**June 2014 Faro Mine Complex Groundwater Sampling**

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# Introduction

Hemmera Envirochem Inc. (“Hemmera”) and Ecological Logistics & Research Ltd. (ELR) were retained by the Government of Yukon (GY), Assessment and Abandoned Mines (AAM) to conduct a groundwater sampling program at the Faro Mine Complex (FMC) during 2014.The program consists of two sampling events: spring (May/June) and fall (September). This report summarizes the activities completed and analytical results from the spring sampling event.

## Site Location

The FMC is located approximately 13 km northeast of the Town of Faro, Yukon (20 km by road). The FMC consists of two distinct areas, the Faro Mine Area and the Vangorda/Grum Area (**Figure 1-1**), which are connected by a 14 km roadway (the Haul Road; **Figure 1-1**). Groundwater sampling stations exist throughout the FMC and surrounding area, a subset of which were sampled during the spring 2014 program. Specific sampling locations and general sample site distribution are described in **Sections 1.2**and **1.3**.

## Scope of Work

The scope of work included the coordination and execution of the spring groundwater sampling program and the preparation of this report. The report provides a summary of the sampling activities, methodologies (including any deviations), laboratory analytical results, concentrations of contaminants exceeding the applicable guidelines, and recommendations relating to sample procedures and monitoring well condition. This report does not provide an interpretation of the analytical results or provide recommendations relating to contaminated groundwater. The spring groundwater sampling event at the FMC was conducted over an eight (8) day period, between June 17 and 24, 2014. The majority of sampling was completed between June 17 and June 21, 2014, and additionally a single day site visit was conducted on June 24, 2014. Sampling was conducted by a team of four (4) field staff from Hemmera and ELR. A total of 65 groundwater wells were included in the spring sampling event (**Table 1-1**), which is a subset of the 100 wells included in the fall sampling event.

At each well (sampling station) the water level and depth to bottom of the well were measured, groundwater was purged, and field parameters were measured (pH, water temperature, and conductivity). Groundwater samples were collected after well measurements and purging, and were analysed for general water quality chemistry (major anions/cations and physical parameters), total metals, and dissolved metals. A detailed description of the sampling methods is provided in **Section 2**, below.

## Sample Sites

Groundwater sampling during the spring sampling event targeted 65 wells across 11 different areas of the FMC (**Table 1-1**). The majority of spring sample sites were located in the Faro Mine Area (45 wells), with the remaining wells located in the Vangorda/Grum Area (20 wells). A large portion of the wells sampled in the Faro Mine Area were located in the S-Wells Area (17 wells; **Figure 1-2**), with additional wells in the surrounding areas. Wells in the Vangorda/Grum Area were primarily located in the vicinity of the Grum Sulphide Cell (**Figure 1-3**). **Table 1-1** summarizes sample sites included in the spring sampling program, **Figures 1-2** and 1-3 show locations and general distribution of the sites. Photographs of each sample site are included as **Appendix B**.

Table 1-1 Summary of Groundwater Sample Sites Identified for 2014 Spring Program

| Area | Well Name | UTM (Zone 8N) | | Well Status | Sample Successfully Collected | QA/QC Sample Collected |
| --- | --- | --- | --- | --- | --- | --- |
| Easting | Northing |
| Northeast Dumps | BH13B | 585748 | 6914495 | Good |  |  |
| BH14A | 585582 | 6914012 | Good |  |  |
| BH14B | 585582 | 6914012 | Good |  |  |
| Mill Area | SRK08-10A | 582719 | 6914051 | Good |  |  |
| SRK08-11A | 582582 | 6914571 | Good |  |  |
| SRK08-11B | 582585 | 6914572 | Good |  |  |
| Main Dump | SRK08-P9 | 583688 | 6913622 | Good |  | Duplicate |
| Intermediate Dump | P96-6 | 584900 | 6913312 | Good |  |  |
| ETA Area | P96-8A | 583222 | 6914073 | Good |  | Duplicate |
| P96-8B | 583222 | 6914073 | Good |  |  |
| P09-ETA-2 | 582699 | 6913811 | Good |  | Duplicate |
| S-Wells Area | S1A | 584433 | 6913114 | Good |  |  |
| S1B | 584433 | 6913114 | Good |  |  |
| S2A | 584470 | 6913117 | Good |  |  |
| S2B | 584470 | 6913117 | Good |  |  |
| P96-7 | 584123 | 6913285 | Good |  |  |
| SRK05-SP-4A | 584503 | 6913117 | Good |  |  |
| SRK05-SP-4B | 584503 | 6913110 | Frozen | - |  |
| SRK05-SP-5 | 584468 | 6913129 | Damaged |  |  |
| SRK08-SP-7A | 584438 | 6913098 | Good |  |  |
| SRK08-SP-7B | 584439 | 6913099 | Good |  | Duplicate |
| SRK08-SP-8A | 584294 | 6912953 | Good |  |  |
| SRK08-SP-8B | 584292 | 6912952 | Good |  |  |
| P09-SIS1 | 584479 | 6913127 | Good |  |  |
| P09-SIS2 | 584485 | 6913122 | Good |  | Duplicate |
| P09-SIS3 | 584495 | 6913121 | Good |  |  |
| P09-SIS4 | 584508 | 6913112 | Good |  |  |
| P09-SIS5 | 584515 | 6913108 | Good |  |  |
| Second Impoundment | P03-06-1 | 582452 | 6913496 | Good |  |  |
| P03-06-2 | 582452 | 6913496 | Good |  |  |
| P03-06-6 | 582452 | 6913496 | Good |  |  |
| P03-06-7 | 582452 | 6913496 | Dry | - |  |
| Intermediate Dam | P01-03 | 580516 | 6914255 | Frozen | - |  |
| P01-04A | 580372 | 6914074 | Good |  |  |
| Intermediate Dam | P01-04B | 580372 | 6914074 | Frozen | - |  |
| X24-96D | 580544 | 6914298 | Good |  |  |
| X25-96A | 580544 | 6914298 | Good |  |  |
| X25-96B | 580407 | 6914119 | Good |  |  |
| Cross Valley Dam | P05-01-03 | 580407 | 6914119 | Good |  |  |
| P05-01-05 | 580056 | 6914508 | Good |  |  |
| P01-11 | 580093 | 6914486 | Good |  |  |
| P09-C2 | 580014 | 6914400 | Good |  |  |
| P09-C3 | 579973 | 6914319 | Good |  | Duplicate |
| Downgradient of CVD | P01-01A | 579701 | 6914854 | Good |  |  |
| P01-01B | 579701 | 6914854 | Good |  |  |
| Vangorda/Grum | P2001-02A | 593132 | 6902864 | Good |  |  |
| P2001-02B | 593132 | 6902864 | Good |  |  |
| P2001-3 | 593095 | 6902880 | Good |  |  |
| P96-9A | 592647 | 6903345 | Good |  |  |
| BH05-9B-R | 592639 | 6903344 | Good |  |  |
| SRK05-5C | 592766 | 6903382 | Good |  |  |
| SRK05-07 | 592371 | 6903187 | Good |  |  |
| SRK05-08 | 592583 | 6903238 | Good |  |  |
| SRK05-9 | 592951 | 6903165 | Good |  |  |
| V34 | 593428 | 6902474 | Good |  |  |
| V35 | 593177 | 6902553 | Good |  |  |
| V36 | 593133 | 6902916 | Good |  |  |
| V37 | 593311 | 6903081 | Good |  |  |
| P09-GS1A | 592494 | 6904829 | Good |  |  |
| P09-GS1B | 592486 | 6904832 | Good |  |  |
| P09-LCD1 | 593358 | 6903313 | Good |  |  |
| P09-LCD4 | 593327 | 6903272 | Good |  |  |
| P09-LCD6 | 593313 | 6903252 | Good |  |  |
| P09-VC1 | 593520 | 6903419 | Good |  |  |
| P09-VC2 | 593515 | 6903432 | Good |  | Duplicate |

