pHase GEOCHEMISTRY

GEOCHEMICAL SOURCE TERM PREDICTIONS

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Palmer Project, Alaska

Report prepared for:

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EXECUTIVE SUMMARY

pHase Geochemistry Inc. has completed source term predictions of water in contact with drift wall rock and waste rock associated with the proposed development drift to support continued exploration at Constantine's Palmer Project. Contact water predictions were further used to estimate portal drainage chemistry and chemistry of recharge in the site area.

Characterization of rock representing the development drift, estimated to be predominantly within hanging wall basalt (95% of the anticipated excavation) and a short section through argillite (5%) has been documented in other reports (pHase, 2018). Results of the characterization work indicated an abundant neutralization potential in the form of calcite and low sulfur content in all the anticipated development rock. Development rock is therefore expected to be entirely non-potentially acid generating (non-PAG) with a low potential for metal leaching.

Kinetic testing in the form of both laboratory-based humidity cells and on-site field barrels were used in this report to provide source term predictions. Prediction methods and input data sources are described. Results indicate that all contact water will remain pH neutral to slightly alkaline with low to moderate sulfate concentrations and negligible trace metals, with concentrations generally similar to groundwater monitored in the area.

Concentrations of nitrogen species are provided based on anticipated explosives use. Results indicate low to moderate nitrogen species concentrations in contact water that will decrease over time as the residues flush from rock surfaces.

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LISTS OF ACRONYMS

ARD	Acid Rock Drainage
HC	Humidity Cell
LAD	Land Application Disposal
ML	Metal Leaching
Non-PAG	Non-Potentially Acid Generating
PAG	Potentially Acid Generating
QEMSCAN	Quantitative Evaluation of Materials by Scanning Electron Microscopy
SW	South Wall
VMS	Volcanogenic Massive Sulfide

GEOCHEMICAL SOURCE TERM PREDICTIONS

PALMER PROJECT, ALASKA

1.0 INTRODUCTION

The Palmer Volcanogenic Massive Sulfide-Sulfate (VMS) Project is a copper-zinc-gold-silver (barite) project located 55 km northwest of the town of Haines in Southeast Alaska, USA. The project is being advanced as a joint venture partnership between Constantine North Inc. (Constantine) incorporated in Alaska (a wholly owned subsidiary of Constantine Metal Resources Ltd.) and Dowa Metals & Mining Alaska Ltd. (Dowa) incorporated in Alaska (a wholly owned subsidiary of Dowa Metals and Mining Co. Ltd. of Japan) with Constantine as operator.

pHase Geochemistry Inc. (pHase) was retained by Constantine to predict geochemical source terms[1] to support permitting related to the proposed development of an exploration drift at the Palmer Project. This report provides the results of source term predictions associated with the proposed underground drift and waste rock brought to surface.

The report is structured as follows:

Section 2 – **Overview:** presents the operational, geological and current acid rock drainage / metal leaching (ARD/ML) information relevant to the Project.

Section 3 – **Methods:** provides the data sources and approach used for source term predictions.

Section 4 – **Results:** provides the calculated source term predictions for the portal discharge and for the waste rock area.

Section 5 – **Summary and Conclusions:** provides the key findings of the geochemical source term predictions.

2.0 OVERVIEW

2.1 Proposed Operational Context

Constantine is evaluating continued exploration of the South Wall Zone in the Glacier Creek prospect area via an underground drift for the purpose of resource definition and exploration drilling. The development would consist of a portal and ramp to access a drilling drift as shown in Figure 1. A number of portal options were evaluated. The selected option, identified as Option 7 and referred to herein as such, includes a portal located in the area immediately southeast of the terminus of the Saksaia Glacier, referred to as the Terminus Area. From the portal, the proposed access ramp would pass under the Saksaia Glacier before turning to the northeast and extending to the South Wall area, where an exploration drift would extend away from the access ramp to serve as a platform for drilling (Core Geoscience, 2018).

[1] The term source term as used in this report refers to rock-water chemistry and represents contact water from specified facilities (mine sources).

A geological cross-section in the area of the proposed exploration drift development is shown in Figure 2. These design plans restrict all development to be entirely within the hanging wall stratigraphy, with no development in the ore horizon, sediments/tuff immediately above the ore horizon, or the footwall rock units.

Much of the waste rock excavated from the drift[2] will be used for constructing avalanche berms & mounds, road surface and building flat laydown areas. Three areas have been selected as potential rock dump sites to store excess waste rock, each with a capacity to store 20,400 to 38,600 cubic meters. Approximately 95% of the waste rock is expected to be basalt with the remaining 5% to be limey argillite. Any seepage from the waste rock will infiltrate to groundwater.

The project design includes a Land Application Disposal (LAD) system of buried pipes. All portal discharge water will be directed to the LAD and also report to groundwater. There is no expected discharge from the mine facilities to surface waters.

A lined temporary waste rock storage site has been included in the engineering designs that could be used for waste storage of any unexpected mine rock with the potential for acid rock drainage/metal leaching (ARD/ML). Seepage from that storage site would be collected in a sediment pond. As no potentially acid generating (PAG) rock is anticipated, no predictions for this facility are provided.

[2] The total volume of waste rock has been estimated to be just under 70,000 m^3 assuming a 10% overbreak and 15% swell factor (Constantine, per. comm.).

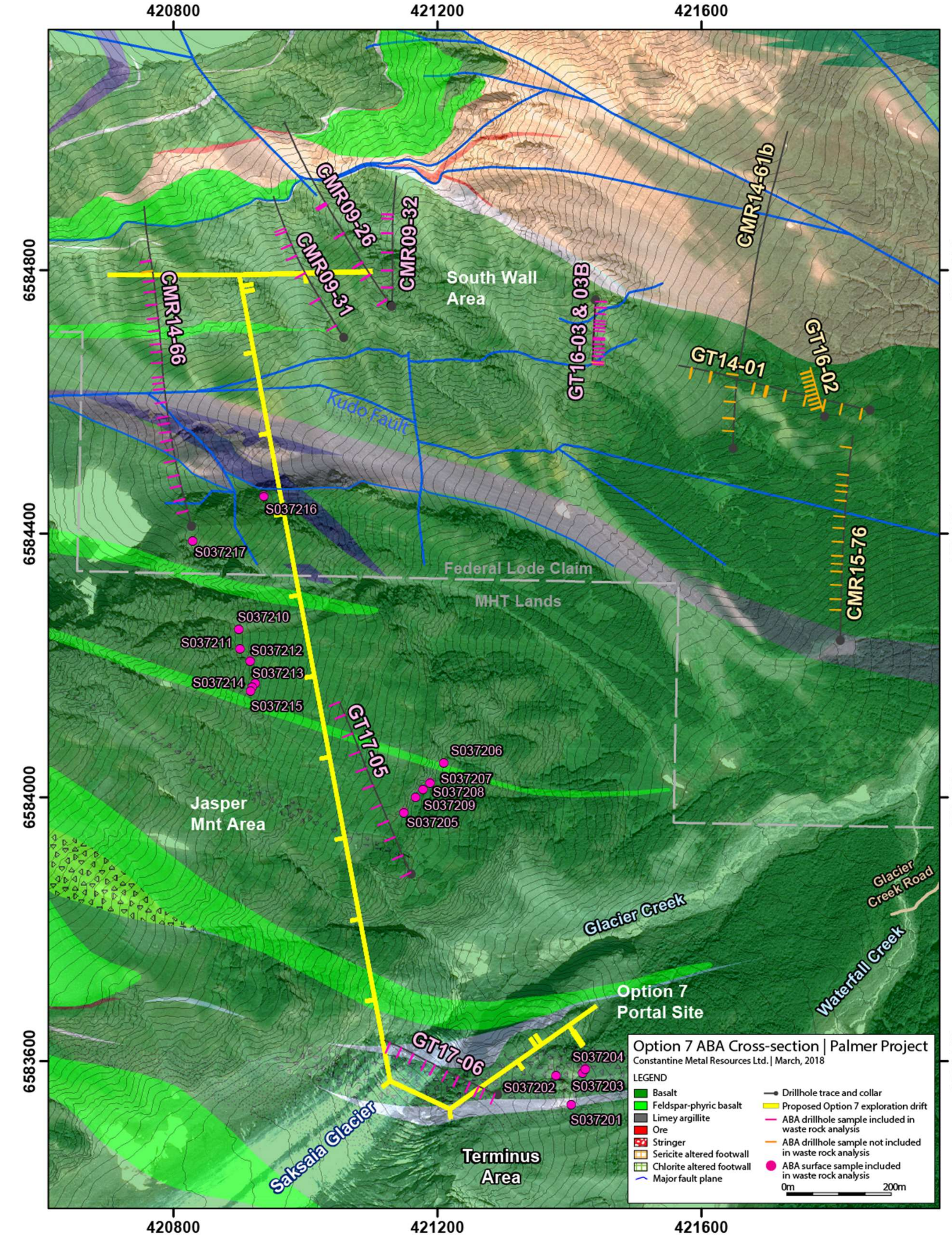


FIGURE 1. PROPOSED EXPLORATION DRIFT.

