REVIEW

Clinton Creek Surface Water Quality and Hydrological Monitoring Plan

Prepared for:
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Assessment and Abandoned Mines
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1.0 INTRODUCTION

Hemmera Envirochem Inc. ("Hemmera") and Ecological Logistics & Research Ltd. (Hemera/ELR) were retained by the Yukon Government (YG), Assessment and Abandoned Mines (AAM) to conduct a review of the water quality and hydrological monitoring program at the Clinton Creek Mine site.

The Clinton Creek Mine Site (herein referred to as the Site) is an abandoned asbestos mine, formerly owned and operated by Cassiar Asbestos Corporation Limited from 1967 to 1978. Mining activities ceased in 1978 when the economic-value of the asbestos operations were exhausted (YG 2013). During operation, approximately 16 million tons of serpentinite rock containing 940,000 tonnes of white asbestos (known as chrysotile) were removed from three pits at the mine site. From 1978 to 1992, the company attempted to implement an abandonment plan and completed limited remedial activities at the Site. Since then, various weather events have destabilized creek channels and caused erosion on Site which has increased the potential for flooding. In 2002, the federal government implemented a stabilizing program at the Site under emergency provisions of the Yukon *Waters Act* (YG 2007) to mitigate further impacts. Upon devolution in 2003, AAM assumed responsibility and control of the care, maintenance and closure of the Site.

1.1 SITE LOCATION AND HYDROLOGICAL SETTING

The Site is located approximately 75 km northwest of Dawson City (100 km by road), in the traditional territory of the Tr'ondëk Hwëch'in First Nation (**Figure 1**). The Site is within the Klondike Plateau Ecoregion of the Boreal Cordillera Ecozone (Smith et al. 1994), near the northern extent of the Klondike Plateau, at the edge of the Tintina Trench.

The Site falls within the drainage of the Forty Mile River, a tributary to the Yukon River. Clinton Creek flows through the Site from the west then continues southeast for approximately 8 km before flowing into the Forty Mile River. Waste rock slumping into the valley have dammed Clinton Creek, forming Hudgeon Lake (**Figure 2**). The four tributaries of Clinton Creek at or near the Site are as follows:

- Easter Creek which flows into Hudgeon Lake;
- Porcupine Creek and Wolverine Creek which flow through the Site to Clinton Creek from the south and north, respectively; and,
- Eagle Creek which flows into Clinton Creek from the north, downstream from the Site (**Figure 3**).

Slumping tailings have interrupted the flow of Wolverine Creek creating two ponds (**Figure 2**). Past mining activities have also formed two pit lakes: Porcupine Pit Lake and Snowshoe Pit Lake. Monitoring programs have categorized stations as reference (R) to indicate background samples, exposed (E), and groundwater seeps (GWCC) as potentially impacted.

- The reference station for Wolverine Creek is labelled R3, with Wolverine Creek exposed station labelled E3 downstream, situated directly before it flows into Clinton Creek.
- The reference station for Clinton Creek is labelled R1, upstream of Hudgeon Lake at upper Clinton Creek, with impact exposure stations for Clinton Creek labelled E1, E2, E4, and E7, downstream of Hudgeon Lake.
- The four confirmed tributaries of Clinton Creek are Easter Creek (drains to Hudgeon Lake), Porcupine Creek and Wolverine Creek (flow through site), and Eagle Creek.

2.0 SURFACE WATER QUALITY PLAN

The following section presents the surface water quality plan recommendations for the Site, based on the Hemmera/ELR review of existing water quality data.

2.1 SAMPLING LOCATIONS AND RATIONALE

Following a review of historical reports describing water quality at the Site, Hemmera/ELR recommends the addition of the following three new water quality stations.

- Two reference stations (R8 and R9) to quantify inputs to Hudgeon Lake.
- One exposure station (E9), which will characterise the inflow of Porcupine Creek to Clinton Creek.

Water chemistry in the GWCC lentic environment is likely undergoing biogeochemical transformation that is important to measure. GWCC-1 and GWCC-2 both drain into the same pond, and past observations have noted that collecting discrete samples at these stations can be complicated by the high water of the pond covering the seep outflows. It is recommended that only one sample be collected from the pond if isolated seeps cannot be identified.

With the addition of the three recommended stations, a total of 7 exposed stations, 8 reference stations and 7 groundwater and pit lake stations are be included in the proposed monitoring plan. Furthermore, it is strongly recommended that seasonality be monitored through the collection of samples in the fall, winter, and spring. The combined data from quantity and quality measurements over multiple flow conditions will allow for chemical loading analysis.

Tables 2 to **4** provide rationales for all the sample stations recommended as part of the program. **Table 2** provides information on the exposed stations, **Table 3** refers to the reference stations and **Table 4** includes groundwater seeps and pit lake stations.

2.2 CONSIDERATION OF NON-MONITORED STREAMS

There are tributaries entering Clinton Creek downstream and upstream of Eagle Creek (Figure 3) where water quality sample collection and hydrological monitoring are not proposed. Currently, it is not considered necessary to collect water quality and hydrological data at all tributary locations along Clinton Creek. There is no evidence to indicate that these un-named tributaries are influenced by the Site. The proposed stations provide sufficient data sets to characterize the water quality and quantity at the Site, and upstream and downstream of the Site. Comparisons can be made between these data sets (e.g., Station E1, E4 all R Stations, and E7). In the future, if a review of these data sets indicates that there are potentially significant influences on water quality and quantity from the non-monitored tributaries, then more detailed investigations can be considered.

