



***Mount Nansen
Aquatic Effects Monitoring Program***

**Prepared for:
Yukon Government
Energy, Mines and Resources
Assessment and Abandoned Mines**

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1. Introduction

The Government of Yukon, Assessment and Abandoned Mines Branch (AAM) is preparing an assessment of the Mount Nansen Care and Maintenance Project (the Project) at the Mount Nansen Site (the Site), which is a former gold and silver mine. As part of these activities, a water treatment plant has been proposed for the Site as an interim mitigation measure until the closure plan is implemented. The main components of existing infrastructure at the Site include the Brown McDade Pit, waste rock, the mill complex, the tailings storage facility (TSF) which consists of a tailings dam, seepage collection dam, and a seepage collection pond. The proposed water treatment plant will be located adjacent to the seepage collection pond. Water from the seepage collection pond would be treated and released to Dome Creek downstream of the TSF.

This document describes an aquatic effects monitoring program (AEMP) for the Project. The AEMP is a monitoring and data collection tool that will be used to assess changes in the aquatic health of the downstream receiving environment and to inform the adaptive management plan (AMP; Appendix 7D of the Project Proposal) and Site compliance objectives. The AEMP provides a structure for monitoring indicators of water quality and aquatic environmental health in the downstream receiving environment from the Site, with a focus on Dome Creek and Victoria Creek.

1.1 Objectives

The AEMP is intended to provide a comprehensive monitoring and data collection program that addresses three objectives:

1. To provide surface water quality to inform the Site AMP and to meet Site compliance requirements;
2. To provide data that informs operators and stakeholders of the performance of the Project during its term; and
3. To provide a structure for establishing a long-term monitoring program that is intended to continue from remediation into closure.