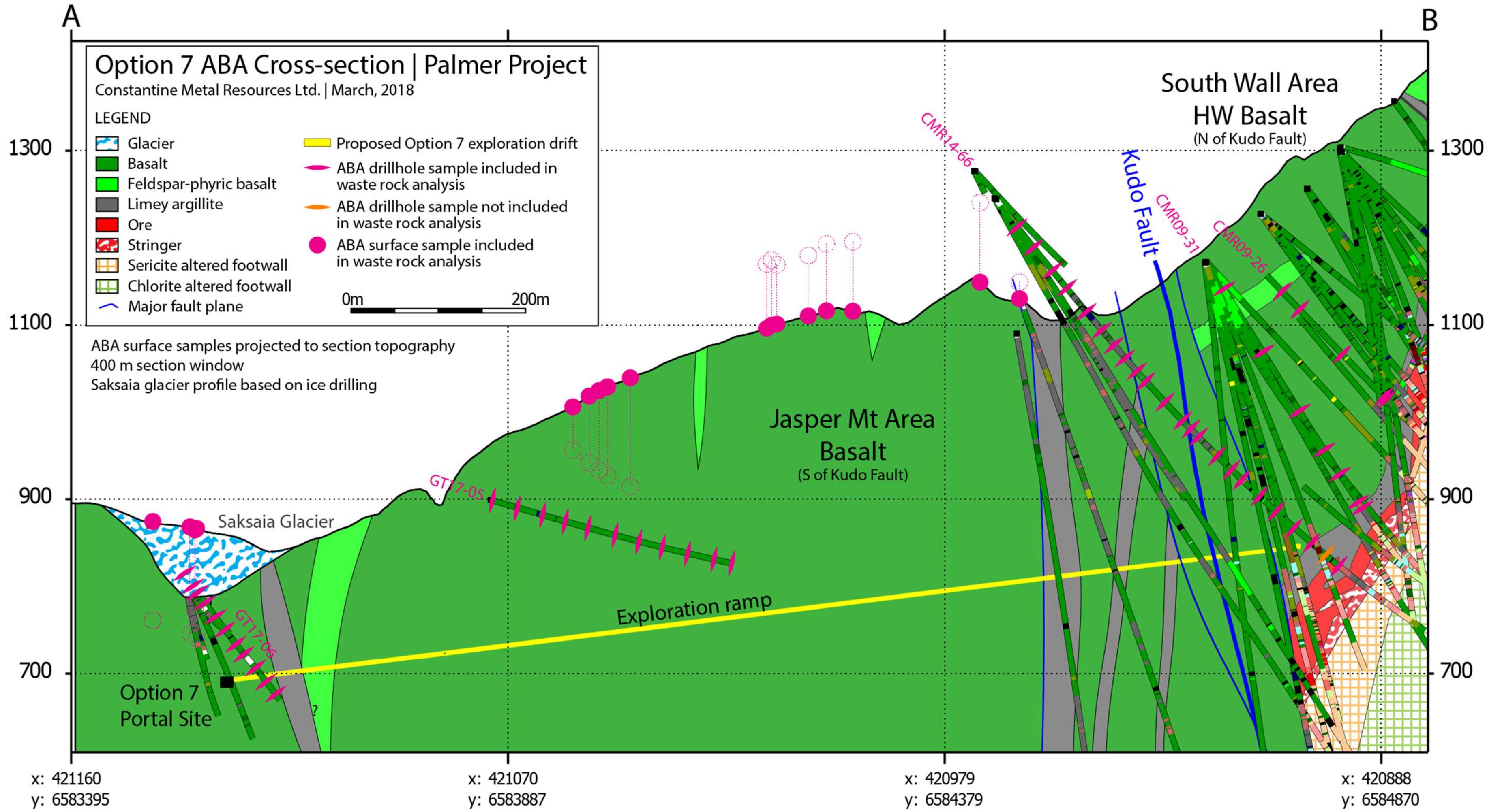


FIGURE 2. CROSS-SECTION IN THE AREA OF PROPOSED EXPLORATION DRIFT DEVELOPMENT.

2.2 Geological Context

The following geology is summarized from excerpts out of the 2015 43-101 Technical Report (Gray and Cunningham-Dunlop, 2015).

The Palmer property lies within a mafic-dominated, bimodal sequence of submarine volcanic and sedimentary rocks belonging to the Alexander Terrane. The Alexander Terrane hosts numerous VMS occurrences throughout Southeast Alaska and northwest B.C. including the Greens Creek and Windy Craggy deposits. The Property is underlain by Paleozoic and lower Mesozoic metasedimentary and metavolcanic rocks that have been intruded locally by Cretaceous and Tertiary granitic plutons.

The Project hosts several mineralized prospects with the Glacier Creek VMS prospect the focus of the majority of exploration. The Glacier Creek deposit consists of seven distinctive zones (lenses) of stratiform massive sulfide-sulfate. These zones of mineralization occur on both limbs of a large-scale, south-overturned anticline that is disrupted by significant faulting and modest offset. Three separate, stratigraphically stacked VMS horizons named South Wall Zones I, II and III, and a zone identified as the South Wall EM Zone, are located on the steeply dipping, south-facing limb of the fold and referred to as the 'South Wall'. The RW Zones, which includes RW East, RW West, and RW Oxide, are located on the north-facing, gently dipping upper limb of the anticline.

Detailed geology and mineralization of all the zones is discussed in greater detail in the 2015 43-101 Technical Report. A simplified account of the South Wall geology is presented here as that is where the proposed exploration drilling will be conducted.

The general stratigraphic package in the South Wall consists of a hanging wall sequence of sulfide poor, carbonate-rich unaltered basalt, and a footwall sequence of moderately to strongly pyrite-quartz-sericite altered volcaniclastic rocks and basalt. A calcareous siltstone/argillite unit a few meters thick commonly separates the hanging wall/footwall sequences, with massive sulfide located at multiple horizons (SW I, II and III) in the footwall sequence, including immediately below the calcareous siltite/argillite unit. The rhyolite unit associated with RW Zone mineralization in the upper limb is absent in the South Wall limb.

VMS mineralization of the South Wall Zones consists of barite, sphalerite, pyrite, chalcopyrite, quartz, and galena, with lesser calcite, magnetite, pyrrhotite, arsenopyrite, chalcocite, tetrahedrite and tenantite. Typical zoning consists of copper-rich massive pyrite-chalcopyrite mineralization grading laterally and vertically outwards into zinc dominant barite-sphalerite-pyrite +/- chalcopyrite mineralization. Further outward, mineralization locally grades into massive carbonate-sphalerite or variably precious-metal enriched low sulfide chert-barite mineralization. Other types of mineralization include copper-rich pyrite and/or pyrrhotite stockwork, and massive pyrrhotite-chalcopyrite.

The proposed exploration drift is designed to stay entirely within the hanging wall sequence of rock units. The access ramp would pass through hanging wall basalts (and subordinate intercalated limey sediments) in the Jasper Mountain Area for most of its length, before passing through limey argillites near the Kudo Fault area and then back into hanging wall basalts of the South Wall area near the intersection of the access ramp and exploration drift (Core Geoscience, 2018). The drift will not encounter VMS mineralization or the footwall sequence. The discussion on VMS mineralization and footwall alteration herein is for information purposes only.

2.3 Current ARD/ML Context

A geochemical characterization program to assess the ARD/ML potential of waste rock that would be generated as part of the exploration drift development was reported by pHase in their report "*Geochemical Characterization in Support of a Proposed Exploration Drift*" (pHase, 2018) and summarized here.

Geochemical sampling and testing programs on potential waste rock material was initiated by Constantine in 2014 as part of the company's baseline environmental program. Samples (n=101) sourced from surface outcrops and drill core were geologically representative of the Option 7 exploration drift (as determined by Constantine) and comprised the three main rock types that would be intersected along the access ramp: Jasper Mountain Basalt (most volumetrically significant), Limey Argillite, and Hanging Wall Basalt in the South Wall area, as well as minor units such as mafic dykes, gabbro, faults etc.

Testwork included static and kinetic testing. Laboratory static tests included acid-base accounting, total inorganic carbon and trace element analyses on all samples, as well as mineralogical analysis via QEMSCAN and particle size analyses on a subset of samples. Kinetic tests included field barrel tests and parallel laboratory humidity cell leach tests on three composite samples representing the three main rock types expected in drift development (Jasper Mountain Basalt, Limey Argillite and Hanging Wall Basalt). The humidity cell program was conducted for 40 cycles while the field barrel tests (initiated summer 2017) are still in progress.

Results indicate that rock expected to be encountered in underground development has abundant neutralization potential and thus buffering capacity, primarily in the form of calcite. Sulfur content in samples tested was generally low and typical of trace to minor amounts of sulfide mineralization in the rock, primarily as pyrite. Sulfur content was typically higher in the Limey Argillite unit than the Jasper Mountain Basalt and Hanging Wall Basalt unit samples.

All rock samples of relevance to the proposed exploration drift classified as non-potentially acid generating (non-PAG). Thus, waste rock encountered during underground drift development is not expected to generate acid rock drainage.

Kinetic test results yielded leachates with alkaline pH and are not expected to generate acid. The potential for metal leaching from the Jasper Mountain and Hanging Wall basalts is low. Leach tests on Limey Argillite indicated an initial flush of soluble selenium from the rock at neutral pH, however, selenium in the humidity cell test declined to lower steady state values. Detailed results of the humidity cell program are reported elsewhere (pHase, in progress).

