Mount Nansen Water Resources Investigations 2015-2016: Methodology

Prepared For
Assessment & Abandoned Mines
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Down to Earth Biology

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1 PROGRAM INTRODUCTION

Yukon Government Assessment and Abandoned Mines (AAM) retained the services of EDI Environmental Dynamics Inc. (EDI) in 2015 to conduct the Water Resource Investigations 2015/16 program at the Mount Nansen Site. This program involves three monitoring components: meteorology, surface water hydrology and surface water quality. Investigations are completed on a monthly basis from April 2015 to March 2016, with two trips in May 2015 to capture the freshet period. Trips are typically scheduled for the middle of each month and take place over two to three days.

This report presents the methodology for the current program. Any updates to the program methodology will be provided in the monthly reports with rationale provided. The following sections include descriptions of site/station locations and program methodology for each component.

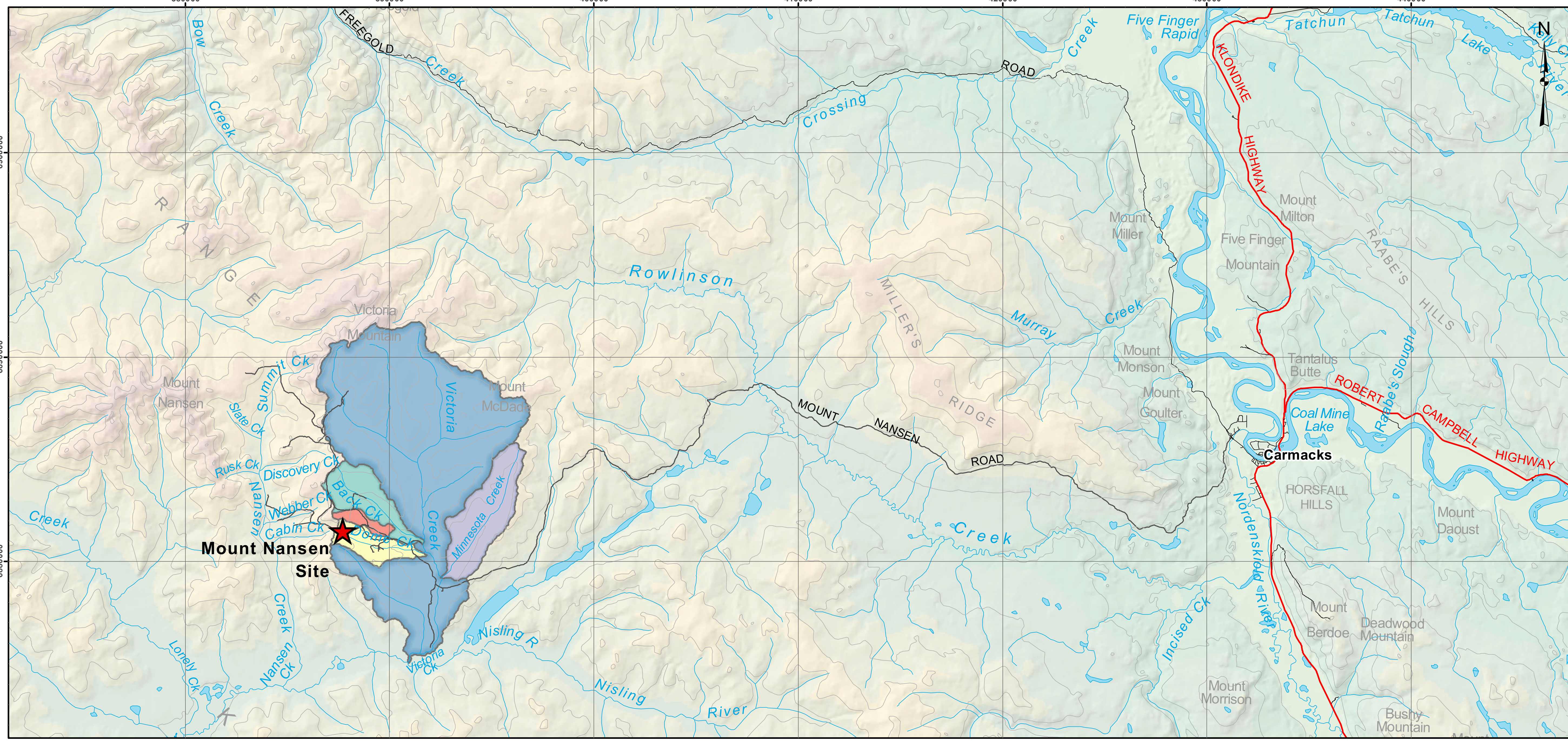
1.1 MONITORING NETWORK DESCRIPTION

The Mount Nansen Site lies within the Victoria Creek drainage which is a tributary to the Nisling River. The abandoned mine infrastructure includes a mill, a tailings and seepage pond facility, a diversion channel, and the Brown-McDade pit lake and waste rock pile area. Several smaller watercourses drain the mine site area, including Dome Creek and Pony Creek. Dome Creek is a tributary to Victoria Creek and originates upstream of the mill, flows through the valley and is diverted around the tailings pond via the diversion channel. Pony Creek lies within the northern portion of the mine site area to the north of the Brown-McDade pit lake. Pony Creek is a tributary to Back Creek, which flows into Victoria Creek upstream of the Dome Creek confluence. Minnesota Creek lies east of the mine site area and is not within the influence of the mine, flowing into Victoria Creek downstream of the Dome Creek confluence. There are also numerous groundwater seeps around the Site, including seepage sites around the mill area and around the waste rock pile and Dome Creek Valley.

The 2015/16 project scope is very similar to the previous year's programs (2014/15). See Figure 1, Figure 2 and Figure 3 for a regional overview of the watersheds present within the study area as well as water resources investigation site and station locations. The list of water quality sites and hydrometric stations that are part of the investigations scope for 2015/16 are provided in Table 1. List of surface water monitoring locations at the Mount Nansen Site (2015/16 Scope of Work).. Refer to Section 2.2 and 2.3 for location and coordinates.

Table 1. List of surface water monitoring locations at the Mount Nansen Site (2015/16 Scope of Work).

Station/Site Name	Hydrology	Water Quality	Station/Site ID
Upper Pony Creek	-	✓	WQ-PC-U
Pony Creek Downstream of Pit	✓	✓	H-PC-DSP/WQ-PC-D
Dome Creek at DX	-	✓	WQ-DC-DX
Dome Creek at DX+105	✓	✓	H/WQ-DC-DX+105
Dome Creek at D1b	✓	✓	H/WQ-DC-D1b
Diversion Channel at Bridge	✓	✓	H/WQ-DC-B
Middle Dome Creek	✓	✓	H-DC-M WP/WQ-DC-U
Dome Creek at Road	✓	✓	H/WQ-DC-R
Seepage Pond Outflow	✓	✓	H/WQ-SEEP
Tailings Pond	✓	✓	H/WQ-TP
Brown-McDade Pit Lake	-	✓	WQ-PIT-1,2,3
Mill Site Seep 08	-	✓	WQ-MS-S-08
Mill Site Seep 03	-	✓	WQ-MS-S-03
Back Creek	✓	✓	H/WQ-BC
Upper Victoria Creek	✓	✓	H/WQ-VC-U
Victoria Creek Downstream of Back Creek	✓	✓	H/WQ-VC-DBC
Victoria Creek Upstream of Minnesota Creek	✓	✓	H/WQ-VC-UMN
Victoria Creek at Road	✓	✓	H/WQ-VC-R
Pump House Well	-	✓	WQ-PW
Dome East Slope Seep 01	-	✓	WQ-DESS-01
Dome East Slope Seep 02	-	✓	WQ-DESS-02
Dome East Slope Seep 03	-	✓	WQ-DESS-03
CH-P-13-01	-	✓	WQ-CH-P-13-01
Lower West Toe of Waste Rock Dump Seep 01	-	✓	WQ-LW-SEEP-01
East Toe of Northwest Pile Seep 01	-	✓	WQ-NW-SEEP-01
Ore Ramp Seep	-	✓	WQ-ORE
Lysimeter 1 – top of northwest pile	-	✓	WQ-L1
Lysimeter 2 – top of west lower pile	-	✓	WQ-L2
Pony Creek Adit Seep	-	✓	WQ-ADIT-SEEP
Mill Site Seep A	-	✓	WQ-MS-S-A
Waste Rock Seep A	-	✓	WQ-WR-SEEP-A
Waste Rock Seep B	-	✓	WQ-WR-SEEP-B



Regional Overview Map of Mount Nansen Site

Legend

Local Drainage Area

- Back Creek
- Dome Creek
- Minnesota Creek
- Pony Creek
- Victoria Creek

- Topographic Contour
- Secondary Road
- Highway

Data sources
1:250,000 Topographic Spatial Data courtesy of Her Majesty the Queen in Right of Canada, Department of Natural Resources. All Rights Reserved.

