**June 2015 Faro Mine Complex Groundwater Sampling**

Prepared for:

**Government of Yukon**

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**TABLE OF CONTENTS**

[1.0 Introduction 1](#_Toc434232928)

[1.1 Site Location 1](#_Toc434232929)

[1.2 Scope of Work 1](#_Toc434232930)

[1.3 Sample Sites 1](#_Toc434232931)

[2.0 Methodology 9](#_Toc434232932)

[2.1 Protocols 9](#_Toc434232933)

[2.2 Well Measurements and Purging 9](#_Toc434232934)

[2.3 Field Parameters 10](#_Toc434232935)

[2.4 Groundwater Quality Sample Collection 10](#_Toc434232936)

[2.5 Data Analysis 11](#_Toc434232937)

[2.6 Quality Assurance and Quality Control (QA/QC) 11](#_Toc434232938)

[2.6.1 Field QA/QC 11](#_Toc434232939)

[2.6.2 Laboratory and Sampling QA/QC 11](#_Toc434232940)

[3.0 Results 13](#_Toc434232941)

[3.1 Groundwater Sampling Summary 13](#_Toc434232942)

[3.2 Analytical Results 17](#_Toc434232943)

[3.2.1 Cross Valley Dam 17](#_Toc434232944)

[3.2.2 Down Gradient of Cross Valley Dam 17](#_Toc434232945)

[3.2.3 ETA 18](#_Toc434232946)

[3.2.4 Haul Road near NFRC 18](#_Toc434232947)

[3.2.5 Intermediate Dam 18](#_Toc434232948)

[3.2.6 Intermediate Dump 19](#_Toc434232949)

[3.2.7 Main Dump 19](#_Toc434232950)

[3.2.8 Mill Area 19](#_Toc434232951)

[3.2.9 NFRC Rock Drain Pond 19](#_Toc434232952)

[3.2.10 Northeast Dumps 20](#_Toc434232953)

[3.2.11 Second Impoundment 20](#_Toc434232954)

[3.2.12 S-Wells Area 20](#_Toc434232955)

[3.2.13 NFRC near S-Wells Area 21](#_Toc434232956)

[3.2.14 Groundwater Vangorda/Grum 21](#_Toc434232957)

[3.3 Quality Assurance and Quality Control Results 22](#_Toc434232958)

[4.0 Recommendations 23](#_Toc434232959)

[5.0 Closure 24](#_Toc434232960)

[6.0 References 25](#_Toc434232961)

[7.0 Statement of Limitations 26](#_Toc434232962)

**List of Tables *(within text)***

[Table 1-1 Summary of Groundwater Sample Sites Identified for the 2015 Spring Program 2](#_Toc434232963)

[Table 2-1 Groundwater Sampling – Field Parameter Purging Criteria 10](#_Toc434232964)

[Table 2-2 Groundwater Sampling – Preservation and Intended Analysis 10](#_Toc434232965)

[Table 3-1 Groundwater Field Parameters and Well Measurements for 2015 Spring Sampling Program 14](#_Toc434232966)

**List of Tables *(following text)***

Table 3-2 Groundwater Sampling Analytical Results and CCME Guideline Exceedances for June 2014 Sampling Program

Table 3-3 Quality Assurance and Quality Control Analytical Results for June 2014 Groundwater Sampling Program

**List of Figures**

[Figure 1-1 Site Location – Faro Mine Complex 5](#_Toc434232967)

[Figure 1-2 Groundwater Sampling Locations – Faro Mine Area 6](#_Toc434232968)

[Figure 1-3 Groundwater Sampling Locations – S-Wells Area 7](#_Toc434232969)

[Figure 1-4 Groundwater Sampling Locations – Vangorda/Grum Area 8](#_Toc434232970)

**List of Appendices**

Appendix A Laboratory Reports

Appendix B Site Photos

Appendix C Field Forms

Appendix D Response to Comments from Draft Report Version

# 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 2015. The program consists of two sampling events: spring (June) and fall (September). This report summarizes the activities completed and the 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 2015 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 (SOW) included the coordination and execution of the spring groundwater sampling program and the preparation of this summary report. This report provides a summary of the sampling program activities, methodologies (including any deviations from standard methodologies), field in-situ and laboratory analytical results, concentrations of contaminants exceeding the applicable guidelines, and recommendations relating to sampling procedures and monitoring well conditions. This report does not provide an interpretation of the analytical results or provide recommendations relating to the program. The spring groundwater sampling event at the FMC was conducted over an eight (8) day period from June 11 to June 15, and June 17 to 19, 2015. A total of 84 groundwater wells were specified by AAM for the spring sampling event (**Table 1-1**).

At each well (sampling station) the depth to groundwater and the depth to bottom of the well were measured, the well was purged appropriately, and field parameters were measured (pH, water temperature, and conductivity). Groundwater samples were collected following purging and were analysed for general groundwater quality chemistry (major anions/cations and physical parameters), and dissolved metals at an accredited laboratory. At the request of AAM, mercury and total metals were not analyzed as part of the spring 2015 monitoring event. A detailed description of the sampling methodology is provided in **Section 2**, below.

## Sample Sites

Groundwater sampling during the spring sampling event targeted 84 groundwater wells across 14 different areas of the FMC (**Table 1-1**). 77 of the 84 wells identified for the spring event were successfully sampled. The majority of spring sample sites were located in the Faro Mine Area (64 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; **Figures 1-2** and **1-3**), with additional wells in the surrounding areas. Wells in the Vangorda/Grum Area were primarily located south east of the Grum Sulphide Cell (**Figure 1-4**). **Table 1-1** summarizes the targeted wells 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 the 2015 Spring Program