Figure 1-1 Site Location – Faro Mine Complex

Figure 1-2 Groundwater Sampling Locations – Faro Mine Area

Figure 1-3 Groundwater Sampling Locations – Vangorda/Grum Area

# Methodology

## Protocols

Groundwater purging and sampling conducted by Hemmera/ELR was in accordance with Yukon Environment’s Protocol for the Contaminated Sites Regulation #7 – Groundwater Monitoring Well Installation, Sampling and Decommissioning (Yukon Environment, March 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 well, the well structure and casing were inspected for damage, closure, and general conditions. Several measurements were recorded from each well, including Depth-to-Water (DTW; m), Depth-to-Bottom (DTB; m), well diameter (cm), and well stick-up height (m).

DTB and DTW were measured using either a Solinst - Model 102 Water Level Meter (for 2.54 cm diameter wells) or a Heron Water Tape (for wells with diameter greater than 2.54 cm). DTB and DTW were measured from (in hierarchical order): 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 was drawn on the highest point of the well and measurement taken from that line if no distinguishable point of measure was present. Based on information reviewed by Hemmera/ELR, it is unknown where the point of measurement was for previous sampling programs. 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 rinsed between each sample site with de-ionized water.

Next, groundwater wells were purged and sampled using dedicated equipment including high density polyethylene (HDPE) tubing and footvalves. In many cases existing tubing found within wells was not considered to be suitable for sampling. In such cases, existing tubing was removed and new tubing installed. Many other wells did not have any dedicated tubing present. Groundwater wells were purged and sampled using one of three (3) techniques: 1) Hydrolift electric pump using Waterra tubing and footvalve, 2) manual purging using Waterra tubing and footvalve, or 3) GeoPump peristaltic pump. 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 and was used as an indication of sample quality. Where possible samples were not collected until turbidity levels were below 50 NTU.

Purge volume measurements were taken using a graduated container and stop watch. All well measurements, purging details, and additional field notes were recorded on field forms, this information is presented in **Table 3-1**.

Table 2-1 Groundwater Sampling – Field Parameter Purging Criteria

|  |  |
| --- | --- |
| Field Parameter | Allowable Variance in 3 Consecutive Readings |
| Temperature (°C) | 3% |
| pH (pH Units) | +0.1 |
| Conductivity (µS/cm) | 3% |

## Field Parameters

Hemmera/ELR measured general field parameters using Hanna 991300 field meters. All field parameters were collected using a flow cell in order to minimize field parameter variability. Field parameters recorded at each sample site included; water temperature (oC), specific conductivity (μs/cm), conductivity (μs/cm), and pH (pH Units). Where possible, field parameters were recorded throughout the purging process at five‑minute intervals. For wells with slow recharge field parameters were recorded at volume related intervals (e.g., every 500 mL). Groundwater turbidity was measured at the time of sample collection using either a LaMotte 2020we or a Hach 2100Q Portable turbidity meter.

## Groundwater Quality Sample Collection

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 Global was the analytical subcontractor chosen for this project, and an example summary of the sample set collected at each sample site, including parameters analysed and preservation techniques, is provided in **Table 2-2**.