2.3 SAMPLING PARAMETERS

2.4 SURFACE WATER QUALITY SAMPLING METHODS

Surface water quality sampling should be conducted in accordance with *Standard Methods for the Examination of Water and Wastewater* (Rice et al., 2012*)*. Field *in-situ* water quality parameters should be measured and laboratory analytical samples collected at each sample station.

The following field parameters should be collected using a YSI type of handheld Meter:

- Water temperature (˚C);
- pH (pH units);
- Conductivity and Specific Conductivity (µs/cm); and,
- Dissolved oxygen (mg/L and percent saturation).
- ORP (Oxidation, reduction Potential) is recommended as it is a complimentary measurement to DO. It should be noted that collecting accurate readings can be challenging. If concentrations are low (as in spring conditions) measurements will not reach equilibrium and should be considered semi-quantitative.

Following the collection of field *in-situ* parameters at each station, samples for laboratory analysis should be collected. Standard protocol dictates that samples be collected directly into laboratory-supplied containers, and field filtered and/or preserved according to laboratory instructions. Nitric acid (HNO_3) is used as a preservative for metals (dissolved and total), hydrochloric acid (HCl) is used to preserve samples for ultra-trace mercury testing, and sulphuric acid (H_2SO_4) is used as a preservative for certain nutrient parameters and dissolved organic carbon (DOC).

Table 1 Analytical Sampling Summary

Parameter Type	Parameter Analyzed	Rationale
Metals	Low Level Dissolved Metals and Hardness	Measuring both dissolved and total fractions is important in identifying cause and potential toxicity. There have been historical exceedances of metals on Site and between seasons. Continued measurement of metals provides evidence of natural signatures. Hardness is important in quantifying buffering capacity but is also necessary in calculating guidelines.
	Low Level Total Metals and Hardness	
	Speciated Chromium - Cr(VI) and Cr(III)	Will aid in understanding oxidation states between Reference, Exposed, and Seep samples.
	Dissolved Mercury	Elevated mercury can be a result of industrial activity and can be toxic to aquatic ecosystems. In previous studies carried out on Site T. Mercury did exceed guidelines. Continuing to document trends in R and E sites can build a case of natural or improving trends.
	Total Mercury	

Parameter Type	Parameter Analyzed	Rationale
Nutrients and Carbon	Nitrate, Nitrite, Ammonia-N and Total Phosphorous	Changes in the physical environment may have an impact on nutrient distribution and therefore primary productivity. Illustrating natural seasonal variability can preclude human induced stressors and provide data that indicates regional levels.
	Dissolved Organic Carbon (DOC)	As an important component to the carbon cycle, identifying base levels of DOC identifies the carbon available to aquatic species, and indicates the potential to bind with trace elements, making these elements bioavailable.
	Sulphate	Sulphates can be released by rock blasting and is a concern for potential acid rock drainage. Previously elevated concentrations of sulphate were measured on Site, a continued record will aid in establishing natural variability or natural regional concentrations.
Physical Parameters	Total Suspended Solids (TSS), conductivity and pH	Important to quantify the input to the Forty Mile River Watershed. An established baseline will illustrate natural seasonal variability.

At each sampling station, UTM coordinates should be recorded using a handheld GPS. The general condition and description of each station should be recorded, including any identifiable features or conditions that may influence water quality results. Photos should be taken at each station for reference purposes and to record sampling conditions. It is recommended that photos be taken facing upstream, downstream, and facing across the sample station at each location.

2.4.1 Sample Care and Shipping

Samples should be placed into coolers immediately following water collection and kept cool with ice during spring and fall sampling, and care made so samples do not freeze during winter sampling events. Samples must be transported as quickly as possible to an accredited laboratory in Whitehorse, Yukon for analysis of short hold time parameters.

2.4.2 Laboratory Analysis

All surface water quality samples collected must be submitted to the analytical laboratory within 72 hours of sampling, and all primary analyses conducted within laboratory hold time limits.

Laboratory analyses for the surface water quality monitoring program employs a variety of laboratory methods to determine the various water quality parameters recommended for this monitoring program. Specific methods are applicable (CCME 2014).

3.0 SURFACE WATER FLOW PLAN (HYDROLOGY)

3.1 SURFACE WATER FLOW MONITORING

Hemmera/ELR has reviewed background information pertaining to the Site and recommend that three hydrology stations be discontinued and that three new hydrology stations be added to the list of stations. It is also recommended that two hydrometric stations (staff gauge with pressure transducer) be installed; one on the upper reaches of Clinton Creek near station E1 (**Figure 2**), and a second on the lower reaches of Clinton Creek near station E4 (**Figure 3**). The rationales for these recommendations and for retaining other existing stations are presented in **Tables 2** to **4**. Information on stream gauging frequency, duration and methods, and the use of hydrometric stations is provided below.