| **Area** | **Well Name** | **UTM (Zone 8N)** | **Well Status** | **Sample Successfully Collected** | **QA/QC Sample Collected** |
| --- | --- | --- | --- | --- | --- |
| **Easting** | **Northing** |
| Cross Valley Dam (CVD) | P01-11 | 580093 | 6914486 | Good |  |  |
| P05-01-03 | 580407 | 6914119 | Good |  |  |
| P05-01-05 | 580056 | 6914508 | Good |  |  |
| P09-C2 | 580014 | 6914400 | Good |  |  |
| P09-C3 | 579973 | 6914319 | Good |  |  |
| Down Gradient of CVD | P01-01A | 579701 | 6914854 | Good |  |  |
| P01-01B | 579701 | 6914854 | Good |  |  |
| Emergency Tailings Area (ETA) | P09-ETA-2 | 583222 | 6914073 | Good |  |  |
| P96-8A | 583222 | 6914073 | Good |  |  |
| P96-8B | 582699 | 6913811 | Good |  |  |
| Haul Road Near NFRC | MW14-02D | 584758 | 6913127 | Good |  | Duplicate |
| MW14-02S | 584758 | 6913127 | Good |  |  |
| MW14-03 | 584613 | 6913290 | Good |  |  |
| MW14-04S | 584658 | 6913321 | Good |  |  |
| MW14-04D | 584648 | 6913321 | Blocked |  |  |
| MW14-05 | 584694 | 6913345 | Good |  |  |
| PW14-01 | 584752 | 6913151 | Good |  |  |
| PW14-06 | 584476 | 6913310 | Good |  |  |
| PW14-07 | 584690 | 6913192 | Good |  |  |
| Intermediate Dam | P01-03 | 580516 | 6914255 | Frozen |  |  |
| P01-04A | 580372 | 6914074 | Frozen |  |  |
| P01-04B | 580544 | 6914298 | Frozen |  |  |
| X24-96D | 580544 | 6914298 | Slow recharge |  |  |
| X25-96A | 580407 | 6914119 | Good |  | Duplicate |
| X25-96B | 580544 | 6914298 | Good |  |  |
| Intermediate Dump | P96-6 | 584900 | 6913312 | Good |  |  |
| Main Dump | SRK08-P9 | 583688 | 6913622 | Good |  |  |
| Mill Area | SRK08-10A | 582719 | 6914051 | Good |  |  |
| SRK08-11A | 582582 | 6914571 | Good |  | Duplicate & Field Blank |
| SRK08-11B | 582585 | 6914572 | Good |  |  |
| NFRC Rock Drain Pond | MW14-12D | 584858 | 6913264 | Good |  |  |
| MW14-12S | 584858 | 6913264 | Frozen |  |  |
| MW14-13 | 584921 | 6913285 | Good |  | Duplicate |
| MW14-14 | 584821 | 6913250 | Good |  |  |
| MW14-15 | 584831 | 6913263 | Good |  |  |
| MW14-16 | 584887 | 6913289 | Good |  |  |
| Northeast Dumps | BH13B | 585746 | 6914494 | Good |  |  |
| BH14A | 585584 | 6914005 | Good |  |  |
| BH14B | 585584 | 6914005 | Good |  |  |
| Second Impoundment | P03-06-1 | 582452 | 6913496 | Good |  |  |
| P03-06-2 | 582452 | 6913496 | Good |  |  |
| P03-06-6 | 582452 | 6913496 | Slow recharge |  |  |
| P03-06-7 | 582452 | 6913496 | Dry |  |  |
| S-Wells Area | P09-SIS1 | 584479 | 6913127 | Good |  |  |
| P09-SIS2 | 584485 | 6913122 | Good |  | Field Blank |
| P09-SIS3 | 584495 | 6913121 | Good |  |  |
| P09-SIS4 | 584508 | 6913112 | Good |  |  |
| P09-SIS5 | 584515 | 6913108 | Good |  |  |
| P96-7 | 584123 | 6913285 | Good |  |  |
| S1A | 584433 | 6913114 | Good |  |  |
| S1B | 584433 | 6913114 | Good |  |  |
| S2A | 584470 | 6913117 | Good |  |  |
| S2B | 584470 | 6913117 | Good |  |  |
| SRK05-SP-4A | 584503 | 6913117 | Good |  | Duplicate & Field Blank |
| SRK05-SP-4B | 584503 | 6913110 | Good |  |  |
| SRK05-SP-5 | 584468 | 6913129 | Good |  |  |
| SRK08-SP-7A | 584438 | 6913098 | Good |  |  |
| SRK08-SP-7B | 584439 | 6913099 | Good |  |  |
| SRK08-SP-8A | 584294 | 6912953 | Good |  |  |
| SRK08-SP-8B | 584292 | 6912952 | Good |  |  |
| NFRC Near S-Wells Area | MW14-08 | 584701 | 6913035 | Good |  |  |
| MW14-09 | 584691 | 6913044 | Frozen |  |  |
| MW14-10 | 584679 | 6913040 | Good |  |  |
| MW14-11 | 584677 | 6913028 | Good |  | Duplicate & Field Blank |
| Vangorda/Grum | BH05-9B-R | 592640 | 6903347 | Good |  |  |
| P09-GS1A | 592494 | 6904829 | Good |  |  |
| P09-GS1B | 592486 | 6904832 | Good |  |  |
| P09-LCD1 | 593358 | 6903313 | Good |  |  |
| P09-LCD4 | 593327 | 6903272 | Slow recharge |  |  |
| P09-LCD6 | 593313 | 6903252 | Good |  | Duplicate |
| P09-VC1 | 593520 | 6903419 | Good |  |  |
| P09-VC2 | 593515 | 6903432 | Good |  |  |
| P2001-02A | 593132 | 6902864 | Slow recharge |  |  |
| P2001-02B | 593132 | 6902864 | Good |  |  |
| P2001-3 | 593095 | 6902880 | Good |  |  |
| P96-9A | 592647 | 6903345 | Good |  |  |
| SRK05-07 | 592371 | 6903187 | Good |  |  |
| SRK05-08 | 592583 | 6903238 | Good |  | Duplicate |
| SRK05-5C | 592766 | 6903382 | Good |  |  |
| SRK05-9 | 592951 | 6903165 | Good |  |  |
| V34 | 593428 | 6902474 | Slow recharge |  |  |
| V35 | 593177 | 6902553 | Slow recharge |  |  |
| V36 | 593133 | 6902916 | Good |  |  |
| V37 | 593311 | 6903081 | Slow recharge |  |  |

Figure 1-1 Site Location – Faro Mine Complex

Figure 1-2 Groundwater Sampling Locations – Faro Mine Area

Figure 1-3 Groundwater Sampling Locations – S-Wells Area

Figure 1-4 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* (Government of Yukon, 2002). The methods were also consistent with the ASTM *D4448-01 Standard Guide for Sampling Groundwater Monitoring Wells* (ASTM, 2013), the *D6452-99 Guide for Purging Methods for Wells used for Groundwater Quality Investigations* (ASTM, 2012) and in accordance with *Standard Methods for the Examination of Water and Wastewater* (Riceet al.,2012*)*.

## Well Measurements and Purging

Upon arriving at each location, 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).

DTW and DTB 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). In order of preference, DTW and DTB were measured from: 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 a measurement was taken from that line if no distinguishable measurement point 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 decontaminated between each sample site using a combination of Alconox low-foaming phosphate-free detergent solution and de-ionized water.

Following the initial checks and measurements described above, groundwater wells were purged and sampled using one of four (4) techniques: 1) Hydrolift electric pump using dedicated high density polyethelene (HDPE) Waterra tubing and footvalve, 2) Manual purging using dedicated HDPE Waterra tubing and footvalve, 3) GeoPump peristaltic pump using dedicated HDPE and silicone tubing, or 4) Grundfos Redi-Flo2 submersible pump using dedicated 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 groundwater equivalent to three standing well volumes of groundwater 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 was less than 50 NTU.