Table 2-2 Groundwater Sampling – Preservation and Intended Analysis

|  |  |  |  |
| --- | --- | --- | --- |
| Bottle Type | Parameters Analyzed | Sample Treatment | Preservation Added |
| 120 mL (Plastic) | Total Metals | Preserved | HNO3 |
| 120 mL (Plastic) | Dissolved Metals | Field Filtered and Preserved | HNO3 |
| 1 L (Plastic) | Acidity, alkalinity, chloride, conductivity, pH, sulphate, total suspended solids (TSS) | - | None |

## 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 3-2**.

## Quality Assurance and Quality Control (QA/QC)

### Field QA/QC

Several controls were used by Hemmera/ELR staff while in the field to help 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 tubing and Waterra footvalves, laboratory provided pre-cleaned sample containers, disposable filters, and disposable syringes. Field staff wore dedicated disposable nitrile gloves for all measurements, purging, and sampling. Water level meters were cleaned using de-ionized water between wells, and field instruments (Hanna field meter and turbidity meters) 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 C** of this report.

### QA/QC

Laboratory QA/QC measures undertaken as part of the spring sampling program include the collection of travel blanks, duplicates, and field blanks, as outlined in the statement of work and as per standard industry practice. Duplicate samples were collected at a ratio of 10% of the regular samples collected (7 duplicates were collected in relation to 65 sample sites). Additionally, one field blank was collected in the field, and one travel blank accompanied the analytical supplies and samples from the lab to the field and back to the lab again.

The variation in sample and sample duplicate values is represented 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 data precision. RPD was calculated according to the following formula:

RPD is not calculated if either the sample or the field duplicate concentration is less than five times the detection limit. QA/QC analytical results including RPD values are presented in **Table 3-3**.

Laboratory replicates and additional quality control measures (i.e. measures against lab standards) were conducted by ALS. Laboratory QA/QC analytical results are included as **Appendix A** and discussed in **Section 3.3**.

# Results

Summary tables of the laboratory analytical results are presented in **Table 3-2** of this report, including comparisons of results to CCME FAL guidelines. A summary of the QA/QC sampling results is also attached, including analytical data for duplicates, field blank, and travel blank (**Table 3-3**). Laboratory analytical reports are provided as **Appendix A**.

## Groundwater Sampling Summary

The majority of spring 2014 groundwater sampling was completed between June 17 and 21, 2014, with an additional four (4) wells (P03-06-1, P03-06-2, P03-06-6, and P03-06-7) visited on June 24, 2014. A return trip to sample wells in the second impoundment area was necessary due to requirement of specialized small diameter footvalves, as discussed with AAM. Weather conditions varied throughout the time of sampling with ambient air temperature ranging from 8 to 12°C. Weather conditions were pre-dominantly overcast with periods of precipitation and clear sunny conditions. All 65 groundwater wells specified for the spring sampling event were visited by Hemmera/ELR during the sampling event. Groundwater samples were successfully collected at 61 of the 65 sampling locations as outlined in **Table 1-1**. Three (3) wells were found frozen (SRK05-SP-4B, P01-03, and P01-04B) and one (1) well was found dry (P03-06-06) during the time of sampling. A summary of groundwater wells sampled during the 2014 spring sampling event, including field parameters and well measurements, is provided in **Table 3-1**. All samples were received by the laboratory within the required holding times and temperature limits.

A summary of the sampling results and guideline exceedances is provided in the following sections, organized by area.

Table 3-1 Groundwater Field Parameters and Well Measurements for 2014 Spring Sampling Program