3.2 FREQUENCY AND DURATION OF FLOW MONITORING

A key objective of the water sampling and flow monitoring on Site is to gain a better understanding of the water quality and hydrological processes. To do this Hemmera/ELR recommend that sampling and monitoring is completed at least three times for at least one complete year to provide seasonal late winter, spring freshet and fall base flow data. After the first complete year, the sampling and monitoring program can be reviewed and decisions can be made whether adjustments to the program are required and if the program should be extended.

3.3 MANUAL STREAM GAUGING METHOD

Manual stream gauging methods for the spring and fall would continue as for previous years (i.e. using a Swoffer meter or similar manual gauging device and following Water Survey of Canada methods to obtain flow data at multiple locations across streams) and employing a velocity-area method to measure discharge at surface water bodies. For the winter flow monitoring, a flow meter may be used (i.e., at open water stations or by cutting multiple holes in the ice across streams), or, depending on the gradient and turbulence of the stream, the under ice salt dilution (“salt slug”) method could be used to collect data to calculate flow. Hemmera/ELR has successfully used this method at multiple sites in the Yukon and the method has been acknowledged as providing comparable results to flow meter gauging (Hudson and Fraser 2002; Hudson and Fraser 2005).

3.4 HYDROMETRIC STATIONS

Two hydrometric stations are recommended for Clinton Creek (**Tables 2** to **3** and **Figures 2** to **3**). A hydrometric station includes a pressure transducer in a protective housing (e.g., metal or PVC pipe) and a staff gauge. Both the housing and staff gauge are usually anchored to a solid object in the stream (e.g., boulder). The pressure transducer housing and staff gauge are surveyed using standard survey equipment and by installing local bench marks. Survey measurements are collected periodically to check if the housing or staff gauge have moved (small movements can be accommodated within the flow

calculations). In combination with the manual flow data collection, the pressure transducer allows pressure data to be collected and stored that translates (through calculations) to a stream discharge volume. As long as manual measurements are also collected periodically then the hydrometric station is used to provide regular pressure (flow) data in lieu of manual data collection. The transducer remains in the housing year-round and can be programmed to collect and store data at different intervals (every 15 minutes is recommended). The stored data are then downloaded during each field visit (through a field laptop computer). The data collected are used to generate a hydrograph for the period of measurement (e.g., all year). It should be noted that pressure transducers can sometimes freeze solid or can be above the water surface for periods of very low flow (e.g., some winter months) but then start to record useable data again as temperatures increase and water levels rise.

Despite the potential gaps in data, pressure transducers provide highly beneficial and cost effective data. A staff gauge would also be installed close to the pressure transducer as an inexpensive method to measure stream depth and provides a back-up to the pressure transducer. Whenever field crews or contractors are on Site, readings can be taken from the staff gauges that can be converted to stream flow. Data from the proposed new meteorological station can also be used to validate data collected by the hydrometric stations (e.g., high rainfall events).

Table 2 Exposed Stations

Station Code	Proposed Station Status	Sampling Conducted	Station Description	Location (UTM, Zone 7N)		Health and Safety Concern?	Seasons to Collect Samples/Monitor Flows	Hydrometric Station? [a]	Rationale
				Easting	Northing	Y/N		Y/N	Hydrology = white box, Water Quality = light green box
E1	Maintain Existing Station and add Hydrometric Station	Water Quality, Hydrology	Clinton Creek downstream of gabions	513645	7147111	Y	Fall, Winter, Spring	Y	• Provides seasonal volume output of Hudgeon Lake. • The 2014 flow gauging station upstream of the Secondary Ford Crossing is not a health and safety concern. • The hydrometric station, E1(H), will provide seasonal high frequency data that will help gain a better understanding of the water flow in Clinton Creek, downstream of Hudgeon Lake. The hydrometric station should be located as close to the outlet of Hudgeon Lake as possible, but due to safety hazards near the toe of the waste rock, its actual location should be based on a Site reconnaissance and discussions with AAM staff about location options. • Maintain water quality sampling for historical data continuity. It is important to capture the water quality from Hudgeon Lake and any subsurface seeps to Clinton Creek along the waste rock pile.
E2	Maintain Existing Water Quality Station. Discontinue Hydrological Monitoring	Water Quality	Clinton Creek, downstream of Porcupine Creek but upstream of Wolverine Creek	514149	7147076	N	Fall, Winter, Spring	N	• Manual gauging not required (see E9, E3 and E4). • As flow inputs at E3 and the new E9 station will be monitored, as well as downstream at E4 then gauging flows at E2 is not considered to be necessary. • Maintain water quality sampling for historical data continuity. It is understood that this station captures drainage from Porcupine Creek and Clinton Creek prior to input from Wolverine Creek.
E3	Maintain Existing Station	Water Quality, Hydrology	Wolverine Creek, upstream of culvert	514178	7147189	N	Fall, Winter, Spring	Y	• Provides seasonal water volumes for Wolverine Creek and tributaries that can be directly compared to the upstream data collected at station R3. • Maintain water quality sampling for historical data continuity. This station captures Wolverine Creek, any contributions from the tailings area and tributaries.
E4	Maintain Existing Station	Water Quality, Hydrology	Clinton Creek downstream of Wolverine Creek but upstream of Eagle Creek	515950	7145287	N	Fall, Winter, Spring	Y	• Provides seasonal water volume of Clinton Creek, downstream of the mine footprint. • The hydrometric station will provide seasonal high frequency data that will help gain a better understanding of the Clinton Creek flows downstream of the mine footprint and at a location not influenced by other streams that are not likely affected by the mine footprint. The hydrometric station would be located in Clinton Creek, a short distance upstream of the mouth of Eagle Creek. • Maintain water quality sampling for historical data continuity. E4 characterises all water quality collected from the mine site and prior to any contribution from Eagle Creek. • It is important to establish the chemical signature prior to any other influence (Eagle creek)
E7	Maintain Existing Station	Water Quality, Hydrology	Clinton Creek near mouth	519400	7142042	N	Fall, Winter, Spring	N	• The station will provide seasonal and final flow input data into the Forty Mile River and can be compared to data collected upstream to calculate the inputs of upstream tributaries that are not monitored. • Maintain water quality sampling for historical data continuity. Important to quantify the quality of water prior to entering the Forty Mile River system.
E8	Maintain Existing Water Quality Station. Discontinue Hydrological Monitoring	Water Quality	Forty Mile River downstream of Clinton Creek	519457	7142788	Y	Fall, Winter, Spring	N	• Discontinue flow gauging as the river is unsafe to cross without specialized equipment. It is understood that the volume contributed from Clinton Creek to Forty Mile River is minimal and will likely not significantly impact flow volumes on Forty Mile River. • It is important to continue the baseline water quality in Forty Mile River to quantify potential impact of Clinton Creek. Data from this station can be compared to R6 to identify any impact.