Purge volume measurements were collected 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 either an YSI Professional Plus multi-parameter meter or a Hanna 991300 field meter (used at certain wells after one of the program YSI Professional Plus meters malfunctioned). All field parameters were collected using a flow through cell in order to minimize field parameter variability. The required field parameters recorded at each sample site included: groundwater temperature (oC), conductivity (μs/cm), and pH (pH units). Where available, Hemmera/ELR also recorded specific conductivity (μs/cm), dissolved oxygen (mg/L), and oxidation-reduction potential (mv). 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 location, 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) | Dissolved Metals (except mercury) | Field Filtered and Preserved | HNO3 |
| 1 L (Plastic) | Acidity, alkalinity, chloride, conductivity, pH, hardness, sulfate, 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 3-1**.

## 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 HDPE tubing and Waterra footvalves, laboratory provided pre-cleaned sample bottles, disposable filters, and disposable syringes. The only exception to this was a Grundfos Redi-Flo2 submersible pump that was required to sample several deep wells in the spring program. Field staff wore dedicated disposable nitrile gloves for all measurements, purging, and sampling. Water level meters and the submersible pump were cleaned using Alconox low-foaming phosphate-free detergent and de-ionized water and between wells, and field instruments (Hanna/YSI field meters 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 all required measurements were taken, and that information was recorded correctly. Field data sheets have been included as **Appendix C** of this report.

### Laboratory and Sampling QA/QC

Laboratory and sampling QA/QC measures taken as part of the spring sampling program include the collection of travel blanks, duplicates, and field blanks, as outlined in the SOW and as per standard industry practice. Duplicate samples were collected at a ratio of 10% of the regular samples (8 duplicates were collected in relation to 77 sample sites). Additionally, four (4) field blanks were collected, and three (3) travel blanks accompanied the analytical supplies and samples during shipping to and from the laboratory.

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% indicates a greater variance than would normally be anticipated and may be due to a number of factors (e.g., short -term change in parameter concentration, sediment in the sample, sampling or instrument error, large relative % difference but very low actual difference in concentration, such as 0.0001 vs 0.0002 mg/L). 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. 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 **Table 3-2** and discussed in **Section 3.3**.

# Results

Summary tables of the laboratory analytical results are presented in **Table 3-1** 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 blanks, and travel blanks (**Table 3-2**). Laboratory analytical reports are provided as **Appendix A**.

