or where a wide range of calibrations are possible, and proper calibration of this parameter is the solution. The sensitivity is important, but it is known and can be avoided by model calibration.
- **Type IV:** There is an insignificant effect on model calibration, but a significant effect on predictive model results (relative to modelling objectives). The model calibration is not affected and does not help constrain this parameter value, while the results of the predictive model are sensitive to this parameter. Type IV sensitivity is cause for concern because non-uniqueness, the model input may allow for a range of valid calibrations, but the choice of value significantly impacts model prediction. It is important to determine the actual value of this parameter and not rely on model calibration to estimate this parameter. It should be measured with robust data (model field audit) and, ideally, the data should represent the same stresses as in the predictive model simulations.

Table 6-17 to Table 6-19 compile the results of the sensitivity analysis, and Table 6-20 the sensitivity types assigned to each parameter. The analysis shows that:

- The hydraulic head calibration is sensitive to variations of recharge, and to the increase only of K in the sand-gravel-rich till and Skeena group units.
- The baseflow calibration is sensitive to variations of recharge, and to the increase of K in the silt-clay-rich till, sand-gravel rich till and Skeena group units.
- The maximum pit inflow predicted by the sensitivity models was about 1,550 m³/d in the case of a higher recharge at 30%, or when the Skeena group K increased by one standard deviation; in comparison the higher case model predictions used for the WBLM (Section 4, Chapter 3 of the EAC Application) predicted a pit inflow of 1,150 m³/d. The pit inflow predictions are found to be sensitive to all parameters except specific yield, and type IV sensitivities are found with a:
 - Decrease to the silt-clay rich till K
 - Decrease to the sand-gravel rich till K
 - Increase or decrease to the Skeena group unit K anisotropy
 - Increase or decrease to the volcanic rocks K
- None of the scenarios predicted that groundwater drawdowns our mounds would reach the areas where private wells are located, downstream of the Project. Drawdown predictions are found to be sensitive to all parameters except for the increase to the sand-gravel rich till K, decrease to Skeena group K, and Skeena group anisotropy, and variations to specific yield. Type IV sensitivities are found with a:
 - Decrease to the silt-clay rich till K
 - Decrease to the sand-gravel rich till K
 - Increase or decrease to the volcanic rocks K
- Alike the base case model, all the sensitivity scenarios show larger effects of the Project on the baseflows in Tenas Creek compared to Goathorn Creek. Significant reductions to baseflows in Tenas Creek occur only in a few cases, when the recharge is increased (-14%) or the sand-gravel rich till K is varied by one standard deviation (- 21%); the other scenarios predict low changes. In Goathorn Creek, the maximum reduction predicted by the sensitivity models is -3%. Baseflow predictions are most sensitive to variations in recharge and sand-gravel rich till K. The variations to K in volcanic rock and the decrease to K in sand-gravel rich till are categorized as Type IV, which emphasizes the importance of actual site values for these parameters.
- The predicted times to private wells are in excess of at least 170 years for all scenarios. The travel times predictions are sensitive to all the tested parameters. Type IV sensitivities are found with a:

- Decrease in sand-gravel rich till K
 - Decrease in silt-clay-rich till K
 - Decrease in Skeena group K
 - Variations the anisotropy in the Skeena group
 - Variations to the specific yield for all units
- The predictions of mine affected groundwater contribution to creeks were not found to be sensitive to any of the tested parameters. The sensitivity scenarios predicted a maximum contribution of 11% in Tenas Creek in the case of the Skeena group K increased by one standard deviation, and 1% in the Goathorn Creek. In terms of travel times before the mine affected groundwater reach the creeks, the WBLM (Section 4, Chapter 3 of the EAC Application) includes additional conservative, with 100% of the potential waste and water management pond loads assumed to discharge into creeks via groundwater paths after 25 years.

Table 6-17: Sensitivity of the model calibration

ID	RPD (%) between base case and sensitivity baseline scenarios	
	Sensitivity to head calibration	Sensitivity to baseflow calibration
Base Case	NRMSE: 3.2%	NRMSE: 3.6%
R+	+3.1%	+233.7%
R-	+1.8%	+23.1%
Kst+	+3.9%	+20.8%
Kst-	+2.0%	-0.9%
Nst+	0%	0%
Nst-	0%	0%
Kct+	+1.8%	+5.7%
Kct-	+0.2%	+0.1%
Nct+	0%	0%
Nct-	0%	0%
Ksk+	+6.9%	+8.8%
Ksk-	+1.9%	-1.4%
Anisk+	+0.1%	+0.1%
Anisk-	+0.5%	+0.7%
Nsk+	0%	0%
Nsk-	0%	0%
Kvl+	+1.9%	+1.7%
Kvl-	+0.1%	+0.2%
Nvl+	0%	0%
Nvl-	0%	0%

Sources: Telkwa_EIA_Mdl list-mdls setup&calib_20210119.xlsx

Notes:

The significance of effects to the model calibration and prediction are indicated by the format of the cell, with dark grey indicating high sensitivity, light grey medium sensitivity, pale yellow low sensitivity, and white no sensitivity.

Table 6-18: Sensitivity analysis of the EOM outputs

ID	RPD (%) between base case and sensitivity EOM scenarios							
	Pit inflow	Total extent of drawdown and mound	Changes to baseflow rates:		Travel time of first particle discharged to:		Contributions of mine affected groundwater to:	
			Tenas Ck u/s Goathorn Ck	Goathorn Ck u/s Telkwa Rv.	Tenas Ck u/s WQS04	Four Ck u/s WQS03DS	Tenas Ck u/s WQS04	Goathorn Ck u/s WQS06
Base Case	Q _{pit} = 550 m ³ /d	Extent = 31 km ²	dQ = 3.2%	dQ = 0.8%	T = 16 years	No particle	Q = 0.4%	Q = 0%
R+	+180.5%	-20.0%	-10.5%	-3.6%	-4.0%	Particle at 11 yr	-0.1%	0.0%
R-	-75.8%	+234.8%	+12.0%	+3.2%	+8.8%	0.0%	+0.1%	0.0%
Kst+	-12.0%	-2.5%	-17.7%	+7.9%	-66.7%	Particle at 18 yr	+1.7%	0.0%
Kst-	+127.7%	+33.4%	-10.6%	-2.9%	-77.0%	Particle at 5 yr	+0.2%	+0.1%
Nst+	0.0%	0.0%	0.0%	0.0%	+24.3%	0.0%	-0.2%	0.0%
Nst-	0.0%	0.0%	0.0%	0.0%	-61.6%	Particle at 18 yr	+1.7%	0.0%
Kct+	-36.8%	+24.1%	+6.8%	+1.2%	+35.5%	0.0%	-0.3%	0.0%
Kct-	+24.7%	+12.4%	-1.1%	-0.1%	-12.2%	0.0%	+0.1%	0.0%
Nct+	0.0%	0.0%	0.0%	0.0%	-3.6%	0.0%	+1.2%	0.0%
Nct-	0.0%	0.0%	0.0%	0.0%	-11.2%	0.0%	+2.7%	0.0%
Ksk+	+160.3%	-12.0%	+6.4%	+2.5%	-78.3%	0.0%	+2.5%	0.0%
Ksk-	-79.6%	-7.0%	-2.1%	+0.3%	35.3%	0.0%	-0.4%	0.0%
Anisk+	+31.5%	+10.4%	+1.3%	+0.1%	-15.9%	0.0%	0.3%	0.0%
Anisk-	+88.9%	+3.7%	+0.3%	+0.1%	+4.4%	0.0%	0.0%	0.0%
Nsk+	0.0%	0.0%	0.0%	0.0%	-15.6%	0.0%	+1.8%	0.0%
Nsk-	0.0%	0.0%	0.0%	0.0%	-1.2%	0.0%	+1.9%	0.0%
Kvl+	-11.5%	+291.6%	+1.1%	+0.6%	+0.8%	0.0%	0.0%	0.0%
Kvl-	-47.4%	-20.2%	-1.2%	-0.9%	+6.6%	0.0%	0.0%	0.0%
Nvl+	0.0%	0.0%	0.0%	0.0%	+6.8%	0.0%	+1.1%	0.0%
Nvl-	0.0%	0.0%	0.0%	0.0%	-10.4%	0.0%	+1.6%	0.0%

Sources: Telkwa_EIA_Mdl list-mdls setup&calib_20210119.xlsx, and Telkwa_EIA_Mdl travel time analz_20210119.xlsx

Notes:

The significance of effects to the model calibration and prediction are indicated by the format of the cell, with dark grey indicating high sensitivity, light grey medium sensitivity, pale yellow low sensitivity, and white no sensitivity.