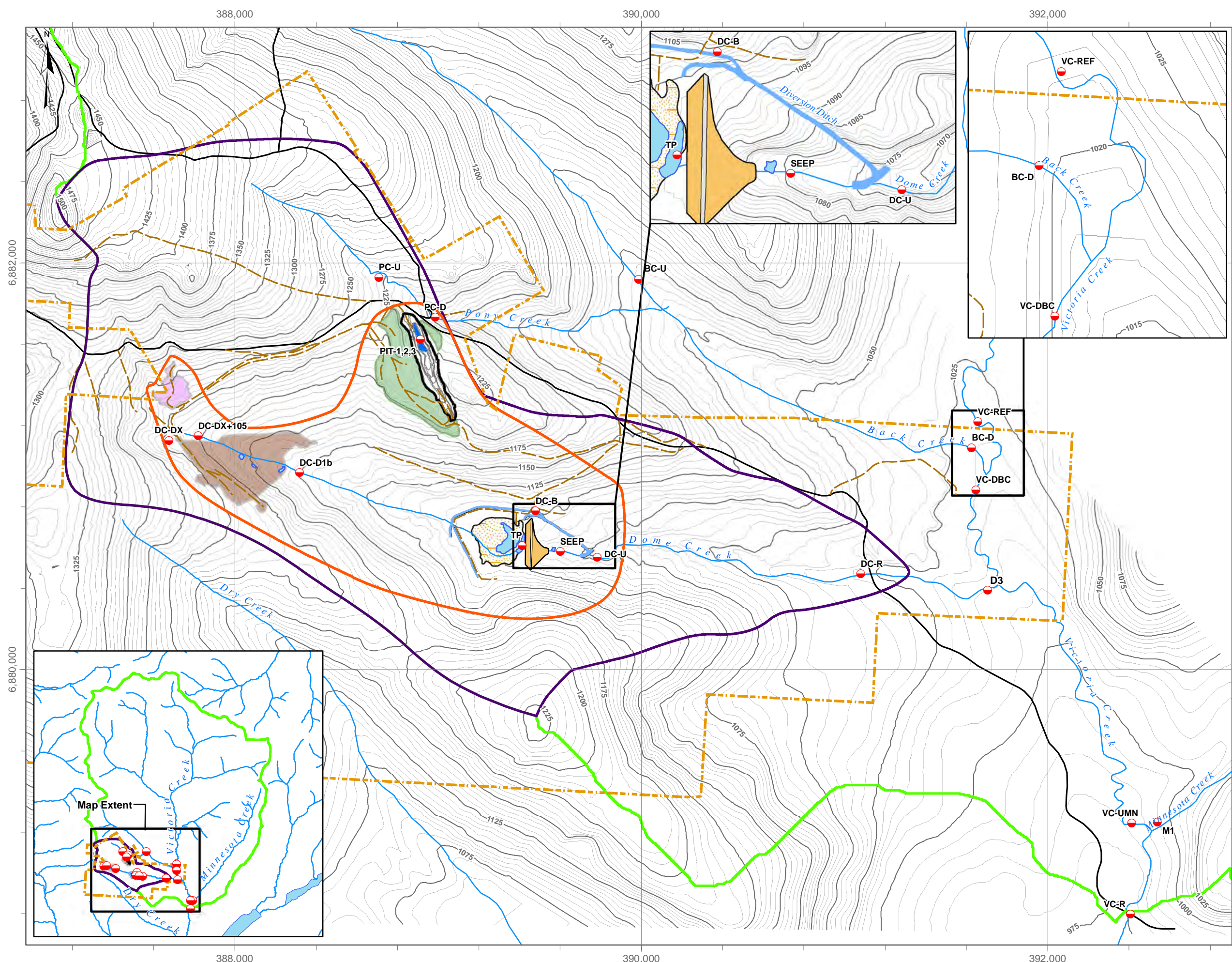
1.2 Location

The Site is located approximately 45 km west of the Town of Carmacks Yukon (70 km by road), within the traditional territory of the Little Salmon Carmacks First Nation (Figure 1.1-1). The Site is located within the Victoria Creek catchment, with surface discharges reporting primarily to Dome Creek (a tributary of Victoria Creek; Figure 1.2-2). Existing

environmental conditions for the Project relevant to the AEMP are described separately in Appendix 6D (Surface Water Quality Existing Environment Summary) and Appendix 6E (Aquatic Environment Existing Conditions) of the Project Proposal.



Figure 1.2-1 Mount Nansen Location Map



LEGEND

- Monitoring Station
- ▭ PSA
- ▭ LSA
- ▭ RSA
- - - Mount Nansen OIC Boundary
- Mill Area
- Mine Camp Area
- Tailings Dam
- Tailings
- Pond
- ▭ Pit Outline
- Waste Rock Area
- - - Mine Road
- Public Road
- 25m Contour
- 5m Contour

Coordinate System: NAD 1983 UTM Zone 8N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter
 1:18,000
 0 200 400 Meters

DATE SAVED:	Mar 30, 2017
DRAWN BY:	GM
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VERSION:	1



PROJECT:
**Mount Nansen
 Care & Maintenance
 Project Proposal**

TITLE:
**Mount Nansen
 Proposed Monitoring Stations**

PROJECT #:	A422-1	FIGURE:	1.2-2
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1.3 Approach

The AEMP has been designed to inform both short- and long-term decision making as it pertains to maintaining and protecting the health of the Project receiving environment (Table 1.3-1). The AEMP has been designed to characterize and monitor for changes in the physical, chemical, and biological environment, through the following components:

- Surface water quality – concentrations of metals, anions, and general chemical parameters (*e.g.*, pH);
- Stream sediments – metal concentrations, particle size, and organic content;
- Periphyton – Chlorophyll *a*, taxonomic composition and community metrics;
- Benthic invertebrates – taxonomic composition and community metrics; and
- Aquatic habitat – flow and velocity, slope, substrate embeddedness, riverbank vegetation, riverbank characterization (*e.g.*, bank width) and substrate.

During the project, surface water quality data outlined in the AEMP will help inform Site water management including water treatment. The AEMP is intended to inform the Adaptive Management Plan (AMP) for the Site as well as compliance requirements (*e.g.*, Water Licence effluent standards). In this regard, certain surface water quality parameters are tied directly into the AMP and associated triggers are intended to function as a quantitative metric for short-term decision-making.

Data collected as part of this AEMP is intended to inform operators and stakeholders on the influence of the project on the receiving environment. The project is anticipated to have a neutral to positive effect on water quality and aquatic environment health in Dome and Victoria Creeks following the implementation of water treatment. The data collection and analysis will help to determine whether effects are being realized in the downstream receiving environment, and whether those effects can be attributable to Site activities or to other activities (*e.g.*, placer mining). This project-term monitoring will include surface water quality, benthic invertebrates, habitat quality, periphyton, and stream sediments. As water quality improves, the aquatic health of lower trophic levels, namely periphyton and benthic invertebrates, is also expected to improve. In this regard, the health of lower trophic levels will function as an indicator of the overall health of aquatic habitat.

