PHASE 2 INITIAL BOREHOLE DRILLING AND TESTING AT IG_BH04/05/06, IGNACE AREA

WP07 Data Report - Opportunistic Groundwater Sampling for IG_BH05

APM-REP-01332-0357 October 2023

WSP Canada Inc.

NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

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REPORT

Phase 2 Initial Borehole Drilling and Testing at IG_BH04/05/06, Ignace Area

WP07 Data Report - Opportunistic Groundwater Sampling for IG_BH05

Submitted to:

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OPPORTUNISTIC GROUNDWATER SAMPLING FOR IG_BH05

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1.0 INTRODUCTION

The Phase 2 Initial Borehole Drilling and Testing at IG_BH04/05/06 project in the Wabigoon Lake Ojibway Nation (WLON) – Ignace area of Ontario, is part of the Phase 2 Geoscientific Preliminary Field Investigations of the Nuclear Waste Management Organization's (NWMO) Adaptive Phased Management (APM) Site Selection Phase.

This project involves testing of deep borehole IG_BH04 and the drilling and testing of deep boreholes IG_BH05 and IG_BH06 in the Revell site within the identified Potential Repository Area (PRA). The work comprised of a total of eleven work packages and was carried out by a team led by Golder Associates Ltd. (now WSP Canada Inc.) on behalf of the NWMO. The IG_BH05 program is described in a Borehole Characterization Plan (BCP) for IG_BH05.

This report describes the methodology, activities and results for Work Package 7 (WP07): Opportunistic Groundwater Sampling for IG_BH05, which includes identification of permeable intervals during drilling (WP02 and WP03) and hydraulic testing (WP06), collection and in-field analysis, and laboratory analysis of samples. This report also describes the analysis of the fresh water collected as part of Work Package 2 (WP02): Borehole Drilling and Flushing for IG_BH05. IG_BH05 is an inclined borehole, all depths referred to in this report are in meters below ground surface along the length of the borehole (mbgs along hole), rather than true vertical depth.

2.0 BACKGROUND INFORMATION

2.1 Geological Setting

The approximately 2.7 billion year old Revell batholith is located in the western part of the Wabigoon Subprovince of the Archean Superior Province. The batholith is roughly elliptical in shape trending northwest, is approximately 40 km in length, 15 km in width, and covers an area of approximately 455 km^2. Based on geophysical modelling, the batholith is approximately 2 km to 3 km thick through the center of the northern portion (SGL 2015). The batholith is surrounded by supracrustal rocks of the Raleigh Lake (to the north and east) and Bending Lake (to the southwest) greenstone belt (Figure 1).

IG_BH05 is located within an investigation area of approximately 19 km^2 in size, situated in the northern portion of the Revell batholith. Bedrock exposure in the area is generally very good due to minimal overburden, few water bodies, and relatively recent logging activities. Ground elevations generally range from 400 to 450 m above sea level. The ground surface broadly slopes towards the northwest as indicated by the flow direction of the main rivers in the area. Local water courses tend to flow to the southwest towards Mennin Lake (Figure 2).

Four main rock units are identified in the supracrustal rock group: mafic metavolcanic rocks, intermediate to felsic metavolcanic rocks, metasedimentary rocks, and mafic intrusive rocks (Figure 1). Sedimentation within the supracrustal rock assemblage was largely synvolcanic, although sediment deposition in the Bending Lake area may have continued past the volcanic period (Stone 2009; Stone 2010a; Stone 2010b). All supracrustal rocks are affected, to varying degrees, by penetrative brittle-ductile to ductile deformation under greenschist- to amphibolite-facies metamorphic conditions (Blackburn and Hinz 1996; Stone et al. 1998). In some locations, primary features, such as pillow basalt or bedding in sedimentary rocks are preserved, in other locations, primary relationships are completely masked by penetrative deformation. Uranium-lead (U-Pb) geochronological analysis of the supracrustal rocks produced ages that range between 2734.6 +/-1.1 Ma and 2725 +/-5 Ma (Stone et al. 2010).