| **Area** | **Well Name** | **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)** | **Criteria (3WV / PS)** | **Draw Down (m)** | **pH** | **Temperature (°C)** | **Conductivity (µS/cm)** | **Field Turbidity (NTU)** | **Method Used** | **Well Diameter (inches)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Northeast Dumps | BH13B | 2014-06-19 | 0.760 | 2.283 | 4.215 | 3.864 | 9.5 | 8:10 | 8:30 | 0:20 | 0.48 | PS | 2.51 | 6.88 | 2.5 | 1150 | 3.8 | Peristaltic | 2 |
| BH14A | 2014-06-19 | 0.020 | 3.182 | 6.400 | 6.436 | 6 | 8:50 | 9:15 | 0:25 | 0.24 | 3WV | 3.84 | 6.75 | 3.8 | 3700 | 10.44 | Peristaltic | 2 |
| BH14B | 2014-06-19 | 0.650 | 3.888 | 10.052 | 12.328 | 12 | 9:20 | 9:45 | 0:25 | 0.48 | 3WV | 6.47 | 6.89 | 6.5 | 3590 | 1.9 | Peristaltic | 2 |
| Mill Area | SRK08-10A | 2014-06-21 | 0.705 | 10.131 | 18.000 | 7.354 | 0:00 | 13:11 | 13:38 | 0:27 | 0.67 | PS | 0.849 | 6.55 | 4.2 | 3780 | 53.7 | Manual Wattera | 2 |
| SRK08-11A | 2014-06-21 | 0.690 | 0.555 | 12.562 | 24.024 | 8 | 10:17 | 10:43 | 0:26 | 0.24 | PS | 0.56 | 7.11 | 6.8 | 1040 | 1.94 | Peristaltic | 2 |
| SRK08-11B | 2014-06-21 | 0.935 | 0.866 | 6.750 | 11.956 | 8 | 9:33 | 10:07 | 0:34 | 0.24 | PS | 0.872 | 6.8 | 11.2 | 970 | 5.07 | Peristaltic | 2 |
| Main Dump | SRK08-P9 | 2014-06-19 | 0.100 | 3.685 | 6.132 | 4.894 | 10.5 | 10:50 | 11:15 | 0:25 | 0.42 | PS | 4.13 | 7.4 | 3.3 | 1420 | 3.91 | Peristaltic | 2 |
| Intermediate Dump | P96-6 | 2014-06-18 | 0.73 | 10.695 | 18.420 | 15.5 | 50 | 15:20 | 15:40 | 0:20 | 2.50 | PS | N/A | 6.7 | 3.1 | 1990 | 6.7 | Manual Wattera | 2 |
| ETA Area | P96-8A | 2014-06-19 | 0.775 | 2.245 | 4.825 | 5.16 | 7 | 12:40 | 13:00 | 0:20 | 0.35 | PS | 2.27 | 3.92 | 8.6 | 8920 | 0.9 | Peristaltic | 2 |
| P96-8B | 2014-06-19 | 0.690 | 2.175 | 9.370 | 14.39 | 16 | 13:05 | 13:25 | 0:20 | 0.8 | 3WV | 2.2 | 5.3 | 6.8 | 8910 | 1.2 | Hydrolift | 2 |
| P09-ETA-2 | 2014-06-18 | 0.690 | 9.494 | 18.443 | 18 | 40 | 11:49 | 12:19 | 0:30 | 1.33 | PS | 9.55 | 6.38 | 3.1 | 7440 | 10.8 | Hydrolift | 2 |
| S-Wells Area | S1A | 2014-06-18 | 1.325 | 4.1105 | 13.110 | 18.287 | 55 | 8:29 | 8:55 | 0:26 | 2.12 | PS | 4.14 | 5.88 | 2.2 | 5420 | 12.4 | Manual Wattera | 2 |
| S1B | 2014-06-18 | 1.180 | 3.798 | 5.185 | 2.818 | 2.5 | 8:00 | 13:10 | 5:10 | 0.01 | 3WV | - | 6.41 | 3 | 600 | 20.2 | Manual Wattera | 2 |
| S2A | 2014-06-21 | 0.340 | 3.600 | 11.715 | 16.088 | 10 | 10:00 | 10:40 | 0:40 | 0.25 | PS | 3.64 | 6.18 | 0.5 | 3060 | 6.98 | Peristaltic | 2 |
| S2B | 2014-06-20 | 0.550 | 3.725 | 7.060 | 6.67 | 12 | 16:35 | 17:20 | 0:45 | 0.27 | PS | 1.3 | 5.96 | 1.3 | 9100 | 11.1 | Peristaltic | 2 |
| P96-7 | 2014-06-18 | 0.850 | 5.255 | 9.880 | 9.25 | 23 | 16:25 | 16:55 | 0:30 | 0.77 | PS | 5.44 | 7.32 | 2 | 2850 | 3.22 | Peristaltic | 2 |
| SRK05-SP-4A | 2014-06-18 | 0.590 | 4.025 | 22.320 | 36.59 | 55 | 11:00 | 11:35 | 0:35 | 1.57 | PS | 4.25 | 6 | 2.7 | 1520 | 3.08 | Hydrolift | 2 |
| SRK05-SP-4B | 2014-06-18 | - | - | 1.500 | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| SRK05-SP-5 | 2014-06-20 | 1.070 | 6.140 | 14.700 | 17.12 | 45 | 16:45 | 17:10 | 0:25 | 1.8 | PS | 9.17 | 5.98 | 1.2 | 10190 | 10.05 | Hydrolift | 2 |
| SRK08-SP-7A | 2014-06-17 | - | 2.052 | 17.735 | 31.3 | 30 | 18:38 | 18:58 | 0:20 | 1.5 | 3WV | 2.37 | 6.37 | 2.1 | 730 | 7.83 | Hydrolift | 2 |
