Appendix G.4

Evaluation of Potential for Aquatic Effects as a Result of Effluent Releases Related to Beaver Dam Mine

Beaver Dam Mine Project - Revised Environmental Impact Statement Marinette, Nova Scotia

SCIENCE INTEGRITY KNOWLEDGE

EVALUATION OF POTENTIAL FOR AQUATIC EFFECTS AS A RESULT OF EFFLUENT RELEASES RELATED TO BEAVER DAM MINE

Atlantic Mining NS Beaver Dam Mine Project

Technical Supporting Document

FINAL REPORT

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AQUATIC EFFECTS ASSESSMENT – BEAVER DAM MINE

Table of Contents

Page

List of Tables

List of Figures

List of Appendices

EVALUATION OF POTENTIAL FOR AQUATIC EFFECTS RELATED TO EFFLUENT EMISSIONS FROM BEAVER DAM MINE

1 INTRODUCTION

The Beaver Dam Mine Site will involve the construction, operation, and decommissioning of a surface gold mine at Marinette, Nova Scotia, if this project is approved. The proposed mine will be a surface mine and is proposed to include mine Haul Roads and associated mine infrastructure for crushing and haul-out (*e.g.* on-site power generation and local supply systems, fuel storage, temporary offices) (GHD, 2015). The proposed plan is to develop the mine, and crush the ore at the site, with subsequent trucking of the crushed ore to the approved Touquoy Mine Site for processing. The total development area of the Beaver Dam Mine Project is approximately 167 hectares (ha), which includes the ore extraction area (surface mine) (30 ha), materials storage (waste rock, overburden) (98 ha), ore stockpiles (10 ha), and the operational facilities (15 ha) (GHD, 2015).

The main elements of the Beaver Dam Mine Project are as follows (GHD, 2015):

- A surface mine from which 46.9 Mt of ore and waste rock will be excavated;
- A proposed ore extraction rate of 2 million t/y.

With respect to project stages, the following is the anticipated operations and closure timings:

- Site preparation and construction (year 1)
- Operation (years 2-5)
    - Pre-production (8 months)
    - Full production (3.3 years)
- Decommissioning and reclamation (years 6 to 8 and beyond)

An Environmental Assessment commenced in 2015, and an Environmental Impact Statement (EIS) for the Beaver Dam Mine Site was submitted for review to both the Canadian Environmental Assessment Agency (CEAA) and Nova Scotia Environment (NSE) in 2017. Several Information Requests (IRs) were provided on the submitted EIS. This aquatic effects assessment is being conducted as part of the re-submission of the EIS of the Beaver Dam Mine.

The Beaver Dam Mine project has two aquatic receiving environments. The first receiving environment is associated with the actual Beaver Dam Mine site and is known as the Killag River. Since the Beaver Dam site is a satellite surface mine operation to the Moose River Consolidated Projects (MRC), the ore from the Beaver Dam Mine project will be processed at the existing Touquoy Mine plant. With the transfer of ore to the Touquoy Mine site, there is need for an additional assessment of potential for aquatic effects associated with the added process emissions related to Beaver Dam ore at the Touquoy facility. Currently, the active Touquoy pit is dewatered and all water is pumped to the Tailings Management Facility (TMF). Effluent passes from the TMF, through a polishing pond and a series of geobags to a constructed wetland and is released into Scraggy Lake (Final Discharge Point; FDP). The Touquoy Mine pit will eventually be exhausted and will be allowed to fill naturally with water. Since processing of

Beaver Dam Mine ore at the Touquoy processing facility will commence after the Touquoy Mine pit is exhausted, tailings generated as a result of processing of Beaver Dam ore at Touquoy will be deposited in the exhausted Touquoy Mine pit. Once the Touquoy Pit fills naturally, and once water quality within the pit meets Metal and Diamond Mine Effluent Regulations (MDMER) discharge criteria, water surplus will be released at a new Effluent Final Discharge Point to the Moose River, via a spillway or channel (Stantec, 2018a). Therefore, this report includes an assessment of both the Killag River, as well as the Moose River, associated with the Beaver Dam Mine project.

As part of the mine planning process, GHD has developed a Mine Water Management Plan (MWMP) for the Beaver Dam Site. This plan serves to predict future water quality at End of Mine (EOM) and Post Closure (PC) in the mine pit on site, as well as in the receiving environment (Killag River). An assimilative capacity study was conducted for the Moose River receiving environment (Stantec, 2018a), to understand potential impacts associated with the processing of Beaver Dam ore and deposition of tailings in the Touquoy Mine pit.

Therefore, this aquatic effects assessment relies on the predicted receiving environment water quality in the Killag River (based on GHD, 2019a), and the Moose River (Stantec, 2018a).

The methods to conduct the aquatic effects assessment are presented in Section 2.0 of the report, whereas the assessment outcomes for the Killag River are presented in Section 3.0, and the assessment outcomes for the Moose River are in Section 4.0. Conclusions can be found in Section 5.0, with references in Section 6.0.

2 METHODS FOR CONDUCTING THE AQUATIC EFFECTS ASSESSMENT

2.1 Receiving Environment Characterization

To conduct the aquatic effects assessment, the receiving environment was characterized, based on available baseline data and descriptive text characterizing the receiving environments.

2.2 Exposure Assessment

To conduct the exposure assessment related to possible future concentrations of metals and other substances in the receiving environment, the predictive water quality modelling conducted by GHD (2019a) and Stantec (2018a) were used to characterize potential future receiving environment chemistry, as a result of mine-related emissions to either of the two environments, over various time frames.

2.3 Toxicity Assessment

Water quality guidelines used in the assessment are selected from the CCME water quality guidelines for the protection of aquatic life (CCME 2018) and the Nova Scotia Tier 1 surface water guidelines for use in freshwater (NSE 2014; many of which are based on CCME). For the selection of guidelines, the Nova Scotia Tier 1 surface water guidelines were given precedent over the CCME water quality guidelines, with the exception of the following cases:

- the Nova Scotia Tier 1 guidelines have not accounted for site-specific toxicity modifying factors (*i.e.*, pH, hardness); or,
- the CCME provides a more updated water quality guideline.

In these cases, the CCME guideline was selected over the Nova Scotia Tier 1 guideline. Table 2-1 presents the CCME and Nova Scotia Tier 1 water quality guidelines along with the selected guideline for each chemical. Where water quality varies between the Killag River and Moose River, the modified guidelines for each site are presented. The chemicals presented in Table 2-1 are based on the metals or substances considered in the predictive modelling for the Killag River (GHD, 2019a) or Moose River (Stantec, 2018a). Not all chemicals are assessed in both receiving environments. Only those chemicals considered in each of the modelling efforts are carried into the assessment of potential for aquatic effects. For example, cyanide treatment is only conducted at the Touquoy site, and hence, cyanide did not merit assessment in Killag River, but was assessed in Moose River. For the specific compounds assessed in the two receiving environments, see Section 3.0 (Killag River) and Section 4.0 (Moose River).

Table 2-1 Selected Water Quality Guidelines for Use in the Assessment

Chemical	*CCME (µg/L)*	*Nova Scotia Tier 1 (µg/L)*	*Selected Guideline*	*Regulation*
Silver	0.25	0.1	0.25	CCME
Aluminum	5/100[a]	5	5	Nova Scotia Tier 1
Antimony	NV	20	20	Nova Scotia Tier 1
Arsenic	5	5	5	Nova Scotia Tier 1
Cadmium	0.04/0.09[b]	0.01	0.04	CCME
Chromium	8.9[c]	1[d]	8.9	CCME
Cobalt	NV	10	10	Nova Scotia Tier 1
Copper	2/4[e]	2	2	Nova Scotia Tier 1
Iron	300	300	300	Nova Scotia Tier 1
Mercury	0.026	0.026	0.026	Nova Scotia Tier 1
Manganese	NV	820	820	Nova Scotia Tier 1
Molybdenum	73	73	73	Nova Scotia Tier 1
Nickel	25	25	25	Nova Scotia Tier 1
Lead	1/7[f]	1	1	Nova Scotia Tier 1
Selenium	1	1	1	Nova Scotia Tier 1
Sulphate	NG	NG	128,000[g]	BC MOE
Thallium	0.8	0.8	0.8	Nova Scotia Tier 1
Uranium	15	300	15	CCME
Zinc	7	30	7	CCME
WAD Cyanide	5	5	5	Nova Scotia Tier 1
Total Cyanide (based on Strong Acid Dissociated)	NG	NG	5[h]	CCME

Nitrite (as N)	NG	60	60	CCME
Total Ammonia - N	NG	Varies with pH and temperature	Varies with pH and temperature	CCME

Notes: NG = No guideline available from that agency

[a] The CCME water quality guideline for aluminum of 5 µg/L is for pH<6.5, and 100 µg/L is for pH ≥6.5. The background pH of the Killag River is 4.59 and 6; and mean pH of Moose River is 6.05; therefore, the guideline of 5 µg/L is appropriate for use at both sites.

[b] The CCME water quality guideline for cadmium of 0.04 µg/L is for water hardness >0 to <17 mg/L, and 0.09 µg/L is for water of 50 mg/L hardness. The background water hardness of the Killag River is between 1.6 and 5.5 mg/L $CaCO_3$; and the mean hardness of Moose River is 5.0 mg/L; therefore, the guideline of 0.04 µg/L is appropriate for use at both sites.

[c] Based on Cr^{3+}; this value was selected as $Cr^{6=}$ is unlikely to be present in the receiving environment

[d] Based on Cr^{6+}

[e] The CCME water quality guideline for copper of 2 µg/L is for water hardness of 0 to <82 mg/L or when the hardness is unknown. When the hardness is >82 to ≤180 mg/L, the following equation is used to calculate the guideline: CWQG (µg/L) = $0.2 * e^{\{0.8545[\ln(\text{hardness})]-1.465\}}$, and at a hardness >180 mg/L, the guideline is 4 µg/L. The background water hardness of the Killag River is between 1.6 and 5.5 mg/L $CaCO_3$ and the mean hardness of Moose River is 5.0 mg/L; therefore, the guideline of 2 µg/L is appropriate for use at both sites.

[f] The CCME water quality guideline for lead of 1 µg/L is for water hardness of 0 to ≤60 mg/L or when the hardness is unknown. When the hardness is >60 to ≤180 mg/L, the following equation is used to calculate the guideline: CWQG (µg/L) = $e^{\{1.273[\ln(\underline{\text{hardness}})]-4.705\}}$, and at a hardness >180 mg/L, the guideline is 7 µg/L. The background water hardness of the Killag River is between 1.6 and 5.5 mg/L $CaCO_3$ and the mean hardness in Moose River is 5.0 mg/L; therefore, the guideline of 1 µg/L is appropriate for use at both sites.

[g] No CCME or NS Tier 1 guideline is available; therefore a guideline from BC Moe was used (https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf)

[h] This guideline is for free CN, and hence does not apply to Total CN. It is used to provide perspective only in the effects assessment.

Where substances were found to exceed the selected guideline, and the 75th percentile of baseline, consideration was given to developing a Site Specific Water Quality Objective (SSWQO), following CCME guidance (CCME, 2007). The typical starting points for assessment of surface water data Canadian Water Quality Guidelines for Protection of Freshwater Aquatic Life (WQGl - FWAL), established by the Canadian Council of Ministers of the Environment (CCME). These guidelines are generic, national recommendations which reflect the most current scientific data at the time they were developed. They are intended to provide protection to all forms of aquatic life and aquatic life cycles, including the most sensitive life stages, at all locations across Canada (CCME, 2007). Since they are generic and do not always account for site-specific factors that can alter toxicity, these national guidelines can be modified using widely accepted procedures, to derive site-adapted or SSWQOs for a given project or location (CCME, 2003). Modifications to the generic guidelines allow for protection of aquatic species accounting for specific conditions in the receiving environment, primarily due to the following reasons (CCME, 2003):

- There may be naturally-occurring levels of substances that are above the generic guidelines. This is commonplace for metals and metalloids near areas of natural enrichment, such as mines.

- There may be certain characteristics of the water at a specific location or site which modify the toxicity of the substance, such that the generic guideline is unnecessarily conservative (protective). These characteristics are known as exposure and toxicity modifying factors (ETMFs), and can include parameters such as pH, temperature, hardness, and organic matter, amongst others (CCME, 2007).

- There may be certain sensitive species considered in the development of the generic guideline which are not present in the area under assessment (e.g., warm water species which are absent from northern environments), and removal of these data allows for a more site-specific guideline to be developed, without compromising protection. In addition, information on toxicity of the substance in question to resident species in the area of interest may be lacking in the existing database, and therefore, there may be interest in expanding the database to include site-specific toxicity data. Or, the existing CCME guideline may be dated and hence, application of more advanced protocols and available data can result in a revised guideline, which is more representative of current scientific practice and available toxicity data.

Based on consideration of all the available information, a revised SSWQO was derived for arsenic, following CCME protocols (CCME, 2007). A SSWQO consistent with CCME (2007) guidance, using a species sensitivity distribution (SSD) approach was used to derive the SSWQO. The SSD approach was comprised of identifying chronic toxicity data for species, analyzing the data using a regression approach and selecting the final chronic effects benchmark. The HC5 (i.e., the concentration that is hazardous to no more than 5% of a species in the community) was selected as the final chronic effects benchmark as per CCME (2007) guidance. The resultant guideline using the protocol is 30 µg/L. The details related to the SSWQO for arsenic are provided in Appendix A.

2.4 Characterization of Potential for Adverse Effects

The resulting future conditions in the receiving environments were compared to either CCME (2018) freshwater aquatic life guidelines (FWAL) and/or Nova Scotia Tier 1 surface water guidelines (NSE, 2014), or SSWQO, as well as to an upper percentile of baseline (75th percentile concentrations of existing near-field baseline water quality stations), to characterize potential risks to aquatic life.

Each aspect of the assessment is provided in Chapter 3 (Killag River assessment), and Chapter 4 (Moose River assessment).

3 KILLAG RIVER ASSESSMENT

3.1 Description of Receiving Environment and Baseline Data

The Killag river is adjacent to the Beaver Dam mine property. The river is a tributary of the West River Sheet Harbour and flows across the eastern portion of the overall Beaver Dam Mine study area. It is approximately 27 km long and is organic-acid stained. The Killag River was damned some time ago, which created a reservoir along the eastern edge of the Study area, known as the Cameron Flowage (see Section 4.0, CRA, 2015, in GHD, 2017). Current land use in the area is sparse, with the exception of timber harvesting.

The Killag River has important fish spawning habitat, and The Nova Scotia Salmon Association has documented the presence of Atlantic salmon in the Killag River. As discussed in the EIS (GHD, 2017), Atlantic salmon are highly sensitive to fluctuations in habitat conditions, particularly pH and temperature. As such, many land use practices and impacts to the freshwater ecosystem can affect the abundance and distribution of salmon. Physical barriers (e.g., dams, improperly installed culverts, etc.) can limit the distribution of the species and fish harvesting can affect their abundance. The Killag River has been categorized as Type II fish habitat (taken from Beak, 1980), which is summarized as:

"Good salmonid rearing habitat with limited spawning, usually only in isolated gravel pockets, good feeding and holding areas for larger fish in deeper pools, pockets, or backwater eddies: flows: heavier riffles to light rapids; current: 0.3- 1.0 m/s; depth: variable from 0.3 - 1.5 m; substrate: larger cobble/rubble size rock to boulders and bedrock, some gravel pockets between larger rocks; general habitat types: run, riffle, pocket water, pool."

The Killag River has low pH, which has been attributed to acid rain, and likely a low carbonate content in the surrounding geology. As such, the Nova Scotia Salmon Association has been operating an acid mitigation project on the West River for over 10 years. This program involves a lime dosing station which is used to increase the pH of the water to a suitable range for juvenile salmon (to approximately 5.5). The Nova Scotia Salmon Association has indicated that this project has resulted in significant increase in smolt populations and improved overall habitat quality within the West River Sheet Harbour. A second lime dosing station was installed in the Killag River, approximately 400 m downstream of the Beaver Dam Mine Site on November 1, 2017. The water quality characteristics collected at SW1 on the Killag in 2014 and 2015 clearly indicate low pH in the receiving environment (See Table 3-1), which are not conducive to supporting salmon, based on the available data. This may have improved since 2015. The Nova Scotia Salmon Association have indicated that maintenance of surface water quality and quantity is imperative to the continued success of ongoing salmon restoration efforts in the West River Sheet Harbour and its tributaries (GHD, 2017).

Table 3-1 outlines the available baseline data from the Killag River, as represented by Station SW1 (which is upstream of the new lime dosing unit). While an additional surface water station is available in the program (Station SW2A), it is north of the Cameron Flowage and distant to the proposed discharge site and hence was not used to characterize receiving environment conditions. Each sample was collected as a grab sample and analyzed for general chemistry and metals (RCAp-MS), mercury (Hg), with additional field measurements were recorded for dissolved oxygen (DO), temperature, total dissolved solids (TDS), conductivity, pH, and/or flow rate. Sampling at the Beaver Dam mine site began in October 2014 and was conducted monthly until August 2015.

Table 3-1 Baseline Surface Water Concentrations Collected from Killag River (Total Metals µg/L; N = 9)[a]

Parameter	*Min*	*Max*	*Mean*	*75th Percentile*	*90th Percentile*	*# of Non-Detects*	*CCME (µg/L)*	*Nova Scotia Tier 1 (µg/L)*
Silver	NDA	NDA	NDA	NDA	NDA	NDA	0.25	0.1
Aluminum	140	400	262	320	344	0/9	5	5
Arsenic	<1	3.7	1.84	2.60	2.9	2/9	5	5
Cadmium	<0.01	0.029	0.0199	0.0240	0.0282	1/9	0.04	0.01
Cobalt	<0.4	0.53	0.307	0.510	0.522	6/9	NV	10
Copper	<2	<2	1	1	1	9/9	2	2
Iron	240	1000	546	670	800	0/9	300	300
Mercury	<0.013	0.032	0.0103	0.0065	0.0184	7/9	0.026	0.026
Manganese	27	79	48.6	58.0	70.2	0/9	NV	820
Molybdenum	<2	1	1	1	1	9/9	73	73
Nickel	<2	2.6	1.18	1	1.32	8/9	25	25
Lead	<0.5	0.57	0.347	0.51	0.546	6/9	1	1
Antimony	<1	<1	0.5	0.5	0.5	9/9	NV	20
Selenium	<1	<1	0.5	0.5	0.5	9/9	1	1
Thallium	<0.1	<0.1	0.05	0.05	0.05	9/9	0.8	0.8
Uranium	<0.1	<0.1	0.05	0.05	0.05	9/9	15	300
Zinc	<5	7.8	4.13	5.10	7	5/9	7	30
pH	4.59	6	5.39	5.59	5.88	9/9	6 – 9.5	6-9.5

Notes:

NV indicates no value provided; NDA indicates no data available; reported pH is based on lab analysis, as field measurements were unusually low (range of 2.63 to 6.48)

[a] Summary statistics were calculated using the maximum value between duplicate samples and half the detection limit value when a chemical was not detected in a sample.

In general, the water quality stations in the study area were found to have elevated concentrations of aluminum and iron [above CCME Freshwater aquatic life guidelines (FWAL)] during most sampling events, which is a common feature of surface water in Nova Scotia. Mercury was identified above the CCME FWAL guidelines at all sampling locations during the last sampling event in August 2015, and arsenic concentrations were identified above the CCME FWAL guidelines at several stations in the study area (SW-4A, SW-5, SW-6A, and SW-10), but not at the station on Killag River (see Table 3-1). Arsenopyrite, an iron arsenic sulfide compound, is common in the surficial and bedrock geology of the area. Lead, cadmium, and copper fluctuate in surface water at most sampling locations and at times slightly exceeded the CCME FWAL across the study area. The relative soft waters in the area also present a challenge for mitigation of metals toxicity in the environment.

3.2 Description of Water Quality Modelling Conducted

The predictive water quality assessment was conducted by GHD (2019a) and involved calculations on a monthly basis for the average year climatic conditions. The approach taken involving monthly predictions enables consideration of water flow fluctuations in the receiving environment, which can affect mixing and dispersion within the river. Using this approach, the month with the greatest potential impact on the receiving environment can be identified, and treatment can be targeted for these types of worst-case conditions. Detailed description of the modelling approach is provided in GHD (2019a) and is summarized here. The modelling used historical rainfall data from the Environment Canada climate station Middle Musquodoboit (ID: 8203535) which has continuous historical daily precipitation data from 1968 to 2005. A water balance model (WBM) (GHD, 2019b) was created in GoldSim and was used to generate precipitation probabilities using a stochastic distribution of the precipitation data. Monthly precipitation totals were calculated from the Middle Musquodoboit Climate Station daily precipitation record for 41-years including 1968 – 2005, 2009, 2014 and 2016. Years that had a significant amount of missing data were excluded from the analysis.

As discussed in GHD (2019a), concentrations of each constituent leaving the site in water were determined by examining the geochemistry of each stockpile (till, waste rock, low grade ore) and the pit wall rock. This analysis was done by Lorax Environmental (Lorax Environmental, 2018). Two concentration ranges were predicted: Base Case conditions, which were representative of the most likely concentration scenario (median); and, Upper Case conditions, which were representative of the likely worst-case (90th percentile) concentration scenario. As discussed in GHD (2019a), for the EOM conditions, the source term model assumed the following:

- The waste rock stockpiles have reached their maximum height but remain uncovered and unrestored;
- The pit is constantly being dewatered and discharged into the north settling pond;
- Standard erosion and sediment control measures have been implemented on the soil and till piles.

For the PC conditions, the source term model assumed the following:

- Waste rock stockpiles have been covered with soil and seeded;
- The low grade ore stockpile has been removed from the Project Site and processed at the Touquoy site;
- The pit has been allowed to naturally fill with water to an elevation of 127 m;
- All site water will drain to the pit prior to discharge into the river;
- Other than what is mentioned above no other reclamation activities have been implement at the Project site.

GHD (2019a) provides further details of the water balance and modelling.

3.3 Discharge Points and Receiving Environment Prediction Points

The only contribution discharge points identified by GHD (2019a) with potential for discharge of impacted mine effluent into the Killag River system are the North Settling Pond (EOM scenario only) and the Pit (PC scenario only). The North Settling Pond is anticipated to be decommissioned for the PC scenario (see GHD, 2019a).

Water quality was predicted at 2 distances downstream of the discharge points; 100m (near field) and approximately 1 km (far field). Based on the water flow characteristics of the receiving environment, full mixing was assumed to occur at the near field prediction node.

Figure 3-1 provides an overview of the discharge and water quality prediction nodes.

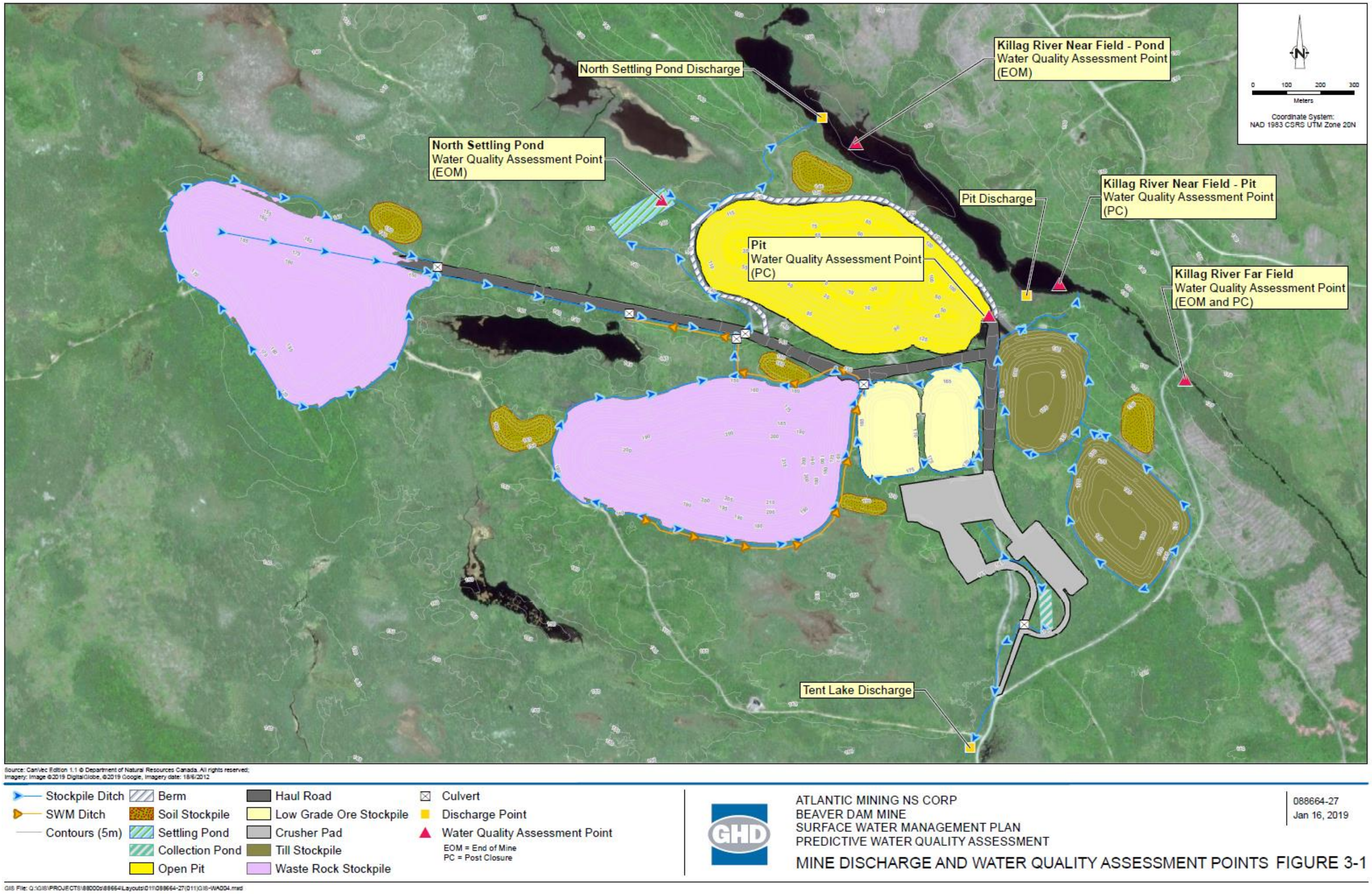

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Figure 3-1 Mine Discharge and Water Quality Assessment Points

3.4 Selected Benchmarks

Benchmark concentrations used for comparison against predicted water concentrations are presented in Table 3-2. Selection of these benchmark concentrations is described in Section 2.3. These benchmark concentrations were based on the greater of either the water quality guideline selected for use in the assessment (see Table 2-1), or the 75th percentile of the baseline surface water concentrations collected from the Killag River (Table 3-1), except for arsenic for which a site-specific water quality objective was calculated and adopted (see Section 2.3 and Appendix A).

Table 3-2 Selected Benchmark Concentrations for Use in the Assessment (µg/L)

Parameter	*Selected Guideline[a]*	*75th Percentile Baseline Concentration*	*Site-Specific Water Quality Objective*	*Selected Benchmark Concentration*
Silver	0.25[b]	NDA	-	0.25
Aluminum	5	320	-	320
Arsenic	5	2.60	30	30
Cadmium	0.04[b]	0.0240	-	0.04
Cobalt	10	0.510	-	10
Copper	2	1	-	2
Iron	300	670	-	670
Mercury	0.026	0.0065	-	0.026
Manganese	820	58.0	-	820
Molybdenum	73	1	-	73
Nickel	25	1	-	25
Lead	1	0.51	-	1
Antimony	20	0.5	-	20
Selenium	1	0.5	-	1
Thallium	0.8	0.05	-	0.8
Uranium	15[b]	0.05	-	15
Zinc	7[b]	5.10	-	7

Notes:

- not calculated; NDA: no data available

[a] Selected guidelines represent Nova Scotia Tier 1 guidelines unless specified otherwise.

[b] Selected guideline adopted from CCME.

3.5 Predicted Water Quality – No Water Treatment Scenario

GHD (2019a) assumed no water quality treatment for the predictions provided herein. Only receiving environment predictions are assessed herein, and discharge predictions relative to MDMER limits are provided in GHD (2019a). The predictions provided by GHD (2019a) include the Project increment + Mean Baseline. Mean baseline metrics are provided in GHD (2019a) and differ slightly from those in Table 2-1, as the mean used in GHD (2019a) included 9 samples + 1 duplicate sample (n = 10). With naturally occurring dilution within the Killag

River, some metals are predicted to be less than mean baseline at the near field prediction node (100 m downstream of point of discharge) and far field prediction node (approximately 1 km downstream from point of discharge).

3.5.1 Near-field Predictions

GHD (2019a) predicted chemical concentrations at the near field Northern Settling Pond discharge point under the EOM scenario and at the Pit lake discharge point under the PC scenario, each for a base case and an upper case. Table 3-3 and Table 3-4 present the chemical concentrations predicted for the near-field area (100 m down stream) of the Northern Settling Pond discharge point under the EOM scenario for the base case and the upper case, respectively. Table 3-5 and Table 3-6 present the chemical concentrations predicted at the near field area (100 m downstream) of the Pit lake discharge point under the PC scenario for the base case and the upper case, respectively. In each table, the predicted chemical concentrations are compared to the selected water quality benchmarks outlined in Section 3.4.

Table 3-3 Constituent Concentrations at Near Field Northern Settling Pond Discharge Point - EOM Conditions Base Case

Constituent	Selected Benchmark Concentration[a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Silver	0.25[b]	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05
Aluminum	320[c]	233.35	235.32	244.08	247.41	232.21	226.68	206.9	195.43	210.8	235.91	241.69	238.28
Arsenic	30[d]	3.58	2.93	2.26	2.27	5.79	4.62	6.44	7.59	6.16	3.46	3.05	3.62
Cadmium	0.04[b]	0.018	0.018	0.018	0.019	0.018	0.018	0.017	0.016	0.017	0.018	0.018	0.018
Cobalt	10	0.31	0.31	0.3	0.31	0.34	0.33	0.36	0.37	0.35	0.32	0.31	0.32
Copper	2	0.96	0.96	0.98	0.98	0.97	0.96	0.93	0.92	0.94	0.97	0.98	0.97
Iron	670[c]	479.38	483.57	500.64	506.85	475.02	464.66	424.17	400.59	432.03	483.56	495.33	488.6
Mercury	0.026	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Manganese	820	49.67	48.77	48.44	48.75	53.19	50.79	52.03	52.91	51.91	49.69	49.52	50.17
Molybdenum	73	1.54	1.4	1.29	1.33	2.17	2.03	2.71	3.14	2.61	1.68	1.51	1.59
Nickel	25	1.02	1.01	1.01	1.02	1.09	1.06	1.11	1.14	1.1	1.04	1.03	1.03
Lead	1	0.33	0.32	0.33	0.33	0.34	0.33	0.32	0.31	0.32	0.33	0.33	0.33
Antimony	20	0.55	0.52	0.5	0.51	0.67	0.59	0.65	0.68	0.64	0.55	0.54	0.57
Selenium	1	0.52	0.5	0.5	0.5	0.58	0.54	0.56	0.57	0.56	0.52	0.52	0.53
Thallium	0.8	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.05	0.05	0.05
Uranium	15[b]	0.73	0.53	0.36	0.39	1.51	1.25	2.02	2.5	1.9	0.82	0.63	0.77
Zinc	7[b]	3.76	3.78	3.85	3.88	3.77	3.71	3.54	3.44	3.57	3.78	3.83	3.81

Notes:

All values are presented as µg/L.

Shaded values indicate an exceedance of the selected benchmark concentration.

[a] Selected benchmarks represent Nova Scotia Tier 1 guidelines unless specified otherwise.

[b] Adopted from CCME.

[c] Based on baseline concentration in the Killag River (75th percentile)

[d] Site-specific water quality guideline

Table 3-4 Constituent Concentrations at Near Field Northern Settling Pond Discharge Point - EOM Conditions Upper Case

Constituent	***Selected Benchmark Concentration[a]***	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Silver	0.25[b]	0.06	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.05	0.05	0.05
Aluminum	320[c]	238.8	240.44	246.63	248.82	236.75	233.36	218.61	210	221.46	240.31	244.57	242.06
Arsenic	30[d]	6.75	5.69	3.53	2.99	9.25	8.56	13.22	16.01	12.36	5.95	4.74	6
Cadmium	0.04[b]	0.025	0.025	0.022	0.02	0.023	0.026	0.031	0.034	0.03	0.023	0.022	0.023
Cobalt	10	0.36	0.35	0.33	0.32	0.39	0.4	0.47	0.52	0.46	0.36	0.34	0.35
Copper	2	1.07	1.06	1.03	1.02	1.08	1.1	1.17	1.22	1.16	1.06	1.04	1.05
Iron	670[c]	532.59	535.13	524.51	517.06	507.96	523.48	529.13	530.93	526.67	522.12	519.55	522.08
Mercury	0.026	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01
Manganese	820	63.48	61.68	54.44	51.64	64.15	66.81	80.24	87.94	77.5	60.08	56.25	59.48
Molybdenum	73	3.32	2.77	2.23	2.32	5.69	5.23	8.04	9.79	7.6	3.81	3.07	3.43
Nickel	25	1.14	1.12	1.07	1.05	1.22	1.22	1.39	1.48	1.36	1.14	1.1	1.13
Lead	1	0.34	0.33	0.33	0.34	0.37	0.35	0.36	0.36	0.36	0.34	0.34	0.35
Antimony	20	0.68	0.6	0.54	0.55	0.94	0.78	0.95	1.07	0.93	0.66	0.63	0.69
Selenium	1	0.57	0.53	0.51	0.52	0.71	0.62	0.7	0.75	0.69	0.57	0.56	0.59
Thallium	0.8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Uranium	15[b]	1.18	0.87	0.56	0.59	2.35	1.99	3.25	4.04	3.06	1.3	0.98	1.21
Zinc	7[b]	4.7	4.67	4.26	4.06	4.42	4.76	5.4	5.76	5.26	4.47	4.27	4.41

Notes:

All values are presented as µg/L.

Shaded values indicate an exceedance of the selected benchmark concentration.

[a] Selected benchmarks represent Nova Scotia Tier 1 guidelines unless specified otherwise.

[b] Adopted from CCME.

[c] Based on baseline concentration in the Killag River (75th percentile)

[d] Site-specific water quality guideline

Table 3-5 Constituent Concentrations at Near Field Pit Lake Discharge Point - PC Conditions Base Case

Constituent	Selected Benchmark Concentration[a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Silver	0.25[b]	0.07	0.07	0.06	0.05	0.09	0.08	0.1	0.12	0.1	0.07	0.06	0.07
Aluminum	320[c]	235	235.82	244.1	247.76	237.89	228.51	208.38	196.67	212.46	236.93	242.96	240.53
Arsenic	30[d]	7.29	6.04	3.62	3.05	10.44	9.29	14.53	17.72	13.57	6.34	5.03	6.5
Cadmium	0.04[b]	0.025	0.023	0.021	0.02	0.029	0.027	0.032	0.035	0.031	0.024	0.022	0.024
Cobalt	10	0.32	0.31	0.3	0.3	0.35	0.33	0.36	0.37	0.35	0.32	0.31	0.32
Copper	2	2.08	1.82	1.36	1.25	2.74	2.47	3.48	4.1	3.3	1.89	1.64	1.94
Iron	670[c]	482.81	484.29	500.87	508.06	489.01	470	429.8	406.45	437.97	486.7	498.78	494.04
Mercury	0.026	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Manganese	820	50.36	49.56	48.58	48.46	52.57	50.7	51.99	52.82	51.77	49.58	49.38	50.25
Molybdenum	73	1.26	1.2	1.08	1.05	1.44	1.35	1.6	1.75	1.56	1.21	1.15	1.23
Nickel	25	1.05	1.03	1	1	1.11	1.07	1.11	1.14	1.1	1.03	1.02	1.05
Lead	1	0.33	0.33	0.33	0.33	0.34	0.33	0.32	0.32	0.32	0.33	0.33	0.33
Antimony	20	0.52	0.51	0.5	0.5	0.55	0.53	0.54	0.55	0.54	0.51	0.51	0.52
Selenium	1	0.51	0.5	0.5	0.5	0.54	0.52	0.53	0.54	0.53	0.51	0.51	0.51
Thallium	0.8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Uranium	15[b]	2.77	2.15	0.99	0.72	4.35	3.77	6.33	7.89	5.86	2.32	1.68	2.4
Zinc	7[b]	5.53	5.13	4.44	4.3	6.59	6.1	7.56	8.45	7.29	5.24	4.89	5.34

Notes:

All values are presented as µg/L.

Shaded values indicate an exceedance of the selected benchmark concentration.

[a] Selected benchmarks represent Nova Scotia Tier 1 guidelines unless specified otherwise.

[b] Adopted from CCME.