Digital Elevation Model provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

This document is not an official land survey and the spatial data presented is subject to change.

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kilometres

Map Scale: 1:200,000 (printed on 11 x 17)
Map Projection: NAD 1983 UTM Zone 8N

Drawn: LG	Checked: MM / JB	Date: 08/05/2015	FIGURE 1

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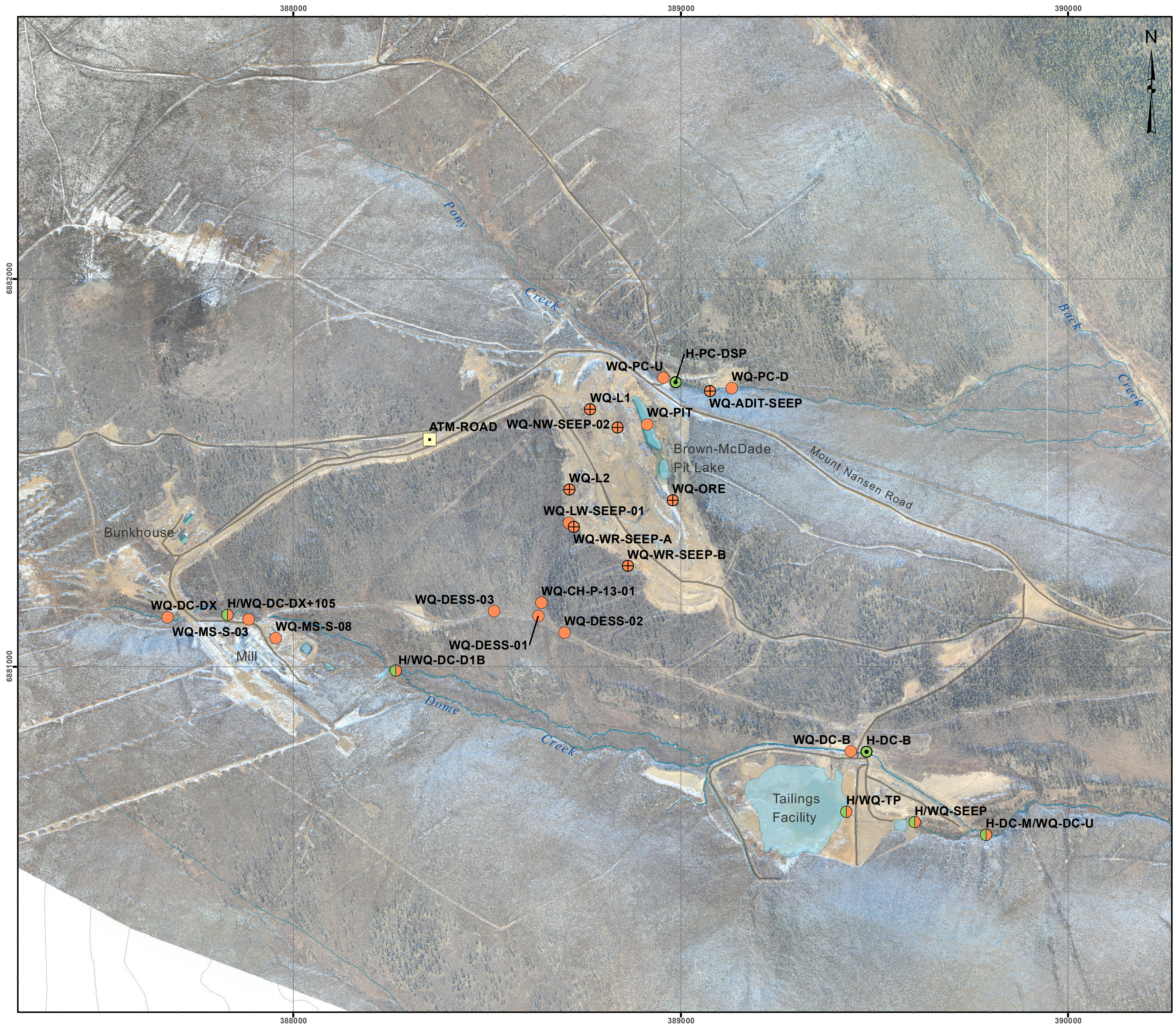

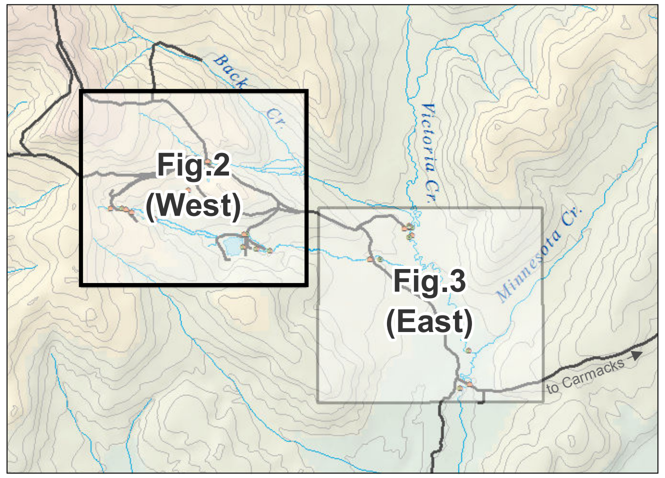

Legend

- Atmospheric Station (label e.g. ATM-ROAD)
- Hydrometric Station and Water Quality Site (label e.g. H/WQ-VC-UMN)
- Hydrometric Station (label e.g. H-VC-R)
- Water Quality Site (label e.g. WQ-PC-U)
- Temporary Water Quality Site (label e.g. WQ-MS-S-03)
- Unpaved Road/Access

Mount Nansen Site (West): Hydrometric Stations and Water Quality Sites

Notes:

1:50,000 and 1:250,000 Topographic Spatial Data provided by Geomatics - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

Watercourse, drainage areas and Mount Nansen Road layers digitized / modified by EDI (2011) using orthophotos provided by Yukon Government, Energy, Mines and Resources (2011).

Imagery provided by Yukon Government - Energy, Mines and Resources - Abandoned Mines Branch.

Project data displayed is site specific. Data collected by EDI Environmental Dynamics Inc. (2014/2015) was obtained using Garmin GPS technology.

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Map Projection: NAD 1983 UTM Zone 8N

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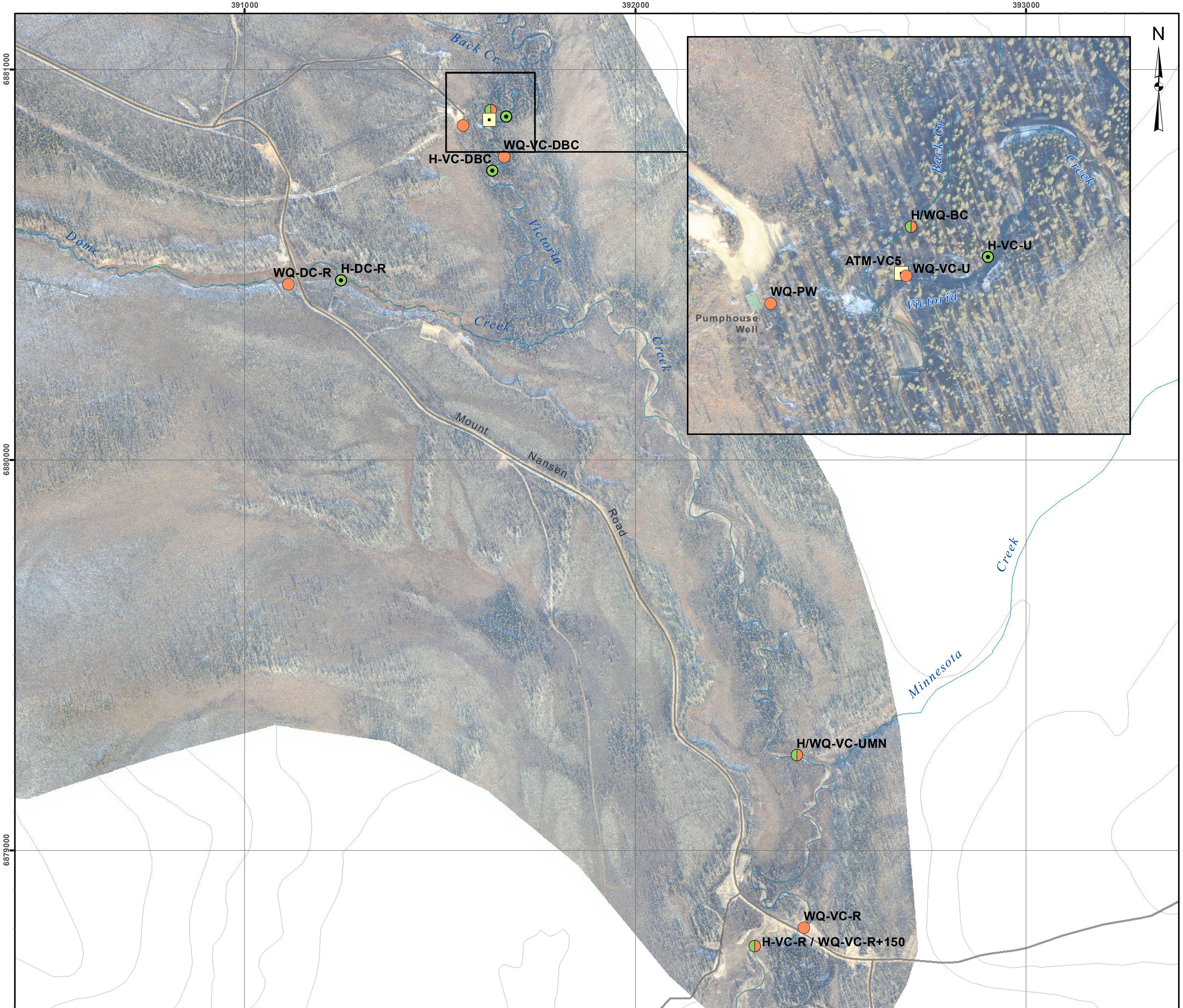
Yukon EDI