## Groundwater Sampling Summary

The spring 2015 groundwater sampling was completed from June 11-15 and June 17-19, 2015. Weather conditions varied throughout the time of sampling with ambient air temperature ranging from 6 to 25°C. The weather conditions were varied and ranged from overcast with periods of precipitation to clear and sunny. All 84 groundwater wells specified for the spring sampling event were visited by Hemmera/ELR during the sampling event. Groundwater samples were successfully collected at 77 of the 84 sampling locations as outlined in **Table 1-1**. Five (5) wells were found frozen (P01-03, P01-04A, P01-04B, MW14-12S and MW14-12S), one (1) well was found dry (P03-06-7), and one well was blocked (MW14-04D). A summary of groundwater wells sampled during the 2015 spring sampling event, including field parameters and well measurements, is provided in **Table 3-3**. 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 2015 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 (pH Units)** | **Temperature (°C)** | **Conductivity****(µS/cm)** | **Field Specific Conductivity****(µS/cm)** | **Oxidation Reduction Potential (mv)** | **Field Turbidity (NTU)** | **Well Diameter (cm)** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Cross Valley Dam (CVD) | P01-11 | 11/06/2015 | 1.205 | 0.982 | 11.012 | 20.04 | 10.50 | 17:02 | 17:25 | 0:23 | 0.46 | PS | 0.000 | 6.78 | 4.60 | 2029.0 | 3534.0 | -48.8 | 26.30 | 5.08 |
| P05-01-033 | 11/06/2015 | 0.580 | 1.470 | 17.771 | 2.07 | 6.00 | 16:05 | 16:35 | 0:30 | 0.20 | PS | - | 6.56 | 4.80 | 2163.0 | 3524.0 | -30.9 | 0.93 | 1.3 |
| P05-01-053 | 11/06/2015 | 0.560 | 1.754 | 6.457 | 0.61 | 2.25 | 15:05 | 15:51 | 0:46 | 0.05 | PS | - | 6.63 | 5.30 | 2119.0 | 3350.0 | -39.2 | 0.03 | 1.3 |
| P09-C2 | 11/06/2015 | 0.890 | 0.653 | 64.000 | 126.70 | 35.00 | 14:10 | 14:40 | 0:30 | 1.17 | PS | 3.092 | 6.60 | 4.90 | 1649.0 | 2668.0 | -12.7 | 8.31 | 5.08 |
| P09-C3 | 10/06/2015 | 0.785 | 1.161 | 52.219 | 102.10 | 72.00 | 15:25 | 16:00 | 0:35 | 2.06 | PS | 0.129 | 6.60 | 3.90 | 871.0 | 1497.0 | -38.0 | 0.57 | 5.08 |
| Down Gradient of CVD | P01-01A4 | 11/06/2015 | 0.580 | 3.624 | 20.283 | 33.36 | 53.00 | 16:45 | 16:54 | 0:09 | 5.89 | PS | - | NR | NR | 1105.0 | NR | 223.2 | 1.29 | 5.08 |
| P01-01B1 | 11/06/2015 | NR | 3.787 | 35.215 | 65.00 | 129.00 | 17:13 | 17:43 | 0:30 | 4.30 | 3WV | 0.093 | NR | NR | 875.0 | NR | 37.0 | 1.02 | 5.08 |
| Emergency Tailings Area (ETA) | P09-ETA-2 | 11/06/2015 | 0.740 | 5.833 | 18.533 | 25.40 | 82.00 | 11:37 | 12:31 | 0:54 | 1.52 | PS | 0.062 | 5.82 | 1.90 | 4795.0 | 8561.0 | -53.4 | 0.24 | 5.08 |
| P96-8A | 10/06/2015 | 0.700 | 2.253 | 4.973 | 5.25 | 5.50 | 16:28 | 16:56 | 0:28 | 0.20 | PS | 0.023 | 3.54 | 4.60 | 5973.0 | 9776.0 | 293.9 | 0.45 | 5.08 |
| P96-8B | 10/06/2015 | 0.610 | 2.200 | 9.426 | 14.50 | 15.00 | 17:07 | 17:59 | 0:52 | 0.29 | PS | 0.000 | 4.96 | 5.10 | 5843.0 | 9421.0 | 115.4 | 1.41 | 5.08 |
| Haul Road Near NFRC | MW14-02D | 17/06/2015 | 0.9 | 58.721 | 78.976 | 40.50 | 75.00 | 14:31 | 15:03 | 0:32 | 2.34 | PS | 3.721 | 5.85 | 5.00 | 316.7 | 589.8 | 41.6 | 11.47 | 5.08 |
| MW14-02S | 17/06/2015 | 0.9 | 58.271 | 67.000 | 76.90 | 90.00 | 15:51 | 16:20 | 0:29 | 3.10 | PS | 0.269 | 7.47 | 8.60 | 104.4 | 151.8 | 83.7 | 8.47 | 10.16 |
| MW14-03 | 18/06/2015 | 0.885 | 53.342 | 65.000 | 206.70 | 217.00 | 12:26 | 14:03 | 1:37 | 2.24 | PS | 5.927 | 7.26 | 11.40 | 631.0 | 855.0 | -37.7 | 11.30 | 15.24 |
| MW14-04S5 | 18/06/2015 | 0.910 | 60.241 | 62.700 | 8.00 | 8.00 | 17:30 | 18:12 | 0:42 | 0.19 | PS | - | 6.87 | 7.90 | 3125.0 | 4640.0 | 189.7 | 1136.00 | 10.16 |
| MW14-05 | 18/06/2015 | 0.860 | 53.541 | 66.500 | 229.70 | 180.00 | 14:44 | 15:28 | 0:44 | 4.09 | PS | 4.569 | 6.60 | 10.50 | 3400.0 | 4700.0 | -11.2 | 45.90 | 15.24 |
| PW14-01 | 17/06/2015 | 1.020 | 58.800 | 78.350 | 345.00 | 120.00 | 17:19 | 18:05 | 0:46 | 2.61 | PS | 1.045 | 6.03 | 3.60 | 455.3 | 763.1 | 32.9 | 4.34 | 10.16 |
| PW14-06 | 10/06/2015 | 1.030 | 47.556 | 63.600 | 126.00 | 125.00 | 11:40 | 13:46 | 2:06 | 0.99 | PS | 0.209 | 4.09 | 22.30 | 16749.0 | 17561.0 | 151.8 | 16.60 | 10.16 |
| PW14-07 | 19/06/2015 | 0.960 | 66.265 | 75.600 | 166.00 | 180.00 | 12:13 | 12:55 | 0:42 | 4.29 | PS | 0.095 | 5.68 | 3.40 | 545.0 | 924.0 | 78.3 | 2.63 | 10.16 |
| Intermediate Dam | X24-96D | 11/06/2015 | 0.842 | 2.621 | 28.589 | 51.90 | 54.00 | 10:48 | 11:48 | 1:00 | 0.90 | 1WV | 28.589 | 6.35 | 5.00 | 1822.0 | 2945.0 | 8.7 | 18.30 | 5.08 |
| X25-96A | 10/06/2015 | 0.608 | 2.059 | 9.460 | 14.80 | 15.00 | 12:27 | 13:04 | 0:37 | 0.41 | PS | 0.002 | 6.70 | 4.00 | 1080.0 | 1801.0 | -52.1 | 0.26 | 5.08 |