[c] Based on baseline concentration in the Killag River (75th percentile)

[d] Site-specific water quality guideline

Table 3-6 Constituent Concentrations at Near Field Pit Lake Discharge Point - PC Conditions Upper Case

Constituent	Selected Benchmark Concentration[a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Silver	0.25[b]	0.1	0.08	0.06	0.06	0.13	0.11	0.16	0.18	0.15	0.09	0.08	0.09
Aluminum	320[c]	238.42	239.11	246.01	249.05	240.78	232.94	216.07	206.26	219.49	239.99	245.04	243.03
Arsenic	30[d]	12.34	10.36	5.58	4.16	16.28	15.6	25.47	31.38	23.58	10.29	7.72	10.33
Cadmium	0.04[b]	0.043	0.038	0.028	0.024	0.051	0.05	0.071	0.084	0.067	0.038	0.032	0.038
Cobalt	10	0.37	0.36	0.32	0.31	0.39	0.39	0.46	0.51	0.45	0.35	0.34	0.36
Copper	2	7.91	6.34	3.37	2.68	11.91	10.43	16.93	20.89	15.74	6.76	5.14	6.96
Iron	670[c]	502.93	503.98	515.03	518.43	511.17	503.77	489.16	481.21	492.69	510.7	515.07	510.74
Mercury	0.026	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01
Manganese	820	64.1	62.5	54.49	51.1	62.6	66.28	79.82	87.57	76.9	59.62	55.78	59.23
Molybdenum	73	2.26	2	1.44	1.29	2.87	2.68	3.85	4.56	3.63	2.02	1.73	2.05
Nickel	25	1.18	1.15	1.06	1.03	1.24	1.23	1.39	1.49	1.36	1.13	1.09	1.14
Lead	1	0.35	0.34	0.33	0.34	0.37	0.35	0.36	0.37	0.36	0.34	0.34	0.35
Antimony	20	0.61	0.58	0.53	0.52	0.69	0.65	0.76	0.82	0.74	0.59	0.56	0.6
Selenium	1	0.56	0.54	0.51	0.51	0.63	0.59	0.65	0.69	0.64	0.55	0.54	0.56
Thallium	0.8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Uranium	15[b]	4.26	3.32	1.51	1.08	6.64	5.79	9.75	12.16	9.02	3.56	2.57	3.67
Zinc	7[b]	6.65	6.16	4.91	4.52	7.52	7.4	9.86	11.33	9.38	6.07	5.43	6.1

Notes:

All values are presented as µg/L.

Shaded values indicate an exceedance of the selected benchmark concentration.

[a] Selected benchmarks represent Nova Scotia Tier 1 guidelines unless specified otherwise.

[b] Adopted from CCME.

[c] Based on baseline concentration in the Killag River.

[d] Site-specific water quality guideline

In the EOM scenario at the near field Northern Settling Pond discharge point, all predicted constituent concentrations were consistently below selected water quality benchmarks in the base case and upper case (Tables 3-3 and 3-4, respectively).

In the PC scenario at the near field Pit lake discharge point, copper and zinc concentrations predicted for several months of the year exceed selected water quality benchmarks in the base case (Table 3-5). In the upper case, zinc concentrations are still predicted to exceed benchmarks for several months while copper concentrations are predicted to exceed year-round. In addition, cadmium concentrations for several months and the arsenic concentration for a single month (August) are predicted to exceed selected water quality benchmarks in the upper case (Table 3-6).

Note that GHD (2019a) identified iron as being elevated, relative to mean baseline, in the EOM near field and far field, upper case, scenarios. Predicted concentrations are only marginally above mean baseline, and well within the baseline range, and hence, the iron concentrations were not considered to represent a risk to aquatic life.

3.5.2 Far-field Predictions

GHD (2019a) predicted chemical concentrations at the far field in Killag River under the EOM and PC scenarios for a base case and an upper case. Table 3-7 and Table 3-8 present the chemical concentrations predicted under the EOM scenario for the base case and the upper case, respectively. Table 3-9 and Table 3-10 present the chemical concentrations predicted under the PC scenario for the base case and the upper case, respectively. In each table, the predicted chemical concentrations are compared to the selected water quality benchmarks outlined in Section 3.4.

Table 3-7 Constituent Concentrations at Far Field in Killag River – EOM Condition Base Case

Constituent	*Selected Benchmark Concentration*[a]	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Silver	0.25[b]	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05
Aluminum	320[c]	230.44	232.44	242.86	247.05	230.84	223.63	201.2	188.26	205.72	233.97	240.55	236.61
Arsenic	30[d]	3.48	2.85	2.22	2.25	5.62	4.48	6.22	7.33	5.95	3.37	2.98	3.53
Cadmium	0.04[b]	0.018	0.018	0.018	0.019	0.018	0.017	0.016	0.016	0.017	0.018	0.018	0.018
Cobalt	10	0.31	0.3	0.3	0.31	0.34	0.33	0.35	0.36	0.34	0.32	0.31	0.31
Copper	2	0.95	0.95	0.97	0.98	0.97	0.94	0.91	0.89	0.91	0.96	0.97	0.96
Iron	670[c]	473.37	477.64	498.13	506.13	472.25	458.41	412.5	385.89	421.63	479.59	493	485.18
Mercury	0.026	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Manganese	820	48.91	48.07	48.13	48.62	52.59	49.92	50.5	51	50.52	49.13	49.17	49.67
Molybdenum	73	1.51	1.37	1.27	1.31	2.12	1.98	2.62	3.03	2.52	1.64	1.48	1.56
Nickel	25	1	0.99	1	1.01	1.08	1.04	1.07	1.09	1.07	1.03	1.02	1.02
Lead	1	0.32	0.32	0.33	0.33	0.33	0.32	0.31	0.3	0.31	0.32	0.33	0.33
Antimony	20	0.54	0.52	0.5	0.51	0.66	0.58	0.63	0.66	0.62	0.54	0.54	0.56
Selenium	1	0.51	0.5	0.49	0.5	0.57	0.53	0.54	0.55	0.54	0.51	0.51	0.52
Thallium	0.8	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05	0.05	0.05
Uranium	15[b]	0.7	0.51	0.34	0.37	1.45	1.2	1.94	2.42	1.83	0.79	0.61	0.74
Zinc	7[b]	3.71	3.73	3.83	3.87	3.74	3.65	3.44	3.31	3.48	3.75	3.81	3.78

Notes:

All values are presented as µg/L.

Shaded values indicate an exceedance of the selected benchmark concentration.

[a] Selected benchmarks represent Nova Scotia Tier 1 guidelines unless specified otherwise.

[b] Adopted from CCME.

[c] Based on baseline concentration in the Killag River (75th percentile)

[d] Site-specific water quality guideline

Table 3-8 Constituent concentrations at Far Field in Killag River – EOM Condition Upper Case

Constituent	*Selected Benchmark Concentration*[a]	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Silver	0.25[b]	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.05	0.05	0.05
Aluminum	320[c]	235.68	237.36	245.31	248.4	235.21	230.05	212.5	202.32	215.99	238.2	243.32	240.24
Arsenic	30[d]	6.53	5.51	3.45	2.93	8.95	8.27	12.76	15.45	11.93	5.77	4.61	5.81
Cadmium	0.04[b]	0.025	0.024	0.021	0.02	0.023	0.025	0.03	0.033	0.029	0.023	0.021	0.023
Cobalt	10	0.35	0.34	0.33	0.32	0.38	0.39	0.46	0.5	0.45	0.36	0.34	0.35
Copper	2	1.05	1.04	1.02	1.01	1.07	1.08	1.14	1.17	1.13	1.05	1.03	1.04
Iron	670[c]	524.5	527.16	521.04	515.92	503.94	514.99	513.67	511.68	512.82	516.63	516.26	517.33
Mercury	0.026	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01
Manganese	820	62.18	60.47	53.89	51.39	63.13	65.33	77.68	84.81	75.17	59.12	55.63	58.61
Molybdenum	73	3.22	2.68	2.18	2.27	5.5	5.06	7.75	9.45	7.34	3.69	2.98	3.32
Nickel	25	1.12	1.1	1.06	1.05	1.2	1.2	1.34	1.43	1.32	1.13	1.09	1.11
Lead	1	0.33	0.33	0.33	0.34	0.37	0.35	0.35	0.35	0.35	0.34	0.34	0.34
Antimony	20	0.66	0.59	0.53	0.54	0.92	0.76	0.92	1.03	0.9	0.65	0.62	0.68
Selenium	1	0.56	0.53	0.51	0.52	0.7	0.61	0.68	0.72	0.67	0.56	0.55	0.58
Thallium	0.8	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.05	0.05	0.05
Uranium	15[b]	1.13	0.84	0.54	0.57	2.27	1.92	3.14	3.9	2.95	1.25	0.95	1.17
Zinc	7[b]	4.61	4.58	4.22	4.05	4.36	4.66	5.23	5.55	5.11	4.41	4.23	4.36

Notes:

All values are presented as µg/L.

Shaded values indicate an exceedance of the selected benchmark concentration.

[a] Selected benchmarks represent Nova Scotia Tier 1 guidelines unless specified otherwise.

[b] Adopted from CCME.

[c] Based on baseline concentration in the Killag River (75th percentile)

[d] Site-specific water quality guideline

Table 3-9 Constituent concentrations at Far Field in Killag River – PC Condition Base Case

Constituent	***Selected Benchmark Concentration***[a]	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***
Silver	0.25[b]	0.07	0.07	0.06	0.05	0.09	0.08	0.1	0.11	0.1	0.07	0.06	0.07
Aluminum	320[c]	232.64	233.54	243.09	247.38	236.51	225.95	203.72	190.82	208.28	235.29	241.95	239.09
Arsenic	30[d]	7.23	5.99	3.6	3.03	10.33	9.21	14.39	17.56	13.44	6.28	4.99	6.44
Cadmium	0.04[b]	0.025	0.023	0.021	0.02	0.029	0.027	0.032	0.035	0.031	0.024	0.022	0.024
Cobalt	10	0.32	0.31	0.3	0.3	0.34	0.33	0.35	0.36	0.35	0.31	0.31	0.32
Copper	2	2.06	1.81	1.35	1.25	2.72	2.45	3.44	4.05	3.26	1.88	1.63	1.92
Iron	670[c]	477.93	479.58	498.79	507.28	486.16	464.72	420.18	394.37	429.34	483.32	496.7	491.07
Mercury	0.026	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Manganese	820	49.86	49.08	48.37	48.37	52.22	50.15	51	51.57	50.87	49.23	49.15	49.93
Molybdenum	73	1.25	1.19	1.07	1.05	1.43	1.34	1.57	1.72	1.53	1.2	1.14	1.22
Nickel	25	1.04	1.02	1	1	1.1	1.05	1.09	1.11	1.08	1.02	1.02	1.04
Lead	1	0.33	0.32	0.33	0.33	0.34	0.32	0.32	0.31	0.32	0.33	0.33	0.33
Antimony	20	0.51	0.5	0.5	0.5	0.55	0.52	0.53	0.54	0.53	0.51	0.51	0.52
Selenium	1	0.51	0.5	0.49	0.5	0.54	0.51	0.52	0.52	0.52	0.5	0.5	0.51
Thallium	0.8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Uranium	15[b]	2.75	2.14	0.98	0.71	4.3	3.73	6.27	7.83	5.81	2.3	1.67	2.38
Zinc	7[b]	5.48	5.09	4.42	4.29	6.54	6.04	7.45	8.32	7.2	5.2	4.86	5.3

Notes:

All values are presented as µg/L.

Shaded values indicate an exceedance of the selected benchmark concentration.

[a] Selected benchmarks represent Nova Scotia Tier 1 guidelines unless specified otherwise.

[b] Adopted from CCME.

[c] Based on baseline concentration in the Killag River (75th percentile)

[d] Site-specific water quality guideline

Table 3-10 Constituent concentrations at Far Field in Killag River – PC Condition Upper Case

Constituent	Selected Benchmark Concentration[a]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Silver	0.25[b]	0.09	0.08	0.06	0.06	0.13	0.11	0.15	0.18	0.15	0.09	0.08	0.09
Aluminum	320[c]	236.47	237.22	245.18	248.74	239.65	230.83	212.23	201.43	216.04	238.64	244.21	241.84
Arsenic	30[d]	12.23	10.27	5.54	4.13	16.1	15.45	25.23	31.09	23.35	10.2	7.65	10.23
Cadmium	0.04[b]	0.042	0.038	0.027	0.024	0.05	0.049	0.071	0.083	0.066	0.038	0.032	0.038
Cobalt	10	0.37	0.36	0.32	0.31	0.39	0.39	0.46	0.5	0.44	0.35	0.33	0.35
Copper	2	7.85	6.29	3.35	2.66	11.78	10.33	16.78	20.71	15.6	6.7	5.09	6.89
Iron	670[c]	497.81	499.03	512.76	517.52	508.04	498.07	478.83	468.28	483.4	507.01	512.78	507.55
Mercury	0.026	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01
Manganese	820	63.42	61.87	54.21	50.99	62.13	65.53	78.5	85.94	75.71	59.14	55.48	58.8
Molybdenum	73	2.24	1.98	1.43	1.28	2.84	2.65	3.81	4.51	3.59	2.01	1.71	2.04
Nickel	25	1.17	1.14	1.05	1.02	1.23	1.21	1.37	1.46	1.34	1.13	1.09	1.13
Lead	1	0.34	0.34	0.33	0.33	0.37	0.35	0.36	0.36	0.36	0.34	0.34	0.35
Antimony	20	0.61	0.58	0.53	0.52	0.69	0.65	0.75	0.81	0.73	0.59	0.56	0.6
Selenium	1	0.56	0.54	0.51	0.51	0.62	0.58	0.64	0.67	0.63	0.55	0.53	0.56
Thallium	0.8	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Uranium	15[b]	4.23	3.3	1.5	1.07	6.56	5.73	9.67	12.06	8.94	3.53	2.54	3.63
Zinc	7[b]	6.59	6.11	4.89	4.51	7.46	7.32	9.73	11.17	9.26	6.02	5.39	6.05

Notes:

All values are presented as µg/L.

Shaded values indicate an exceedance of the selected benchmark concentration.

[a] Selected benchmarks represent Nova Scotia Tier 1 guidelines unless specified otherwise.

[b] Adopted from CCME.

[c] Based on baseline concentration in the Killag River (75th percentile)

[d] Site-specific water quality guideline

In the EOM scenario at the far field in the Killag River, all predicted constituent concentrations were consistently below selected water quality benchmarks in the base case and upper case (Table 3-7 and 3-8, respectively).

In the PC scenario at the far field in the Killag River, copper and zinc concentrations predicted for several months of the year exceed selected water quality benchmarks in the base case (Table 3-9). In the upper case, zinc concentrations are still predicted to exceed benchmarks for several months while copper concentrations are predicted to exceed year-round. In addition, cadmium concentrations for several months and the arsenic concentration for a single month (August) are predicted to exceed selected water quality benchmarks in the upper case (Table 3-10).

Each of these exceedances is discussed further, relative to the likelihood of toxicity, as follows:

- **Arsenic**: An arsenic SSWQO was developed for this project, using the CCME (2007) Species Sensitivity Distribution approach (SSD). All predictions in the EOM and PC scenarios were less than the SSWQO of 30 µg/L, with the exception of a single month, where a concentration of 31.1 µg/L was predicted for the month of August. This predicted value is still below the Lowest effect concentration of 48 µg/L (*Scenedesmus obliquus*; growth endpoint) in the SSD. Toxicity potential associated with this minor elevation, relative to the SSWQO, is considered to be low.
- **Cadmium**: Cadmium does not exceed the aquatic life guideline in any scenario, with the exception of the PC near field and far field scenarios, for the upper case. In these two situations, cadmium is predicted to range from 0.042 to 0.087 µg/L (see Table 3-6 and 3-10). Cadmium toxicity is modified by hardness, and hardness within the Killag River is soft (< 10 mg/L $CaCO_3$). Baseline data are limited (N = 9). Based on the available data, and consideration of toxicity data as cited in CCME (2014), the predicted concentrations would be unlikely to cause toxicity in fish, aquatic plants or in most invertebrate species. The predicted concentrations are within the range of concentrations that may be associated with some toxicity in Daphnia magna, depending on concentrations of modifying factors, such as hardness. While the available data suggest that some toxicity is possible due to the low hardness in the receiving environment, further refinement of source terms in the model, and additional baseline data, will assist in understanding toxicity potential.
- **Copper**: Predicted concentrations do not exceed the guideline in the EOM scenarios, but do exceed guidelines in the PC scenario, for both near field and far field, in the base case and upper case. Concentrations range from 2 to 4 µg/L in the base case, and 2.6 to 20 µg/L in the upper case, relative to a guideline of 2 µg/L. The potential for toxicity is highest in the upper case scenario, particularly in light of the soft waters in the Killag River. Therefore, risk mitigation may be necessary for copper, following refinement of modelling and expansion of baseline data understanding. The current baseline dataset has non-detectable copper concentrations, with a detection limit if 2 µg/L, which is the same as the guideline for copper. The predicted concentrations are added to ½ of the Method Detection Limit (1 µg/L), which may not accurately reflect copper concentrations within the Killag River. Based on the existing information, there is a potential for toxicity associated with copper, and hence, mitigation, such as treatment, may be necessary.

- **Zinc**: Predicted concentrations of zinc do not exceed the NS Tier 1 standard of 30 µg/L in any scenario. The predicted concentrations do not exceed the new CCME guideline for zinc in the EOM scenarios, but do exceed the guideline in the PC scenarios (Base case predictions are 7.3 to 8.5 µg/L in the near field, and 7.2 to 8.3 µg/L in the far field, and range from 7.3 to 11.3 µg/L in the PC upper case far field scenarios, relative to a guideline of 7 µg/L). The Lowest observed effect concentration (LOEC) listed in the CCME (2018) fact sheet is 9.89 µg/L (11 week study; development; Chironomid sp.; normalized to 50 mg/L $CaCO_3$ and Dissolved Organic Carbon (DOC) of 0.5 mg/L). Some of the predicted concentrations are within the range of background (< 5 to 7.8 µg/L; based on limited sample size N=9). While the waters of the Killag River are soft (< 10 mg/L $CaCO_3$), the DOC is currently not known, and could provide adequate protection, for several months indicating elevated levels. Since many of these exceedances are marginal, relative to the guideline, and since background levels based on limited sampling are elevated relative to the guideline, the likelihood of toxicity occurring in the Base case scenarios is considered to be low. Similarly, within the PC scenario, 2 of 5 months with predicted exceedances are within the range of baseline concentrations (suggesting changes in water quality that are similar to naturally occurring conditions), and other predictions are in close approximation to the LOEC of 9.89 µg/L, or slightly higher. The new CCME guideline is a dissolved zinc guideline, as opposed to total zinc. At this time, dissolved zinc levels are unknown, as only total metals baseline data are available. Consideration of dissolved zinc, as well as DOC, may reveal predictions are within guideline levels. Based on the marginal degree of exceedance, and the existing baseline data range, predicted zinc concentrations are considered to have a low potential for toxicity. Expansion of the baseline dataset, including dissolved zinc levels and DOC, as well as additional refinement of source terms in the water modelling, will assist in refinement of this conclusion.

3.6 Predicted Water Quality – With Treatment

Table 3-11 summarizes the scenarios evaluated above in Section 3.5 which had exceedances over the selected benchmarks, suggesting a need for water treatment.

Table 3-11 Summary of Metals Exceeding Selected Aquatic Life Benchmarks in Killag River and Comments Related to Water Treatment Needs

Scenario	Exceedances over Benchmarks		Comments Related to Water Treatment Needs
	Metal/Metalloid	Frequency (months)	
Near Field			
EOM Base Case	NE	NE	No apparent need for treatment
EOM Upper Case	NE	NE	No apparent need for treatment
PC Base Case	Cu; Zn	6; 3[a]	Copper merits further evaluation to determine need for water treatment. Zinc exceedances are marginal, and zinc is considered to have a low potential for risk to aquatic life. Copper and Zinc predictions were added to mean baseline, which is ½ of the detection limit (Copper MDL:

			2 µg/L; zinc MDL: 5 µg/L). Collection of more robust baseline data with improved detection limits may reveal Baseline + Project concentrations remain within benchmarks and treatment requirements are minimal
PC Upper Case	As; Cd; Cu; Zn	1;6;12;5[a]	See above for Copper and Zinc discussion; Arsenic involves a single month which is marginally in exceedance of the SSWQO; risk potential is considered low. Cadmium exceedance is predicted over 6 months. Increased water hardness, relative to cadmium or copper, would assist in mitigating toxicity potential. Copper and potentially cadmium merit further evaluation to determine need for water treatment.
Far Field			
EOM Base Case	NE	NE	No apparent need for treatment
EOM Upper Case	NE	NE	No apparent need for treatment
PC Base Case	Cu; Zn	6;3	See above discussion
PC Upper Case	As; Cd; Cu; Zn	1;6;12;5[a]	See above discussion

NE = No exceedance

[a] No exceedance over NS Tier 1 value; exceeds newer CCME guideline, but in some instances, predicted values are within baseline range

As discussed in GHD (2019a), based on the outcomes of the predictive modelling there is likely a need for some form of water quality treatment. The focus of water treatment based on existing modelling and data would be copper. Refinement of source terms and expansion of the baseline dataset will assist in confirming treatment needs for copper, and whether additional metals/metalloids, such as zinc and arsenic (which have a low risk potential, and hence are not currently meriting treatment) or cadmium, also require treatment. Atlantic Gold has indicated that a water treatment system will be designed to ensure that all site effluent water meets MDMER (at point of release) and CCME or Site Specific objectives (at an appropriate distance downstream, following some mixing). Water quality will be continuously measured in the North Settling Pond, during EOM conditions, and the pit lake, during PC conditions, so that a treatment system, if required, can be scaled as needed to meet effluent discharge guidelines. Sufficient freeboard will be provided in both the North Settling Pond and the pit lake to allow for adequate timing to adjust the treatment process as needed.

GHD (2019a) provides summaries of the anticipated constituent loading removals from the site effluent water required to meet regulatory guideline limits during EOM conditions at the Killag River (Near Field), as well as PC conditions at the Killag River (Near Field) and Far field. The proposed water quality treatment system will be designed to remove the necessary predicted constituent loadings, but will consider the loadings in concert with an expanded baseline database, and refinement of source terms used in the modelling effort. The predicted increments developed by GHD (2019a) are added to the mean of baseline concentrations, which currently only includes 9 samples. Therefore, a better understanding of baseline concentrations of metals will be important, including increased number of samples, total and dissolved metals data, improved detection limits for several metals (e.g., copper and zinc, which have elevated detection limits, and are largely non-detect), such that the predicted increments can be re-examined in light of improved baseline understanding. Some predicted exceedances may not present a risk, following refinement of detection limits and a more robust baseline dataset.

3.7 Summary – Killag River

Under the EOM scenarios, predicted near-field (northern settling pond discharge) and far-field chemical concentrations in the base case and upper case are consistently below selected water quality benchmarks without water treatment. Under the PC scenarios, there is little difference between predicted chemical concentrations at near-field (pit lake discharge) and far-field locations for each assessment each case. In base case PC scenarios, copper and zinc concentrations are predicted to exceed selected water quality benchmarks at both locations without water treatment. At both locations, copper is predicted to exceed in January and from May to September, while zinc is predicted to exceed from July to September. In the upper case PC scenarios, arsenic is predicted to exceed the selected water quality benchmark in August, cadmium is predicted to exceed in January and from May to September, copper is predicted to exceed year-round, and zinc is predicted to exceed from May to September, without water treatment. Zinc and arsenic exceedances are concluded to have a low potential for toxicity, based on the marginal degree of exceedance, relative to the guidelines for these substances. Cadmium may be associated with some potential for toxicity, but the highest exceedances are within two-fold of the guideline, and hence, may have limited toxic potential, depending on baseline water quality characteristics. Copper predictions are more noticeably elevated, relative to the guideline, and hence, have a higher potential for toxicity.

Atlantic Gold Corporation is committed to water treatment, if necessary, to meet appropriate guidelines or site specific water quality objectives in the receiving environment following an appropriate degree of mixing (based on either baseline metrics, such as aluminium or iron, or toxicity data, such as arsenic). As such, metals considered to pose a risk in the receiving environment will be dealt with through appropriate and targeted water treatment, which will be determined based on the following:

- Review and updating of source terms within the water quality modelling to ensure the most accurate data is used to predict potential for impacts;
- An expanded database of baseline data will be important in evaluating need for treatment for some elements, as some elements currently predicted to exceed benchmarks may be within benchmarks when more robust baseline data with improved detection limits are obtained.

4 MOOSE RIVER ASSESSMENT

4.1 Description of Receiving Environment and Baseline Data

As summarized by GHD (2017), Moose River is the largest watercourse at the Touquoy site, and it flows along the western border of the property. As discussed in Chapter 6.6 of the EIS (Surface Water Quality and Quantity), where Moose River is adjacent to the Mine Pit (at surface water monitoring station SW-2, which is the most relevant surface water monitoring station for the assessment of potential aquatic effects associated with discharge from the Touquoy Pit), it is a 3rd order watercourse with an approximately 12.5 m bankfull width as measured in the 2017 hydrometric program. The substrate was noted in the 2017 hydrometric monitoring report is characteristically muddy consisting predominantly of cobbles and small boulders, silt/sand with gravel. An unnamed tributary to Moose River flows south through the Touquoy property, between the open pit and tailings management area. A first order unnamed tributary to the latter, south of the proposed pit, flows southward. Fish River drains Square Lake, northeast of the property, to Scraggy Lake. Fish River then flows west and then south into Lake Charlotte, eventually emptying into Ship Harbour. The Fish River Watershed river system is significant for trout, gaspereau and Atlantic salmon populations. A study area and site map is presented in Figure 4-1.

As discussed in GHD (2017), the tributary to Moose River is very small north of the Mooseland Road and was dry for much of 2005 and 2006. Fish habitat is marginal, dependent on surface flow, and at flow levels observed in 2005 and 2006, expected to be limited to fish excursions during high flows. The culvert at the Mooseland Road was installed incorrectly and is hung, thus preventing fish passage during average and low flow conditions. From the wetland area, downstream there is limited potential for seasonal brook trout habitat. Two small juvenile brook trout were captured just downstream of the woods road (south of the wetland). Moose River may host a small salmon population. Some years, however, Moose River dries up into a series of pools.

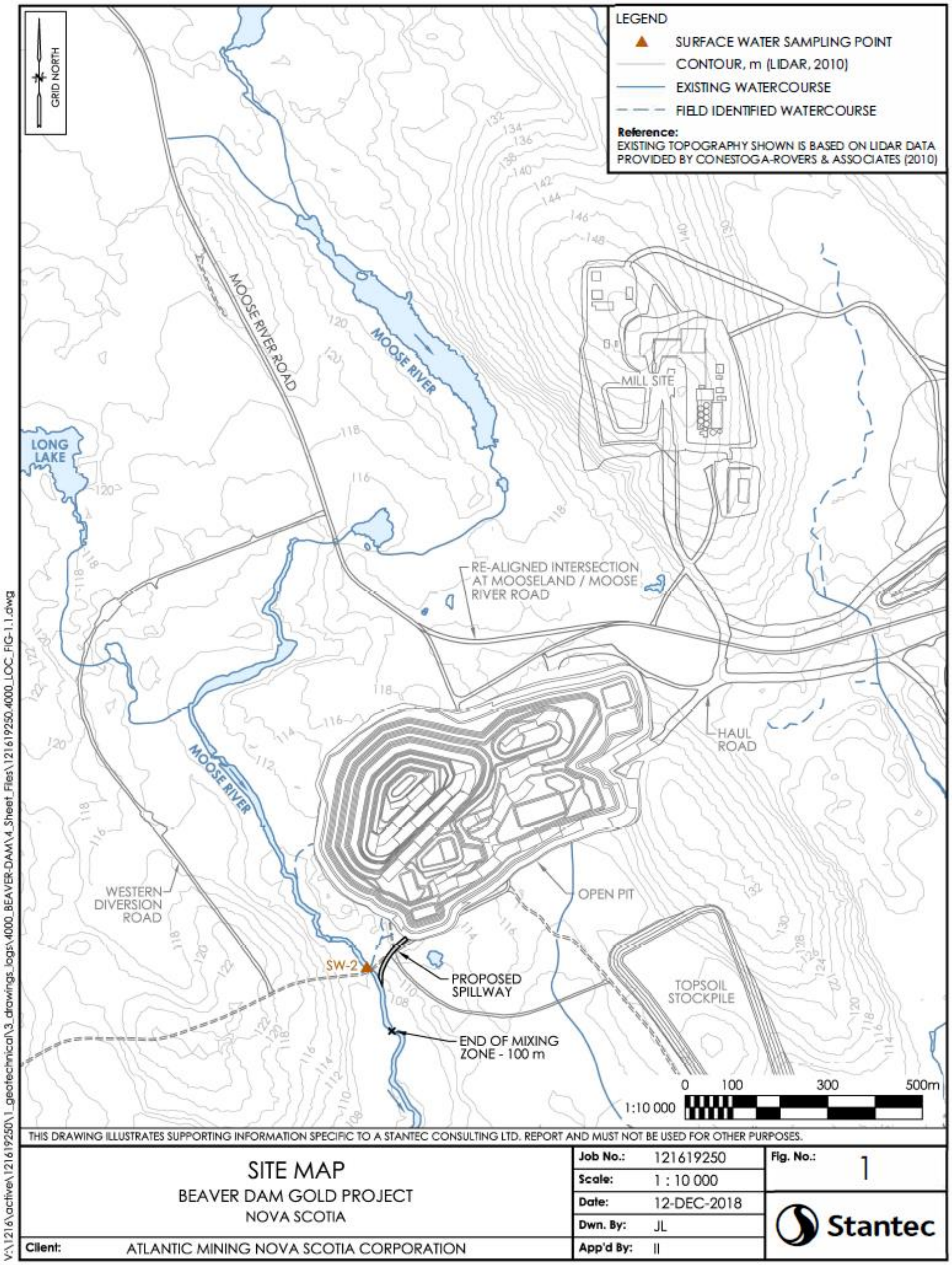

Figure 4-1 Site Map of Beaver Dam Gold Project

Baseline data for surface waters in the area is presented in Table 4-1. The data in Table 4-1 are for surface water monitoring station SW-2, which is where discharge from the Mine Pit at Touquoy will be released, once the pit fills. This station is the most representative of the receiving environment conditions for the assessment of aquatic effects. As discussed in Section 6.6 of the EIS (Surface Water), dissolved ions are low and the water is very soft, indicating little mineral content and influence from weathered rock. The watersheds in the area of Beaver Dam Mine have been logged extensively, yet turbidity is low, indicating a lack of silt in the soils and/or little erosion from logging practices. Alkalinity is low at all sampling locations throughout the Project Area (PA). This is anticipated due to the surficial geology being resistant to weathering and containing little carbonate. pH was generally low in all sampling locations and outside the range identified in the CCME. In addition, as discussed in Chapter 6.6 of the EIS (Surface Water; 6.6.3.2.2), arsenic was noted to consistently exceed the Tier 1 EQS at SW-2 downstream of the open pit in both 2016 and 2017. These elevated arsenic concentrations are not attributed to operation and may be from historical tailing piles and/or the Touquoy ore body itself. A remedial action plan is currently underway by AMNS that involves the delineation, removal, and management of these historical tailings piles around the open pit area. In general, water quality exceedances for aluminum, iron, arsenic, cadmium are commonplace in the environment, even at surface water quality monitoring stations upgradient of the mine (“background” stations) (Stantec, 2018b).

Table 4-1 Baseline Surface Water Concentrations Collected from Moose River (Total Metals mg/L)

Chemical	*Min*	*Max*	*Mean*	*75th Percentile*	*# of Non-Detects*	*CCME (mg/L)*	*Nova Scotia Tier 1 (mg/L)*
Aluminium	0.073	0.35	0.169	0.187	0/22	0.005	0.005
Arsenic	0.004	0.03	0.012	0.018	0/22	0.005	0.005
Calcium	0.84	1.7	1.2	1.3	0/22	NV	NV
Cadmium	<0.00001	0.00004	0.000014	0.000019	7/22	0.00004	0.00001
Cobalt	<0.0004	0.00071	<0.0004	<0.0004	21/22	NV	0.01
Chromium	<0.001	0.0017	<0.001	<0.001	20/22	8.9	NV
Copper	<0.002	<0.002	<0.002	<0.002	22/22	0.002	0.002
Iron	0.19	0.85	0.48	0.62	0/22	0.3	0.3
Lead	<0.0005	0.00086	<0.0005	<0.0005	20/22	0.001	0.001
Mercury	<0.000013	0.00002	<0.000013	<0.000013	20/22	0.000026	0.000026
Magnesium	0.35	0.75	0.488	0.52	0/22	NV	NV
Manganese	0.029	0.18	0.06	0.07	0/22	NV	0.82
Molybdenum	<0.002	<0.002	<0.002	<0.002	22/22	0.073	0.073
Nickel	<0.002	<0.002	<0.002	<0.002	22/22	0.025	0.025
Tin	<0.002	<0.002	<0.001	<0.001	22/22	NV	NV
Selenium	<0.001	<0.001	<0.001	<0.001	22/22	0.001	0.001
Silver	<0.0001	<0.0001	<0.0001	<0.0001	22/22	0.00025	0.0001
Dissolved Sulphate	<2	2.6	<2	<2	19/22	NV	NV
Thallium	<0.0001	<0.0001	<0.0001	<0.0001	22/22	0.0008	0.0008

Uranium	<0.0001	<0.0001	<0.0001	<0.0001	22/22	0.015	0.3
Zinc	<0.005	0.0061	<0.005	<0.005	19/22	0.007	0.03
WAD Cyanide	<0.003	0.004	<0.003	<0.003	21/22	NV	0.005
Total Cyanide (based on Strong Acid Dissociated)	<0.001	0.002	<0.005	<0.005	19/22	NV	0.005
Nitrate (as N)	<0.05	0.18	<0.05	0.054	15/22	13	NV
Nitrite (as N)	<0.01	<0.01	<0.01	<0.01	22/22	0.06	NV
Ammonia	<0.05	0.14	<0.05	0.062	13/21	23.7	NV
pH	4.9	6.89	6.05	6.24	22/22	6-9	NV
Hardness (mg/L $CaCO_3$)	3.5	7.3	5.0	5.25	22/22	NV	NV

Notes:
NV indicates no value provided

As discussed in Stantec (2018a,b), arsenic concentrations varied throughout the stations in the surface water monitoring program near the mine. Moose River experiences levels above the CCME guideline in the summer (lower water flow). This is likely due to arsenopyrite, an iron arsenic sulfide compound, which is common in the surficial and bedrock geology of the area. Other exceedances over freshwater aquatic life guidelines occurred with lead, cadmium, copper, selenium, and zinc, which fluctuated throughout the year at most sampling locations and sometimes slightly exceed the guidelines. Alkalinity is low at all sampling locations throughout the study area, again due to naturally occurring surficial geology being resistant to weathering and containing little carbonate. Similarly, pH was generally low in all sampling locations and outside the range identified in the CCME guidelines; however, this a common feature of surface water in Nova Scotia being influenced by acidic precipitation originating in the northeast United States. At the Touquoy site, pH measures were highly variable, in particular on Moose River, where on several sampling events at two sampling stations, the pH varies by two orders of magnitude. locations.

4.2 Description of Water Quality Modelling Conducted

Stantec (2018a) conducted an assimilative capacity modelling exercise, to predict future water quality in the receiving environment, Moose River. The methodology used followed CCME (2003), which is a framework established for assessing assimilative capacity of receiving environments. As outlined by Stantec (2018a), this approach involved identifying parameters of potential concern within the proposed discharge (such as those that may exceed applicable regulatory limits within the open pit effluent); establishing water quality objectives for the receiving environment (in this case, CCME and NS Tier 1 standards); establishing background parameter concentrations, in the instance that some compounds may be naturally elevated above regulatory objectives; determination of the initial mixing zone; and, development of end of pipe effluent discharge limits which will meet ambient water quality objectives at the edge of the mixing zone.

The specific details of the hydrology of the receiving environment are presented in Stantec (2018a). A water balance model was developed to predict the Open pit effluent overflow to

Moose River at mine closure. Effluent water quality was predicted using the water quality and quantity model and groundwater flow model (see Stantec 2018a). Water quality modelling considered pore water within the tailings, as well as groundwater inflow quality in the pit floor and walls, and dilution from surface runoff, as well as direct precipitation and process water surplus, etc (Stantec, 2018a). Both an average concentration within the open pit and a maximum concentration were predicted.

Based on the modelling conducted, only aluminium, arsenic, cobalt, copper and nitrate were predicted to be present in effluent discharge from the Open Pit at concentrations exceeding NS Tier 1 (2014) or CCME FWAL guidelines, and hence, only these compounds were carried forward for receiving environment predictions (see Stantec, 2018a; Table 5). The modelling effort also examined the potential seepage from the Open Pit via groundwater to the Moose River receiving environment, and none of the elements were predicted to be present in groundwater at concentrations approaching either NS Tier 1 (2013) or CCME FWAL guidelines (see Table 6; Stantec, 2018a).