Legend

- Atmospheric Station (label e.g. ATM-ROAD)
- Hydrometric Station and Water Quality Site (label e.g. H/WQ-VC-UMN)
- Hydrometric Station (label e.g. H-VC-R)
- Water Quality Site (label e.g. WQ-PC-U)
- Temporary Water Quality Site (label e.g. WQ-MS-S-03)
- Unpaved Road/Access

Mount Nansen Site (East): Hydrometric Stations and Water Quality Sites

Notes:

1:50,000 and 1:250,000 Topographic Spatial Data provided by Geomatics - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.

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Metres

Map Scale = 1:10,000 (printed on 11 x 17)
Map Projection: NAD 1983 UTM Zone 8N

Drawn: LG	Checked: MM / JB	Date: 08/05/2015	FIGURE 3

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2 PROGRAM METHODOLOGY

2.1 METEOROLOGY

A Campbell Scientific meteorological station (ATM-ROAD AAM) was established at the Mount Nansen Site in October 2011. The station is located adjacent to the Mount Nansen Road, east of the camp at an elevation of 1,255 m above sea level (Figure 2).

The ATM-ROAD station records air and ground temperature, humidity, rainfall, snow depth, net shortwave and longwave radiation, total radiation, wind speed, wind direction and battery voltage (Table 2). There is also a barometric logger, which collects barometric pressure and air temperature for use in the hydrometric program (Section 2.2).

Table 2. Summary of weather data parameters collected at Mount Nansen Meteorological Station (ATM-ROAD AAM).

Meteorological Parameter	Units	Notes
Daily Collection		
Air Temperature Maximum	°C	Measured every 5 minutes; Daily maximum value is reported
Air Temperature Minimum	°C	Measured every 5 minutes; Daily minimum value is reported
Humidity Maximum	%	Measured every 5 minutes; Daily maximum value is reported
Humidity Minimum	%	Measured every 5 minutes; Daily minimum value is reported
Snow Depth	cm	Reports the depth of snow at the end of the day
Battery Voltage	Volts	Measured every 5 minutes; Daily minimum value is reported
Hourly Collection		
Net Shortwave	W/m^2	Measured every 5 minutes; Hourly average is reported
Net Longwave	W/m^2	Measured every 5 minutes; Hourly average is reported
Net Total Radiation	W/m^2	Measured every 5 minutes; Hourly average is reported
Wind Speed	m/s	Measured every 5 minutes; Hourly average is reported
Wind Direction	degrees	Measured every 5 minutes; Hourly average is reported
Rainfall	mm	Total hourly rainfall
Snow Depth	cm	Hourly sample recorded
Air Temperature	°C	Measured every 5 minutes; Hourly average is reported
Humidity	%	Measured every 5 minutes; Hourly average is reported
Ground Temperature Surface	°C	Hourly sample recorded
Barometric Pressure	mbar	Hourly sample recorded

2.1.1 DATA DELIVERABLES

The maintenance and calibration of ATM-ROAD AAM sensors and infrastructure is conducted by Northern Avcom and data is accessible through an internet download. EDI is responsible for downloading and compiling these raw data into a database (Table 3) and conducting a basic quality control/quality assurance review to identify issues with the sensors, calibration and general function of the telemetry system. If any corrections are required to the data, changes will be made as required, to the hourly dataset in Aquarius Workstation Time Series Software (Aquatic Informatics Inc.) and exported into a corrected data table in the Microsoft Access database (Table 3). A copy of an updated meteorological database will be provided with each monthly monitoring report. In addition, plots for each parameter will be included in the monthly reports corresponding with end of the open water season (approximately October 31, 2015) and the end of the winter season (April 30, 2016).

Table 3. Meteorological database tables and content description.

Database Table Name	Description
lut_Met_Parameters	A description of the sensors and infrastructure at the station
lut_Met_Stn_Information	Basic metadata about the station including location and elevation
lut_Met_Stn_Operations	Operational history of the station including calibration dates, time periods where sensors are offline and a summary of data corrections
tbl_RAW_Daily_Weather	Raw daily data with an abbreviated selection of parameters
tbl_RAW_Hourly_Weather	Raw hourly data for the complete selection of station parameters
tbl_RAW_Thermister	Raw thermistor data
tbl_CORRECTED_Hourly_Weather	Corrected daily weather data, as required

2.2 HYDROLOGY

The Mount Nansen hydrometric program is designed to collect baseline hydrometric measurements and to support engineering design, water balance modeling, water quality modeling and water management planning. The creeks on the project site are relatively small and exhibit channel instability, particularly in Dome Creek. As a result, hydrometric monitoring efforts will be adapted to the dynamics hydraulic conditions to provide the most accurate and appropriate discharge method. The hydrometric program includes four types of stations; the stations and monitoring rationale are presented in the list below and Table 4:

1. **Atmospheric:** A continuous barometric data logger is used to compensate water level loggers for atmospheric pressure.
2. **Instantaneous:** Stage and/or discharge measurements are instantaneous and collected manually during each field visit.
3. **Continuous:** Water level loggers measure stage at 15 minute intervals continuously during the open water season. Instantaneous stage and discharge measurements are obtained on each field visit to develop the open water stage-discharge rating curve that converts the continuous stage data to discharge values.
4. **Continuous Winter:** Water level loggers measure stage at 15 minute intervals continuously during the winter season to facilitate an understanding of water level changes in the winter periods.

Instantaneous discharge measurements are obtained on each field visit; however, no rating curve is applied to the winter stage data.

Table 4. Mount Nansen hydrometric and atmospheric station information.

HID[1]	Hydrometric Station Name	Type[2]	Location [3] Easting	Northing	Drainage Area (km^2)	Elevation [4] (m)
ATM-VC5	Barometric at Victoria Creek	ATM	391626	6880872	-	1015
H-PC-DSP	Pony Creek Downstream of Pit	C	388986	6881734	1.0	1191
H-DC-DX+105	Dome Creek at DX+105	I	387820	6881150	0.9	1204
H-DC-D1b	Dome Creek at D1b	I	388262	6881000	1.4	1156
H-DC-B	Diversion Channel at Bridge	C	389480	6880780	3.0	1095
H-DC-M WP	Middle Dome Creek Weir Pond	C/CW	389788	6880565	3.3	1065
H-TP	Tailings Pond	I	389427	6880625	-	1093
H-SEEP	Seepage Pond Outflow	I	389604	6880598	-	1072
H-DC-R	Dome Creek at Road	C	392540	6879249	4.5	1020
H-BC	Back Creek	C	391626	6880901	10.4	1021
H-VC-U	Upper Victoria Creek	C/CW	391667	6880882	64.6	1019
H-VC-DBC	Victoria Creek Downstream of Back Creek	C/CW	391627	6880840	75.0	1017
H-VC-UMN	Victoria Creek Upstream of Minnesota Creek	C/CW	392413	6879244	83.4	986
H-VC-R	Victoria Creek at Road	C/CW	392305	6878755	97.7	975

Notes:

1 - HID = unique station identifier that corresponds with hydrometric database tables.