u/s, upstream

Table 6-19: Sensitivity analysis of the post-closure outputs

ID	RPD (%) between base case and sensitivity post-closure scenarios							
	Total extent of drawdown and mound	Changes to baseflow rates:		Travel time to discharge 50% of all particles respectively migrating to WQS04, WQS03DS or WQS06			Contributions of mine affected groundwater to:	
		Tenas Ck u/s Goathorn Ck	Goathorn Ck u/s Telkwa Rv.	Tenas Ck u/s WQS04	Four Ck u/s WQS03DS	Goathorn Ck u/s WQS06	Tenas Ck u/s WQS04	Goathorn Ck u/s WQS06
Base Case	Extent = 28 km ²	dQ = 2.9%	dQ = 1.1%	T = 60 years	T = 96 years	T = 125 years	Q = 6%	Q = 0.3%
R+	-15.0%	-9.9%	-3.7%	-33.3%	-13.1%	+32.4%	-4.4%	-0.4%
R-	+265.1%	+11.3%	+3.0%	-7.9%	+7.4%	+84.7%	+2.2%	+1.1%
Kst+	-5.2%	-17.0%	+7.6%	-74.3%	-56.4%	-63.8%	-1.4%	0.6%
Kst-	+33.5%	-10.6%	-3.2%	+190.1%	+90.6%	+343.1%	-1.8%	+0.1%
Nst+	0.0%	0.0%	0.0%	+1.7%	+32.9%	+20.0%	-0.1%	0.0%
Nst-	0.0%	0.0%	0.0%	-59.0%	-50.3%	-52.3%	+0.1%	0.0%
Kct+	+4.4%	+6.8%	+1.2%	-18.7%	-7.6%	+205.5%	+1.1%	-0.4%
Kct-	+12.5%	-1.2%	-0.3%	-20.4%	+6.0%	-15.1%	-1.9%	0.3%
Nct+	0.0%	0.0%	0.0%	-11.0%	+10.9%	+3.7%	-0.1%	+0.1%
Nct-	0.0%	0.0%	0.0%	-18.8%	-3.8%	-9.4%	0.0%	0.0%
Ksk+	+19.2%	+7.2%	+3.4%	-1.5%	-10.2%	-19.1%	+4.6%	-0.5%
Ksk-	-2.2%	-2.3%	-0.2%	-1.2%	+19.9%	-6.4%	-2.1%	0.0%
Anisk+	+9.3%	+1.5%	+0.2%	-31.3%	+2.9%	+70.5%	-0.9%	+0.8%
Anisk-	+2.1%	+0.3%	+0.0%	-22.6%	2.4%	4.5%	-0.5%	+0.4%
Nsk+	0.0%	0.0%	0.0%	-7.9%	+1.3%	-2.7%	-0.1%	0.0%
Nsk-	0.0%	0.0%	0.0%	-20.3%	+3.3%	+1.2%	0.0%	0.0%
Kvl+	+315.7%	+1.6%	+0.4%	-7.3%	+8.0%	+89.1%	+0.3%	+0.1%
Kvl-	-18.3%	-0.8%	-0.7%	-12.2%	+4.6%	-8.0%	-0.4%	+0.4%
Nvl+	0.0%	0.0%	0.0%	-12.1%	+2.9%	-4.9%	-0.1%	0.1%
Nvl-	0.0%	0.0%	0.0%	-21.5%	+0.5%	-2.4%	0.0%	0.0%

Sources: Telkwa_EIA_Mdl list-mdls setup&calib_20210119.xlsx, and Telkwa_EIA_Mdl travel time analz_20210119.xlsx

Notes:

The significance of effects to the model calibration and prediction are indicated by the format of the cell, with dark grey indicating high sensitivity, light grey medium sensitivity, pale yellow low sensitivity, and white no sensitivity.

u/s, upstream

Table 6-20: Sensitivity types related for the predictions of changes to heads

		Change in calibration									
		Insignificant					Significant				
Change in prediction results	Insignificant	Type I					Type II				
		Pit inflow	Changes to head	Changes to baseflow	Travel times	Mine affected contributions to baseflows	Pit inflow	Changes to head	Changes to baseflow	Travel times	Mine affected contributions to baseflows
		Nst+/- Nct+/- Nsk+/- Nvl+/-	Ksk- Anisk+/- Nst+/- Nct+/- Nsk+/- Nvl+/-	Kct- Ksk- Anisk+/- Nst+/- Nct+/- Nsk+/- Nvl+/-	Kvl+/-	Kst- Kct- Ksk- Anisk+/- Kvl+/- Nst+/- Nct+/- Nsk+/- Nvl+/-	-	Kst+	Kct+ Ksk+	-	R+/- Kst+ Kct+ Ksk+
	Significant	Pit inflow	Changes to head	Changes to baseflow	Travel times	Mine affected contributions to baseflows	Pit inflow	Changes to head	Changes to baseflow	Travel times	Mine affected contributions to baseflows
		Kst- Kct- Ksk- Anisk+/- Kvl+/-	Kst- Kct- Kvl+/-	Kst- Kvl+/-	Kst- Kct- Ksk- Anisk+/- Nst+/- Nct+/- Nsk+/- Nvl+/-	-	R+/- Kst+ Kct+ Ksk+	R+/- Kct+ Ksk+	R+/- Kst+	R+/- Kct+ Ksk+	-

6.8 Limitations of the Groundwater Model

The British Columbia Groundwater Modeling Guidelines (BC MOE 2012) defines three levels of modeling complexity based on potential impacts, modeling objectives, hydrogeological framework and data availability. The model developed here may be classified as moderate complexity, defined as follows: *“These are conceptual or numerical models based on a reasonable, though limited, dataset and having limited calibration. These models may be used to determine the potential range of change or to “bracket” potential effects that may occur due to a given stress.”* Hence, while specific results are calculated during the modelling process, there always remains a degree of uncertainty associated with these estimates.

- The model is based on a unique conceptualisation of the 3D geology, constructed from the analyses of drillhole intercepts (TCL’s database), geological maps (surface and bedrock geology, regional and local maps, 2D cross sections; Clague 1984, MEMPR 1993, BCGS 2005, TCL 2018), and considerations on the ability of a unit to convey groundwater. While geological structures have been mapped and do not appear to influence the flow system, it is not possible to confirm if other large-scale fractures and/or faults are connected and if they act as a conduit or as barrier to flows.
- The characterization of aquitards or aquicludes is uncertain because historical hydraulic conductivity measurements tended to be biased towards specific units (coal) and high permeability intervals in bedrock and overburden. The local heterogeneities that cause perched groundwater lenses in the till, and the potential influence of thick low K mudstone are not well characterized.
- The baseflows are estimated from historical stream flow records of a regional station in Goathorn Creek. The estimation remains uncertain because there is no site data to calibrate the baseflow separation analysis, in particular for the freshet and the high flow periods.
- The base case model results are deemed reasonable considering the calibrated properties are aligned with the average site observations and model integrated all the available data. However, model was only calibrated to steady state conditions and the results have highest confidence in the vicinity of the mine area, where there are relatively more data. Actual ground conditions and properties may vary locally where data are not available; additional collection of K and Sy values would increase the confidence in the model predictions, in particular where parameters are identified as Type IV.
- The groundwater drawdowns and baseflow reductions predicted by the numerical model during mining conditions are biased high because the modelling assumes steady state conditions have been reached, when in reality they most likely won’t have by the end of operations.

7 Conclusions

The models developed for the Tenas Project were based on climate and hydrology data, regional and local geology, site drillholes, and site groundwater data. The level of details, methods, and quality of the information were considered to be adequate for a Joint Application for a Mines Act permit, and for an effluent discharge permit.

The hydrogeological conceptual model was used as a basis to develop two numerical models:

Base Case: fit model to field data, with a final NRMSE of 3.2% for hydraulic heads and 3.6% for baseflows.

High Case: maximized hydraulic conductivity scenario, while still maintaining calibration near the minimum generally accepted in BC (10% NRMSE).

The models relied on steady-state conditions to predict at EoY1, EoY7, EOM, and post-closure conditions.

The conclusions of the modelling can be summarized as follows:

- Pit inflows are expected to range between 310 and 850 m³/d for the base case, and 400 and 1,110 m³/d for the high case. Under groundwater conditions alone, inflows of these magnitudes are typically managed with pit sumps and do not require active dewatering systems.
- Neither mining induced drawdown nor mounding are expected to reach private well locations during the life of mine or post-closure.
- The mining scenario shows maximum reductions of baseflows occur prior to construction of the waste and water management facilities (i.e., about 7% at Tenas Creek, 14% at Four Creek, 3% at the Goathorn Creek, and less than 1% at the Telkwa River). The potential contributions of mine affected groundwater to baseflows, after 25 years of operations, were 0.3% for Tenas Creek, 0.1% for Goathorn Creek, and less than 0.1% for the Telkwa River.
- The post-closure scenario indicates baseflows will either remain unchanged or slightly increase, with a 0.7% increase at Tenas Creek, 7% decrease at Four Creek, 0.1% decrease at the Goathorn Creek, and less than 0.1% decrease at the Telkwa River. The predicted long-term contributions of mine affected groundwater to baseflows were 7.7% for Tenas Creek, 3.4% for Goathorn Creek, and 0.6% for the Telkwa River.
- Mine affected particles are predicted to slowly migrate towards three private wells 3.8 km north of the Project and west of Goathorn Creek (Goalder, Baker, and Mapletoft); however, travel times are expected to be in excess of 400 years for the base case, 300 years for the high case, and less than 170 years for all sensitivities. The wells located east of Goathorn Creek are not located along particle paths.

- Three private wells (Goalder, Mapletoft, and Baker) located in the Telkwa River valley are potentially within the paths of mine affected groundwater. No constituent is predicted to exceed the BC-DWG in the base case scenario, and only cobalt exceeds the BC-DWG in the high case scenario (max. predicted 2.3 µg/L, BC-DWG for cobalt 1 µg/L). The processes of diffusion, dispersion, or natural attenuation, and the predicted travel times (i.e., > 400 years) between the Project and the Telkwa alluvial floodplain were not considered in the analysis.

The modeling presented herein provides forecasts of the expected Project behavior, derived from the available hydrogeological information. The steady state conditions were found to reasonably simulate the site observations and the regional behaviour, with the highest confidence in the vicinity of the Project. Upgrades to the model should be considered as additional information becomes available. Specifically, consideration should be given to:

- The installation of additional monitoring wells downstream and outside the Project footprint, and in the volcanic rock particularly, would increase the confidence in the model predictions,
- Conducting pump tests, with nearby observation wells, to confirm the current assumptions on specific yields, and
- Monitoring seasonal baseflow rates in Tenas Creek and Goathorn Creek, with specific emphasis during the low flow periods.

This additional information would serve to validate the current model predictions.