Three main suites of plutonic rock are recognized in the Revell batholith, including, from oldest to youngest: a Biotite Tonalite to Granodiorite suite, a Hornblende Tonalite to Granodiorite suite, and a Biotite Granite to

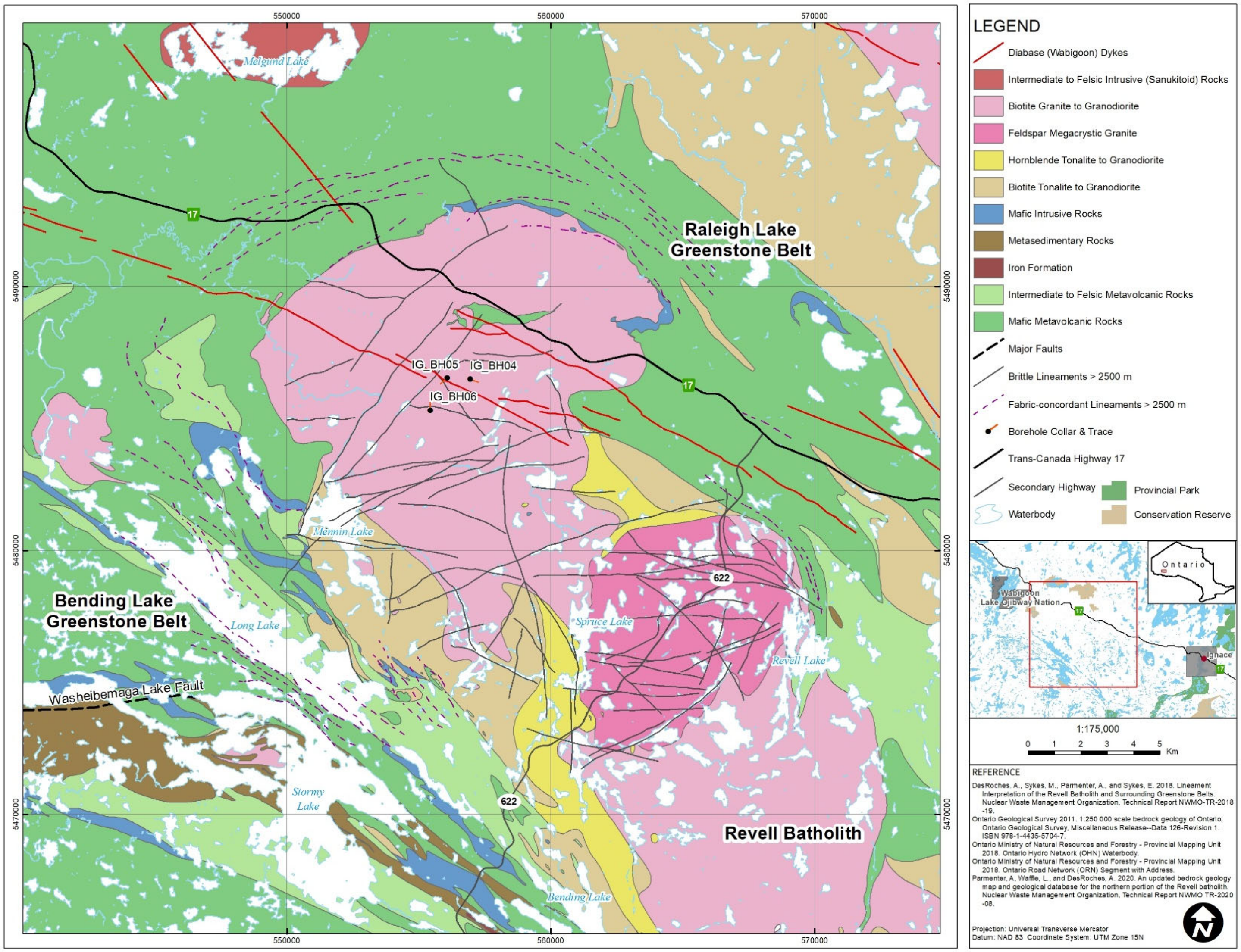
Granodiorite suite (Figure 1). Plutonic rocks of the Biotite Tonalite to Granodiorite suite occur along the southwestern and northeastern margins of the Revell batholith. The principal type of rock within this suite is a white to grey, medium-grained, variably massive to foliated or weakly gneissic, biotite tonalite to granodiorite. One sample of foliated and medium-grained biotite tonalite produced a U-Pb age of 2734.2+/-0.8 Ma (Stone et al. 2010). The Hornblende Tonalite to Granodiorite suite occurs in two irregularly-shaped zones surrounding the central core of the Revell batholith. Rocks of the Hornblende Tonalite to Granodiorite suite range compositionally from tonalite through granodiorite to granite and also include significant proportions of quartz diorite and quartz monzodiorite. One sample of coarse-grained grey mesocratic hornblende tonalite produced a U-Pb age of 2732.3+/-0.8 Ma (Stone et al. 2010). Rocks of the Biotite Granite to Granodiorite suite underlie most of the northern, central and southern portions of the Revell batholith. Rocks of this suite are typically coarse-grained, massive to weakly foliated, and white to pink in colour. The Biotite Granite to Granodiorite suite ranges compositionally from granite through granodiorite to tonalite. A distinct potassium (K)-Feldspar Megacrystic Granite phase of the Biotite Granite to Granodiorite suite occurs as an oval-shaped body in the central portion of the Revell batholith (Figure 1). One sample of coarse-grained, pink, massive K-feldspar megacrystic biotite granite produced a U-Pb age of 2694.0+/-0.9 Ma (Stone et al. 2010).