Finally, the AEMP will provide a structure for long-term monitoring of the Site that can continue through the eventual remediation of the Site. This will include the establishment of study control, which is described later in this document. The monitoring components intended for longer-term monitoring are the same as for the Project term, and include sediment, periphyton, benthos, and aquatic habitat.

Using the analysis outlined in Section 3, spatial and temporal trends in these aquatic indicators will provide important context for informing Site management over time as it pertains to overall aquatic health of the receiving environment, including whether surface water quality triggers outlined in the AMP are sufficiently protective.

Table 1.3-1 AEMP Objectives, Results, and Project Goals

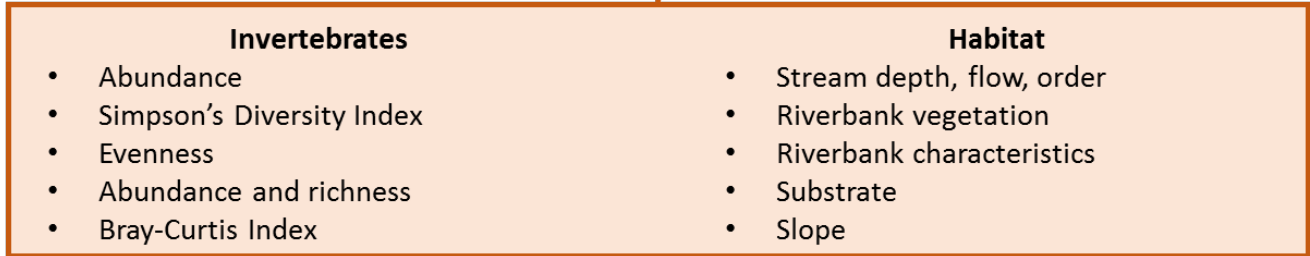
Objective	Component	Monitoring Result or Project Goal
Provide surface water quality data to inform AMP and compliance requirements	Surface water quality	Goal to maintain surface water quality results within AMP triggers or standards.
Inform operators and stakeholders of project performance and status of the aquatic ecosystem during term of project	Surface water quality	Goal of an improvement in the quality of treatment-related parameters
	Benthic invertebrates	Goal of a measurable increase in community metrics or stream health indices that demonstrate an improvement in aquatic health.
	Stream sediment	Goal of no measurable change, or a measurable decrease in stream sediment metals.
	Periphyton	Goal of a measurable increase in community metrics or abundance that demonstrates an improvement in aquatic health.
Establish a long-term monitoring program for the Site	Surface water quality	Monthly water quality data collection that is consistent with past data and also appropriate for current Project.
	Benthic invertebrates	
	Stream sediment	Annual data collection through the life of the project and beyond.
	Periphyton	

1.4 Establishment of Study Control

The AEMP will employ two approaches to study control to assess spatial and temporal trends of aquatic health indicators:

- The Before-After, Control-Impact (BACI) approach will be used to evaluate changes in water quality, sediment and periphyton over time. This approach is applicable to sites like Mount Nansen where references sites for water quality, sediment, and periphyton monitoring have not been established.
- A Reference Condition Approach (RCA) will be implemented to evaluate spatial and temporal changes in aquatic biota including benthic invertebrates and aquatic habitat. Invertebrate and aquatic habitat monitoring will be collected using the Canadian Aquatic Biomonitoring Network (CABIN) protocol, as outlined in Section 2. The CABIN protocol follows standardized protocols across Canada in support of a nation-wide, online, reference database. The RCA approach relies on the identification of a suitable reference site based on habitat characteristics. In the event suitable reference sites are not available within the CABIN database, the study control for benthic invertebrates and aquatic habitat monitoring will defer to the BACI approach outline above and as illustrated in Figure 1.4-2.

Data Collection by the Canadian Aquatic Biomonitoring Network (CABIN) Method



Are relevant reference sites available in the CABIN database?