Station Code	Proposed Station Status	Sampling Conducted	Station Description	Location (UTM, Zone 7N)		Health and Safety Concern?	Seasons to Collect Samples/Monitor Flows	Hydrometric Station? [a]	Rationale
				Easting	Northing	Y/N		Y/N	Hydrology = white box, Water Quality = light green box
E9	Proposed New Station	Water Quality, Hydrology	Porcupine Creek upstream of the confluence with Clinton Creek and downstream of the main waste rock pile	513793 (estimated)	7146789 (estimated)	N	Fall, Winter, Spring	N	• A manual gauging station will provide seasonal flow contribution of Porcupine Creek to Clinton Creek. • Flows can be compared to inputs at R7, upstream of the waste rock. • This station should capture the influence of Porcupine Creek on Clinton Creek and the results can be compared to those at R7, upstream of the waste rock. The precise location of the station will need to be determined in the field. • Similar location to previous E5 station (Minnow, 2010)

Notes:

1. It is proposed that sites that are italicized and underlined be removed from the program.
2. Site codes with a bold font indicate a proposed new station.
3. [a] A hydrometric station would include a staff gauge and an all-season pressure transducer contained in a protective housing.
4. Station names R5 and E5 had previously been used by Minnow (2010) and so should not be re-used as station names at different locations to maintain consistency and prevent future misinterpretation of data.

Table 3 Reference Stations:

Station Code	Proposed Station Status	Sampling Conducted	Station Description	Location (UTM, Zone 7N)		Health and Safety Concern?	Seasons to Sample/Monitor Flow	Hydrometric Station? [a]	Rationale
				Easting	Northing	Y/N		Y/N	Hydrology = white box, Water Quality = light green box
R1	Maintain Existing Station	Water Quality, Hydrology	Clinton Creek upstream of Hudgeon Lake	510718	7147525	N	Fall, Winter, Spring	N	• Station provides flow input data to Hudgeon Lake. • Gauged along with other Hudgeon Lake stream inputs to allow lake input data to be compared to output data at E1. • Maintain water quality sampling for historical data continuity. • This station is important as it allows for quantification of inputs from Clinton Creek to Hudgeon Lake.
R2	Maintain Existing Station	Water Quality, Hydrology	Easter Creek upstream of Hudgeon Lake	512023	7148061	N	Fall, Winter, Spring	N	• Station provides flow input data to Hudgeon Lake. • Gauged along with other Hudgeon Lake stream inputs to allow lake input data to be compared to output data at E1. • Maintain water quality sampling for historical data continuity. • Data from this station allows for quantification of inputs from Easter Creek to Hudgeon Lake.
R3	Maintain Existing Station	Water Quality, Hydrology	Wolverine Creek, upstream of tailings	513952	7148677	Y	Fall, Winter, Spring	N	• Station provides background flow volume for Wolverine Creek, upstream of the tailings and can be compared to the output data downstream at E3. • Access to the station involves crossing the tailings which may be unstable in places. • Maintain water quality sampling for historical data continuity. • Historical data indicates elevated metals at this reference station. Evaluation of potential impact from tailings to this station should be executed. It is recommended that this station be moved further north.

