**Report**

**Mount Nansen June 2015**

**Groundwater Monitoring and Sampling**

Prepared for:

**Government of Yukon**

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File: 1343-005.09

October 2015

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# Introduction

Hemmera Envirochem Inc. (“Hemmera”) and Ecological Logistics & Research Ltd. (Hemmera/ELR) were retained by the Government of Yukon (GY), Assessment and Abandoned Mines (AAM) to conduct a groundwater monitoring and sampling program at the Mount Nansen Site (the Site) in June, 2015. Hemmera/ELR’s scope of work includes the monitoring of groundwater wells and collection of groundwater samples from a series of existing groundwater wells at the Site. This report summarizes the monitoring and sampling activities, a description of methodologies and field conditions encountered, a summary of field *in-situ* and laboratory analytical results including a comparison to applicable guidelines, a description of any observations or occurrences that may have influenced program results, and recommendations relating to sample procedures and monitoring well conditions. This report does not provide an interpretation of the results, nor does it provide recommendations relating to groundwater quality at the Site.

## Site Location

The Mount Nansen Site (the Site) is located approximately 45 kilometres (km) west of the Village of Carmacks (70 km by road). This Type II abandoned mine site consists of three (3) primary areas of existing infrastructure: the Brown McDade Pit, a Mill Complex, and a Tailings Facility (**Figure 1-1**). Groundwater monitoring wells exist throughout the Site, a subset of which were sampled during the June 2015 groundwater monitoring and sampling program. The groundwater monitoring locations included in this program are described in **Sections 1.2** and **1.3**.

## Scope of Work

The scope of work for this program included the coordination and execution of the June groundwater monitoring and sampling, analysis of groundwater samples, and the presentation of results in a report.

Groundwater sampling at the Site was conducted over a four (4) day period, between June 1 and 4, 2015. Sampling was conducted by a team of four (4) qualified field staff from Hemmera/ELR (Rusto Martinka, Jarrod Coburne, Aaron Nicholson, and Michelle McKay). A total of 65 groundwater wells were included in the June sampling event (**Table 1-1**). It was not possible to sample two (2) of the groundwater wells listed in the scope of work as both wells were previously destroyed (MP09-01 and GSI-PC-01-B). Four (4) of the remaining 63 groundwater wells assessed were known to be difficult to sample, as noted during previous sampling events; two (2) were reported as damaged (CH-P-13-03/10 and MW09-01), one (1) reported as blocked (CH-P-13-04/35), and one (1) reported as dry and damaged (CH-P-13-02/10). Part of Hemmera/ELR’s June 2015 scope of work was to further investigate these wells using a down-well camera.

At each well (sampling station) headspace gas concentrations were measured, well and water level parameters were measured (depth to water, depth to bottom, well diameter, and well stick-up height), the well was purged, and then prescribed *in-situ* groundwater quality parameters were measured. Lastly, groundwater samples were collected for laboratory analysis. A detailed description of the sampling methods and measured groundwater quality parameters is provided in **Section 2**, below.

## Sample Sites

The groundwater wells included in the June monitoring and sampling event were grouped into six (6) main areas of the Mount Nansen Site (**Table 1-1**). The majority of groundwater wells were located around existing infrastructure including the tailings facility, and seepage dam (25 wells), the Brown McDade Pit (13 wells) and the Mill Complex (9 wells). Additional wells (primarily drive-point piezometer installations) were sampled in the vicinity of Dome Creek (9 wells) and Pony Creek (9 wells). **Table 1-1** provides the location, status, and sample recovery for groundwater wells included in the June sampling program. The well locations are also illustrated in **Figures 1-2** and **1-3**. Photographs of each sample site visited in June are included in **Appendix A**.

Figure 1-1 Site Location – Mount Nansen Site

Table 1-1 Summary of Groundwater Well Locations and Samples Collected

| **Area** | **Well Name** | **UTM (Zone 08N)** | **Status1,2** | **Sample Collected** | **QA/QC Sample Collected** |
| --- | --- | --- | --- | --- | --- |
| **Easting** | **Northing** |
| Dome Creek | GSI-DC-01B | 387675 | 6881124 | Dry | - | - |
| GSI-DC-02B | 387879 | 6881129 | Frozen | - | - |
| GSI-DC-03B | 388107 | 6881079 | Frozen | - | - |
| GSI-DC-05B | 388725 | 6880836 | Frozen | - | - |
| GSI-DC-06B | 389788 | 6880567 | Frozen | - | - |
| GSI-DC-07B | 390065 | 6880641 | Frozen | - | - |
| GSI-DC-08-B | 390311 | 6880583 | Frozen | - | - |
| GSI-DC-09-B | 390614 | 6880494 | Frozen | - | - |
| GSI-DC-10-B | 390859 | 6880447 | Frozen | - | - |
| Mill Complex | GSI-HA-01A | 387842 | 6881132 | Direct Sampled1 | ✓ | - |
| GSI-HA-02A | 387861 | 6881135 | Direct Sampled1 | ✓ | - |
| GSI-HA-03A | 387878 | 6881131 | Direct Sampled1 | ✓ | - |
| GSI-HA-04A | 387916 | 6881130 | Frozen | - | - |
| GSI-HA-05A | 387898 | 6881125 | Direct Sampled1 | ✓ | - |
| MW09-16 | 387992 | 6881094 | Good | ✓ | Duplicate |
| MW09-17 | 388075 | 6880970 | Good | ✓ | - |
| MW09-18 | 388054 | 6880986 | Good | ✓ | - |
| MW09-19 | 388051 | 6881016 | Good | ✓ | Field Blank |
| Brown McDade Pit | CH-P-13-01/10 | 388657 | 6881116 | Frozen | - | - |
| CH-P-13-03/10 | 389145 | 6881105 | Frozen2 | - | - |
| CH-P-13-03/50 | 389143 | 6881110 | Insufficient Volume  | - | - |
| CH-P-13-04/10 | 389138 | 6881472 | Frozen | - | - |
| CH-P-13-04/35 | 389138 | 6881472 | Frozen2 | - | - |
| CH-P-13-05/50 | 388954 | 6881466 | Good | ✓ | - |
| GLL07-01 | 388851 | 6881783 | Frozen  | - | - |
| GLL07-02 | 389069 | 6881703 | Dry | - | - |
| GLL07-03 | 388959 | 6881477 | Dry | - | - |
| MW09-13 | 389006 | 6881664 | Frozen | - | - |
| MW09-14 | 389008 | 6881669 | Frozen | - | - |
| MW09-15 | 388920 | 6881727 | Frozen | - | - |
| CH-P-13-02/10 | 388924 | 6881014 | Dry/Damaged2 | - | - |
| Pony Creek | GSI-PC-01-B | N/A | N/A | Destroyed3 | - | - |
| GSI-PC-02-B | 388907 | 6881786 | Frozen | - | - |
| GSI-PC-03-B | 389256 | 6881706 | Direct Sampled1 | ✓ | - |
| GSI-PC-04-B | 389586 | 6881656 | Frozen | - | - |
| GSI-PC-05-B | 389713 | 6881661 | Frozen | - | - |
| MP09-01 | N/A | N/A | Destroyed3 | - | - |
| MP09-02 | 388867 | 6881816 | Frozen2 | - | - |
| MP09-03 | 388956 | 6881739 | Frozen | - | - |
| MP09-08 | 389160 | 6881718 | Frozen | - | - |
| Seepage Dam | W14103083BH01 | 389522 | 6880669 | Frozen | - | - |
| W14103083BH02 | 389561 | 6880665 | Frozen | - | - |
| W14103083BH04 | 389544 | 6880666 | Frozen | - | - |
| Tailings Facility | MP09-04 | 389575 | 6880609 | Frozen | - | - |
| MP09-05 | 389548 | 6880590 | Good | ✓ | Duplicate, Field Blank |
| MP09-09 | 389240 | 6880681 | Good | ✓ | - |
| MP09-10 | 389241 | 6880684 | Frozen | - | - |
| MP09-11 | 389220 | 6880619 | Good | ✓ | - |
| MP09-12 | 389220 | 6880619 | Frozen | - | - |
| MP09-14 | 389138 | 6880722 | Direct Sampled1 | ✓ | - |
| MW09-01 | 389396 | 6880563 | Damaged2 | ✓ | - |
| MW09-02 | 389393 | 6880562 | Good | ✓ | - |
| MW09-03 | 389411 | 6880555 | Good | ✓ | - |
| MW09-04 | 389420 | 6880557 | Good | ✓ | Duplicate, Field Blank |
| MW09-05 | 389413 | 6880656 | Dry | - | - |
| MW09-06 | 389411 | 6880653 | Good | ✓ | - |
| MW09-07 | 389322 | 6880699 | Dry | - | - |
| MW09-08 | 389620 | 6880576 | Good | ✓ | - |
| MW09-11 | 389037 | 6880711 | Dry | - | - |
| MW09-20 | 389592 | 6880586 | Dry | - | - |
| MW09-21 | 389536 | 6880577 | Frozen | - | - |
| MW09-22 | 389495 | 6880549 | Good | ✓ | Field Blank |
| MW09-23 | 389459 | 6880553 | Damaged | ✓ | - |
| MW09-24 | 389561 | 6880624 | Good | ✓ | - |
| W14103083BH03 | 389132 | 6880730 | Good | ✓ | - |