The bedrock surrounding IG_BH05 is composed mainly of massive to weakly foliated felsic intrusive rocks that vary in composition between granodiorite and tonalite, and together form a relatively homogeneous intrusive complex. Bedrock identified as tonalite transitions gradationally into granodiorite and no distinct contact relationships between these two rock types are typically observed (SRK and Golder 2015; Golder and PGW 2017). Massive to weakly foliated granite is identified at the ground surface to the northwest of the feldspar-megacrystic granite. The granite is observed to intrude into the granodiorite-tonalite bedrock, indicating it is distinct from, and younger than, the intrusive complex (Golder and PGW 2017).

West-northwest trending mafic dykes interpreted from aeromagnetic data extend across the northern portion of the Revell batholith and into the surrounding greenstone belts. One mafic dyke occurrence, located to the northwest of IG_BH01, is approximately 15-20 m wide (Figure 1). All of these mafic dykes have a similar character and are interpreted to be part of the Wabigoon dyke swarm. One sample from the same Wabigoon swarm produced a U-Pb age of 1887+/-13 Ma (Stone et al. 2010), indicating that these mafic dykes are Proterozoic in age. It is assumed based on surface measurements that these mafic dykes are sub-vertical (Golder and PGW 2017).

Long, narrow valleys are located along the western and southern limits of the investigation area (Figure 2). These local valleys host creeks and small lakes that drain to the southwest and may represent the surface expression of structural features that extend into the bedrock. A broad valley is located along the eastern limits of the investigation area and hosts a more continuous, un-named water body that flows to the south. The linear and segmented nature of this waterbody's shorelines may also represent the surface expression of structural features that extend into the bedrock.

Regional observations from mapping have indicated that structural features are widely spaced (typical 30 to 500 cm spacing range) and dominantly comprised of sub-vertical joints with two dominant orientations, northeast and northwest trending (Golder and PGW 2017). Interpreted bedrock lineaments generally follow these same dominant orientations in the northern portion of the Revell batholith (Figure 1 DesRoches et al. 2018). Minor sub-horizontal joints have been observed with minimal alteration, suggesting they are younger and perhaps related to glacial unloading. One mapped regional-scale fault, the Washeibemaga Lake fault, trends east and is located to the west of the Revell batholith (Figure 1). Ductile lineaments, also shown on Figure 2, follow the trend of foliation mapped in the surrounding greenstone belts. Additional details of the lithological units and structures found at surface within the investigation area are reported in Golder and PGW (2017).



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Projection: Universal Transverse Mercator
Datum: NAD 83 Coordinate System: UTM Zone 15N

Figure 1: Geological Setting and Location of Boreholes IG_BH04, IG_BH05, and IG_BH06 in the Northern Portion of the Revell Batholith