| SRK08-SP-7B | 2014-06-17 | - | 2.138 | 8.668 | 13.1 | 7.5 | 17:55 | 18:20 | 0:25 | 0.3 | PS | 2.16 | 6.71 | 1.9 | 320 | 2.22 | Peristaltic | 2 |
| SRK08-SP-8A | 2014-06-18 | 1.180 | 1.667 | 11.330 | 19.326 | 45 | 17:30 | 17:45 | 0:15 | 3 | PS | N/A | 6.17 | 1.8 | 2310 | 24.1 | Manual Wattera | 2 |
| SRK08-SP-8B | 2014-06-18 | 1.020 | 1.715 | 7.032 | 10.634 | 15 | 17:20 | 17:45 | 0:25 | 0.6 | PS | 1.9 | 6.16 | 1.9 | 2320 | 20 | Peristaltic | 2 |
| P09-SIS1 | 2014-06-18 | 0.990 | 4.335 | 6.570 | 4.5 | 9.5 | 8:50 | 9:15 | 0:25 | 0.38 | PS | 5.45 | 6.52 | 3.8 | 7740 | 33.5 | Peristaltic | 2 |
| P09-SIS2 | 2014-06-18 | 1.100 | 3.745 | 6.330 | 5.1 | 7 | 8:05 | 8:30 | 0:25 | 0.28 | PS | 3.8 | 5.55 | 4.4 | 10310 | 5.96 | Peristaltic | 2 |
| P09-SIS3 | 2014-06-18 | 1.050 | 3.746 | 4.606 | 2.5 | 10 | 10:10 | 10:30 | 0:20 | 0.5 | PS | 3.76 | 5.93 | 2.8 | 10670 | 1.92 | Peristaltic | 2 |
| P09-SIS4 | 2014-06-18 | 0.960 | 3.820 | 4.435 | 2 | 4.5 | 11:25 | 11:50 | 0:25 | 0.23 | PS | 4.2 | 6.33 | 3.8 | 5800 | 13.5 | Peristaltic | 2 |
| P09-SIS5 | 2014-06-18 | 1.120 | 3.485 | 4.600 | 2.23 | 3 | 12:00 | 12:30 | 0:30 | 0.10 | PS | 4.42 | 6.41 | 5.6 | 4610 | 13.1 | Peristaltic | 2 |
| Second Impoundment | P03-06-1 | 2014-06-24 | 0.800 | 12.292 | 26.565 | - | 1 | 14:45 | 15:20 | 0:35 | 0.03 | PS | - | 4.82 | 8.3 | - | 40.3 | Manual Wattera | 0.625 |
| P03-06-2 | 2014-06-24 | 0.850 | 12.197 | 23.695 | - | 15 | 13:55 | 14:20 | 0:25 | 0.60 | PS | - | 4.96 | 5.3 | - | 1167 Au | Manual Wattera | 0.625 |
| P03-06-6 | 2014-06-24 | 0.980 | 12.282 | 13.480 | - | - | 12:45 | 13:10 | 0:25 | - | PS | - | 5.76 | 9.5 | - | O/R | Manual Wattera | 0.625 |
| P03-06-7 | 2014-06-24 | 1.00 | - | 11.816 | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.625 |
| Intermediate Dam | P01-03 | 2014-06-21 | 0.495 | - | 2.745 | - | - | - | - | - | - | - | - | - | - | - | - | - | 2 |
| P01-04A | 2014-06-18 | 0.310 | - | 2.620 | ~65 | 50 | 17:36 | 17:56 | 0:20 | 2.50 | PS | - | 6.72 | 3.2 | 1140 | 1.55 | Hydrolift | 2 |
| P01-04B | 2014-06-21 | 0.317 | 2.199 | 2.274 | - | - | - | - | - | N/A | - | - | - | - | - | - | - | 2 |
| X24-96D | 2014-06-18 | 0.970 | 3.975 | 25.510 | 43 | 47 | 15:20 | 15:50 | 0:30 | 1.57 | 3WV | 9.06 | 6.14 | 3.6 | 3720 | 5.67 | Hydrolift | 2 |
| X25-96A | 2014-06-18 | 0.650 | 3.262 | 9.510 | 12.695 | 9 | 16:52 | 14:15 | 0:23 | 0.39 | PS | 3.27 | 6.94 | 5.2 | 1650 | 2.63 | Peristaltic | 2 |
| X25-96B | 2014-06-18 | 0.620 | 3.145 | 19.750 | 33.74 | 35 | 16:15 | 16:46 | 0:31 | 1.13 | 3WV | 3.15 | 7.48 | 4.6 | 1710 | 0.68 | Hydrolift | 2 |
| Cross Valley Dam | P05-01-03 | 2014-06-19 | 0.540 | 1.552 | 17.788 | - | 4.75 | 14:24 | 14:45 | 0:31 | 0.15 | PS | 1.555 | 6.50 | 5.8 | 3400 | 9.04 | Peristaltic | 0.25 |
| P05-01-05 | 2014-06-19 | 0.600 | 1.955 | 6.555 | 0.5842 | 6 | 13:35 | 13:55 | 0:20 | 0.30 | PS | 1.94 | 6.55 | 5.2 | 3320 | 7.47 | Peristaltic | 0.5 |
| P01-11 | 2014-06-19 | 1.240 | 1.100 | 11.070 | 20.259 | 80 | 11:08 | 11:42 | 0:34 | 2.35 | PS | 1.113 | 6.68 | 5.5 | 3340 | 31.2 | Manual Wattera | 2 |
| P09-C2 | 2014-06-19 | 0.870 | 2.585 | >60 | 124.795 | 35 | 12:32 | 13:03 | 0:31 | 1.13 | PS | 3.8 | 6.52 | 5.3 | 2570 | 42.3 | Hydrolift | 2 |
| P09-C3 | 2014-06-19 | 0.850 | 1.173 | 52.270 | 101.797 | 37.5 | 9:45 | 10:00 | 0:15 | 2.50 | PS | 1.505 | 6.77 | 4.3 | 1400 | 4.1 | Hydrolift | 2 |