**Notes: 1** Direct sampling was completed at sample stations where insufficient volume had been encountered during the June 2014 groundwater sampling (Hemmera, 2014a). This insufficient volume limited standard purging and sampling methodologies.

**2** Groundwater wells previously reported as damaged (MW09-01 and CH-P-13-03/10), dry/damaged (CH-P-13-02/10), or blocked (CH-P-13-04/35) were investigated during the June 2015 sampling event using a down well camera. Further information regarding the status of damaged wells is provided in **Section 3.2.**

**3** Destroyed wells are included in the scope of work and are therefore listed above in the summary table. These wells are not further discussed in this report.

Figure 1-2 Groundwater Sampling Locations – Dome Creek and Tailings Facility

Figure 1-3 Groundwater Sampling Locations – Mill Complex and Brown McDade Pit

# Methodology

## Protocols

Groundwater purging, monitoring and sampling conducted by Hemmera/ELR were completed in accordance with the Groundwater Sampling Standard Operating Procedures included in the document *Scope of Work: Groundwater Sampling Program – Mount Nansen Site 2015*. These procedures were consistent with Environment Yukon’s *Protocol for the Contaminated Sites Regulation #7 - Sampling and Decommissioning* (Environment Yukon, 2011). Methods used were also consistent with the ASTM D4448-01 *Standard Guide for Sampling Groundwater Monitoring Wells* (ASTM, 2013), and the D6452-99 *Guide for Purging Methods for Wells used for Groundwater Quality Investigations* (ASTM, 2012).

## Well Measurements and Purging

Upon arriving at each sample station, headspace gases were measured prior to any other well measurements. Oxygen (%), carbon dioxide (ppm), and methane (%LEL) were measured using a RAE Systems MultiRAE Four-Gas Monitor with photoionization detector (PID).

The well structure and casing were inspected for damage, closure, and general conditions. Depth to water (DTW; m), depth to bottom (DTB; m), well diameter (cm), and well stick-up height (m) were then recorded at each well.

DTB and DTW were measured using either a Solinst - Model 102 Water Level Meter (for 2.54 cm diameter wells) or a Solinst – Model 122 Interface Meter (for wells with diameter greater than 2.54 cm). DTB and DTW were measured from (in order of preference): 1) a black mark drawn on the top of the well; 2) the bottom of the most significant notch found on the top of the PVC if a mark was not present; or 3) a line that was drawn on the highest point of the well if no distinguishable point of measure was present. Stick-up height was measured from the lowest point on the bottom of the well casing to the highest point (or distinguishing mark) on the well. Water level meters were cleaned between each sample site using Alconox low-foaming phosphate-free detergent solution and deionized water.

Following initial inspection and measurements, groundwater wells were purged and sampled using dedicated equipment. Groundwater wells were purged and sampled using one of two (2) techniques: 1) manual purging using high density polyethylene (HDPE) Waterra tubing and a footvalve, or 2) GeoPump peristaltic pump with HDPE tubing. The purging technique chosen for each well was that which would produce the most representative groundwater sample.

Groundwater wells were determined to be sufficiently purged when either three successive field parameter measurements were recorded to be within an allowable tolerance level (as summarized in **Table 2-1**, below) or when a volume of water equivalent to three standing well volumes of water had been purged.

Groundwater turbidity measured in Nephelometric Turbidity Units (NTU) was also measured prior to sampling (described below in **Section 2.4**) and was used as an indication of sample quality. Where possible, samples were not collected until turbidity was less than 50 NTU. Purge volumes and purge rates were measured using a graduated container and stop watch. All well measurements, purging details, and additional field notes were recorded on customized field forms in order to minimize the potential for field errors; this information is presented in **Table 3-2**.

Table 2-1 Groundwater Sampling – Field Parameter Purging Criteria

|  |  |
| --- | --- |
| **Field Parameter** | **Allowable Variance** |
| Temperature (°C) | ± 3% |
| pH | ± 0.1 |
| Conductivity (µS/cm) | ± 3% |
| Specific Conductivity (µS/cm) | ± 3% |

## Direct Sampling

During previous events a select number of groundwater wells were found to have an insufficient volume of groundwater to sample, based on having a limited standing water volume or recharge rate (based on criteria established at that time; Hemmera, 2014a). While these criteria allowed for clear field decisions by the crew, it limited the number of wells that were sampled during the event. An alternate sampling strategy was established by AAM’s consultant (AMEC) in order to obtain samples from low producing wells, which was followed during the June 2015 sampling event. At all of the wells previously identified as having insufficient volume of water, Hemmera/ELR direct sampled (analytical samples collected prior to purging or collecting field parameter measurements), after which time field parameter measurements were collected if possible. Additionally, a priority ranking order for analytical sample collection previously established by AAM’s consultant (AMEC) was used when collected samples at directly sampled wells (as summarized in **Table 2-2**). This ranking system is used to ensure that samples for higher priority parameters were collected at each well if limited recharge or volume was encountered. Where sample collection was limited, Hemmera/ELR also re-visited wells where feasible to in an attempt to collect a more thorough sample set.

In addition to the priority ranking order, Hemmera/ELR also considered the minimum sample volumes required for laboratory procedures (provided to Hemmera/ELR by ALS Laboratories). Where well volume was limited, minimum volumes were collected to maximize the number of program parameters collected.

## Field Parameters

Hemmera/ELR measured *in-situ* water quality parameters using a YSI Professional Plus field meter or YSI 556 Handheld Multiparameter Instrument, Lamotte 2020we turbidity meters, and Hach DR 890 Portable Colorimeters. Flow-through cells were used with the YSI meters to minimize field parameter variability. The *in-situ* groundwater quality parameters recorded at each sample station included; water temperature (oC), specific conductivity (μs/cm), conductivity (μs/cm), oxidation/reduction potential (ORP; mv), pH (pH units), sulphide (mg/l), dissolved oxygen (mg/l), and turbidity (NTU).