Receiving environment concentrations of the selected compounds of potential concern (aluminium, arsenic, cobalt, copper and nitrate) were predicted using CORMIX, version 11, and all assumptions and model inputs are provided in Stantec (2018a).

4.3 Selected Benchmarks

Benchmark concentrations used for comparison against predicted water concentrations are presented in Table 4-2. Selection of these benchmark concentrations is described in Section 2.3. These benchmark concentrations were based on the greater of either the water quality guideline selected for use in the assessment (see Table 2-1), or the 75th percentile of the baseline surface water concentrations collected from the Moose River (Table 4-2), except for arsenic for which a site-specific water quality objective was calculated and adopted (see Section 2.3 and Appendix A). As discussed previously, only those chemicals determined to merit further evaluation in the receiving environment by Stantec (2018a) are listed in Table 4-2. Note that GHD (2019a) modelling was provided in µg/L, and the Stantec (2018a) modelling was provided in mg/L. The units used by the authors of these reports were retained in this assessment, to allow comparisons to the original reports, as needed, without confusion.

Table 4-2 Selected Benchmark Concentrations for Use in the Moose River Assessment (mg/L)

Parameter	*Selected Guideline*[a]	*75th Percentile Baseline Concentration*	*Site-Specific Water Quality Objective*	*Selected Benchmark Concentration*
Aluminum	0.005	0.187	-	0.187
Arsenic	0.005	0.018	0.030	0.030
Chromium	0.0089[b]	<0.001	-	0.0089
Cobalt	0.010	<0.0004	-	0.010
Copper	0.002	<0.002	-	0.002
Sulphate	128[c]	<2	-	128
WAD Cyanide	0.005[b,d]	<0.003	-	0.005[b,d]

Total Cyanide (based on Strong Acid Dissociated)	0.005[b,d]	<0.005	-	0.005[b,d]
Nitrite (as N)	0.06[b]	<0.01	-	0.06
Total Ammonia - N	Varies with pH and temperature	0.062	-	1.97[b,e]

Notes:

- not calculated; NDA: no data available

[a] Selected guidelines represent Nova Scotia Tier 1 guidelines unless specified otherwise; see Table 2-1

[b] Selected guideline adopted from CCME.

[c] Selected guideline from BC MOE (see Table 2-1)

[d] based on free cyanide; the application of this guideline for Total Cyanide is overly conservative, and is applied for discussion purposes

[e] Ammonia toxicity increases with increasing temperature and pH. Using the maximum pH from Table 4-1 (6.89), and maximum temperature provided in CCME, 2010 (30 degrees C), a Total ammonia - N guideline of 2.39 mg/L ammonia-N is selected.

4.4 Predicted Water Quality

Predicted future water quality in the effluent from the Open Pit, groundwater and receiving environment of Moose River is provided in Table 4-3. The parameters in the effluent identified by Stantec (2018a) as being in exceedance of regulatory limits included aluminium, arsenic, WAD and Total cyanide, cobalt, copper and nitrite. In addition, as indicated in Table 4-4 some compounds had no regulatory limits identified in either NS Tier 1 (2014), or CCME, and hence, these were included in the aquatic effects assessment, using guidelines from other jurisdictions, where available. These include sulphate and ammonia. The maximum predicted concentration in effluent, as well as the maximum predicted concentration in seepage were both assessed. Where predicted concentrations exceed regulatory guidelines, they are further discussed relative to background concentrations in the receiving environment, and available site specific water quality objectives (arsenic) or other toxicity data and information. Note that the predicted arsenic concentrations in effluent are currently greater than the MDMER limit of 0.3 mg/L (commencing on June 1, 2021), at 0.86 mg/L (Table 6; Stantec, 2018a), and hence, treatment will be required for arsenic to ensure the MDMER limit of 0.3 mg/L is met. For the purposes of predicting receiving environment concentrations at the end of the 100 m mixing zone, arsenic was assumed to meet the MDMER limit of 0.3 mg/L (Stantec, 2018a). The predicted water quality concentrations at the edge of a 100 m mixing zone in the receiver are presented in Table 4-4, relative to the selected benchmarks in Table 4-2.

Table 4-3 Water Quality Modelling Results for Effluent, Groundwater Seepage, and Predicted concentrations at end of 100 m Mixing Zone in Receiving Environment of Moose River, relative to Selected Benchmarks

WQ Parameter[a]	Effluent Max, mg/L[a]	Seepage, Average, mg/L[a]	Receiver, 75th percentile	Concentration at end of 100 m mixing zone	Selected Benchmarks
Aluminum	0.04	Below DL	0.187	0.184	0.187
Arsenic	0.3	0.002	0.018	0.023	0.030
Chromium[b]	0.00038[b]	Below DL[c]	<0.001	0.0005[h]	0.0089
Sulphate[b]	219.0[b]	0.62[c]	< 2.0	5.29[h]	128

WAD Cyanide	0.123	Below DL	<0.003	0.002	0.005
Total Cyanide	0.351[b]	Below DL[c]	<0.001[d]	0.007[h]	0.005
Cobalt	0.064	Below DL	<0.0004	0.0012	0.010
Copper	0.036	Below DL	<0.002	0.0007	0.002
Nitrite (as N)	1.74	Below DL	<0.01	0.034	0.06
Total Ammonia - N	0.88	0.023[c]	0.062	0.077[i]	1.97

Notes:

* Free form of cyanide;

[a] From table 8 of Stantec, 2018, unless indicated

[b] From Table 5 of Stantec, 2018;

[c] From Table 6 of Stantec, 2018;

[d] Total cyanide receiver concentrations are based on Strong Acid Dissociated concentrations

[e] For hexavalent chromium

[f] For Trivalent chromium

[g] No CCME guideline is available; therefore a guideline from BC Moe was used (https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf)

[h] Calculated using a dilution ratio of 51, as per Table 7 of Stantec, 2018, and receiving environment concentration (assumed at ½ the detection limit);

[i] Value provided via email from Stantec, 2019

Based on the predicted future concentrations, relative to available water quality guidelines, total cyanide merits further evaluation. A discussion is also provided for arsenic, as the CCME guideline of 5 µg/L is superseded in this project by a SSQWO of 30 µg/L, to provide additional context.

Arsenic:

While predicted receiving environment concentrations of arsenic at the end of the 100 m mixing zone within Moose River (0.023 mg/L) exceed the CCME FWAL guideline of 0.005 mg/L, this guideline was derived some time ago using a safety factor applied to the Lowest Observed Effect Level [the 14-day EC50 (growth) of 50 µg/L for the algae *Scenedesmus obliquus* (Vocke et al., 1980), with a safety factor of 0.1 (CCME, 1991)]. The Vocke et al. (1980) study was the most sensitive freshwater organism to arsenic identified by the CCME, following consideration of data from 21 different species of fish, 14 species of invertebrates and 14 species of plants. Other regulatory guidelines are also available from other jurisdictions, such as the National recommended water quality criterion known as the Criterion Continuous Concentration (CCC) from the US EPA (US EPA, 2018; arsenic criteria developed in 1995). The CCC is "an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect". The CCC for arsenic are based on the amount of dissolved metal in the water column and is 150 µg/L (0.150 mg/L) and was derived on 1995.

Using the CCME protocol for development of water quality guidelines (CCME, 2007), a Species Sensitivity Distribution approach was used to develop a site specific water quality objective (SSWQO), as discussed in Section 2.3. Details are presented in Appendix A. The value developed is 0.030 mg/L (30 µg/L) and concentrations predicted in receiving environment of

Moose River are below this value. The predicted receiving environment concentration of 0.023 mg/L is below any of the no observed effect concentration (NOEC) or low observed effect concentration (LOEC) data for arsenic provided in Table A-2 for chronic studies. Hence, risks to aquatic life are anticipated to be low.

Total Cyanide:

The chemistry of cyanide is complex, and the toxicity of various cyanide complexes varies widely. So, the form of cyanide in the environment greatly affects the toxicity of the compound. The most toxic form of cyanide is free cyanide, which includes the cyanide ion ($^{-}$ CN) and HCN (ICMC, 2018). Cyanide is highly reactive, and readily forms simple salts with earth cations and ionic complexes. The strength of the bonds of these associations vary depending upon the salt, and the pH of the environment. Weak or moderately stable complexes are known as WAD (weak acid dissociable), and typically involve cations such as cadmium, copper and zinc. WAD cyanide is less toxic than free cyanide, but when they dissociate they release free cyanide and the metal cation. Typically, WAD complexes dissociate and release HCN under mildly acidic conditions such as those ranging from pH 3 – 6 (OI, 2009). Cyanide can also form very stable complexes with gold, mercury, cobalt and iron. The stability of these complexes in the environment depends on pH in the environment, but strong metals-cyanide complexes (SAD) typically require strongly acidic conditions (pH<2) to dissociate and release HCN (OI, 2009). The term "total cyanide" typically refers to the sum of all cyanide species that are converted to HCN following digestion in a strong acid solution (Total cyanide = free cyanide + WAD + SAD). Other cyanide compounds, such as thiocyanate and cyanate, are markedly less toxic than free cyanide (ICMC, 2018).

With this in mind, a measured or estimated Total Cyanide concentration can range from including 100% SAD forms of cyanide, to 100% free cyanide, depending upon the chemistry of the effluent, and the receiving environment. Some SAD forms of cyanide (iron cyanide complexes) can dissociate in sunlight and release free CN (ICMC, 2018). Other environmental fate processes, such as volatilization, wherein the amount of cyanide lost increases with decreasing pH, and biodegradation, where aerobic conditions result in microbial degradation of cyanide to ammonia, and subsequently, nitrate (ICMC, 2018). Therefore, environmental fate of cyanides in the receiving environment is modified by a number of factors.

It is important to note that the NS Tier 1 guideline of 5 µg/L (which is based on the CCME guideline), is for free cyanide. This guideline is not a relevant guideline to compare Total cyanide, SAD or even WAD forms of cyanide to, as it is based on the free ion, as opposed to bound forms of cyanide, which have far lower toxic potential. Based on the receiving environment predictions in Table 4-3, WAD cyanide is less than half of the Total Cyanide predicted concentration (0.002 mg/L WAD, compared to 0.007 mg/L Total). This implies that the majority of the Total Cyanide prediction would be SAD, and hence, unlikely to dissociate in the receiving environment (mean pH in receiving environment is 6.05; see Table 4-1). Predicted WAD concentrations in the receiving environment are below the NS Tier 1 guideline, indicating acceptable levels of risk to aquatic life. The predicted Total Cyanide concentration in the receiving environment only marginally exceeds the free cyanide guideline, and since the majority of the predicted cyanide is anticipated to be SAD, risk to aquatic life are predicted to be low.

4.5 Summary – Moose River

Based on the predictive modelling conducted, only Total cyanide was predicted to exceed the NS Tier 1 guideline, which is based on free cyanide, and hence not a relevant benchmark for comparison purposes. Based on the available toxicity data and predictions, Total Cyanide is unlikely to be present in concentrations of concern to aquatic life. Arsenic predictions exceed the CCME guideline of 5 µg/L, but not the SSWQO of 30 µg/L, and hence, risks to aquatic life related to arsenic are anticipated to be low

5 UNCERTAINITIES AND LIMITATIONS

As inherent in any risk assessment study, there are limitations, uncertainties and conservative assumptions applicable to this screening level risk assessment, as follows:

- Modelling was conducted to predict surface water concentrations in Killag River and Moose River. Uncertainties associated with the modelling studies are provided in GHD (2019) and Stantec (2018). Conservative assumptions were applied in both modelling exercises, and hence, predicted concentrations should be conservative. For example, to calculate the receiving environment for Moose River, the most conservative dilution ratio (51), was used, using the maximum Open Pit concentrations (Stantec, 2018).
- Baseline data to characterize existing metals concentrations in Killag river are limited (N = 9 samples). In addition, some detection limits are elevated, relative to aquatic life guidelines. Since mean baseline concentrations were added to the predicted increment from the Project, in situations where the mean baseline metric is based on non-detect data and half of the detection limit was used to represent baseline, this characterization is uncertain. Gathering additional baseline data, with improved detection limits will reduce uncertainties in these predictions and assist in identifying water treatment needs.
- The water quality in both Moose River and Killag River is soft. Some mine effluents have increased hardness which can assist in ameliorating receiving environment conditions. In addition, the Killag River has naturally low pH, and the Nova Scotia Salmon Association has been operating an acid mitigation project on the West River for over 10 years. This program involves a lime dosing station which is used to increase the pH of the water to a suitable range for juvenile salmon (to approximately 5.5). The Nova Scotia Salmon Association has indicated that this project has resulted in significant increase in smolt populations and improved overall habitat quality within the West River Sheet Harbour. A second lime dosing station was installed 400 m downstream from the Beaver Dam site, which could substantially improve downstream water quality (pH) and fish survivorship, as current, naturally occurring pH levels are below the CCME required range. Additional baseline data collection will assist in understanding current water quality conditions in the Killag River.
- Toxicity data were assessed to derive the arsenic SSWQO, as per standard methods provided by CCME (2007). Speciation of arsenic in the receiving environments could vary, depending upon various water quality parameters. In all cases, where toxicity data

for both arsenic V and arsenic III were available, the data with the greatest toxicity were selected irrespective of receiving environment conditions. In addition, chronic test time frames were selected over those of shorter durations.

- Toxicity data for certain receptor groups are limited, including amphibians and reptiles. Specific targeted literature searches were conducted to identify any available data for these receptor groups. The standard CCME (2007) protocol was used to derive the SSWQO, and where amphibian and reptile data were available, they were included.

6 CONCLUSIONS

For Killag River, predicted near-field (northern settling pond discharge) and far-field chemical concentrations in the base case and upper case of the EOM scenarios were consistently below selected water quality benchmarks without any included water treatment. Hence, this scenario does not present a risk to the receiving environment. Under the PC scenarios, base case predictions suggest that copper and, to a lesser degree, zinc concentrations will exceed selected water quality benchmarks if no water treatment is included. In the upper case PC scenarios, arsenic is predicted to exceed the site specific water quality benchmark in August, cadmium and zinc are predicted to exceed guidelines in several months, and copper is predicted to exceed guidelines year-round, in the absence of water treatment. Zinc and arsenic exceedances are concluded to have a low potential for toxicity, based on the marginal degree of exceedance, relative to the guidelines for these substances. Cadmium may be associated with some potential for toxicity, but the highest exceedances are within two-fold of the guideline, and hence, may have limited toxic potential, depending on baseline water quality characteristics. Copper predictions are more noticeably elevated, relative to the guideline, and hence, have a higher potential for toxicity.

Atlantic Gold Corporation is committed to water treatment, if necessary, to meet appropriate guidelines or site specific water quality objectives (based on either baseline metrics, such as aluminium or iron, or toxicity data, such as arsenic) in the receiving environment following an appropriate degree of mixing. As such, metals considered to pose a risk in the receiving environment will be dealt with through appropriate and targeted water treatment, which will be determined based on the following:

- Review and updating of source terms within the water quality modelling to ensure the most accurate data is used to predict potential for impacts;
- An expanded database of baseline data will be important in evaluating need for treatment for some elements, as some elements currently predicted to exceed benchmarks may be within benchmarks when more robust baseline data with improved detection limits are obtained.

For Moose River, Total cyanide is predicted to be above a free cyanide guideline in the receiving environment. The free cyanide guideline is not an appropriate benchmark for Total cyanide, and examination of the possible concentrations of WAD and SAD cyanide within the predictions indicate that Total cyanide in the receiving environment is unlikely to pose a risk to aquatic life.

7 REFERENCES

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APPENDIX A
ARSENIC SITE-SPECIFIC WATER QUALITY OBJECTIVE

1.0 INTRODUCTION

The typical starting point for assessment of surface water data in an aquatic effects assessment are the Canadian Water Quality Guidelines for Protection of Freshwater Aquatic Life (WQGl - FWAL), established by the Canadian Council of Ministers of the Environment (CCME). These guidelines are generic, national recommendations which reflect the most current scientific data at the time they were developed. They are intended to provide protection to all forms of aquatic life and aquatic life cycles, including the most sensitive life stages, at all locations across Canada (CCME, 2007). Since they are generic and do not account for site-specific factors that can alter toxicity, these national guidelines can be modified using widely accepted procedures, to derive site-adapted or site-specific water quality objectives (SSWQOs) for a given project or location (CCME, 2003). Modifications to the generic guidelines allow for protection of aquatic species accounting for specific conditions in the receiving environment, primarily due to the following reasons (CCME, 2003):

- There may be naturally-occurring levels of substances that are above the generic guidelines. This is commonplace for metals and metalloids near areas of natural enrichment, such as mines.

- There may be certain characteristics of the water at a specific location or site which modify the toxicity of the substance, such that the generic guideline is unnecessarily conservative (protective). These characteristics are known as exposure and toxicity modifying factors (ETMFs), and can include parameters such as pH, temperature, hardness, and organic matter, amongst others (CCME, 2007).

- There may be certain sensitive species considered in the development of the generic guideline which are not present in the area under assessment (e.g., warm water species which are absent from Canadian environments), and removal of these data allows for a more site-specific guideline to be developed, without compromising protection. In addition, information on toxicity of the substance in question to resident species in the area of interest may be lacking in the existing database, and therefore, there may be interest in expanding the database to include site-specific toxicity data. Or, the existing CCME guideline may be dated and hence, application of more advanced protocols and more recently published data can result in a revised guideline, which is more representative of current scientific practice and available toxicity data.

The purpose of this report is to develop SSWQO for arsenic, based on the assessment of toxicity data and the application of more advanced water quality objective protocols for the Beaver Dam Mine Project. The SSWQO developed in this report will be used to assess surface water arsenic concentrations in the aquatic effects assessment.

2.0 METHODOLOGY

As discussed in CCME (2003), there are typically four possible approaches that can be taken to derive a SSWQO, as follows:

The Background Concentration Approach: This approach can be taken in instances where natural background concentrations exceed the WQGl-FWAL, typically due to natural enrichment (in the case of metals/metalloids). A statistical approach is used to determine the upper limit of natural background, based on available data, which may differ depending upon the number of samples and non-detectable results for a given parameter.

The Recalculation Procedure: This approach could involve the recalculation of the generic FWAL guideline, through removal of data on species that are not relevant to the Beaver Dam Mine area (such as warm water species, etc.), and more recently published data which has become available since the existing guideline was developed. In addition, this procedure would use more recently developed techniques recommended by the CCME in their 2007 protocol. Minimum data requirements outlined in the protocol (CCME, 2007) must be met, and therefore, literature-based data can be supplemented with additional toxicity testing on resident species, if data are limited.

This approach is particularly of interest where existing guidelines are old, and hence may not include scientific literature published in recent years. The CCME (2007) protocol prefers that a Species Sensitivity Distribution (SSD) approach be used to calculate the revised guideline, where there are sufficient data.

Water Effect Ratio (WER) Procedure: This approach allows for site-specific toxicity tests using indicator species and/or resident species which are conducted in side-by-side tests with site water and laboratory water. Using this approach, ETMFs inherent in the site water are accounted for in the toxicity tests. By conducting concurrent toxicity tests using two water types, a ratio of effects between laboratory water and site water can be developed, based on the concept that the laboratory water is representative of that typically utilized in studies captured within the WQGl-FWAL. This ratio is subsequently applied to the WQGl-FWAL to derive a SSWQO.

The Resident Species Approach: This approach involves generating a complete set of toxicity data, using resident species and site water. This approach is typically selected when there are limited toxicity data, or where the ETMF associated with a site may have a significant influence on the guideline.

For the purposes of this assessment, the recalculation procedure was used to derive a SSWQO for arsenic using the SSD approach as per guidance from the CCME (2007) protocol.

2.1 Review of Environmental Fate and Exposure Toxicity Modifying Factors (EMTFs)

2.1.1 Environmental Fate

Arsenic is a ubiquitous metalloid which occurs naturally in the earth's crust (Sharma and Sohn, 2009; HC and EC, 1993). Arsenic exists in four oxidation states: +V (arsenate), +III (arsenite), 0 (arsenic), and –III (arsine). Arsenic compounds can be grouped from a biological and toxicological perspective as inorganic arsenic compounds, organic arsenic compounds and arsine gas (IARC, 2012). In nature, arsenic is most often found in its sulfide form (either alone or with various metals such as silver, lead, copper, nickel, antimony, cobalt and iron), but occasionally occurs as a solid in the elemental state (HC and EC, 1993; IARC, 2012).

Arsenic is mobilized through natural processes such as weathering and erosion of soil and rocks, biological activity and volcanic emissions, and through anthropogenic activities such as smelting of metal ores, coal fired power generation, and use in pesticides and in wood preservers (Smedley and Kinniburgh, 2002; ATSDR, 2007; HC and EC, 1993).

In freshwater, the most prevalent dissolved forms of arsenic are inorganic As V (arsenate) and As III (arsenite). Under aerobic conditions, As V is more stable than As III (WHO, 2001). In lake and river waters, As V is generally the dominant species (e.g., Pettine et al., 1992); however relative portions of As III and As V vary depending upon input sources, redox conditions and biological activity (Smedley and Kinniburgh, 2002). Organic species produced by microbial activity may also be found in freshwater, but to a lesser degree than the inorganic forms. When present in freshwater systems, monomethylarsonic acid (MMA or monomethyl arsenate) and dimethylarsinic acid (DMA or dimethylarsenate), both in the As V state, are the most common forms of dissolved organic arsenic (Braman and Foreback, 1973; Cullen and Reimer, 1989; Markley, 2004; Vukasinovic-Pesic et al., 2005; Smedley and Kinniburgh, 2002). In summer, levels of MMA and DMA have been reported to increase due to increased microbial activity (e.g., Hasegawa, 1997).

The form and concentration of arsenic in water is dependent upon several factors including:

- water oxygen levels (e.g., arsenate predominates under oxidizing / high dissolved O_2 conditions, arsenite predominates under reducing / low dissolved O_2 conditions);
- the degree of biological activity (which is associated with the conversion of inorganic to organic arsenic);
- the type of water source (e.g., freshwater, seawater or groundwater); and,
- how close the water source is to areas naturally enriched in arsenic and / or anthropogenic arsenic sources (Seyler and Martin, 1989; WHO, 2000, 2001).

For the purposes of the assessment, both As V and As III were considered in the development of the arsenic SSWQO as it is possible that both forms exist in the aquatic environment in the area of the Beaver Dam Mine Project.

Natural concentrations of arsenic can be significantly elevated in areas of arsenic-enriched bedrock (HC and EC, 1993). In surface waters, typical arsenic concentrations are <10 µg/L, and are frequently <1 µg/L. Near anthropogenic sources, concentrations have been reported to be as high as 5 mg/L (IARC, 2012; Smedley and Kinniburgh, 2002). In Canada, arsenic concentrations in uncontaminated surface waters are typically <2 µg/L (CCME, 2001).

Arsenic water concentrations tend to be higher in summer than in winter which is likely due to the release of arsenic by surface sediments that have become anoxic causing a release into the water column of arsenic adsorbed on iron and manganese oxides (Singh et al., 1988; Crecelius et al., 1994).

While arsenic can bioaccumulate in aquatic organisms such as algae, crustaceans and fish, it does not appear to biomagnify in freshwater food chains (Eisler, 1988).

2.1.2 Exposure Toxicity Modifying Factors

The toxicity of arsenic is highly dependent on its chemical speciation which influences its mobility in water. The main processes controlling arsenic mobility in water are adsorption (e.g., attachment of arsenic to iron oxide / iron oxyhydroxide surfaces) and desorption reactions and solid-phase precipitation and dissolution reactions (Vukasinovic-Pesic et al., 2005; Senn and Hemond, 2002). Dissolved arsenic can be removed from solution, thereby decreasing bioavailability, through a variety of processes including: biotic uptake, absorption onto iron and manganese hydroxides or clay particles, fixation by organic matter, or to a lesser degree, by precipitation or co-precipitation (Frost and Griffin, 1977; Pierce and Moore, 1982; Thanabalasingam and Pickering, 1986; Korte and Fernando, 1991; Markley, 2004). These processes are, in turn, influenced by pH, redox potential (Eh), organic matter, key inorganic substances such as sulfide and phosphate, and adsorbents (Sharma and Sohn, 2009). The most important factors controlling arsenic speciation have been reported to be Eh and pH (Smedley and Kinniburgh, 2002).

Differing major and minor species of As III, As V, MMA and DMA will be present depending upon pH (Sharma and Sohn, 2009). In natural waters, as the pH increases, arsenate (As V) tends to become less strongly sorbed. When pH increases above 8.5, the concentration of arsenic in solution increases as a result of either i) the adsorbed arsenic desorbing from the surfaces of mineral oxides (especially iron oxides) or ii) the increased pH prevents these anions from being adsorbed (Vukasinovic-Pesic et al., 2005; Smedley and Kinniburgh, 2002). At near neutral pH levels, arsenic can stay in solution at relatively high concentrations (Smedley and Kinniburgh, 2002). Under strongly reducing conditions and at near neutral pH, As desorbs from mineral oxides (Smedley and Kinniburghm 2002). At low to near-neutral pH and under oxidizing conditions, arsenic is strongly adsorbed by oxide minerals as the arsenate ion (As V). Arsenic behaves differently from most metals, which occur in solution as cations, where an increase in pH decreases solubility (Smedley and Kinniburgh, 2002; Vukasinovic-Pesic et al., 2005).

Arsenic, similar to other heavy metalloids (e.g., selenium, antimony, molybdenum, vanadium, chromium) is an oxyanion-forming element (i.e., compound with generic chemical formula $A_xO_y^{z-}$ where A represents an element and O represents oxygen) (Smedley and Kinnburgh, 2002). Arsenic is however, relatively mobile under a wide range of redox conditions (both oxidizing and reducing). This differs from other heavy metalloids (e.g., Se, Cr) which become immobilized under reducing environments (Smedley and Kinnburgh, 2002).

The distribution of arsenic species as a function of pH and Eh were illustrated in Smedley and Kinnburgh (2002) and copied below (Figure A-1). At low pH (<6.9) and under oxidizing conditions (high Eh values) inorganic arsenic occurs mainly as $H_2AsO_4^-$ and as pH increases, $HAsO_4^{-2}$ becomes dominant. Under reducing conditions (low Eh) and at pH <9.2, $H_3AsO_3^0$ predominates (Smedley and Kinnburgh, 2002).

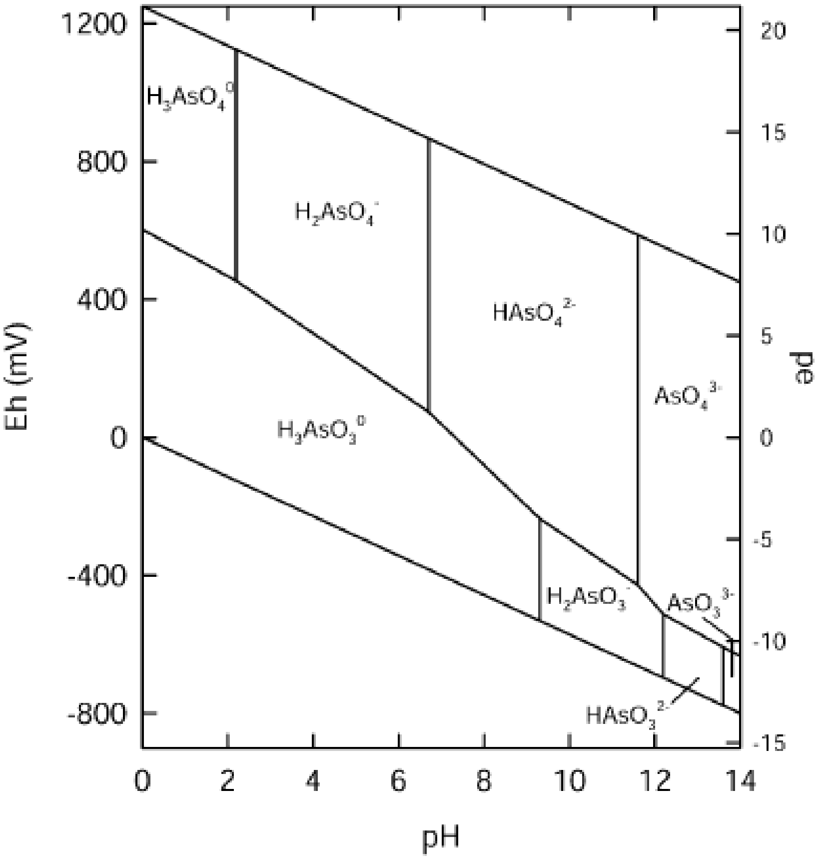

Figure A-1 Eh-pH Diagram for Aqueous Species in the System As-O_2-H_2O at 25°C and 1 Bar Total Pressure (as presented in Smedley and Kinnburgh, 2002)

Anions such as phosphate, carbonate, bicarbonate, silicate and possibly dissolved organic matter (DOM) can outcompete arsenic for sorption sites which can inhibit arsenic adsorption or increase arsenic leaching from mineral surfaces (Sharma and Sohn, 2009; Campos, 2002; Vukasinovic-Pesic et al., 2005, Smedley and Kinnburgh, 2002). This will result in higher concentrations of dissolved arsenic in surface waters.

In summary, arsenic toxicity in surface water is influenced primarily by pH, Eh, and the presence of other anions.

2.2 Data Considered in the Derivation of the Existing CCME Arsenic Guideline

The CCME WQGl was developed following a review of toxicity data from 21 different species of fish, 14 species of invertebrates and 14 species of plants (CCME, 2001). Toxicity endpoints upon which the chronic CCME (2001) WQGl-FW was developed are provided in Table A-1, where available. Note that chronic data for *Anabus testudineus* (climbing perch) and *Clarius batrachus* (walking catfish) are not included in Table A-1, as these species are not relevant to Canadian waters. The final guideline derived by the CCME was based on the 14-day EC50 (growth) for the algae *Scenedesmus obliquus* (Vocke et al., 1980), which was the most sensitive freshwater organism to arsenic identified. The 50 µg/L EC50 was multiplied by a safety factor of 0.1, to obtain the current guideline value of 5 µg/L (CCME, 1991).

Table A-1 Chronic Toxicity Data for Species Used by CCME for Arsenic WQGl-FW Derivation [1]

Species Used in Toxicity Study	Toxicity Endpoint	Metric	Value (µg/L)	Chemical Form	Reference
Bosmina longirostris	Immobility	96-hour EC50	850	Sodium arsenate	Passino and Novak, 1984
Oncorhynchus mykiss	Lethality	28 day LC50	550	NA	Birge et al., 1978
Cyclops vernalis	Reduced growth (20%)	14 day EC20	320	NA	Borgmann et al., 1980
Daphnia magna	Reproduction (16% ↓ in reproduction)	21 day EC16	520	Sodium arsenate	Biesinger and Christensen, 1972
Gammarus pseudolimnaeus	Lethality	7 day LC80	960	NA	Spehar et al., 1980
Ceriodaphnia dubia	Immobilization	7 day LOEC	1000	NA	Spehar and Fiant, 1986
Scenedesmus obliquus	Growth	14 day EC50	50	Inorganic AsV	Vocke et al., 1980
Melosira granulata	Growth	14 day EC50	75	NA	Planas and Healey, 1978
Ochromonas vallesiaca	Growth	14 day EC50	75	NA	Planas and Healey, 1978

Notes:
NA = not available
1. Data obtained from CCME (2001).

2.3 Review of Available Arsenic Toxicity Data

Toxicity data for use in the derivation of the arsenic SSWQO were compiled from a number of sources, including the following:

- CCME, 2001 Water quality guideline document for arsenic
- US EPA ECOTOX database (www.epa.gov/ecotox/); all forms of arsenic were searched
- Literature searches for arsenic toxicity review papers

A summary of the identified toxicity data for arsenic is provided in Table A-2. Toxicity data for tropical species were excluded as they do not inhabit waterbodies in the region of the Beaver Dam Mine Project. It should also be noted that this is not a comprehensive arsenic review, however, this review is considered to capture most relevant toxicity studies. It was assumed that the CCME conducted a thorough literature search in the derivation of the guideline, and hence the starting point for the literature search was literature commencing following that point. In addition, not all studies were reviewed in detail. The focus of this research was to identify chronic studies, using standardized accepted protocols, on relevant species to Canadian waters.

Chronic test durations are discussed in CCME (2007) and include tests for non-lethal endpoints with durations greater than or equal to 21 days for fish (juveniles or adults), or greater than or equal to 7 days for egg and larval studies. For aquatic invertebrates, chronic test durations are considered to be greater than or equal to 96-h for non-lethal endpoints for shorter-lived invertebrates (e.g., *D. magna)*, for nonlethal endpoints of ≥ 7 days duration for longer-lived invertebrates (e.g., crayfish), and lethal endpoints from tests of ≥ 21 days duration for longer-lived invertebrates. Lethal endpoints from shorter-lived invertebrates from tests with <21-day exposure periods are considered on a case-by-case basis. For algal species, all toxicity tests with algae with exposure durations of longer than 24 hours are considered long-term exposure tests because of the length of the algal life cycle compared to the duration of the exposure.

Only those studies of acceptable quality were included in Table A-2. See Attachment 1 for summaries of acceptability rankings.

2.4.1 Identifying Relevant Chronic Toxicity Data

To calculate a chronic SSD, the CCME (2007) has set out the following minimum data requirements which must be met for a Type A guideline:

- Fish: Three studies on freshwater fish species, including one salmonid and one non-salmonid.
- Invertebrates: Three studies on freshwater aquatic / semi-aquatic invertebrate species, at least one of which is a planktonic crustacean species. For semi-aquatic species, life stage tested must be aquatic.
- Plants / Algae: At least one study on freshwater vascular plant or freshwater algal species. Where plants or algae are identified as being among the most sensitive species, the chemical of interest is classified as phytotoxic and three studies on freshwater plant or algal species are then required to derive a long term SSD.

Freshwater toxicity data for arsenic was summarized in Table A-2. Each of these toxicity studies were evaluated for quality and categorized as Primary, Secondary or Unacceptable (see

Attachment 1). Toxicity data from Primary and Secondary studies are considered acceptable for use in the derivation of a SSWQO, however unacceptable data are not. Note that studies by Birge were considered suspect based on a review of the U.S. EPA’s water quality criteria for aluminum and arsenic, which revealed that the corresponding data from these studies were listed as ‘other data’ but were not included in the datasets used for criteria derivation; no reason was given for this exclusion. The Birge (1978) and Birge et al. (1978) data have been found to yield anomalously low toxic concentrations for numerous microelements and were excluded from the SSD. Therefore, the results from these experiments were considered questionable and were not included.

Briefly, for Primary studies, toxicity test must have used currently acceptable standard methods and measured concentrations must be reported. Studies must have sensitive test endpoints with preferred test endpoints for Primary studies including effects on embryonic development, hatching, or germination success; survival of juvenile stages, growth, reproduction; and survival of adults. Other effects such as behavioural or endocrine-disrupting effects can be used if it can be demonstrated these effects are a result of the exposure, they result in an adverse ecological effect and the studies are scientifically sound. For secondary studies, the requirements for standard test methods and measured concentrations are less stringent. The same preferred test endpoints exist for Secondary studies in addition to pathological and behavioural effects (if ecological relevance can be shown, but the requirement for this is not a stringent as it is for primary data) and physiological effects. Toxicity data that do not meet the criteria for either Primary or Secondary studies are considered to be Unacceptable. Additional clarification of Primary, Secondary and Unacceptable studies is provided in CCME (2007).

From the compiled freshwater arsenic toxicity data (Table A-2), those studies designated as Primary or Secondary were considered for use in deriving the SSD.