| Downgradient of CVD | P01-01A | 2014-06-19 | 0.620 | 3.596 | 20.345 | 34.03 | 30 | 8:17 | 8:32 | 0:15 | 2.00 | PS | 3.625 | 6.97 | 1.6 | 1670 | 1.3 | Hydrolift | 2 |
| P01-01B | 2014-06-19 | 0.570 | 3.710 | 35.505 | 64.607 | 35 | 8:41 | 8:56 | 0:15 | 2.33 | PS | 3.745 | 7.25 | 1.9 | 1460 | 0.6 | Hydrolift | 2 |
| Vangorda/Grum | P2001-02A | 2014-06-19 | 0.630 | 4.155 | 6.605 | 4 | 7 | 17:25 | 17:45 | 0:20 | 0.35 | PS | 4.91 | 6.83 | 4.1 | 2780 | 20.5 | Peristaltic | 2 |
| P2001-02B | 2014-06-20 | 0.570 | 4.020 | 27.700 | 45 | 50 | 7:50 | 8:15 | 0:25 | 2.00 | PS | 12.96 | 6.95 | 3.5 | 2740 | 59.5 | Hydrolift | 2 |
| P2001-3 | 2014-06-19 | - | 37.125 | 62.420 | 50.59 | 150 | 17:00 | 17:40 | 0:40 | 3.75 | PS | N/A | 7.47 | 4.3 | 1030 | 46.8 | Hydrolift | 2 |
| P96-9A | 2014-06-20 | 0.930 | 5.660 | 9.355 | 7.39 | 9.5 | 13:45 | 14:05 | 0:20 | 0.48 | PS | 5.78 | 6.80 | 2.1 | 3000 | 1.93 | Peristaltic | 2 |
| BH05-9B-R | 2014-06-20 | 0.950 | 0.200 | 19.900 | 39.4 | 50 | 13:00 | 13:25 | 0:25 | 2.00 | PS | 3.82 | 8.07 | 3.6 | 650 | 3.87 | Hydrolift | 2 |
| SRK05-5C | 2014-06-20 | 1.00 | 1.461 | 3.670 | 2.209 | 12 | 11:50 | 12:25 | 0:35 | 0.34 | PS | 1.72 | 7.79 | 5.2 | 540 | 13.7 | Peristaltic | 1 |
| SRK05-07 | 2014-06-20 | 0.800 | 5.354 | 6.250 | 1.792 | 4.5 | 10:30 | 10:50 | 0:20 | 0.23 | PS | 5.55 | 7.04 | 3.5 | 3170 | 2.79 | Peristaltic | 2 |
| SRK05-08 | 2014-06-20 | 0.780 | 5.496 | 8.475 | 5.958 | 9 | 11:05 | 11:25 | 0:20 | 0.45 | PS | 5.91 | 6.99 | 3.6 | 2510 | 3.29 | Peristaltic | 2 |
| SRK05-9 | 2014-06-20 | - | 1.830 | 3.965 | 1.0675 | 4.5 | 15:05 | 15:35 | 0:30 | 0.15 | PS | 1.84 | 7.50 | 1.1 | 1870 | 2.39 | Peristaltic | 1 |
| V34 | 2014-06-19 | 0.580 | 5.710 | 12.820 | 14.22 | 15 | 15:30 | 15:55 | 0:25 | 1.67 | 3WV | 8.2 | 7.21 | 3.5 | 2110 | 33.5 | Hydrolift | 2 |
| V35 | 2014-06-19 | 0.530 | 7.585 | 15.880 | 16.59 | 15 | 16:10 | 16:35 | 0:15 | 1.00 | PS | 10.69 | 7.22 | 4.7 | 3100 | 1.16 | Hydrolift | 2 |
| V36 | 2014-06-19 | - | 8.724 | 11.878 | 6.408 | 20 | 17:25 | 17:56 | 0:31 | 0.65 | PS | 8.932 | 7.03 | 4 | 2630 | 16.4 | Manual Wattera | 2 |
| V37 | 2014-06-20 | 0.750 | 8.754 | 14.510 | 11.696 | 18 | 8:04 | 8:42 | 0:38 | 0.47 | PS | 11.79 | 7.66 | 3.5 | 1150 | 7.34 | Hydrolift | 2 |
| P09-GS1A | 2014-06-20 | 1.230 | 2.224 | 7.382 | 10.5 | 8 | 14:20 | 14:41 | 0:21 | 0.38 | PS | 2.228 | 7.08 | 5.9 | 1150 | 20 | Peristaltic | 2 |
| P09-GS1B | 2014-06-20 | 0.920 | 2.050 | 29.690 | 55 | 9 | 15:00 | 15:25 | 0:25 | 0.36 | PS | 3.65 | 6.87 | 3.7 | 1450 | 15.1 | Peristaltic | 2 |
| P09-LCD1 | 2014-06-20 | 0.930 | 3.764 | 7.410 | 7.3 | 5 | 10:25 | 10:40 | 0:15 | 0.33 | PS | 3.801 | 7.36 | 3.5 | 920 | 13.8 | Peristaltic | 2 |
| P09-LCD4 | 2014-06-21 | 0.960 | 2.152 | 12.282 | 20 | 27 | 11:03 | 17:10 | 1:07 | 0.40 | PS | N/A | 7.32 | 3 | 900 | 1100 AU | Manual Wattera | 2 |
| P09-LCD6 | 2014-06-20 | 0.760 | 5.776 | 7.996 | 4.4 | 7 | 11:34 | 12.09 | 0:35 | 0.20 | PS | 5.81 | 7.31 | 3.6 | 1030 | 41 | Peristaltic | 2 |
| P09-VC1 | 2014-06-20 | 0.850 | 3.791 | 58.000 | 110 | 140 | 9:55 | 10:15 | 0:20 | 7.00 | PS | 10.69 | 8.11 | 3.6 | 390 | 10.26 | Hydrolift | 2 |
| P09-VC2 | 2014-06-20 | 0.950 | 1.526 | 19.860 | 37 | 45 | 9:25 | 9:50 | 0:25 | 1.80 | PS | 2.41 | 7.42 | 3.6 | 440 | 4.47 | Hydrolift | 2 |