| X25-96B | 10/06/2015 | 0.600 | 1.940 | 19.886 | 35.89 | 10.00 | 13:26 | 13:51 | 0:25 | 0.40 | PS | 0.005 | 7.31 | 4.10 | 1092.0 | 1817.0 | -107.3 | 0.07 | 5.08 |
| Intermediate Dump | P96-6 | 14/06/2015 | 0.600 | 11.751 | 18.085 | 13.00 | 18.00 | 14:29 | 14:42 | 0:13 | 1.38 | PS | -0.003 | 6.52 | 1.90 | 713.0 | 1279.0 | 238.0 | 2.34 | 5.08 |
| Main Dump | SRK08-P9 | 11/06/2015 | 0.090 | 3.999 | 6.189 | 4.38 | 5.00 | 11:21 | 11:50 | 0:29 | 0.17 | PS | 0.487 | 7.05 | 2.00 | 887.0 | 1583.0 | 78.7 | 1.67 | 5.08 |
| Mill Area | SRK08-10A | 11/06/2015 | 0.710 | 10.862 | 13.740 | 6.00 | 15.00 | 10:26 | 10:38 | 0:12 | 1.25 | PS | 0.897 | 6.32 | 3.90 | 2380.0 | 3985.0 | 120.4 | 45.70 | 5.08 |
| SRK08-11A | 11/06/2015 | 0.640 | 1.220 | 12.448 | 24.00 | 25.00 | 9:27 | 9:40 | 0:13 | 1.92 | PS | 0.768 | 6.97 | 2.40 | 598.0 | 1052.0 | 86.1 | 3.55 | 5.08 |
| SRK08-11B | 11/06/2015 | 1.000 | 0.860 | 6.739 | 12.00 | 12.00 | 8:45 | 9:26 | 0:41 | 0.29 | PS | 0.020 | 6.66 | 2.10 | 600.0 | 1065.0 | 91.7 | 1.54 | 5.08 |
| NFRC Rock Drain Pond | MW14-12D | 14/06/2015 | 0.960 | 1.820 | 6.343 | 11.00 | 14.00 | 12:21 | 13:02 | 0:41 | 0.34 | PS | 0.033 | 6.13 | 2.10 | 317.4 | 563.0 | 227.6 | 2.53 | 5.08 |
| MW14-13 | 14/06/2015 | 0.963 | 3.169 | 5.019 | 4.00 | 5.10 | 10:52 | 11:18 | 0:26 | 0.20 | PS | 0.006 | 5.88 | 3.00 | 810.0 | 1401.0 | 250.2 | 2.01 | 5.08 |
| MW14-14 | 14/06/2015 | 0.925 | 1.504 | 3.518 | 1.00 | 1.00 | 15:40 | 15:50 | 0:10 | 0.10 | 1WV | 1.971 | 6.51 | 5.90 | 1525.0 | 1532.0 | 207.5 | 38.10 | 2.54 |
| MW14-15 | 14/06/2015 | 1.195 | 0.646 | 2.752 | 1.00 | 3.15 | 13:27 | 14:01 | 0:34 | 0.09 | PS | 0.376 | 6.72 | 3.50 | 586.0 | 988.0 | 199.1 | 46.00 | 2.54 |
| MW14-16 | 14/06/2015 | 0.978 | 4.800 | 6.895 | 4.00 | 5.20 | 11:38 | 12:05 | 0:27 | 0.19 | PS | 0.008 | 6.12 | 2.50 | 539.0 | 947.0 | 263.0 | 0.62 | 5.08 |
| Northeast Dumps | BH13B | 11/06/2015 | 0.750 | 2.557 | 4.404 | 3.70 | 4.00 | 12:52 | 13:19 | 0:27 | 0.15 | PS | 0.283 | 6.63 | 0.70 | 584.0 | 1090.0 | 110.5 | 0.98 | 5.08 |
| BH14A | 11/06/2015 | 0.045 | 3.857 | 6.449 | 5.20 | 5.00 | 13:53 | 14:23 | 0:30 | 0.17 | PS | 0.634 | 6.42 | 1.90 | 2453.0 | 4389.0 | 121.2 | 3.37 | 5.08 |
| BH14B | 11/06/2015 | 0.670 | 4.491 | 10.114 | 11.50 | 15.00 | 14:30 | 14:39 | 0:09 | 1.67 | PS | 5.169 | 6.78 | 2.70 | 2277.0 | 3959.0 | 110.2 | 32.80 | 5.08 |
| Second Impoundment | P03-06-13 | 10/06/2015 | 0.778 | 14.409 | 26.538 | 1.50 | 5.00 | 10:16 | 10:41 | 0:25 | 0.20 | 3WV | - | 4.60 | 5.40 | 3160.0 | 5021.0 | 153.2 | 1.52 | 1.3 |
| P03-06-23 | 15/06/2015 | 0.770 | 12.221 | 23.665 | 2.00 | 6.00 | 8:51 | 9:01 | 0:10 | 0.60 | 3WV | - | 5.30 | 4.10 | 589.0 | - | - | 1515.00 | 1.3 |
| P03-06-63 | 11/06/2015 | 0.900 | 12.424 | 13.611 | 0.15 | 0.55 | 9:53 | 10:00 | 0:07 | 0.08 | 3WV | - | 3.28 | 6.10 | 656.0 | 949.0 | 367.1 | 697.00 | 1.3 |
| S-Wells Area | P09-SIS12 | 14/06/2015 | 1.010 | 4.915 | 6.481 | 3.00 | 3.50 | 16:48 | 17:12 | 0:24 | 0.15 | PS | 0.910 | 7.21 | 4.20 | >3999 | - | - | 43.00 | 5.08 |
| P09-SIS22 | 14/06/2015 | 1.140 | 4.050 | 6.328 | 4.60 | 6.00 | 17:24 | 17:51 | 0:27 | 0.22 | PS | 0.050 | 5.55 | 4.20 | 6.5 | - | - | 0.74 | 5.08 |
| P09-SIS3 | 14/06/2015 | 1.036 | 3.994 | 4.628 | 1.00 | 2.60 | 16:52 | 17:08 | 0:16 | 0.16 | PS | 0.031 | 5.87 | 3.00 | 6380.0 | 11028.0 | 321.7 | 0.87 | 5.08 |
| P09-SIS42 | 15/06/2015 | 0.970 | 4.163 | 4.448 | 0.60 | 1.15 | 10:26 | 10:40 | 0:14 | 0.08 | 2WV | 0.262 | 6.22 | 3.40 | >3999 | - | - | 29.00 | 5.08 |
| P09-SIS52 | 15/06/2015 | 1.140 | 3.822 | 4.605 | 1.50 | 1.80 | 9:49 | 10:09 | 0:20 | 0.09 | 1WV | 0.578 | 6.45 | 4.30 | >3999 | - | - | 56.90 | 5.08 |
| P96-72 | 14/06/2015 | 0.760 | 6.645 | 9.877 | 6.40 | 6.00 | 8:28 | 9:04 | 0:36 | 0.17 | PS | 0.173 | 7.22 | 1.20 | 2835.0 | - | - | 0.45 | 5.08 |
| S1A2 | 13/06/2015 | 1.340 | 4.720 | 12.720 | 16.00 | 20.00 | 16:04 | 16:14 | 0:10 | 2.00 | PS | 0.020 | 7.21 | 2.00 | 1633.0 | - | - | 9.20 | 5.08 |
| S1B2 | 15/06/2015 | 1.160 | 4.566 | 5.175 | 1.20 | 1.30 | 14:39 | 14:46 | 0:07 | 0.19 | 1WV | 0.479 | 6.69 | 7.70 | 936.0 | - | - | 13.70 | 5.08 |
| S2A2 | 14/06/2015 | 1.230 | 5.210 | 12.710 | 15.00 | 45.00 | 15:12 | 15:33 | 0:21 | 2.14 | 3WV | 5.200 | 6.01 | 2.50 | 1701.0 | - | - | 70.50 | 5.08 |
| S2B2 | 14/06/2015 | 0.515 | 4.468 | 7.065 | 5.20 | 7.00 | 16:06 | 16:39 | 0:33 | 0.21 | PS | 1.552 | 5.91 | 3.00 | >3999 | - | - | 27.80 | 5.08 |
| SRK05-SP-4A2 | 13/06/2015 | 0.690 | 4.636 | 22.401 | 36.00 | 40.00 | 2:21 | 2:36 | 0:15 | 2.67 | PS | 0.355 | 5.81 | 4.99 | 1288.0 | - | - | 8.35 | 5.08 |