2 - Station Type: ATM = atmospheric pressure monitoring; C = continuous water level monitoring with instantaneous discharge rating measurements; I = instantaneous stage and/or discharge measurement; CW = continuous winter water level monitoring with instantaneous discharge rating measurements.

3 - NAD 83, UTM Zone 8.

4 - Elevations for hydrometric stations are estimates based on field data collected by handheld Garmin GPS units and digital spatial data (DEM) provided by AAM.

The barometric sensor and data logger at the meteorological station (ATM-ROAD AAM, Elev. = 1,255 m) is used as a redundant logger for the barometric logger located near Victoria Creek (ATM-VC5). There is an elevation difference of 240 m between ATM-ROAD AAM and ATM-VC5 therefore elevation corrections prescribed by Solinst Canada Ltd. are applied to the ATM-ROAD AAM data in the case that the ATM-VC5 logger malfunctions. (Note: the barometric units collected by ATM-ROAD AAM are millibars whereas ATM-VC5 barometric units are kilo Pascals; unit conversion is required).

The hydraulic conditions encountered at the Mount Nansen hydrometric stations vary in each watershed and change seasonally. In addition, Back Creek, Dome Creek and Pony Creek are relatively small channels that typically require non-standard discharge measurement methods to be employed (i.e., alternative methods to the velocity-area mid-section method). Hydraulic conditions during the winter months also require alternative hydrometric measurements depending on the ice conditions. The following is a list of hydrometric measurement methods used in the Mount Nansen hydrometric monitoring network that are described in the sections to follow:

- the velocity-area mid-section method (standardized),
- volumetric measurements,
- v-notch weir measurements, and
- salt dilution gauging (brine salt slug injection) method.

The velocity-area mid-section method is standardized by British Columbia's Resources Information Standards Committee (RISC 2009), however many of the channels at the Site are inappropriate for using this method (i.e., too shallow, too narrow or low discharge). In such cases, alternative methods including salt-dilution gauging and volumetric measurements are used. Typically, an elevation survey is completed during each hydrometric station visit where there are continuous data loggers installed; surveys are used to monitor shifts in benchmarks, station, and staff gauge elevations. Surveys are not completed during the winter because stage elevations are affected by ice, changing the relationship between stage and discharge; rating curves are not developed for the winter period.

Given the small channel sizes and low seasonal discharges at many stations, the minimum reportable discharge is set to 0.001 m3/s or 1 L/s; this value is lower than what is typically reported for other hydrometric programs (e.g., Water Survey of Canada uses +/-0.01 m3/s for open water conditions). Field methods used at Mount Nansen can accommodate this higher resolution of discharge under ideal conditions, however measurement uncertainty for each method should be considered when interpreting results. Measurement uncertainty is based on instrument accuracy and channel conditions at the time of measurement. If discharge is calculated to be less than 0.001 m3/s it will be reported as 0.000 m3/s, and flagged as 'below reportable confidence limits' in the hydrometric database (Section 2.2.10).

The following sections provide details on each method used and the methodology for developing rating curves and continuous stage and discharge hydrographs.

2.2.1 VELOCITY-AREA MID-SECTION

The velocity-area mid-section method will be used to determine discharge at hydrometric stations where channel criteria meet those outlined in standard guidance documents (RISC 2009; WSC 1999). Cross-section locations will be established for each hydrometric station where this method is applied; these cross-sections will be located in close proximity to continuous data logger installations.

The current meter that will be used to obtain the velocity measurements is a 2-dimension, side looking, FlowTracker Handheld Acoustic Doppler Velocimeter (ADV) (Sontek/YSI Inc. 2009). The FlowTracker is used by both the Water Survey of Canada and the U.S. Geological Survey. The FlowTracker computer calculates discharge using the mid-section method and calculates the statistical discharge uncertainty based on methods developed by the U.S. Geological Survey (Cohn et al. 2006). This method of calculating uncertainty accounts for the uncertainty associated with width, depth and accuracy of the FlowTracker calibration and the effects of channel variability on depth and velocity across the cross-section (Sontek/YSI 1999). The statistical discharge uncertainty calculated by the FlowTracker at Mount Nansen is typically less than ±5%. An uncertainty of ±10% is considered by industry as acceptable for the velocity-area mid-section method. The statistical uncertainty was applied for all velocity-area discharge measurements obtained with the ADV. The ADV also provides a variety of quality control and assurance assessments in real-time, reducing field measurement error. The absence of moving parts on the acoustic sensor also decreases measurement error during winter conditions.

The ADV automatically calculates discharge using the following velocity-area mid-section equations; the continuity relationship for discharge (*Q*),

$$Q = v \cdot A = bdv \qquad [1]$$

Where depth (d), velocity (v) and width (b) measurements will be obtained for at least 20 panels across the metering cross-section; in some cases where low flow or winter conditions are non-ideal, measurements will be obtained twice with 10 panels or alternative discharge methods will be considered (*e.g.,* salt tracer or volumetric). The cross-section panel width and depth are multiplied by the velocity (averaged over 40 seconds) to obtain an instantaneous discharge measurement (*q*) for each panel (RISC 2009). Panel discharges are subsequently summed to obtain total discharge. The discharge for the first and last panels is calculated using half the distance from the edge to the first and last mid-panel verticals.

The velocity-area discharge calculation is described by the following equations:

$$q_n = v_n d_n \frac{(b_{n+1} - b_{n-1})}{2} \qquad [2]$$

$$Q = q_1 + q_2 + q_3 + q_4 + q_5 + \cdots q_n \qquad [3]$$

Where SI units of m^3/s, m/s, and m are used for discharge, velocity and depth respectively.

2.2.2 SALT DILUTION GAUGING

Salt dilution gauging will be used at hydrometric stations where the channel conditions were not suitable for using a velocimeter and the velocity-area mid-section method. Typically this occurs when water depths are less than 0.05 m, channel widths are less than 3.0 m, or during winter months when ice conditions are poor for conducting velocity-area measurements beneath the ice.

There are three different methods of salt dilution gauging: constant rate injection (brine); slug injection (brine) and dry salt injection. Method selection depends on the magnitude of discharge to be measured, channel conditions and feasibility for remote sites because the required equipment varies for each method. All methods require the selection of an input (injection) site and a downstream electrical conductivity measurement site. The distance between these sites (mixing length) is optimized for the minimum distance required for complete mixing of the fully dissolved salt tracer in the water column and across the channel.

Specific channel conditions during open water and winter periods will be required for successful salt dilution gauging. These criteria will ensure that complete lateral and vertical mixing occurs in as short a distance as possible: minimal pools; no backwater areas; no braiding; little to no in-stream vegetation; and no losses or gains of water (Moore 2004a; Moore 2004b; Laberge Environmental Services 1999; Kite 1994). The tracer methods and calculations provided by Moore (2004a; 2004b; 2005) will be employed as they are thought to be significantly more robust and adaptable to site-specific stream conditions than those presented in the other salt tracer references; however, it should be noted that the water temperatures are substantially lower and electrical conductivities substantially higher than those in Moore (2004a; 2004b; 2005).

The gram conductivity of salt, the conductivity of 1 g NaCl in 1 m^3 of solution at 25 °C, is non-linear at higher background conductivities (Laberge Environmental Services 1999). Background specific conductance at the Mount Nansen hydrometric stations range widely, from ~29 µS/cm to upwards of 1,500 µS/cm. The field protocols presented in Moore (2004a; 2004b; 2005) account for the non-linearity of the gram conductivity but require that additional field calibration tests for each visit and each gauging location are collected.

The slug injection (brine) method is selected for use at the Mount Nansen Site hydrometric stations because this method is most feasible for the remote sites, channel conditions, discharges and the most efficient method for the field monitoring program. In addition, the use of brine slugs allows for shorter mixing lengths to be used; ideal for channels at Mount Nansen. Measurement reaches are carefully selected to meet the measurement criteria and overlap with the physical location of continuous water level loggers. The same measurement reach will be used for each field visit unless changes to the channel conditions warrant minor adjustments to the mixing length.