Station Code	Proposed Station Status	Sampling Conducted	Station Description	Location (UTM, Zone 7N)		Health and Safety Concern?	Seasons to Sample/Monitor Flow	Hydrometric Station? [a]	Rationale
				Easting	Northing	Y/N		Y/N	Hydrology = white box, Water Quality = light green box
R4	Maintain Existing Station	Water Quality, Hydrology	Eagle Creek, upstream of culvert	515981	7145344	N	Fall, Winter, Spring	N	• Station provides flow input data from Eagle Creek into Clinton Creek which is collected to assess flows at E7 (mouth of Clinton Creek). • Maintain water quality sampling for historical data continuity. • Elevated metals have been measured at R4. Measuring this input into Clinton Creek will support discussion that the same elevated metals at E7 may be contributed from Eagle Creek rather than the mine site drainage. • Last tributary measured to Clinton Creek before the outlet at E7.
R6	Maintain Existing Water Quality Station Discontinue Hydrological Monitoring	Water Quality	Forty Mile River, upstream of Clinton Creek	519437	7141958	Y (for hydrology only)	Fall, Winter, Spring	N	• Discontinue hydrology as the river is not safe to cross without specialized equipment and the volumes are too high to be influenced by Clinton Creek inputs. • Maintain water quality sampling for historical data continuity • Important to collect water quality data at a location on Forty Mile River prior to the inflow of Clinton Creek and compared to E8 to quantify the impact on the river.
R7	Maintain Existing Station	Water Quality, Hydrology	Porcupine Creek, upstream of waste rock	513026	7145669	N	Fall, Winter, Spring	N	• Station provides background flow input data into Porcupine Creek that can be directly compared to outputs downstream at E9. • This station provides reference chemistry for Porcupine Creek. The beaver activity influenced creek and groundwater seeps infers multiple impacts and therefore makes it important to measure background quality.
R8	Proposed New Station	Water Quality, Hydrology	Unnamed creek that enters Hudgeon Lake west of Easter Creek	511791 (estimated)	7147926 (estimated)	N	Fall, Winter, Spring	N	• Station provides flow input data to Hudgeon Lake. • Gauged along with other Hudgeon Lake stream inputs to allow lake input data to be compared to output data at E1. • Proposed stations R8 and R9 should be assessed for water quality to provide data on all possible contributions to Hudgeon Lake.
R9	Proposed New Station	Water Quality, Hydrology	Unnamed stream input on the south side of Hudgeon Lake	512336 (estimated)	7146584 (estimated)	N	Fall, Winter, Spring	N	• Station provides flow input data for Hudgeon Lake. • Gauged along with other Hudgeon Lake stream inputs to allow lake input data to be compared to output data at E1. • Proposed stations R8 and R9 should be assessed for water quality to provide data on all possible contributions to Hudgeon Lake.

Notes:

5. It is proposed that station codes that are italicized and underlined be removed from the program.
6. Site codes with a bold font indicate a proposed new station.
7. [a] A hydrometric station would include a staff gauge and an all-season pressure transducer contained in a protective housing.
8. Station names R5 and E5 had previously been used by Minnow (2010) and so should not be re-used as station names at different locations to maintain consistency and prevent future misinterpretation of data.

Table 4 Groundwater Seeps, Porcupine Pit Lake, Snowshoe Pit Lake

Station Code	Proposed Station Status	Sampling Conducted	Station Description	Location (UTM, Zone 7N)		Health and Safety Concern?	Seasons to Collect Samples/Monitor Flows	Hydrometric Station? [a]	Rationale
				Easting	Northing	Y/N		Y/N	Hydrology = white box, Water Quality = light green box
GWCC-1	Maintain Existing Station	Water Quality	Toe of the Waste Rock dump flowing into ponded area at Porcupine Creek	513902	7146960	N	Fall, Winter, Spring	N	• Continuing to quantify typical groundwater seepage is important (some metals are elevated compared to natural systems) • If discrete samples cannot be collected due to elevated water conditions it is recommended that one sample be collected from the pond that GWCC-1 and GWCC-2 drain to.
GWCC-2	Maintain Existing Station	Water Quality	Toe of the Waste Rock dump flowing into ponded area approx. 10 m northwest of GWCC-1	513899	7146968	N	Fall, Winter, Spring	N	• Continuing to quantify typical groundwater seepage is important (some metals are elevated compared to natural systems) • If discrete samples cannot be collected due to elevated water conditions it is recommended that one sample be collected from the pond that GWCC-1 and GWCC-2 drain to.
GWCC-3	Maintain Existing Station	Water Quality	Toe of the Waste Rock dump flowing into side channel, approx. 10 m northwest of GWCC-2	513882	7147038	N	Fall, Winter, Spring	N	• Stations GWCC-4 through GWCC-1 provide a gradient from more natural conditions to conditions likely influenced by the waste rock. Recommended that these seeps continue to be sampled as long as discrete samples can be identified.
GWCC-4	Maintain Existing Station	Water Quality	Toe of the Waste Rock dump flowing into side channel, approx. 10 m northwest of GWCC-3	513868	7147052	N	Fall, Winter, Spring	N	• Maintain water quality sampling for historical data continuity. • This seep appears to have a different chemical signature to other seeps, likely reflects more natural conditions.
GWCC-5	Maintain Existing Station	Water Quality, Hydrology	Groundwater flows in old Clinton Creek channel	513984	7147127	N	Fall, Winter, Spring	N	• Manual gauging is required to understand the surface water flow associated with Clinton Creek. • Past field observations have included multiple seeps into old Clinton Creek. This station quantifies the chemical signature of multiple seep areas in old Clinton Creek. • The next station to compare quality to is E2.
PL	Maintain Existing Station	Water Quality	Porcupine Pit Lake from shore	513290	7146350	Y	Fall, Winter, Spring	N	• Access to this station was surrounded by evidence of recent rock falls in 2014. • It was determined that with no easy exit strategy this sample was omitted in 2014. • It is recommended that this sample be collected in the future if safety allows. • Previous data indicates elevated metals that should be quantified.
SL	Maintain Existing Station	Water Quality	Snowshoe Pit Lake from shore	513824	7146703	N	Fall, Winter, Spring	N	• Important to continue to quantify the water in Snowshoe Pit Lake in the case of interaction with Porcupine Creek and other nearby water bodies.