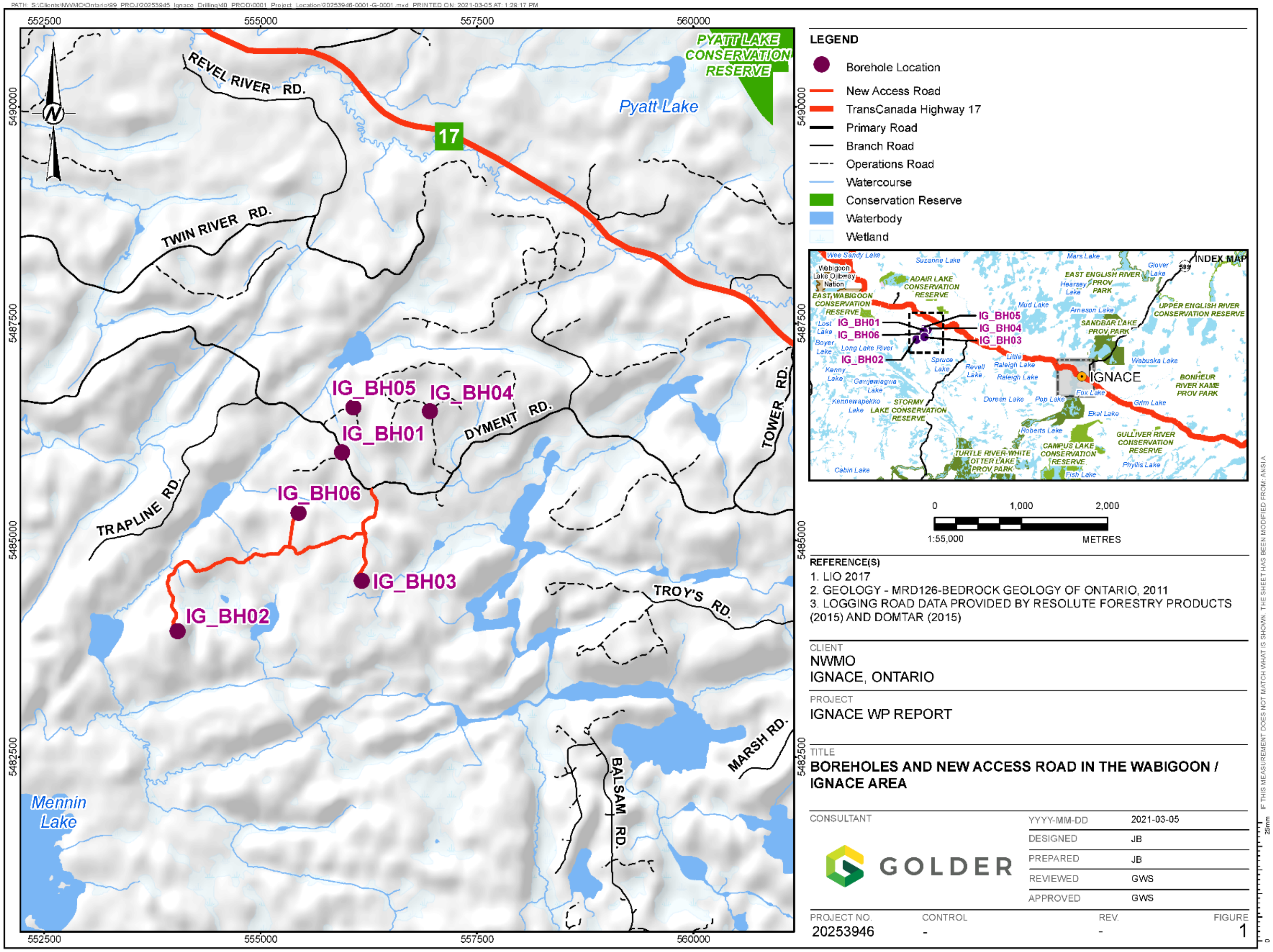

Figure 2: Location of IG_BH05 in Relation to the Ignace Area

3.0 DESCRIPTION OF ACTIVITIES

3.1 Types of Samples Collected

The following samples were collected for laboratory analysis and in-field as described in the following section.

- Water source samples – These were collected under WP02 to characterize the source water prior to introducing it to the drill system. They were denoted IG_BH05_WSXXX (“water source”) and included laboratory analyses, in-field parameters and in-field geochemistry analyses.
- Drilling water return, designated IG_BH05_DWXXX, included the following types of samples:
  - Archive samples of the drill water return were collected under WP02 every 50 m during drilling.
  - Drillwater additive
- No viable Opportunistic Groundwater samples were collected and therefore no associated drill water samples for QAQC or microbiology were collected.
- No post drilling sample collection was attempted due to the low available purge rates for all intervals assessed under WP06.

A summary description and details of all analyses for all fluid samples collected for IG_BH05 can be found in Table A-1 (Appendix A).

3.2 Technical Objectives

The technical and scientific objectives of WP07 sampling were the following:

- Identification, while drilling and post-drilling during WP06 packer testing, of permeable intervals for collecting OGW samples;
- Collection and preservation of OGW sample volumes for geochemical analysis;
- Measurement of field parameters (tracer concentrations [fluorescein], temperature, pH, oxidation-reduction potential [ORP], electrical conductivity [EC] and turbidity) and in-field analysis (alkalinity, dissolved oxygen [DO], total dissolved sulphide, and ferrous iron);
- Laboratory analysis of collected OGW samples;
- Determining chemical and isotopic character of groundwater with depth; and
- Identify the presence or absence of recent, older post-glacial and glacial recharge, interglacial recharge and very old pre-glacial groundwater with depth.