3.0 METHODS

The Palmer source term predictions utilize an empirical approach based on two separate datasets. The first utilizes laboratory-based humidity cell data (provided in Appendix A) which is scaled-up to anticipated field conditions. The second utilizes field barrel data (Appendix B) representing leachate from rock exposed to site climate conditions. Both approaches are presented herein.

In addition to the above, nitrogen species resulting from explosives use were predicted using methods provided in Ferguson and Leask (1998) and MDAG (2008).

These methods are described in more detail below.

3.1 Data Sources

Inputs to the above calculations include chemistry data, or quality and recharge rates (through waste rock) and inflow to the drift, or quantity. Data sources for each of these inputs are summarized below.

3.1.1. Water Quality

Water chemistry data utilized for the source term calculations included the following:

- Humidity cell test results
- Field barrel data
- Groundwater data to represent inflows to development drift

HUMIDITY CELL DATA

Humidity cell data used in calculations is represented as release rates from the samples in units of mg/kg/wk. Samples representing each of the three main lithological units expected in drift development (Jasper Mountain Basalt, Limey Argillite and Hanging Wall Basalt) were tested for 40 weeks. Results are provided in Appendix A. Weekly release rates were averaged for two time periods representing the initial flush (first 10 weeks of testing) and the steady-state stable rates (cycles 11 through 40) which were then scaled as described in Section 3.1.

FIELD BARREL DATA

Field barrel data was also used as a separate method of assessing potential source chemistry. Four field barrels are currently being monitored, including one each for the three main rock units in the development drift and a fourth barrel that is collecting rain water. Average concentrations for the data record were used as described in Section 3.2. Data is provided in Appendix B.

GROUNDWATER DATA

Groundwater that will infiltrate the development drift is represented by water quality samples collected at monitoring well P29. Results are reproduced in Appendix C.

3.1.2. Inflows and Recharge Rates

INFLOW ESTIMATES

Inflow estimates from the underground portal were provided by Tundra Consulting LLC (Tundra, 2018). Tundra estimated the final portal discharge rate to be about 13 L/s.

RECHARGE RATES

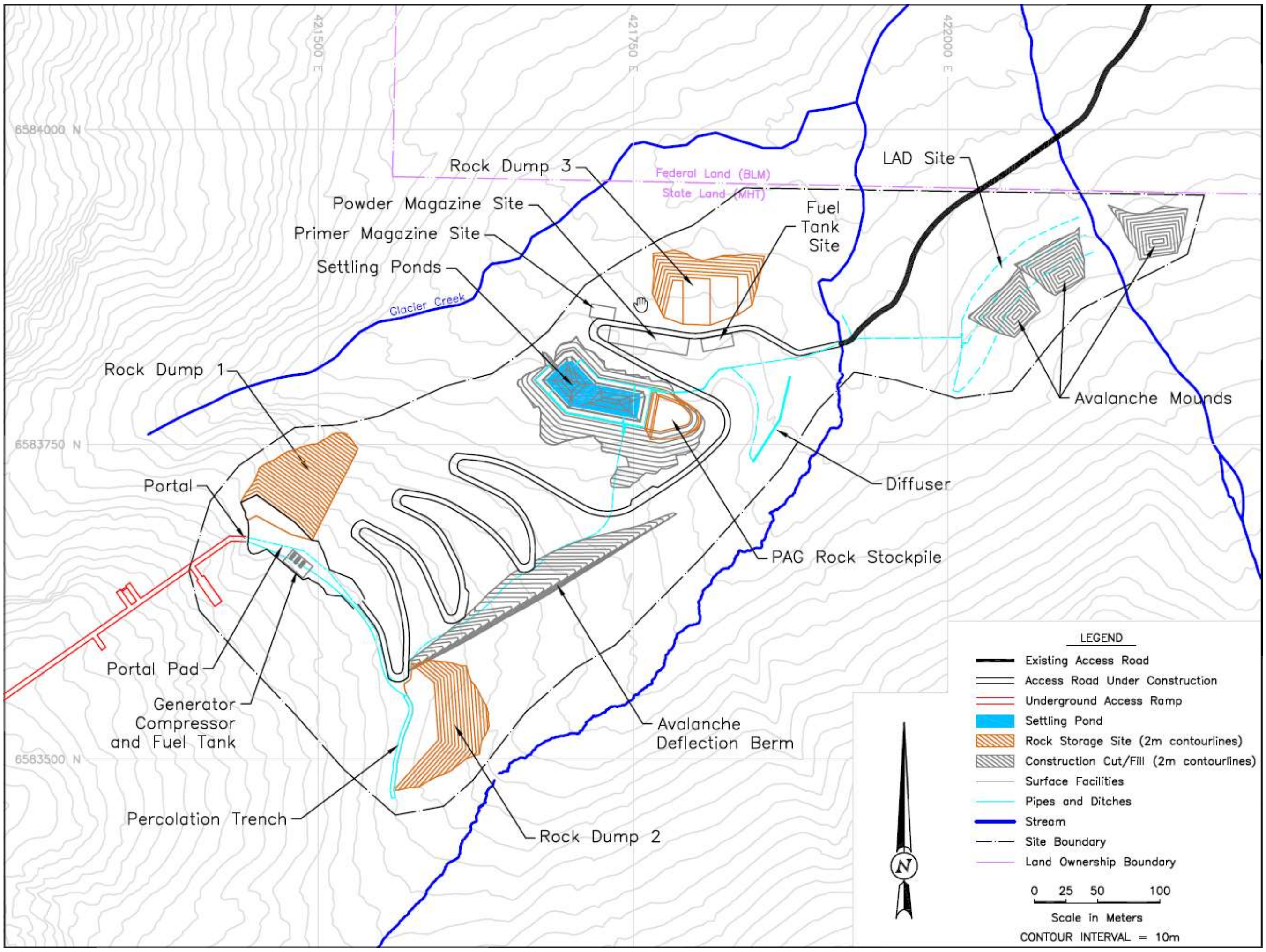
Localized recharge rates through the waste rock and adjacent undisturbed areas (Figure 3), referred to here as the site area recharge were estimated based on climate data as provided in Table 1 (see also Appendix D). For the purposes of this prediction, it was conservatively assumed that all precipitation (rainfall and snowfall) onto waste rock in the area would infiltrate to groundwater. For undisturbed areas however, a run-off coefficient of 70% was assumed whereby 70% of the precipitation as rainfall and snowfall would report to surface waters and the rest would infiltrate to groundwater[3].

TABLE 1. REGIONAL METEOROLOGICAL STATION FOR PALMER PROJECT

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall	(mm)	35	28	24	49	49	37	36	72	148	153	32	40	703
Snowfall	(cm)	165	111	83	21	2.6	0	0	0	0.8	35	128	177	724
Precipitation	(mm)	200	139	106	70	52	37	36	72	149	188	160	217	1427

Note. Data is a summary of 1981 to 2010 Monthly Climate Normals Station Data, Pleasant Camp, BC

[3] Value used is the same as that referenced for a steep grassed slope in Garcia (2016).



(source: Constantine Metals, November 2018)

FIGURE 3. SITE AREA LAYOUT.

3.2 Scaling Humidity Cell Data

Calculations of the initial pore water leachable mass, or load, for each parameter were calculated as given by equation 1:

$$M_{adj} = R \times k_{rm} \times k_{gs} \times k_t \times k_f \qquad \text{[Equation 1]}$$

Where:

M_{adj} = the adjusted leachable mass/load (in mg/wk)

R = element leach rate as observed by laboratory humidity cell testing (in mg/kg/wk)

k_{rm} = reactive rock mass and material mixtures (in kg)

k_{gs} = adjustment factor to correct for grain size effects (unitless)

k_t = adjustment factor to correct for temperature effects (unitless)

k_f = adjustment factor to correct for flow path effects or degree of flushing (unitless)

The adjusted leachable mass for each parameter was converted to concentration as follows:

$$C_{adj} = (M_{adj} / Q) \quad \text{[Equation 2]}$$

Where:

C_{adj} = the adjusted field concentration (in mg/L)

M_{adj} = the adjusted leachable mass/load (in mg/wk)

Q = flows in contact with leachable rock (in L/wk)

3.3 Utilizing Field Barrel Data

The field barrel data at the Palmer Project provides an on-site kinetic dataset that can be used as a comparison to the scaled-up humidity cell predictions. For this assessment, a field-barrel-based concentration to represent wall rock and waste rock was calculated as per equation 3.

$$C_{FB} = (f_A \times C_A) + (f_B \times C_B) + (f_C \times C_C) \quad \text{[Equation 3]}$$

Where:

C_{FB} is the concentration based on field barrel leachate (in mg/L)

f_A is the fraction of drift or waste rock represented by lithology A

C_A is the average field barrel leachate concentration of lithology A in mg/L

F_B is the fraction of drift or waste rock represented by lithology B

C_B is the average field barrel leachate concentration of lithology B in mg/L

F_C is the fraction of drift or waste rock represented by lithology C

C_C is the average field barrel leachate concentration of lithology C in mg/L

3.4 Nitrogen Species Resulting From Explosives Use

Predictions for nitrogen species resulting from blasting residues were calculated as per equation 4 below.

$$L_N = L_{ANFO} \times L/100 \times P/100 \quad \text{[Equation 4]}$$

Where:

L_N is average loading of nitrogen species in kg N/d

L_{ANFO} is average explosives usage in kg N/d

L is the percentage of leached nitrogen relative to the total amount used in the explosives

P is the percentage of the selected nitrogen species relative to the sum of nitrate, nitrite and ammonia

Values for L_{ANFO} were provided by Constantine. Values for L and P were taken from literature (MDAG, 2008).