Notes:

9. It is proposed that station codes that are italicized and underlined be removed from the program.
10. Site codes with a bold font indicate a proposed new station.
11. [a] A hydrometric station would include a staff gauge and an all-season pressure transducer contained in a protective housing.
12. Station names R5 and E5 had previously been used by Minnow (2010) and so should not be re-used as station names at different locations to maintain consistency and prevent future misinterpretation of data.

4.0 RECOMMENDATIONS

Further to the above surface water quality plan prepared to the Site, based on a review of the available Site information and Hemmera/ELR observation during previous sampling events, the following is also recommended:

1. An analysis be completed that compares the cost of a ground-access only sampling and monitoring program to an aerial access monitoring and sampling program, given that commercial helicopters are based in Dawson City, approximately 20 minutes flight time from Clinton Creek. Completing the program by helicopter will reduce staff time on Site and may off-set the costs associated with a ground-based only program. The analysis should consider construction costs for helicopter pads at key locations to allow safe and easy access for the aircraft and field crew (e.g., sampling and monitoring stations around Hudgeon Lake, R3, and R7).
2. If any structural works are planned at Site (e.g., erosion control work, structural alterations to riprap) then some use could be made of heavy equipment to ensure there are suitable boulders (or concrete blocks) in place along Clinton Creek to provide potential anchor points for the hydrometric stations (transducer housing and staff gauge).
3. If safety allows, it is recommended that staff gauges be installed in Snowshoe and Porcupine Lakes. This would allow for insight into seasonal fluctuations in these ponds and to inform opinions on hydrological inputs and outputs to and from the ponds.
4. Time should be built into future sampling and monitoring programs at Site to allow crews to clear and mark safe access trails to sampling points (e.g., along Wolverine Creek to R3, and to the head waters of Porcupine Creek (R7).
5. A late winter snow depth and density survey should be considered as this will help validate precipitation data collected by the proposed meteorological station and be used as part of future hydrological analysis for the Site (e.g., water balance calculations).
6. Semi-permanent station name tags should be produced that can be located at the sampling and monitoring stations to provide long-term consistency of sampling locations and minimize field sampling errors.
7. Remove the beaver dam on Porcupine Creek to allow the pond to drain. This will allow groundwater seeps that were beneath the waterline to be sampled and potentially provide a suitable flow gauging location to be identified for station E9.
8. Sample station E1 should be relocated to a safe area that can be consistently sampled in the future. During the 2014 program, samples were collected for station E1 at a location downstream of the primary ford structure after discussion with AAM. The Clinton Creek – Site Hazards document (AAM, 2014) identified the area upstream of the primary ford as a potentially hazardous location, and therefore the station was relocated.

5.0 CLOSING

We sincerely appreciate the opportunity to have assisted you with this project and if there are any questions, please do not hesitate to contact the undersigned by phone at 604.669.0424.