## Analytical Results

Discussion of analytical results including a brief summary of CCME FAL guideline exceedances and factors which may influence data precision are provided below. In many instances reported detection limits (DL) exceed applicable CCME FAL standards (values shaded light greyin **Table 3-2**). Samples with high levels of contamination require dilution in order to analyse the sample and this results in a higher detection limit. In the case of mercury, low-level analytical methods are required to achieve detection limits relevant to the guidelines. A separate bottle for mercury was not part of the laboratory program during this sample event, therefore the low-level analytical methods were not used. For the purpose of this report, samples where the reported DL is higher than the applicable guideline have not been reported as CCME FAL exceedances.

### Cross Valley Dam

Groundwater wells located in the Cross Valley Dam (CVD) area were sampled on June 19, 2014. Samples were obtained from all four (4) wells within this area identified for the sampling event.

Concentrations of dissolved arsenic, cadmium, iron and silver in water exceeded the CCME FAL guidelines in all samples collected from the CVD area. Concentrations of total aluminum, arsenic, cadmium, chromium, copper, iron, lead, and silver in water also exceeded the CCME FAL guidelines each of the four wells.

The CVD wells visited were in good condition and no additional concerns were identified in the field that may have affected data quality. Groundwater turbidity of all CVD samples was below 50 NTU.

### Down Gradient of Cross Valley Dam

Groundwater wells located down gradient of the CVD area were sampled on June 19, 2014. Samples were obtained from both wells (2) within this area identified for the sampling event.

Concentrations of dissolved cadmium and iron in water exceeded the CCME FAL guidelines in samples collected from both wells down gradient of the CVD area. Concentrations of total cadmium and iron in water also exceeded the CCME FAL guidelines in both wells.

Hemmera/ELR staff noted that wells located down gradient of the CVD area did not have PVC caps or J-plugs covering the wells, which can allow for potential contamination. Groundwater turbidity in all samples within this area was below 50 NTU.

### ETA Area

Groundwater wells located in the ETA Area were sampled between June 18 and 19, 2014. Samples were obtained from all three (3) wells in this area identified for the sampling event.

Groundwater pH in the ETA area was not in compliance with CCME FAL guidelines in all three samples (ranging from 4.16 to 6.35). Concentrations of dissolved aluminum, arsenic, cadmium, copper, iron, lead, nickel, uranium, and zinc in water exceeded the CCME FAL guidelines in the three samples. Concentrations of total aluminum, arsenic, cadmium, copper, iron, lead, nickel, uranium, and zinc in water also exceeded the CCME FAL guidelines.

No additional concerns were identified in the field that may affect data quality. Groundwater turbidity in all samples collected within the ETA area was below 50 NTU.

### Intermediate Dam

Groundwater wells located within the intermediate dam area were sampled on June 18, 2014. Samples were obtained from four (4) of the six (6) wells within this area identified for the sampling event. The other two (2) wells (P01-03 and P01-04B) were both frozen during the time of sampling.

Concentrations of both total and dissolved cadmium, dissolved aluminum, iron, nickel, silver, and zinc in water exceeded the CCME FAL guidelines in samples collected within the intermediate dam area.

No additional concerns were identified in the field that may affect data quality. Groundwater turbidity in all samples collected within the intermediate dam area was below 50 NTU.

### Intermediate Dump

Only one (1) groundwater well located within the intermediate dump area was included in the spring sampling event (well P96-6), which was sampled on June 18, 2014.

Concentrations of dissolved selenium, uranium, and zinc in water exceeded the CCME FAL guidelines in samples from this well. Concentrations of total aluminum, iron, selenium, uranium, and zinc in water also exceeded the CCME FAL standards.

Hemmera/ELR staff found that the PVC stick-up of well P96-6 was disconnected from its coupling, leaving the potential for casing materials to fall into the well and potential resulting contamination. The turbidity of groundwater from well P96-6 at the time of sampling was 6.7 NTU.

### Main Dump

One (1) groundwater well located within the main dump area was included in the spring sampling event, which was sampled on June 19, 2014.

Concentrations of dissolved selenium in water exceeded the CCME FAL guidelines in samples from this well. Concentrations of total aluminum, chromium, and selenium in water also exceeded the CCME FAL standards.

Hemmera/ELR staff found that the PVC stick-up of well SRK08-P9 was broken at the ground level, and that there was no metal casing protecting well stick-up. The turbidity of groundwater from well SRK08-P9 at the time of sample was 3.91 NTU.

### Mill Area

Groundwater wells located in the mill area were sampled on June 21, 2014. Samples were obtained from all three (3) wells in this area identified for the sampling event.

Concentrations of dissolved cadmium, uranium, and zinc in water exceeded the CCME FAL guidelines in samples collected within the mill area. Concentrations of total aluminum, cadmium, chromium, copper, iron, lead, uranium, and zinc in water also exceeded the CCME FAL guidelines.

The turbidity of groundwater collected from well SRK08-10A was slightly above the 50 NTU criteria (53.7 NTU) during sampling. Groundwater turbidity in all other mill area samples was below 50 NTU.

### Northeast Dumps

Groundwater wells located in the northeast dumps area were sampled on June 19, 2014. Samples were obtained from all three (3) wells in this area identified for the sampling event.

Concentrations of dissolved cadmium, lead, nickel, selenium, uranium, and zinc in water exceeded the CCME FAL guidelines in samples collected within the northeast dumps area. Concentrations of total aluminum, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, silver, uranium, and zinc in water also exceeded the CCME FAL guidelines.

Hemmera/ELR staff found that the well stick-up of well BH14A had been buried in soil due to a small landslide. Additionally, no metal casing protecting the well stick-ups existed for any wells located in the northeast dump area. Groundwater turbidity of all samples within the northeast dumps area was below 50 NTU.

### Second Impoundment

Groundwater wells located in the Second Impoundment area were sampled on June 24, 2014. Samples were obtained from three (3) of the four (4) wells in this area identified for the sampling event. Well P03-06-06 was dry during the time of sampling.

Groundwater pH in the second impoundment area was below CCME FAL guidelines in all three samples collected. Concentrations of dissolved aluminum, arsenic, cadmium, copper, iron, lead, nickel, uranium, and zinc in water exceeded the CCME FAL guidelines in samples collected from the second impoundment area. Concentrations of total aluminum, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel, silver, thallium, uranium, and zinc in water also exceeded the CCME FAL guidelines.

Groundwater samples collected from the second impoundment area were extremely turbid, with values ranging from 40.3 NTU to ‘out-of-range’ on the turbidity meter (>4000 NTU).