Salt injection sites are located upstream of constrictions (*e.g.,* culverts) where possible to facilitate full mixing. A conductivity meter records specific conductance at a location downstream during the salt trial (approximately 40 m downstream for the smaller creeks and approximately 90 m for Victoria Creek, depending on channel conditions). A YSI ProPlus Multi-Meter with logging capabilities is used. Background electrical conductivity is logged for several minutes before the slug injection to allow for the instrument to equilibrate and to measure the range of background variability. Specific electrical conductance[1] (SPC) is measured (logged) because the values are compensated for water temperature. A known mass of salt (NaCl) is dissolved into a graduated bucket of stream water at the injection site. Once fully dissolved, the salt slug is injected at the upstream site and the electrical conductivity of the salt wave is measured at the downstream

[1] Specific electrical conductivity measured by the YSI ProPlus and the YSI 556 multi-meters are linearly compensated for temperature. The multi-meters are calibrated daily during each field visit before use.

location at two to five second intervals depending on the stream velocity. Two trials are conducted at each station. When possible, a secondary method of discharge measurement is used to validate the salt dilution measurement (*i.e.,* volumetric discharge measurement, ADV measurement).

The formula used to calculate discharge for the Mount Nansen salt slug injections is:

$$Q = \frac{V_{SS}}{1000 \cdot CF.T \cdot \tau \cdot \sum(SPC_t - SPC_O)} \qquad [4]$$

Where Q is discharge (m3/s), Vss is the volume of salt slug injection (L), τ is the time interval in seconds and SPC_t and SPC_O are the measured and background conductivity at time interval t, respectively. The CF.T value is the calibration factor that accounts for the non-linearity of electrical conductance and salt concentration in stream water. The CF.T value is taken as the slope of the line of SPC and relative concentration of the salt slug in an aliquot of sample stream water. The target peak specific conductance for the salt wave is an increase of at least ten-times the resolution of the conductivity meter used. Typically, an increase between 10% and 50% of SPC_O is achieved, above the required increase of 2 to 5 μS/cm.

Stream discharge is calculated for each salt slug trial using Equation [4] and averaged to provide a discharge estimate. The average estimated measurement accuracy for the salt dilution gauging method is ± 20%. However, salt dilution gauging accuracy will vary between each station due to differences in individual channel conditions and stream water velocities.

In some instances where ambient air temperatures are prohibitively cold (*i.e.,* <-30°C), the dry salt slug injection method using a mass-balance approach is used. This is due to limitations that rapidly freezing water places on equipment, field procedures and safety of field personnel. The formula for calculating discharge using the dry salt slug injection differs slightly from equation [4], and follows the calculations provided by Moore (2004). The discharge calculation formula for the dry salt slug injection is:

$$Q = \frac{m}{\sum(EC - EC_0) \cdot CF \cdot t_{int}} \qquad [5]$$

Where m is the mass of salt used for the dry slug injection, EC is the electrical conductivity measured at a defined time interval (t_{int}), EC_0 is the background electrical conductivity. CF is a site-specific constant that is determined by measuring changes in specific conductivity with known masses of salt. Stream discharge is calculated using equation 5 for each salt slug trial during the monitoring period. The estimated measurement accuracy for dry salt slug injection is ±30%. However, the discharge uncertainty varies considerably between each station due to differences in channel conditions and stream water velocities.

2.2.3 VOLUMETRIC

Channel constrictions created by culverts, pipes and weirs provide an opportunity to measure stream flow by measuring the time to fill a bucket of known volume; this is the volumetric method of discharge measurement. Volumetric discharge measurement is ideal for low flows because all of the stream flow is captured in a bucket of a known volume at a confined outlet or constriction in the channel. The volumetric method for measuring discharge will be used periodically at several stations at Mount Nansen where a culvert v-notch weir or pipe is available (H-PC-DSP; H-SEEP; H-DC-M WP). During extreme low flows it is also possible to obtain volumetric estimates at H-DC-DX+105.

The volumetric measurement is completed using a graduated 20 L bucket and a timing device. The time required to fill the volume is recorded over five separate volumetric trials. All five volumetric trials are averaged to provide a discharge estimate. The estimated measurement accuracy is ± 10 %.

The volumetric measurement method that is employed at H-SEEP (Tailings Dam Seepage Pond pump pipe outlet) is used to validate daily instantaneous measurements read at the flow meter attached to the pump that is used to manage water levels in the Seepage Pond. Daily flow meter readings are collected by the site maintenance staff and data is maintained by AAM. EDI staff collects concurrent flow meter readings when volumetric measurements are made at the pipe outlet.

2.2.4 ICE-COVER HYDROMETRICS

Instantaneous hydrologic measurements will be completed year round for all stations that are not frozen to the channel bed. Measurements completed during periods when the channel is ice covered have lower accuracy than open channel measurements because the standard hydrometric methods are based on open channel hydraulic relationships between the impelling and resisting forces of flow. Ice increases the resistance to flow, slowing velocities and increasing the water surface elevation (backwater effect). Frazil ice, anchor ice, slush and ice jams influence the water surface profile and effective depth of flow in the channel. As a result, the relationship between stage and discharge changes during the winter. Cold temperatures frequently cause problems with measurement equipment, including continuous water level loggers. In the Yukon, winter measurement instruments are usually working at or beyond the cold temperature operating limits of the instrumentation and resultant data will be carefully analyzed for quality. All measurements collected during ice conditions will be flagged in the data record with 'B'; the standard data flag used by the WSC indicating backwater or ice effects. Measurements influenced by ice are not included in the open water stage-discharge rating curve development.

Hydrometric measurement methods are selected on a site by site basis to determine which method will provide the highest quality data and will be based on professional judgment of the channel hydraulics and ice conditions. In many of the streams at the Mount Nansen Site, multiple layers of ice are present with flow travelling through complex networks within and on the surface of the ice. In such conditions, discharge measurements become increasingly uncertain and are not performed. Typically in Victoria Creek, the velocity-area and salt dilution methods are both feasible during ice-cover periods when ice thicknesses and ambient air temperatures are not prohibitive. Salt dilution can be used on the smaller channels if they are not frozen to the bed and there is sufficient flow.

2.2.5 HYDROMETRIC LEVELING SURVEYS

Hydrometric leveling surveys are performed during each open water season visit to stations where continuous data loggers are installed. The purpose of these surveys is to tie the data logger water levels to the local station datum. Each station has a local, relative datum defined by benchmarks in close proximity to the data logger and stilling well. Three benchmarks are installed at each continuous station as per RISC (2009) Data Grade A guidelines. Each survey includes a survey with a level and rod for Benchmark 1 (BM1), Benchmark 2 (BM2), Benchmark 3 (BM3), the top of the staff gauge (TOS), the water surface elevation (WATER) and the elevation of the fixed-length logger apparatus (TOR). The elevation of Benchmark 1 at every station defines a local elevation of 3.000 m above datum. The local datum is always located below the elevation of zero flow. The benchmarks and the top of the staff gauge are regularly checked for shifting as a result of periglacial processes and survey error. While there is some apparent movement in the benchmark elevations and occasionally anomalous survey data, the water surface elevation data will be carefully reviewed using staff gauge readings and the field records of stilling well maintenance (logger or staff gauge shifts) before applying local datum offsets to the raw data logger record. All suspect data is excluded from the corrected data. All stage data is presented in metres referenced to the local datum unless otherwise noted.

2.2.6 HYDROMETRIC VALIDATION & QA/QC PROGRAM

The velocity-area, weir and volumetric hydrometric measurement methods used for the Mount Nansen hydrometric program are standardized by the WSC and the USGS. Several stations do not meet standardized criteria; alternative methods (*e.g.,* salt dilution gauging) are used at these stations. In some cases, concurrent standardized methods (*e.g.,* velocity-area measurements) allow for the validation and calibration of alternate methods. Concurrent measurements also facilitate uncertainty estimates for stream discharge measurements and will be collected where feasible and appropriate.

Quality control and quality assurance (QA/QC) checks begin during field visits. The Flow Tracker ADV provides numerous QA/QC checks in real-time during velocity measurements that allow the field crew to increase the precision of the measurements. Upon return from the field, data entry staff perform preliminary checks and reviews of the raw data and discharge calculations prior to the production of trip and monthly reports. A third round of QA/QC is completed during data entry into the hydrometric database. A final QA/QC is completed during the development of rating curves and hydrographs for each hydrometric station.

2.2.7 RATING CURVE DEVELOPMENT

Rating curves are based on open channel hydraulic relationships between stage (water level) and discharge. They are based on open-water conditions only and are not representative of ice-cover channel conditions. The y-axis represents the recorded stage level at the gauge and the x-axis the discharge. The rating curve equation represents the hydraulic reaction of flow through a smoothly varying channel with increasing stage (or a constant control point at all stages) (Maidment 1993). The rating curve equation [6] has the form:

$$Q = C(h + a)^N \qquad [6]$$

Where *Q* is discharge in m^3/s, *C* is typically proportional to the channel width, (*h*+*a*) represents the depth of water above the stage of zero flow (water level where flow becomes zero) and the value of N is a function of the channel geometry (Maidment, 1993). If the pressure transducer is below the point of zero flow, the value of '*a*' is negative; conversely a positive '*a*' value indicates that it is above. Typically as the stage increases, the hydraulic control shifts from low flow hydraulic control to channel friction control or to ice related controls. As a result multiple rating curve expressions for a single channel and various stages are often required to accurately represent the full range of flows.