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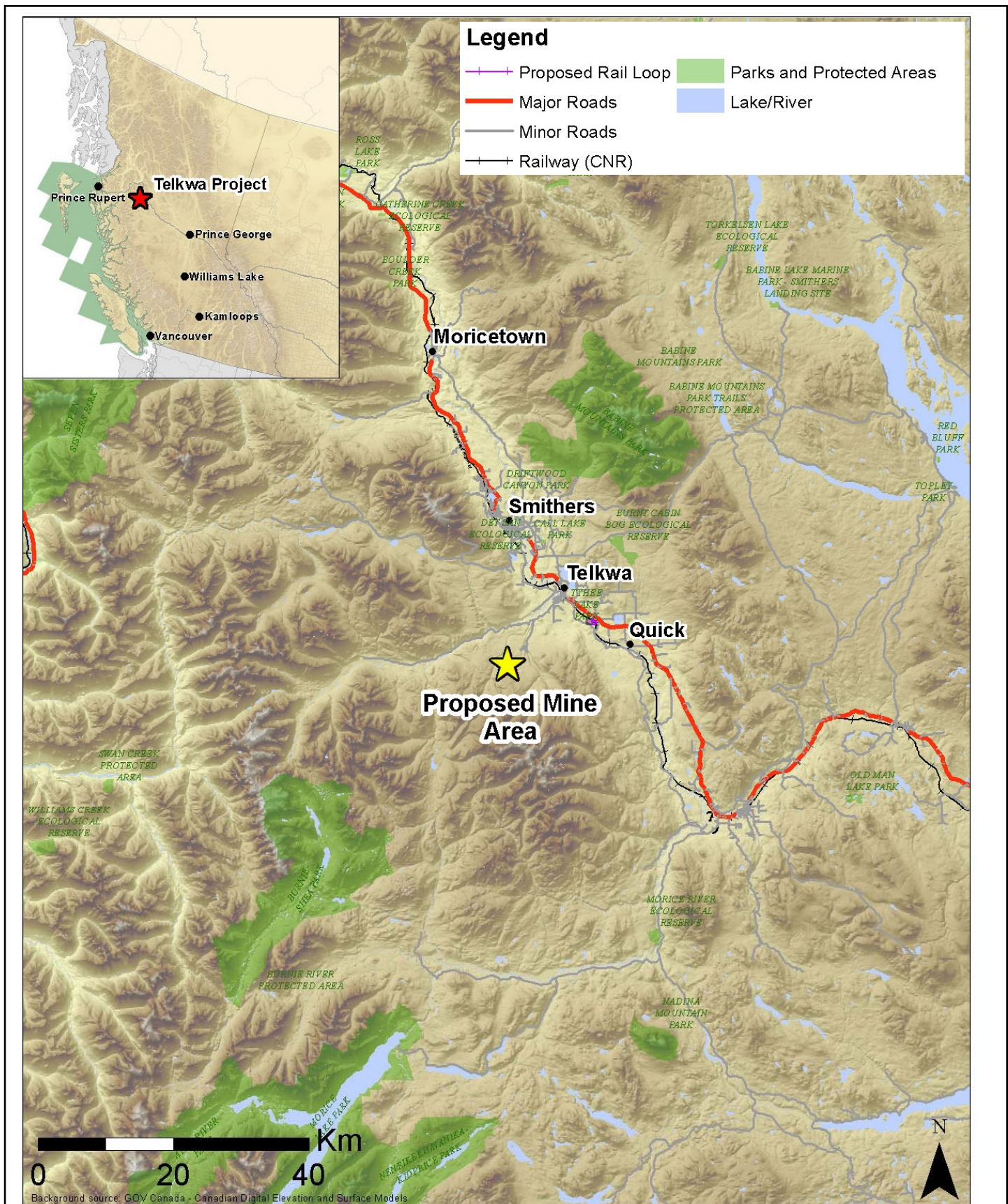
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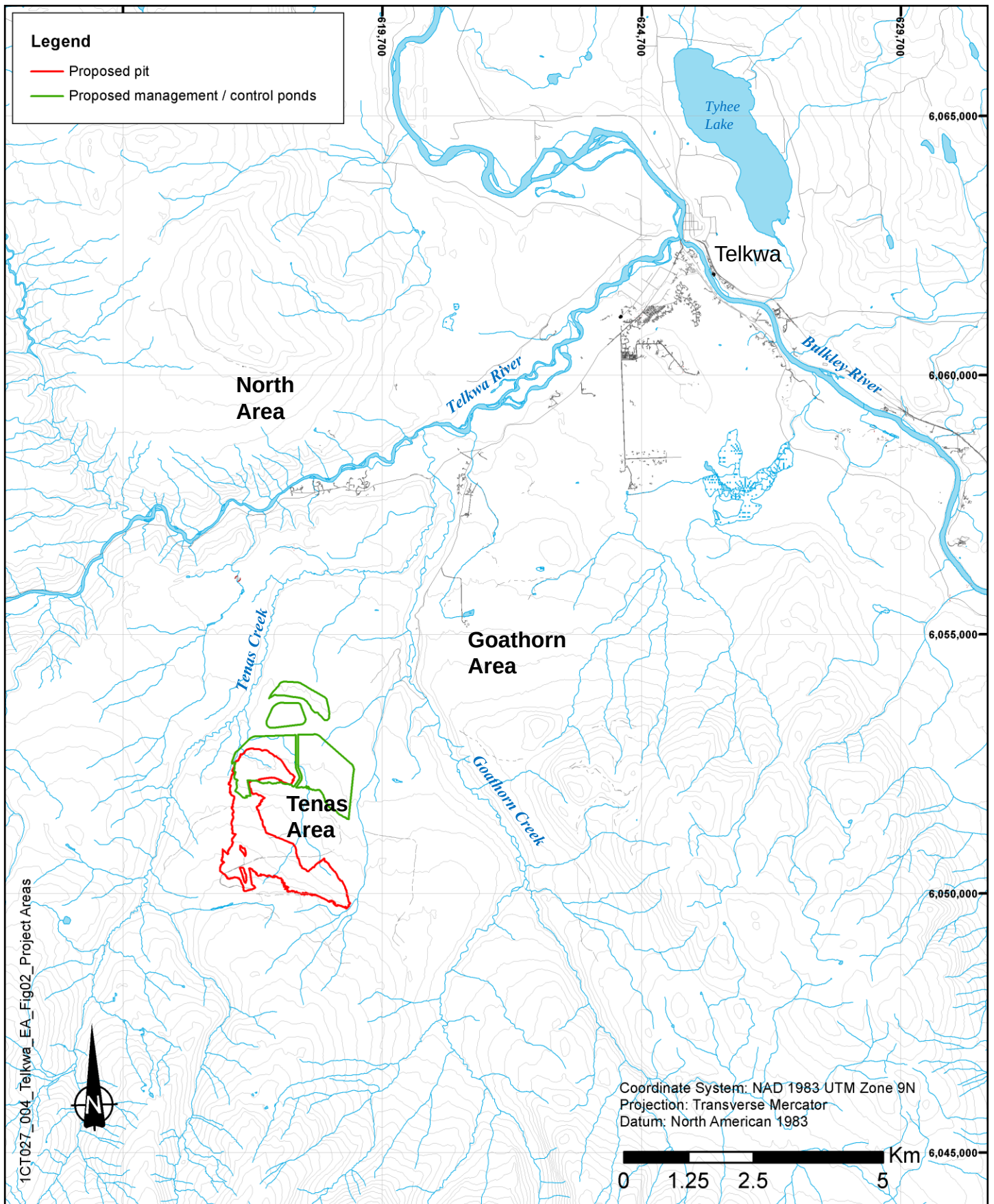
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Figures

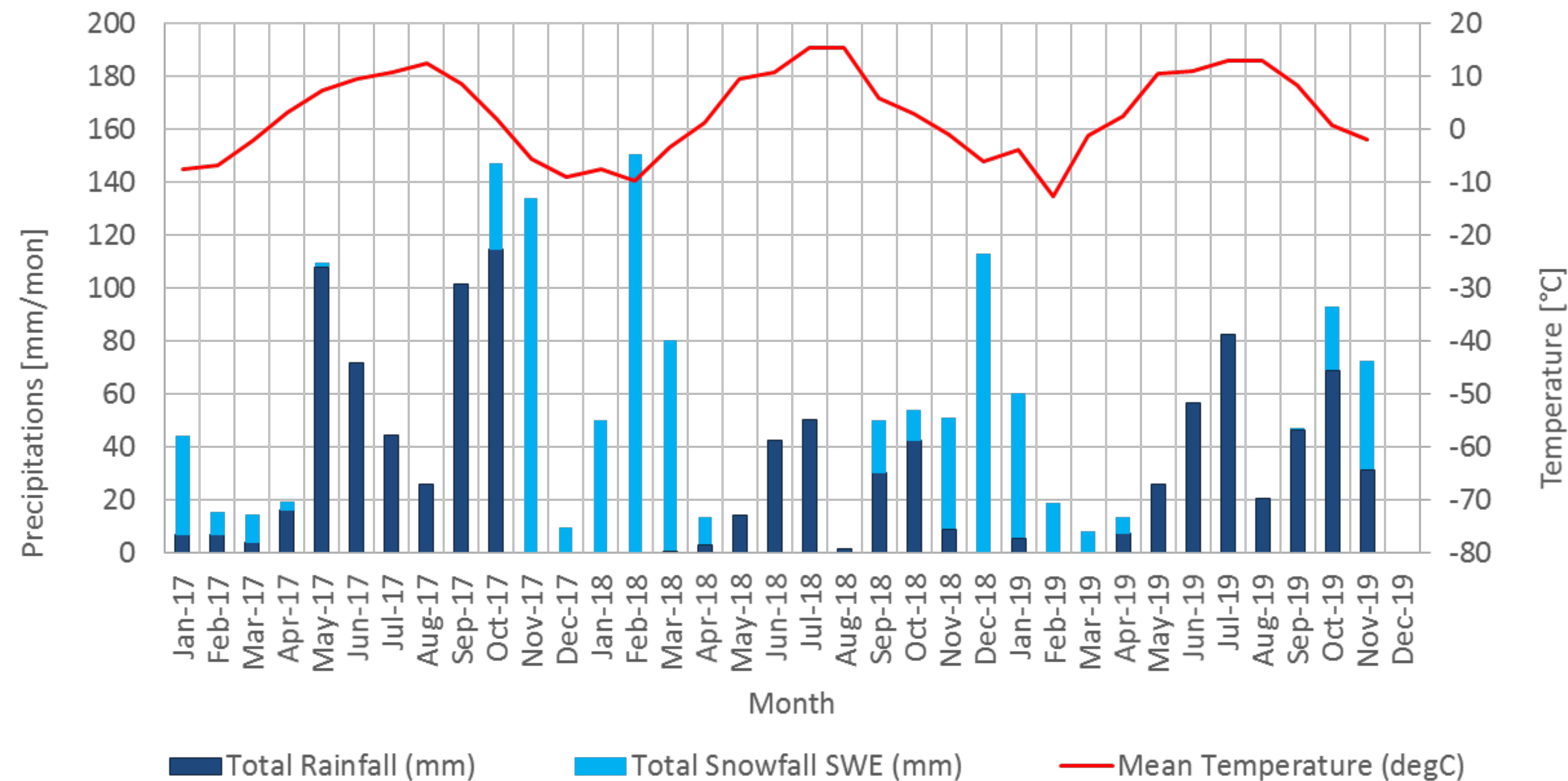


		Groundwater Technical Report		
		Project Location		
Job No: 1CT027.004	Tenas Project	Date: 12/11/2018	Approved: GF	Figure: 1
Filename: Fig1_Projet Location.pptx				