Predictions represent average nitrate concentrations at full build out of the development drift.

3.5 Water Quality of Development Drift

Water flowing from the development drift will be a mixture of load from infiltrating groundwater and from solubility constituents in the wall rock as water is in contact with the workings. The prediction of drainage out of the drift was determined using equation 5.

$$C_{drift} = \frac{Q_{wall}C_{wall} + Q_{inflow}C_{inflow}}{Q_{drift}} \qquad \text{[Equation 5]}$$

Where:

C_{drift} is water chemistry of drift water in mg/L

Q_{drift} is estimated flow from the development drift in L/s

Q_{wall} is water flow associated with the wall rock in L/s

C_{wall} is the source term concentrations for the wall rock in mg/L

Q_{inflow} is estimated inflow to the development drift in L/s

C_{inflow} is the concentration of groundwater inflow to the development drift in mg/L

3.6 Water Quality from Site Area Recharge

Water infiltrating through waste rock is expected to recharge to groundwater. Locally, this seepage will mix with infiltrating water through undisturbed areas. In order to estimate a combined influence of infiltration through undisturbed areas and waste rock areas, referred to here as site area recharge, a load balance for the localized waste rock area was completed using equation 6 below.

$$C_{recharge} = \frac{Q_{wr}C_{wr} + Q_{undisturbed}C_{undisturbed}}{Q_{recharge}} \qquad \text{[Equation 6]}$$

Where:

$C_{recharge}$ is recharge chemistry in the site area in mg/L

$Q_{recharge}$ is estimated recharge rate, or flow in L/s

Q_{wr} is seepage from the waste rock in L/s

C_{wr} is the average source term concentrations for the waste rock in mg/L

$Q_{undisturbed}$ is estimated recharge rate, or flow from undisturbed areas in the waste rock area in L/s

$C_{undisturbed}$ is the average source term concentrations from undisturbed areas in the waste rock area in mg/L

4.0 RESULTS

The methods and data sources described in Section 3 were used to develop predicted source term chemistries for the development drift and the waste rock contact waters. Results are provided in this section.

4.1 Development Drift

An initial estimate of the reactive mass or load generated from the underground drift for each element (M_{adj}, in mg/wk) was calculated using equation 1. Inputs and assumptions used to calculate the load are discussed below.

Element leach rates (R) used as the starting input values for the 'scaled-up' concentrations were derived from results of laboratory humidity cell tests that are currently in progress on the three main rock types for the Palmer Project: Jasper Mountain Basalt, Limey Argillite and Hanging Wall Basalt. Leach rates representing the initial flush (first ten weeks of testing) and 'steady-state' conditions (weeks eleven through forty of testing) for each of the rock are provided in Appendix A. For the underground wall rock, predictions were based on the stable 'steady state' release rates as the underground rock is not envisioned to be affected by seasonal periods of dry and wet flushing in the same way as rock exposed on surface may be.

Calculated leach rates for the three main rock types were weighted using the estimated volume proportions of each of the rock types in the underground drift. Estimates of reactive rock mass (k_{rm}, in kg) for the underground workings were based on surface areas of exposed underground walls with an assumed reactive wall thickness or zone of 2.0 m depth and an assumed density for basalt of 3 g/cm^3 (3000 kg/m^3). Surface areas for the underground workings were calculated based on the geology and dimensions for the various sections of the underground drift (including access ramp, exploration drift, muck bay, shop) as provided by Constantine and shown in Table 2.

Correction factors applied to the leach rates to adjust for grain size effects (k_{gs}), temperature effects (k_t) and flow path effects or flushing (k_f) for the underground drift source term prediction are summarized in Table 3.

TABLE 2. PALMER UNDERGROUND DRIFT – GEOLOGY, DIMENSIONS AND VOLUMES.

Drift Section	From	To	Length	Design Volume	10% Overbreak	15% Swell	Total Loose Volume	Geology	Dimensions
	(m)	(m)	(m)	(m³)	(m³)	(m³)	(m³)		
Section 1	0	218	218	5160	516	851	6527	Jasper Mt Basalt	Access Ramp is ~5m x 5m arched
Section 1	218	228	10	237	24	39	299	Argillite	Access Ramp is ~5m x 5m arched
Section 1	228	270	42	994	99	164	1258	Jasper Mt Basalt	Access Ramp is ~5m x 5m arched
Section 2	270	370	100	2367	237	391	2994	Jasper Mt Basalt	Access Ramp is ~5m x 5m arched
Section 3	370	427	57	1349	135	223	1707	Jasper Mt Basalt	Access Ramp is ~5m x 5m arched
Section 3	427	459	32	757	76	125	958	Argillite	Access Ramp is ~5m x 5m arched
Section 3	459	1309	850	20120	2012	3320	25451	Jasper Mt Basalt	Access Ramp is ~5m x 5m arched
Section 3	1309	1357	48	1136	114	187	1437	Argillite	Access Ramp is ~5m x 5m arched
Section 3	1357	1394	37	876	88	145	1108	Jasper Mt Basalt	Access Ramp is ~5m x 5m arched
Section 3	1394	1411	17	402	40	66	509	Argillite	Access Ramp is ~5m x 5m arched
Section 3	1411	1454	43	1018	102	168	1288	Jasper Mt Basalt	Access Ramp is ~5m x 5m arched
Section 3	1454	1469	15	355	36	59	449	Argillite	Access Ramp is ~5m x 5m arched
Section 3	1469	1511	42	994	99	164	1258	Jasper Mt Basalt (Kudo Main @~1470m)	Access Ramp is ~5m x 5m arched
Section 3	1511	1623	112	2651	265	437	3354	SW Basalt (end of drift)	Access Ramp is ~5m x 5m arched
Exploration Drift			400	9468	947	1562	11977	SW Basalt	Exploration Drift is ~5m x 5m arched
Muck Bays			132	3300	330	545	4175	11 Muck Bays (Jsp Mt Basalt)	Muck Bay is ~12m x 5m x 5m arched
Sumps			30	750	75	124	949	2 Sumps (Jsp Mt Basalt)	Sump is ~15m x 5m x 5m arched
Muck Bays			36	900	90	149	1139	3 Muck Bays (SW Basalt)	Muck Bay is ~12m x 5m x 5m arched
Sumps			30	750	75	124	949	2 Sumps (SW Basalt)	Sump is ~15m x 5m x 5m arched
Shop			35	1470	147	243	1860	Shop (Jsp Mt Basalt)	Shop is ~(25m x 6 x 6) + (10 x 5 x 5)
		Total	**2,286**	**55,054**	**5,505**	**9,084**	**69,644**		

Source: excel file Option 7 ABA calc(HB-29Oct2018).xlsx (Constantine email October 29, 2018)

TABLE 3. SUMMARY OF CORRECTION FACTORS FOR DEVELOPMENT DRIFT SCALE-UP CALCUATIONS.

Adjustment	Scaling Factor for Development Drift
Grain Size Effects	0.2
Temperature Effects	0.3
Flow Path Effects	1.0
Combined Scaling Factor	0.06

The adjustment for grain size effects (k_{gs}) takes into account the differences between the grain size of the sample subjected to humidity cell testwork (typically -6mm particle size) and that anticipated from blasted and fractured wall rock. The correction for the underground wall rock was assigned a value of 0.2, or 20% of the entire mass is assumed to be present in this more reactive, small particle size fraction. This assumption is based on professional experience elsewhere and is similar to that referenced in literature (e.g. MDAG, 2013).

The adjustment for temperature effects (k_t) was based on the Arrhenius equation for pyrite activation energies of 50 and 60 KJ/mol as shown in Figure 4. A value of 0.3 was selected for the Palmer Project, corresponding to the average measured temperature of about 6 to 8 degrees C.