By taking the log of both sides of the rating curve in equation [7], we obtain:

$$\log Q = logC + N\,log(h + a) \qquad [7]$$

the rating curve equation [8] takes the linear form *y*=*mx*+*b* and can be fit to the discharge rating points as a straight line. Rating curves may be developed using several different methods including fitting the calibration points by eye and the maximum likelihood solution. Given the small size of the channels at the Mount Nansen Site, the narrow range of stage changes, and channel instabilities, each rating curve is developed by fitting by eye within the Aquarius Time-Series Software environment (Aquarius Informatics Inc. 2014).

Rating curves are developed for stations with continuous water level loggers using surveyed water levels (stage) and instantaneous discharge measurements. A rating curve is considered preliminary if the following conditions are met: there are less than 10 reliable rating measurements (RISC 2009), if rating measurements do not capture an acceptable range of flows (i.e., 10 %-200 % of mean discharge [MD]), or, if there is a high rating curve error.

Rating curves are developed with rating measurements obtained when the channel is ice free. Any rating measurement obtained during ice conditions are reported simply as instantaneous measurements. Rating curves are valid only for a defined rating period. A rating period represents a section of time where both the channel and hydrometric installation are stable.

Timely monitoring events during the spring freshet period allow the capture of higher spring flows. A conservative approach was adopted for presenting the continuous hydrometric record in the report deliverables. Predicting flood or low flows can introduce error into hydrologic analysis and should be carefully considered in the context of channel hydraulic geometry.

2.2.8 CONTINUOUS STAGE & DISCHARGE

There are nine continuous Solinst Edge pressure transducers installed at Mount Nansen and one barometric pressure transducer to compensate the stream loggers for atmospheric pressure (Table 4). Continuous stage records are collected at 15 minute intervals. The pressure transducers are downloaded on each site visit. Continuous discharge is calculated using the stage-discharge rating curve developed for the rating period at each respective station. The continuous stage record (rather than discharge record) is presented for stations where developing reliable rating curves is considered unsuitable due to channel conditions and available measurement techniques. Examples of these stations are H-PC-DSP and H-DC-M.

2.2.9 DATA MANAGEMENT

Hydrometric data is compiled into a Microsoft Access database after each visit to the Mount Nansen Site. The hydrometric database is designed to hold raw and corrected field data including hydrometric station metadata, station history, field measurements, survey data and data logger files. The hydrometric database is also used for QA/QC and generating report summaries.

2.2.10 DATA DELIVERABLES

The deliverables for the hydrometric monitoring component of the water resources investigation includes:

- Monthly Report
  - Instantaneous discharge values and hydrographs for each station
  - Notation of QA/QC issues and corrections (if required)
  - Up to date hydrometric database
- Open Water / End of Winter Enhanced Monthly Report
  - Instantaneous discharge values and hydrographs for each station
  - Notation of QA/QC issues and corrections (if required)
  - Up to date hydrometric database
  - Rating curves for stations with continuous stage loggers
  - Continuous stage and discharge hydrographs

If any corrections are required to the data, changes will be made as required to continuous stage, discharge records in Aquarius Workstation Time Series Software (Aquatic Informatics Inc.) and exported into a corrected data table in the database (Table 5). A copy of an updated hydrological database will be provided with each monthly monitoring report. In addition, rating curves and continuous hydrographs will be included in the monthly reports corresponding with end of the open water season (approximately October 31, 2015) and the end of the winter season (April 30, 2016).

Table 5. Hydrological database tables and content descriptions.

Database Table Name	Description
lut_hydrometric_data_flags	List of hydrometric data flags associated with the discharge measurements
lut_hydrometric_Qmeas_type	List of the hydrometric measurement method used for each discharge value
lut_hydrometric_station_ID	Unique hydrometric station identifier (HID)
lut_hydrometric_survey_flags	List of data flags for the hydrometric survey data
lut_hydrometric_survey_points	List of hydrometric survey points captured in hydrometric surveys
tbl_hydrometric_station_history	Operational history for each hydrometric station including data logger serial numbers, installation locations and dates.
tbl_logger_YSISalt	YSI data electrical conductivity logger record (Raw) for salt dilution gauging used in the salt tracer calculations.
tbl_Q_Measurement	Master summary of all discharge measurements and methods for each site visit. Unique measurement identifier (MID).
tbl_site_visit_MID	Unique measurement identifier assigned to each station for each site visit. If multiple measurement methods are used at a station during a single site visit the measurements have a single MID
tbl_survey_data	Hydrometric level survey data.

2.3 WATER QUALITY

Water quality sampling will occur on a monthly basis from April 2015 to March 2016, with two trips in May 2015 to capture the freshet period. There are a total of 29 water quality sites in the 2015/16 scope of work, with the potential for additional sites during freshet and at the request of AAM. The water quality program includes collecting water samples at each site depending on suitable conditions for laboratory analysis, as well as collection of in situ water quality data, site photographs, and a description of site conditions. A list of sampling sites, coordinates and sampling information is provided in Table 6.

The sampling frequency varies by site, as some sites are sampled monthly, during freshet only, on a seasonal basis, or only up to two to three times per year. In addition to the sampling schedule, samples are only collected when conditions are suitable. During the summer months, some sites become dry for short periods of time (e.g., portions of Pony Creek flow underground when weather conditions are hot and dry). During the winter period, many sites on Dome Creek, Pony Creek and Back Creek freeze to substrate as early as November and can remain frozen into May. Aufeis conditions commonly develop within Dome Creek, with thick ice developing in layers. Overflow ice build-up is also common on Victoria Creek upstream of the Mount Nansen Road crossing, which prevents sampling at the WQ-VC-R site during the winter. Since this site represents the most downstream receiving environment, a more suitable winter sampling location is used downstream of the road crossing (WQ-VC-R+150).

Table 6. Mount Nansen water quality site and sampling information.

Water Quality Site Name	Site ID	Site Location [1] Easting	Northing	Sampling Frequency	Type of Lab Analysis [2]
Pony Creek upstream	WQ-PC-U	388955	6881745	Monthly	Standard Package
Pony Creek downstream	WQ-PC-D	389131	6881719	Monthly	Standard Package
Pit Lake (3 samples)	WQ-PIT-1,2,3	388913	6881625	Monthly	Pit Lake Package
Dome Creek at DX	WQ-DC-DX	387674	6881127	Monthly	Standard Package
Dome Creek at DX+105	WQ-DC-DX+105	387820	6881150	Monthly	Standard Package
Dome Creek at D1b	WQ-DC-D1b	388264	6880989	Monthly	Standard Package
Diversion Channel at Bridge	WQ-DC-B	389439	6880781	Monthly	Standard Package
Upper Dome Creek	WQ-DC-U	389788	6880565	Monthly	Standard Package
Dome Creek at Road	WQ-DC-R	391111	6880449	Monthly	Standard Package
Tailings Pond	WQ-TP	389427	6880625	Monthly	Standard Package
Seepage Pond Outlet Pipe	WQ-SEEP	389604	6880598	Variable[3]	Standard Package, LC50
Mill Site Seep 03	WQ-MS-S-03	387884	6881121	3X Per Year	Standard Package
Mill Site Seep 08	WQ-MS-S-08	387954	6881073	3X Per Year	Standard Package
Back Creek	WQ-BC	391626	6880901	Monthly	Standard Package
Upper Victoria Creek	WQ-VC-U	391626	6880872	Monthly	Standard Package
Victoria Creek downstream Back Creek	WQ-VC-DBC	391633	6880740	Monthly	Standard Package
Victoria upstream of Minnesota	WQ-VC-UMN	392413	6879244	Monthly	Standard Package
Victoria Creek at Road	WQ-VC-R	392431	6878802	Monthly	Standard Package
Victoria Creek at Road (winter location)	WQ-VC-R+150	392305	6878755	Monthly	Standard Package
Pump House Well	WQ-PW	391558	6880856	Monthly	Drinking Water Package, Bacteriological Sample
Dome East Slope Seep 01	WQ-DESS-01	388632	6881131	Seasonal[4]	Standard Package