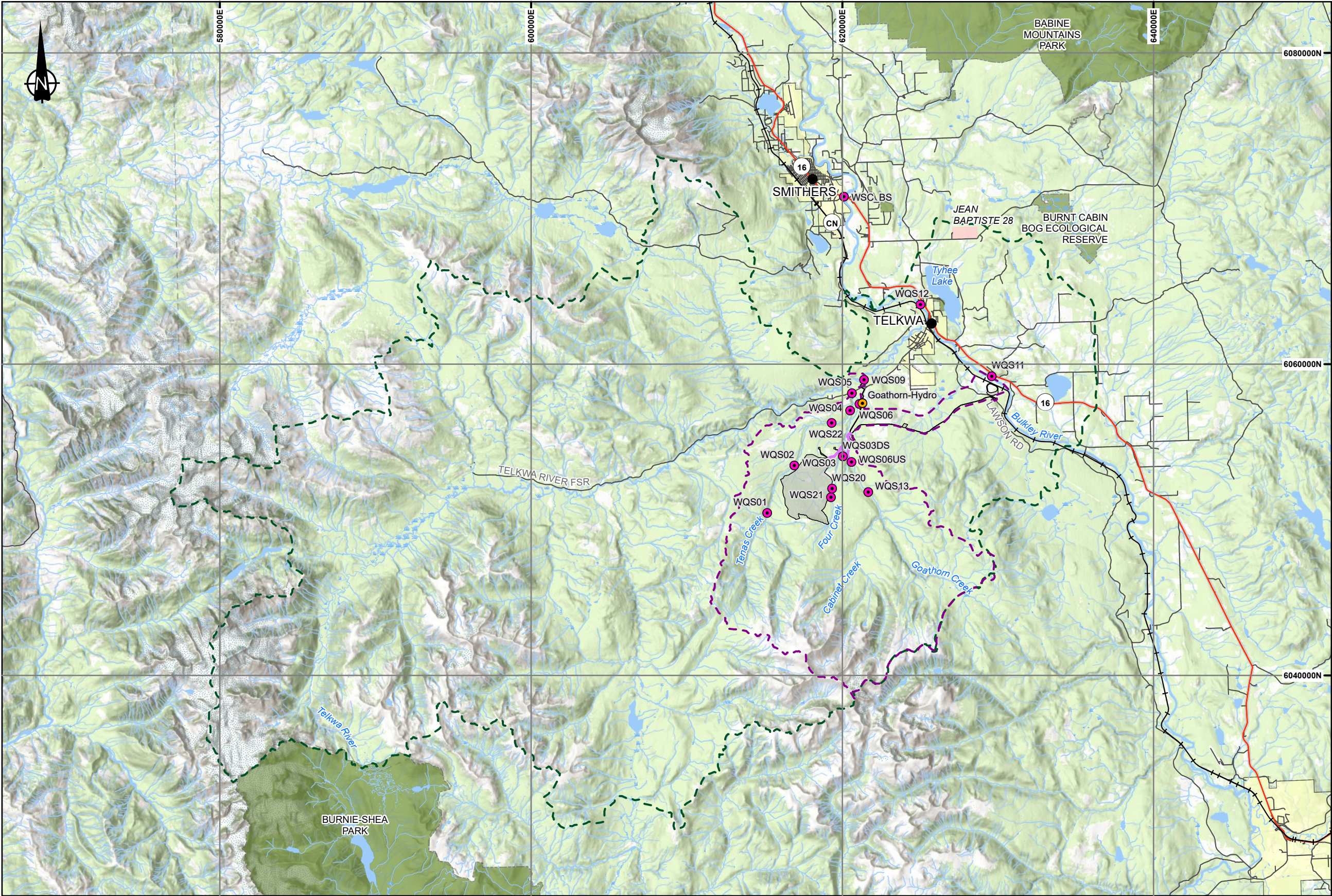


		Groundwater Technical Report		
		Project Areas		
Job No: 1CT027.004	Tenas Project	Date: Nov 2020	Approved: GF	Figure: 2
Filename: Fig02_Project Areas.pptx				