Table A-2 Arsenic Chronic Toxicity Data

Species	Chemical	Water Quality Parameters			Test Duration / Life Stage	Chronic Value (µg/L)	Reference
		pH	T (ºC)	Alkalinity / Hardness (mg/L; $CaCO_3$)			
Aquatic Invertebrate							
Daphnia magna (Water flea)	Sodium arsenite (As III)	7.2 – 8.1	20.8	37 – 45/46 - 49	28 day survival; reproduction NOEC	633	Lima et al., 1984
Daphnia magna	Sodium arsenite (As III)	7.2 – 8.1	20.8	37 – 45/46 - 49	28 day survival; reproduction LOEC	1320	Lima et al., 1984
Daphnia magna	Arsenite (As III)	7.4	21.5 +/-3	45.5/47.2	28 day (growth and reproduction) NOEC	630	Call et al, 1983
Daphnia magna	Arsenite (As III)	7.4	21.5 +/-3	45.5/47.2	28 day (growth and reproduction) LOEC	1320	Call et al, 1983
Daphnia magna	Sodium arsenate (Na_2HAsO_4)	7.4 – 8.2	NR	42.3 / 45.3	21 day EC16 (16% ↓ in reproduction)	520	Biesinger and Christensen, 1972
Daphnia magna	Arsenic III	6.9 – 7.3	14 - 16	40 – 44/42 - 45	14 day Survival and Reproduction; NOEC	955	Spehar et al, 1980
Daphnia magna	Arsenic V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	14 day Survival and Reproduction; NOEC	932	Spehar et al, 1980
Daphnia magna	Arsenic trioxide (As_2O_3)	Measured but NR	21+1	NR	21 day IC10 (reproduction)	1300	Tisler and Zagorc-Koncan, 2002
Cyclops vernalis; *C. bicuspidatusthomasi* (Copepod)	Sodium arsenite (As III)	7.6 - 8.8	15	88 / 139	14 day EC20	320	Borgmann et al., 1980
Hyallela azteca (Amphipod)	Sodium arsenate (Na_2HAsO_4)	7.23 – 8.83	25	84 / 124	7 day LC50	483	Borgmann et al., 2005
Ceriodaphnia dubia (Water flea)	Sodium Arsenate (As V)	7.9	25.8	50.5/119.4	8 day survival (IC 12.5)	1020	Naddy et al, 1995
Ceriodaphnia dubia	Specific form NR; data for low UV radiation	7.29 – 9.27	25	NR	24 day to 3rd generation NOEC brood size	1000	Hansen et al, 2002
Ceriodaphnia dubia	Specific form NR; data for low UV radiation	7.29 – 9.27	25	NR	24 day to 3rd generation survival NOEC	1500	Hansen et al, 2002

Ceriodaphnia dubia	Sodium arsenite (As III)	8.1 – 8.2	25 +/- 2	97 – 112/100 – 165	7 day MATC (immobilization)	1140	Spehar and Fiandt, 1986
Pteronarcys dorstata (Stonefly)	Arsenic III	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day Survival; NOEC	961	Spehar et al, 1980
Pteronarcys dorstata	Arsenic V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day Survival; NOEC	973	Spehar et al, 1980
G. fossarum (Amphipod)	As^{3+} (sodium arsenite)	8	12 +/- 2	NR	10-day LC50	200	Canivet et al, 2001
G. pseudolimnaeus (amphipod)	As^{3+}	6.9 – 7.3	14 - 16	40 – 44/42 - 45	7 day LC80 14 day LC15	960 88	Spehar et al, 1980
G. pseudolimnaeus (amphipod)	As V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	14 day LC20	973	Spehar et al, 1980
H. campanulate (snail)	As^{3+}	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC5 (LOEC)	960	Spehar et al, 1980
H. campanulate (snail)	As V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC10 (LOEC)	973	Spehar et al, 1980
S. emarginata (snail)	As^{3+}	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC0 (NOEC)	960	Spehar et al, 1980
S. emarginata (snail)	As V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC10 (LOEC)	973	Spehar et al, 1980
H. sulfurea (Ephemeroptera)	As^{3+}	8	12 +/- 2	NR	10-day LC50	1650	Canivet et al, 2001[a]
A. aquaticus (Isopod)	As^{3+}	8	12 +/- 2	NR	10-day LC50	2300	Canivet et al, 2001
N. rhenorhodanensis (Amphipod)	As^{3+}	8	12 +/- 2	NR	10-day LC50	3900	Canivet et al, 2001
H. pellucidula (Trichoptera)	As^{3+}	8	12 +/- 2	NR	10-day LC50	2400	Canivet et al, 2001
Physa fontinalis (Snail)	As^{3+}	8	12 +/- 2	NR	10-day LC50	2200	Canivet et al, 2001
G. pulex (amphipod)	Arsenic acid (H_3AsO_4)	NR	10.0	NR	10 day Survival; LC10	376.5	Vellinger et al. 2013[a]
Aquatic Plant / Algae							
Melosira granulata (Diatom)	Na_3AsO_4 (arsenate)	NR	20	NR	IC20/ LOEC (growth) (8 – 24 days)	75	Planas and Healey, 1978
Ochromonas vallesiaca (Algae)	Na_3AsO_4 (arsenate)	NR	20	NR	IC35/ LOEC (growth) (8 – 24 days)	75	Planas and Healey, 1978
Ankistrodesmus falcatus (Algae)	Disodium arsenate	7	24 +/- 2	-/-	14 day EC50 (growth)	256	Vocke et al, 1980
Scenedesmus obliquus (Green algae)	Disodium arsenate	7	24 +/- 2	-/-	14 day EC50 (growth)	48	Vocke et al, 1980

Scenedesmus subspicatus (Green algae)	Arsenic trioxide (As_2O_3)	NR	21+1	NR	72 hour EC10 (growth – biomass)	9400	Tisler and Zagorc-Koncan, 2002
Chlorella sp. (Algae)	As (III)	7.6	27	NR	72 IC50 growth	25,200	Levy et al, 2005
Chlorella sp. (Algae)	As (V)	7.6	27	NR	LOEC/72 h IC50 growth	1930/ 25400	Levy et al, 2005
Monoraphidium arcuatum (Algae)	As (III)	7.6	27	NR	LOEC/ 72 h IC50 growth	3750/ 14600	Levy et al, 2005
Monoraphidium arcuatum (Algae)	As(V)	7.6	27	NR	LOEC/ 72 h IC50 growth	81/254	Levy et al, 2005
Freshwater Fish and Amphibians							
Pimephales promelas (Fathead minnow)	Sodium arsenite (As III)	7.2 – 8.1	23 - 25	37 – 45/46 - 49	29 day post-fertilization (weight, length) NOEC	2130	Lima et al., 1984
Pimephales promelas	Sodium arsenite (As III)	7.2 – 8.1	23 - 25	37 – 45/46 - 49	29 day post-fertilization (weight, length) LOEC	4300	Lima et al., 1984
Pimephales promelas	Sodium arsenite (As III)	7.4	25 +/- 3	42.4/43.9	32 day (growth) MATC	3330	Spehar and Fiandt, 1986
Pimephales promelas	Arsenite (As III)	7.2	23 +/- 2.7	38/49.2	30 day post fertilization (growth) NOEC	2130	Call et al, 1983
Pimephales promelas	Arsenite (As III)	7.2	23 +/- 2.7	38/49.2	30 day post fertilization (growth) LOEC	4300	Call et al, 1983
Pimephales promelas	Sodium arsenate (As V)	6.7 - 7.8	25	- /45 - 48	30 day early life stage test ; growth; NOEC	530	DeFoe, 1982
Pimephales promelas	Sodium arsenate (As V)	6.7 - 7.8	25	- /45 - 48	30 day early life stage test ; growth; LOEC	1500	DeFoe, 1982
Rana pipiens (Northern leopard frog*)*	Arsenic V	7.9	22 - 23	170	113-day survival, growth, and metamorphosis NOEC	1000	Chen et al. 2009
Micropterus salmoides (Largemouth bass)	$NaAsO_2$	NR	NR	NR	28-day LC1	4601	Birge et al, 1978
Oncorhynchus kisutch (Coho salmon)	As_2O_3	8.2	3.8 – 13.8	88/ 69	6 month LOEC (juvenile migration)	300	Nichols et al, 1984
Oncorhynchus kisutch	As_2O_3	8.2	3.8 – 13.8	88/ 69	6 month NOEC (juvenile survival, growth)	300	Nichols et al, 1984
Oncorhynchus mykiss (Rainbow trout)	$NaAsO_2$	NR	NR	NR	28-day LC1	40	Birge et al, 1978
Oncorhynchus mykiss	Arsenic III	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day Survival; NOEC	961	Spehar et al, 1980

Oncorhynchus mykiss	Arsenic V	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day Survival; NOEC	973	Spehar et al, 1980
Oncorhynchus mykiss	$NaAsO_2$	7.4	13 +/- 0.5	-/104	28 day LC1	39.7	Birge, 1978
Oncorhynchus mykiss	$NaAsO_2$	7.4	13 +/- 0.5	-/104	28 day LC50	540	Birge, 1978
Oncorhynchus mykiss	Arsenic III (As_2O_3)	7.8	13.4	282/380	181-d growth LOEC 181-d growth NOEC 181-d threshold of chronic toxicity	9640 2480 4900	Rankin and Dixon, 1994

Notes:

T = temperature; NR = not reported

A Data generated by Canivet et al, 2001 and Vellinger et al, 2013 are included in Table A-2 for completeness, but are not considered for the SSD as a 10-day LC50 is not considered long enough to be classified as a chronic study

2.4 Arsenic SSD

Consistent with CCME (2007) guidance, a species sensitivity distribution (SSD) approach was used to derive a Type A guideline. The SSD approach was comprised of identifying chronic toxicity data for species relevant to the Beaver Dam Mine area, analyzing the data using a regression approach and selecting the final chronic effects benchmark. The HC5 (*i.e.*, the concentration that is hazardous to no more than 5% of a species in the community) was selected as the final chronic effects benchmark as per CCME (2007) guidance.

Further details of the approach are provided in the following sections.

2.4.2 SSD Modelling

Data for the aquatic community including freshwater fish, invertebrates, and aquatic vascular and non-vascular plants were used to develop a species sensitivity distribution for arsenic. SSD Master v3 (CCME, 2007) was used to fit four sigmoid-shaped (cumulative distribution function – CDF) models to the chronic toxicity values for freshwater species. SSD Master v3 was designed to facilitate the derivation and selection of appropriate SSD models for use in benchmark setting and risk assessment. The CCME currently uses this application in the development of Type A water quality guidelines for the protection of aquatic life. SSD Master v3 evaluates the data using four models including the Normal, Logistic, Extreme Value (Gompertz) and Gumbel (Fisher-Tippett) models (CCME, 2007). In arithmetic space the Weibull model is also available. The application is fully automated and Excel-based. SSD Master v3 uses the standard Excel Solver add-in to fit the CDF models. Solver proceeds through different combinations of model parameter values until the sum of square error term cannot be further minimized. The application automatically generates residual plots and goodness-of-fit, probability-probability (p-p) and quantile-quantile (q-q) plots, as well as plots of the SSDs and associated approximate confidence intervals.

As is evident in Table A-2, there were a number of test durations, endpoints, and effects reported in the arsenic freshwater toxicity studies. Based on guidance for a CCME WQGl - FWAL (CCME, 2007), the most sensitive endpoint (i.e., growth, reproduction, and mortality) based on appropriate standard test durations are preferred. For the development of a long-term WQGl - FWAL, growth and reproduction endpoints (non-lethal) are preferred. Ideally, the data used to generate the SSD would be regression based (ECx/LCx) for no to low toxic effects (e.g., EC<25). The preferred order of endpoints is: ECx/ICx representing a no-effects threshold >EC10/IC10 > EC11-25/IC11-25 > MATC > NOEC > LOEC> nonlethal EC26-49/IC26-49 > nonlethal EC50/IC50 (CCME, 2007).

In the case of arsenic, there is a varied dataset available with many endpoints and durations for numerous species (Table A-2). The most common endpoint available for most taxa is the no observed effect concentration (NOEC). This is not the preferred endpoint for WQGl - FWAL development as it typically has a significant amount of uncertainty associated with it. NOECs and LOECs are generally poor predictors of low toxic effects (Moore and Caux, 1997). However, there are sufficient NOECs to derive an SSD for the aquatic community using the

CCME WQGl Type A approach, based on the data available. The one exception is for aquatic plants. There are few aquatic plant studies available that are relevant and of acceptable quality. The available data report only LOECs, EC50 and EC10 data for growth (Table A-2), but all of these studies are of an acceptable duration to represent chronic exposures. While only LOECs, EC50 and EC10 data were available for use in the SSD modeling, the effects reported occurred at much lower concentration than were associated with no-effects in other studies, with the exception of the EC10 (growth – biomass) for *Scenedesmus subspicatus* of 9400µg/L (Tisler and Zagorc-Koncan, 2002). As such, all of these data with alternative endpoints (non – NOEC studies) were considered appropriate for use in the SSD modeling.

When deriving an SSD for an aquatic community, it is important to ensure that no one species over-weights the SSD due to its relative sensitivity/tolerance. In many datasets, standard test organisms (e.g., fathead minnow, *Daphna magna*) can bias the results due to the abundance of data for those species. Therefore, when multiple data were available for the same species, the geometric mean of these values was used to represent that species in the SSD. This calculation was required for *Daphnia magna*, *Pimphales promelas*, and *Ceriodaphnia dubia*.

Also, when arsenic III and V data were present for a single species, only the most sensitive dataset was entered into the SSD.

Table A-3 presents the dataset used in the generation of the SSD.

Certain studies had to be excluded, despite being of adequate quality, due to their duration, relative to chronic exposures. These include Canivet et al (2001) and Vellinger et al (2013), which only involved 10 day study durations. Due to the survival endpoint in these studies, and the species tested, a duration of > 21 days would be required for these data to be included in a chronic SSD (as per CCME protocols). Similarly, some of Spehar et al (1980) data for amphipods was of shorter duration (7 day to 14 day) and therefore had to be excluded.

Table A-3 Data Selected and Geometric Means for the same Species for the Species Sensitivity Distribution for Arsenic

Species	Chemical	Water Quality Parameters			Test Duration / Life Stage	Chronic Value (µg/L)	Geometric Mean Value (µg/L)	End Point	Reference	Rating
		pH	**T (°C)**	**Alkalinity / Hardness (mg/L; $CaCO_3$)**						
Aquatic Invertebrates										
Daphnia magna	Sodium arsenite (As III)	7.2 – 8.1	20.8	37 – 45/46 - 49	28 day survival; reproduction NOEC	633	631.5	NOEC	Lima et al., 1984	P
Daphnia magna	Arsenite (As III)	7.4	21.5 +/- 3	45.5/47.2	28 day (growth and reproduction) NOEC	630		NOEC	Call et al, 1983	P
Ceriodaphnia dubia	Specific form not stated; low UV radiation only reported	7.29 – 9.27	25	NR	24 day to 3rd generation NOEC brood size	1000	1224.7	NOEC	Hansen et al, 2002	S
Ceriodaphnia dubia	Specific form not stated; low UV radiation only reported	7.29 – 9.27	25	NR	24 day to 3rd generation survival NOEC	1500		NOEC	Hansen et al, 2002	S
Cyclops vernalis; C. bicuspidatus thomasi (Copepod)	Sodium arsenite (As III)	7.6 - 8.8	15	88 / 139	14 day EC20	320		EC20	Borgmann et al., 1980	S
H. campanulate (snail)	As^{3+}	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC5 (LOEC)	960		LOEC	Spehar et al, 1980	P
S. emarginata (snail)	As^{3+}	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day LC0 (NOEC)	960		LOEC	Spehar et al, 1980	P
Pteronarcys dorstata	Arsenic III	6.9 – 7.3	14 - 16	40 – 44/42 - 45	28 day Survival; NOEC	961		NOEC	Spehar et al, 1980	P
Aquatic Plants										
Ankistrodesmus falcatus (Algae)	Disodium arsenate	7	24 +/- 2	-/-	14 day EC50 (growth)	256		EC50	Vocke et al, 1980	P

Species	Chemical	Water Quality Parameters			Test Duration / Life Stage	Chronic Value (µg/L)	Geometric Mean Value (µg/L)	End Point	Reference	Rating
		pH	T (ºC)	Alkalinity / Hardness (mg/L; $CaCO_3$)						
Chlorella sp. (Algae)	As (V)	7.6	27	NR	LOEC/72 h IC50 growth	1930		LOEC	Levy et al, 2005	S
Monoraphidium Arcuatum (Algae)	As(V)	7.6	27	NR	LOEC/ 72 h IC50 growth	81		LOEC	Levy et al, 2005	S
Scenedesmus obliquus (Green algae)	Disodium arsenate	7	24 +/- 2	-/-	14 day EC50 (growth)	48		EC50	Vocke et al, 1980	P
Scenedesmus subspicatus (Green algae)	Arsenic trioxide (As_2O_3)	NR	21+1	NR	72 hour EC10 (growth – biomass)	9400	9400	EC10	Tisler and Zagorc-Koncan, 2002	P
Melosira granulata	Na_3AsO_4 (arsenate)	NR	20	NR	LOEC (growth) (8 – 24 days)	75	75	LOEC	Planas and Healey, 1978	S
Ochromonas vallesiaca	Na_3AsO_4 (arsenate)	NR	20	NR	LOEC (growth) (8 – 24 days)	75	75	LOEC	Planas and Healey, 1978	S
Freshwater Fish and Amphibians										
Pimephales promelas	Sodium arsenite	7.2 – 8.1	23 - 25	37 – 45/46 - 49	29 day post-fertilization (weight and length) NOEC	2130	1339.7	NOEC	Lima et al., 1984	P
Pimephales promelas	Arsenite	7.2	23 +/- 2.7	38/49.2	30 day post fertilization (growth) NOEC	2130		NOEC	Call et al, 1983	P
Pimephales promelas	Sodium arsenate	6.7 - 7.8	25	- /45 - 48	30 day early life stage test ; growth; NOEC	530		NOEC	DeFoe, 1982	S
Oncorhynchus kisutch	As_2O_3	8.2	3.8 – 13.8	88/ 69	6 month survival and growth (juvenile): NOEC	300		NOEC	Nichols et al, 1984	P
Oncorhynchus mykiss	Arsenic III	7.8	13.4	282/380	181-d growth NOEC	2480		NOEC	Rankin and Dixon, 1994	P

Species	Chemical	Water Quality Parameters			Test Duration / Life Stage	Chronic Value (µg/L)	Geometric Mean Value (µg/L)	End Point	Reference	Rating
		pH	T (ºC)	Alkalinity / Hardness (mg/L; $CaCO_3$)						
Rana pipiens (Northern leopard frog)	Arsenic V	7.9	22 - 23	170	113-day survival, growth, and metamorphosis NOEC	1000		NOEC	Chen et al. 2009	S

2.4.3 SSD Results

Table A-4 presents the data selected to model the SSD and the associated plotting positions in the graph.

Table A-4 Data Selected for the Species Sensitivity Distribution and Associated Plotting Positions

Taxon Grouping	Species	Concentration (µg/L)	Log Concentration	Plotting Position	Species Number
Plant	*Scenedesmus obliquus*	48	1.681241237	0.03	1
Plant	*Melosira granulata*	75	1.875061263	0.08	2
Plant	*Ochromonas vallesiaca*	75	1.875061263	0.14	3
Plant	*M.arcuatum*	81	1.908485019	0.19	4
Plant	*Ankistrodesmus falcatus*	256	2.408239965	0.25	5
Fish	*Oncorhynchus kisutch*	300	2.477121255	0.31	6
Invertebrate	*Cyclops vernalis; C. bicuspidatusthomasi*	320	2.505149978	0.36	7
Invertebrate	*Gammarus pulex*	376.5	2.575764981	0.42	8
Invertebrate	*Daphnia magna*	631.5	2.800373355	0.47	9
Invertebrate	*H. campanulate*	960	2.982271233	0.53	10
Invertebrate	*S. emarginata*	960	2.982271233	0.58	11
Invertebrate	*Pteronarcys dorstata*	961	2.982723388	0.64	12
Amphibian_Reptile	*rana pipens*	1000	3	0.69	13
Invertebrate	*Ceriodaphnia dubia*	1224.7	3.088029718	0.75	14
Fish	*Pimephales promelas*	1339.7	3.127007557	0.81	15
Plant	*Chlorella*	1930	3.285557309	0.86	16
Fish	*Oncorhynchus mykiss*	2480	3.394451681	0.92	17
Plant	*Scenedesmus subspicatus*	9400	3.973127854	0.97	18

Overall, the extreme value distribution provided the best overall fit for the generation of an SSD for the aquatic community according to the Anderson-Darling (AD) goodness-of-fit test statistic (AD statistic = 0.440, $p > 0.05$) and the Mean Square Error in the Lower Tail (MSE lower tail: 0.0286). However, for the purposes of the SSWQO, the fit of the distribution around the HC5 value in the lower tail is of greater importance. Visual inspection of the curve (Figure A-1) indicates that the extreme value model does not represent the data in the lower tail as well as the normal model, which comes much closer to the lowest value in the dataset (48 µg/L for *Scenedesmus obliquus*) (Figure A-2). Comparison of the confidence limits around the HC5 values for the extreme value and normal distributions indicates that the confidence limits around the HC5 of the extreme value distribution (lower confidence limit = 17.56 µg/L; upper confidence limit = 48.87 µg/L; HC5 = 29.29 µg/L) is also wider than that for the normal distribution (lower confidence limit = 41.94 µg/L; upper confidence limit = 68.38 µg/L; HC5 = 53.55 µg/L). A summary of the model results is presented in Table A-5 for comparison purposes. Therefore, based on overall fit, the extreme value distribution provides a better fitting model; however, based on the fit at the lower tail of the distribution, the normal distribution provides a better fitting model and as such, likely provides a more realistic prediction of the HC5. To be conservative however, the HC5 from the extreme value model was selected for use as it provides a lower HC5 (selected extreme value model HC5 is 29.29 µg/L; rounded to 30 µg/L).

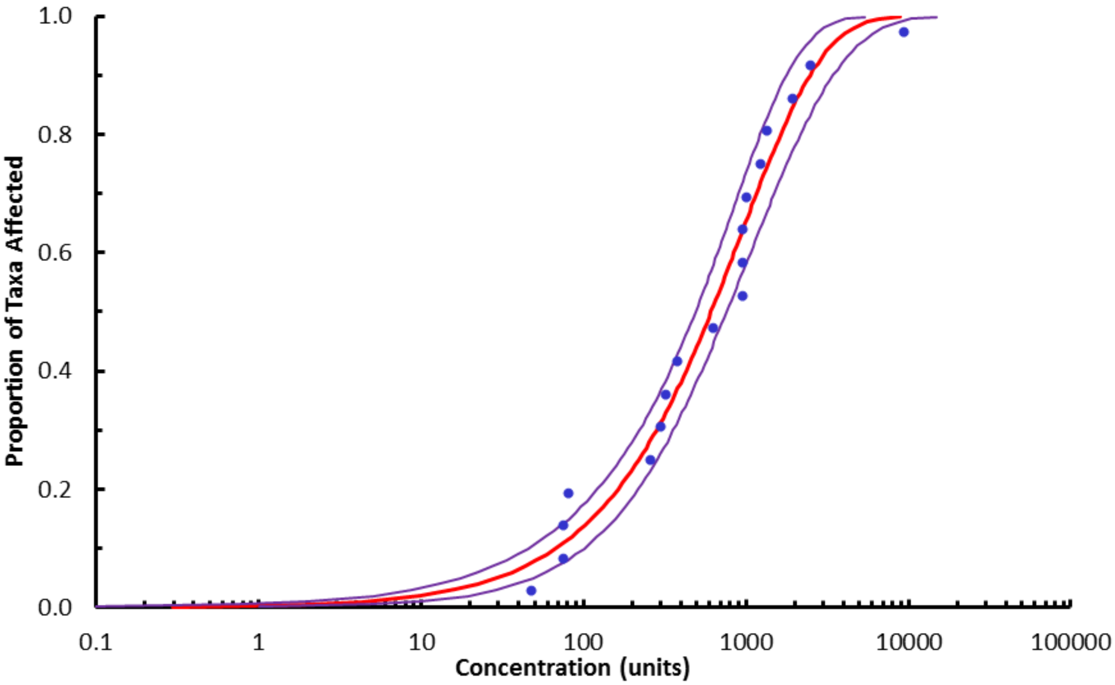

Figure A-1 SSD Based on the Sensitivity of the Freshwater Aquatic Community to Arsenic using the Extreme Value Model

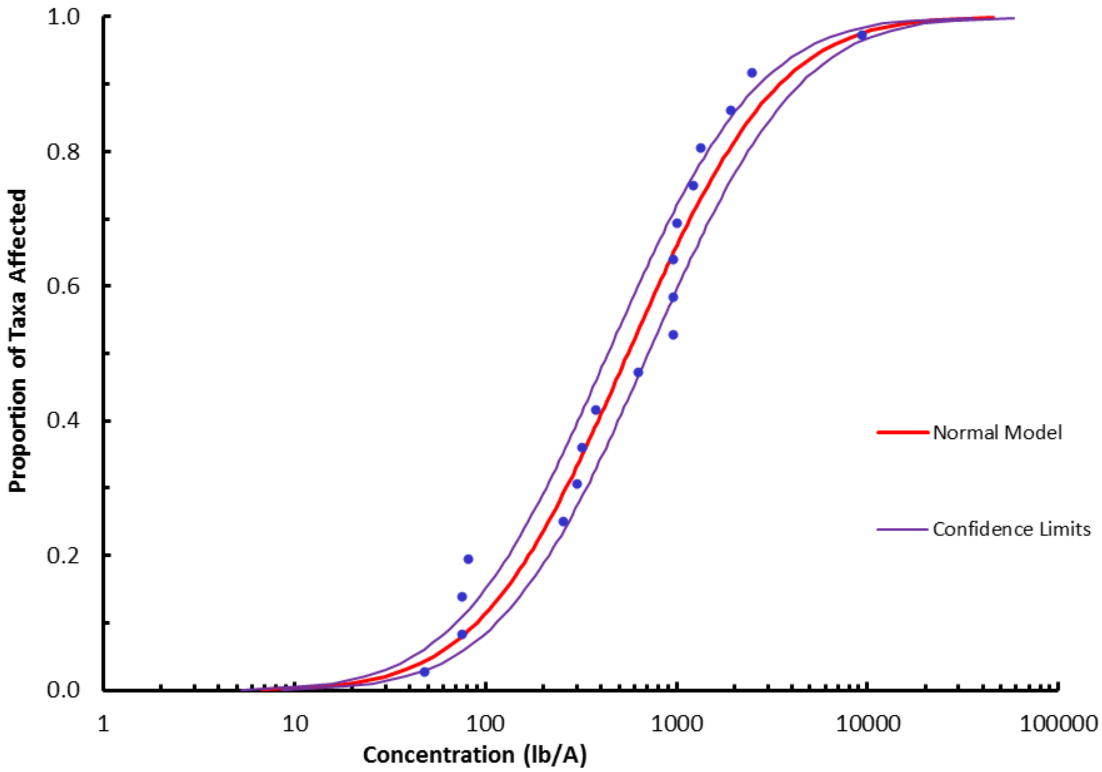

Figure A-2 SSD Based on the Sensitivity of the Freshwater Aquatic Community to Arsenic using the Normal Model

Table A-5 Comparison of Goodness of Fit Statistics and Model Results (HC5 in µg/L) based on the results from SSD Master v3

Result	**Normal**	**Logistic**	**Extreme Value**	**Gumbel**
MSE	0.0035	0.0034	0.0025	0.0057
MSE Lower Tail	0.0368	0.0353	0.0286	0.0554
Data from specified distribution? Anderson-Darling (n>5)	Yes	Yes	Yes	Yes
Anderson-Darling Statistic (A^2)	0.417	0.404	0.440	0.789
HC50 (µg/L)	558.376	565.929	610.058	514.600
HC5 (µg/L)	53.55	45.93	29.29	76.32
Lower confidence limit on the mean (expected HC5)	41.94	31.86	17.56	46.50
Upper confidence limit on the mean (expected HC5)	68.38	66.22	48.87	125.27

The equation for the extreme value model is:

$$f(x) = 1 - e^{-e^{(X-\mu)/S}}$$

Where, *f(x)* = proportion of taxa affected;

x = concentration metameter;

μ = location parameter; and

s = scale parameter (always positive).

The fitted model parameters were: *μ* = 2.97 and *s* = 0.506 for the toxicity dataset used in µg/L. The HC5 (concentration that will affect 5% of species in the SSD) was 29.29 µg/L with an approximate lower confidence limit (LCL) of 17.56 µg/L and upper confidence limit (UCL) of 48.87 µg/L.

2.4.4 Proposed SSWQO for Arsenic

The HC5 value of **30 µg/L** (29.29 µg/L rounded upwards) is proposed as the SSWQO for arsenic at the Beaver Dam Mine Area.

While this HC5 value is above the CCME WQGl-FWAL of 5 µg/L (2001), it is more conservative than the toxicity endpoint upon which the CCME WQGl-FWAL is based (i.e., 14-day EC50 (growth) of 48 µg/L for the algae *Scenedesmus obliquus* (Vocke et al., 1980), which was the most sensitive freshwater organism to arsenic identified).

This proposed SSWQO for arsenic is less than the U.S. EPA (1995) CCC for arsenic of 150 µg/L based on dissolved concentrations.

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ATLANTIC GOLD

Appendix G.5

Water Balance Analysis
Beaver Dam Mine Site

Water Balance Analysis

Beaver Dam Mine Site

Atlantic Gold Corporation

GHD | 455 Phillip Street Waterloo Ontario N2L 3X2 Canada | 088664 | Report No 12 | February 22 2019

Table of Contents

Figure Index

Table Index

1. Introduction

GHD Limited (GHD) was retained by Atlantic Gold Corporation (AGC) to develop a Mine Water Management Plan (MWMP) for the Beaver Dam Gold Mine (Project) in Marinette, Halifax County, Nova Scotia (Site). The MWMP is in support of the Environmental Impact Statement (EIS). As part of the MWMP, GHD has completed a water balance analysis for three life-cycle stages of mine development including baseline, End-of-Mine (EOM), and Post-Closure (PC) stages. Each life-cycle is compared to the baseline stage to predict the changes to annual runoff to each of the Site discharge points. The methodology and results for the water balance analysis are presented in this memorandum.

2. Background

The proposed Project Site comprises approximately 145 hectares (ha) of lakes, rivers, and forested land that is in varying degrees of re-growth due to historical logging. The Project is part of the Moose River Consolidated (MRC) Project, which includes the existing and fully permitted Touquoy Gold Project, located nearby in Moose River Gold Mines, Nova Scotia. The Project will operate as a satellite surface mine to the MRC Project, and the ore that is mined from the Project Site will be processed at the existing Touquoy plant. The Project is anticipated to begin construction in 2021, come into production in 2022, cease operations in 2026, and then be reclaimed.

The Project's MWMP aims to mitigate the operational risks and environmental impacts of the Project on the receiving environment. The objective of the water balance analysis is to assess the short and long-term impacts of the Project on the receiving environment. Monthly and annual total runoff volumes are compared between the three mine life-cycle stages (baseline, EOM and PC) at three discharge points including Mud Lake, Tent Lake, and the Killag River. In addition, a long-term water balance analysis is performed for the open pit mine to determine the time required for the pit to fill with water as part of the Project's proposed reclamation plan.

2.1 Data Collection

The following sections discuss the datasets that were collected to facilitate the water balance analysis.

2.1.1 Topographic Data

Contour datasets were used to delineate the subcatchment areas for the Project Site and its upstream contributing drainage area.

A Nova Scotia Department of Natural Resources (Forestry Division) hydrologically-corrected 20 m digital elevation model (DEM) was used to generate contours for the off-Site/upstream portion of the contributing drainage area for baseline, EOM, and PC conditions. High-resolution Light Detection and Ranging (LiDAR) data was collected for the Project Site by Leading Edge Geomatics by contract to

GHD in 2015. The LiDAR data was used to generate on-site contours for baseline conditions. In addition, proposed contours were developed to represent the topography of the proposed mine features and used to delineate on-site subcatchment areas for EOM and PC conditions.

2.1.2 Climate Data

Average daily temperature values and daily precipitation totals were obtained from the Environment Canada Middle Musquodoboit Climate Station (Climate ID 8203535) from 1961 to 2017. The station was selected based on its proximity to the Project Site, and relatively long and current record. Total monthly precipitation and monthly average temperatures were derived from the daily records and used in the analysis.

Monthly lake evaporation normals were obtained from the Environment Canada Truro Station (Climate ID 8205990). The Truro station is the closest climate station to the Project Site that collects lake evaporation data. Monthly potential evapotranspiration normals were calculated using the Hamon equation (1961). The Hamon equation requires monthly average hours of daylight and monthly average temperature as input. Monthly average hours of daylight were calculated for Halifax, Nova Scotia using the Sunrise and Sunset Calculator (https://www.timeanddate.com/sun/, last accessed 6 November 2018). Monthly average temperature values were obtained from the Environment Canada Middle Musquodoboit Station.

Table 2-1 presents total precipitation, average temperature, lake evaporation, and potential evapotranspiration values that are used in the analysis.

Table 2-1 Climate Normals (Data taken from Middle Musquodoboit and Truro Environment Canada Climate Stations)

	January	February	March	April	May	June	July	August	September	October	November	December
Temperature[1] (°C)	-6.0	-5.6	-1.3	4.1	9.8	14.8	18.5	18.3	14.0	8.5	3.6	-2.4
Precipitation[1] (mm)	127.4	101.2	124.5	105.9	102.4	95.7	96.8	98.6	99.9	124.2	135.8	138.2
Lake Evaporation[2] (mm/day)	0.0	0.0	0.0	0.0	2.9	3.4	3.8	3.1	2.3	1.3	0.0	0.0
PET[3] (mm/day)	0.0	0.0	0.0	1.1	1.9	2.9	3.5	2.9	1.8	1.0	0.5	0.0

Notes:

1. Values obtained from the Middle Musquodoboit climate station 8203535
2. Values obtained from the Truro climate station 8205990
3. Potential Evapotranspiration was calculated using the Hamon equaton (1961)

2.1.3 Groundwater Inflows

Groundwater inflow to the open pit mine was obtained from the GHD groundwater model for the Project Site (GHD, 2018). A peak groundwater inflow rate of 636 m^3/day is used in this analysis.

3. Methodology

GHD developed a predictive water balance model (WBM) to assess the environmental impacts of the proposed Project from baseline to EOM and PC conditions. The WBM was developed using the GoldSim software. GoldSim is a highly graphical program used for carrying out dynamic, probabilistic simulations to support decision making (https://www.goldsim.com/Web/Home/, last accessed 20 November 2018). GoldSim is especially well-suited to simulating dynamic, computationally intensive, but well-defined network models such as a water balance. GoldSim permits inputs to be entered as probability distributions, performs Monte Carlo simulations, tracks outputs from those simulations, and provides a graphic interface to facilitate the review and identification of interactions between system components.

The WBM was developed to utilize climate inputs at a daily time-step; allowing the results to be summarized at a daily, monthly or annual time step. The WBM was computed for the three mine life cycles (baseline, EOM and PC) at three discharge locations (Killag River, Mud Lake and Tent Lake).

3.1 Climate Data Inputs

Mine water balances model the interactions between site processes, climate inputs, and hydrologic responses. In order to capture uncertain hydrologic processes, climate input parameters are modelled stochastically. The use of stochastic climate inputs allows the user to make informed decisions regarding mine water management during the operational stage of the mine. At this point in time water demands are expected to be minimal during mine operation; however, this model has been constructed in a way to allow for it to be easily updated during operations to support decision making and ensure proper water management.

Average daily temperature and total daily precipitation are modelled stochastically. Temperature data is included in the WBM to partition precipitation into rainfall and snowfall, and to simulate the snowmelt process. Precipitation data is included in the WBM as a key water balance input. Average daily temperatures are modelled using a normal distribution.

Monthly precipitation totals are calculated from the Middle Musquodoboit Climate Station daily precipitation record for 41-years including 1968 – 2005, 2009, 2014 and 2016. The years that have a significant amount of missing data are excluded from the analysis. Monthly precipitation totals are represented by lognormal distributions for each month of the year. The Kolmogorov-Smirnov test was performed to assess the fit of the lognormal distribution to the monthly precipitation totals. The null hypothesis is that the observed and simulated precipitation datasets have the same underlying distribution. The results show that the null hypothesis is accepted at the 5% level of significance for all twelve monthly distributions; therefore, the lognormal distribution can be used to accurately represent monthly precipitation totals in the WBM. Rainfall occurrence is modelled using a second order Markov Chain. Monthly precipitation totals are sampled from the probability distributions on wet days, and are divided by the number of days per month and the fraction of wet days per month to calculate daily precipitation totals.

Lake evaporation and potential evapotranspiration normals are input as constant and discrete values to the WBM.

3.2 Modelling Hydrological Processes

This section describes the hydrological processes represented in the WBM including rainfall and snowmelt generation, and rainfall-runoff modelling.

3.2.1 Rainfall and Snowmelt Generation

Daily precipitation totals are partitioned into rainfall and snowfall based on the average daily temperature simulated by the WBM. Precipitation occurring on a day in which the average daily temperature is less than 0 degrees Celsius is modelled as snowfall. Precipitation occurring on a day in which the average daily temperature is equal to or greater than 0 degrees Celsius is modelled as rainfall.

When snowfall occurs it accumulates into a ‘snowpack’ that is modelled as a storage element in the WBM. The input to the snowpack is snowfall, and output from the snowpack is snowmelt. Snowmelt occurs when the average daily temperature is greater than 0 degrees Celsius, and it is calculated using the degree-day method (USDA, 2004).

3.2.2 Rainfall-Runoff Modelling

The Australian water balance model (AWBM) is used to calculate runoff depths from rainfall/snowmelt for all natural subcatchment areas at a daily time step (Boughton, 2004).