Water Quality Site Name	Site ID	Site Location [1] Easting	Northing	Sampling Frequency	Type of Lab Analysis [2]
Dome East Slope Seep 02	WQ-DESS-02	388699	6881087	Seasonal [4]	Standard Package
Dome East Slope Seep 03	WQ-DESS-03	388518	6881143	Seasonal [4]	Standard Package
Upwelling near CH-P-13-01	WQ-CH-P-13-01	388640	6881165	Monthly	Standard Package
Lower West Toe of Waste Rock Pile Seep	WQ-LW-Seep-01	388711	6881371	Seasonal [4]	Standard Package
East Toe of NW Waste Rock Pile Seep	WQ-NW-SEEP-02	388837	6881617	Freshet[5]	Standard Package
Ore Ramp	WQ-ORE	388986	6881432	Freshet[5]	Standard Package
Lysimeter 1	WQ-L1	388766	6881664	Freshet[5]	Standard Package
Lysimeter 2	WQ-L2	388712	6881457	Freshet[5]	Standard Package
Pony Creek Adit Seep	WQ-ADIT-SEEP	389081	6881709	2X per Year	Standard Package
Mill Site Seep A	WQ-MS-S-A	387952	6881103	Freshet[5]	Standard Package
Waste Rock Seep A	WQ-WR-SEEP-A	388723	6881360	Freshet[5]	Standard Package
Waste Rock Seep B	WQ-WR-SEEP-B	388863	6881259	Freshet[5]	Standard Package
Waste Rock Seep C	WQ-WR-SEEP-B	388948	6881140	Freshet[5]	Standard Package

Notes:

1 - NAD 83, UTM Zone 8. 2 - Parameters included in various sampling packages are explained in greater detail in Appendix A. 3 - Sampling frequency for this site was variable as the WQ-SEEP site is sampled on a monthly basis for the standard package samples and every second month for the LC50 sample. 4 - Sampling frequency for these sites is seasonal as these seeps are to be sampled during freshet and then once during the summer, fall, and prior to winter freeze-up. 5 – Freshet sampling only during May 2015.

2.3.1 FIELD SAMPLING METHODS

Water samples are collected at each sample site from the same location each month. Laboratory-cleaned bottles are filled using clean techniques (i.e., nitrile gloves, appropriate bottle handling) and samples are filtered and preserved on site, as per instructions by accredited lab. Samples are kept in coolers immediately following collection, and later transferred to the Mount Nansen Site sample refrigerator until they can be transferred to Whitehorse on the final day of each sampling event. Chain of Custody forms, supplied by the lab, are included in each sample cooler, and samples are delivered to the accredited lab upon arrival back in Whitehorse, YT to ensure lab holding times were met. The bacteriological sample collected at the pump house well each month is submitted to Yukon Government Environmental Health Services in Whitehorse, YT for analysis. More details on lab analysis are included in Section 2.3.2.

Samples from the pit lake are taken from the same general location in the middle of the lake from the deepest location, at three different depths, from the surface, at mid depth and just off the bottom. When the pit lake is ice free, a row boat is used to access the sampling location, and samples are collected using a Kemmerer sampler. In the event that ice covers the water surface, an ice auger is used to access the water column. The lysimeter sites (sampled during freshet) also require special sampling equipment including a peristaltic pump to collect water from the lysimeter for sampling.

In situ water quality parameters collected at each site include turbidity, water temperature, specific conductivity and pH. Dissolved oxygen is only collected at the pit lake as well as from fish bearing streams year round (Victoria Creek and Back Creek). An Oakton T100 turbidity meter is used to collect in situ turbidity (NTU). This meter is calibrated on a monthly basis according to instrument specifications. A YSI ProPlus multi-meter is used to collect in situ water temperature (degrees Celsius), pH (pH units), specific conductivity (µS/cm). Field crews calibrate the YSI meter prior to each trip and as required in the field. A YSI ProODO meter is used to measure dissolved oxygen (mg/L) from the pit lake (this probe does not require any calibration).

Field data is recorded on standard field datasheets including site name, sample identifier, sample date and time, in situ data, photo numbers and a record of qualitative site conditions including flow stage (low, moderate, high), turbidity (clear, low, moderate, high), and ice observations (when present).

2.3.2 LABORATORY ANALYSIS

There are several lab analyses packages used for the water resources investigations program. A 'standard site package' includes lab analysis of cyanides, routine physical tests, anions and nutrients, total metals, and dissolved metals. The 'pit lake package' is similar to the standard package, but excludes cyanide parameters. The 'drinking water package' includes physical tests, anions and nutrients, total metals and bacteriological tests (total coliforms and E. coli). The parameters included in each package are outlined in Table 7. The detection limits for the various parameters can vary between packages based on the standard lab testing procedures.

A toxicity test for rainbow trout (LC50) is completed for one sample at one site (WQ-SEEP) every second month. An LT50 test used to be completed for this site up to the end of the 2014/15 program, providing a 'pass/fail' result for the 96-hour test as well as value for percent fish survival. The LT50 results have passed consistently over the last few years of the program; however, recent results towards the latter end of the 2014/15 program were showing declining survival rates and AAM requested that the test switch to an LC50 to determine the degree of toxicity.

Table 7. Laboratory analysis parameters included in various 'packages' created for surface water quality sampling at Mount Nansen.

Analysis Package	Parameters Included
Standard Site Package	**Cyanides:** Cyanate, Total Cyanide (as Strong Acid Dissociable), Weak Acid Dissociable, Thiocyanate **Physical Tests:** Conductivity, Hardness, pH, Total Dissolved Solids, Total Suspended Solids **Anions and Nutrients:** Bicarbonate, Carbonate, Hydroxide, Total Alkalinity, Total Ammonia, Chloride, Fluoride[1], Nitrate, Nitrite, Sulphate **Total Metals:** Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Mercury, Molybdenum, Nickel, Phosphorus, Potassium, Selenium, Silicon, Silver, Sodium, Strontium, Sulfur, Thallium, Tin, Titanium, Uranium, Vanadium, Zinc. **Dissolved Metals:** Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Mercury, Molybdenum, Nickel, Phosphorus, Potassium, Selenium, Silicon, Silver, Sodium, Strontium, Sulfur, Thallium, Tin, Titanium, Uranium, Vanadium, Zinc.
Pit Lake Package	**Physical Tests:** Conductivity, Hardness, pH, Total Dissolved Solids, Total Suspended Solids **Anions and Nutrients**: Bicarbonate, Carbonate, Hydroxide, Total Alkalinity, Total Ammonia, Chloride, Fluoride[1], Nitrate, Nitrite, Sulphate **Total Metals:** Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Mercury, Molybdenum, Nickel, Phosphorus, Potassium, Selenium, Silicon, Silver, Sodium, Strontium, Sulfur, Thallium, Tin, Titanium, Uranium, Vanadium, Zinc. **Dissolved Metals:** Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Mercury, Molybdenum, Nickel, Phosphorus, Potassium, Selenium, Silicon, Silver, Sodium, Strontium, Sulfur, Thallium, Tin, Titanium, Uranium, Vanadium, Zinc.
Drinking Water Package	**Physical Tests:** True Colour, Conductivity, Hardness, pH, Total Dissolved Solids, Turbidity **Anions and Nutrients:** Alkalinity, Total, Chloride, Fluoride[1], Nitrate, Nitrite, Sulphate **Total Metals:** Aluminum, Antimony, Arsenic, Barium, Boron, Cadmium, Calcium, Chromium, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Potassium, Selenium, Sodium, Uranium, Zinc.
LC50 Package	**LC50** test conducted with rainbow trout.

Note: 1- The instrumentation used for the fluoride analysis is typically done with ion chromatography (IC) with the other anions (chloride, nitrate, nitrite, sulphate, etc). However, in some cases where there is high specific conductivity and sulphates, the samples must be diluted to protect instrumentation with detection limits adjusted. When the detection limit for fluoride is adjusted, it is adjusted above the interim guideline value. When this case occurs, the fluoride sample will be analyzed using the selective electrode method (SIE) to ensure that the reporting limit does not increase beyond the 0.12 mg/L guideline value.

2.3.3 QA/QC SAMPLE PROGRAM

The water quality field program also includes collection of QA/QC samples, including: replicate samples, field blanks, and travel blanks. These are described in detail below:

- Replicate samples are essentially sample replicates collected at the same date, time and location as the regular sample. All sampling methodology is the same, as if it is a separate site. Replicates are collected from one to three sites, randomly selected, during each trip, depending on the total number of sites per trip, to cover approximately 10% of the total sites sampled. The replicate samples are collected to check the accuracy and precision of the laboratory analysis, as well as a measure of the variability in water quality at a site for a given time.
- The field blank samples are collected on site, where a set of sample bottles is filled with deionized water at some point during the sampling trip. Sampling methodology is the same as if sampling from a stream, with filtering and preserving as required. The purpose of a field blank is to identify any contamination introduced to the sample during the act of field sampling (i.e., sample filling/handling, exposure to questionable air quality) or via the supplies (filter, syringe, bottle, or preservative).
- The travel blank is a sample set provided by the laboratory to be carried by the staff to and from site during the field work. The travel blank is not opened at any time during the trip. The purpose of including a travel blank is to identify any contamination of the sample caused during transportation or storage.