During purging, field parameters were monitored at 5 minute intervals, or at volume related intervals (e.g., every 500 mL) in the case of wells with slow recharge. The final set of in situ measurements were recorded at the conclusion of purging.

## Groundwater Sampling

Groundwater quality samples were collected and preserved in accordance with laboratory directions, and using techniques consistent with *Standard Methods for the Examination of Water and Wastewater* (Rice et al., 2012). ALS was the analytical subcontractor chosen for this project, and a summary of the sample bottle set (including parameters analysed and preservation techniques) is provided in **Table 2-2**.

In addition to the analytical parameters provided to Hemmera/ELR in the SOW, a separate dissolved alkalinity sample was added to each bottle set during this event. Field filtering was used to remove any acid or alkaline-generating solids that are not representative of an equilibrium condition (and that could have affected alkalinity results). Field filtered and unfiltered alkalinity results were then compared to test whether unfiltered results were representative (equivalent to filtered results). For this, a threshold of 20% Relative Percent Difference (RPD) was used, as described in **Section 2.8.2** below.

Table 2-2 Groundwater Sampling Parameter Priority, Preservation, and Intended Analysis

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Priority | Bottle Type | Parameters Analyzed | Minimum Volume | Sample Treatment | Preservative Added |
| 1a | 120 ml (plastic) | Dissolved Metals | 100 ml | Field Filtered and Preserved | HNO3 |
| 1b | 40 ml (glass) | Dissolved Mercury | 15 mL | Field Filtered and Preserved | HCl |
| 2 | 1 L (plastic) | General Chemistry | 200 ml | - | - |
| 3 | 145 ml (plastic) | Cyanide (total, free, weak acid dissociable) | 120 ml | Preserved | NaOH |
| 4 | 250 ml (glass amber) | Ammonia (NH3) | 120 ml | Preserved | H2SO4 |
| 5 | 120 ml (plastic) | Thiocyanate (SCN) | 50 ml | Preserved | HNO3 |
| 6 | 120 ml (plastic) | Sulphide | 100 ml | Preserved | Zinc Acetate, capped and mixed, then NaOH |
| 7 | 250 ml (glass amber) | Total Inorganic Carbon (TIC) | 100 ml | - | - |
| 8 | 120 ml (plastic) | Dissolved Alkalinity | 100 ml | Field Filtered | - |

## Down Well Camera Investigations

As agreed to with AAM, four (4) groundwater wells previously reported as damaged (MW09-01 and CH-P-13-03/10), dry/damaged (CH-P-13-02/10), or blocked (CH-P-13-04/35) were investigated during the June 2015 sampling event using a down-well camera. Wells five centimeters (5 cm) in diameter were investigated using an Insight Vision Digital Express D2 Sewer Camera. The camera had a built-in LED light ring that illuminated the pipe being inspected and allowed for recording of both video and digital imagery. Groundwater well CH-P-04/35 which had a narrower diameter of 3.8 cm was investigated using a smaller diameter illuminated camera with digital display. The results of these investigations are provided in **Section 3.2.**

## Data Analysis

Groundwater analytical results were compared to the Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Freshwater Aquatic Life (FAL; CCME, 2014). All relevant CCME FAL guidelines are presented in **Table A**.

## Quality Assurance and Quality Control

### Field QA/QC

Several controls were used by Hemmera/ELR staff while in the field to ensure that sample integrity was maintained and that data were recorded completely and accurately. All equipment used during the sampling process was dedicated to individual wells, including HDPE tubing and Waterra footvalves, laboratory provided pre-cleaned sample bottles, disposable filters, and disposable syringes. Field staff wore dedicated disposable nitrile gloves for all measurements, purging, and sampling. Water level meters were cleaned between well locations using Alconox low-foaming phosphate-free detergent and deionized water, and field instruments (YSI field meters, turbidity meters, and portable colorimeters) were checked and/or calibrated before each site visit to ensure the parameters recorded were as accurate as possible.

Project-specific field data sheets were created for the sampling event to help ensure that all required measurements were taken, and that information was recorded correctly. Field data sheets have been included as **Appendix B** of this report.

### Analytical QA/QC

Analytical QA/QC measures were included in the June sampling program as outlined in the scope of work and as per standard industry practice. This included the collection of field duplicates and field blanks, and the use of travel blanks. Duplicate samples were collected at a ratio of 10% of the regular samples (1 duplicate was collected for every 10 samples), and a field blank was prepared for each day field sampling was conducted (a total of 4 field blanks were prepared). Two travel blanks accompanied the analytical supplies and samples from the laboratory to the field, and back to the laboratory again (1 for each shipment).

The variation between sample and duplicate values was calculated as relative percent difference (RPD). RPD provides a measure of the relative difference between two values in comparison to their mean value, and is calculated as the difference between a sample and its field duplicate over the average of two values. RPD values greater than 20% indicate a potential error that has affected the precision of sampling or analysis. RPD was calculated according to the following formula:

$$\%RPD=\left(\frac{\left(\frac{x\_{1}-x\_{2}}{x\_{1}+x\_{2}}\right)}{2}\right) x 100$$

RPD is not calculated if either the sample or the field duplicate concentration is less than five times the detection limit.

The analytical results for field and travel blanks were reviewed to determine whether any of the parameters tested were detected (i.e., result exceeding the detection limit). In such cases, the parameter or element in question and its concentration were reviewed to determine potential sources of contamination or error.

# Results

A summary of laboratory analytical results is presented in **Table A** of this report, including a comparison of results to CCME FAL guidelines. A summary of the QA/QC sampling results is presented in **Table B**, including analytical data for duplicates, field blanks, and travel blanks. Laboratory analytical reports are appended to this report (**Appendix C**).

## Groundwater Sampling Summary

Groundwater sampling was completed between June 1 and 4, 2015. Weather conditions varied throughout the time of sampling with ambient air temperature ranging from 5 to 20°C.

Of the 65 wells specified for the June 2015 sampling event, 63 were located and assessed during the June program. The other two (2) groundwater wells listed in the scope of work that had previously been reported as destroyed, and not repairable, are not further discussed in this report (GSI-PC-01-B and MP09-01).

Of the 63 wells located, twenty-four (24) wells were sampled; eighteen (18) using purging and sample methods as per the program protocols, and six (6) sampled directly without purging according to the sample priority ranking. In five (5) of the six (6) direct sampled wells, volumes were insufficient to collect a full sample set. **Table 3-1** provides a summary of sample success.

Of the remaining 39 of 63 wells assessed but not sampled during the program, 30 wells were frozen, seven (7) wells were dry, one (1) well had insufficient volume for sampling, and one (1) well was reported as both dry and damaged and could not be sampled. Despite not collecting water quality samples these wells were still assessed and water/ice depth, well depth, and headspace gas measurements were collected where possible. Headspace gas measurements were obtained from all 39 of these wells (as specified in **Table 3-2**). A summary of the overall condition (status) and sampling result for groundwater wells is provided in **Table 1-1**, and a summary of all well measurements, purge details, and *in-situ* parameter results is provided in **Table 3-2**.