The AWBM calculates runoff based on the ‘surplus’ of rainfall/snowmelt from the soil storage element, after it has reached its storage capacity or ‘available water capacity’. Rainfall and snowmelt are added to the soil storage element as inputs, and potential evapotranspiration is subtracted from the soil storage element as the output. Actual evapotranspiration is equal to potential evapotranspiration when there is sufficient water within the soil storage element to meet the evapotranspiration/energy demand. Otherwise, actual evapotranspiration is equal to the depth of water available within the storage element. Surplus is equal to the overflow rate from the soil storage element, after the available water capacity is exceeded. An available water capacity of 150 millimetres (mm) is selected for this study based on the Water Balance Report for the Touquoy Project Site (Stantec, 2016), and A Monthly Water-Balance Model Driven by a Graphical User Interface (USGS, 2007).

Surplus is partitioned into surface runoff and baseflow recharge using a baseflow index (BFI). A BFI of 0.23 was determined for the Project Site from the groundwater assessment. The BFI represents the fraction of surplus that recharges the baseflow storage element, and (1-BFI) represents the fraction of the surplus that discharges as surface runoff. Baseflow is calculated using the baseflow recession constant (Kb). A recession constant of 0.98 was calculated as part of the groundwater assessment for the Project Site. Baseflow is equal to (1-Kb) multiplied by the available water within the baseflow storage element at a daily time step. Total runoff from the natural subcatchment areas is calculated as the sum of surface runoff and baseflow runoff at a daily time step.

For the areas of proposed development at the Project Site, evaporation and runoff are calculated as percentages of the daily rainfall/snowmelt. The percentages are constant values that were determined from field observations at the Touquoy Project Site for the EOM and PC life-cycle stages, provided by Stantec (pers. Comm., 2018). It is assumed that these percentages can be applied to the Beaver Dam Project Site based on its proximity and similar material to the Touquoy Project Site.

Stockpile seepage also contributes to the total runoff from the developed areas of the Project Site. Seepage rates are calculated based on the difference between the infiltration percentage to the stockpile and the sum of the groundwater recharge percentage and the absorption percentage of the stockpile material. The groundwater recharge percentage for the stockpiles is set equal that of the natural area surrounding the Project Site, which experiences approximately 23% infiltration into the groundwater system on an annual basis (GHD, 2019). The volume of water that is absorbed by the stockpile is determined based on an estimated 20-year time-to-saturation of the stockpiles, provided by Stantec (pers. comm, 2018), and the field capacities of the stockpile materials.

Field capacity is defined as the water content of the soil when the water in the pore spaces of a soil begins to drain. A field capacity of 0.004 is selected for the waste rock material, which is equivalent to the field capacity of gravel (Zhan et al,. 2016). A field capacity of 0.19 is selected for till, which is equivalent to the field capacity of sandy loam, the predominate soil in the area (Rawls et al., 1983). Based on assumed field capacities of 0.004 and 0.19 for waste rock/ore and till, respectively, and the 20-year time-to-saturation of the stockpiles, it is determined that approximately 0.4% of the total rainfall/snowmelt will remain in the waste rock and ore stockpiles, and 14% of total rainfall/snowmelt will remain in the till stockpile. Water that is unable to infiltrate into the groundwater system or be absorbed by the stockpile material will discharge from the stockpiles as seepage. Due to the slow movement of water through the stockpile, the seepage discharge rate from the stockpiles is assumed to be lagged by one month. Thus, the percentage of rainfall/snowmelt that is stockpile seepage is equal to the difference between the previous month's infiltration percentage and the sum of stockpile absorption and groundwater recharge percentages. Daily average seepage rates were calculated outside of the WBM, and used as input to the model as a monthly time series.

Table 3-1 provides a summary of the percentages of the daily rainfall/snowmelt applied to the stockpile areas in the WBM to calculate evaporation, infiltration, absorption, seepage, and runoff.

Table 3-1 Infiltration, Runoff and Evaporation Percentages of Daily Rainfall

Stockpile Type	Infiltration Parameters				Surface Runoff (%)	Evaporation (%)
	Infiltration (%)	Recharge (%)	Absorption (%)	Seepage (%)		
Waste Rock, EOM[1]	90.0%	23.0%	0.4%	66.6%	5.0%	5.0%
Waste Rock, PC[2]	42.5%	23.0%	0.4%	19.1%	22.5%	35.0%
Till Pile, EOM	16.0%	23.0%	14.0%	0%	49.0%	35.0%
Till Pile, PC	16.0%	23.0%	0%	0%	49.0%	35.0%
Ore Pile, EOM	90.0%	23.0%	0.4%	66.6%	5.0%	5.0%
Ore Pile, PC	42.5%	23.0%	0.4%	19.1%	22.5%	35.0%

Notes:

[1] EOM – End of mine

[2] PC – Post-closure

Figure 3-1 and Figure 3-2 shows how the rainfall-runoff modelling process is represented in the WBM. Figure 3-1 shows the inputs to and outputs from the soil storage element in units of depth per time. The inputs are rainfall and snowmelt, and the outputs are actual evapotranspiration and surplus. The hydrology calculations shown on Figure 3-1 are consistent between existing, EOM, and PC conditions.

All subsequent hydrology calculations are specific to the mine life-cycle stage. Figure 3-2 presents the hydrology calculations for operating conditions as an example. The surplus from the soil storage element is multiplied by the respective catchment area, and partitioned into surface runoff and baseflow runoff in units of volume per time. Additional runoff contributions from the developed areas include direct runoff from impervious surfaces, stockpile seepage, and discharge from the mine pit and settling ponds.

Figure 3-3 shows the daily output from the WBM for Mud Lake under EOM conditions. The baseflow runoff, surface runoff, and total runoff are presented for the duration of the EOM life-cycle stage.

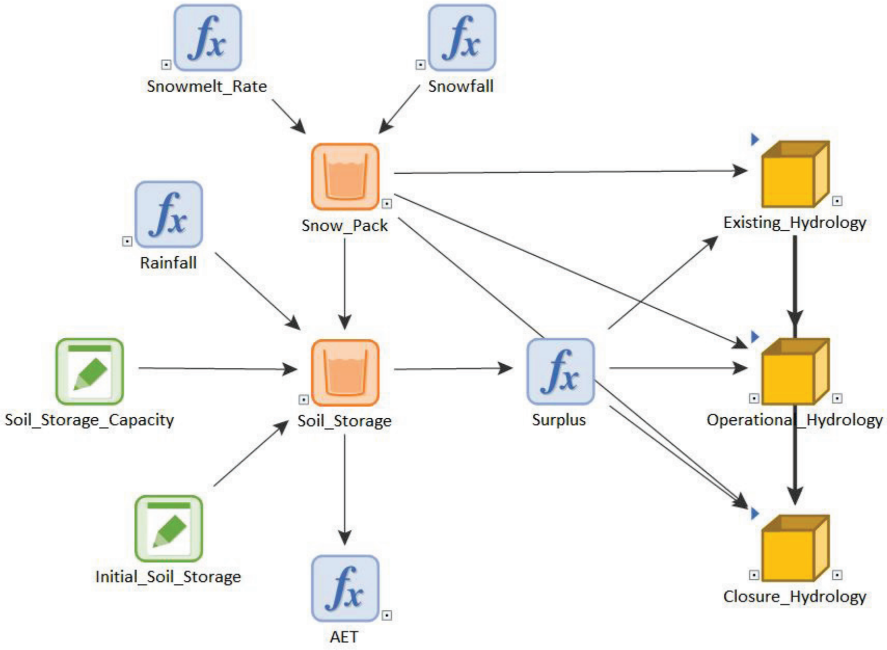


Figure 3-1 GoldSim Rainfall-Runoff Model Diagram

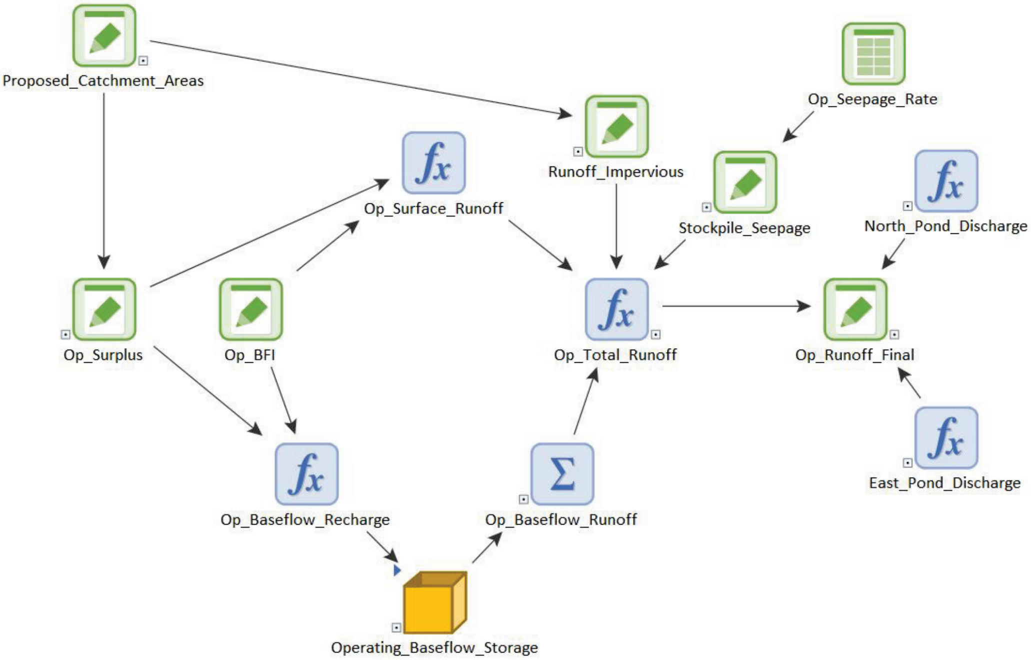


Figure 3-2 GoldSim End-of-Mine Hydrology Diagram

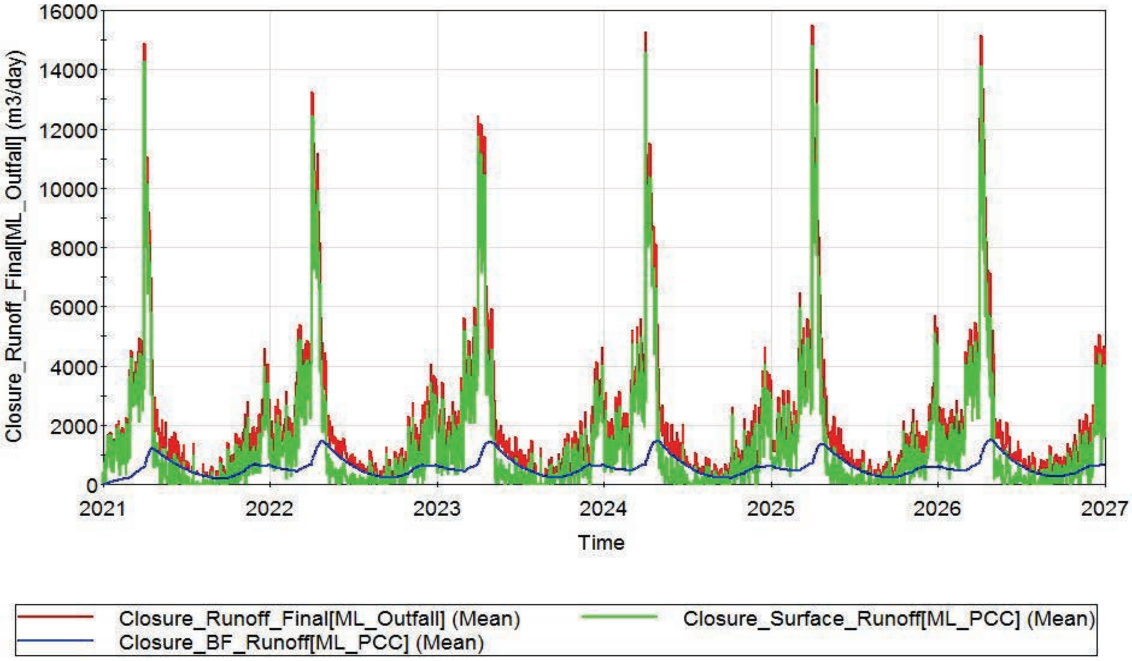


Figure 3-3 Daily Output - Runoff to Mud Lake during Post-Closure Conditions

3.2.3 Modelling Project Site Elements

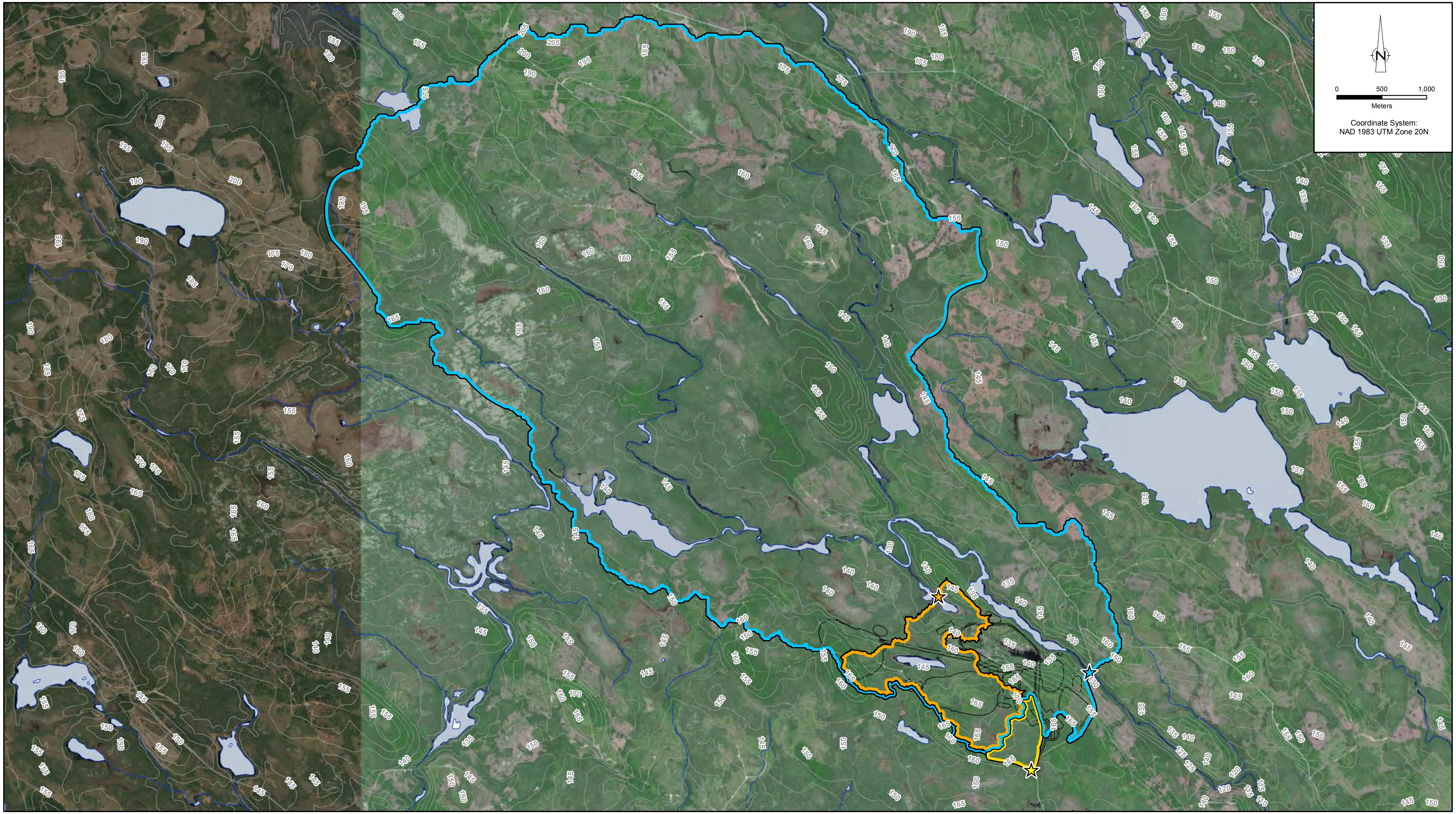
This section describes the interaction between the hydrology and mine features under baseline, EOM, and PC conditions. Runoff volumes are calculated at the Project Site outfalls to the Killag River, Mud Lake (including Crusher Lake) and Tent Lake.

Baseline Conditions

The subcatchment areas and outfall locations of the Project Site under baseline conditions are presented on Figure 3-4 and Figure 3-5. The Project Site discharges to two outfalls including the Killag River and Tent Lake. The contributing drainage area to the Project Site outfall to the Killag River (herein referred to as the Killag River outfall) encompasses the Mud Lake subcatchment areas. All subcatchment areas are natural with lakes, wetlands, and forested land cover.

End-of-Mine Conditions

The subcatchment areas and outfall locations of the Project Site under operating conditions are presented on Figure 3-6. The Project Site discharges to the Killag River and Tent Lake outfalls. The contributing drainage area to the Killag River outfall encompasses the Mud Lake (including Crusher Lake), Till Stockpile, and North Settling Pond subcatchment areas. The Mud Lake and Crusher Lake catchment areas experience the largest reduction in subcatchment area between baseline and EOM due to the construction of the waste rock stockpile, 43% and 52% respectively. The contributing drainage area to Tent Lake encompasses the East Collection Pond subcatchment area that represents the proposed crusher pad and is increased from baseline condition by 28.7%.



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Drainage Areas

- 🟦 Contributing Area to Killag River (~3871.7 ha)
- 🟧 Contributing Area to Mud Lake(~166.3 ha)
- 🟨 Contributing Area to Tent Lake (~28.4 ha)

Outlets

- ★ Killag River
- ★ Mud Lake
- ★ Tent Lake

☐ Proposed Mine Footprint

— Contours (5m)

NOTES:

1. Mud Lake and Tent Lake Contributing Areas derived from LiDAR measurements supplied by Leading Edge Geomatics, 2015.
2. Killag River Contributing Area derived from a combination of LiDAR measurements, Nova Scotia Department of Natural Resources (Forestry Division) hydrologically-corrected 20m DEM, and interpretations from satellite imagery and topographic maps.

ATLANTIC MINING NS CORP
BEAVER DAM MINE
SURFACE WATER MANAGEMENT PLAN
WATER BALANCE ANALYSIS

BASELINE WATER BALANCE - CONTRIBUTING DRAINAGE AREAS

FIGURE 3-4

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Jan 17, 2019

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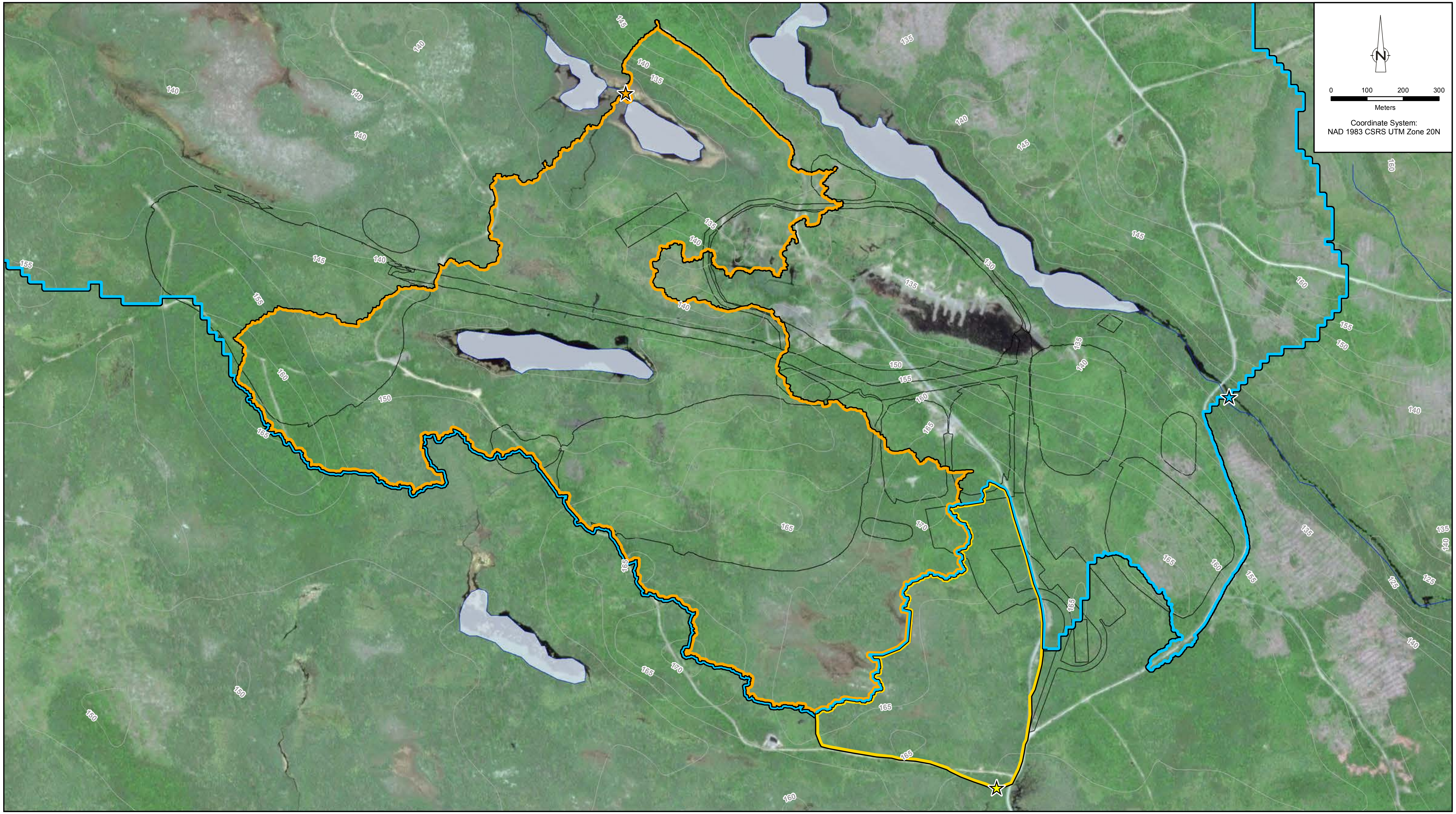

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Drainage Areas

🟦	Contributing Area to Killag River (~3871.7 ha)
🟧	Contributing Area to Mud Lake(~166.3 ha)
🟨	Contributing Area to Tent Lake (~28.4 ha)

Outlets

★	Killag River
★	Mud Lake
★	Tent Lake

☐	Proposed Mine Footprint
—	Contours (5m)

NOTES:

1. Mud Lake and Tent Lake Contributing Areas derived from LiDAR measurements supplied by Leading Edge Geomatics, 2015.
2. Killag River Contributing Area derived from a combination of LiDAR measurements, Nova Scotia Department of Natural Resources (Forestry Division) hydrologically-corrected 20m DEM, and interpretations from satellite imagery and topographic maps.

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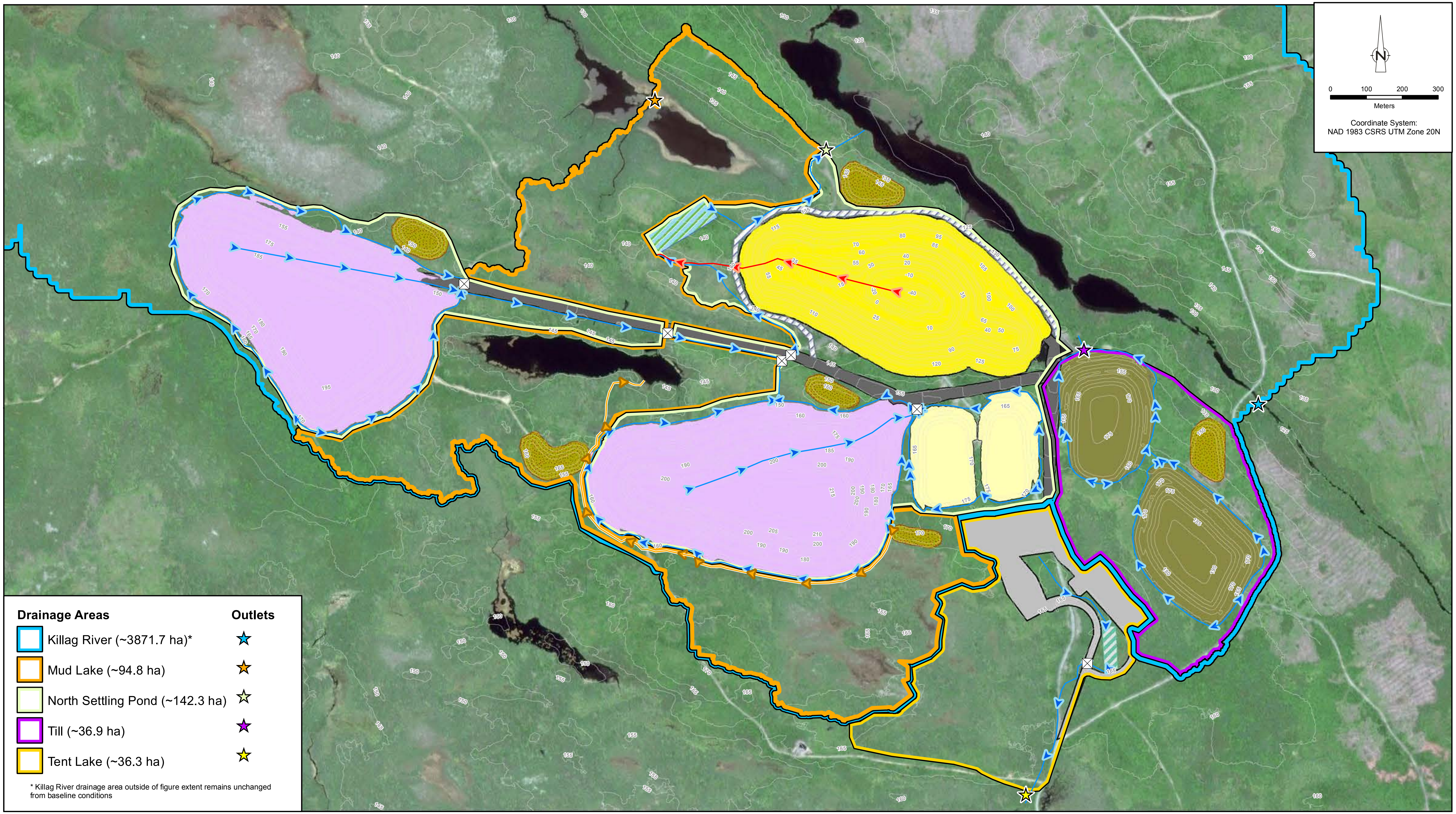
BEAVER DAM MINE
SURFACE WATER MANAGEMENT PLAN
WATER BALANCE ANALYSIS
BASELINE WATER BALANCE - CONTRIBUTING DRAINAGE AREAS
(DETAILED VIEW)

088664-27
Jan 17, 2019

FIGURE 3-5

GIS File: Q:\GIS\PROJECTS\88000s\88664\Layouts\012\088664-27(012)GIS-WA002.mxd



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Imagery: Image ©2019 DigitalGlobe, ©2019 Google, Imagery date: 18/6/2012

NOTES:
1. Mud Lake and Tent Lake Contributing Areas derived from LiDAR measurements supplied by Leading Edge Geomatics, 2015.
2. Killag River Contributing Area derived from a combination of LiDAR measurements, Nova Scotia Department of Natural Resources (Forestry Division) hydrologically-corrected 20m DEM, and interpretations from satellite imagery and topographic maps.

➤	Pumping Path	▨	Berm	■	Haul Road
➤	Stockpile Ditch	▨	Soil Stockpile	■	Low Grade Ore Stockpile
➤	SWM Ditch	▨	Settling Pond	■	Crusher Pad
—	Contours (5m)	▨	Collection Pond	■	Till Stockpile
☒	Culvert	■	Open Pit	■	Waste Rock Stockpile

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BEAVER DAM MINE
SURFACE WATER MANAGEMENT PLAN
WATER BALANCE ANALYSIS

CONTRIBUTING DRAINAGE AREAS – EOM CONDITIONS

088664-27
Feb 22, 2019

FIGURE 3-6

GIS File: Q:\GIS\PROJECTS\88000s\88664\Layouts\012\088664-27(012)GIS-WA003.mxd

Runoff from the North Settling Pond subcatchment area is routed through the North Settling Pond storage element. Inputs to the North Settling Pond storage element include pumped water from the open Mine Pit, and runoff from the North Settling Pond subcatchment area, which includes the waste rock stockpiles, ore stockpile, and a portion of haul road. Output from the North Pond includes overflow from the North Settling Pond storage element. The North Settling Pond storage element has a permanent pool capacity of approximately 7,500 m^3 and an active storage capacity of approximately 6,600 m^3. Overflow from the North Settling Pond storage element is directed to the Killag River outfall.

Runoff from the East Collection Pond subcatchment area is routed through the East Collection Pond storage element. Inputs to the East Collection Pond storage element include runoff from the East Collection Pond subcatchment area, which encompasses the crusher pad and a portion haul road. Output from the East Collection Pond storage element includes the overflow volumes. The East Collection Pond storage element has a permanent pool capacity of approximately 1,300 m^3 and an active storage capacity of approximately 500 m^3. Overflow from the East Collection Pond storage element is directed to the Tent Lake outfall.

The Mine Pit is located within the Killag River contributing drainage area, and it has a proposed maximum footprint of 28.4 ha. The area within the berm surrounding the Mine Pit is 35 ha. The Mine Pit is represented by a storage element in the WBM. Inputs to the Mine Pit storage element include groundwater inflows and direct precipitation. Outputs from the Mine Pit storage element include lake evaporation and pumped water to the North Settling Pond. The pumping rate from the Mine Pit to the North Settling Pond is set equal to the difference between the inputs to and outputs from the Mine Pit storage element.

Figure 3-7 shows how the Mine Pit storage element is represented in the WBM.

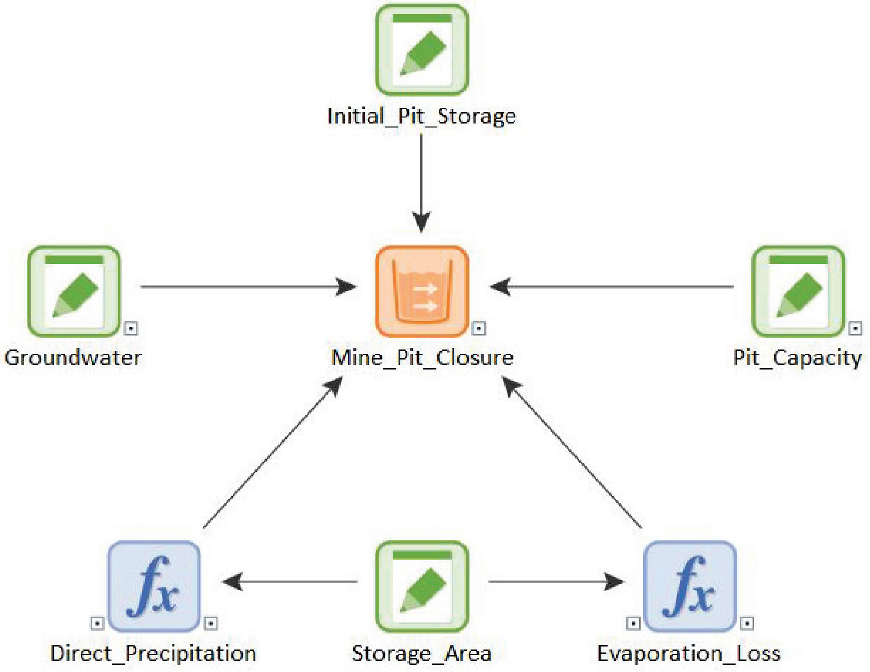


Figure 3-7 GoldSim Mine Pit Storage Element

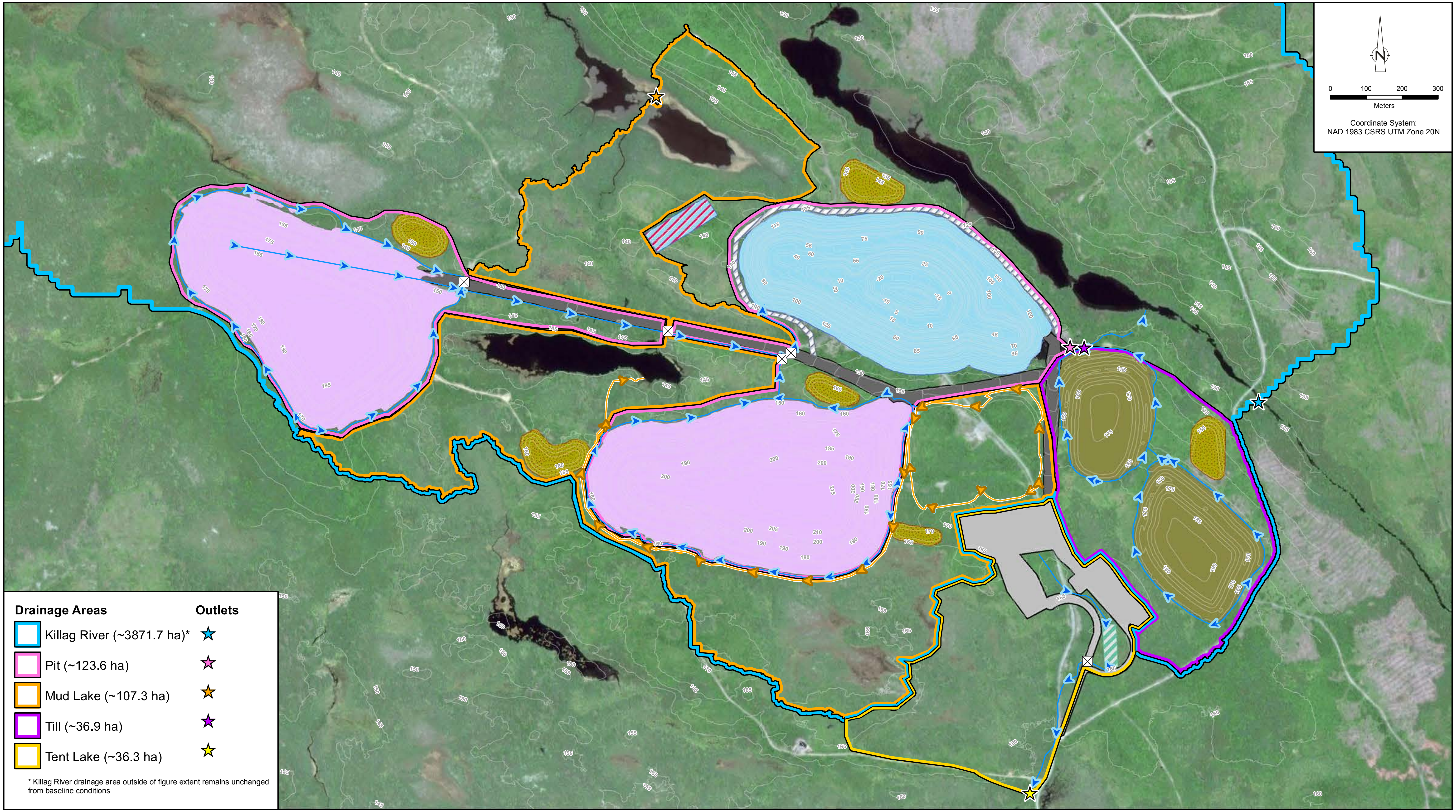
Post-Closure Conditions

The subcatchment areas and outfall locations of the Project Site during PC conditions are presented on Figure 3-8. As part of the Project Site reclamation plan, the Mine Pit will be filled with water from groundwater inflows and direct precipitation. Water will no longer be pumped from the Mine Pit to the North Settling Pond, and runoff from the waste rock piles will be diverted into the Mine Pit. Overflow from the Mine Pit will be directed to the Killag River. The capacity of the Mine Pit is approximately 16,000,000 m^3. The LGO stockpile area will be reclaimed and the clean surface water runoff will be redirected to Mud Lake, increasing the Mud Lake subcatchment area by 13.2%.

A summary of the catchment areas under baseline, EOM, and PC conditions is provided in Table 3-2.

Table 3-2 Summary of Catchment Areas under Baseline, End-of-Mine and Post-Closure Conditions

Catchment Area	Baseline Conditions	EOM Conditions	PC Conditions
Killag River (ha)	3871.7	3871.7	3871.7
Crusher Lake (ha)	109.5	52.4	52.4
Mud Lake (ha)	166.3	94.8	107.3
Tent Lake (ha)	28.4	36.3	36.3



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Imagery: Image ©2019 DigitalGlobe, ©2019 Google, Imagery date: 18/6/2012

NOTES:
1. Mud Lake and Tent Lake Contributing Areas derived from LiDAR measurements supplied by Leading Edge Geomatics, 2015.
2. Killag River Contributing Area derived from a combination of LiDAR measurements, Nova Scotia Department of Natural Resources (Forestry Division) hydrologically-corrected 20m DEM, and interpretations from satellite imagery and topographic maps.