Source: Tenas Deposit met 2017-2019 daily comp.xlsx



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LEGEND

WBLM Nodes

Hydrometric Stations

City/Town

LSA Boundary

RSA Boundary

Tenas Access Corridor

Rail Line

Highway

Road

Project Area

Waterbody

Wetland

Watercourse

Park or Protected Area

First Nation Reserve

Municipal Area

NOTES

1. All mapped features are approximate and should be used for discussion purposed only.

REFERENCES

NAD 1983 UTM Zone 9N

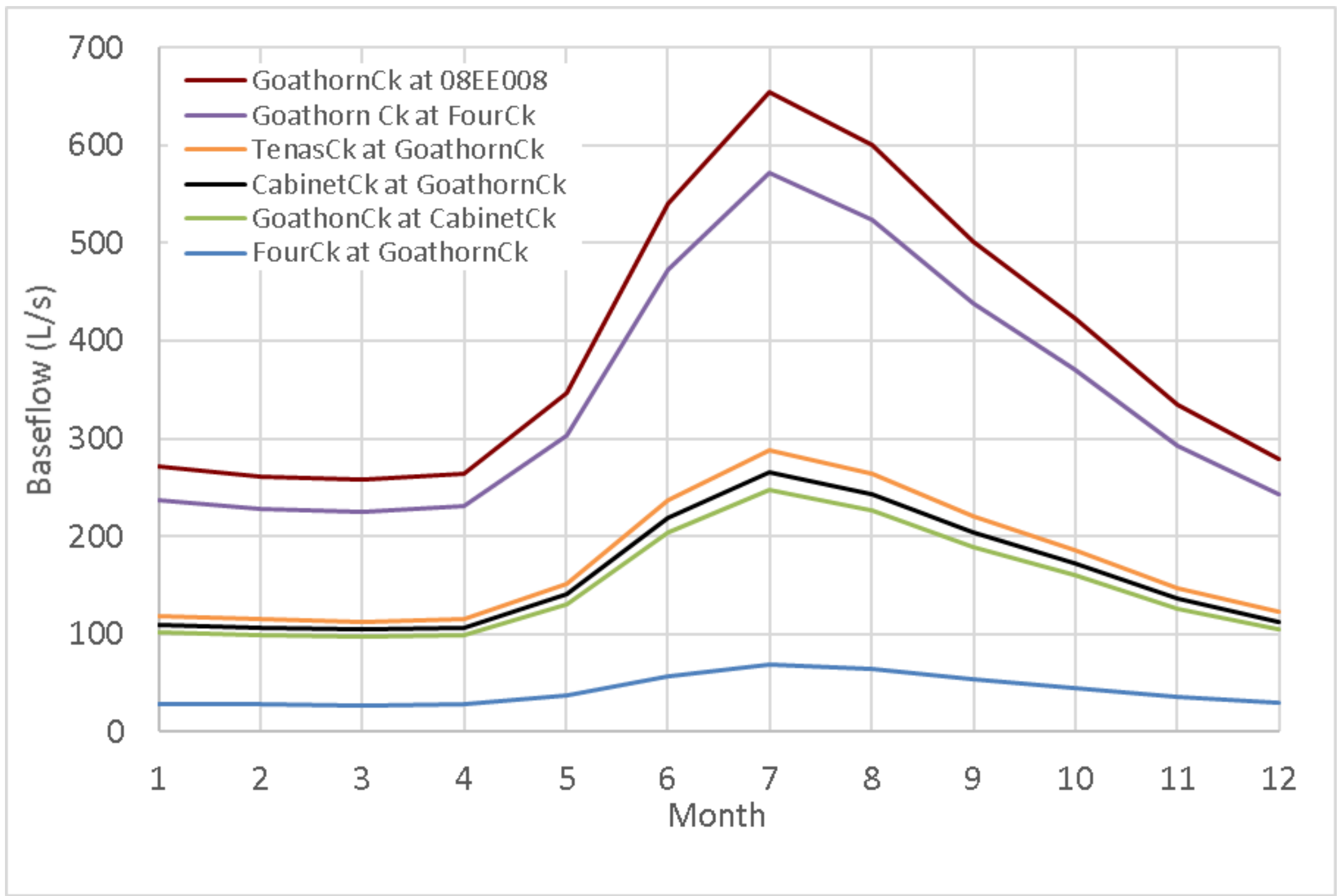
Project features: Allegiance Coal, 2020

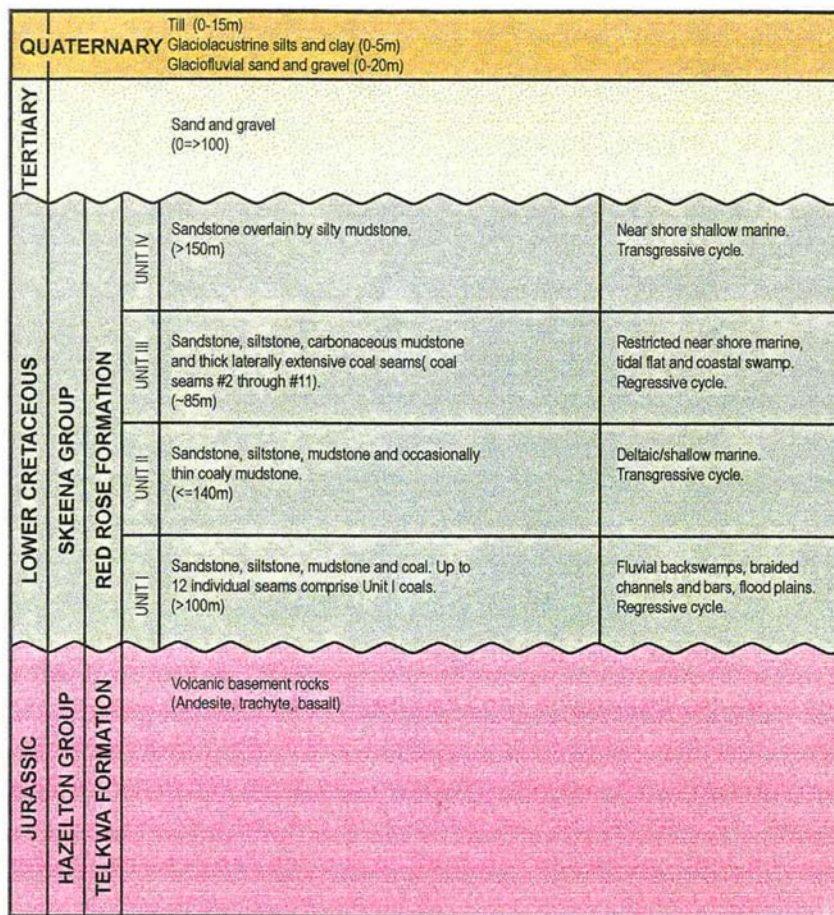
Basedata: Government of British Columbia

Basemap: World Topo Base

025005000750010000

Meters



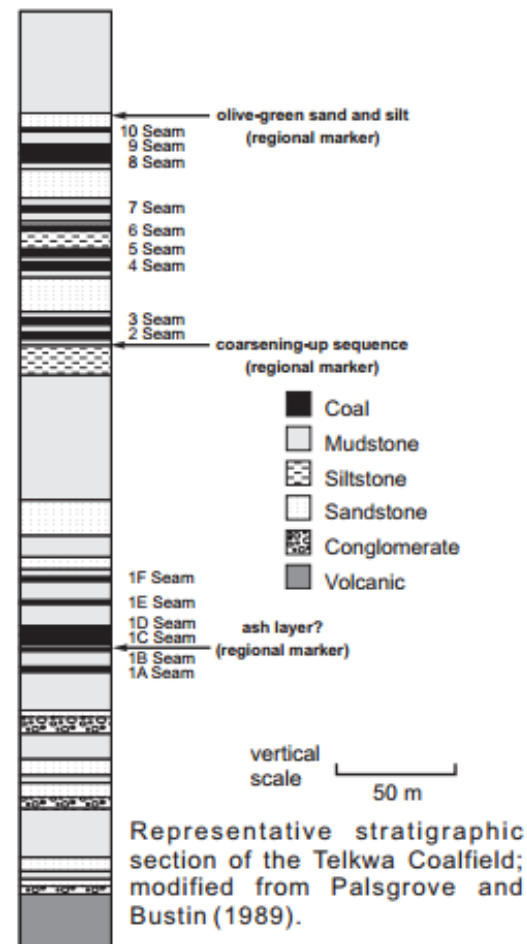


Notes:

1. All formation thicknesses are approximate and could locally vary significantly (esp. Quaternary and Tertiary).
2. Bedrock geology after Manalta (1998).

Simplified Stratigraphic Column (Piteau, 1998).