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6.0 REFERENCES

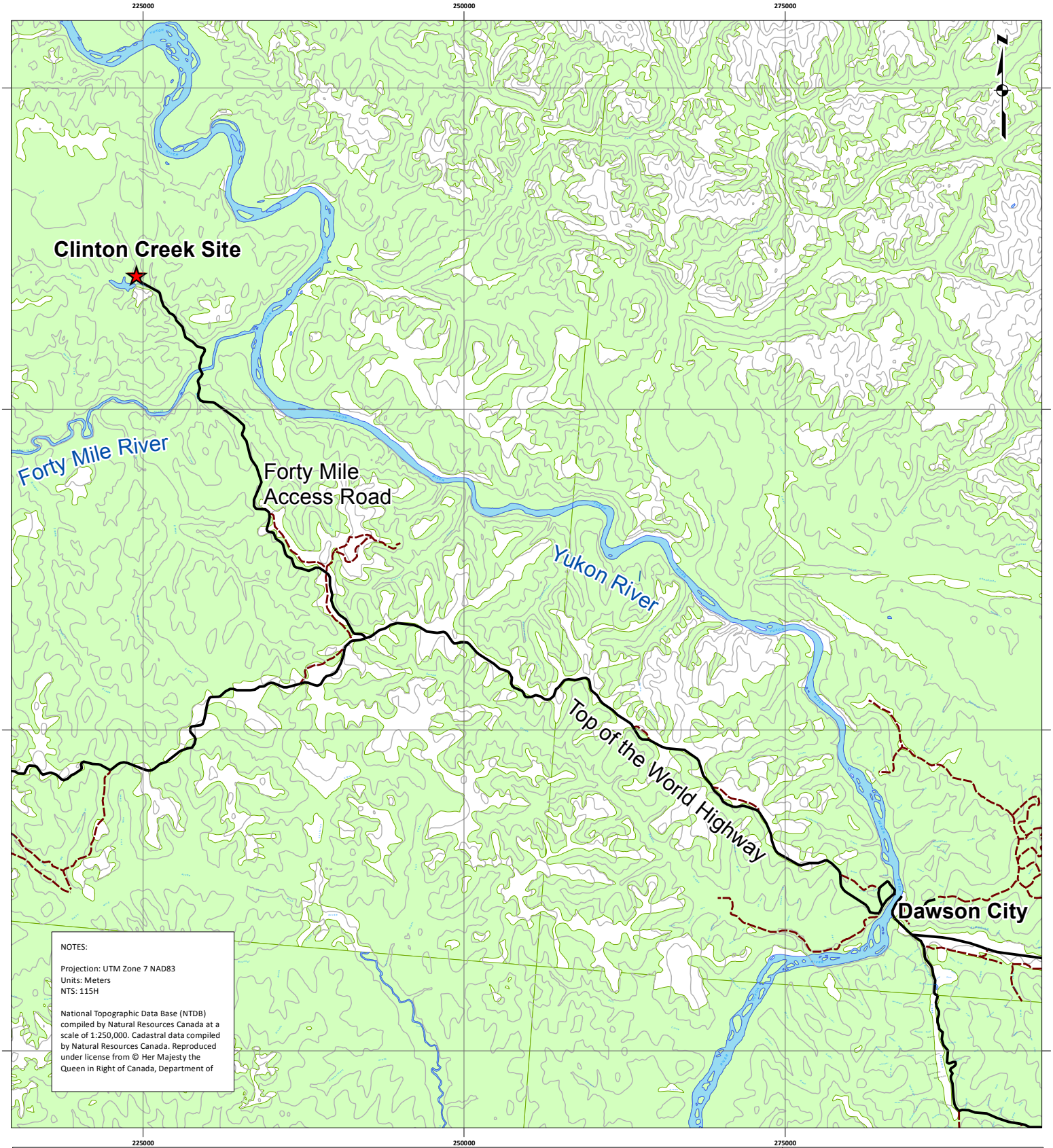
Assessment and Abandoned Mines (AAM). 2014. Clinton Creek – Site Hazards. Government of Yukon, Clinton Creek – Health and Safety. September 4, 2014.

Canadian Council of Ministers of the Environment (CCME). 2014. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Accessed online at http://st-ts.ccme.ca/, March 2014.

Hudson, R and Fraser, J. 2002. Alternative methods of flow rating in small coastal streams. In Forest research Extension Note. EN-014, Hydrology. March 2002. Available at http://www.for.gov.bc.ca/rco/research/hydroreports/en014.pdf. Accessed March 19, 2015.

Hudson, R and Fraser, J. 2005. Introduction to salt dilution gauging for streamflow measurement Part IV. The Mass Balance (or Dry Injection Method). In Streamline. Watershed Management Bulletin. Vol 9/No.1 Fall 2005. Available at: http://www.siferp.org/sites/default/files/publications/articles/streamline_vol9_no1_art2.pdf. Accessed March 19, 2015.

Rice, E.W., Baird, R.B., Eaton, A.D., & Clesceri, L.S. 2012. Standard Methods for the Examination of Water and Wastewater, 22nd Edition. American Public Health Association. ISBN: 9780875530130



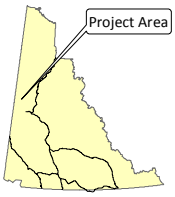
[redacted]

[redacted]

Client: [redacted]

Legend

- Clinton Creek Site
- Road
- Limited-use road
- Wetlands
- Waterbodies
- Vegetation



Scale: 1:400,000

8 4 0 8 Km

Clinton Creek Surface Water Quality and Hydrological Monitoring Plan

Figure 1

Project Area Overview

Date: Mar.22, 2015	Drawn by: CJ
ELR Project #: 15-195 Hemmera Project #: 1343-005.04	Rev. #: 1