Table 3-1 Summary of Samples Collected During June 2015 Sampling Program

| Well Name | Dissolved Metals | Dissolved Mercury | Physical Parameters | Anions/ Nutrients | Cyanide | Ammonia | Thiocyanate | Sulphide | Total Inorganic Carbon | Dissolved Alkalinity |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Priority | 1a | 1b | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| GSI-HA-01A | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| GSI-HA-02A | ✓ | ✓ | - | - | - | - | - | - | - | - |
| GSI-HA-03A | ✓ | ✓ | - | - | - | - | - | - | - | - |
| GSI-HA-05A | ✓ | - | - | - | - | - | - | - | - | - |
| MW09-16 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-17 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-18 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-19 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| CH-P-13-05/50 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| GSI-PC-03B | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - | - | - |
| MP09-05 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MP09-09 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MP09-11 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MP09-14 | ✓ | ✓ | - | - | - | - | - | - | - | - |
| MW09-01 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-02 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-03 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-04 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-06 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-08 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-22 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-23 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| MW09-24 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| W14103083BH03 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

**Notes:** Refer to section 2.2 for details concerning direct sampling methodologies, including minimum volume collection. Samples were collected based on field priority ranking as specified in **Table 2-2**.

Table 3-2 Groundwater Field Parameters and Well Measurements for June 2015 Sampling Program