In the crystalline rock of the Revel Batholith, groundwater was expected to be encountered through fractures in the bedrock. A maximum of 10 sample intervals were planned, following the depth guidelines below:

- 1 sample in the upper 100 m;
- 3 samples in the upper 400 m (including the 1 sample in the upper 100 m); and
- 7 samples in the potential repository zone (400 to 800 m) or below the repository horizon (if active or flowing feature(s) are encountered).

3.3 Methodology

3.3.1 Roles and Responsibilities

WSP drilling supervisors were responsible for all activities associated with WP07 on site sampling, including:

- Equipment decontamination;
- Lowering the wireline packer assembly to isolate the sample interval;
- Purging the sample interval;
- Collection of the OGW sample;
- Sample in-field geochemistry analyses; and
- Submitting samples for laboratory analysis by Bureau Veritas Laboratories (BV), Isotope Tracer Technologies (IT2) and the University of Ottawa (UofO).

The WSP WP07 Lead corresponded with the NWMO WP07 Lead and provided direction to the field staff on confirmation to proceed with purging assessments and sample collection (if applicable).

Data Delivery

The data delivery associated with this Work Package was provided to the NWMO and contains the following components, referred to throughout this report:

- DQC workbooks for each sample (these include all notes associated with in-field and laboratory activities, instrument calibration records and purging data for opportunistic groundwater sample attempts);
- Chain of custody records and sample submission reports from BV, IT2 and UofO;
- Certificates of analyses for all samples from BV, IT2 and UofO.
- Calculation file for charge balance and alkalinity speciation of water samples;
- Raw downhole pressure data collected during groundwater sample purge rate assessments; and
- Importer template file (csv) containing results from analytical laboratory testing.

3.3.2 Source Water and Water Tracing

Fresh water was brought from a municipal source in Ignace. Municipal water in Ignace is sourced from Michel Lake and treated to adhere to Ontario drinking water standards; the water undergoes filtering processes and is chlorinated. Once water was collected from Ignace and brought to site, it was stored in designated tanks. As described in the Work Package 2 (WP02) Drilling and Flushing Report (WSP Golder, 2022a), samples were collected from these freshwater tanks (water source samples) for initial characterization before a fluorescein tracer was added to achieve the desired concentration of 100 ppb for drilling and flushing activities. After sampling and tracer addition, the fresh water was introduced to the borehole and drill fluid system with approval from the WSP drilling supervisor.

All drill fluid parameters (fluorescein concentration, temperature, pH, electrical conductivity (EC), ORP, dissolved oxygen (DO), turbidity and density) were measured from the return fluid at the completion of each run. This data is presented in the WP02 Data Report. Drill fluid parameters pertaining to collected samples are included in the acQuire data delivery (DE-07). As described in the WP02 report (WSP Golder, 2022a), the drill fluid volume change was measured on a run to run basis through manual measurements of the drill fluid system. The drill fluid recycling system used a centrifuge to remove solid cuttings from the return fluid. All drill fluid data and observations are presented in the WP02 Drilling and Coring Report (WSP Golder, 2022a).

3.3.3 Interval Selection

During drilling, potential opportunistic groundwater sample intervals were identified by a combination of the following:

- Indications from core sample descriptions, such as fractured zones, weathered or stained fractures, large fracture apertures;
- Drilling fluid circulation measurements, such as fluid loss or gain, changes in drilling fluid parameters (see Table 1);
- Drill pump pressure changes that may indicate loss of circulation or the presence of a water producing feature; and
- Drilling performance indicators, such as rod drops, changes in advance rates, or changes in drive head torque.

The observed criteria to initiate WP07 are described in the “Justification to Initiate WP07” tab of the DQC workbooks. Although no OGW’s were collected, the sample collection process for the initial stages is presented in the DQC workbooks, including the equipment decontamination, test zone specifications and purge rate assessment.

Table 1: Drill Fluid Field Parameters Measured, and Triggers Observed to Initiate WP07

Field Parameter	Instrument	Trigger to Initiate WP07
Fluorescein dye (tracer)	Aquafluor Handheld Fluorimeter/Turbidimeter	20% decrease in concentration from previous drill fluid source. Note: Minimum detection limit of the fluorimeter (0.4 ppb)
Turbidity	Horiba U52-2, multiparameter probe	10% change from previous drill fluid source
Dissolved Oxygen		10% change from previous drill fluid source
Electrical conductivity		10% change from previous drill fluid source
pH		change of at least 0.5 from previous drill fluid source
Temperature		N/A
ORP		N/A
Density	Hydrometer	N/A

Potential post-drilling sample intervals were identified based on observations from borehole geophysical surveys (WP05), however preliminary hydraulic conductivity estimates while completing WP06 indicated that none of the intervals could sustain the required purge rate. Therefore, no post-drilling opportunistic groundwater samples were collected.