Lower Skeena Group



Job No: 1CT027.004
Filename: Fig6_Strat Cols.pptx

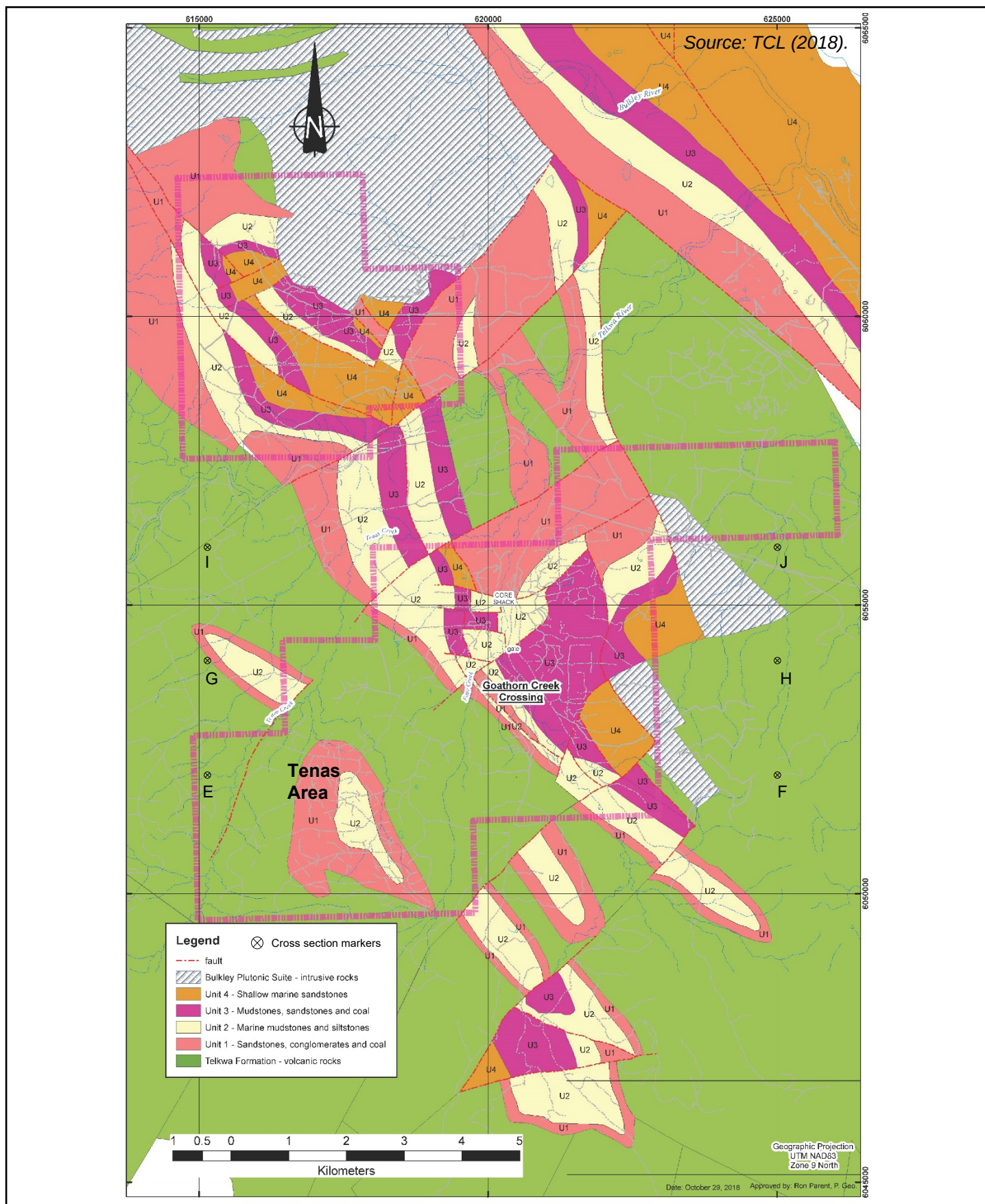


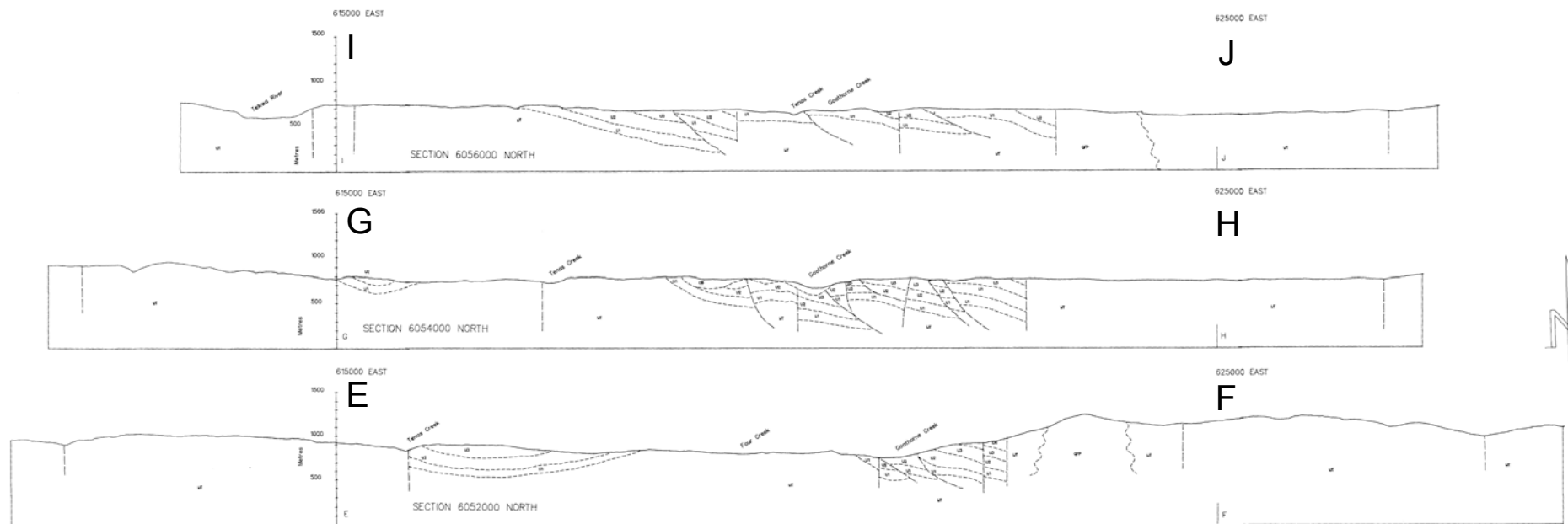
Tenas Project

Groundwater Technical Report

Stratigraphic column of the Telkwa Project area

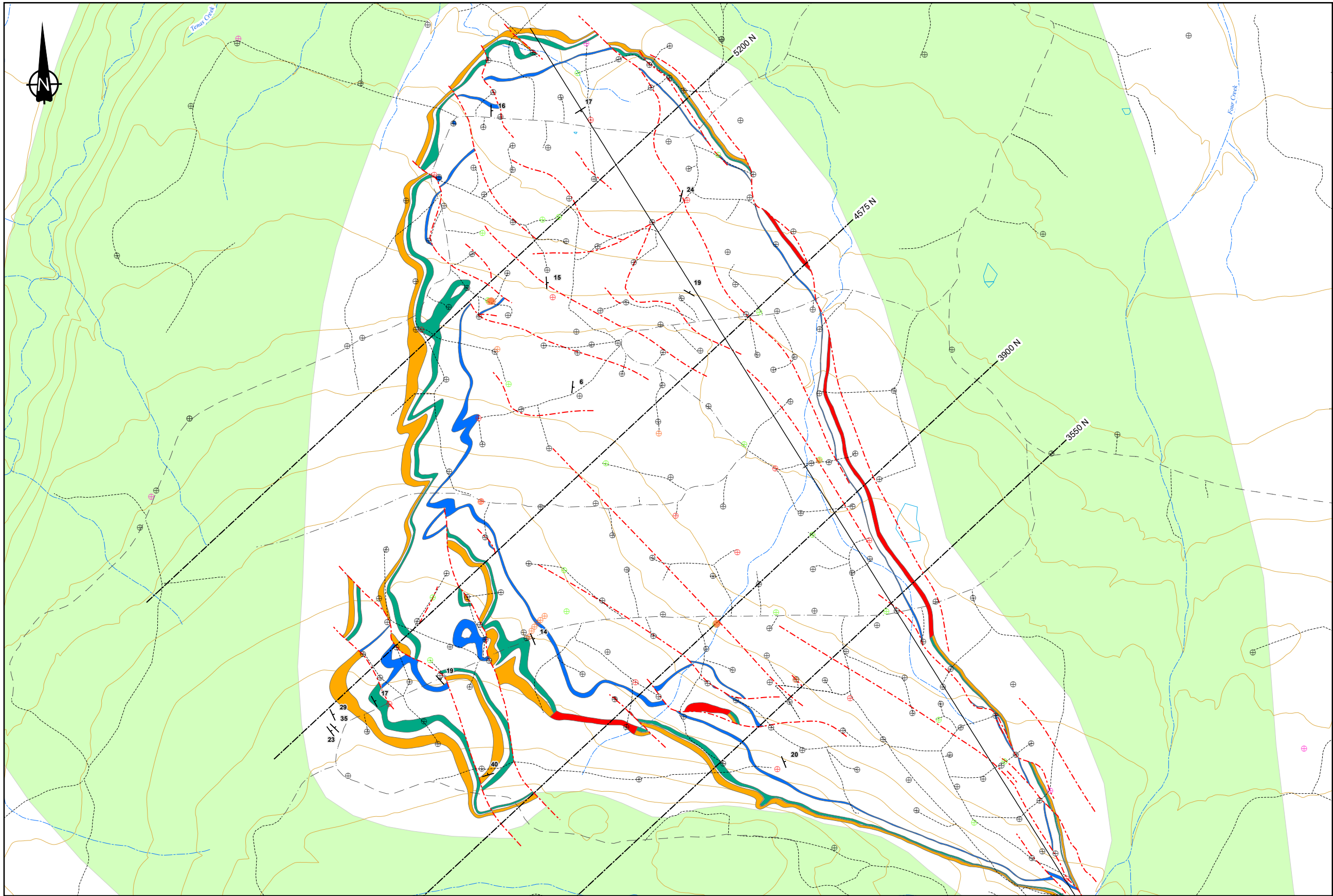
Date: Nov. 2018
Approved: GF
Figure: 6





		Groundwater Technical Report		
		Cross sections of the Telkwa coal field (Palsgrove, 1991)		
Job No: 1CT027.004 Filename: Fig8_CS Telkwa coal field.pptx	Tenas Project	Date: Nov.2018	Approved: GF	Figure: 8

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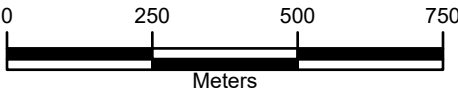


LEGEND

- Existing Drillholes
- ARD Core
 - Bulk Sample Core
 - Core
 - Rotary Core
 - Rotary Bulk Samples
 - Rotary
 - Bedding
 - Syncline
 - Fault
 - Seam C
 - Seam 1 Lower
 - Seam 1 Upper
 - Seam 1
 - Hazleton Volcanics
 - Creeks
 - Cross Sections
 - Forest Service Road
 - Existing Trails
 - Contours (20m)

NOTES
1. All mapped features are approximate and should be used for discussion purposed only.

REFERENCES
NAD 1983 UTM Zone 9N
Figure produced by SRK, project features provided by Allegiance Coal, 2020



SRK JOB NO: 1CT027.004
FILENAME: Fig09_Tenas_Geological_Map.pdf



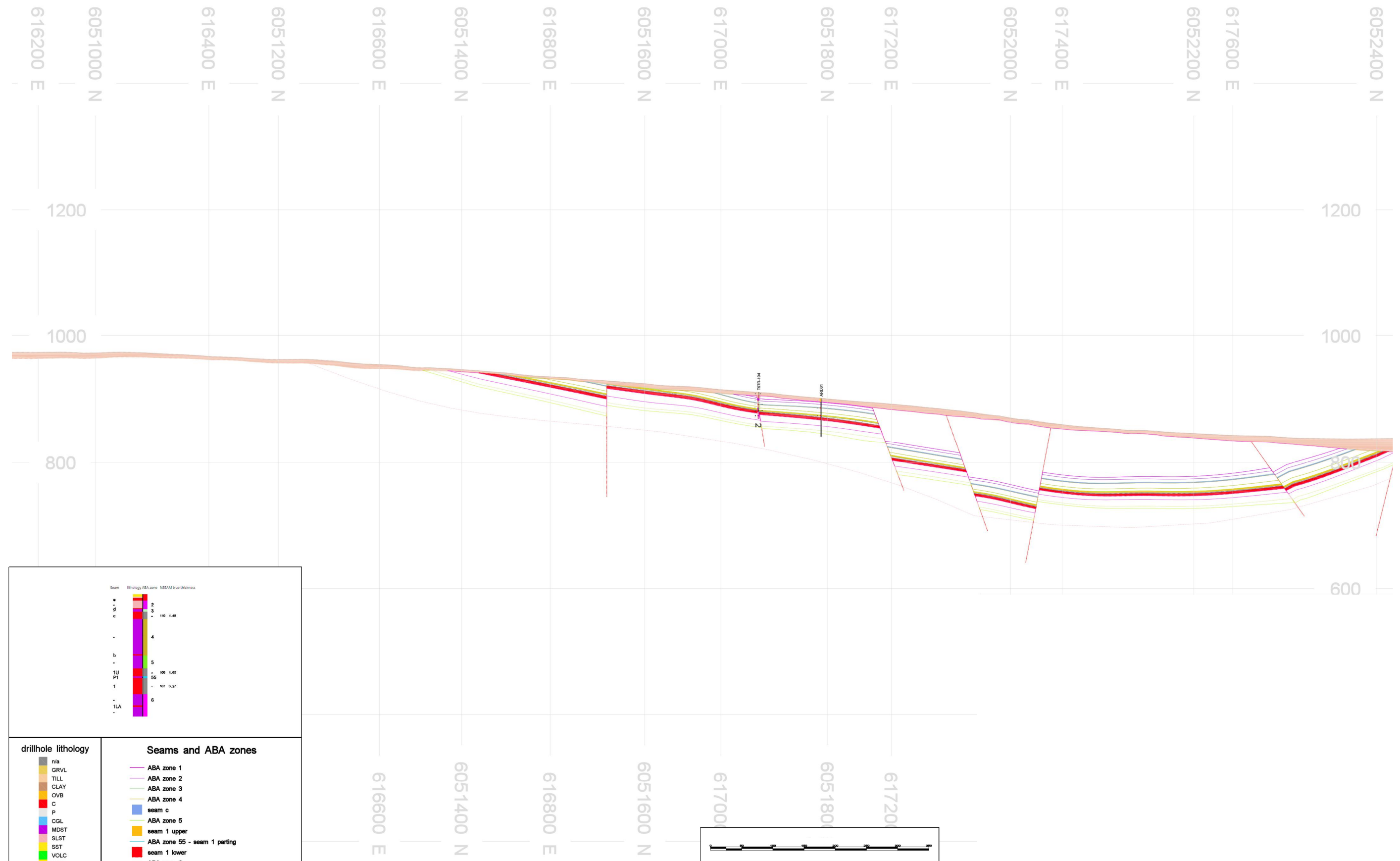
Tenas Project

Groundwater Technical Report

**Geological Map of the
Tenas Area**

Date:	Jan 2021	Approved:	GF	Figure:	9
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Seam

lithology/ABA zone

NSEAM true thickness

2	110	1.45
3		
4		
5		
55	106	1.90
1	107	3.27
6		

drillhole lithology

n/a
GRVL
TILL
CLAY
OVB
C
P
CGL
MDST
SLST
SST
VOLC
SDST
SILT
SAND

Seams and ABA zones

ABA zone 1
ABA zone 2
ABA zone 3
ABA zone 4
seam c
ABA zone 5
seam 1 upper
ABA zone 55 - seam 1 parting
seam 1 lower
ABA zone 6
ABA zone 7
ABA zone 8