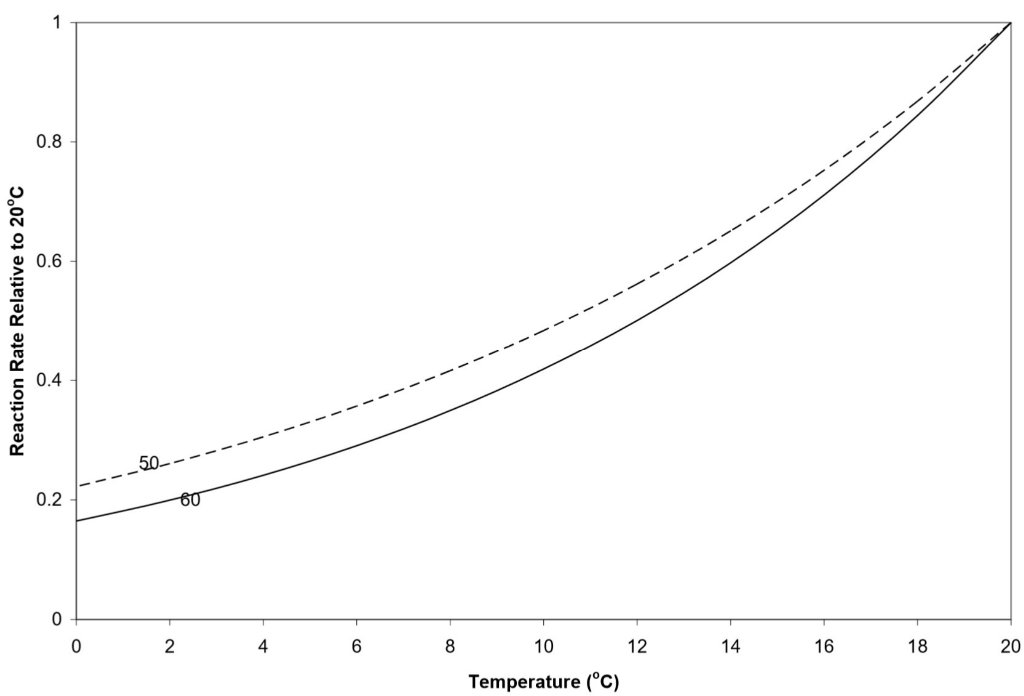


FIGURE 4. PYRITE REACTION RATE AS A FUNCTION OF TEMPERATURE FOR PYRITE ACTIVATION ENERGIES OF 50 AND 60 KJ/MOL (SOURCE MEND, 2006).

The adjustment for flow path development (k_f) is to account for the proportion of rock that is in contact with water. For the purposes of this prediction, it was assumed that all of the wall rock surface area will be flushed, or a factor of 1.0 which is considered a very conservative assumption.

The resulting combined scaling factor applied was 0.06 which is similar to factors referenced in literature (MDAG, 2013). Predicted concentrations (C_{adj}, in mg/L) based on the adjusted initial flush and steady state leach rates (M_{adj}) and estimated inflow of 13 L/s with chemistry represented by average values from monitoring well P29 are provided in Table 4 and identified as "GW + Scaled HC Concentration".

As described in Section 3, field barrel concentrations were also used to provide another assessment of potential drift water chemistry. Contact water from on-site field barrel monitoring tests was mixed proportionally by rock type as in equation 3 and using the lithological proportions as provided in Table 2. Estimates using this second approach are also provided in Table 4 and identified as "GW + Field Barrel Concentration".

To account for nitrogen species loading to the portal water chemistry as a result of blasting, predictions for ammonia, nitrate and nitrite were estimated using methods described in Section 3.3. It is estimated that approximately 110,000 kg of explosives will be used for drift development[4]. The percentage of nitrogen leached relative to the total amount used and the relative percentage as nitrate, nitrite and ammonia were taken from literature. For this prediction, the percentage leached was assumed to be between 6 and 12% of the total explosives usage and speciated as 56% nitrate, 4% nitrite and 40% ammonia based on an underground mine case study (MDAG, 2008).

The predicted source term concentration representing the development drift is provided in the last column of Table 4 and to be conservative represents the maximum value of either the scaled humidity cell-based prediction or mixed field-barrel leachate prediction (minimum value for alkalinity) with nitrogen species calculated based on assumed explosives usage.

Predicted chemistry from the development drift indicate marginally higher concentrations expected over natural background groundwater, with water expected to be slightly alkaline with respect to pH with marginally higher concentrations of parameters such as sulphate, fluoride, aluminum and iron due to contact with wall rock and nitrogen species (nitrate and ammonia predominantly) due to explosives residues. Trace metal concentrations are expected to remain low.

[4] H. Bogert, pers. comm. (email dated May 31, 2018).

TABLE 4. PREDICTED SOURCE TERM FOR DEVELOPMENT DRIFT WATER CHEMISTRY (IN MG/L).

	Average Background Groundwater (GW) at Station P29	GW + Scaled HC Concentration	GW + Field Barrel Concentration	Conservative Predicted Drift Water Chemistry
pH	8.8	8.9	8.2	8.9
Hardness as $CaCO_3$	255	109	255	255
Alkalinity as $CaCO_3$	73	58	73	58
Br	0.05	0.8	0.05	0.8
Cl	0.56	13	0.56	13
F	0.07	0.41	0.07	0.41
SO4	201	246	201	246
NH3 as N	0.03	n.d.	n.d.	0.8
NO3 as N	0.005	n.d.	n.d.	1.1
NO2 as N	0.001	n.d.	n.d.	0.08
Al	0.004	2.9	0.004	2.9
Sb	0.0001	0.003	0.0001	0.003
As	0.0002	0.003	0.0002	0.003
Ba	0.03	0.23	0.03	0.23
Be	0.00002	0.0015	0.00002	0.0015
Bi	0.00005	0.0075	0.00005	0.0075
B	0.02	0.17	0.02	0.17
Cd	0.00001	0.00016	0.00001	0.00016
Ca	82	22	82	82
Cr	0.0001	0.008	0.0001	0.008
Co	0.0001	0.002	0.0001	0.002
Cu	0.0005	0.008	0.0005	0.008
Fe	0.23	0.68	0.23	0.68
Pb	0.00006	0.0008	0.0001	0.0008
Li	0.001	0.016	0.001	0.016
Mg	13	45	13	45
Mn	0.08	0.33	0.08	0.33
Hg	0.000005	0.00009	0.000005	0.00009
Mo	0.015	0.020	0.015	0.020
Ni	0.0005	0.008	0.001	0.008
P	0.002	4.4	0.002	4.4
K	3.3	72	3.3	72
Se	0.00005	0.0028	0.0001	0.0028
Si	5.1	5.4	5.1	5.4
Ag	0.00001	0.00016	0.00001	0.00016
Na	4.5	14	4.5	14
Sr	1.7	2.8	1.7	2.8
Tl	0.00001	0.00017	0.00001	0.00017
Sn	0.0001	0.0016	0.0001	0.0016
Ti	0.0003	0.15	0.0003	0.15
U	0.00002	0.0005	0.00002	0.0005
V	0.0005	0.11	0.0005	0.11
Zn	0.0006	0.05	0.0006	0.05

Notes:

HC = humidity cell

n.d. – not determined

Total metals given for groundwater data (P29), HC and FB chemistries are as dissolved based on lab methods (i.e. filtered leachate)

Nitrogen species – account for explosives residues as calculated separately from humidity cell or field barrel-based predictions

4.2 Waste Rock Site Area

Contact water chemistry predictions for the waste rock were completed using the same methodologies as for the development drift.

An initial estimate of the reactive mass or load generated from the waste rock for each element (M_{adj}, in mg/wk) was calculated from equation 1. Leach rates (R) used as the starting input values for the 'scaled-up' concentrations were derived from lab humidity cell tests on the three main rock types at the Palmer Project as provided in Appendix A and discussed in Section 3.2.1. Leach rates representing the initial flush (first ten weeks) were used in the waste rock prediction calculation to approximate an upper bound chemistry and rates representing the stable steady state release rates (weeks eleven through forty) were used to represent more typical conditions. Calculated leach rates for the three main rock types were weighted using the estimated volume proportions of each of the rock types expected in the waste rock brought to surface (Table 2) to provide typical mixed waste rock leach rates from the waste rock.

Estimates of reactive rock mass (k_{rm}, in kg) were based on the total loose volume (m^3) of waste rock expected, as provided by Constantine and shown in Table 2, and an assumed loose density for basalt of 2.5 g/cm^3 (2500 kg/m^3) Correction factors applied to the leach rates to adjust for grain size effects (k_{gs}), temperature effects (k_t) and flow path effects (k_f) for the waste rock source term prediction are summarized in Table 5. Adjustments for the waste rock were assumed to be similar to those applied to the drift wall rock. The exception was the adjustment for temperature which assumed a slightly colder temperature (6 °C average) in the on-surface waste rock compared to the development drift. Estimates of infiltration were made based on total average precipitation of 1427 mm/yr [5] (Appendix D) and an estimated 22,500 m^2 of waste rock (H. Bogert, email communication dated November 1st, 2018).

TABLE 5. SUMMARY OF CORRECTION FACTORS FOR WASTE ROCK SCALE-UP CALCUATIONS.

Adjustment	Correction Factor for Waste Rock
Grain Size Effects	0.2
Temperature Effects	0.2
Flow Path Effects	1.0
Combined Scaling Factor	0.04

Nitrogen species were calculated as described in Section 3.3 and provided by equation 4.

As with the prediction for the development drift, the lithologically-weighted field barrel leachate was also calculated as another means of predicting contact water chemistry. In addition, the maximum values from the humidity cell tests were also applied in the same manner (i.e. mixed proportionally to expected lithology). Both proportionally-mixed water chemistries are also provided in Table 6.

Based on the above methods, waste rock contact water is predicted to remain pH neutral with low to moderate sulfate concentrations not dissimilar from groundwater monitored in the area. Nitrogen species are expected to be moderate in contact water but will decrease over time as the waste rock flushes. Predicted concentrations of trace metals are low, though molybdenum concentrations in contact water may be elevated relative to background values.

[5] Climate data from Pleasant Camp (BC) Annual precipitation (rainfall and snowfall) based on a 30-year record (1981-2010) as provided in Appendix C.