Stockpile Ditch
SWM Ditch
Contours (5m)
Berm
Soil Stockpile
Decommissioned Settling Pond
Collection Pond
Pit Lake
Haul Road
Crusher Pad
Till Stockpile
Waste Rock Stockpile
☒ Culvert

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WATER BALANCE ANALYSIS

088664-27
Feb 22, 2019

CONTRIBUTING DRAINAGE AREAS – PC CONDITIONS

FIGURE 3-8

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4. Results

This section presents the WBM results for baseline, EOM, and PC conditions. The purpose of the water balance analysis is to assess the impact of the proposed Project on the receiving environment by comparing the total runoff volume discharged to three outlet locations between the three mine life-cycle stages. The WBM is run at a daily time step and the results are summarized at monthly and annual time steps for an average water year (i.e., October - September). The precipitation and temperature values in the water balance are sampled from the respective probability distributions described in Section 3.1 for 50-years to account for the climate variability between years. The results are presented as average values of the 50-year simulation.

4.1 Killag River

Table 4-1 presents monthly and annual total precipitation, evaporation, storage, and runoff volumes for the Killag River catchment area for baseline, EOM, and PC conditions. Evaporation is calculated as the sum of all actual evapotranspiration and lake evaporation losses. Storage is calculated as the difference between precipitation and the sum of evaporation and runoff.

Monthly runoff values are highest in April due to the combination of rainfall and snowmelt from the snowpack. Monthly runoff values are lowest in July, August, and September due to the lower precipitation and higher evaporation rates. Monthly runoff values are also low in January and February due to the accumulation of snowfall in the snowpack that does not contribute to runoff until daily temperatures exceed 0 degrees Celsius, triggering snowmelt. The right-most column of Table 4-1 presents the percent change in total annual runoff from baseline to EOM and from baseline to PC conditions. A positive value indicates an increase and a negative value indicates a decrease in total annual runoff.

There is a 0.91% and 0.03% increase in total annual runoff between baseline and EOM and between baseline and PC conditions, respectively. The percent changes in annual runoff are low due to the relatively small area of the Project Site compared to the contributing drainage area to the Killag River outfall. The difference between the annual runoff values under EOM and PC conditions is partially attributed to the varying seepage rates from the waste rock, ore, and till stockpiles. Seepage rates are related to the infiltration rates to the stockpiles that are dependent on the permeability of the stockpile cover material. The difference in annual runoff is also attributed to the difference between the pumping rate from the Mine Pit during EOM conditions, and the overflow rate from the Mine Pit under PC conditions.

Theoretically, storage values should be equal to zero on an annual basis; however, the results of the multi-year assessment show that annual storage fluctuates between small positive and small negative values. Under baseline conditions, the 50-year average annual storage is approximately 0.03% of the annual precipitation. Under EOM and PC conditions, the 50-year average annual storage is approximately 0.07% and 0.06% of the annual precipitation, respectively. The small increase in annual storage volumes between baseline and EOM/PC conditions can be attributed to the infiltration and absorption of the stockpile materials.

4.2 Mud Lake

Table 4-2 presents the monthly and annual water balance results for the Mud Lake catchment area for baseline, EOM, and PC conditions. Monthly runoff values are highest in April and lowest in July, August, and September. The percent changes in total annual runoff from baseline to EOM conditions and from baseline to PC conditions are -43.0% and -35.5%, respectively. The negative values indicate that there are decreases in annual runoff from baseline conditions. The percent changes are proportional to the reductions in catchment areas. The increase in the percent change in annual runoff from EOM to PC conditions is also attributed to the increase in catchment area. Under EOM conditions, the low grade ore stockpiles discharge to the North Settling Pond and the Killag River. Under PC conditions, the low grade ore stockpiles are removed and the area where they were located discharges to Mud Lake, resulting in an increase in contributing drainage area.

Under baseline, EOM and PC conditions, the annual storage is approximately 0.02% of the annual precipitation.

4.2.1 Crusher Lake

Crusher Lake is part of the Mud Lake catchment area and it too will experience a decrease in total annual runoff. Although the runoff volumes were not calculated directly for Crusher Lake, the percent changes in total annual runoff will be proportional to the reductions in catchment areas as was determined for Mud Lake. Monthly runoff values are highest in April and lowest in July, August, and September. The percent changes in total annual runoff from baseline to EOM conditions and from baseline to PC conditions are both -52.1%. The negative values indicate that there are decreases in annual runoff from baseline conditions.

4.3 Tent Lake

Table 4-3 presents the monthly and annual water balance results for the Tent Lake catchment area for baseline, EOM, and PC conditions. Monthly runoff values are highest in April and lowest in July, August, and September. The percent change in total annual runoff from baseline to EOM and from baseline to PC conditions is 53.1%, indicating there is an increase in annual runoff from baseline conditions. The proposed development within the Tent Lake catchment area includes the construction of the crusher pad and the East Collection Pond that results in an increase in catchment area of approximately 27.8%. The increase in runoff volume is also attributed to the increase in impervious surface area between baseline and EOM/PC conditions due to the construction of the proposed impermeable crusher pad.

Under baseline, EOM and PC conditions, the annual storage is approximately 0.02% of the annual precipitation.

Table 4-1 Monthly and Annual Water Balance Results for the Killag River Outfall

Baseline Conditions														Change in Annual Runoff from Baseline Conditions
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	
Precipitation (m^3)	4,827,949	5,227,077	5,388,281	4,955,843	3,903,560	4,758,936	4,157,607	3,996,394	3,719,953	3,773,253	3,880,248	3,834,210	52,423,311	-
Evaporation (m^3)	1,180,331	638,626	0	0	0	0	1,335,000	2,332,000	3,355,000	4,189,605	3,510,522	2,093,669	18,634,753	-
Storage (m^3)	1,123,389	633,467	2,461,145	3,126,071	2,196,571	605,615	-6,879,982	-1,303,358	-1,192,991	-1,272,834	-296,592	815,269	15,769	-
Runoff (m^3)	2,524,228	3,954,984	2,927,136	1,829,773	1,706,989	4,153,321	9,702,589	2,967,752	1,557,944	856,483	666,318	925,272	33,772,789	-
End-of-Mine Conditions														Change in Annual Runoff from Baseline Conditions
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	
Precipitation (m^3)	4,827,949	5,227,077	5,388,281	4,955,843	3,903,560	4,758,936	4,157,607	3,996,394	3,719,953	3,773,253	3,880,248	3,834,210	52,423,311	-
Evaporation (m^3)	1,165,834	631,230	7,803	4,088	4,180	11,914	1,323,070	2,292,282	3,282,906	4,095,126	3,432,570	2,054,415	18,305,419	-
Storage (m^3)	1,104,276	629,513	2,406,297	3,076,085	2,172,387	632,770	-6,702,575	-1,370,572	-1,164,701	-1,242,700	-291,758	789,824	38,846	-
Runoff (m^3)	2,557,839	3,966,334	2,974,181	1,875,670	1,726,993	4,114,252	9,537,112	3,074,684	1,601,748	920,827	739,436	989,971	34,079,047	0.91%
Post-Closure Conditions														Change in Annual Runoff from Baseline Conditions
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	
Precipitation (m^3)	4,827,949	5,227,077	5,388,281	4,955,843	3,903,560	4,758,936	4,157,607	3,996,394	3,719,953	3,773,253	3,880,248	3,834,210	52,423,311	-
Evaporation (m^3)	1,192,316	658,382	22,499	11,788	12,052	34,353	1,385,764	2,318,718	3,309,180	4,123,685	3,460,004	2,078,230	18,606,970	-
Storage (m^3)	1,095,246	622,061	2,425,235	3,087,448	2,169,690	603,022	-6,779,470	-1,295,604	-1,158,711	-1,236,132	-288,806	789,696	33,676	-
Runoff (m^3)	2,540,386	3,946,634	2,940,547	1,856,607	1,721,818	4,121,561	9,551,312	2,973,281	1,569,485	885,700	709,050	966,284	33,782,666	0.03%

Table 4-2 Monthly and Annual Water Balance Results for the Mud Lake Outfall

Baseline Conditions													Change in Annual Runoff from Baseline Conditions
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	
Precipitation (m^3)	207,373	224,516	231,516	212,867	167,668	204,409	178,581	171,656	159,782	162,052	166,534	164,690	2,251,569	-
Evaporation (m^3)	50,711	27,431	0	0	0	0	57,358	100,181	144,087	179,956	150,791	89,929	800,444	-
Storage (m^3)	48,239	27,209	105,713	134,273	94,348	26,013	-295,528	-55,998	-51,223	-54,693	-12,877	35,018	494	-
Runoff (m^3)	108,422	169,877	125,729	78,593	73,320	178,396	416,751	127,473	66,918	36,788	28,620	39,743	1,450,632	-
End-of-Mine Conditions														Change in Annual Runoff from Baseline Conditions
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	
Precipitation (m^3)	118,214	127,987	131,934	121,345	95,580	116,524	101,801	97,853	91,084	92,378	94,933	93,882	1,283,516	-
Evaporation (m^3)	28,908	15,637	0	0	0	0	32,697	57,109	82,137	102,585	85,959	51,264	456,296	-
Storage (m^3)	27,499	15,510	60,262	76,543	53,784	14,829	-168,467	-31,922	-29,200	-31,178	-7,340	19,962	281	-
Runoff (m^3)	61,807	96,839	71,672	44,802	41,796	101,696	237,571	72,666	38,147	20,971	16,315	22,656	826,938	-43.0%
Post-Closure Conditions														Change in Annual Runoff from Baseline Conditions
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	
Precipitation (m^3)	133,801	144,862	149,330	137,346	108,183	131,889	115,224	110,756	103,094	104,559	107,451	106,261	1,452,756	
Evaporation (m^3)	32,720	17,699	0	0	0	0	37,009	64,639	92,968	116,110	97,293	58,024	516,460	
Storage (m^3)	31,126	17,556	68,208	86,636	60,875	16,784	-190,681	-36,131	-33,050	-35,288	-8,308	22,594	320	
Runoff (m^3)	69,956	109,608	81,123	50,710	47,307	115,105	268,896	82,248	43,177	23,737	18,466	25,643	935,976	-35.5%

Table 4-3 Monthly and Annual Water Balance Results for the Tent Lake Outfall

Baseline Conditions													Change in Annual Runoff from Baseline Conditions
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	
Precipitation (m^3)	35,414	38,342	39,525	36,352	28,634	34,908	30,497	29,315	27,287	27,674	28,440	28,125	384,513	-
Evaporation (m^3)	8,660	4,684	0	0	0	0	9,795	17,109	24,607	30,732	25,751	15,358	136,696	-
Storage (m^3)	8,238	4,647	18,053	22,931	16,112	4,442	-50,469	-9,564	-8,748	-9,340	-2,199	5,980	84	-
Runoff (m^3)	18,516	29,011	21,471	13,422	12,521	30,466	71,171	21,769	11,428	6,283	4,888	6,787	247,733	-
End-of-Mine Conditions														Change in Annual Runoff from Baseline Conditions
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	
Precipitation (m^3)	45,266	49,007	50,519	46,465	36,595	44,618	38,981	37,469	34,877	35,373	36,351	35,948	491,470	-
Evaporation (m^3)	7,105	3,843	0	0	0	0	8,036	14,036	20,188	25,214	21,127	12,600	112,148	-
Storage (m^3)	6,759	3,812	22,835	30,178	20,929	4,251	-68,210	-8,708	-7,177	-7,663	-1,804	4,906	108	-
Runoff (m^3)	31,402	41,352	27,684	16,287	15,666	40,368	99,154	32,141	21,866	17,822	17,028	18,442	379,213	53.1%
Post-Closure Conditions														Change in Annual Runoff from Baseline Conditions
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	
Precipitation (m^3)	45,266	49,007	50,519	46,465	36,595	44,618	38,981	37,469	34,877	35,373	36,351	35,948	491,470	-
Evaporation (m^3)	7,105	3,843	0	0	0	0	8,036	14,036	20,188	25,214	21,127	12,600	112,148	-
Storage (m^3)	6,759	3,812	22,835	30,178	20,929	4,251	-68,210	-8,708	-7,177	-7,663	-1,804	4,906	108	-
Runoff (m^3)	31,402	41,352	27,684	16,287	15,666	40,368	99,154	32,141	21,866	17,822	17,028	18,442	379,213	53.1%

5. Mine Pit - Filling Time Calculation

As part of the proposed reclamation plan, the Mine Pit will be allowed to naturally fill with water. As part of the PC WBM a pit filling time is calculated. Table 5-1 presents the inputs to and the results for the pit filling time calculation. The inputs to the Mine Pit include groundwater inflow, direct precipitation minus evaporation, pit wall runoff and mine site runoff. Groundwater inflow rates were calculated based on the stage of the water in the Mine Pit. Utilizing the GHD groundwater model (GHD, 2019) a groundwater inflow curve was developed to use in the pit filling time calculation. Direct precipitation and evaporation is calculated by multiplying the difference between the total annual precipitation and total annual lake evaporation rate by the surface area of the water in the Mine Pit. The surface area of the water in the Mine Pit varies based on the stage of the water. The surface areas are provided at ten (10) m increments. Pit wall runoff is calculated by multiplying the total annual precipitation by the surface area of the Mine Pit above the stage and the runoff coefficient of the pit wall. A runoff coefficient of 0.85 is used based on field observations made at the Touquoy Project Site provided by Stantec (pers. comm., 2018). The time to fill the pit is equal to the sum of the volume of water in the pit divided by the total inflow rate to the pit at each stage. Based on these calculations the pit filling time is equal to 13.8 years.

Table 5-1 Pit Filling Time Calculation

Stage Elevation	Surface Area	Volume	Groundwater Inflow	Precipitation Evaporation	Pit Wall Runoff	Surface Water Ditch Inflow	Time to Fill to Level
m	m^2	m^3	m^3/day	m^3/day	m^3/day	m^3/day	days
127	250,679	15,922,102	495	579	314	1,588	567
120	233,141	14,234,298	606	538	369	1,588	705
110	205,312	12,047,184	621	474	457	1,588	631
100	189,323	10,065,681	624	437	508	1,588	556
90	163,450	8,309,266	627	377	590	1,588	493
80	150,309	6,740,655	629	347	631	1,588	435
70	127,595	5,351,578	631	295	703	1,588	377
60	115,159	4,137,642	632	266	743	1,588	320
50	90,705	3,104,288	633	209	820	1,588	252
40	74,025	2,284,510	634	171	873	1,588	198
30	55,930	1,638,735	635	129	930	1,588	157
20	46,784	1,124,288	635	108	959	1,588	119
10	32,266	731,422	636	74	1,005	1,588	85
0	24,826	449,162	636	57	1,028	1,588	61
-10	15,949	246,236	636	37	1,056	1,588	40
-20	10,808	112,633	636	25	1,072	1,588	22
-30	4,632	38,139	636	11	1,092	1,588	11
Total (days)							**5,031**
Total (years)							**13.8**

6. Conclusion

The results from the water balance analysis can be used to assess the impact of the proposed mine development on the receiving environment in terms of the change in water volume discharged to the Killag River, Mud Lake, Crusher Lake and Tent Lake outfalls. The results can also be used to form the basis for the development of mitigation measures to reduce the impact of the proposed development on the receiving environment. The proposed mine development results in a 0.91% and 0.03% increase in runoff volume discharged to the Killag River under EOM and PC conditions, respectively. The small impact is due to the relatively small area of the Project Site compared to the large contributing drainage area to the Killag River outfall. The proposed mine development results in a 43.0% and 35.5% reduction in annual runoff volume discharged to Mud Lake under EOM and PC conditions, respectively. The proposed mine development results in a 52.0% reduction in annual runoff volume discharged to Crusher Lake under EOM and PC conditions. The proposed mine development results in a 53.1% increase in annual runoff volume discharged to Tent Lake under both EOM and PC conditions. The time for the Mine Pit to fill with water is estimated to be 13.8 years from the end of the EOM stage.

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Zhan, L., Li, G., Jiao, T., Lan, J., and Chen, Y., MOE Key Laboratory of Soft Soils and Geoenvironmental Engineering. Department of Civil Engineering, Zhejiang University, Hangzhou.

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ATLANTIC GOLD

Appendix G.6

Assimilative Capacity Study of Moose River – Touquoy Open Pit Discharge

Stantec

Beaver Dam Gold Project Assimilative Capacity Study of Moose River – Touquoy Open Pit Discharge

FINAL REPORT

January 21, 2019

File: 121619250

Prepared for:

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Suite 3083, Three Bentall Centre
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Markham, ON L3R 0B8

Sign-off Sheet

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

APPENDIX A WATER QUALITY PARAMETERS AND STATISTICS

BEAVER DAM GOLD PROJECT
ASSIMILATIVE CAPACITY STUDY OF MOOSE RIVER – TOUQUOY OPEN PIT DISCHARGE

January 21, 2019

1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) was retained by Atlantic Mining Nova Scotia Corporation (AMNS) to conduct an assimilative capacity study of Moose River of the effluent discharge and seepage from the exhausted open pit as part of the Beaver Dam Mine project. The Open Pit is a part of the existing Touquoy Gold Mine which is located in Halifax County, Nova Scotia, approximately 60 km northeast Halifax, Nova Scotia. The study is focused on the water surplus in the exhausted Touquoy open pit during reclamation/closure phase discharged via a proposed spillway to Moose River at the final discharge point, considering the tailings deposited in the pit from Beaver Dam ore processing and overflows under natural conditions via a proposed spillway to Moose River.

The objective of the assimilative capacity study is to define parameters of potential concern for the effluent, characterize the mixing zone for the Open Pit effluent and propose maximum effluent limits for the parameters of potential concern.

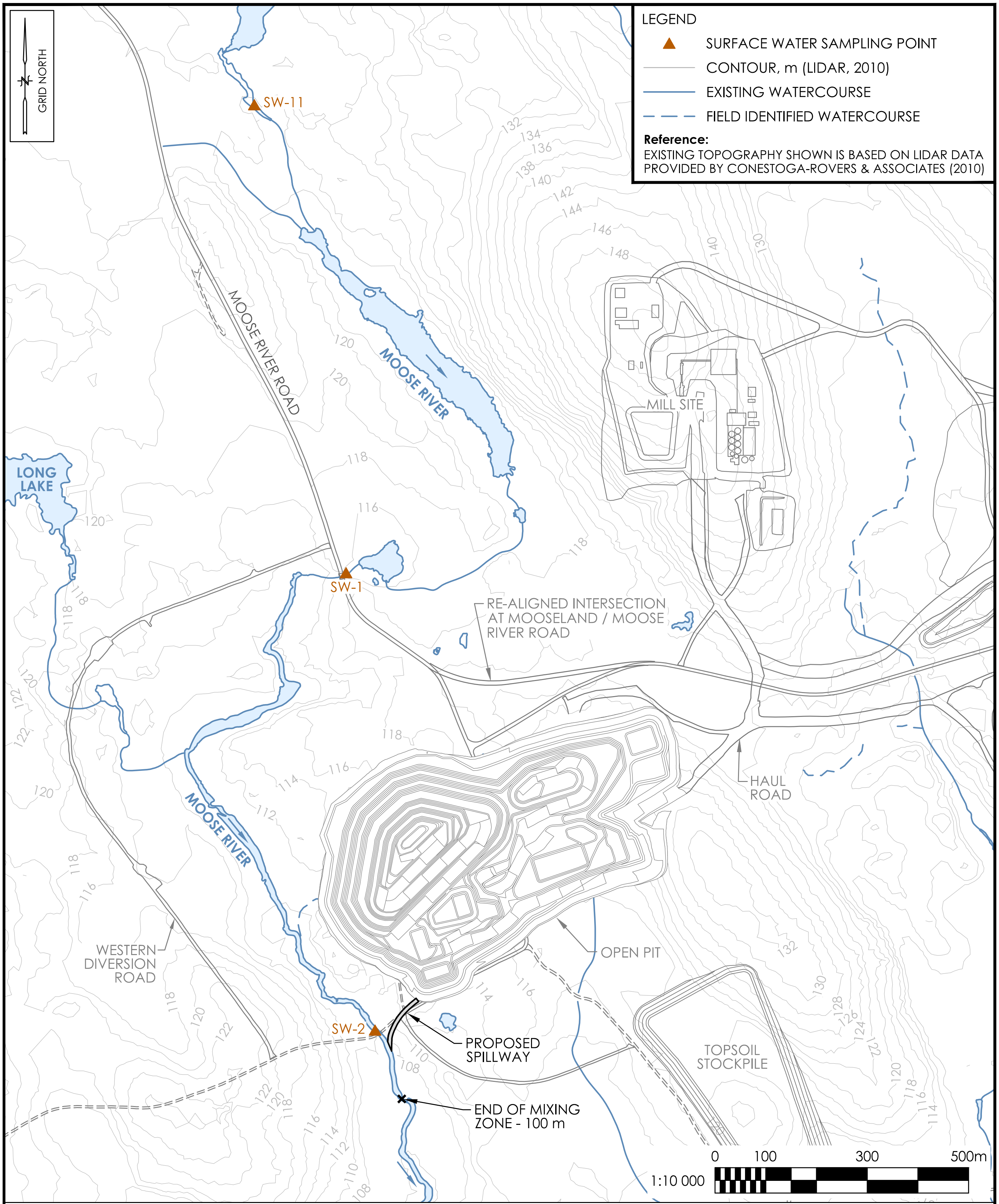
2.0 BACKGROUND

The Touquoy Mine Site in Halifax County, Nova Scotia comprises an area approximately 176 hectares (ha); of that area the existing open pit is approximately 40 ha. Site areas associated with major project components include the Mill Site (Plant Management Areas, PLM), Open Pit, Tailings Management Facility (TMF), Waste Rock Pile, and ancillary facilities. The open pit is located between Moose River on the west and Watercourse No. 4 on the east that each flow north to south adjacent to the limits of the open pit.

The existing Touquoy open pit is actively dewatered and pumped to the TMF. Water in the TMF is decanted to the effluent treatment plant for treatment. Effluent then drains to the polishing pond through a series of geobags, then to a constructed wetland where water infiltrates through the berm and finger drains to Scraggy Lake, the receiving water body for the mine site. The approved Touquoy Environmental Assessment stated that the exhausted open pit would be allowed to fill naturally with water over a period of time through the collection of direct precipitation, surface flow and groundwater inflow. No change to this method is planned for the deposition of Beaver Dam tailings, except that the time frame for refilling will be shorter given the decrease in available volume taken by the tailings.

The overall concept of the Beaver Dam Gold project is to process Beaver Dam Gold reserve ore of approximately 7.25 Million tonnes (Mt) at the existing Touquoy mill site. Beaver Dam ore processing will commence once Touquoy ore reserve is depleted corresponding to the commencement of the Touquoy reclamation phase. Over approximately 3 years of operations, tailings generated by processing the Beaver Dam ore will be deposited in the exhausted Touquoy open pit to an elevation of 90.5 m Canadian Geodetic Vertical Datum (CGVD) 2013. Over several years, the pit will be allowed to naturally fill through runoff, direct precipitation, and groundwater inflow resulting in approximately 17.5 m of water cover over the tailings surface. Once water quality in the pit lake meets the MDMER discharge criteria, water surplus from natural processing (e.g. snowmelt or rainfall events) will be released to Moose River via a spillway/channel.

Figure 1 presents the study area including the Open Pit, surface water monitoring station SW-2 and proposed spillway to convey overflow from the pit to Moose River. The spillway is 110 m long with an invert elevation of 108.0 m at the Open Pit and elevation of 107.5 m at the outlet to Moose river at the bank. The channel will have an approximate slope of 0.45% (**Figure 2**).



LEGEND

▲ SURFACE WATER SAMPLING POINT

— CONTOUR, m (LIDAR, 2010)

— EXISTING WATERCOURSE

– – FIELD IDENTIFIED WATERCOURSE

Reference:
EXISTING TOPOGRAPHY SHOWN IS BASED ON LIDAR DATA PROVIDED BY CONESTOGA-ROVERS & ASSOCIATES (2010)

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SITE MAP
BEAVER DAM GOLD PROJECT
NOVA SCOTIA

Client:	ATLANTIC MINING NOVA SCOTIA CORPORATION
Job No.:	121619250
Scale:	1 : 10 000
Date:	16-JAN-2019
Dwn. By:	JL
App'd By:	II
Fig. No.:	1

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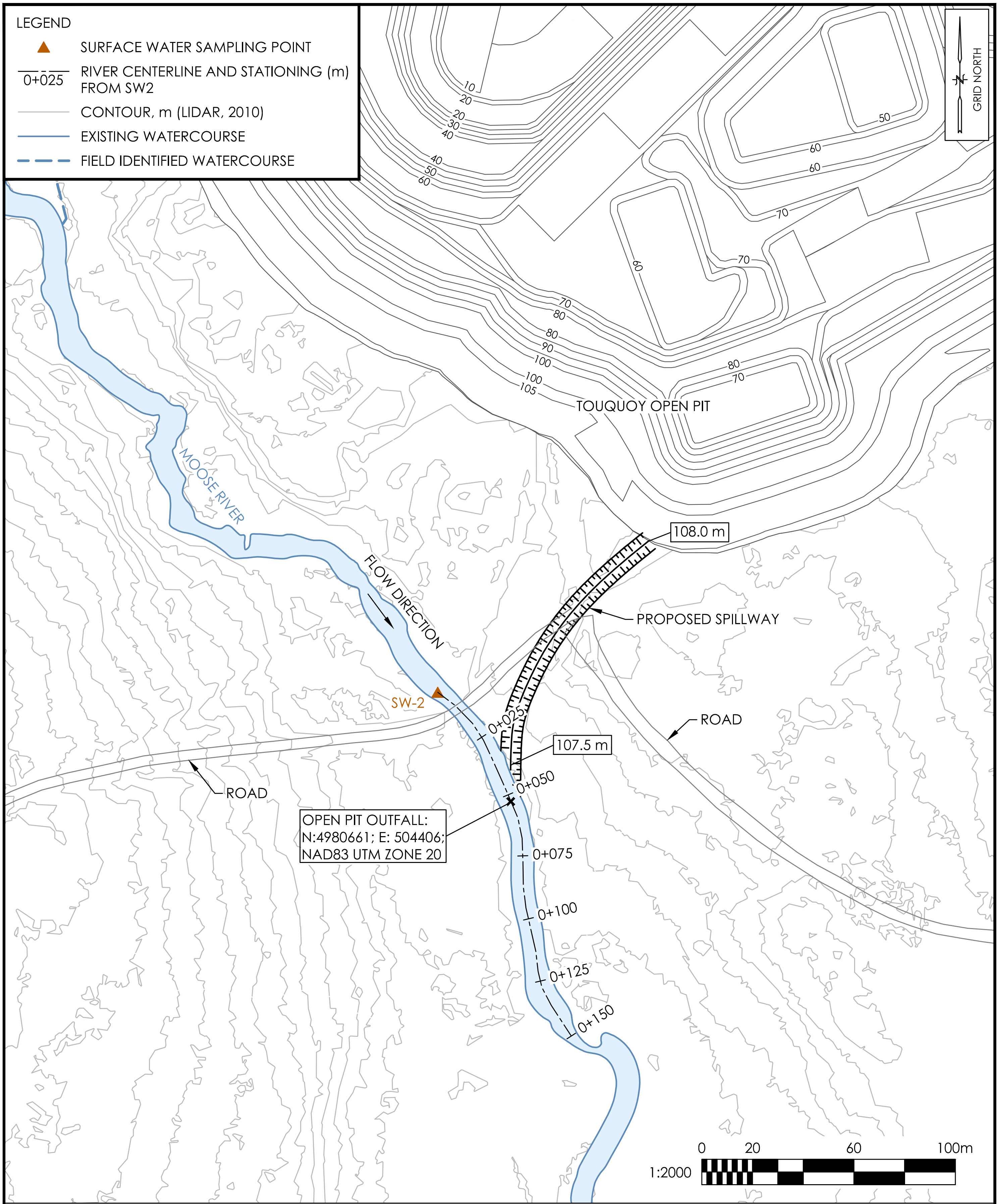

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LOCATION OF OPEN PIT OUTFALL

BEAVER DAM GOLD PROJECT
NOVA SCOTIA

Client: ATLANTIC MINING NOVA SCOTIA CORPORATION

Job No.:	121619250
Scale:	1 : 2000
Date:	16-JAN-2019
Dwn. By:	JL
App'd By:	RJ
Fig. No.:	2

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3.0 REGULATORY FRAMEWORK

Effluent discharge from the Open Pit is regulated by the Metal and Diamond Mining Effluent Regulation (MDMER). The new revised Schedule 4 - Table 2 of MDMER will be applicable to existing mines starting June 1, 2021. These new MDMER limits are presented in **Table 1** and anticipated to be in force at the time the open pit discharges are likely to begin. Waste water treatment will be required for parameters which exceed the MDMER limits in the effluent.

Table 1: MDMER Limits for Mine Effluent after June 1, 2021

Parameter	MDMER, Table 2, Schedule 4 (mg/L)
Arsenic	0.3
Copper	0.3
Cyanide	0.5
Lead	0.1
Nickel	0.5
Zinc	0.5
Un-ionized ammonia (as N)	0.5

The Canadian Council Ministers of the Environment (CCME) framework for assessing assimilative capacity of the receiver (CCME 2003) was used in this study. The key steps outlined in the CCME guidance are as follows:

1. Identifying physical/chemical and/or biological parameters of potential concern for the proposed discharge. Parameters of potential concern are defined as those which exceed the applicable regulatory limits in the Open Pit overflow effluent.

2. Establishing appropriate (i.e. freshwater) ambient Water Quality Objectives (WQOs) for receiving waters. The NSE Tier 1 Environmental Quality Standards (NSEQS 2010) and CCME limits were used as WQOs for this study.

3. If the background concentration of a parameters of potential concern in the receiving environment is higher than the WQO on which the discharge limit is established, the discharge limit should not be more stringent than the natural background concentration.

4. Determining the areal extent of the initial mixing zone (IMZ) in the area of the outfall in the receiving water. CCME (2003) defines the mixing zone as, "*an area contiguous with a point source (effluent) where the effluent mixes with ambient water and where concentrations of some substances may not comply with water quality guidelines or objectives*".

5. Developing use-protection-based effluent discharge limits at the end-of-pipe which will meet ambient WQOs at the edge of the mixing zone (through modelling and other methods).

As per Chapter 6 of CCME (2003) the conditions within a mixing zone should not result in the bioaccumulation of chemicals (e.g., metals) to levels that are harmful or toxic.

4.0 RECEIVING WATER HYDROLOGY

The Open Pit effluent will reach Moose River in close proximity to SW-2. The upstream Moose River catchment area at SW-2 is 39.03 km^2. No long-term hydrometric stations exist on Moose River around the project site.

In the absence of long-term local hydrologic records, regional relationships were developed using selected Water Survey of Canada (WSC) stations to transpose flow data to the project site. The WSC stations were selected based on criteria including catchment area, station location, and period of record. Transpositional scaling is based on the assumption of homogeneity (due to their proximity and similar climate and land use conditions) between the selected regional WSC stations.

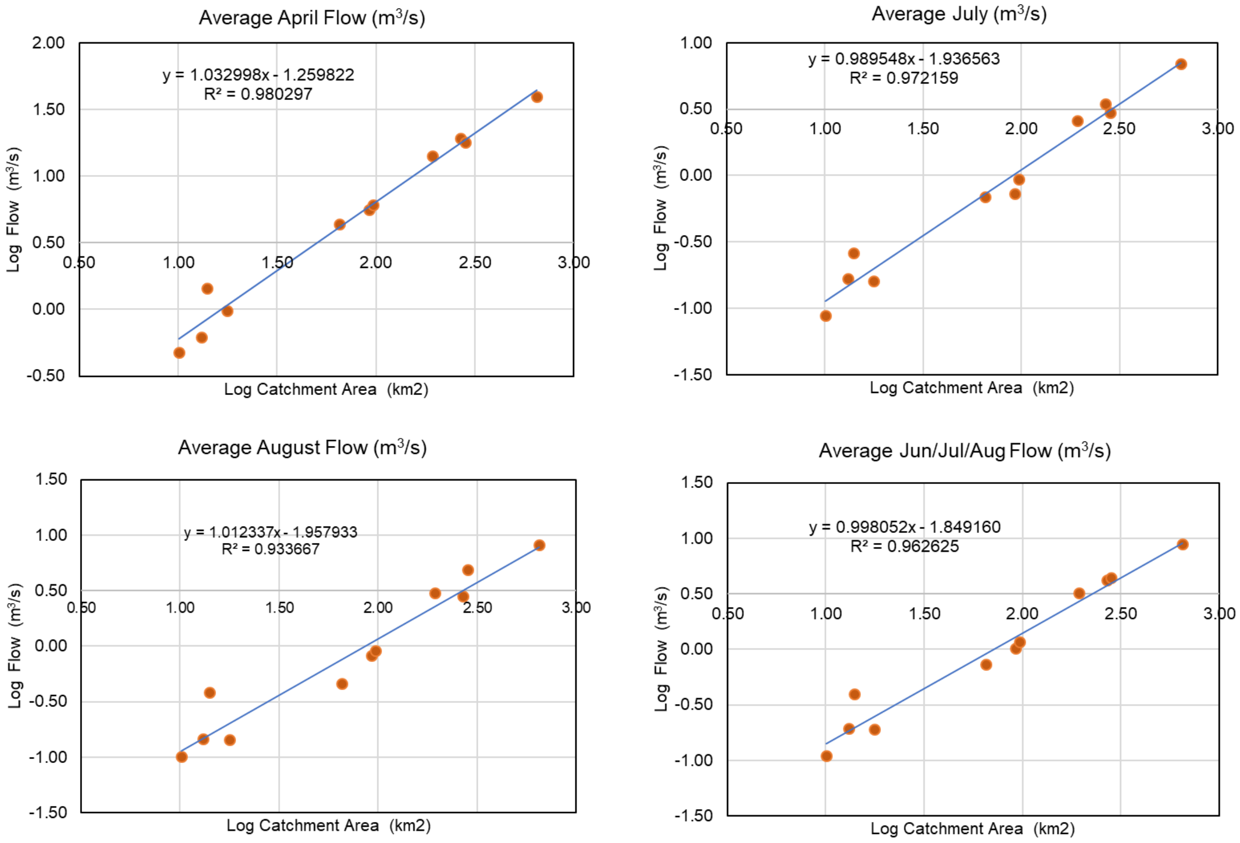
There are limited gauging station datasets available in Nova Scotia near the site that meet the primary selection criteria (e.g., catchment area, distance to project site). The WSC stations selected for the regional hydrology assessment are summarized in **Table 2**.

Table 2: WSC Regional Hydrology Stations

Station ID	Station Name	Drainage Area (km^2)	Years of Record	Record Period	Distance to Site (km)
01DH003	FRASER BROOK NEAR ARCHIBALD	10.1	26	1965-1990	45
01EJ004	LITTLE SACKVILLE RIVER AT MIDDLE SACKVILLE	13.1	39	1980-2018	65
01FG001	RIVER DENYS AT BIG MARSH	14.0	14	2005-2018	167
01EE005	MOOSE PIT BROOK AT TUPPER LAKE	17.7	38	1981-2018	192
01EH006	CANAAN RIVER AT OUTLET OF CONNAUGHT LAKE	65.4	11	1986-1996	107
01DP004	MIDDLE RIVER OF PICTOU AT ROCKLIN	92.2	54	1965-2018	58
01DG003	BEAVERBANK RIVER NEAR KINSAC	96.9	98	1921-2018	60
01FA001	RIVER INHABITANTS AT GLENORA	193	54	1965-2018	150
01ED013	SHELBURNE RIVER AT POLLARD'S FALLS BRIDGE	268	20	1999-2018	202
01EO003	EAST RIVER ST. MARYS AT NEWTOWN	282	15	1965-1979	75
01EK001	MUSQUODOBOIT RIVER AT CRAWFORD FALLS	650	82	1915-1996	27

Average monthly flows for Moose River at SW-2 were derived using the regional relationships. **Figure 3** presents the regression analysis completed to determine the relationship between catchment areas and average flow in April, August and June-July-August for the selected WSC stations. April was selected as this month corresponds to the highest flows in the region and summer months typically correspond to the lowest flows.

Figure 3: Regional Regression Analysis



Average April Flow (m^3/s)

Average July (m^3/s)

Average August Flow (m^3/s)

Average Jun/Jul/Aug Flow (m^3/s)

As presented on **Figure 3**, strong linear trends exist between the average monthly flow rates of the selected monitoring stations and drainage area for April, August, and June to August with a correlation coefficient R^2 of 0.98, 0.93, and 0.96, respectively. From these regional relationships, it can be inferred that the average April and August flows for SW-2 in the Moose River (catchment area of 39.03 km^2) are estimated to be 2.42 m^3/s and 0.45 m^3/s, respectively. Results of the statistical analysis on the regional flow records indicated that generally the peak and low flow events occur in April and August, respectively.

5.0 RECEIVING WATER QUALITY

The effluent will be discharged to Moose River via a spillway as presented on **Figure 2**. A monitoring program has been ongoing since 2016 to monitor background water quality in Moose River at three monitoring stations SW-1, SW-2, and SW-11. **Table 3** summarizes the location of each monitoring station.