| **Area** | **Location ID** | **Sample Date** | **Stick up Height (m)** | **Depth To Water (m)** | **Depth to Bottom (m)** | **Standing Water Volume (L)** | **Volume Purged (L)** | **Purge Start Time** | **Purge End Time** | **Elapsed Purge Time** | **Purge Rate (l/min)** | **Criteria1 (3WV/PS/DS)** | **Draw Down (m)** | **pH** | **Temperature (ºC)** | **Conductivity (µS/cm)** | **Specific Conductivity (µS/cm)** | **ORP (mV)** | **Dissolved Oxygen (mg/L)** | **Dissolved Sulphide (mg/L)** | **Methane (%LEL)** | **Oxygen (%)** | **Carbon Dioxide (ppm)** | **Field Turbidity (NTU)** | **Method Used** | **Well Diameter (cm)6** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Dome Creek | GSI-DC-01A | 01/06/2015 | 0.92 | Dry | 1.306 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.6 | 570 | - |  | 1.3 |
| GSI-DC-01B | 01/06/2015 | 0.94 | Dry | 1.611 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.6 | 0 | - |  | 1.3 |
| GSI-DC-02A | 01/06/2015 | 0.86 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 650 | - |  | 1.3 |
| GSI-DC-02B | 01/06/2015 | 0.94 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 540 | - |  | 1.3 |
| GSI-DC-03A | 02/06/2015 | 0.05 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 600 | - |  | 1.3 |
| GSI-DC-03B | 02/06/2015 | 0.12 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.5 | 950 | - |  | 1.3 |
| GSI-DC-05A | 03/06/2015 | 0.64 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.6 | 480 | - |  | 1.3 |
| GSI-DC-05B | 03/06/2015 | 0.113 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.6 | 1200 | - |  | 1.3 |
| GSI-DC-06A2 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |  | - |
| GSI-DC-06B | 04/06/2015 | 0.53 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.5 | 460 | - |  | 1.3 |
| GSI-DC-07A | 04/06/2015 | 0.97 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 710 | - |  | 1.3 |
| GSI-DC-07B | 04/06/2015 | 0.95 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.6 | 500 | - |  | 1.3 |
| GSI-DC-08A | 04/06/2015 | 0.95 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 1.3 |
| GSI-DC-08B | 04/06/2015 | 0.31 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 80 | - |  | 1.3 |
| GSI-DC-09A | 04/06/2015 | 1.06 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 1060 | - |  | 1.3 |
| GSI-DC-09B | 04/06/2015 | - | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 510 | - |  | 1.3 |
| GSI-DC-10A | 04/06/2015 | 1.06 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.5 | 0 | - |  | 1.3 |
| GSI-DC-10B | 04/06/2015 | 0.98 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 1.3 |
| Mill Complex | GSI-HA-01A | 02/06/2015 13:50 | 1.20 | 2.391 | 3.121 | 0.090 | - | - | - | - | - | DS | - | 7.15 | 5.2 | 688 | 1106 | -40.2 | - | - | 0 | 20.6 | 570 | - | peristaltic | 1.3 |
| GSI-HA-02A3 | 01/06/2015 15:30 | 0.26 | 1.891 | 2.409 | 0.007 | - | - | - | - | - | DS | - | - | - | - | - | - | - | - | 0 | 20.6 | 600 | - | peristaltic | 1.3 |
| GSI-HA-03A3 | 01/06/2015 16:15 | 0.97 | 0.942 | 1.355 | 0.007 | - | - | - | - | - | DS | - | - | - | - | - | - | - | - | 0 | 20.9 | 480 | - | peristaltic | 1.3 |
| GSI-HA-04A | 01/06/2015 | 0.61 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.6 | 650 | - |  | 1.3 |
| GSI-HA-05A3 | 01/06/2015 16:45 | 1.03 | 1.015 | 1.481 | 0.006 | - | - | - | - | - | DS | - | - | - | - | - | - | - | - | 0 | 20.9 | 480 | - | peristaltic | 1.3 |
| MW09-16 | 01/06/2015 18:00 | 1.31 | 1.830 | 2.745 | 1.8 | 6.0 | 17:33 | 18:08 | 0:35 | 0.17 | PS | 0 | 6.75 | 5.0 | 1257 | 2036 | 128.7 | 0.05 | 0 | 0 | 19.5 | 3160 | 0.89 | peristaltic | 5.0 |
| MW09-17 | 02/06/2015 11:35 | 0.99 | 4.949 | 5.711 | 1.5 | 5.5 | 11:05 | 11:30 | 0:25 | 0.22 | PS | 0 | 6.92 | 1.2 | 1572 | 2884 | 84.0 | 0.86 | 0.07 | 0 | 8.0 | 320 | 0.02 | peristaltic | 5.0 |
| MW09-18 | 02/06/2015 10:10 | 0.88 | 4.598 | 7.799 | 6.4 | 7.0 | 9:32 | 10:07 | 0:35 | 0.20 | PS | 0.08 | 6.94 | 1.4 | 1495 | 2700 | 66.2 | 0.52 | 0.01 | 0 | 20.6 | 870 | 0.51 | peristaltic | 5.0 |
| MW09-19 | 02/06/2015 8:30 | 1.08 | 2.565 | 5.885 | 6.6 | 7.0 | 7:59 | 8:30 | 0:31 | 0.23 | PS | 0.60 | 6.77 | 0.7 | 1344 | 2507 | -86.8 | 1.14 | 0.05 | 0 | 20.5 | 760 | 0.22 | peristaltic | 5.0 |
| Brown McDade Pit | CH-P-13-01/10 | 01/06/2015 | 0.52 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 3.8 |
| CH-P-13-03/10 | 01/06/2015 | 0.69 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.3 | 300 | - |  | 3.8 |
| CH-P-13-03/50 | 04/06/2015 | 0.58 | 50.224 | 50.600 | 0.191 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.1 | 0 | - |  | 2.5 |
| CH-P-13-04/10 | 01/06/2015 | 0.65 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 3.8 |
| CH-P-13-04/35 | 01/06/2015 | 0.70 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 2.5 |
| CH-P-13-05/50 | 02/06/2015 17:00 | 0.79 | 29.585 | 50.310 | 10.5 | 30.0 | 16:36 | 16:55 | 0:19 | 1.58 | PS | - | 6.19 | 2.9 | 1682 | 2912 | 121.6 | 3.17 | 1.77 | 0 | 20.4 | 0 | 118 | waterra | 2.5 |
| GLL07-01 | 01/06/2015 | 0.80 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.3 | 0 | - |  | 5.0 |
| GLL07-02 | 03/06/2015 | 1.37 | Dry | 7.094 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 15.2 |
| GLL07-03 | 01/06/2015 | 1.11 | Dry | 11.652 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 19.8 | 0 | - |  | 5.0 |
| MW09-13 | 01/06/2015 | 0.76 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 5.0 |
| MW09-14 | 01/06/2015 | 0.74 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 5.0 |
| MW09-15 | 01/06/2015 | 0.9 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 5 |
| CH-P-13-02/10 | 01/06/2015 | 0.63 | Dry | 8.202 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 3.8 |
| Pony Creek | GSI-PC-02A | 03/06/2015 | 0.9 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.3 | 0 | - |  | 1.3 |
| GSI-PC-02B | 03/06/2015 | 0.905 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.3 | 0 | - |  | 1.3 |
| GSI-PC-03A | 03/06/2015 | 0.93 | 1.131 | 1.354 | 0.028 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.2 | 0 | - |  | 1.3 |
| GSI-PC-03B | 04/06/2015 17:41 | 0.95 | 1.008 | 2.798 | 0.227 | - | - | - | - | - | DS | - | - | - | - | - | - | - | - | 0 | 20.2 | 0 | - | peristaltic | 1.3 |
| GSI-PC-04A | 03/06/2015 | 0.9 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 1.3 |
| GSI-PC-04B | 03/06/2015 | 0.9 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 1.3 |
| GSI-PC-05A | 03/06/2015 | 0.87 | Dry | 1.127 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 1.3 |
| GSI-PC-05B | 03/06/2015 | 0.9 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 19.8 | 890 | - |  | 1.3 |
| MP09-02 | 03/06/2015 | 1.12 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 1.3 |
| MP09-03 | 03/06/2015 | 0.8 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 1.3 |
| MP09-08 | 03/06/2015 | 0.99 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 0 | - |  | 1.3 |
| Seepage Dam | W14103083BH01 | 03/06/2015 | 0.635 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 620 | - |  | 5 |
| W14103083BH02 | 03/06/2015 | 0.79 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 460 | - |  | 5.0 |
| W14103083BH04 | 03/06/2015 | 0.795 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 840 | - |  | 5.0 |
| Tailings Facility | MP09-04 | 04/06/2015 | 1.205 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.6 | 620 | - |  | 3.8 |
| MP09-05 | 03/06/2015 17:45 | 1.114 | 1.437 | 1.670 | 1.3 | 4.5 | 17:23 | 17:43 | 0:20 | 0.23 | PS | 0.05 | 6.66 | 2.7 | 1361 | 2369 | -46.9 | 0.07 | 0 | 0 | 20.9 | 500 | 1.87 | peristaltic | 3.8 |
| MP09-09 | 04/06/2015 8:05 | 2.451 | 3.591 | 5.634 | 4.1 | 5.0 | 11:00 | 11:36 | 0:36 | 0.14 | PS | - | 9.31 | 1.5 | 388 | 707 | 80.5 | 0.79 | 0.36 | 0 | 20.9 | 430 | 45.86 | bailer | 3.2 |
| MP09-10 | 02/06/2015 | 2.163 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 450 | - |  | 3.2 |
| MP09-11 | 04/06/2015 9:10 | 1.807 | 2.308 | 4.971 | 2.9 | 6.0 | 12:18 | 12:56 | 0:38 | 0.16 | PS | - | 7.65 | 1.4 | 454 | 818 | -126.4 | 3.14 | 1.26 | 0 | 20.9 | 500 | 159.00 | bailer | 3.2 |
| MP09-12 | 02/06/2015 | 1.831 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 510 | - |  | 3.2 |
| MP09-144 | 02/06/2015 14:50 | 0.96 | 1.089 | 1.609 | 0.3 | - | - | - | - | - | DS | - | - | - | - | - | - | - | - | 0 | 20.5 | 570 | - | peristaltic | 2.5 |
| MW09-01 | 03/06/2015 12:15 | 0.82 | 7.147 | 9.060 | 4.0 | 3.0 | 11:05 | 11:22 | 0:17 | 0.18 | PS | - | 7.13 | 4.8 | 1731 | 2821 | -11.5 | 1.78 | 2.20 | 0 | 20.4 | 0 | 2643 | bailer | 3.8 |
| MW09-02 | 02/06/2015 10:20 | 0.7 | 3.137 | 4.715 | 3.2 | 5.75 | 9:46 | 10:18 | 0:32 | 0.18 | PS | 0.90 | 7.18 | 3.9 | 1753 | 2934 | -87.3 | 0.48 | 0.02 | 0 | 20.4 | 0 | 5.29 | peristaltic | 5.0 |
| MW09-03 | 02/06/2015 15:10 | 0.42 | 6.924 | 9.93 | 6.0 | 7.0 | 14:27 | 15:00 | 0:33 | 0.21 | PS | 0.23 | 7.21 | 3.2 | 1557 | 2666 | 12.4 | 0.22 | 0.03 | 0 | 20.3 | 0 | 0.77 | peristaltic | 5.0 |
| MW09-04 | 02/06/2015 13:50 | 0.38 | 4.631 | 7.675 | 6.0 | 6.0 | 13:05 | 13:45 | 0:40 | 0.15 | PS | 1.10 | 8.03 | 4.3 | 1640 | 2706 | 32.7 | 0.29 | 0.07 | 0 | 20.3 | 0 | 2.43 | peristaltic | 5.0 |
| MW09-05 | 03/06/2015 | 1.097 | Dry | 7.552 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 9.6 | 6430 | - |  | 5.0 |
| MW09-06 | 03/06/2015 13:55 | 1.996 | 3.055 | 6.020 | 5.9 | 6.0 | 14:09 | 14:42 | 0:33 | 0.18 | PS | 0.26 | 7.44 | 5.7 | 1354 | 2135 | 108.6 | 0.05 | 0.09 | 0 | 20.5 | 700 | 18.41 | peristaltic | 5.0 |
| MW09-07 | 03/06/2015 | 1.359 | Dry | 3.404 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.4 | 810 | - |  | 5.0 |
| MW09-08 | 04/06/2015 13:10 | 1.113 | 1.281 | 3.897 | 5.2 | 9.8 | 12:12 | 13:02 | 0:50 | 0.20 | PS | 0.08 | 6.67 | 2.3 | 197 | 349 | -96.0 | 0.06 | 0.02 | 0 | 20.9 | 730 | 2.14 | peristaltic | 5.0 |
| MW09-11 | 02/06/2015 | 0.825 | Dry | 4.910 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.5 | 1700 | - |  | 5.0 |
| MW09-20 | 04/06/2015 | 0.923 | Dry | 3.684 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 950 | - |  | 5.0 |
| MW09-21 | 03/06/2015 | 0.744 | Frozen | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0 | 20.9 | 460 | - |  | 5.0 |
| MW09-224 | 04/06/2015 10:10 | 0.889 | 4.531 | 5.267 | 1.4 | 1.0 | 16:17 | 16:22 | 0:05 | 0.20 | PS | - | 6.25 | 3.4 | 991 | 1674 | 17.7 | 0.26 | 0.07 | 0 | 20.6 | 2350 | 12.60 | peristaltic | 5.0 |
| MW09-234 | 04/06/2015 8:20 | 0.17 | 12.748 | 15.890 | 6.0 | 20.0 | 13:06 | 13:25 | 0:19 | 1.05 | PS | - | 6.90 | 0.9 | 1180 | 2189 | -51.3 | 2.47 | 0.64 | 0 | 20.4 | 0 | 66.00 | waterra | 5.0 |
| MW09-24 | 04/06/2015 14:40 | 0.64 | 9.540 | 11.190 | 3.3 | 20.0 | 11:43 | 11:54 | 0:11 | 1.82 | PS | - | 7.03 | 0.7 | 499 | 933 | 121.1 | 8.27 | 0.04 | 0 | 20.4 | 200 | 7.06 | bailer | 5.0 |
| W14103083BH03 | 03/06/2015 8:45 | 0.75 | 1.621 | - | 0.5 | 5.0 | 8:23 | 8:58 | 0:35 | 0.14 | PS | 0.50 | 6.88 | 2.1 | 683 | 1215 | 66.7 | 5.15 | 0.05 | 0 | 20.9 | 530 | 2.18 | peristaltic | 5.0 |

**Notes:**To maximize the sample return for analytical analysis, field parameters were not collected at all direct sampled wells.