Waste rock seepage as well as recharge from undisturbed areas within the site boundary will infiltrate to groundwater. For the purposes of this assessment, it was assumed that all precipitation on waste rock would infiltrate; however, only 30% of that falling on undisturbed areas would report to groundwater. Estimates of infiltration or recharge rates assumed a site surface area of 41 acres (or 165,921 m^2 (Figure 3)) consisting of an estimated 22,500 m^2 of waste rock and the remaining 143,421 m^2 consisting of undisturbed areas (H. Bogarty, email communication dated November 1st, 2018).

Concentrations of infiltration through undisturbed areas was assumed to be the maximum concentrations monitored in the fourth field barrel, or 'blank' barrel that monitors incident precipitation chemistry. As a conservative assessment of waste rock seepage concentrations to groundwater, the source term used was taken as the upper bound chemistry from the scaled-up humidity cell. The area-weighted concentration of infiltration through the site area (consisting of both waste rock and undisturbed area) is shown on the furthest right column in Table 6.

When recharge reports to groundwater, it would mix within the groundwater system. Predicting the effect on local groundwater is outside the scope of this assessment. A comparison to local groundwater (in P29) however suggests that the effect would be negligible.

TABLE 6. PREDICTED SOURCE TERM FOR WASTE ROCK WATER CHEMISTRY AND UNDISTURBED AREAS (IN MG/L).

	Natural Area Undisturbed Area Infiltration	Predicted Range of Waste Rock Chemistry				Area-Weighted Recharge Chemistry
		Upper Bound Scaled HC Prediction	Expected Case Scaled HC Prediction	Field Barrel Leachate mixed by proportion	Max HC concentration mixed by proportion	
pH	7.9	7.8	8.3	8.2	8.3	8.1
Hard as $CaCO_3$	1.15	136	64	127	132	48
Alkalinity as $CaCO_3$	1.6	180	162	75	67	63
Br	0.05	0.27	0.27	0.05	0.05	0.13
Cl	0.4	10.0	3.9	1.0	10.0	3.7
F	0.02	0.46	0.12	0.05	0.16	0.17
SO_4	1.1	181	25	73	132	63
NH_3 as N	0.010	n.d.	n.d.	n.d.	n.d.	0.5
NO_3 as N	0.014	n.d.	n.d.	n.d.	n.d.	0.7
NO_2 as N	0.001	n.d.	n.d.	n.d.	n.d.	0.05
Al	0.003	0.18	0.19	0.06	0.35	0.07
Sb	0.0001	0.003	0.001	0.001	0.001	0.001
As	0.0004	0.0006	0.0012	0.0007	0.0005	0.0005
Ba	0.016	0.20	0.29	0.06	0.07	0.08
Be	0.00002	0.0005	0.0005	0.0000	0.0001	0.0002
Bi	0.00005	0.003	0.003	0.0001	0.001	0.001
B	0.01	0.07	0.05	0.02	0.02	0.03
Cd	0.00001	0.0001	0.0001	0.00001	0.00001	0.00001
Ca	0.32	3.4	2.8	38	38	1
Cr	0.0004	0.003	0.003	0.000	0.001	0.001
Co	0.0001	0.001	0.001	0.0002	0.0001	0.000
Cu	0.0003	0.003	0.003	0.001	0.001	0.001
Fe	0.011	0.16	0.16	0.01	0.03	0.06
Pb	0.001	0.0003	0.0003	0.0001	0.0001	0.0010
Li	0.001	0.006	0.005	0.001	0.001	0.002
Mg	0.085	31	14	7.7	9.0	11
Mn	0.01	0.08	0.08	0.01	0.02	0.03
Hg	0.000005	0.00003	0.00003	0.00001	0.00001	0.00001

	Natural Area Undisturbed Area Infiltration	Predicted Range of Waste Rock Chemistry				Area-Weighted Recharge Chemistry
		Upper Bound Scaled HC Prediction	Expected Case Scaled HC Prediction	Field Barrel Leachate mixed by proportion	Max HC concentration mixed by proportion	
Mo	0.0001	0.017	0.002	0.009	0.012	0.006
Ni	0.0005	0.003	0.003	0.001	0.001	0.001
P	0.05	1.6	1.6	0.1	0.3	0.6
K	0.16	56	27	8.5	23	19
Se	0.00005	0.005	0.002	0.003	0.002	0.0019
Si	0.11	1.6	1.6	1.8	1.9	0.6
Ag	0.00001	0.0001	0.0001	0.00001	0.00001	0.00003
Na	0.20	31	3.2	3.9	20	11
Sr	0.001	0.90	0.43	0.56	0.41	0.31
Tl	0.00001	0.0001	0.0001	0.00002	0.00002	0.00003
Sn	0.001	0.0006	0.0005	0.0007	0.0002	0.0006
Ti	0.0003	0.05	0.05	0.0003	0.010	0.02
U	0.00001	0.00	0.00	0.001	0.0001	0.0001
V	0.0005	0.03	0.04	0.002	0.009	0.01
Zn	0.002	0.02	0.02	0.001	0.003	0.01

Notes:

HC = humidity cell
Hardness calculated based on calcium and magnesium concentrations
Nitrogen species – account for explosives residues

5.0 SUMMARY AND CONCLUSIONS

This report describes predictions of source terms and estimated chemistries of portal drainage and recharge from the site area to support the proposed development drift for continued exploration at Constantine's Palmer Project. The development drift would be developed within the hanging wall unit with 95% of the anticipated excavation to be within basalt and roughly 5% through a limey argillite unit.

Characterization of rock representing the development drift wall rock and waste rock has been described elsewhere (pHase, 2018) and indicated that there is abundant neutralization potential in the form of calcite and low sulfur content. Based on that testwork, development rock is expected to be entirely non-potentially acid generating (non-PAG) and metal leaching potential is low. Kinetic testing in the form of both laboratory-based humidity cells and on-site field barrels was included in the characterization program. The results were used in this evaluation to provide source term predictions for development wall rock and waste rock excavated from the drift.

The drift wall rock is not anticipated to contribute significant loading to underground waters and drainage from the development drift will be dominated by the chemistry of the influent groundwater. Predicted chemistries are slightly alkaline with low concentrations of parameters of concern. In alkaline pH, concentrations of aluminum and molybdenum could be slightly above baseline chemistry and nitrogen species due to explosives usage could be slightly elevated during active construction but would decrease with time after construction is completed.

Predictions have not considered potential increases in parameters such as alkalinity, calcium or pH as a result of grout usage underground. If significant amounts of grout are needed during drift development, it might be anticipated that pH in the development drift waters would be elevated (alkaline) for a period of time.

Contact water from the waste rock brought to surface is expected to be pH neutral to slightly alkaline with low to moderate sulfate concentrations similar to groundwater monitored in the area. Nitrogen species are expected to be moderate in contact water but will decrease over time as the waste rock flushes. Predicted concentrations of trace metals are low, though molybdenum concentrations in contact water may be elevated relative to background values. Predicted recharge from the waste rock and undisturbed rock within the site area is provided. Expected recharge will be pH neutral with low concentrations of parameters of interest.

A summary of selected species most likely to be influenced by rock weathering is provided below as extracted from Tables 4 and 6.

TABLE 7. SUMMARY OF PREDICTED PORTAL DRAINAGE AND SITE RECHARGE CONCENTRATIONS FOR KEY PARAMETERS (IN MG/L).

	Conservative Predicted Drift Water Chemistry	Area-Weighted Site Recharge Chemistry
Alk as $CaCO_3$	58	63
SO_4	246	63
Al	2.9	0.07
Cu	0.008	0.001
Fe	0.68	0.06
Mg	45	11
Mn	0.33	0.03
Mo	0.020	0.006
Ni	0.008	0.001
Se	0.0028	0.0019
Zn	0.05	0.01

Note. See full chemistry in Tables 4 and 6 respectively.

This report titled "**Geochemical Source Term Predictions, Palmer Project"** was prepared by pHase Geochemistry Inc. for Constantine and provides the methods and results of source term predictions for the underground development drift and recharge from waste rock and nearby undisturbed areas within the project site.