YES

NO

Proceed with Reference Condition Approach (RCA):

- Compare reference and exposure sites (geographically)
- Assess temporal trends

Proceed with Before After Control Impact (BACI) Method:

- Assess temporal trends
- Analysis using indicator species
- Presence of EPT taxa
- Presence of tolerant taxa (degraded water quality)

Statistical Analysis:

- ANOVA
- NMDS Analysis
- Regression Analysis

Figure 1.4-1 Study Control Approach for Assessment of Benthic Invertebrates and Aquatic Habitat Monitoring Data

2. **Methods**

Monitoring will be conducted in accordance with methods described in the British Columbia (BC) Ministry of Environment (MOE) Field Sampling Manual (BC MOE, 2013), Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators (BC MOE, 2012), and the Canadian Aquatic Biomonitoring Network (CABIN) Field Manual (Environment Canada, 2012). All taxonomic and elemental analyses will be performed by laboratories certified by the Canadian Association for Laboratory Accreditation (CALA).

2.1 Sampling Locations and Frequency

Proposed AEMP sampling locations are generally consistent with those currently used at the Site, and are illustrated in Figure 1.2-2. The watercourses included in the AEMP are within a local study area (LSA) and regional study area (RSA), and are tributaries of Victoria Creek (Figure 1.2-2). The LSA boundary is generally coincident with the Order in Council (OIC) boundary (Figure 1.2-2) and includes the Dome Creek catchment and the upper portion of the Pony Creek catchment (where direct local effects may occur). Nearly all components of the Site are located within the Dome Creek catchment, including the mill and TSF. Discharge from the WTP reports to Dome Creek which then flows to Victoria Creek. As a result, Dome Creek has the greatest potential to be affected by Site activities.

The RSA is the broader area within which Project effects may interact with those of other projects and activities (*e.g.*, placer mining) on a regional scale. The RSA includes the Back, Dry, Victoria, and Minnesota Creek watershed boundaries (Figure 1.2-2).

A summary of proposed aquatic monitoring stations, rationale for selection, and frequency of data collection is provided in Table 2.2-1. Annual collection of sediment, periphyton, and benthic invertebrates and habitat characteristics (Figure 1.2-2) should be aligned and conducted at the end of summer (August to mid-September) when the productivity of aquatic systems is expected to be the highest.

Active placer mining is currently occurring upstream of the Site in Pony and Back Creeks. Relative to placer mining, Project effects on water quality, water quantity, and stream sediments are not discernable in Pony and Back Creeks. As a result, proposed monitoring within these drainages is limited to surface water quality and sediments (Table 2.2-1). In the event that water quality trends increase over time and are discernable from placer mining activity, the monitoring plan for these watercourses will be revisited.

Compliance and surveillance monitoring are proposed for the Site and will be confirmed through the water licensing process. Compliance and surveillance monitoring will focus on the receiving environment downstream of the point of discharge from the water

treatment plant. Proposed compliance monitoring sites include discharge from the water treatment facility (primary compliance) and in fish-bearing habitat in the downstream receiving environment in Victoria Creek (secondary compliance). As it pertains to compliance, weekly monitoring of discharge from the water treatment facility is proposed and discharge limits will be determined through the water licensing process. Victoria Creek upstream of Minnesota Creek (VC-UMN) is proposed as the secondary compliance monitoring location as it is readily accessible, baseline is well established, monitoring can be done through winter (unlike Victoria Creek at the road crossing, which freezes in winter), and is upstream of Minnesota Creek which is a source of dilution. Water quality guidelines (e.g., CCME) are generally expected to be met at VC-UMN, except when total suspended solids exacerbated by placer mining may result in elevated total metals (e.g., during freshet). Surveillance monitoring is a form of non-compliance monitoring and is intended to inform management decisions and risk associated with water quality conditions at the Site and potential changes over time as outlined in the AMP. Surveillance monitoring is proposed for Dome Creek given the historical absence of fish and includes locations upstream (DC-B) and downstream of point of discharge for the Site.

2.2 Water Quality

Surface water quality is the key indicator and primary tool for evaluating environmental compliance and health of the aquatic environment. The existing AMP for the Site outlines specific methods for assessing the surface water quality data collected under the direction of this AEMP, including the identification of triggers and evaluating trends. Further, the AMP specifies sampling frequencies and water quality parameters of interest. The AEMP design has taken the needs of the AMP into account (i.e., sites and frequency).