Table 3: Water Quality Monitoring Stations on Moose River

Site	Location	Rationale	Location Description
SW-1	504325E, 4981604N	Background	Moose River – adjacent to site and upstream of Moose River road culvert and open pit.
SW-2	504378E, 4980703N	Downstream – Near-field	Moose River – downstream of Facility and upstream of Bridge, just below the open pit.
SW-11	504140E, 4982529N	Background	Moose River – upstream of the Site to represent relatively un-impacted conditions upstream of the facility.

Surface water monitoring station SW-2 is located immediately upstream of the proposed effluent location (**Figure 1**) and therefore was used to characterize ambient water quality.

Table 4 summarizes the 2016 and 2017 water quality data at SW-2 for total metals, cyanides. The table also presents the NSE Tier 1 Environmental Quality Standards (EQS) and CCME guidelines for the protection of freshwater aquatic life (FAL). Moose River at SW-2 has four parameters which exceed either the NSE Tier 1 EQS or CCME FAL guidelines: aluminum, arsenic, cadmium and iron.

Tables A-1 to A-3 in **Appendix A** present a complete list of monitored water quality parameters and statistics.

Table 4: Background Water Quality at SW-2

Water Quality Parameter	Average Concentration mg/L	75th Percentile mg/L	NSE Tier 1 EQS Freshwater mg/L	CCME FAL mg/L
Aluminum	**0.169**	**0.187**	**0.005**	0.1
Arsenic	**0.012**	**0.018**	**0.005**	**0.005**
Calcium	1.2	1.3		
Cadmium	**0.000014**	**0.000019**	**0.00001**	0.0009
Cobalt	<0.0004	<0.0004	0.01	
Chromium	<0.001	<0.001		
Copper	<0.002	<0.002	0.002	0.002
Iron	**0.48**	**0.62**	**0.3**	**0.3**
Lead	<0.0005	<0.0005	0.001	0.001
Mercury	<0.000013	<0.000013	0.000026	0.000026
Magnesium	0.488	0.52		

Table 4: Background Water Quality at SW-2

Water Quality Parameter	Average Concentration mg/L	75th Percentile mg/L	NSE Tier 1 EQS Freshwater mg/L	CCME FAL mg/L
Manganese	0.06	0.07	0.82	
Molybdenum	<0.002	<0.002	0.073	0.073
Nickle	<0.002	<0.002	0.025	0.025
Tin	<0.001	<0.001	0.02	
Selenium	<0.001	<0.001	0.001	0.001
Silver	<0.0001	<0.0001	0.0001	0.00025
Sulphate	<2	<2		
Thallium	<0.0001	<0.0001	0.0008	0.0008
Uranium	<0.0001	<0.0001	0.3	0.15
Zinc	<0.005	<0.005	0.03	0.007
WAD Cyanide	<0.003	<0.003		
Total Cyanide	<0.005	<0.005		
Nitrate (as N)	<0.05	0.054		13
Nitrite (as N)	<0.01	<0.01		0.06
Ammonia (as N)	<0.05	0.062		

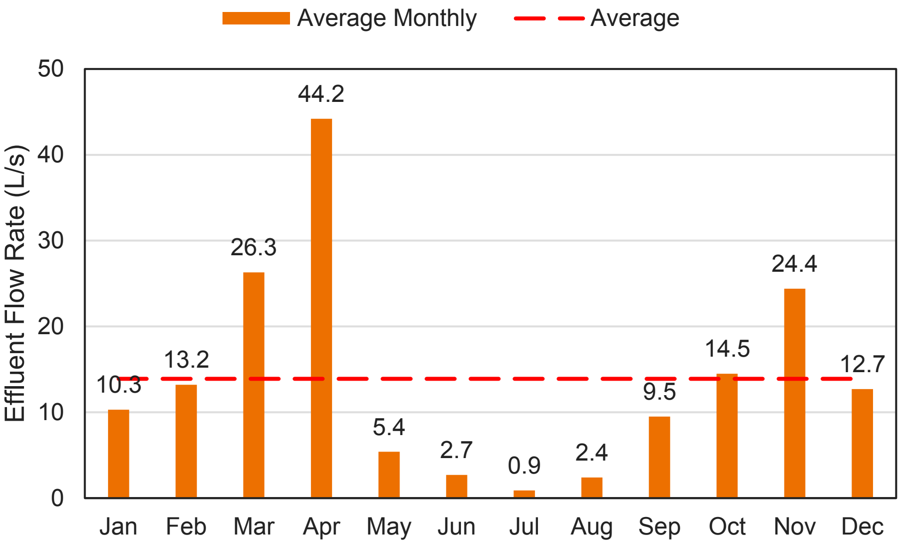
Note: Bold values indicate exceedance of water quality objectives, empty field indicates no water quality value.

6.0 EFFLUENT WATER QUANTITY AND QUALITY

An environment water balance was used to predict the Open Pit effluent overflow to Moose River at mine closure (Stantec 2018b). **Figure 4** shows the average predicted monthly open pit overflow under climate normal conditions. As shown in the table, average monthly effluent flow will seasonally vary from 0.9 L/s in July to 44.2 L/s in April. The average monthly effluent flow rate to Moose River will be 13.9 L/s.

The Open Pit seepage rate to the river was simulated using a groundwater flow model (Stantec 2018a). Average daily seepage rate to Moose River was estimated at 310 m^3/day or 3.6 L/s.

Figure 4: Monthly Effluent Flow Rates



Effluent water quality was predicted using the water quality and quantity model and groundwater flow model (Stantec 2018a and Stantec 2018b). Water quality modelling considered the pore water quality in the tailings and the groundwater inflow quality in the pit floor/ walls, dilution from surface runoff, direct precipitation, and process water surplus, and the geochemistry of the individual water quality parameters. **Table 5** presents a list of predictions of the average and maximum concentrations in the effluent for metal parameters and nitrogen species. Concentrations of aluminum, arsenic, cobalt, copper, and nitrite in the effluent water quality have exceedance of one or both of the NSE Tier 1 EQS or CCME FAL guidelines, including. In addition, the effluent concentration of arsenic is predicted to exceed the 2021 MDMER discharge limit for an existing mine (i.e., 0.3 mg/L), therefore, arsenic treatment will be required prior to release of the effluent to environment.

Total cyanide and weakly acid-dissociable (WAD) cyanide have relatively high concentrations in the effluent, although they are below the MDMER discharge limit for cyanide (i.e., 0.5 mg/L for total cyanide). There are no NSE Tier 1 EQS or CCME FAL guidelines for these forms of cyanide. Further discussion about cyanide is presented in Section 10.0.

Table 5: Predicted Effluent Water Quality Parameters and Limits

Water Quality Parameter	Average Concentration in Open Pit Discharge mg/L	Maximum Concentration in Open Pit Discharge mg/L	MDMER (after 2021) mg/L	NSE Tier 1 EQS Freshwater mg/L	CCME FAL mg/L
Aluminum	**0.017**	**0.04**		**0.005**	0.1
Arsenic	**0.23**	**0.86**	**0.3**	**0.005**	**0.005**
Calcium	26.9	60.6			
Cadmium	0.00001	0.00001		0.00001	0.0009
Cobalt	**0.013**	**0.064**		**0.01**	
Chromium	0.00016	0.00038			
Copper	**0.007**	**0.036**	0.3	**0.002**	**0.002**
Iron	0.013	0.032		0.3	0.3
Lead	0.0001	0.0002	0.1	0.001	0.001
Mercury	0.00001	0.00002		0.000026	0.000026
Magnesium	3.36	5.47			
Manganese	0.07	0.12		0.82	
Molybdenum	0.004	0.008		0.073	0.073
Nickle	0.007	0.016	0.5	0.025	0.025
Tin	0.001	0.004		0.02	
Selenium	0.0002	0.0007		0.001	0.001
Silver	0.00001	0.00003		0.0001	0.00025
Sulphate	79.8	219.0			
Thallium	0.00002	0.00004		0.0008	0.0008
Uranium	0.003	0.003		0.3	0.15
Zinc	0.001	0.002	0.5	0.03	0.007
WAD Cyanide	0.024	0.123			
Total Cyanide	0.069	0.351	0.5		
Nitrate (as N)	1.60	4.87			13
Nitrite (as N)	**0.35**	**1.74**			**0.06**
Ammonia (as N)	0.07	0.88			

Note: Bold values indicate exceedance of water quality objectives, empty field indicates no water quality value.

7.0 GROUNDWATER SEEPAGE FROM OPEN PIT TO MOOSE RIVER

Groundwater seepage from the Open Pit discharging directly to Moose River was predicted using a groundwater model (Stantec 2018b). Based on climate normal conditions, the predicted seepage rate from the Open Pit to the river is 3.6 L/s. **Table 6** presents a list of average water quality concentrations in the seepage. No parameters in the seepage are predicted to exceed the NSE Tier 1 EQS or CCME.

Table 6: Predicted Water Quality of Seepage from Open Pit

Water Quality Parameter	Average Concentration in Seepage mg/L	MDMER (after 2021) mg/L	NSE Tier 1 EQS Freshwater mg/L	CCME FAL mg/L
Aluminum	Below DL		0.005	0.1
Arsenic	0.002	0.3	0.005	0.005
Calcium	0.06			
Cadmium	Below DL		0.00001	0.0009
Cobalt	Below DL		0.01	
Chromium	Below DL			
Copper	0.000007	0.3	0.002	0.002
Iron	Below DL		0.3	0.3
Lead	Below DL	0.1	0.001	0.001
Mercury	Below DL		0.000026	0.000026
Magnesium	0.01			
Manganese	0.0002		0.82	
Molybdenum	Below DL		0.073	0.073
Nickle	Below DL	0.5	0.025	0.025
Tin	Below DL		0.02	
Selenium	Below DL		0.0001	0.00025
Silver	Below DL		0.0001	0.0001
Sulphate	0.62			
Thallium	Below DL		0.0008	0.0008
Uranium	Below DL		0.3	0.15
Zinc	Below DL	0.5	0.03	0.007
WAD Cyanide	Below DL			
Total Cyanide	Below DL	0.5		
Nitrate (as N)	Below DL			
Nitrite (as N)	Below DL			0.06
Ammonia (as N)	0.023			

DL – Detection Limit

8.0 ASSIMILATION RATIOS

Assimilation or dilution ratio analysis was conducted to find the worst-case month for dilution and mixing, i.e., the month with the lowest assimilative capacity. The Open Pit effluent post-mine closure will be driven by the same metrological factors (precipitation, evaporation, snowmelt) as the whole Moose River catchment. A very low flow in the river will correspond to a very low effluent flow from the Open Pit. The same relationship will occur with high flows.

Table 7 presents the dilution ratios of the effluent with the receiver water assuming full mixing. The dilution ratios were calculated as a ratio of flow in the receiver to the effluent flow plus seepage for the same month. A ratio between the catchment area of Moose River at SW-2 (39 km^2) and catchment area of the Open Pit (0.41 km^2) is 95 to 1.

The minimum dilution ratio of 51 is observed in April and therefore the lowest assimilative capacity of the Moose River is observed when flows in the river and effluent are the highest. It happens because the Open Pit effluent and river flow are driven by the same meteorological factors and summer flow from a small catchment has exponentially smaller flow than flow from a larger catchment. In part because larger area in summer is mainly fed by groundwater.

Table 7: Dilution Ratio in the Receiver at the Edge of the Mixing Zone

Month	Receiver Flow (L/s)	Effluent Flow (L/s)	Seepage Flow (L/s)	Dilution Ratio
June/July/August	548	2	3.6	98
July	435	0.9	3.6	97
August	450	2.4	3.6	75
April	2,420	44.2	3.6	51

9.0 MIXING ZONE STUDY

The approach to modelling the areal extent of the initial mixing zone involved the application of an effluent plume model. The Cornell Mixing Zone Expert System (CORMIX), version 11.0 (Doneker and Jirka, 2017) was used in this study. CORMIX is a software system for the analysis, prediction, and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. The major emphasis is on the geometry and dilution characteristics of the initial mixing zone, but the system also predicts the behavior of the discharge plume at larger distances. The basic CORMIX methodology relies on the assumption of steady ambient conditions. Background information regarding the physical characteristics of the receiving waters was used as input to the model, which is provided below.

9.1 CORMIX MODEL INPUTS

The required model inputs for the ambient conditions include flows, water density, wind, and depth of water in Moose River. Ambient flow affects the near-field transport and shape of the resulting plume from the effluent. Boundary ambient conditions are defined by average river depth at the outfall and in the mixing zone. Two different scenarios were modelled using CORMIX: a high flow scenario (April) and a low flow scenario (August). Model inputs are summarized below:

- The average flow in Moose river in April is 2,420 L/s, the climate normal effluent flow is 44.2 L/s in April and seepage rate is 3.6 L/s under the same climate conditions. The average flow in the river in August is 435 L/s, August effluent flow is 0.9 L/s and seepage rate is 3.6 L/s.

- The Moose River channel geometry at the outfall was estimated based on river bathymetry data measured at SW-2 as part of the on-going hydrometric monitoring program for Touquoy operations. Channel width with active flow at the discharge point is 8 m. The average water depth used in the model is 1.0 for low flow conditions and 1.5 m for high water conditions.

- The horizontal angle (sigma) of spillway channel to the bank was assumed 45˚ based on proposed spillway design. The spillway was assumed to have a trapezoidal shape with a bottom width of 3 m and side slopes of 2:1. Longitudinal slope of the spillway is 0.45%.

- Both the effluent and receiver were assumed to have the same temperature of 10°C and same density of 1,000.5 kg/m^3.

- The Manning's "n" roughness coefficient used in the model, which represents the roughness or friction applied to the flow by the channel and based on the bottom substrate, was assumed to be 0.035 for low flow conditions and 0.04 for high flow conditions.

- Winds in CORMIX can affect the circulation, mixing, and plume movement in the river channel. The mean wind speed of 4.2 m/s from at the Halifax Stanfield International Airport was used in the model.

9.2 ASSUMPTIONS

The following assumptions of the modelling investigation were made in the assimilative capacity study:

- Steady ambient and effluent conditions were assumed in CORMIX;
- Outfall configuration (spillway size and slope) was based on available preliminary design;
- CORMIX parameters were derived based on available field data and literature;
- Bathymetry information in the mixing zone was based on cross-section information at SW-2; and
- Modelling was conservatively focused on dilution and mixing ratios and decay and bioaccumulation were not simulated.

10.0 RESULTS AND DILUTION RATIOS

The distance from the effluent discharge location to the boundary of the mixing zone applied in this study is limited to 100 m as per guidance from NSE (Environment Canada 2006).

For both the low flow (August) and high flow (April) scenarios, the CORMIX model showed that a dilution ratio of 51 is achieved within 100 m from the outfall. For the low flow conditions, the dilution ratio of 51 was reached in 74 m and for the high flow conditions it was reached in 98 m form the outfall.

Concentrations of the parameters of potential concern at the end of the mixing zone were calculated conservatively. The maximum Open Pit concentrations were used to define the effluent and the 75th percentile was used to define the ambient water quality conditions. The seepage load (concentration times seepage rate) was also incorporated.

The focus of assessment was on six parameters of potential concern with concentrations predicted to exceed the NSE Tier 1 EQS or CCME limits: aluminum, arsenic, cobalt, copper, nitrite, and cyanide. Concentrations of the parameters of potential concern at the end of the mixing zone are presented in **Table 8**.

Aluminum is predicted to have lower concentration in the effluent in comparison with the ambient background. Therefore, the predicted aluminum concentration at the end of the mixing zone will be slightly lower than background, but still above the NSE Tier 1 EQS and CCME limits, resulting in a slight improvement in ambient aluminum concentrations.

Predicted average arsenic concentration in the effluent is 0.23 mg/L and maximum concentration is 0.86 mg/L. The MDMER limit after June 1, 2021 is 0.3 mg/L, therefore, arsenic will require treatment prior to discharge. After arsenic treatment to the MDMER limit of 0.30 mg/L its concentration at the end of the mixing zone is predicted at 0.023 mg/L. High arsenic background concentration limits mixing potential of this parameter. The arsenic concentration at the 100 m mixing zone boundary is above the NSE Tier 1 EQS and CCME limits, therefore, an environmental effects assessment will be required. Based on the CCME guideline (2001), the predicted arsenic concentration of 0.023 mg/L is below the reported lowest toxic levels for fish, algae and aquatic plants.

Concentrations of cobalt, copper and nitrite in the receiver and in the seepage are below the analytical detection limit. Assuming the minimum dilution ratio of 51 times at the end of the mixing zone the resulting concentrations for these three parameters will be below the NSE Tier 1 EQS and CCME limits (**Table 8**).

Table 8: Water Quality Modelling Results, mg/L

WQ Parameter	Effluent Max, mg/L	Seepage, Average, mg/L	Receiver, 75th percentile	NSE Tier 1 EQS	CCME	Concentration at end of 100 m mixing zone
Aluminum	0.04	Below DL	0.187	0.005	0.1	0.184
Arsenic	0.3	0.002	0.018	0.005	0.005	0.023
WAD Cyanide	0.123	Below DL	<0.003		0.005*	0.002
Cobalt	0.064	Below DL	<0.0004	0.01		0.0012
Copper	0.036	Below DL	<0.002	0.002	0.002	0.0007
Nitrite (as N)	1.74	Below DL	<0.01		0.06	0.034

* Free form of cyanide

Cyanide is presented in water in three forms: total, weakly acid-dissociable (WAD) and free. There are no provincial or federal limits for total and WAD cyanide, however, there is a limit of 0.005 mg/L for free cyanide. The maximum WAD concentration in the effluent is 0.123 mg/L. Conservatively assuming that WAD is equal to the free form the resulting concentration of free cyanide at the end of the mixing zone will be 0.002 mg/L which is less that applicable provincial and federal limits for free cyanide.

11.0 CONCLUSIONS

It was determined that a 100-m mixing zone would be appropriate for the Open Pit effluent on the basis of requirements of Nova Scotia Environment.

Ambient water quality was characterized using the 2016 and 2017 water quality data at SW-2. Moose River at SW-2 has four parameters which exceed either the NSE Tier 1 EQS or CCME: total aluminum, arsenic, cadmium and iron.

Total aluminum, arsenic, cobalt, copper, cyanide and nitrite were identified to have exceedances of either the NSE Tier 1 EQS or CCME in the Open Pit effluent. Only arsenic concentration exceeds the MDMER limit for existing mines, therefore, arsenic treatment will be required prior to release of the effluent to environment.

Groundwater seepage from the Open Pit to Moose River is predicted at 3.6 L/s. No parameters in the seepage exceed the NSE Tier 1 EQS or CCME limits.

The lowest assimilative capacity of Moose River is observed in April when flows in the river and effluent are the highest. The minimum dilution ratio based on April flows assuming full mixing is 51 times.

The CORMIX (version 11.0) three-dimensional model was used to derive the effluent criteria for the open pit effluent discharge to Moose River. The outfall configuration, bathymetry and flows were modeled conservatively based on available information.

The CORMIX model showed that a dilution ratio of 51 is achieved within 100 m from the outfall for both the low and high flow scenarios. Concentrations of the parameters of potential concern at the end of the mixing zone were calculated conservatively i.e. using the maximum Open Pit concentrations, the 75th percentile for ambient water quality and incorporating seepage load.

Concentrations of the parameters of potential concern at the end of the mixing zone are presented in **Table 8**. The predicted aluminum concentration at the end of the mixing zone will be slightly lower than background, but above the NSE Tier 1 EQS and CCME limits. The predicted arsenic concentration of 0.023 mg/L is above the NSE Tier 1 EQS and CCME limits but below the reported lowest toxic levels for fish, algae and aquatic plants. Conservatively assuming that WAD is equal to the free form the resulting concentration of free cyanide at the end of the mixing zone will be 0.002 mg/L which is less that applicable provincial and federal limits for free cyanide. Concentrations of cobalt, copper and nitrite at the end of the mixing zone are predicted to be below the NSE Tier 1 EQS and CCME limits.

12.0 CLOSURE

This report has been prepared for the sole benefit of the Atlantic Mining Nova Scotia Corporation (AMNS). This report may not be used by any other person or entity without the express written consent of Stantec Consulting Ltd. and AMNS.

Any use that a third party makes of this report, or any reliance on decisions made based on it, are the responsibility of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made, or actions taken, based on this report.

The information and conclusions contained in this report are based upon work undertaken by trained professional and technical staff in accordance with generally accepted engineering and scientific practices current at the time the work was performed. Conclusions and recommendations presented in this report should not be construed as legal advice.

The conclusions presented in this report represent the best technical judgment of Stantec Consulting Ltd. based on the data obtained from the work. If any conditions become apparent that differ from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein.

13.0 REFERENCES

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APPENDIX A

Water Quality Parameters and Statistics

Table A.1 Surface Water Analytical Data - SW-2

Parameter	Units	2016-2017 Statistics						2016 Statistics			2017 Statistics			NSE Tier 1 EQS Freshwater
	Units	Minimum	Mean	Maximum	Median	75th	Count	Minimum	Mean	Maximum	Minimum	Mean	Maximum	
Anion Sum	me/L	0.10	0.14	0.21	0.14	0.165	22	0.12	0.149	0.21	0.1	0.14	0.17	-
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	-
Calculated TDS	mg/L	8.00	11.25	14.00	11.00	13	12	-	-	-	8	11.3	14	-
Carb. Alkalinity (calc. as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	-
Cation Sum	me/L	0.18	0.25	0.31	0.26	0.28	22	0.18	0.256	0.31	0.18	0.239	0.3	-
Colour	TCU	23.00	66.27	140.00	60.00	74	22	23	62.6	140	44	69.3	110	-
Conductivity	µS/cm	21.00	26.00	35.00	24.50	28	22	22	26.2	35	21	25.8	33	-
Dissolved Chloride (Cl)	mg/L	3.60	4.80	5.90	4.75	5.275	22	4.2	4.84	5.3	3.6	4.77	5.9	-
Dissolved Fluoride (F-)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Dissolved Sulphate (SO4)	mg/L	<2.0	<2.0	2.6	<2.0	<2.0	22	<2	<2	2.6	<2	<2	2	-
Hardness (CaCO3)	mg/L	3.50	5.00	7.30	4.85	5.25	22	3.5	5.14	7.3	3.8	4.89	6.7	-
Ion Balance (% Difference)	%	10.50	26.35	40.90	27.55	30.15	22	14.3	26.4	40.9	10.5	26.3	40.5	-
Langelier Index (@ 20C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Langelier Index (@ 4C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate (N)	mg/L	<0.050	<0.050	0.18	<0.050	0.054	22	<0.05	0.0507	0.18	<0.05	<0.05	0.12	-
Nitrate + Nitrite (N)	mg/L	<0.050	<0.050	0.18	<0.050	0.054	22	<0.05	0.0507	0.18	<0.05	<0.05	0.12	-
Nitrite (N)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	22	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
Nitrogen (Ammonia Nitrogen)	mg/L	<0.050	<0.050	0.14	<0.050	0.062	21	<0.05	<0.05	0.095	<0.05	<0.05	0.14	-
Orthophosphate (P)	mg/L	<0.010	<0.010	0.011	<0.010	<0.010	22	<0.01	<0.01	0.011	<0.01	<0.01	0.011	-
pH	pH	4.90	6.05	6.89	6.05	6.2375	22	4.9	6.03	6.89	5.63	6.07	6.47	-
Reactive Silica (SiO2)	mg/L	<0.50	1.16	2.50	1.090	1.875	22	<0.5	1.02	2.5	<0.5	1.27	2.2	-
Saturation pH (@ 20C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Saturation pH (@ 4C)	N/A	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Alkalinity (Total as CaCO3)	mg/L	<5.0	<5.0	<5.0	<5.0	<5.0	22	<5	<5	<5	<5	<5	<5	-
Total Chemical Oxygen Demand	mg/L	14.00	27.36	67.00	24.50	27.75	22	14	27.8	67	20	27	43	-
Total Mercury (Hg)	µg/L	<0.013	<0.013	0.02	<0.013	<0.013	22	<0.013	<0.013	<0.013	<0.013	<0.013	0.02	0.026
Total Organic Carbon (C)	mg/L	3.90	7.90	19.00	6.95	9.375	22	3.9	7.49	19	4.4	8.25	13	-
Total Suspended Solids	mg/L	<1.0	2.68	32	<1.0	1.2	22	<1	4.86	32	<1	<1	<2	-
Total Dissolved Solids	mg/L	9.00	11.90	15.00	11.00	13.5	10	9	11.9	15	-	-	-	-
Turbidity	NTU	0.43	1.17	3.30	1.10	1.375	22	0.58	1.34	3.3	0.43	1.02	1.8	-
Dissolved Aluminum (Al)	mg/L	70.00	176.00	270.00	170.00	220	5	-	-	-	70	176	270	10
Dissolved Antimony (Sb)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	20
Dissolved Arsenic (As)	mg/L	5.10	8.64	13.00	6.90	13	5	-	-	-	5.1	8.64	13	5
Dissolved Barium (Ba)	mg/L	2.80	4.58	6.50	4.70	5.2	5	-	-	-	2.8	4.58	6.5	1000
Dissolved Beryllium (Be)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	5.3
Dissolved Bismuth (Bi)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	-
Dissolved Boron (B)	mg/L	<50	<50	<50	<50	<50	5	-	-	-	<50	<50	<50	1200
Dissolved Cadmium (Cd)	mg/L	<0.010	0.014	0.027	0.017	0.018	5	-	-	-	<0.01	0.0144	0.027	0.01
Dissolved Calcium (Ca)	mg/L	1100.00	1340.00	1700.00	1300.00	1500	5	-	-	-	1100	1340	1700	-
Dissolved Chromium (Cr)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	-
Dissolved Cobalt (Co)	mg/L	<0.40	<0.40	<0.40	<0.40	<0.40	5	-	-	-	<0.4	<0.4	<0.4	10
Dissolved Copper (Cu)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	2
Dissolved Iron (Fe)	mg/L	310.00	438.00	660.00	450.00	450	5	-	-	-	310	438	660	300
Dissolved Lead (Pb)	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	5	-	-	-	<0.5	<0.5	<0.5	1
Dissolved Magnesium (Mg)	mg/L	450.00	538.00	620.00	510.00	620	5	-	-	-	450	538	620	-
Dissolved Manganese (Mn)	mg/L	20.00	51.60	84.00	57.00	66	5	-	-	-	20	51.6	84	820
Dissolved Molybdenum (Mo)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	73
Dissolved Nickel (Ni)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	25
Dissolved Phosphorus (P)	mg/L	<100	<100	<100	<100	<100	5	-	-	-	<100	<100	<100	-

Parameter	Units	2016-2017 Statistics						2016 Baseline Statistics			2017 Statistics			NSE Tier 1 EQS Freshwater
	Units	Minimum	Mean	Maximum	Median	75th	Count	Minimum	Mean	Maximum	Minimum	Mean	Maximum	
Dissolved Potassium (K)	mg/L	180.00	220.00	320.00	210.00	210	5	-	-	-	180	220	320	-
Dissolved Selenium (Se)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	5	-	-	-	<1	<1	<1	1
Dissolved Silver (Ag)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	5	-	-	-	<0.1	<0.1	<0.1	0.1
Dissolved Sodium (Na)	mg/L	2600.00	2860.00	3100.00	3000.00	3000	5	-	-	-	2600	2860	3100	-
Dissolved Strontium (Sr)	mg/L	5.40	6.88	8.80	6.40	7.9	5	-	-	-	5.4	6.88	8.8	21000
Dissolved Thallium (Tl)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	5	-	-	-	<0.1	<0.1	<0.1	0.8
Dissolved Tin (Sn)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	-
Dissolved Titanium (Ti)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	-
Dissolved Uranium (U)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	5	-	-	-	<0.1	<0.1	<0.1	300
Dissolved Vanadium (V)	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	5	-	-	-	<2	<2	<2	6
Dissolved Zinc (Zn)	mg/L	<5.0	<5.0	5.60	<5.0	<5.0	5	-	-	-	<5	<5	5.6	30
Cyanate	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	22	<0.005	<0.005	<0.005	<0.05	<0.05	<0.05	-
Strong Acid Dissoc. Cyanide (CN)	mg/L	<0.0010	<0.0010	0.002	<0.0010	<0.0010	22	<0.001	<0.001	0.0012	<0.001	<0.001	0.0018	0.005
Thiocyanate	mg/L	<0.17	<0.17	<0.17	<0.17	<0.17	22	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	-
Weak Acid Dissociable Cyanide (CN-)	mg/L	<0.003	<0.003	0.004	<0.003	<0.003	22	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	-
Benzene	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	22	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0013	2100
Toluene	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	22	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0013	700
Ethylbenzene	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	22	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0013	320
Total Xylenes	mg/L	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	22	<0.002	<0.002	<0.002	<0.002	<0.002	<0.0026	330
>C10-C16 Hydrocarbons	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	22	<0.05	<0.05	<0.05	<0.01	<0.01	<0.013	-
C6 - C10 (less BTEX)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	22	<0.01	<0.01	<0.01	<0.05	<0.05	<0.05	-
>C16-C21 Hydrocarbons	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	22	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	-
>C21-<C32 Hydrocarbons	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-
Modified TPH (Tier1)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.15
Hydrocarbon Resemblance	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-
Radium-226		<0.050	<0.050	<0.050	<0.050	<0.050	2	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0
Total Aluminum (Al)	µg/L	73.00	169.23	350.00	165.00	187.5	22	73	171	350	100	168	260	10
Total Antimony (Sb)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	20
Total Arsenic (As)	µg/L	4.00	12.25	30.00	7.85	17.75	22	4	14.7	30	4.6	10.2	19	5
Total Barium (Ba)	µg/L	2.50	4.11	8.60	3.80	4.375	22	2.5	4.3	8.6	3	3.96	5.8	1000
Total Beryllium (Be)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	5.3
Total Bismuth (Bi)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	-
Total Boron (B)	µg/L	<50	<50	<50	<50	<50	22	<50	<50	<50	<50	<50	<50	1200
Total Cadmium (Cd)	µg/L	<0.010	0.014	0.04	0.014	0.019	22	<0.01	0.0162	0.04	0.01	0.0128	0.022	0.01
Total Calcium (Ca)	µg/L	840.00	1198.18	1700.00	1200.00	1300	22	840	1230	1700	920	1170	1600	-
Total Chromium (Cr)	µg/L	<1.0	<1.0	1.7	<1.0	<1.0	22	<1	<1	1.7	<1	<1	<1	-
Total Cobalt (Co)	µg/L	<0.40	<0.40	0.71	<0.40	<0.40	22	<0.4	<0.4	0.71	<0.4	<0.4	<0.4	10
Total Copper (Cu)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	2
Total Iron (Fe)	µg/L	190.00	483.18	850.00	485.00	617.5	22	190	481	810	200	485	850	300
Total Lead (Pb)	µg/L	<0.50	<0.50	0.86	<0.50	<0.50	22	<0.5	<0.5	0.86	<0.5	<0.5	<0.5	1
Total Magnesium (Mg)	µg/L	350.00	488.18	750.00	460.00	520	22	350	503	750	370	476	630	-
Total Manganese (Mn)	µg/L	29.00	60.00	180.00	54.00	68.5	22	35	70.1	180	29	51.6	88	820
Total Molybdenum (Mo)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	73
Total Nickel (Ni)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	25
Total Phosphorus (P)	µg/L	<100	<100	<100	<100	<100	22	<100	<100	<100	<100	<100	<100	-
Total Potassium (K)	µg/L	130.00	215.91	530.00	190.00	240	22	150	256	530	130	183	310	-
Total Selenium (Se)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	22	<1	<1	<1	<1	<1	<1	1
Total Silver (Ag)	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1
Total Sodium (Na)	µg/L	2100.00	2772.73	3500.00	2800.00	3000	22	2200	2850	3500	2100	2710	3400	-
Total Strontium (Sr)	µg/L	4.50	6.30	11.00	5.85	6.65	22	4.5	6.39	11	4.6	6.22	8.8	21000

Parameter	Units	2016-2017 Statistics						2016 Baseline Statistics			2017 Statistics			NSE Tier 1
	Units	Minimum	Mean	Maximum	Median	75th	Count	Minimum	Mean	Maximum	Minimum	Mean	Maximum	
Total Thallium (Tl)	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.8
Total Tin (Sn)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	-
Total Titanium (Ti)	µg/L	<2.0	<2.0	3.70	2.15	2.5	22	2	<2	3.5	<2	2.07	3.7	-
Total Uranium (U)	µg/L	<0.10	<0.10	<0.10	<0.10	<0.10	22	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	300
Total Vanadium (V)	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0	22	<2	<2	<2	<2	<2	<2	6
Total Zinc (Zn)	µg/L	<5.0	<5.0	6.1	<5.0	<5.0	22	<5	<5	6.1	<5	<5	6	30

Table A.2 2016 Surface Water Monitoring - SW-2

Parameter	March	April	May	June	July	August	September	October	November	December
Anion Sum	0.15	0.12	0.14	0.14	0.13	0.15	0.21	0.13	0.19	0.13
Bicarb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Calculated TDS	-	-	-	-	-	-	-	-	-	-
Carb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cation Sum	0.21	0.18	0.26	0.25	0.28	0.28	0.28	0.31	0.28	0.23
Colour	49	57	52	68	53	33	23	140	74	77
Conductivity	22	22	23	23	24	28	31	35	27	27
Dissolved Chloride (Cl)	5.3	4.2	5	4.8	4.5	5.3	5.1	4.7	5	4.5
Dissolved Fluoride (F-)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Sulphate (SO4)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.6	<2.0	2.2	<2.0
Hardness (CaCO3)	4.4	3.5	4.6	5	5.5	5.1	4.9	7.3	6	5.1
Ion Balance (% Difference)	16.7	20	30	28.2	36.6	30.2	14.3	40.9	19.2	27.8
Langelier Index (@ 20C)	-	-	-	-	-	-	-	-	-	-
Langelier Index (@ 4C)	-	-	-	-	-	-	-	-	-	-
Nitrate (N)	<0.050	<0.050	<0.050	<0.050	0.055	0.052	0.18	<0.050	<0.050	0.07
Nitrate + Nitrite (N)	<0.050	<0.050	<0.050	<0.050	0.055	0.052	0.18	<0.050	<0.050	0.07
Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nitrogen (Ammonia Nitrogen)	<0.050	<0.050	0.062	<0.050	0.095	<0.050	0.062	<0.050	0.091	<0.050
Orthophosphate (P)	0.01	<0.010	<0.010	0.011	0.01	0.011	<0.010	<0.010	<0.010	0.011
pH	6.17	5.62	6.24	5.93	6.66	6.16	6.89	4.9	5.86	5.82
Reactive Silica (SiO2)	1.3	0.88	<0.50	<0.50	0.52	<0.50	<0.50	2.5	1.8	2.2
Saturation pH (@ 20C)	-	-	-	-	-	-	-	-	-	-
Saturation pH (@ 4C)	-	-	-	-	-	-	-	-	-	-
Total Alkalinity (Total as CaCO3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Total Chemical Oxygen Demand	21	17	22	23	24	27	14	67	38	25
Total Mercury (Hg)	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013
Total Organic Carbon (C)	5	4.9	5.5	6.2	7.1	4.6	3.9	19	9.4	9.3
Total Suspended Solids	<1.0	<1.0	<1.0	2.4	<1.0	<1.0	32	1.2	<1.0	10
Total Dissolved Solids	11	9	11	10	11	11	15	14	15	12
Turbidity	1.4	1.3	1.1	1	1.4	1	0.58	3.3	1.4	0.91
Dissolved Aluminum (Al)	-	-	-	-	-	-	-	-	-	-
Dissolved Antimony (Sb)	-	-	-	-	-	-	-	-	-	-
Dissolved Arsenic (As)	-	-	-	-	-	-	-	-	-	-
Dissolved Barium (Ba)	-	-	-	-	-	-	-	-	-	-
Dissolved Beryllium (Be)	-	-	-	-	-	-	-	-	-	-
Dissolved Bismuth (Bi)	-	-	-	-	-	-	-	-	-	-
Dissolved Boron (B)	-	-	-	-	-	-	-	-	-	-
Dissolved Cadmium (Cd)	-	-	-	-	-	-	-	-	-	-
Dissolved Calcium (Ca)	-	-	-	-	-	-	-	-	-	-
Dissolved Chromium (Cr)	-	-	-	-	-	-	-	-	-	-
Dissolved Cobalt (Co)	-	-	-	-	-	-	-	-	-	-
Dissolved Copper (Cu)	-	-	-	-	-	-	-	-	-	-
Dissolved Iron (Fe)	-	-	-	-	-	-	-	-	-	-
Dissolved Lead (Pb)	-	-	-	-	-	-	-	-	-	-
Dissolved Magnesium (Mg)	-	-	-	-	-	-	-	-	-	-