3.3.4 Interval Isolation

For sample intervals identified during drilling, an inflatable wireline packer tool was used to isolate the bottom of the borehole, with the configuration shown in Figure 3. Recorded measurements and calculations for the interval configurations can be found in the “Test Zone Specification” tab of the DQC workbooks for intervals identified during drilling.

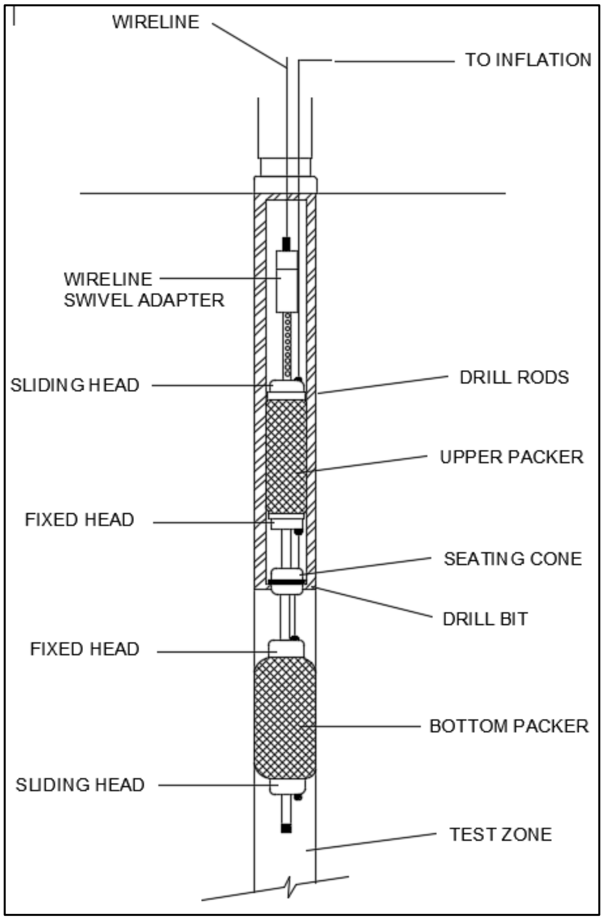

Figure 3: Wireline packer schematic

3.3.5 Assessing Feasibility of Sample Collection

For sample intervals identified during drilling, the interval’s ability to sustain the minimum required purge rate of 10 system volumes (borehole volume of isolated interval + volume of water in drill pipe) in 72 hours was assessed by performing a multiple step, constant rate pumping test, as documented in the “Purge Rate Assessment” tab of the DQC workbooks. The available purge rates for potential sample intervals identified during the post-drilling hydraulic testing were estimated based on preliminary field assessments of the intervals’ transmissivity.

3.3.6 Purging

If sample collection from the selected interval was determined to be feasible, purging was carried out to remove the drill fluid from the drill rods, the sample interval and the rock formation to obtain a groundwater sample that was representative of the isolated interval. For the single sample attempt during drilling of IG_BH05 (Interval 3; see Section 4.1), interval purging was attempted using a Solinst Model 407 1” bladder pump, lowered into the drill rods. Purged water was conveyed to surface via 12.7 mm diameter poly tubing connected to the pump. The purge rate was recorded in the ‘Purge Water Volume and Field Parameters’ tab of the DQC workbook provided to the NWMO in the data deliverable.

3.3.7 Collection of Field Parameters

During purging, the drill fluid field parameters (fluorescein concentration, pH, ORP, DO, EC, turbidity and temperature) were monitored with a Horiba U52-2 multi-parameter water quality meter and recorded approximately every 30 minutes. The Horiba was set up on surface during purging using a flow-through cell and readings were recorded in the ‘Purge Water Volume and Field Parameters’ tab of the DQC workbook.

Analytical in-field parameter measurements, including alkalinity, total dissolved sulfide, DO (colorimetric method) and ferrous iron, were not performed as sample collection was not initiated.

3.3.8 Sample Collection

No OGW samples were collected during the drilling of IG_BH05 (see Section 4.1 for details).