| SRK05-SP-4B | 14/06/2015 | 0.798 | 4.124 | 4.730 | 1.20 | 2.25 | 17:25 | 17:44 | 0:19 | 0.12 | 2WV | 0.312 | 6.10 | 2.10 | 4846.0 | 8593.0 | 76.0 | 3.48 | 5.08 |
| SRK05-SP-52 | 13/06/2015 | 1.000 | 6.857 | 14.582 | 16.00 | 48.00 | 15:03 | 15:23 | 0:20 | 2.40 | 3WV | 0.053 | 5.97 | 2.80 | 487.0 | - | - | 43.60 | 5.08 |
| SRK08-SP-7A2 | 13/06/2015 | NR | 2.630 | 17.728 | 30.00 | 32.00 | 15:35 | 15:45 | 0:10 | 3.20 | PS | 0.510 | 7.21 | 3.14 | 762.0 | - | - | 31.00 | 5.08 |
| SRK08-SP-7B2 | 14/06/2015 | 1.090 | 2.738 | 8.725 | 12.00 | 12.00 | 13:46 | 14:28 | 0:42 | 0.29 | PS | 0.003 | 6.28 | 2.40 | 265.0 | - | - | 6.56 | 5.08 |
| SRK08-SP-8A2 | 14/06/2015 | 1.190 | 1.951 | 8.520 | 12.00 | 18.00 | 9:35 | 9:44 | 0:09 | 2.00 | PS | 0.012 | 6.12 | 1.96 | 2141.0 | - | - | 95.00 | 5.08 |
| SRK08-SP-8B2 | 14/06/2015 | 1.030 | 1.924 | 7.035 | 10.00 | 19.00 | 9:49 | 9:56 | 0:07 | 2.71 | PS | 0.011 | 6.14 | 0.50 | 2170.0 | - | - | 61.10 | 5.08 |
| NFRC Near S-Wells Area | MW14-082 | 14/06/2015 | 1.002 | 1.396 | 2.190 | 1.59 | 4.80 | 11:36 | 13:06 | 1:30 | 0.16 | 3WV | 0.757 | 7.01 | 3.10 | 657.0 | - | - | 57.30 | 5.08 |
| MW14-102 | 14/06/2015 | 0.735 | 3.485 | 5.540 | 4.00 | 5.00 | 11:59 | 12:23 | 0:24 | 0.21 | PS | 0.340 | 7.11 | 2.00 | 938.0 | - | - | 9.19 | 5.08 |
| MW14-112 | 14/06/2015 | 0.725 | 1.915 | 4.430 | 5.00 | 5.00 | 10:43 | 11:07 | 0:24 | 0.21 | PS | 0.830 | 6.60 | 2.40 | 614.0 | - | - | 5.21 | 5.08 |
| Vangorda/Grum | BH05-9B-R | 12/06/2015 | 0.915 | 0.020 | 19.854 | 40.00 | 56.00 | 11:50 | 12:06 | 0:16 | 3.50 | PS | 8.015 | 8.05 | 3.20 | 362.7 | 621.0 | -97.6 | 725.00 | 5.08 |
| P09-GS1A2 | 13/06/2015 | 1.385 | 2.345 | 7.390 | 10.00 | 10.00 | 9:08 | 9:54 | 0:46 | 0.22 | PS | 0.010 | 6.91 | 4.30 | 1613.0 | - | - | 0.02 | 5.08 |
| P09-GS1B2 | 13/06/2015 | 0.965 | 2.088 | 29.555 | 53.00 | 60.00 | 9:05 | 9:35 | 0:30 | 2.00 | PS | 13.832 | 6.93 | 4.30 | 1552.0 | - | - | 9.69 | 5.08 |
| P09-LCD1 | 13/06/2015 | 0.930 | 3.756 | 7.407 | 8.00 | 9.00 | 14:59 | 15:24 | 0:25 | 0.36 | PS | 0.040 | 7.37 | 3.40 | 575.0 | 981.0 | -99.1 | 71.27 | 5.08 |
| P09-LCD4 | 14/06/2015 | 0.970 | 1.594 | 12.283 | 21.40 | 22.00 | 13:56 | 14:30 | 0:34 | 0.65 | 1WV | 8.851 | 8.10 | 6.80 | 981.0 | - | - | 95.00 | 5.08 |
| P09-LCD6 | 13/06/2015 | 0.690 | 5.842 | 7.960 | 4.00 | 5.20 | 14:01 | 14:21 | 0:20 | 0.26 | PS | 0.066 | 7.39 | 4.00 | 618.0 | 1032.0 | -119.3 | 2.97 | 5.08 |
| P09-VC1 | 12/06/2015 | 0.100 | 3.816 | 67.973 | 128.00 | 135.00 | 16:19 | 17:00 | 0:41 | 3.29 | PS | 11.294 | 8.46 | 3.80 | 215.6 | 362.5 | -165.2 | 20.70 | 5.08 |
| P09-VC2 | 12/06/2015 | 0.864 | 1.500 | 19.375 | 36.00 | 50.00 | 15:35 | 16:01 | 0:26 | 1.92 | PS | 0.982 | 7.65 | 3.80 | 224.2 | 377.7 | -86.5 | 826.00 | 5.08 |
| P2001-02A | 14/06/2015 | 0.640 | 4.298 | 6.353 | 4.10 | 4.95 | 11:12 | 11:52 | 0:40 | 0.12 | 1WV | 1.632 | 7.00 | 4.70 | 1958.0 | 3219.0 | -15.0 | 21.10 | 5.08 |
| P2001-02B2 | 14/06/2015 | 0.420 | 4.130 | 27.560 | 46.90 | 100.00 | 11:13 | NR | NR | NR | 2WV | 23.430 | 7.40 | 4.90 | 3960.0 | - | - | 11.60 | 5.08 |
| P2001-3 | 13/06/2015 | 0.755 | 37.224 | 62.165 | 49.88 | 160.00 | 9:17 | 10:12 | 0:55 | 2.91 | 3WV | - | 7.50 | 3.00 | 565.0 | 972.0 | 121.3 | 39.90 | 5.08 |
| P96-9A | 12/06/2015 | 0.954 | 5.623 | 9.400 | 8.00 | 14.00 | 12:15 | 12:24 | 0:09 | 1.56 | PS | 1.032 | 6.97 | 1.40 | 1467.0 | 2674.0 | 140.8 | 8.83 | 5.08 |
| SRK05-07 | 12/06/2015 | 0.670 | 4.688 | 6.526 | 4.00 | 4.20 | 9:00 | 9:35 | 0:35 | 0.12 | PS | 0.748 | 7.07 | 3.80 | 1849.0 | 3104.0 | 211.8 | 2.06 | 5.08 |
| SRK05-08 | 12/06/2015 | NR | 5.521 | 8.500 | 6.00 | 6.05 | 10:15 | 11:10 | 0:55 | 0.11 | PS | 0.313 | 7.10 | 4.90 | 1534.0 | 2482.0 | 222.8 | 1.50 | 5.08 |
| SRK05-5C | 12/06/2015 | 0.960 | 1.465 | 3.718 | 2.48 | 4.90 | 13:28 | 13:58 | 0:30 | 0.16 | PS | 0.200 | 7.86 | 5.20 | 460.7 | 745.0 | -73.9 | 3.36 | 3.81 |
| SRK05-9 | 12/06/2015 | 0.560 | 2.703 | 3.962 | 2.00 | 6.50 | 14:42 | 15:02 | 0:20 | 0.33 | 3WV | -0.775 | 7.43 | 2.00 | 737.0 | 1439.0 | 202.9 | 11.78 | 3.81 |
| V34 | 13/06/2015 | 0.547 | 5.851 | 12.331 | 14.00 | 14.50 | 16:02 | 16:28 | 0:26 | 0.56 | 1WV | 2.304 | 7.21 | 4.40 | 1337.0 | 2203.0 | 44.3 | 13.06 | 5.08 |
| V35 | 13/06/2015 | 0.490 | 8.311 | 16.021 | 16.00 | 16.00 | 16:40 | 16:58 | 0:18 | 0.89 | 1WV | 2.539 | 7.37 | 7.10 | 2416.0 | 3671.0 | 162.9 | 4.13 | 5.08 |
| V366 | 13/06/2015 | 0.498 | 8.716 | 11.745 | 6.00 | 8.00 | 9:32 | 10:05 | 0:33 | 0.24 | PS | 0.076 | 7.10 | 3.20 | 1719.0 | 2943.0 | 134.0 | 4.87 | 5.08 |
| V372 | 13/06/2015 | 0.480 | 8.686 | 14.500 | 12.00 | 18.00 | 17:23 | 17:39 | 0:16 | 1.125 | 1WV | 14.500 | 7.30 | 4.70 | 1344.0 | - | - | 26.40 | 5.08 |