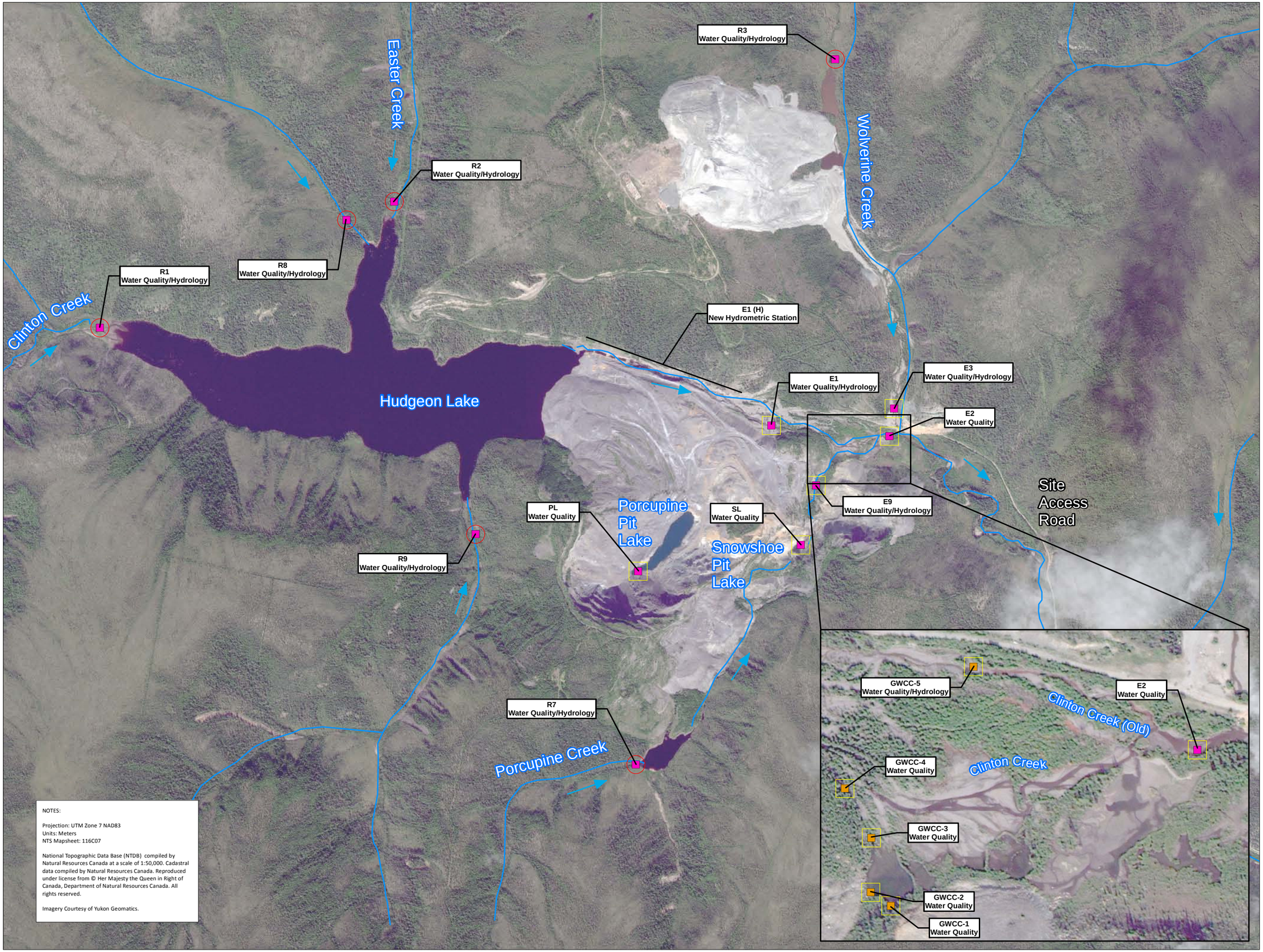
Clinton Creek Surface Water Quality and Hydrological Monitoring Plan

Ecological Logistics & Research Ltd.

HEMMERA

Client:

Yukon Energy, Mines and Resources
Assessment and Abandoned Mines



NOTES:

Projection: UTM Zone 7 NAD83
Units: Meters
NTS Mapsheet: 116C07

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Imagery Courtesy of Yukon Geomatics.

Legend

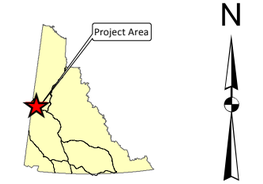
Water Type

- Surface Water
- Groundwater

Site Type

- Exposed
- Reference

- Topographic Watercourse Data
  (may not be truly representative of on-site conditions)



0 155 310 620
Meters

FIGURE 2
Sampling Stations
Site Area

Date: Mar.29, 2015	Scale: 1:15,000
ELR Project #: 15-195 Hemmera Project #: 1343-005.04	Rev. #: 3

Clinton Creek Surface Water Quality and Hydrological Monitoring Plan

Ecological Logistics & Research Ltd.

HEMMERA

Client:

Yukon Energy, Mines and Resources
Assessment and Abandoned Mines

Clinton Creek

Eagle Creek

R4
Water Quality/Hydrology

E4 (H)
New Hydrometric Station

E4
Water Quality/Hydrology

Site Access Road

Forty Mile River

E8
Water Quality

Clinton Creek

E7
Water Quality/Hydrology

R6
Water Quality

NOTES:

Projection: UTM Zone 7 NAD83
Units: Meters
NTS Mapsheet: 116C07

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Imagery Courtesy of Yukon Geomatics.

Legend

Water Type

Surface Water

Site Type

Exposed

Reference

Topographic Watercourse Data
(may not be truly representative of on-site conditions)

N

0 190 380 760

Meters

FIGURE 3

Sampling Stations

Forty Mile River Area

Date: Mar. 29, 2015	Scale: 1:18,000
ELR Project #: 15-195 Hemmera Project #: 1343-005.04	Rev. #: 3