3.3.9 QA/QC

A Data Quality Confirmation (DQC) workbook was filled out for each fluid sample collected (water source, drill water or groundwater) for IG_BH05. For each sample attempt, a Data Quality Confirmation (DQC) workbook was filled out by the field staff on site to record the sample attempt interval details, equipment decontamination, purge rate assessment, Horiba calibration details and purge water parameters, if applicable. The DQC workbooks were completed over the duration of the sampling attempt period, from identification of the potential interval to the attempted collection of the actual sample. For the water source and drill water additive samples, modified DQC workbooks were filled out to include field parameters, analytical in-field parameters, instrument calibration documentation, laboratory sample collection forms and chain of custody completion checklists.

Instrument Calibration Checks

Instrument calibration checks were typically carried out for the Horiba probe and AquaFluor at the start of every dayshift during regular drilling activities (WP02).

Full manual calibration checks and calibrations of each sensor of the Horiba probe were carried out according to the manufacturer’s instructions prior to in-field geochemistry analyses for water source or drill water samples, and groundwater sample purging events. The appropriate reference solutions were used for each sensor’s calibration, as listed in the “pH, Eh, Cond, Turb, DO” tab of the DQC workbooks.

Drill Fluid Sampling

No drill fluid samples were collected for attempted sample intervals where no groundwater sample was ultimately collected.

Equipment Decontamination

All equipment lowered downhole was decontaminated prior to use. Field staff used new, powder-free latex or nitrile gloves while cleaning and handling decontaminated equipment. Alconox® powdered detergent was used with distilled water to remove any dirt, grease or residue from the equipment, followed by a thorough rinse with laboratory grade deionized water. The equipment was then laid on a clean surface and allowed to dry free from dust and contaminants before going downhole. If the equipment was cleaned pre-emptively, it was stored in new plastic bags until required for use. The packer assembly, water level tape indicator, RST pressure transducer, Solinst Model 407 1” bladder pump, Grundfos submersible pump with electrical cable and Waterra tubing, the flow-through cell, and the in-situ sample probe were decontaminated as required and recorded in the “Equipment Decontamination” tab of the DQC workbooks for each interval.

Field Blanks and Duplicates

No QA/QC samples were collected for attempted sample intervals where no groundwater sample was ultimately collected.

Sample Handling and Laboratory Documentation

Both BV and IT2 adhere to the requirements of ISO 17025:2005. Chain of custody (COC) forms were filled out by site staff to ship all samples to the required laboratories. If multiple samples were sent in a single shipment, they were included on a single COC and all results that followed contained all samples that were shipped together in a single report. The DE-09 Chain of Custody object in acQuire was used to document COCs and reconcile samples sent to the laboratories with results received from the laboratories.

Sample bottle labels were filled out before the samples were collected in the bottles. Information on sample bottle labels included the sample name, date and time collected, preservative and analysis required. Once the collected samples were transferred to the sample bottles as listed in Table 2, the bottles were temporarily stored in a refrigerator on site. As part of the WP02 daily quality confirmation checks, the temperatures of the refrigerators were checked to ensure they remained at 4˚C. Sample bottles were packed in coolers with ice packs and the appropriate COC for shipment to the laboratories.

Samples for noble gas analysis (concentration and isotopic ratios) were collected by pumping sample water through copper tubing and clamping both ends, so that the collected sample volume was not in contact with the atmosphere. The samples contained in the clamped copper tubing were similarly stored in the refrigerator on site and packed in coolers with ice for shipment to the lab.

Upon receipt by BV, IT2 and UofO, WSP was notified via email and a sample submission report was provided. Each lab included a copy of the COCs, verifying the received condition of the sample and confirming the analyses to be performed. The documented received sample condition from the laboratories included the temperature received and any broken bottles.

Table 2: Sample bottle / collection requirements for Bureau Veritas Laboratories, Isotope Tracer Technologies, the University of Ottawa and the University of Waterloo