**Notes:**

NR = Not recorded in the field

‘-‘ = Not Applicable.

1 Field pH, temperature, and specific conductivity were not measured at sample site P01-01B due to malfunctioning equipment sensors.

2 Field specific conductivity and oxygen reduction potential were not measured at locations where the Hanna 991300 field meter was used.

3Drawdown could not be measured at this sample site due to the narrow well diameter.

4Drawdown could not be measured at this sample site due to an ice blockage in the well casing. YSI Professional Plus meter malfunctioned at this well and therefore reliable specific conductivity, temperature, and pH readings were not recorded.

5Drawdown could not be measured due to excessive friction with moving Waterra tubing.

6V35 had been purged dry and allowed to recharge. Despite the noted elevated temperature, the other field parameters are considered to be the best available considering the purge method.

## Analytical Results

Analytical results, including a brief summary of CCME FAL guideline exceedances and factors which may have influenced data precision, are provided below. In some instances the laboratory detection limits (DL) exceeded applicable CCME FAL standards (values shaded in light grey in **Table 3-1**). This occurs when samples with high levels of some elements or compounds require dilution in order for the lab to properly analyse the sample. Accordingly, the laboratory detection limit must then be increased. For the purpose of this report, samples where the reported DL is greater 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 either June 10 or 11, 2015. Samples were obtained from all seven (7) 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 the Cross Valley Dam area.

One of the CVD wells (P09-C2) had been damaged and the well was repaired. A new monument was installed (using cement), and 1 m of 2” PVC pipe and a PVC coupler were used to extend the well casing from the break in the pipe. A J-Plug was used to cap the well.

The other 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 less than 50 NTU.

### Down Gradient of Cross Valley Dam

Groundwater wells located down gradient of the CVD area were sampled on June 11, 2015. 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 one of the two wells.

Drawdown in one well (P01-01A) could not be monitored during purging due to the build-up of ice in the well that blocked the passage of the tape.

Field water quality meter error messages were noted at both wells (P01-01A and P01-01B), potentially due to the cold temperatures and condensation. Field temperature, specific conductivity and pH readings could not be collected during groundwater purging or sampling at well P01-01A and P01-01B due to the malfunctioning of the field meter (which was replaced shortly thereafter).

Groundwater turbidity in both samples within this area was less than 50 NTU.

### ETA

Groundwater wells located in the ETA Area were sampled on June 10 and 11, 2015. Samples were obtained from all three (3) wells in this area identified for the sampling event.

Field groundwater pH in the ETA area was not in compliance with CCME FAL guidelines in all three samples (ranging from 3.54 to 5.82).

Concentrations of dissolved aluminum, arsenic, cadmium, copper, iron, lead, nickel, uranium and zinc in water exceeded the CCME FAL guidelines in the ETA. Field and laboratory pH were below the CCME FAL guideline range for all sites in this area.

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

### Haul Road near NFRC

Groundwater wells located within the Haul Road area (near NFRC) were sampled on June 10, 17, 18, and 19 June 2015. Samples were obtained from eight (8) of the nine (9) wells within this area identified for the sampling event.

Concentrations of aluminum, arsenic, cadmium, iron, lead, nickel, thallium, uranium and zinc in water exceeded the CCME FAL guideline values in this area. Field and lab pH were also below the CCME FAL guideline range at more than one well in this area.

Groundwater turbidity was very high in one well (MW14-04S) at 1,136 NTU. The samples collected from the other wells in the area were all less than 50 NTU.

Well MW14-04D became blocked during the sampling process when a bailers became lodged with what is believed to be a previous bailer down the well. Efforts were made to free the bailer during the sampling visit, but were unsuccessful. Hemmera/ELR will be attempting again to clear the well during the next site visit.

### Intermediate Dam

Groundwater wells located within the intermediate dam area were sampled on June 10 and 11, 2015. Samples were obtained from three (3) of the six (6) wells within this area identified for the sampling event. Three (3) wells (P01-03 and P01-04A, and P01-04B) were frozen during the time of sampling.

Field pH was below the CCME FAL guideline range at one of the three (3) wells.

Concentrations of dissolved, aluminum, cadmium, iron, nickel and zinc in water exceeded the CCME FAL guidelines in at least one of the three 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 less than 50 NTU.

### Intermediate Dump

Only one (1) groundwater well located within the intermediate dump area was included in the spring 2015 sampling event (well P96-6), which was sampled on June 14, 2014.

Concentrations of dissolved selenium, uranium, and zinc in water exceeded the CCME FAL guidelines in this well.

The turbidity of groundwater from well P96-6 at the time of sampling was 2.34 NTU.

### Main Dump

One (1) groundwater well located within the main dump area was included in the spring sampling event (SRK08-P9), which was sampled on June 11, 2015.

Concentrations of dissolved selenium in water exceeded the CCME FAL guidelines in this well.

Hemmera/ELR staff found that the PVC stick-up of well SRK08-P9 was broken close to ground level with no metal casing protecting the well stick-up. A basic wooden frame was present over the well. The turbidity of groundwater from well SRK08-P9 at the time of sampling was 1.67 NTU.

### Mill Area

Three (3) groundwater wells located in the mill area were sampled on June 11, 2015.

Concentrations of dissolved aluminum, cadmium, uranium, and zinc in water exceeded the CCME FAL guidelines in samples collected within the mill area.

Field pH was below the CCME-FAL guideline range at one (1) of the three (3) sampled wells. The turbidity of the groundwater samples collected from the three (3) wells was less than 50 NTU.

### NFRC Rock Drain Pond

Five (5) of the six (6) groundwater wells in the Rock Drain Pond Area were sampled on June 14 and 15, 2015. One (1) well (MW14-12S) was found to be frozen and was not sampled.

Field and laboratory pH were below the CCME FAL guideline range at three (3) of the five (5) samples collected within the rock drain pond area. Concentrations of aluminum, cadmium, and zinc in water exceeded the CCME FAL guideline values in samples collected within the rock drain pond area.

The turbidity of all the groundwater samples collected within the rock drain pond area was less than 50 NTU.

### Northeast Dumps

All three (3) groundwater wells located in the northeast dumps area were sampled on June 11, 2015.

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

Field pH was below the CCME FAL guideline range at one (1) of the three (3) sampled wells.

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 between June 10 and 15, 2015. Samples were obtained from three (3) of the four (4) wells in this area identified for the sampling event. Well P03-06-7 was dry at the time of sampling.

Field and laboratory pH in the second impoundment area was less than the CCME FAL guideline range at all three (3) wells.