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APPENDIX A: HUMIDITY CELL LABORATORY LEACH RATES USED FOR SCALE-UP CALCULATIONS

Appendix A. Palmer Humidity Cell Leach Rates used for Scale-up Calculations

		Acidity	Alkalinity	NH3	Br	Cl	F	NO3	NO2	P	SO4	CN (WAD)	Al	Sb	As	Ba
		mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk
Jasper Mtn Basalt	Initial flush	0.57	26.2	0.0048	0.024	1.20	0.0495	0.0062	0.0031	0.00098	21.0	0.0024	0.145	0.00029	0.000048	0.0064
Jasper Mtn Basalt	Stable	0.95	24.5	0.0025	0.024	0.40	0.0111	0.0027	0.0006	0.00096	1.54	0.0024	0.157	0.00010	0.000102	0.0050
Limey Argillite	Initial flush	0.56	42.3	0.0380	0.024	0.28	0.0356	0.0088	0.0026	0.00096	25.6	0.0024	0.055	0.00041	0.000181	0.0092
Limey Argillite	Stable	0.93	39.2	0.0026	0.024	0.24	0.0113	0.0024	0.0006	0.00096	15.9	0.0024	0.021	0.00010	0.000053	0.0071
HW Basalt	Initial flush	0.54	29.5	0.0032	0.024	0.33	0.0247	0.0057	0.0019	0.00119	4.54	0.0024	0.100	0.00016	0.000049	0.0508
HW Basalt	Stable	0.96	25.1	0.0024	0.024	0.25	0.0096	0.0024	0.0005	0.00096	1.55	0.0024	0.097	0.00005	0.000130	0.0871

		Be	Bi	B	Cd	Ca	Cr	Co	Cu	Fe	Pb	Li	Mg	Mn	Hg	Mo
		mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk
Jasper Mtn Basalt	Initial flush	0.000048	0.000240	0.0069	0.00000479	9.4	0.000240	0.000048	0.00024	0.0144	0.000024	0.00048	2.84	0.0087	0.0000024	0.00190
Jasper Mtn Basalt	Stable	0.000048	0.000238	0.0048	0.00000477	6.76	0.000238	0.000048	0.00024	0.0143	0.000024	0.00048	1.05	0.0081	0.0000026	0.00015
Limey Argillite	Initial flush	0.000048	0.000241	0.0099	0.00000481	10.3	0.000241	0.000050	0.00024	0.0144	0.000024	0.00079	8.36	0.0050	0.0000024	0.00263
Limey Argillite	Stable	0.000048	0.000239	0.0048	0.00000478	9.75	0.000239	0.000053	0.00024	0.0143	0.000024	0.00049	6.73	0.0061	0.0000026	0.00090
HW Basalt	Initial flush	0.000048	0.000240	0.0056	0.00000480	5.49	0.000240	0.000048	0.00025	0.0144	0.000024	0.00048	1.41	0.0046	0.0000024	0.00078
HW Basalt	Stable	0.000048	0.000239	0.0048	0.00000478	6.82	0.000239	0.000048	0.00025	0.0143	0.000024	0.00048	0.80	0.0057	0.0000025	0.00006

		Ni	P	K	Se	Si	Ag	Na	Sr	S	Tl	Sn	Ti	U	V	Zn
		mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk	mg/kg/wk
Jasper Mtn Basalt	Initial flush	0.000240	0.144	4.99	0.00021	0.70	0.0000048	3.06	0.09	7.2	0.0000059	0.000056	0.00479	0.000011	0.00220	0.00144
Jasper Mtn Basalt	Stable	0.000238	0.143	2.23	0.00009	0.72	0.0000048	0.31	0.04	0.47	0.0000049	0.000048	0.00477	0.000016	0.00364	0.00143
Limey Argillite	Initial flush	0.000241	0.144	3.05	0.00505	0.70	0.0000048	1.60	0.22	9.0	0.0000048	0.000048	0.00481	0.000309	0.00048	0.00144
Limey Argillite	Stable	0.000239	0.143	0.46	0.00131	0.40	0.0000048	0.12	0.11	5.39	0.0000048	0.000048	0.00478	0.000139	0.00048	0.00143
HW Basalt	Initial flush	0.000240	0.144	5.89	0.00033	1.01	0.0000048	2.91	0.04	1.57	0.0000057	0.000048	0.00480	0.000015	0.00345	0.00144
HW Basalt	Stable	0.000239	0.143	3.26	0.00022	0.94	0.0000048	0.30	0.03	0.49	0.0000052	0.000048	0.00478	0.000025	0.00298	0.00144

Initial flush = average of first 5 weeks

Stable = average of last 5 weeks (last calculated up to week 29)

APPENDIX B: FIELD BARREL LEACHATE CHEMISTRY

Appendix B. On-site Field Barrel Data, Palmer Project

		Barrel 1_Jasper Mt Basalt			Barrel 2_Limey Argillite			Barrel 3_HW Basalt		
		13-Sep-17	16-Oct-17	3-Jun-18	13-Sep-17	16-Oct-17	3-Jun-18	13-Sep-17	16-Oct-17	3-Jun-18
Acidity	mg/L	*1*	1.2	1.2	*1*	1.2	*1*	*1*	*1*	*1*
CN (WAD)	mg/L	0.005	0.005	0.005	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*	*0.005*
Alkalinity	mg/L	40.6	93.8	78.2	51.2	99.9	86.2	49.3	96	82
Br	mg/L	0.05	0.05	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*
Cl	mg/L	*2.32*	1.86	*0.5*	0.82	0.76	*0.5*	0.86	0.77	*0.5*
F	mg/L	0.052	0.115	0.043	0.074	0.125	0.059	0.027	0.044	*0.02*
SO4	mg/L	2.58	17.2	26.5	41.6	204	69.5	4.66	13.1	5.6
NH3-Total	mg/L	*0.0256*	0.0257	0.0244	0.091	0.125	0.0187	0.019	0.018	*0.005*
NO3	mg/L	0.0476	0.005	0.0285	0.049	0.0843	0.117	0.0299	*0.005*	*0.005*
NO2	mg/L	*0.0014*	0.001	0.0045	0.0029	0.0353	0.0019	*0.001*	*0.001*	*0.001*
Dissolved Concentrations										
Al	mg/L	0.137	0.04	0.0274	0.0638	0.0141	0.0082	0.195	0.042	0.027
Sb	mg/L	0.00027	0.00052	0.0006	0.00107	0.00203	0.00133	0.00014	0.00031	0.0003
As	mg/L	0.00011	0.00096	0.00038	0.00469	0.00335	0.00208	0.00011	0.00105	0.00037
Ba	mg/L	0.0109	0.0368	0.0383	0.0126	0.036	0.0143	0.025	0.0838	0.131
Be	mg/L	*0.00002*	*0.00002*	*0.00002*	*0.00002*	*0.00002*	*0.00002*	*0.00002*	*0.00002*	*0.00002*
Bi	mg/L	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*	*0.00005*
B	mg/L	0.012	0.03	0.017	0.017	0.039	0.025	*0.01*	*0.01*	*0.01*
Cd	mg/L	*0.000005*	0.0000088	*0.000005*	*0.000005*	0.0000263	0.0000061	*0.000005*	*0.000005*	*0.000005*
Ca	mg/L	9.33	22.8	28.3	14.7	49.9	15.4	6.58	20.4	21.8
Cr	mg/L	0.00012	0.0007	0.00017	0.00037	0.00068	*0.0001*	0.00028	0.00049	0.00114
Co	mg/L	*0.0001*	*0.0001*	*0.0001*	0.00016	0.00114	0.00028	*0.0001*	*0.0001*	*0.0001*
Cu	mg/L	0.00032	0.00032	0.00024	0.00023	0.00026	*0.0002*	0.00139	0.00131	0.00091
Fe	mg/L	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	0.032	*0.01*	*0.01*
Pb	mg/L	*0.00005*	*0.00005*	*0.00005*	*0.00005*	0.000052	*0.00005*	*0.00005*	*0.00005*	*0.00005*
Li	mg/L	*0.001*	*0.001*	*0.001*	*0.001*	0.0022	0.0018	*0.001*	*0.001*	*0.001*
Mg	mg/L	1.26	5.55	4.27	7.61	34	24.4	0.7	3.84	3.34
Mn	mg/L	0.00597	0.0159	0.0146	0.00662	0.0184	0.00128	0.00472	0.0102	0.00036
Hg	mg/L	*0.000005*	*0.000005*	*0.000005*	*0.000005*	*0.000005*	*0.000005*	*0.000005*	*0.000005*	*0.000005*
Mo	mg/L	0.00207	0.00624	0.00423	0.00391	0.017	0.0173	0.00135	0.0048	0.00234
Ni	mg/L	*0.0005*	*0.0005*	*0.0005*	0.00117	0.00593	0.0032	*0.0005*	*0.0005*	*0.0005*
P	mg/L	-	*0.05*	*0.05*	-	*0.05*	*0.05*	-	*0.05*	*0.05*
K	mg/L	4.42	9.53	7.18	4.17	7.53	5.06	3.56	8.74	7.94
Se	mg/L	0.00038	0.00059	0.000503	0.00367	0.0126	0.00567	0.000788	0.00116	0.000414
Si	mg/L	0.846	1.69	1.6	0.797	1.71	1.04	0.892	1.95	1.83
Ag	mg/L	*0.00001*	*0.00001*	*0.00001*	*0.00001*	*0.00001*	*0.00001*	*0.00001*	*0.00001*	*0.00001*
Na	mg/L	3.83	6.61	1.67	4.08	7.48	2.06	5.78	13.8	3.7
Sr	mg/L	0.127	0.341	0.396	0.754	2.84	1.3	0.0292	0.127	0.128
Tl	mg/L	0.000012	0.000045	0.000017	*0.00001*	0.000044	*0.00001*	*0.00001*	*0.00001*	*0.00001*
Sn	mg/L	*0.0001*	0.00079	0.00111	0.0001	0.00114	0.00122	0.00011	0.00065	0.00077
Ti	mg/L	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	*0.0003*	0.00108	*0.0003*	*0.0003*
U	mg/L	*0.00001*	0.000026	0.000095	0.000694	0.00586	0.00152	0.000021	0.000103	0.000293
V	mg/L	0.00124	0.0011	0.00138	*0.0005*	*0.0005*	*0.0005*	0.0026	0.00153	0.00157
Zn	mg/L	*0.001*	*0.001*	*0.001*	*0.001*	0.0032	*0.001*	*0.001*	*0.001*	*0.001*

Notes:
red italics = value reported as less than laboratory detection limit (detection limit shown).