As outlined in Table 2.2-1, water sampling will be conducted monthly except for during spring freshet, when sampling may occur more frequently to capture naturally variable conditions during this high flow period, with more frequent sampling to occur in Dome Creek downstream of WTP discharge. Water sampling in the fall (August or September) will take place at the same time as stream sediment, periphyton and benthic macroinvertebrate / aquatic habitat sampling. Sampling of effluent from the water treatment plant will be conducted weekly, except for internal monitoring specific to plant performance, which is not specified here. Some water quality stations cannot be sampled during winter months (e.g., DC-R) when frozen conditions extend to the creek bottom. *In situ* water quality parameters will be collected during water quality sample collection including turbidity, water temperature, conductivity, oxidation-reduction potential (ORP), dissolved oxygen, and pH.

**Table 2.2-1
Aquatic Monitoring Program Stations for the Mount Nansen Project**

Site	Location Description and Purpose	Water Quality (n = 1)	Sediment (n = 3)	Benthic Invertebrate Community and Aquatic Environment as per CABIN (n = 1)	Periphyton Community (n = 1) and Chlorophyll <i>a</i> (n = 1)
BACK CREEK					
BC-U	Upstream of Pony Creek and within placer disturbance area; monitor placer effects upstream of the Project	Monthly	Annually	-	-
BC-D	Upstream of confluence with Victoria Creek; measure contribution from Back Creek	Monthly	Annually	-	-
DOME CREEK					
DC-DX	Upstream of Mill Area and road; monitor conditions upstream of the Project	Monthly	-	-	-
DC-D1b	Downstream of Mill Area; monitor effects from Mill Area	Monthly	Annually	Annually	Annually
DC-B ³	Diversion Channel at Bridge; control monitoring upstream of TSF	Monthly	-	-	-
DC-U ³	Downstream of TSF, seepage pond, and WTP; monitor local effects from TSF and seepage pond	Monthly	Annually	Annually	Annually
DC-R ³	At Mount Nansen Road – may extend downstream in winter; monitor net effects from Project and pathway to Victoria Creek	Monthly	Annually	Annually	Annually
DC-M	At mouth, last stream reach prior to confluence with Victoria Creek; monitor lower-most Dome Creek		Annually	Annually	Annually
SITE FACILITIES					
PIT-1,2,3	Open pit at specified depths, open season and access dependent	Monthly	-	-	-
TP	Tailings pond	Monthly	-	-	-
SEEP	Seepage collection pond	Monthly	-	-	-
WTP ¹	Water treatment plant effluent	Weekly			
PONY CREEK					
PC-U	Upstream of the Project, downstream of placer activity; monitor placer effects upstream of the Project	Monthly	Annually	-	-
PC-D	Downstream of the Project; monitor net effects from placer and the Project	Monthly	Annually	-	-
VICTORIA CREEK					
VC-REF	Reference station upstream of Back Creek; monitor conditions upstream of the Project	Monthly	Annually	Annually	Annually
VC-DBC	Downstream of Back Creek and before Dome Creek confluence with Victoria Creek; monitor effects to Victoria Creek upstream of Dome Creek	Monthly	Annually	Annually	Annually
VC-UMN ²	Upstream of Minnesota Creek; monitor effects downstream of Dome Creek and upstream of Minnesota Creek	Monthly	Annually	Annually	Annually
VC-R	At Mount Nansen Road – may extend downstream in winter; downstream monitoring of all potential effects from the Project	Monthly	Annually	Annually	Annually
MINNESOTA CREEK					
MN	Minnesota Creek before confluence with Victoria Creek; background inputs to Victoria Creek between VC-UMN and VC-R.	Monthly	Annually	-	-

Notes: "n" denotes number of samples collected per site; - denotes not collected; Proposed water treatment plant compliance monitoring where: ¹primary compliance; ²secondary compliance; and ³surveillance monitoring.

Collected water samples will be analyzed for general chemistry including total suspended solids (TSS), alkalinity and anions, nutrients, cyanide (total, free, and weak acid dissociable), total and dissolved metals, total organic carbon (TOC) and dissolved organic carbon (DOC). Where required, samples will be filtered and/or preserved on Site as per laboratory protocols. Samples will be kept refrigerated and shipped in a timely manner to be compliant with laboratory holding times. The water quality program will include a Quality Assurance and Quality Control (QA/QC) protocol consisting of duplicates for 10% of the collected samples, field and travel blanks, in addition to laboratory quality objectives. Relative percent difference (RPD) will be calculated for metals results on sample/duplicate pairs.