SRK JOB NO.: 1CT027.004
FILE NAME: 1CT027.004 Tenas Geological Model Sections.dwg



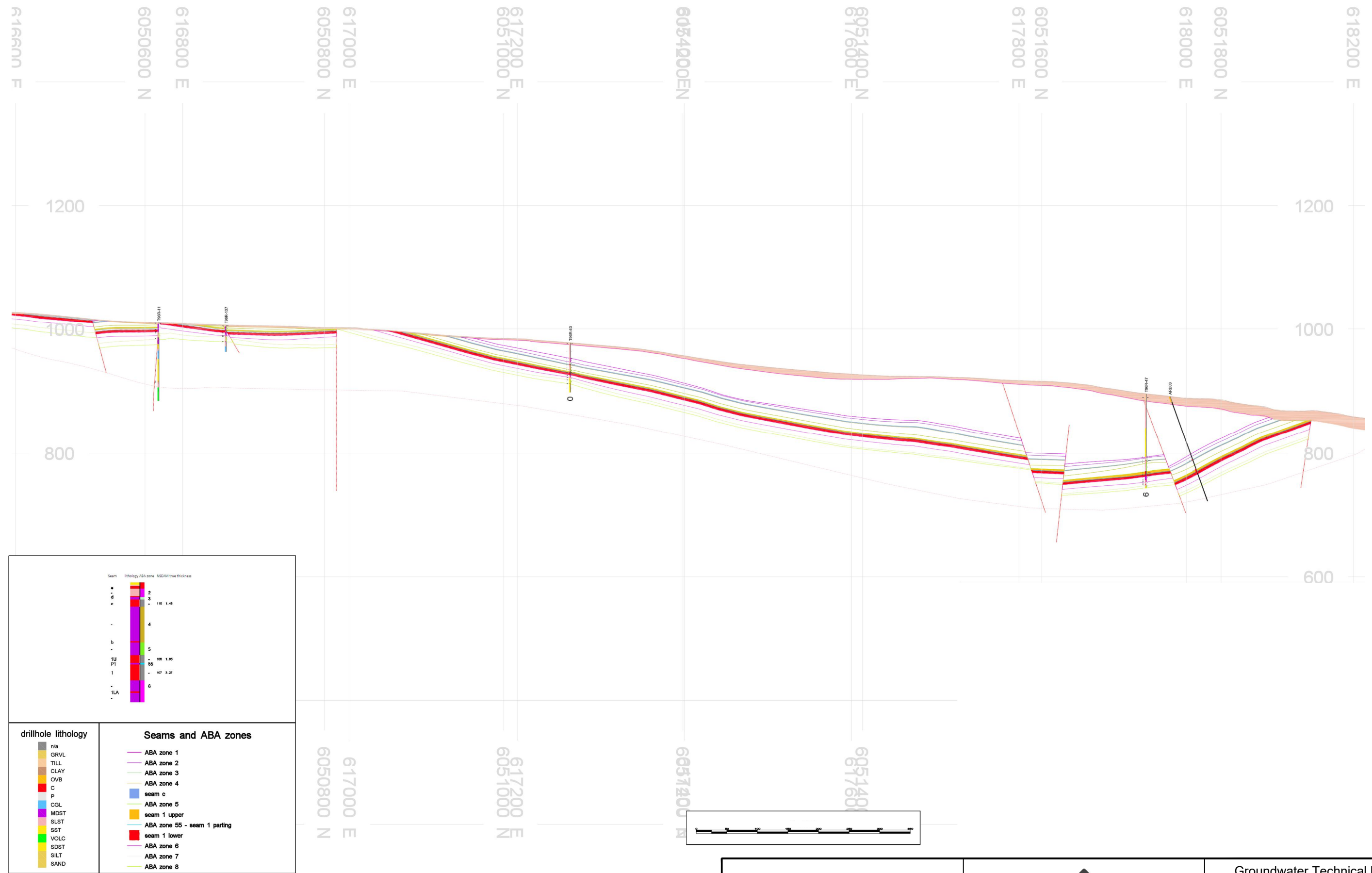
Tenas Project

Groundwater Technical Report

SEC 5200 facing NW (317 az)

DATE: January 2021	APPROVED: GF	FIGURE: 10
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Groundwater Technical Report

SEC 4575 facing NW (317 az)

SRK JOB NO.: 1CT027.004

FILE NAME: 1CT027.004 Tenas Geological Model Sections.dwg

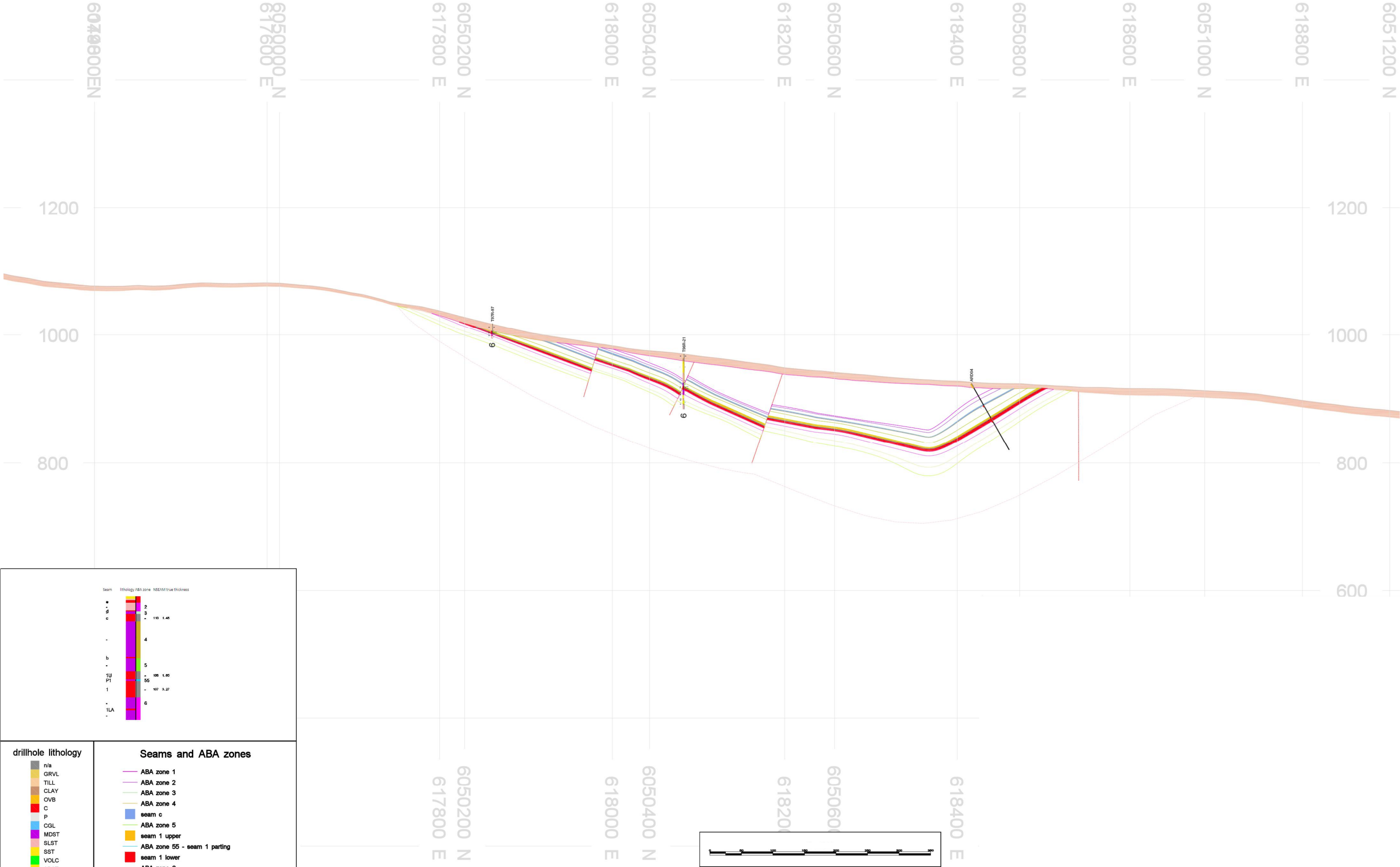
Tenas Project

DATE:
January 2021

APPROVED:
GF

FIGURE:
12

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Seam	lithology/ABA zone	NSEAM true thickness
2		
3		
c		110 1.45
4		
5		
55		106 1.90
1		107 3.27
6		
TLA		

drillhole lithology	Seams and ABA zones
n/a	ABA zone 1
GRVL	ABA zone 2
TILL	ABA zone 3
CLAY	ABA zone 4
OVB	seam c
C	ABA zone 5
P	seam 1 upper
CGL	ABA zone 55 - seam 1 parting
MDST	seam 1 lower
SLST	ABA zone 6
SST	ABA zone 7
VOLC	ABA zone 8
SDST	
SILT	
SAND	



Groundwater Technical Report

SEC 3550 facing NW (317 az)

SRK JOB NO.: 1CT027.004
FILE NAME: 1CT027.004 Tenas Geological Model Sections.dwg

Tenas Project

DATE: January 2021
APPROVED: GF
FIGURE: 13

Volcanics



Volcanics



Weathered Volcanics



		Groundwater Technical Report		
		Example Photos of Volcanic Units		
Job No: 1CT017.004 Filename: Fig14_Volcanics_Photos.pptx	Tenas Project	Date: Apr 2019	Approved: GF	Figure: 14