APPENDIX C: GROUNDWATER DATA (MONITORING WELL P29)

Appendix C. Groundwater Data at Monitoring Well P29

Station P29 representative of GW in area of proposed Option 7 adit

				Conventionals									Anions					
				Acidity as CaCO3	Temp	EC	DO	pH	TDS	Hard as CaCO3	TSS	Turbidity	CN	Alk as CaCO3	Br	Cl	F	SO4
				N	N	N	N	N	N	N	N	0.10	D	N	N	N	N	N
Station ID	Station Description	Sample Date	Sample Event	mg/L	deg C	uS/cm	mg/L	SU	mg/L	mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
P29	Hari Pad Geotech hole; GT-17-05	29-July-2017	July 2017	*1*	7	540.5	0.86	9.3	375	244	*3*		*0.005*	62	*0.05*	0.83	0.075	197
P29	Hari Pad Geotech hole; GT-17-05	10-Aug-2017	August 2017	*1*	6.8	541	0.66	8.97	347	258	*3*		*0.005*	78	*0.05*	0.5	0.079	196
P29	Hari Pad Geotech hole; GT-17-05	31-Aug-2017	August 2017	*1*	4.8	535.1	1.13	8.95	344	250	*3*		*0.005*	74.7	*0.05*	*0.5*	0.073	199
P29	Hari Pad Geotech hole; GT-17-05	2-Aug-2018		1.6					414	262	*3*	1.54	*0.005*	75.2	*0.05*	*0.5*	0.070	206
P29	Hari Pad Geotech hole; GT-17-05	19-Aug-2018		1.9					393	247	*3*	1.73	*0.005*	72.3	*0.05*	*0.5*	0.071	206
P29	Hari Pad Geotech hole; GT-17-05	19-Sep-2018		1.2		535		8.11		270		2.41	*0.005*	74.5	*0.05*	*0.5*	0.068	199
AVERAGE				1.34	5.8	537.0333	0.895	8.676667	374.5	257.4	3	1.893333	0.005	74.94	0.05	0.5	0.0722	201.2

Appendix C. Groundwater Data at Monitoring Well P29

Station P29 representative of GW in area of proposed Option 7 adit

				Nutrients						Total Metals								
				NH3 as N	NO3+NO2 as N	NO3 as N	NO2 as N	Phosphorus (P)-Total Dissolved	Phosphorus (P)-Total	Al	Sb	As	Ba	Be	Bi	B	Cd	Ca
				N	N	N	N	0.0020	0.0020	T	T	T	T	T	T	T	T	T
Station ID	Station Description	Sample Date	Sample Event	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
P29	Hari Pad Geotech hole; GT-17-05	29-July-2017	July 2017	0.0328	*0.0051*	*0.005*	*0.001*			0.0049	0.00023	0.00021	0.0313	*0.00002*	*0.00005*	0.027	*0.000005*	77.9
P29	Hari Pad Geotech hole; GT-17-05	10-Aug-2017	August 2017	0.029	--	--	--			0.0039	0.00013	0.00022	0.0312	*0.00002*	*0.00005*	0.025	*0.000005*	81.7
P29	Hari Pad Geotech hole; GT-17-05	31-Aug-2017	August 2017	0.0306	*0.0051*	--	--			0.0050	0.00010	0.00020	0.0298	*0.00002*	*0.00005*	0.022	*0.000005*	82.3
P29	Hari Pad Geotech hole; GT-17-05	2-Aug-2018		0.0267	*0.0051*	*0.005*	*0.001*	*0.002*	*0.002*	0.0031	*0.0001*	0.00017	0.0288	*0.00002*	*0.00005*	0.024	0.0000119	84.0
P29	Hari Pad Geotech hole; GT-17-05	19-Aug-2018		0.0270	*0.0051*	*0.005*	*0.001*	*0.002*	*0.002*	0.0037	*0.0001*	0.00019	0.0307	*0.00002*	*0.00005*	0.024	*0.000005*	87.3
P29	Hari Pad Geotech hole; GT-17-05	19-Sep-2018		0.0198	*0.0051*	*0.005*	*0.001*	*0.002*	*0.002*	0.0034	*0.0001*	0.00017	0.0264	*0.00002*	*0.00005*	0.025	0.0000099	81.2
AVERAGE				0.02662	0.0051	0.005	0.001	0.002	0.002	0.00382	0.000106	0.00019	0.02938	0.00002	0.00005	0.024	0.00000736	83.3

Appendix C. Groundwater Data at Monitoring Well P29

Station P29 representative of GW in area of proposed Option 7 adit

				Total Metals														
				Cr	Co	Cu	Fe	Pb	Li	Mg	Mn	Hg	Mo	Ni	P	K	Se	Si
				T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Station ID	Station Description	Sample Date	Sample Event	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
P29	Hari Pad Geotech hole; GT-17-05	29-July-2017	July 2017	*0.0001*	*0.0001*	*0.0005*	0.166	*0.00005*	0.0018	12	0.0614	*0.000005*	0.0156	*0.0005*	*0.002*	3.23	*0.00005*	5.27
P29	Hari Pad Geotech hole; GT-17-05	10-Aug-2017	August 2017	0.00012	*0.0001*	*0.0005*	0.197	*0.00005*	0.0015	12.5	0.0737	*0.000005*	0.0153	*0.0005*	*0.002*	3.41	*0.00005*	5.34
P29	Hari Pad Geotech hole; GT-17-05	31-Aug-2017	August 2017	*0.0001*	*0.0001*	*0.0005*	0.175	*0.00005*	0.0011	12.5	0.0733	*0.000005*	0.0157	*0.0005*	*0.002*	3.20	*0.00005*	5.16
P29	Hari Pad Geotech hole; GT-17-05	2-Aug-2018		*0.0001*	*0.0001*	*0.0005*	0.297	*0.00005*	0.0013	14.1	0.0833	*0.000005*	0.0163	<0.00050		3.32	*0.00005*	4.93
P29	Hari Pad Geotech hole; GT-17-05	19-Aug-2018		*0.0001*	*0.0001*	*0.0005*	0.243	0.000111	0.0012	13.6	0.0845	*0.000005*	0.0157	<0.00050		3.26	*0.00005*	5.25
P29	Hari Pad Geotech hole; GT-17-05	19-Sep-2018		*0.0001*	*0.0001*	*0.0005*	0.322	*0.00005*	0.0012	13.1	0.0780	*0.000005*	0.0141	<0.00050	<0.050	3.14	*0.00005*	4.83
AVERAGE				0.000104	0.0001	0.0005	0.2468	0.0000622	0.00126	13.16	0.07856	0.000005	0.01542	0.0005	0.002	3.266	0.00005	5.102

Appendix C. Groundwater Data at Monitoring Well P29

Station P29 representative of GW in area of proposed Option 7 adit

				Total Metals									
				Ag	Na	Sr	Tl	Sn	Ti	U	V	Zn	Zr
				T	T	T	T	T	T	T	T	T	T
Station ID	Station Description	Sample Date	Sample Event	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
P29	Hari Pad Geotech hole; GT-17-05	29-July-2017	July 2017	*0.00001*	4.62	1.72	0.00002	*0.0001*	*0.0003*	0.000024	*0.0005*	0.00088	
P29	Hari Pad Geotech hole; GT-17-05	10-Aug-2017	August 2017	*0.00001*	4.68	1.74	0.000016	*0.0001*	*0.0003*	0.000024	*0.0005*	0.00111	
P29	Hari Pad Geotech hole; GT-17-05	31-Aug-2017	August 2017	*0.00001*	4.34	1.82	0.000014	*0.0001*	*0.0003*	0.000023	*0.0005*	*0.0005*	
P29	Hari Pad Geotech hole; GT-17-05	2-Aug-2018		*0.00001*	4.54	1.77	*0.00001*	*0.0001*	*0.0003*	0.000016	*0.0005*	0.00054	
P29	Hari Pad Geotech hole; GT-17-05	19-Aug-2018		*0.00001*	4.43	1.81	0.000012	*0.0001*	*0.0003*	0.000015	*0.0005*	*0.0003*	
P29	Hari Pad Geotech hole; GT-17-05	19-Sep-2018		*0.00001*	4.30	1.50	*0.00001*	*0.0001*	*0.0003*	0.000017	*0.0005*	*0.0003*	*0.0003*
AVERAGE				0.00001	4.458	1.728	0.0000124	0.0001	0.0003	0.000019	0.0005	0.00055	

APPENDIX D: CLIMATE DATA

Appendix D. Climate Data

Regional Meteorological Station for Palmer Project = Pleasant Camp, British Columbia, Canada

1981 to 2010 Monthly Climate Normals Station Data, Pleasant Camp, BC

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	35	27.8	23.6	48.9	49.4	37.4	35.8	72.4	148	153	32	39.8	703.1
Snowfall (cm)	165.4	111.4	82.6	20.8	2.6	0	0	0	0.8	35	128	177.4	723.8
Precipitation (mm)	200.4	139.1	106.2	69.7	51.9	37.4	35.8	72.4	148.8	188.1	160	217.3	1426.9