2.3 Stream Sediment Quality

Stream sediments often are used as a monitoring tool to support assessments of water quality and benthic invertebrate communities. Sediments can be a repository for several compounds including metals, and these compounds can enter aquatic systems causing toxicity to aquatic biota. This process can lead to a “shift” in benthic community structure and, therefore, can indirectly affect organisms at higher trophic levels such as fish.

Sediments will be collected annually from the locations listed in Table 2.2-1, at the same time that surface water quality, periphyton, and benthic macroinvertebrate samples are collected. Samples will be collected in triplicate, refrigerated, and shipped to analytical laboratory. At the laboratory, samples will be dried and sieved to determine particle size fractions. The 100 µm fraction will be analyzed for metals, as well as organics content using loss on ignition (LOI) at 600°C.

For QA/QC purposes, duplicate samples will be collected at a rate of 10% of the total collected sediment samples, with sample duplicate pairs being compared through relative percent difference. Data will be screened against the interim sediment quality guidelines (ISQG) and the probable effect levels (PEL) established by the Canadian Council of Ministers of the Environment (CCME, 2017) and evaluated for trends. In addition, trends in metal concentrations will be evaluated over time using applicable statistics approaches (e.g., regression) as described in Section 3.

2.4 Aquatic Biota

Aquatic biological monitoring includes periphyton and benthic invertebrates and corresponding aquatic habitat. Annual monitoring of aquatic biota is proposed for a three-year period at project startup (following implementation of water treatment) to establish a new baseline. After this baseline has been established, biological monitoring every three years is proposed.

2.4.1 Periphyton

Periphyton will be used as a medium through which to monitor for changes in overall aquatic environmental health, through measures of primary productivity and periphyton community structure downstream of Site discharges and in other Site watercourses. Periphyton are sensitive to changes in water chemistry, particularly to nutrient and metal levels, and therefore are useful indicators of physical and chemical changes in the aquatic environment.

Periphyton will be collected from submerged rocks for taxonomic analysis and chlorophyll-*a* determinations. If adequate sample volumes are not available from rock substrates, artificial substrates may be considered as an alternative. Five-sample composites will be collected at each Site in late August or early September (when systems productivity is expected to be the highest). Samples will be collected in accordance with approved protocols, such as those provided in the British Columbia Ministry of Environment (BC MOE 2013). Applicable field QA/QC methods will be employed to reduce the risk of potential contamination and/or sample deterioration. Collected samples will be sent to a taxonomist for the determinations of community metrics and to an analytical laboratory for chlorophyll *a* analysis.

Collected data will be compared temporally and geographically between relevant stations. Relationships between water quality and sediment data with periphyton communities will be evaluated by regression or correlation analysis based on data variability as outlined in Section 3.

2.4.2 Benthic Invertebrates and Aquatic Habitat

Benthic invertebrates are an important component of aquatic systems and are a valuable monitoring tool (*e.g.*, sedentary, diverse species). The community composition of benthic invertebrates can be used as an indicator of changing environmental conditions as they are sensitive to nutrients and several metals of concern (*e.g.*, total arsenic and iron).

The CABIN protocol will be used to sample benthic invertebrates and aquatic habitat. The CABIN protocol provides a nationally standardized method to assess freshwater ecosystems (benthic invertebrates and their habitat) based on the RCA. The CABIN protocol includes documentation of biotic and abiotic stream characteristics to develop a database relating benthic invertebrate community structure to stream habitat. Therefore, the CABIN database contains information on benthic community metrics and habitat characterization for many stream systems in northern BC and the Yukon. The data in the database can be filtered to identify reference sites that could potentially be applicable to streams in the Project area, based on key stream morphology characteristics (*e.g.*, stream order).

CABIN sampling will be conducted in late August or early September when productivity is expected to be the highest. Benthic invertebrate sample collection will be performed using a kick net (400 μm mesh net and a detachable collection vessel) for the standard time of 3 minutes. Contents collected within the kick net after the 3 minute sampling period will be transferred to a wide-mouth jar and preserved with 10 percent buffered formalin for preservation prior to shipping to the taxonomic laboratory member of the taxonomic certification program operated through the Society of Freshwater Science (<http://www.nabstcp.com/>). This program was initiated to ensure standards for high quality data among taxonomy labs in North America. Taxonomic characterization will be performed to the lowest practical level (generally family), and a standard recount during the taxonomic identification process is conducted as a QA/QC measure.