1 3WV = Three well volumes purged prior to sample collection, PS = field parameters stabilized prior to sample collection, and DS = sample collected directly without purging.

2 Field measurements for groundwater well GSI-DC-06A were not collected during the June 2015 sampling event.

3 Due to low well volumes (direct sampling), field parameters were not measured.

4 Samples were collected following a period of recharge, typically the day following the well dry. Drawdown is not recorded in this situation.

\* Shaded rows indicate monitoring stations where analytical samples were collected.

## Analytical Results

Analytical results, including a brief summary of CCME FAL guideline exceedances and a description of factors that may have influenced data precision, are provided below. Details regarding well status, including a description of damaged or underperforming wells, are also discussed.

In several instances, the reported laboratory reportable detection limits (RDL) for parameters exceeded applicable CCME FAL standards (lightly shaded values in**Table A**). In these cases, samples having elevated levels of certain parameters required laboratory dilution in order to perform the required analyses, thereby resulting in an elevated RDL. For the purpose of this report, samples where the reported RDL is greater than the applicable guideline have not been reported as CCME FAL exceedances.

### Dome Creek

Groundwater wells along Dome Creek were monitored between June 2 and June 4, 2015. No samples were obtained from the nine (9) drive-point piezometers located in this area. Sample site GSI-DC-01B was found dry at the time of sampling. Sample sites GSI-DC-02B, GSI-DC-03B, GSI-DC-05B, GSI-DC-06B, GSI-DC-07B, GSI-DC-08B, GSI-DC-09-B and GSI-DC-10B were found frozen during the time of sampling. A summary of field measurements, including headspace gases, is provided in **Table 3-2**.

The measurement of in-situ headspace vapours was made difficult at the Dome Creek sample sites due to dedicated sampling tubing being present in these small diameter wells. There was no space in the well head to sample vapours until dedicated sampling equipment was removed, after which time well head gases may have dispersed. All drive-point piezometers located within this area are properly sealed with PVC caps. Deeper wells (B wells) are improperly sealed with a plastic bag and elastic band.

### Mill Complex

Groundwater in the Mill Complex Area was sampled on June 1 and June 2, 2015. Samples were obtained from five (5) of the nine (9) wells identified in this area. Sample site GSI-HA-04A was found frozen at the time of sampling. Drive-points GSI-HA-01A, GSI-HA-02A, GSI-HA-03A, and GSI-HA-05A were sampled directly without purging. A summary of the samples collected is provided in **Table 3-1**.

Field dissolved oxygen concentrations were less than the CCME FAL guideline for all measurements collected in this area. Concentrations of fluoride, as well as dissolved arsenic, copper, iron and zinc exceeded the CCME FAL guidelines at one or more sample locations in Mill Complex area.

Monitoring wells MW09-18 and MW09-16 have vents installed on the side of the PVC stand pipe, which could have influenced *in-situ* gas concentrations.

Where measured, groundwater turbidity of all samples collected within this area was less than 50 NTU (**Table 3-2**).

### Brown McDade Pit

Groundwater wells in the Brown McDade Pit area were sampled between June 1 and June 4, 2015. Samples were obtained from one (1) of the 13 sample sites located within this area (CH-P-13-05/50). Eight (8) wells were frozen during the time of sampling (CH-P-13-01/10, CH-P-13-03/10, CH-P-13-04/10, CH-P-13-04/35, GLL07-01, MW09-13, MW09-14, and MW09-15), three (3) wells (GLL07-02, GLL07-03, and CH-P-13-02/10) were either dry and/or damaged, and one well (CH-P-13-03/50) had insufficient water volume to collect a sample. A summary of the samples collected is provided in **Table 3-1**.

The field dissolved oxygen concentration was less than the CCME FAL guidelines for the one measurement collected in this area. Field pH was also less than CCME FAL guidelines in this area. Concentrations of fluoride, as well as dissolved arsenic, copper, iron and zinc exceeded the CCME FAL guidelines at this sample location.

Groundwater at sample location CH-P-13-05/50 was extremely turbid (118 NTU) during the time of sampling (**Table 3-2**).

Monitoring wells CH-P-13-04/10, CH-P-13-05/50, GLL07-01, GLL07-02, GLL07-03, and MW09-13 had either vents installed on the side of the PVC stand pipe or were missing a proper seal, which may have influenced *in-situ* gas concentrations.

CH-P-13-02/10 was found dry during the time of sampling. During previous sample events, bentonite was found present at the bottom of the well and therefore the well status had been listed as dry/damaged. The well was further investigated during the June 2015 sampling event using a camera. Camera footage obtained at this location confirmed the presence of bentonite and filter pack (filter sand) at the bottom of well. Bentonite was also observed seeping into the well from the top portion of the well screen. The bottom portion of well screen appears to be free of bentonite seepage, presumably due to presence of water (i.e. previous groundwater flow has cleaned/cleared the lower portion of the screen). Based on these observations, it appears as though the influx of bentonite into the well may be the result of improper well installation or movement of the well over time. The well may not be salvageable.

Sampling location CH-P-13-03/10 was also investigated using a camera during June 2015 sampling event. During a previous sampling program, the upper PVC stick-up of this well was observed as being detached from the casing, allowing sand/filter pack material to drain into the well. Camera footage obtained at this site has confirmed the presence of sand at the bottom of the well. Filter pack/sand was located inside monument, approximately 2 ft. up the side of the PVC. The well stick up was repaired in Fall 2014 using a primer and glue (designed for PVC) to re-secure the PVC stick up to the well casing, but it was not possible to clean out the sand pack material at that time.

Sampling location CH-P-13-04/35 was also investigated using a camera during June 2015 sampling event. This well had been recorded as “blocked” in previous sampling events. Camera investigations of the well confirmed that the blockage was ice. The status of CH-P-04/35 has been revised to “frozen”.

### Pony Creek

Groundwater wells along Pony Creek were monitored between June 3 and June 4, 2015. Samples were obtained from one (1) of the seven (7) sample sites in this area during the sampling event. The six (6) remaining wells located within this area were found frozen during the time of sampling (GSI-PC-02B, GSI-PC-04B, GSI-PC-05B, MP09-02, MP09-03, and MP09-08).

Drive-point GSI-PC-03B was sampled directly without purging. Concentrations of dissolved arsenic, iron and uranium exceeded the CCME FAL guidelines at this sample location (GSI-PC-03B).

Monitoring wells MP09-08 and MP09-03 were not sealed properly, which may have influenced *in-situ* gas concentrations.