Concentrations of dissolved aluminum, arsenic, cadmium, copper, iron, lead, nickel, and zinc in water exceeded the CCME FAL guidelines in samples collected from the second impoundment area.

The well casings were too narrow to measure drawdown during the purging process.

Groundwater samples collected from two of the three wells in the second impoundment area were extremely turbid, with values ranging from 697 NTU to 1,515 NTU.

### S-Wells Area

Groundwater wells located in the S-Wells area were sampled between June 13 and June 15, 2015. Samples were obtained from all seventeen (17) wells in the area identified for the sampling event.

Concentrations of dissolved aluminum, cadmium, copper, iron, nickel, uranium, and zinc in water exceeded the CCME FAL guidelines in samples collected from the S-Wells area. Additionally, field and/or lab pH was below the CCME FAL guideline range at 14 of the wells from the S-Wells area.

The stick-up of well S2A is crooked and the coupler, which is about one metre below the top of the casing, is cracked and requires replacement.

Wells P09-SIS1 and SRK08-SP-7A did not have PVC well caps or J-plugs because of the presence of a transducer support cable.

Wells SRK05-SP-4A and SRK05-SP-5 were both found broken at ground level although samples were obtained.

Groundwater turbidity of five (5) samples within the S-Wells area was greater than 50 NTU.

### NFRC near S-Wells Area

Three (3) of the four (4) targeted wells in this area were sampled June 14, 2015. One (1) well was found to be frozen (ME14-09).

Concentrations of dissolved arsenic, iron, selenium exceeded the CCME FAL guidelines in samples collected from the NFRC near S-Wells Area.

The water sample from MW14-08 was collected from water that was above an ice plug in the well and therefore maynot be representative of the groundwater quality.

Sample turbidity in one (1) of the three (3) sampled wells (MW14-08) was greater than 50 NTU (57.30).

### Groundwater Vangorda/Grum

Groundwater wells located in the Vangorda/Grum area were sampled between June 12 and June 14, 2015. Samples were obtained from all 20 wells in this area identified for the sampling event.

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

A J-plug was installed on well V37. Groundwater turbidity of all but four (4) of the twenty (20) collected samples within the Vangorda/Grum area was less than 50 NTU. Well V35 was purged dry and allowed to recharge prior to sampling. In-situ temperature measured at the time of sampling was noted to be higher than expected (7.1 ⁰C). The field meter was working properly at the time of sampling and there was groundwater recharge, therefore the other in-situ parameter readings are considered to be the most representative available given the purging method.

Well P09-GS1A appears to have been heaved approximately 0.2 m above grade. Two feet of 6" PVC pipe was placed over the well with a 6” slip cap fitted on top to protect the well. The well stick up cover was removed.

Sediment was noted in the bottom of P09-LCD4. Bentonite was noted in well P2001-02B and debris has sloughed into the well. The top 0.94 m of PVC casing at well P09-VC2 was detached but the well was sampled.

## Quality Assurance and Quality Control Results

A total of eight (8) duplicate groundwater samples were collected during the spring sampling event. Three (3) travel blanks provided by the laboratory accompanied the samples throughout the sampling program. Four (4) field blanks were prepared on-site on between June 11 and 14, 2015. Detailed results of QA/QC sampling program are provided in **Table 3-2**, including RPD values for all the collected duplicate and sample pairs.

Travel blank analytical results were reported below detection limits for all analysed parameters, indicating that there was no evidence of contamination during the transportation process. Analytical results for field blanks FB-1, FB-2, and FB-4 were also reported below detection limits for all analyzed parameters. Aluminum (0.002 mg/L) and zirconium (0.00081) were detected in field blank FB-3, indicating very slight environmental influence introduced from the air or from the samplers. The level of influence detected amongst the four field blanks is considered to be acceptable and does not represent any type of systematic contamination issue.

All RPD values for duplicate samples were within an acceptable range of variability (below 20%), with the exception of the following results:

* TSS in MW14-11 (RPD 47.7%)
* TSS in P09-LCD6 (RPD 20.5%)
* TSS in SRK08-11A (RPD 28.6%)
* Acidity in MW14-02D (RPD 21.7%)
* Acidity in MW14-13 (RPD 38.2%)
* Lead in MW14-02D (RPD 37%)
* Sulfate in SRK05-SP-4A (RPD 68.3%)
* Sulfate P09-LCD6 (RPD 35.6%)

TSS is expected to have more variability than other parameters; the TSS concentrations in in all the samples with a high RPD are considered to represent a valid range of values for a solution of suspended, rather than dissolved constituents.

The RPDs greater than 20% for acidity indicate a sampling or analytical bias. Sample variation is considered to be caused by variable results 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).

The RPDs greater than 20% for both lead and sulfate indicate a sampling or analytical bias. The RPD for other lead and sulfate QA/QC samples was within 20%, thus there does not seem to be a systemic bias. The dissolved lead concentrations are already very small concentrations (e.g., 0.000262 ml/L) and therefore small variations in these low values can produce a high RPD. In the case of sample MW14-02D the duplicate lead analytical result was only marginally greater than 5 times the detection limit for that sample (0.000262 mg/L compared to 0.0020 mg/L).

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 of replicate samples. In some cases RPD was not available due to result(s) being less than detection limit. All replicate samples, where RPD calculations were available, were within the allowable limits specified by the laboratory. All measures against laboratory 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 2015 groundwater sampling program.

1. Damaged or degraded wells should be repaired. This includes wells where well stick-up is above the height of the well monument or where the PVC casing has been damaged above ground level and a well repair is possible. Wells that are unable to close properly or are cracked or broken are at risk of contamination. Damaged or degraded wells observed during the spring sampling event include: SRK08-P9, P09-VC2, SRK05-SP-4A, SRK05-SP-5, and S2A.
2. Attempts should be made to retrieve the bailers that are in the well MW14-04D. The well logs should be reviewed to help inform the best retrieval method to use.

# 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

ASTM Standard D4448-01. 2013. Standard Guide for Sampling Groundwater Monitoring Wells. ASTM International, West Conshohocken, PA, 2013, [www.astm.org](http://www.astm.org/).

ASTM Standard D6452-99 2012 Guide for Purging Methods for Wells used for Groundwater Quality investigations. ASTM International, West Conshohocken, PA, 2012, [www.astm.org](http://www.astm.org/).

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

Rice, E.W., Baird, R.B., Eaton, A.D., and Clesceri, L.S. 2006. Standard Methods for the Examination of Water and Wastewater. 22nd Edition. American Water Works Association.

Government of Yukon. 2002. Environment Act O.I.C. 2002/171 Contaminated Sites Regulation.

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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.

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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.

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TABLES

Appendix A

Laboratory Reports

Appendix B

Site Photos

Appendix C

Field Forms

Appendix D

Response to Comments from Draft Report Version

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