Sandstone



Coal



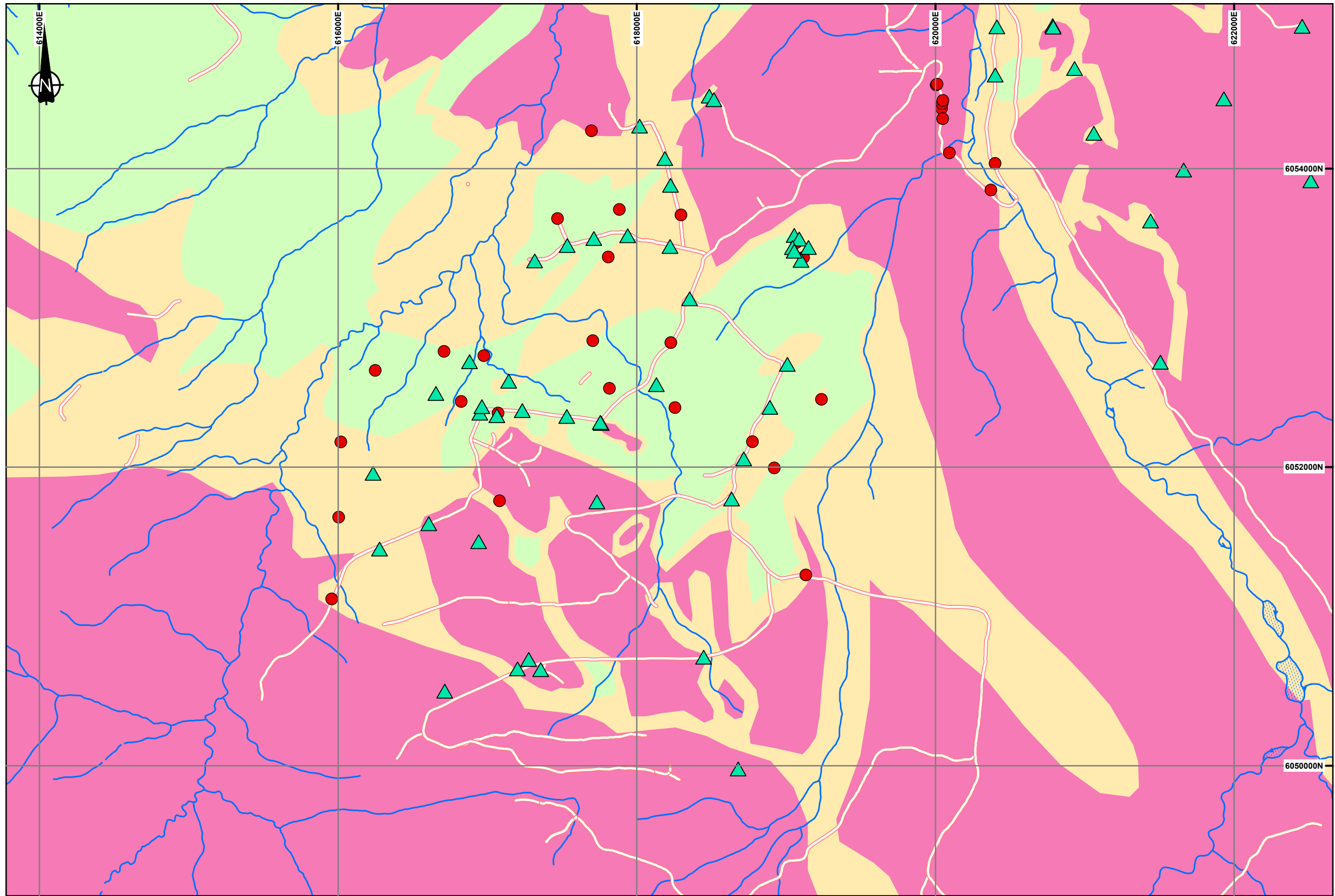
Mudstone/Siltstone



Interbedded Coal and Siltstone



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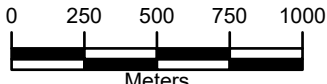


LEGEND

- Test Pit
- Sonic
- Upper Till
- Lower Till
- Sand and Gravel
- Creeks
- Roads

NOTES
1. All mapped features are approximate and should be used for discussion purposed only.

REFERENCES
NAD 1983 UTM Zone 9N
Figure produced by SRK, data provided by Allegiance Coal, 2020



 SRK JOB NO: 1CT027.004 FILENAME: Fig16_Surficial_Geology.pdf	 Tenas Project	Groundwater Technical Report		
		Tenas Creek Surficial Geology		
		Date: Jan 2021	Approved: GF	Figure: 16

Till (Diamond)



Till (Shelby)



Clayey/Silty Sand



Sand and Gravel



Till

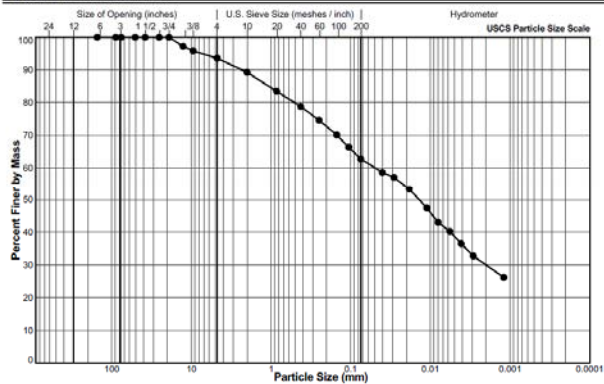


SUMMARY OF PARTICLE SIZE DISTRIBUTION

ASTM D 422

Client: SRK Consulting (Canada) Inc.
Project: Telkwa Coal Limited, Physical Properties Testing
Location: Prince Rupert, BC
Project No.: 1784620 Phase: 2000

Sample Location: T18-135
Sample No.: SPT-01
Depth Interval (m): 1.50 to 1.95
Lab Schedule No.:



Sieve Size (US)	Particle Size (mm)	Percent Passing
6"	152.4	100.0
3.6"	88.9	100.0
3"	76.2	100.0
2"	50.8	100.0
1.5"	38.1	100.0
1"	25.4	100.0
3/4"	19.1	100.0
1/2"	12.7	97.2
3/8"	9.5	95.8
#4 US MESH	4.75	93.5
#10 US MESH	2	89.2
#20 US MESH	0.85	83.4
#40 US MESH	0.425	78.8
#60 US MESH	0.25	74.8
#100 US MESH	0.15	70.1
#140 US MESH	0.106	66.3
#200 US MESH	0.075	62.7
	0.0425	58.3
	0.025	57.1
	0.015	53.4
	0.011	47.5
	0.008	43.0
	0.005	40.3
	0.004	36.8
	0.0025	32.7
	0.0012	26.2

BOULDER	COBBLE	GRAVEL		SAND			FINES (SR, Clay)
		Coarse	Fine	Coarse	Medium	Fine	
DC		3/28/2018		LH		5/4/2018	
Tech		Date		Checked		Date	

Source: SRK Consulting (Canada) Inc. 1784620 Phase: 2000. Sample: T18-135. Sample No.: SPT-01. Depth Interval: 1.50 to 1.95 m. Lab Schedule No.: 1784620-01.

GOLDER Associates Ltd.
4000 - 3611 North Fraser Way Burnaby, British Columbia, Canada V5J 5J2
Tel: +1 (604) 412 0559 Fax: +1 (604) 412 0516 www.golder.com

Sand and Gravel

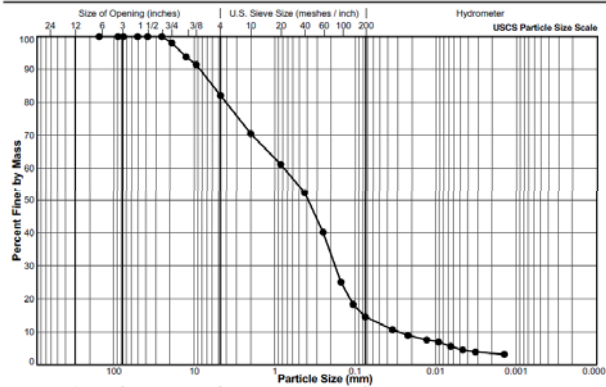


SUMMARY OF PARTICLE SIZE DISTRIBUTION

ASTM D 422

Client: SRK Consulting (Canada) Inc.
Project: Telkwa Coal Limited, Physical Properties Testing
Location: Prince Rupert, BC
Project No.: 1784620 Phase: 2000

Sample Location: T18-035
Sample No.: BLK-02
Depth Interval (m): 9.00 to 9.30
Lab Schedule No.:



Sieve Size (US)	Particle Size (mm)	Percent Passing
6"	152.4	100.0
3.6"	88.9	100.0
3"	76.2	100.0
2"	50.8	100.0
1.5"	38.1	100.0
1"	25.4	100.0
3/4"	19.1	98.1
1/2"	12.7	93.8
3/8"	9.5	91.4
#4 US MESH	4.75	82.1
#10 US MESH	2	70.4
#20 US MESH	0.85	61.1
#40 US MESH	0.425	52.9
#60 US MESH	0.25	45.2
#100 US MESH	0.15	36.1
#140 US MESH	0.106	28.3
#200 US MESH	0.075	14.6
	0.0425	10.7
	0.025	8.9
	0.015	7.8
	0.008	6.9
	0.005	5.6
	0.004	4.5
	0.0025	3.9
	0.0012	3.2

BOULDER	COBBLE	GRAVEL		SAND			FINES (Sil, Clay)
		Coarse	Fine	Coarse	Medium	Fine	
SJ/DC		4/26/2018		LH		5/4/2018	
Tech		Date		Checked		Date	

Source: SRK Consulting (Canada) Inc. 1784620 Phase: 2000. Sample: T18-035. Sample No.: BLK-02. Depth Interval: 9.00 to 9.30 m. Lab Schedule No.: 1784620-01.

GOLDER Associates Ltd.
4000 - 3611 North Fraser Way Burnaby, British Columbia, Canada V5J 5J2
Tel: +1 (604) 412 0559 Fax: +1 (604) 412 0516 www.golder.com



Groundwater Technical Report

Example of Overburden Particle Size Distribution

Job No: 1CT017.004
Filename: Fig18_OverburdenPSD.pptx

Tenas Project

Date: Apr 2019
Approved: GF
Figure: 18