### Seepage Dam

Groundwater wells in the Seepage Dam area were monitored on June 3, 2015. No samples were obtained from any of the three (3) sample sites in this area during the sampling event. All three (3) wells (W14103083BH01, W14103083BH02 and W14103083BH04) were frozen during the time of sampling.

Monitoring wells located in the Seepage Dam area were not properly sealed, which may influence *in-situ* gas concentrations in future sampling events. Instrument wires installed in the well head prevented *in-situ* gas measurements at these sites.

### Tailings Facility

Groundwater wells in the Tailings Facility area were sampled between June 2 and June 4, 2015. Samples were obtained from 14 of the 22 sample sites located in this area (MP09-05, MP09-09, MP09-11, MP09-14, MW09-01, MW09-02, MW09-03, MW09-04, MW09-06, MW09-08, MW09-22, MW09-23, MW09-24, and W14103083BH03).

Four (4) wells were frozen during the time of sampling (MP09-04, MP09-10, MP09-12, and MW09-21), and four (4) were dry (MW09-05, MW09-07, MW09-11 and MW09-20). Of the 14 samples collected within this area, one (1; MP09-14) was collected directly without purging. A summary of the samples collected is provided in **Table 3-1**.

Where measured, field dissolved oxygen concentrations were less than the CCME FAL guideline at all sample sites located within this area. Both field and laboratory pH measurements were recorded both less than and greater than the CCME FAL guideline at one or more sample location within this area. Concentrations of fluoride, total ammonia, nitrite, free cyanide, as well as dissolved arsenic, copper, iron, mercury, selenium, silver, thallium, and zinc exceeded the CCME FAL guidelines at one or more sample location in this area.

The measured groundwater turbidity at sample sites MP09-11 and MW09-01 was greater than the desired threshold of 50 NTU (159 NTU and 2643 NTU; **Table 3-2**).

Although samples were obtained from well MW09-01, groundwater at this location was extremely turbid during previous sampling events. This well was further investigated during the June 2015 sampling event using a down-well camera. Camera footage obtained at this location showed a significant quantity of tailings throughout the well casing. The well also had a large gash/opening at the top of PVC (i.e., the top portion of well stick-up). Tailings and water likely enter the well through this opening during periods of high water level. Although this well has a relatively high stick-up (0.82 m), the presence of tailings throughout the well casing suggests that surface water was entering the well through the top of the PVC.

Sample site MW09-23 has also been noted as damaged (Hemmera, 2015) during previous sampling events. The well appears to have been buckled at an angle during earthworks on the tailings dam, and could only be sampled using waterra tubing. The transducer installed at this location was also in poor condition (wires frayed). The wires on this instrument were replaced during the June 2015 sampling event.

Monitoring wells MP09-09, MP09-10, MP09-11, MP09-12, MP09-14, MW09-01, MW09-07, MW09-08, MW09-20, MW09-22, MW09-23, and W14103083BH03 had either vents installed on the side of the PVC stand pipe or were missing a proper cap/seal, which could have influenced *in-situ* gas concentrations.

## Quality Assurance and Quality Control Results

Three (3) duplicate groundwater samples were collected during the fall sampling event. Two (2) travel blanks were provided by the laboratory and accompanied the samples throughout the sampling program. One (1) field blank was prepared on site for each day of sampling (4 field blanks in total). Detailed results of QA/QC sampling are provided in **Table B**, including RPD values for all duplicate and sample pairs collected.

### Field and Travel Blanks

The majority of travel blank analytical results were reported as less than the RDL, indicating minimal evidence of contamination during the transportation process (**Table B**)

A detectable concentration of ammonia was recorded in the travel blank included with the first sample shipment (0.0071 mg/L), and a detectable concentration of total organic carbon (TOC; 0.52 mg/L) was recorded in the travel blank included with the second shipment. The program analytical supplier (ALS) indicated that the detection of low levels of ammonia should not be considered an indication of contamination as low concentrations of ammonia are occasionally found in travel blanks that are prepared too early in advance of the field program. Detection of low levels of TOC is not considered adequate evidence to suggest sample contamination. All other parameters in both travel blanks were below RDL.

All field blank analytical results were reported as less than the RDL (**Table B**).

### Field Duplicates

#### MW09-04 and DUP-1

Duplicate and duplicate pair analytical results show that all RPD values for samples MW09-04 and DUP-1 were below the 20% RPD threshold limit, suggesting no contamination or bias in sampling (**Table B**).

#### MW09-16 and DUP-2

Duplicate and duplicate pair analytical results show that all RPD values for samples MW09-16 and DUP-2 were below the 20% RPD threshold limit, suggesting no contamination or bias in sampling (**Table B**).

#### MP09-05 and DUP-4

Duplicate and duplicate pair analytical results show that all RPD values for samples MW09-05 and DUP-3 were below the 20% RPD threshold limit, suggesting no contamination or bias in sampling (**Table B**).

### Quality Assurance and Quality Control Summary

Results for the QA/QC analytical program show minimal evidence of contamination or sampling bias during the transportation and field collection process. Overall, across four collected field blanks, all values were below RDL, indicating no contamination was incurred from the surrounding environment at these locations. The minimal positive results in the travel blanks did not suggest any type of contamination during transportation, and all sample and duplicate pair analytical results show an acceptable level of variability (RPD < 20%), suggesting that sound sampling and QA/QC practices were employed.

## Analytical Test of Filtered Alkalinity

Filtered alkalinity samples were collected to test whether acid or alkaline-generating solids maybe affecting alkalinity results. Filtered and non-filtered alkalinity were both assessed from 18 sample locations (**Table 3-3**) during the June 2015 program, and analyzed for all QA/QC samples (duplicates, field blanks, and travel blanks). The two (2) other wells sampled did not have sufficient groundwater to collect filtered alkalinity (**Table 3-1**). A summary of filtered and unfiltered alkalinity results is provided in **Table 3-3**.

Table 3-3 Comparison of Alkalinity and Filtered Alkalinity Results

|  |  |  |  |
| --- | --- | --- | --- |
| Well Name | Non-Filtered Alkalinity | Filtered Alkalinity | RPD |
| mg/L | mg/L | % |
| GSI-HA-01A | 257 | 242 | *6.0* |
| MW09-16 | 224 | 221 | *1.3* |
| DUP-2 (MW09-16) | 240 | - | *nc* |
| MW09-17 | 425 | 423 | *0.5* |
| MW09-18 | 396 | 415 | *4.7* |
| MW09-19 | 403 | 409 | *1.5* |
| CH-P-13-05/50 | 76.8 | 71.0 | *7.8* |
| GSI-PC-03B | 935 | - | *nc* |
| MP09-05 | 280 | 282 | *0.7* |
| DUP-4 (MP09-05) | 277 | 288 | *3.9* |
| MP09-09 | 63.9 | 62.8 | *1.7* |
| MP09-11 | 386 | 395 | *2.3* |
| MW09-01 | 255 | 264 | *3.5* |
| MW09-02 | 26.6 | 25.9 | *2.7* |
| MW09-03 | 137 | 121 | *12.4* |
| MW09-04 | 100 | - | *nc* |
| DUP-1 (MW09-04) | 97.0 | 96.3 | *0.7* |
| MW09-06 | 182 | 185 | *1.6* |
| MW09-08 | 125 | 130 | *3.9* |
| MW09-22 | 70.6 | 117 | ***49.5*** |
| MW09-23 | 336 | 349 | *3.8* |
| MW09-24 | 280 | 282 | *0.7* |
| W14103083BH03 | 378 | 376 | *0.5* |

**Note:** nc = not calculated. RPD is not calculated if either the sample or the field duplicate concentration is less than five times the detection limit.