Parameter	March	April	May	June	July	August	September	October	November	December
Dissolved Manganese (Mn)	-	-	-	-	-	-	-	-	-	-
Dissolved Molybdenum (Mo)	-	-	-	-	-	-	-	-	-	-
Dissolved Nickel (Ni)	-	-	-	-	-	-	-	-	-	-
Dissolved Phosphorus (P)	-	-	-	-	-	-	-	-	-	-
Dissolved Potassium (K)	-	-	-	-	-	-	-	-	-	-
Dissolved Selenium (Se)	-	-	-	-	-	-	-	-	-	-
Dissolved Silver (Ag)	-	-	-	-	-	-	-	-	-	-
Dissolved Sodium (Na)	-	-	-	-	-	-	-	-	-	-
Dissolved Strontium (Sr)	-	-	-	-	-	-	-	-	-	-
Dissolved Thallium (Tl)	-	-	-	-	-	-	-	-	-	-
Dissolved Tin (Sn)	-	-	-	-	-	-	-	-	-	-
Dissolved Titanium (Ti)	-	-	-	-	-	-	-	-	-	-
Dissolved Uranium (U)	-	-	-	-	-	-	-	-	-	-
Dissolved Vanadium (V)	-	-	-	-	-	-	-	-	-	-
Dissolved Zinc (Zn)	-	-	-	-	-	-	-	-	-	-
Cyanate	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strong Acid Dissoc. Cyanide (CN)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0012	<0.0010	<0.0010
Thiocyanate	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Weak Acid Dissociable Cyanide (CN-)	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.003
Benzene	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Toluene	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethylbenzene	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Xylenes	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
>C10-C16 Hydrocarbons	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
C6 - C10 (less BTEX)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
>C16-C21 Hydrocarbons	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
>C21-<C32 Hydrocarbons	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Modified TPH (Tier1)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Hydrocarbon Resemblance	-	-	-	-	-	-	-	-	-	-
Radium-226	-	-	-	-	-	<0.050	-	-	-	-
Total Aluminum (Al)	150	140	170	140	170	100	73	350	210	210
Total Antimony (Sb)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Arsenic (As)	5.2	4	30	23	29	20	17	8	5.7	4.9
Total Barium (Ba)	3.6	3.9	3.9	3.6	3.2	3	2.5	8.6	5.8	4.9
Total Beryllium (Be)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Bismuth (Bi)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Boron (B)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Total Cadmium (Cd)	0.015	0.016	0.025	<0.010	<0.010	<0.010	<0.010	0.04	0.024	0.022
Total Calcium (Ca)	1000	840	1200	1200	1400	1200	1200	1700	1400	1200
Total Chromium (Cr)	<1.0	<1.0	1.6	<1.0	<1.0	<1.0	1.7	<1.0	<1.0	<1.0
Total Cobalt (Co)	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	0.71	<0.40	<0.40
Total Copper (Cu)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Iron (Fe)	240	190	580	530	810	480	490	690	430	370
Total Lead (Pb)	<0.50	<0.50	0.86	<0.50	<0.50	<0.50	<0.50	0.52	<0.50	<0.50
Total Magnesium (Mg)	430	350	420	470	520	500	450	750	590	550
Total Manganese (Mn)	43.00	35.00	89.00	55.00	64.00	37.00	53.00	180.00	75.00	70.00

Parameter	March	April	May	June	July	August	September	October	November	December
Total Molybdenum (Mo)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Nickel (Ni)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Phosphorus (P)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Total Potassium (K)	240	210	300	180	150	160	240	530	310	240
Total Selenium (Se)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Silver (Ag)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Sodium (Na)	2400	2200	3100	2800	3000	3500	3500	2700	2900	2400
Total Strontium (Sr)	5.1	4.5	5.2	5.6	6.7	5.9	5.4	11	7.8	6.7
Total Thallium (Tl)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Tin (Sn)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Titanium (Ti)	2.1	<2.0	2.8	<2.0	2.5	<2.0	<2.0	3.5	<2.0	2
Total Uranium (U)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Vanadium (V)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Zinc (Zn)	<5.0	<5.0	6.1	<5.0	<5.0	<5.0	<5.0	6.1	<5.0	<5.0

Table A.3 2017 Surface Water Monitoring - SW-2

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Anion Sum	0.17	0.12	0.17	0.1	0.12	0.12	0.11	0.13	0.15	0.15	0.17	0.17
Bicarb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Calculated TDS	13	10	12	8	10	9	10	10	14	12	14	13
Carb. Alkalinity (calc. as CaCO3)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cation Sum	0.26	0.21	0.21	0.18	0.21	0.24	0.26	0.23	0.3	0.26	0.28	0.23
Colour	61	55	44	52	74	63	59	48	110	72	110	84
Conductivity	29	24	25	21	22	24	24	24	29	27	33	28
Dissolved Chloride (Cl)	5.8	4.3	4.6	3.6	4	4.3	3.9	4.3	5.4	5.2	5.9	5.9
Dissolved Fluoride (F-)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Sulphate (SO4)	<2.0	<2.0	2	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Hardness (CaCO3)	4.7	4.5	4.3	3.8	4.3	4.4	5	4.7	6.7	5.3	6.2	4.8
Ion Balance (% Difference)	20.9	27.3	10.5	28.6	27.3	33.3	40.5	27.8	33.3	26.8	24.4	15
Langelier Index (@ 20C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Langelier Index (@ 4C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Nitrate (N)	0.073	<0.050	<0.050	<0.050	0.12	<0.050	<0.050	0.092	<0.050	<0.050	<0.050	<0.050
Nitrate + Nitrite (N)	0.073	<0.050	<0.050	<0.050	0.12	<0.050	<0.050	0.092	<0.050	<0.050	<0.050	<0.050
Nitrite (N)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nitrogen (Ammonia Nitrogen)	0.082	<0.050	<0.050	-	0.14	0.05	<0.050	0.062	<0.050	<0.050	<0.050	<0.050
Orthophosphate (P)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.011	<0.010	<0.010	<0.010	<0.010	<0.010
pH	5.63	6.03	5.96	5.92	6.28	6.33	6.47	6.23	6.18	6.06	5.84	5.97
Reactive Silica (SiO2)	1.9	1.8	1.3	0.74	0.71	<0.50	0.51	0.52	2.1	1.3	2.2	1.9
Saturation pH (@ 20C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Saturation pH (@ 4C)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
Total Alkalinity (Total as CaCO3)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Total Chemical Oxygen Demand	27	23	21	24	20	27	22	26	35	28	43	28
Total Mercury (Hg)	<0.013	<0.013	<0.013	<0.013	<0.013	0.02	<0.013	<0.013	0.013	<0.013	<0.013	<0.013
Total Organic Carbon (C)	6.5	5.7	4.4	4.7	6.9	7.2	7.6	7	13	10	13	13
Total Suspended Solids	<1.0	<1.0	<1.0	1.6	<2.0	1.4	<2.0	<1.0	1.2	<1.0	1.2	<1.0
Total Dissolved Solids	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	1.2	1.1	0.96	1.2	1.4	1.1	0.66	0.43	0.7	0.71	1.8	1
Dissolved Aluminum (Al)	-	-	-	-	-	-	-	70	220	150	270	170
Dissolved Antimony (Sb)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Arsenic (As)	-	-	-	-	-	-	-	13	13	6.9	5.2	5.1
Dissolved Barium (Ba)	-	-	-	-	-	-	-	2.8	5.2	3.7	6.5	4.7
Dissolved Beryllium (Be)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Bismuth (Bi)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Boron (B)	-	-	-	-	-	-	-	<50	<50	<50	<50	<50
Dissolved Cadmium (Cd)	-	-	-	-	-	-	-	<0.010	0.018	<0.010	0.027	**0.017**
Dissolved Calcium (Ca)	-	-	-	-	-	-	-	1100	1700	1300	1500	1100
Dissolved Chromium (Cr)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Cobalt (Co)	-	-	-	-	-	-	-	<0.40	<0.40	<0.40	<0.40	<0.40
Dissolved Copper (Cu)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Iron (Fe)	-	-	-	-	-	-	-	320	660	450	450	310
Dissolved Lead (Pb)	-	-	-	-	-	-	-	<0.50	<0.50	<0.50	<0.50	<0.50
Dissolved Magnesium (Mg)	-	-	-	-	-	-	-	450	620	490	620	510

Parameter	January	February	March	April	May	June	July	August	September	October	November	December
Dissolved Manganese (Mn)	-	-	-	-	-	-	-	20	66	31	84	57
Dissolved Molybdenum (Mo)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Nickel (Ni)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Phosphorus (P)	-	-	-	-	-	-	-	<100	<100	<100	<100	<100
Dissolved Potassium (K)	-	-	-	-	-	-	-	180	210	180	320	210
Dissolved Selenium (Se)	-	-	-	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0
Dissolved Silver (Ag)	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Sodium (Na)	-	-	-	-	-	-	-	2600	3100	3000	3000	2600
Dissolved Strontium (Sr)	-	-	-	-	-	-	-	5.4	8.8	6.4	7.9	5.9
Dissolved Thallium (Tl)	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Tin (Sn)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Titanium (Ti)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Uranium (U)	-	-	-	-	-	-	-	<0.10	<0.10	<0.10	<0.10	<0.10
Dissolved Vanadium (V)	-	-	-	-	-	-	-	<2.0	<2.0	<2.0	<2.0	<2.0
Dissolved Zinc (Zn)	-	-	-	-	-	-	-	<5.0	<5.0	<5.0	5.6	<5.0
Cyanate	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Strong Acid Dissoc. Cyanide (CN)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	0.0018	<0.0010	0.001	0.0013	<0.0010	<0.0010	<0.0010
Thiocyanate	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17	<0.17
Weak Acid Dissociable Cyanide (CN-)	<0.003	<0.003	<0.003	<0.003	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Benzene	<0.0010	<0.0010	<0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Toluene	<0.0010	<0.0010	<0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethylbenzene	<0.0010	<0.0010	<0.0013	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Xylenes	<0.0020	<0.0020	<0.0026	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020
>C10-C16 Hydrocarbons	<0.010	<0.010	<0.013	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
C6 - C10 (less BTEX)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
>C16-C21 Hydrocarbons	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
>C21-<C32 Hydrocarbons	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Modified TPH (Tier1)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Hydrocarbon Resemblance	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radium-226	-	-	-	<0.050	-	-	-	-	-	-	-	-
Total Aluminum (Al)	190	150	140	130	170	160	140	100	220	170	260	180
Total Antimony (Sb)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Arsenic (As)	4.6	4.7	6.9	6.2	11	18	19	17	16	7.7	6.1	5.5
Total Barium (Ba)	4.3	3.9	3.7	3.2	3.9	3.4	3.4	3	5.1	3.4	5.8	4.4
Total Beryllium (Be)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Bismuth (Bi)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Boron (B)	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Total Cadmium (Cd)	0.018	0.012	0.016	0.018	0.013	<0.010	<0.010	<0.010	0.01	**0.011**	**0.022**	**0.019**
Total Calcium (Ca)	1100	1100	1000	920	1000	1100	1300	1200	1600	1300	1400	1000
Total Chromium (Cr)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Cobalt (Co)	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40
Total Copper (Cu)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Iron (Fe)	320	290	250	200	340	630	750	610	850	590	620	370
Total Lead (Pb)	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Total Magnesium (Mg)	490	460	420	370	430	420	460	460	600	520	630	450
Total Manganese (Mn)	61	51	42	35	58	52	41	29	71	35	88	56

Parameter	61	51	42	35	58	52	41	29	71	35	88	56
Total Molybdenum (Mo)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Nickel (Ni)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Phosphorus (P)	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Total Potassium (K)	150	150	170	200	170	170	130	150	220	160	310	210
Total Selenium (Se)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Silver (Ag)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Sodium (Na)	3200	2400	2500	2100	2300	2800	2900	2600	3400	3000	3000	2300
Total Strontium (Sr)	6.1	5.8	5.6	4.6	5.6	5.6	6.5	5.7	8.8	6.4	7.5	6.4
Total Thallium (Tl)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Tin (Sn)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Titanium (Ti)	<2.0	<2.0	<2.0	<2.0	2.2	2.4	2.7	2.2	3.7	3	2.2	2.5
Total Uranium (U)	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Vanadium (V)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Total Zinc (Zn)	<5.0	<5.0	<5.0	<5.0	6	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0

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Appendix G.7

Beaver Dam Conceptual Treatment Approach

Wood Environment & Infrastructure Solutions,
a Division of Wood Canada Limited
900 Maple Grove Road, Unit 10
Cambridge, ON N3H 4R7
Canada
T: 519-650-7100

Technical Memo

To: Jim Millard, Atlantic Gold Corporation

From: Jered Munro, Wood
Katy Falk, Wood

Reviewer: Clifton Warren, Wood

cc: Meghan Milloy, McCallum Environmental

Project No.: TPC182121

Date: 26 February 2019

Re: Beaver Dam Mine Site Conceptual Minewater Treatment Design

---

1.0 Introduction

Wood Environment & Infrastructure Solutions (Wood) was retained by Atlantic Gold Corporation (AGC) to develop a conceptual treatment process for the Beaver Dam Gold Mine Project. In addition, a list of possible chemical reagents and preliminary predicted annual consumption rates are provided. This information is intended to support the Beaver Dam Mine Project - Environmental Impact Statement.

The proposed water treatment plant is a component of the Beaver Dam Gold Mine Project located near Trafalgar, Halifax County, Nova Scotia. GHD Consultants has prepared Water Balance Analysis[1] and Predictive Water Quality Assessment Reports[2] for the Beaver Dam Mine Site to predict the quality and quantity of mine contact water generated from the site and its potential impacts to the Killag River. Modelling was completed for two temporal scenarios: operations phase at end-of-mine and the post-closure phase. The results of the modelling from the report indicate that treatment of the minewater may be required under certain environmental conditions to maintain compliance with the MDMER effluent criteria and applicable receiving environment criteria at the near-field mixing zone downstream of the point of treated minewater discharge into the river.

2.0 Design Conditions

The basis of design for the Conceptual treatment process is defined by the data provided in the GHD Water balance and Predictive Quality Reports[1,2,].

2.1 Design Considerations

2.1.1 Minewater Treatment System Requirements

It is expected that the following criteria will inform the design of the minewater treatment process:

- Provide sufficient treatment to meet the effluent criteria summarized in the GHD Reports[1,2,].

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[1] Water Balance Analysis, Beaver Dam Mine Site, Prepared by GHD Consultants for Atlantic Gold Corporation, January 17, 2019

[2] Predictive Water Quality Assessment, Beaver Dam Mine Site, Prepared by GHR Consultants for Atlantic Gold Corporation, January 18, 2019

- Be sized for the maximum design flow identified in the end of mine and post closure conditions as presented in the GHD Reports[1,2].
- Include adequate storage capacity in the pit to allow for process downtime and maintenance.
- Automate the main treatment processes to allow un-manned operation during weekends, evenings, and weekdays when an operator is not present.
- Include a centralized control system that can be monitored remotely via an internet connection.
- Provide sufficient chemical storage and containment for at least one week of run time at average conditions.
- Where possible place critical process tanks and equipment indoors to prevent vandalism and alleviate security concerns.
- Comply with applicable, relevant, or appropriate regulations and standards (federal, provincial, and local).
- Comply with appropriate industry, professional engineering, and technical standards.

The approach to the development of a minewater treatment system is two-fold as follows:

1. Consideration of the requirements to treat existing wastewater discharges for the end-of-mine operations phase; and
2. Continuation of treatment of mine drainage through the post-closure phase.

It is noted that the current process at the Touquoy Mine utilizes Geotubes for the processing of minewater after mixing and co-precipitation. Although this system appears to be operating well under the current effluent quality management strategy, this technology may not be the best suited for the longer term mine drainage requirement after mine closure. It is noted that for each phase, the characteristics of the minewater requiring treatment will be different.

The proposed treatment strategy developed and documented below consists of:

1. A proven conventional physico-chemical treatment approach meeting both short-term and long-term objectives; and/or
2. Continued utilization of the Geotube approach or variant thereof as a stand-alone treatment process and/or in conjunction with components of the conventional physico-chemical treatment method.

2.2 Minewater Pumping System Design

2.2.1 Minewater Transmission Piping

During operations at the Beaver Dam Mine Site, the mine contact water will be directed to the North Settling Pond and be conveyed via an HDPE piping system to the treatment plant. During Closure and Post-Closure Conditions, the site contact water will be conveyed to an open pit. The collected water will be pumped to a treatment plant on a seasonal basis. The treated effluent from the Treatment Plant will be discharged to the Killag River via a suitably armoured discharge ditch or a pipeline outfall.

The piping will be run above ground and will not require freeze protection as the intent is to operate on a seasonal basis.

Pipe size will be selected to provide suitably low pressure drop at the maximum flow condition. The layout will be developed to provide reliable flow conditions, with minimal piping lengths.

2.2.2 Pumps, Electrical, and Controls

The pit pumps will be selected to provide sufficient head to overcome the static head of the pit depth and dynamic pressure losses due to friction from piping and fittings.

The pumps will have integral dry-run protection, to prevent damage to the pumps in the event that the pit level drops below the suction of the pumps.

Each pit pump will have variable speed control, to allow control of the pit water level. The pumps will be controlled by the treatment systems centralized programmable logic controller (PLC) that will utilize a level sensing transmitter to control the operation of the pumps. The run time of each pump will be totalized by the PLC to provide appropriate maintenance intervals.

2.3 Minewater Treatment System Process Design

The minewater treatment system that is being proposed has been selected and is based on the predicted water quantity and quality estimates in the GHD Reports[1,2,] and treatment data collected from the Effluent Treatment Plant at the Atlantic Gold Mine Site. Due to the variability in the physical characteristics of the environment and its impact on the actual water quality that will be present on-site, Wood has included treatment processes that are not only intended to be required for treatment of the minewater for both phases but that can also be employed in order to ensure the required effluent quality is consistently achieved through the post-closure period based on current understanding of the regulations and site-specific effluent criteria. The process flow diagram is presented as Figure 1.

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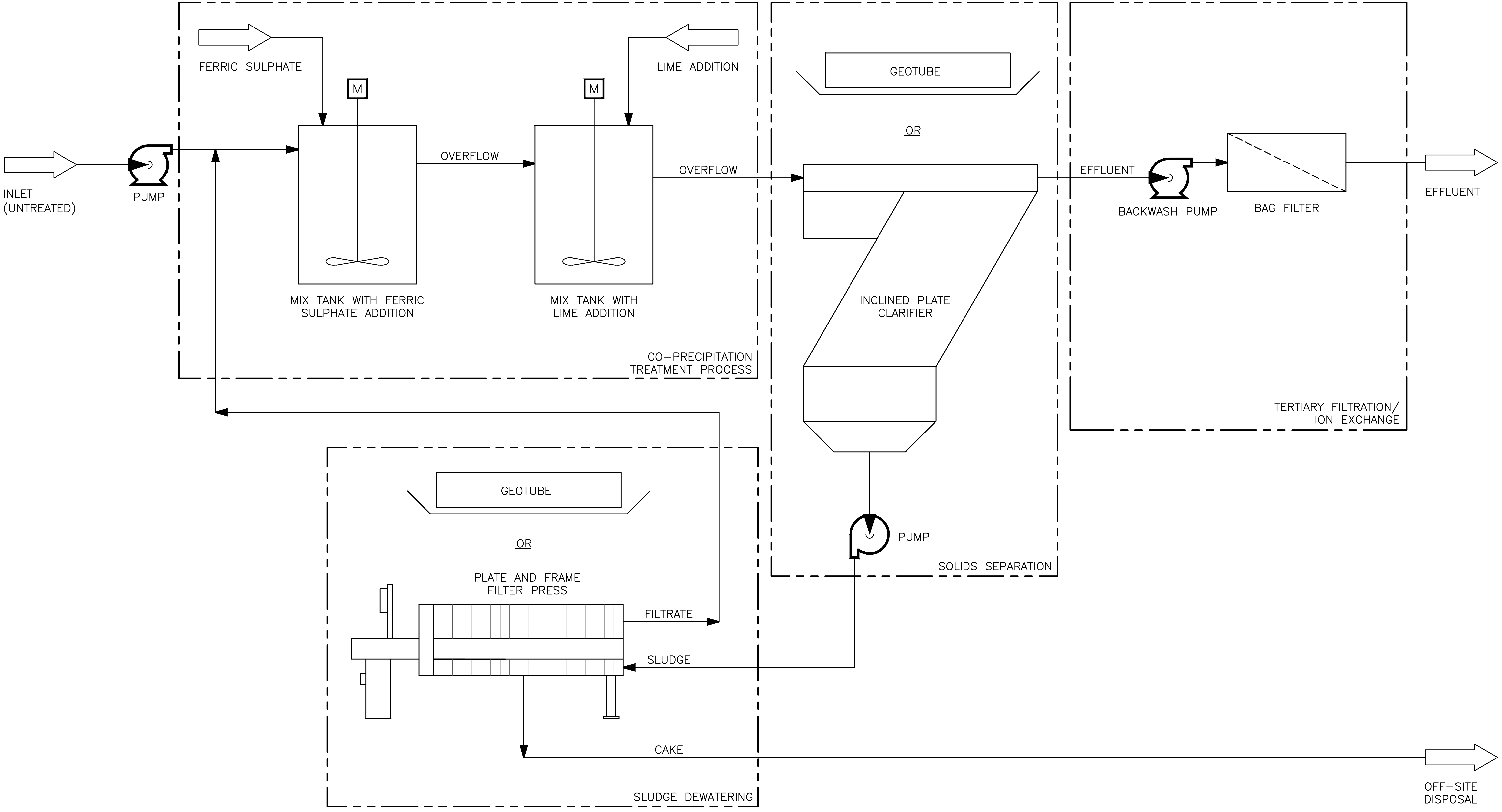

ATLANTIC GOLD
TREATMENT SYSTEM

PROCESS FLOW DIAGRAM

Project No.	-
Date	FEBRUARY 2019
Scale	N.T.S.
Drawing No.	F-01

2.3.1 Process Design

The mine water treatment system will be designed to provide removal of the contaminants identified in Table 3.9 and 3.13 of the Predictive Water Quality Assessment report[2]. The predictions from the modelling in the water quality report indicate that arsenic, copper, zinc, cadmium and iron will require treatment for the post-closure phase in order to achieve effluent concentrations that meet the required MDMER criteria at the discharge location as well as the applicable receiving water quality criteria at near field monitoring point on the Killag River, just downstream from a 100 m mixing zone. The flow rates and parameters required to be treated and removed (kg/yr) for the end-of-mine operations phase and post closure conditions, as based on the GHD Reports[1,2,] , are provided in **Error! Reference source not found.**

Table 1: Treatment System Design Basis

	Operations Phase End-of-Mine	Post-Closure Phase
Flow (average m^3/yr)[1]	1,600,000	1,200,000
Flow (average m^3/hr)[3]	448m^3/hr	336m^3/hr
Arsenic (kg/yr)	0.0	25.7
Iron (kg/yr)	13.5	0.0
Copper (kg/yr)	0.0	26.0
Zinc (kg/yr)	0.0	2.6
Cadmium (kg/yr)	0.0	0.0[4]

The conceptual treatment system would consist of a combination of the following treatment processes as required; oxidation (as required), co-precipitation, clarification/filtration, pH adjustment (as required), filtration, and adsorption/ion exchange (as required).

For the purposes of the conceptual treatment design, the solids-laden effluent from the chemical precipitation step could be filtered using the passive Geotube filtration technology or through a clarification step which would produce an underflow at a lower volume and higher concentration of solids stream. This underflow stream could be dewatered using the Geotube filtration process or a mechanical dewatering process such as a filter press. The dewatered residuals could be stored at a permitted storage location on-site or at permitted off-site approved waste disposal site. The options for treatment and use of the Geotube process in the context of the overall treatment strategy are further described below and consist of providing more detail for the conventional physico-chemical treatment system which is to be considered as the preferred long-term option to the current Geotube process or variant thereof. A schematic of the proposed process system is included in Figure 1.

2.3.1.1 Chemical Oxidation (as Required)

It is not expected that oxidation will be required but may be dependent on the form of the dissolved metals species that are present. In the event that oxidation is required, minewater from the pit will be pumped to an oxidation tank. The flow will be measured by an influent flow meter before it enters the oxidation tank. The oxidation tank and downstream co-precipitation system consisting of first, a mix tank for primary coagulant

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[3] Average flow is assumed at 80% uptime for a 6-month operating period.

[4] Cadmium removal is not required based on effluent criteria however pH adjustment may be required to reduce toxicity for site specific requirements.

addition (ferric sulphate) and, followed by a second mix tank for lime addition will be completely-mixed to provide load equalization which will help to dampen changes in influent concentration of the various parameters.

The purpose of the oxidation tank is to provide mixing time for the addition of a chemical oxidant such as potassium permanganate ($KMnO_4$), Hydrogen Peroxide, Fenton's Reagent prior to Physico-chemical treatment. The addition of an oxidant will cause both arsenic (III) and iron (II) to be oxidized to arsenic (V) and iron (III) respectively. The higher oxidation states of arsenic and iron precipitate more readily.

The oxidation tank working volume should be sized to provide approximately 10 to 30 minutes of residence time at the average treatment flow rate depending on the water matrix and chemistry that is selected. Mixing may be provided by a top-mounted mixer. The tank will be completely mixed to ensure sufficient distribution of the oxidant and reduce the likelihood of short-circuiting.

During the filling stage of the Beaver Dams Pit, treatability testing will be required to confirm the pit water quality and to determine the recommended dosage for the treatment system at the Beaver Dam pit. The oxidant handling system should be designed to provide a range of dosages to provide the required flexibility for changes in the minewater quality, and to service the full range of minewater flows that are realized.

Due to the flows required for seasonal treatment, a bulk handling system is typically employed for make down of the required chemistry. It is expected that if required, flexible intermediate bulk containers (FIBC) of oxidant would be purchased from a local chemical supplier and delivered to the AGC site as-needed. The system will incorporate instrumentation to allow a known mass/volume of oxidant to be incorporated in a make-up tank. The make-up tank will have a volume which will allow approximately 7 days of run time before becoming empty.

The solution will be fed to the oxidation tank via a vendor-supplied dosing skid including two diaphragm metering pumps to ensure accurate dosing. The solution will be fed to the system at a rate that is proportional to the influent minewater flow.

An oxidation-reduction potential (ORP) meter will be installed in the oxidation tank to ensure oxidative conditions are maintained. A warning alarm will be initiated if the ORP is outside of the expected range to alert the operator that there is a potential problem with the oxidant dosing system.

2.3.1.2 Co-Precipitation

After the oxidation step, the minewater will be pumped to the two (2) tank co-precipitation system. Ferric Sulphate will be added to the first tank at a predetermined ratio to provide adequate iron for co-precipitation of arsenic. It is expected that a weight ratio of between 15:1 and 55:1 of ferric cation to the metals requiring treatment will be needed depending on the water matrix and the removal efficiency that is required to achieve the effluent criteria. Cadmium is also expected to be co-precipitated with the addition on ferric sulphate. Lime will be added to the second tank to raise the pH to a target value to induce the co-precipitation of arsenic with the iron that has been added to the minewater. This is a recognized method for the removal of arsenic and is successfully employed at the existing Touquoy Mine Site. Increasing the pH is also expected to precipitate copper. The two-stage system is the preferred co-precipitation method to be implemented if multiple pH ranges or better pH control are needed. Alternatively, a single tank system could be used but will not provide the same level of process flexibility on control as a two (2) tank system.

The iron (III) present will form hydroxides at the elevated pH and tend to precipitate, while forming metal complexes with the arsenic. These precipitates will settle out in the inclined plate clarifier and be removed from the minewater stream.

The co-precipitation tank should have a working volume to provide approximately 10 to 30 minutes of retention time. The tank will be completely mixed.

2.3.1.3 Solids Separation

Following precipitation of metals, the resulting suspended solids will be removed by a solids separation process. The clarified effluent will be discharged to the environment if meeting effluent criteria. Additional treatment processes downstream of the clarification step will be employed if further treatment is required. It is expected that one of two processes would be considered for solids separation.

Clarifier Option

The minewater could be conveyed by gravity from the co-precipitation tank to an inclined plate clarifier. The clarifier system will be provided with integral flash mix and flocculation tanks. A polymer flocculant will be added directly to the flash mix tank at a rate proportional to the influent minewater flow rate. The polymer will further agglomerate the pre-treated minewater from the co-precipitation process resulting in the production large floc formations of bridged particulates and promoting sweep floc, uniform rapid settling through the clarification step.

The polymer will be purchased as neat liquid and will be diluted to a concentration of between 0.1 and 0.5% (wt/wt) in batches with a vendor-supplied make down system designed especially for effective wetting of the polymer for optimum effectiveness.

The rapid mix tank will provide complete mixing of the minewater and the dilute polymer solution. The flocculation tank will provide a period of slow mixing to allow proper floc formation. The flocculated minewater will flow into the inclined plate area, allowing the solids to settle to the sludge hopper, and with the clarified minewater discharged as overflow from the effluent weir.

Geotube Option

As an alternative to the Clarifier Option, the minewater could be conveyed by gravity from the co-precipitation process to a Geotube array. The pre-treated minewater from oxidation (if required) and co-precipitation would flow by gravity into the Geotubes with the precipitated solids retained inside the Geotube and with the clarified effluent passing through the permeable fabric into a collection point for discharge via gravity or through a pumped pressure system to a permitted discharge location/structure.

2.3.1.4 pH adjustment

The treatment process may require operation of the process at elevated pH to achieve the optimum precipitation of metals. The pH adjustment will first be achieved in the co-precipitation process through the controlled dosage with lime and as required to best co-precipitate metals, including arsenic in the effective pH range for these materials. This may require operating the co-precipitation process at a pH range above the acceptable upper limit required for effluent discharge. The various aspects and process design requirements for metals removal will consider arsenic adsorption and/or required bonding with the co-precipitated materials.

Once the co-precipitated materials are removed by clarification (conventional physico-chemical treatment) or by the usage of Geotubes for liquid/solids phase separation, further pH adjustment may be required on the clarified effluent to meet discharge criteria. The pH would be lowered by the addition of 93-97% sulfuric acid (H_2SO_4). It is recommended that the pH tank would have a working volume that provides suitable residence time to achieve pH neutralization and stabilization. The pH tank would be completely mixed with a top mounted mixer.

Acid would be added to the pH adjust tank via a vendor-supplied dosing skid, utilizing diaphragm metering pumps. The wetted parts of the pumps, and the acid tubing will be Teflon® or other material selected to ensure compatibility with concentrated sulfuric acid. The rate of acid addition will be controlled by a pH control loop in the PLC.

Concentrated acid would be delivered in 1 m3 chemical totes. The totes will be placed on pre-fabricated spill-containment platforms as soon as they are delivered to provide secondary containment in the event of a leak. Two totes will be on site at any given time, to allow one to be in use while the second is being replaced.

2.3.1.5 Filtration and Adsorption (as Required)

Depending on the effectiveness of the upstream treatment processes, the actual water matrix and the permitted effluent concentrations to meet discharge criteria, additional effluent polishing steps may be required to achieve, in particular, low levels of arsenic. These effluent polishing steps may include conventional filtration followed by adsorption on a media such as activated alumina or a titanium based media.

After pH neutralization (where required), the minewater will be transferred from the pH tank to the downstream effluent polishing system. The transfer system will include pumps to operate the filters and the adsorption process including backwashing provisions.

The conventional filters will remove any remaining particulate to prevent potential clogging and fouling of the downstream adsorption process.

For the adsorption process, an empty bed contact time used will be used as recommended by the media manufacturer sufficient to size the full-scale equipment. The equipment will be verified through treatability testing. The adsorption system will consist of a two-tank configuration operated in series. Once the target bed volumes of minewater have been treated, or breakthrough of arsenic is detected in samples collected after the first tank, the media in the first tank would be replaced, and the second tank would become the primary tank. The spent media will either be returned to the vendor to be recycled or will be transported to an appropriate waste facility.

2.3.1.6 Sludge Management

Precipitated solids can be managed using several treatment techniques and will dependent on the level of treatment required. For the conventional physico-chemical treatment system, solids management consists of collecting underflow solids from the clarification processes and thickening of these solids before dewatering. The thickened sludge would then be dewatered through a filter press or comparable equipment.

It is expected that thickening would provide lower volume of sludge storage volume due to increased solids concentration but will require a more complex process to achieve. The underflow from a clarification step would be pumped to a sludge storage /thickening tank with an air-diaphragm pump. The sludge storage tank will have a working volume adequate to accommodate three days of production. The sludge would be treated in batches through a dewatering process such as a filter press. The filter press requires operator attention, so the sludge dewatering process is typically manually initiated when an operator is on site.

Alternatively, and through using the Geotube option, the sludge underflow from clarification could be transferred to geotubes for thickening and dewatering. The geotubes would then be disposed of when filled and once thickening and in-situ dewatering is accomplished.

2.3.1.7 Chemical Reagents

The estimated preliminary chemical consumption rates are outlined in Table 2. The estimates are based on the upper case flows and quantities estimated by GHD[1,2]. Reagents will be stored in accordance with applicable regulatory requirements. Proper containment and separation of chemicals will be provided.

Table 2: Reagent Consumption Estimate

	Estimated Minimum		**Estimated Maximum**	
	Dose	**Consumption**	**Dose**	**Consumption**
		kg/yr		kg/yr
Oxidation Chemicals	Not Expected to be Required		Not Expected to be Required	
Ferric Sulphate 50%	15 wt Fe/wt As	30,000[5]	120 wt Fe/ wt As	270,000
Lime Slurry 10%[6]	0.025 kg/m^3	30,000	0.147 kg/m^3	240,000
Sulphuric Acid	Not Expected to be Required		Not Expected to be Required	
Polymer [6]	0.001 kg/m^3	2,000	0.005 kg/m^3	9,000

2.3.1.8 Instrumentation and Control

The system will be designed to be automated to the extent practical. It is estimated the system will require two visits to the site per week by a qualified operator. The frequency may be higher during periods of high minewater flow.

The treatment system will include a significant amount of instrumentation for control and monitoring purposes. The primary treatment equipment and instrumentation will be automated with a single, centralized programmable logic controller (PLC). The system will be operated through a human machine interface (HMI) located in the treatment building. The system will also have remote monitoring and data collection capabilities through an internet interface, to allow the operator to view the status of the system at any time from an alternate location. The control system will also have dial-out functionality so that critical alarms can trigger an automated call to the operator's mobile phone.

The control system will include data logging and tracking of all process inputs.

2.3.2 Treatment System Pad and Building

The treatment system will require a building structure to house the proposed equipment, process pumping systems and tankage.

2.3.2.1 Building Pad

The surface of the building pad will be predominantly 3/4-inch crushed rock; however, a sloped concrete pad should be considered for offloading of chemicals to provide a location for collection if a spill were to occur during unloading.

2.3.2.2 Treatment Building

A treatment building will be considered for housing the treatment system and would consist of a pre-fabricated or pre-engineered structure. The building would contain the treatment equipment, chemical storage tanks, a washroom, an electrical room, and a combined office and lab area for bench scale testing and process monitoring.

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[5] Chemical Dosing estimated based on existing Atlantic Gold ETP dosing requirements at Touquoy Mine Site.

[6] Based on understanding of existing treatment system design at Touquoy Mine Site.

Pre-engineered metal clad buildings are typically cost-effective and have a long lifespan with relatively low maintenance.

The building would include two man-doors: one for everyday access and the second for emergency egress. The building will also include a 12-foot roll-up door to allow access for bulk chemical deliveries and to move equipment in and out of the building for maintenance purposes.

If year-round treatment was employed the building would be heated to maintain the interior temperature above a minimum of 10˚C. The building would need to be insulated with a minimum of R20 insulation for the walls and R30 for the roof. An exhaust fan will be utilized to prevent excess heat build-up in the summer.

2.3.2.3 Layout

The building layout will incorporate the following considerations when determining the layout for the design.

- If required, adsorption tanks or columns should be positioned close to the roll-up door since the media will need to be removed and replaced periodically.
- Coagulant and acid storage and dosing areas should be separated from the lime storage and dosing areas due to chemical compatibility.
- If employed, the dewatering process should be positioned near the outside wall to allow easy transportation of the solids.

2.3.2.4 Utilities

Power for the building, including three-phase power for large motors, and single-phase power for small motors, lighting, and instrumentation, will be required from either a fixed transmission system or on-site generator.

Power will be supplied to each of the pit through buried utility trenches, from a distribution panel in the electrical room.

Potable water will be required for chemical make down and general cleaning and housekeeping operations. A storage tank and pressurized supply system will be required as part of the design considerations.

An internet connection for the remote monitoring of the control system, as well as for alarm call-outs to the operator's mobile phone will be required.

2.3.2.5 Security

Due to concerns over potential property damage or malicious interference, all critical process equipment and chemical storage tanks will be housed inside the treatment building. The treatment building doors will remain locked at all times. The building will have no windows to minimize the potential for vandalism damage.

The roll-off containers for the solids storage will be stored outside in a fenced area with a locked gate.

Sincerely,

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited

<Original signed by>

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