Benthic invertebrate community data will be summarized to produce community metrics including Simpson's Diversity Index (D), evenness (E), taxon abundance, Bray-Curtis index and richness as generally required by applicable regulatory agencies (i.e., a for the Metal Mine Effluent Environmental Effects Monitoring programs). Additional comparisons such as Shannon-Weiner Diversity, Ephemeroptera-Plecoptera-Trichoptera (EPT) Index, and dominant or indicator taxa will also be included if necessary to maintain consistency with previous benthic studies or if directed by regulatory agencies. The detailed methods for data analysis are outlined in Section 3.

3. Data Application and Analysis

3.1 Surface Water Quality to Inform AMP and Compliance

As earlier stated, surface water quality data collected as part of the AEMP will be used to inform management decisions and risk associated with current and future water quality conditions downstream of the Site, as per the AMP. For Site compliance, monitoring frequency, locations, and parameters will be confirmed through the water licensing process.

Following the establishment of baseline and following demonstration of water treatment performance, additional aquatic monitoring elements outlined within this AEMP (e.g., periphyton, benthic invertebrates and aquatic habitat) may also be incorporated directly into specific events defined within the AMP. This process of evaluation and integration should be conducted at regular intervals consistent with AEMP data collection and analysis (e.g., annually during baseline period or every three years during regular monitoring), and should involve Project stakeholders.

3.2 Project Term Monitoring and Long-term Monitoring

Statistical comparisons of water quality, stream sediment and periphyton, as well as ancillary data from the benthic invertebrate samples and habitat characterization, will be conducted regularly (annually following data collection). The results of the analysis will be shared with Project stakeholders to evaluate project success, inform management decisions, and evaluate risks to the aquatic environment downstream of the Site.

Changes to physical indicators as well as water and sediment quality will be evaluated using the BACI design as described in Section 1.4 (Figure 1.4-2), which evaluates changes at each site over time. Analysis of Variance (ANOVA) will be used to evaluate changes and statistically compare whether there are significant time-related trends in data. Monitoring data will also be compared to applicable water and sediment guidelines on an ongoing basis to allow for an analysis of trends over time (e.g. frequency of exceedences over time).

Biological indicators (periphyton and benthic invertebrate community) will be used as “markers” from which to evaluate trends in water and sediment quality over time. Temporal changes in periphyton community structure and Chlorophyll *a* concentrations will be evaluated using the BACI approach (Figure 1.4-2) to evaluate the direction (positive or negative) and magnitude of effects related to changes in water quality. ANOVA will be used to evaluate changes and statistically compare whether there are significant time-related trends in data. Regression analyses will be used to determine whether significant

relationships exist between any observed changes to water quality and shifts in periphyton community structure.

The assessment of benthic invertebrate and related aquatic habitat data (CABIN sampling) is anticipated to be the key component to evaluating trends in aquatic environment health in the Site receiving environment. The approach for assessing benthic invertebrates will depend on the availability of suitable reference sites, as described in Section 1.4 (Figure 1.4-2). If suitable reference sites are available, communities (sites) will be compared using a RCA using reference sites obtained from the CABIN database. If reference sites from the CABIN database are not suitable for streams within the Project area (e.g., matching stream morphology and/or habitat characteristics) then potential changes in benthic community will be identified using a control-impact or a BACI design (as described in Section 1.4). In addition, non-metric multidimensional scaling (NMDS) will be used to identify similarities and benthic community trends.

The methods of data analysis for these two approaches are similar. Endpoints that describe the benthic invertebrate community in exposure sites will be compared to endpoints from reference locations, if available, to assess whether there is a statistically significant change in sites over time or significant difference between the sites. In addition to benthic invertebrate data, data from aquatic habitat, surface water quality, and stream sediments will be also evaluated to assess whether changes in benthic invertebrate communities are significant and if they are associated with changes in water quality. Summary data will also be calculated for each site, including arithmetic mean, standard deviation, standard error, median, minimum, and maximum. In the case that the BACI approach is used, then community descriptors will be used to evaluate changes at sites over time, including community metrics, EPT (ephemeroptera, plecoptera, trichoptera), or tolerant taxa presence (Figure 1.4-2).

References

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