Of the 23 samples above RDL, filtered and unfiltered alkalinity only varied significantly (i.e., RPD > 20%) at one (1) sample site (MW09-22; 49.5% RPD), suggesting the presence of acid-generating solids at that site. Based on these results and those observed in similar comparison from March 2015 groundwater sampling at the Site (RPD > 20% at one of eight samples at Site MW09-18; Hemmera/ELR 2015), the results suggest that there is not a consistent or repeatable effect of solids on non-filtered alkalinity, and that ongoing filtering of alkalinity samples is likely not an ongoing recommendation for the program. This conclusion will be made following the final trail of filtered and unfiltered alkalinity which was conducted during September 2015 groundwater sampling.

# Recommendations

Hemmera/ELR have prepared the following recommendations based on the observations and results of the June 2015 groundwater sampling program.

1. Damaged or degraded wells should be repaired, if possible. Damaged wells were investigated during the June 2015 sampling event using a down-well camera (as specified by AAM).

Damaged or degraded wells noted during the June 2015 sampling event include the following, CH-P-13-02/10, MW09-23, CH-P-13-03/10, MW09-01, CH-P-13-04/35, and CH-P-13-05/50.

CH-P-13-02/10 was found dry during the time of sampling. During previous sample events, bentonite was found present at the bottom of the well and therefore the well status had been listed as dry/damaged. Camera footage obtained at this sample site confirms the presence of bentonite and filter pack (filter sand) at the bottom of well. Bentonite was also found seeping in the top portion of the well screen. The bottom portion of well screen appears to be free of bentonite seepage, presumably due to presence of water (i.e. groundwater flow has cleaned/cleared the lower portion of the screen). Based on the camera footage, there appears to be an issue with the well installation. Bentonite/filter pack is typically installed above the top of the screen; however, in this case it appears an insufficient amount of filter pack was installed to cover the entire screen. This has caused the overlaying bentonite to seep into screen slits in the upper portion of the screen. Based on the field observations, we do not believe that this well can be repaired and should continue to be used in its current condition, or be re-installed (re-drilled).

Sample site MW09-23 was recorded as being damaged (Hemmera, 2015) during previous sampling events (the PVC is bent at the surface). The well appears to have been buckled at an angle during earthworks on the tailings dam, and could only be sampled using Waterra tubing. The transducer installed at this location was also in poor condition (wires frayed). The wires on this instrument were replaced during the June 2015 sampling event. For sampling, Waterra tubing could continue to be used at this well (does not interfere with the transducer wiring and produces a clean, representative sample). Alternatively, a dedicated plastic submersible pump could be considered to reduce turbidity and improve the quality of sample at this location.

Sampling location CH-P-13-03/10 was investigated during June 2015 sampling event. During a previous sampling program, the upper PVC stick-up of this well became detached from the well casing, allowing sand/filter pack material to drain into the well. Camera footage obtained from the sample site confirmed the presence of sand at the bottom of the well. Hemmera/ELR recommends that the well be re-developed to remove the sand. The following methods should be considered: 1) Injecting water into the well and using air lift method to clear the well (using air compressor). Well logs should be reviewed prior to implementing this method to assess the hydraulic conductivity of the surrounding formation. A low hydraulic conductivity is required in order to saturate the sand and mobilize using an air compressor. This method may require a substantial volume of water. 2) Use a vacuum truck to remove sand. Vacuum head would need to be small enough to fit in the casing.

MW09-01 could not be sampled during previous events due to an excessive quantity of tailings present in the groundwater. Although samples were obtained from well MW09-01 during the June 2015 sampling event, groundwater at this location has been extremely turbid during previous sampling events. Camera footage obtained at this location shows a significant quantity of tailing throughout the well casing. The well also has a large gash/opening at the top of PVC. Tailings likely enter the well through this opening during periods of high water. The opening at the top of PVC should be sealed. This well should be cleaned of fines and debris which may be possible through a combination of open-ended standard or large diameter Waterra tubing (to capture sediment in the end of the tubing), followed by redevelopment using Waterra tubing and a surge block. Re-development may take several sampling events to complete, and may require the addition of water to re-suspend the fines present.

Sampling location CH-P-13-04/35 was also investigated using a camera during June 2015 sampling event. This well had been recorded as “blocked” in previous sampling events. Camera investigations of the well confirmed that the blockage was ice. The status of CH-P-04/35 has been revised to “frozen”. No future action is required at this location.

In addition to previously recorded damaged wells, groundwater at sample location CH-P-13-05/50 was extremely turbid (118 NTU) during the time of sampling (**Table 3-2**). This well should also be re-developed using Waterra tubing and a surge block during a future monitoring event in order to obtain a more representative sample.

1. Monitoring wells should be fitted for the measurement of in-situ headspace vapour. This would include installing PVC caps or J-plugs on each well, and blocking vents currently installed on the side of some of the PVC wells. Wells which are not properly fitted for in-situ headspace vapour monitoring include; MW09-18, MW09-16, CH-P-13-04/10, CH-P-13-05/50, GLL07-01, GLL07-02, GLL07-03, MW09-13, MP09-08, MP09-03, W14103083BH01, W14103083BH02, W14103083BH04, MP09-09, MP09-10, MP09-11, MP09-12, MP09-14, MW09-01, MW09-07, MW09-08, MW09-20, MW09-22, MW09-23, and W14103083BH03.

# Closure

We have appreciated the opportunity of working with you on this project and trust that this report is satisfactory to your requirements. Please feel free to contact the undersigned regarding any questions or further information that you may require.

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# Statement of Limitations

This report was prepared by Hemmera Envirochem Inc. (“Hemmera”), based on fieldwork conducted by Hemmera, for the sole benefit and exclusive use of the Yukon Government. The material in it reflects Hemmera’s best judgment in light of the information available to it at the time of preparing this Report. Any use that a third party makes of this Report, or any reliance on or decision made based on it, is the responsibility of such third parties. Hemmera accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this Report.

Hemmera has performed the work as described above and made the findings and conclusions set out in this Report in a manner consistent with the level of care and skill normally exercised by members of the environmental science profession practicing under similar conditions at the time the work was performed.

This Report represents a reasonable review of the information available to Hemmera within the established Scope, work schedule and budgetary constraints. It is possible that the levels of contamination or hazardous materials may vary across the Site, and hence currently unrecognised contamination or potentially hazardous materials may exist at the Site. No warranty, expressed or implied, is given concerning the presence or level of contamination on the Site, except as specifically noted in this Report. The conclusions and recommendations contained in this Report are based upon applicable legislation existing at the time the Report was drafted. Any changes in the legislation may alter the conclusions and/or recommendations contained in the Report. Regulatory implications discussed in this Report were based on the applicable legislation existing at the time this Report was written.

In preparing this Report, Hemmera has relied in good faith on information provided by others as noted in this Report, and has assumed that the information provided by those individuals is both factual and accurate. Hemmera accepts no responsibility for any deficiency, misstatement or inaccuracy in this Report resulting from the information provided by those individuals.

The liability of Hemmera to the Yukon Government shall be limited to injury or loss caused by the negligent acts of Hemmera. The total aggregate liability of Hemmera related to this agreement shall not exceed the lesser of the actual damages incurred, or the total fee of Hemmera for services rendered on this project.

tables

Appendix A

Site Photographs

Appendix B

Field Forms

Appendix C

Laboratory Reports

Appendix D

Response to Comments Received in Draft Report