### S-Wells Area

Groundwater wells located in the S-Wells area were sampled between June 17 and June 21, 2014. Samples were obtained from 16 of the 17 wells in this area identified for the sampling event. Well SRK05-SP-4B was frozen during the time of sampling.

Concentrations of dissolved aluminum, arsenic, cadmium, copper, iron, nickel, uranium, and zinc in water exceeded the CCME FAL guidelines in samples collected from the S-Wells area. Concentrations of total aluminum, arsenic, cadmium, chromium, copper, iron, nickel, silver and zinc in water also exceeded the CCME FAL guidelines.

Wells P09-SIS1 and SRK08-SP-7A did not have PVC well caps or J-plugs and therefore have risk of contamination. Metal casing on wells SRK08-SP-7B and SRK08-SP-8A did not close properly due to the well stick-up being higher than the well casing. Wells SRK05-SP-4A and SRK05-SP-5 were both found broken at ground level. Soil was found inside well SRK05-SP-5 and it is recommended that this site be re-developed. Re-development (i.e. purging the well until groundwater runs clear) will clear the well of fine sediment, and restore the water producing zone of the screened section to its original condition.

Groundwater turbidity of all collected samples within the S-Wells area was below 50 NTU.

### Groundwater Vangorda/Grum

Groundwater wells located in the Vangorda/Grum area were sampled between June 19 and June 21, 2014. Samples were obtained from all 20 wells in this area identified for the sampling event.

Concentrations of dissolved aluminum, arsenic, cadmium, chromium, copper, iron, selenium, thallium, uranium, and zinc in water exceeded the CCME FAL guidelines in samples collected from the Vangorda/Grum area. Concentrations of total aluminum, arsenic, cadmium, chromium, copper, lead, mercury, selenium, silver, thallium and zinc in water also exceeded the CCME FAL guidelines.

Wells V35 and V36 did not have PVC well caps or J-plugs and therefore have risk of contamination. Samples collected from well P09-LCD4 were extremely turbid (1100 AU) due to low purge volumes and rate of recharge. Groundwater turbidity of all other collected samples within the Vangorda/Grum area was below 50 NTU.

## Quality Assurance and Quality Control Results

A total of seven (7) duplicate groundwater samples were collected during the spring sampling event. A single travel blank was provided by the laboratory and accompanied the samples throughout the sampling program. A single field blank was prepared on-site on June 18, 2014. Detailed results of QA/QC sampling program is provided in **Table 3-3**, including RPD values for all duplicate and sample pairs collected.

Field blank and travel blank analytical results were reported below detection limits for all analysed parameters, indicating that there was no evidence of contamination during the sampling or transportation process. All RPD values were within an acceptable range of variability (below 20%), with the exception of TSS in SRK08-7B (RPD=28.6%), and acidity in PC09-C3 (RPD=89.5%).

TSS is expected to have more variability than other parameters; the TSS in SRK08-7B are considered to represent a valid range of values for a solution of suspended, rather than dissolved, constituents.

The 89.5% RPD for acidity indicates a sampling or analytical bias. The RPD for other acidity QA/QC samples was within 20%; thus there does not seem to be a systemic bias. Sample variation is considered to be the likely cause of the single variable result for acidity. Sampling using unfiltered methods can introduce sediment; if the sediment is acid-generating, the inclusion of the solid phase can bias the result[[1]](#footnote-1).

Laboratory replicates and additional quality control measures (i.e. measures against lab standards) were conducted by ALS (**Appendix A**). RPD was calculated for the majority replicate samples, in some cases RPD was not available due to result(s) being below detection limit. All replicate samples, where RPD calculation were available, were within the allowable limits specified by the laboratory. All measures against lab standards were also within the acceptable limits specified by the laboratory.

# Recommendations

Hemmera/ELR have prepared the following recommendations based on the observations and results of the spring 2014 groundwater sampling program.

1. Groundwater wells should be properly sealed with PVC caps or J-plugs. Wells without caps have risk of becoming contaminated which may affect data precision or quality. Wells were found without caps include; P01-01A, P01-01B, P09-SIS1, SRK08-SP-7A, V35 and V36.
2. Damaged or degraded wells should be repaired. This includes wells where stick-up height is above the height of the well casing. Wells which are unable to close properly are at risk of contamination. Damaged or degraded wells include the following; P96-6, SRK08-P9, BH14A, SRK08-SP-7B, SRK08-SP-8A, SRK05-SP-4A and SRK05-SP-5.
3. Low-flow sampling techniques were used to collect samples at wells that had likely been sampled previously by another method (as noted in **Section 2.2**, pre-existing tubing found within wells indicated a prior sampling method by Waterra inertial footvalve). To avoid creation of turbulent conditions, inclusion of particles not normally mobile in groundwater, and a positive bias to unfiltered results, it is recommended that low-flow sampling be used for wells where a significant drawdown would occur by the use of other methods.
4. To avoid inclusion of acid or alkaline-generating solids that are not representative of an equilibrium condition with groundwater, it is recommended that samples for analysis of acidity, alkalinity, and hardness be field-filtered.
5. To avoid degassing of carbon dioxide, precipitation of calcium carbonate in sample bottles, and exclusion of the representative precipitate component from analysis, it is recommended that samples for analysis of alkalinity be collected in a separate bottle with zero headspace and that the laboratory be instructed to analyze the contents of the entire bottle.

# 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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# References

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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 Government of Yukon. 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 Government of Yukon 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.

FIGURES

TABLES

Appendix A

Laboratory Reports

Appendix B

Site Photos

Appendix C

Field Forms

1. Similarly, the inclusion of particulate calcium carbonate can bias the result of an alkalinity sample. [↑](#footnote-ref-1)