Following receipt of the laboratory analysis results, a review of the QA/QC sample results is completed. Field and travel blank sample data is also reviewed to ensure that concentrations of all potential contaminants are low to below detection limits. For replicate samples, relative percent difference (RPD) is calculated to express precision of the sample and its replicate using the formula below:

$$\%RPD = \left(\frac{(x_1 - x_2)}{\frac{(x_1 + x_2)}{2}} \right) \times 100\%$$

Where replicate results were less than 5-times the detection limit, the difference between the sample and the duplicate should be no greater than 2-times the detection limit to be considered precise. If the difference between the sample and replicate are greater than 2-times the detection limit, the RPD value must be reported. For analytical results greater than 5-times the detection limit, RPD values less than 20% are considered precise. RPD values greater than 50% indicate problems or errors that affect precision of the analytical result (Table 8).

Table 8. QA/QC assessment categories and results wording.

Category	QA/QC Result
<DL	Adequately Precise
<2XDL	Adequately Precise
RPD<20%	Adequately Precise
RPD>20%	Imprecise or Intrinsically High Variability
RPD>50%	Error or Problem

Notes: DL = detection limit and RPD = relative percent difference

2.3.4 DATA MANAGEMENT & ANALYSIS

Once field crews return from the field, all in situ data is revised and entered into the project water quality database (Microsoft Access). Ten percent of the data entered into the database is reviewed on the raw field sheets for QA/QC purposes. Upon receipt of the lab data, it is also appended to the project database.

Data are reviewed and parameters of concern are compared with the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of freshwater 'aquatic life' (CCME-AL; CCME 2015; Table 9), and with the Effluent Quality Standards (EQS) outlined in Yukon Water Board Water license No. QZ94-004, issued to BYG Natural Resources Inc. on February 13, 1996 (Table 10). Drinking water quality from the WQ-PW site is compared to the applicable Guidelines for Canadian Drinking Water Quality (Health Canada 2012; Table 11).

Table 9. CCME-AL guidelines applicable to Mount Nansen surface water quality sampling program (CCME 2015).

Water Quality Parameter	CCME AL Guideline	Comments
Aluminum	0.1 mg/L	CCME is 0.1 at pH ≥ 6.5, if pH is lower than 6.5, guideline is set at 0.005 mg/L
Ammonia	0.75 mg/L	Guideline is temperature and pH dependent. This represents a highly conservative guideline calculated for a pH of 8.5 and a water temperature of 0°C. Guideline decreases with increasing pH and temperature.
Arsenic	0.005 mg/L	-
Cadmium	0.00009 mg/L	Guideline is hardness dependent; this value is for a sample water hardness of 50 mg/L. A hardness dependent guideline of 0.04 µg/L is used when water hardness is >0 to <17 mg/L. At hardness >280 mg/L the guideline is 0.37 µg/L. At hardness ≥17 to ≤280 mg/L the guideline in µg/L is calculated using the following equation: Hardness Adjusted Guideline = $10^{[0.83(\log[\text{hardness}])-2.46]}$
Chloride	120 mg/L	-
Chromium	0.0089 mg/L	Interim guideline
Copper	0.002 mg/L	Guideline is hardness dependent; this value is for an unknown

Water Quality Parameter	CCME AL Guideline	Comments
		hardness or hardness between 0 to <82 mg/L. At hardness >180 mg/L, the guideline is 4 µg/L. At hardness ≥82 to ≤180 mg/L, the guideline in µg/L is calculated using the following equation: Hardness Adjusted Guideline = $e^{0.8545\ (LN[hardness]-1.465}*0.2$
Fluoride	0.120 mg/L	Interim guideline
Iron	0.3 mg/L	-
Lead	0.003 mg/L	Guideline is hardness dependent; this value is for a hardness of 100 mg/L. When hardness is 0 to ≤60 mg/L the guideline is 1 µg/L. At hardness >180 mg/L, the guideline is 7 µg/L. At hardness >60 to ≤180 mg/L the guideline in µg/L is calculated using the following equation: Hardness Adjusted Guideline = $e^{[1.273\ (LN[hardness]-4.705]}$
Molybdenum	0.0073 mg/L	-
Nickel	0.1 mg/L	Guideline is hardness dependent; this value is for a hardness of 100 mg/L. When hardness is 0 to ≤60 mg/L the guideline is 25 µg/L. At hardness >180 mg/L, the guideline is 150 µg/L. At hardness >60 to ≤180 mg/L the guideline in µg/L is calculated using the following equation: Hardness Adjusted Guideline = $e^{[0.76\ (LN[hardness]+1.06]}$
Nitrate	13 mg/L	-
Nitrite	0.06 mg/L	-
pH	6.5 - 9.0	-
Selenium	0.001 mg/L	-
Silver	0.0001 mg/L	-
Thallium	0.0008 mg/L	-
Uranium	0.015 mg/L	-
Zinc	0.03 mg/L	-

Table 10. Mount Nansen Effluent Quality Standards outlined in Yukon Water Licence #QZ94-004.

Water Quality Parameter	Effluent Discharge Standard
pH	6.0 to 8.5 pH
Total Suspended Solids (TSS)	50 mg/L
Toxicity (LT50 – 96 hr. for rainbow trout, pH non-adjusted)	100%
WAD Cyanide	0.1 mg/L
Total (SAD) Cyanide	0.3 mg/L
Antimony (Total)	0.15 mg/L
Arsenic (Dissolved)	0.15 mg/L
Barium (Total)	1.0 mg/L

Water Quality Parameter	Effluent Discharge Standard
Cadmium (Total)	0.02 mg/L
Chromium (Total)	0.04 mg/L
Copper (Total)	0.2 mg/L
Iron (Total)	1.0 mg/L
Lead (Total)	0.1 mg/L
Manganese (Total)	0.5 mg/L
Mercury (Total)	0.005 mg/L
Nickel (Total)	0.3 mg/L
Silver (Total)	0.10 mg/L
Zinc (Total)	0.3 mg/L

Table 11. Applicable guidelines for Canadian Drinking Water Quality for WQ-PW (Health Canada 2012).

Water Quality Parameter	Health Canada Guideline
Antimony	0.006 mg/L
Arsenic	0.010 mg/L
Barium	1.0 mg/L
Boron	5.0 mg/L
Cadmium	0.005 mg/L
Chromium	0.05 mg/L
Fluoride	1.5 mg/L
Lead	0.010 mg/L
Mercury	0.001 mg/L
Nitrate	45 mg/L
Selenium	0.01 mg/L
Uranium	0.02 mg/L

2.3.5 DATA DELIVERABLES

All water quality data is entered into a Microsoft Access database, as mentioned in Section 2.3.4, including lab data results and in situ data results. A copy of an updated water quality database is provided with each monthly monitoring report. Table 12 includes a summary of tables within the database.

Table 12. Water quality database tables and content description.

Database Table Name	Description
Tbl_WQ_Site_Info	List of sites and locations of water quality sites at Mount Nansen from 2013 to present. Updated when new sites are added to the program or when sites are discontinued.
TBL_WQ_Sampling_Data	List of sites where samples were collected each trip, including WQID (site name) and the corresponding EDI identifier (unique sample ID). There are check boxes for whether an LT50/LC50, bacteriological sample, or QA/QC sample were collected.
TBL_WQ_InSitu_Data_2015-16	Record of in situ data collected each trip. Includes WQID, date, temperature, specific conductivity, pH, turbidity, dissolved oxygen, flow level, water clarity, and other comments.
TBL_WQ_Result_Data_2015-16	Lab results for each sample (identified with unique EDI identifier). EDI identifier is linked to site WQ ID through the TBL_WQ_Sampling_Data.
TBL_BacT_Data	Lab results for the bacteriological sample collected at WQ-PW.
TBL_LT50_LC50_Data	Lab results for the LT50 or LC50 collected at WQ-SEEP.
LUT_Flow_Level	Lookup table for list of flow level values (used in drop down list for above TBL_WQ_InSitu_Data_2015-16).
LUT_Water_Clarity	Lookup table for list of water clarity values (used in drop down list for above TBL_WQ_InSitu_Data_2015-16).
QRY_WQ_Result_Table_2015-16	A query that links three tables together so that results from in situ data and lab data are displayed with the WQID and EDI Identifier.

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