Parameter Group	Parameter List	Bottle Type Requirement	Sample Volume Requirement	Field Filtering Requirement	Preservative Requirement	Analytical Laboratory
Major Elements & Metals	Na, K, Ca, Mg, Sr, Li, Si, Al, B, S_{Total}, $Fe_{TotalDiss}$ (Dissolved Metals by ICPMS)	HDPE plastic bottles	120 mL	Yes, 0.45 µm filter	Trace grade nitric acid	Bureau Vertias (BV)
Trace Elements, Anions & Nutrients	Cu, Ni, Zn, Pb, Cd, Al, As, Se, Bi, U, Cs, Rb, Ba, Cr, Co, Th, Zr					
	SiO_2 & I	HDPE plastic bottles	250 mL	Yes, 0.45 µm filter	None	
	S^{2-}	HDPE plastic bottles	125 mL	Yes, 0.45 µm filter	Zinc acetate and sodium hydroxide solution	
	NH_4 (ammonium), $NH_3 + NH_4$ (total ammonia)	Clear glass vial	40 mL	Yes, 0.45 µm filter	Trace grade sulphuric acid	
	N_{total}, P_{total}, TOC	HDPE plastic bottles	120 mL	Yes, 0.45 µm filter	Trace grade sulphuric acid	
	DOC	HDPE plastic bottles	120 mL	Yes, 0.45 µm filter	None	
	Br, F, Cl, I, SO_4, PO_4, NO_3, NO_2, HCO_3	HDPE plastic bottles	500 mL	Yes, 0.45 µm filter	None	
Physical – Chemical	pH, Alkalinity, TIC					
Rare Earth Elements	Ce to Y	HDPE plastic bottles	2 X 1 L	Yes, 0.45 µm filter	None	
Radioisotopes	^{238}U, ^{234}U, ^{40}K, ^{222}Rn, ^{223}Ra, ^{224}Ra, ^{226}Ra, ^{228}Ra, ^{227}Th, ^{232}Th, ^{230}Th, Gross Alpha &					
			5 X 1 L	Yes, 0.45 µm filter	Trace grade nitric acid	

Parameter Group	Parameter List	Bottle Type Requirement	Sample Volume Requirement	Field Filtering Requirement	Preservative Requirement	Analytical Laboratory
	Beta, ^{210}Po, ^{210}Pb, ^{90}Sr					
Stable Isotopes	δ^{18}O, δ2H	HDPE plastic bottles	60 mL	Yes, 0.45 µm filter	None	Isotope Tracer Technologies (IT2)
	^{87}Sr/^{86}Sr	HDPE plastic bottle	1000 mL	Yes, 0.45 µm filter	None	
	δ^{13}C DIC	Amber glass vials, teflon cap	2 x 40 mL glass vials with septa caps (x2 per sample)	Yes, 0.45 µm filter	Zinc chloride	
	^{37}Cl	HDPE plastic bottle	1000 mL	Yes, 0.45 µm filter	None	
Radioisotopes	^{36}Cl					
	^{129}I	HDPE plastic bottle	500 mL	Yes, 0.45 µm filter	None	
	^{14}C-DIC	Glass bottle	1000 mL	Yes, 0.45 µm filter	Zinc chloride	
	^{3}H	HDPE plastic bottle	500 mL	Yes, 0.45 µm filter	None	
Noble gas concentration & isotopic ratios	He, Ar, Ne	Copper Tubing	-	None	None	University of Ottawa
	(^{3,4}He, ^{20,22}Ne, ^{21,22}Ne, ^{40,36}Ar)					
Microbiology	DNA	Filter (S2GVU02RE and S2VPU02RE)	Filter up to 1000 ml through provided filter	Yes, through provided filter	None	University of Waterloo
	PLFA	Filter (S2GVU02RE)	Filter up to 1000 ml through provided filter	Yes, through provided filter	None	
	Cell Count	Preloaded tube	50 ml	None	Glutaraldehyde	

3.3.10 Methods of Chemical and Isotopic Analysis

For the commercial and in-field analyses, information on the chemical and isotopic analyses, including the method, accuracy, and method detection limit (MDL) for each parameter is attached in Appendix A (Table A-2).

4.0 RESULTS

Sample intervals were expected to be identified during drilling from drill fluid volume losses or apparent gains and / or drill fluid parameter changes, as outlined in Table 1. During the drilling of IG_BH05, there were no intervals encountered where there was sufficient inflow into the borehole for the purge volume requirements to be met and therefore no opportunistic groundwater samples were collected. Two intervals where triggers were identified to perform a purge rate assessment were not permeable and were abandoned after the multiple step constant rate test. One interval proceeded to purging, however the interval's permeability was not great enough to sustain a continuous purge rate over a 72-hour period.

WSP drilling supervisors (WP02) were responsible for the field identification of potential sample intervals and corresponded with the WSP work package Lead for WP07 when these were identified. As discussed in the WP02 Drilling and Coring Data Report (WSP Golder, 2022a), parameter triggers for DO, EC and pH were encountered with some frequency, but were typically attributed to the addition of fresh, traced water and subsequent equalizing in the drill system. The drill fluid was observed to become increasingly saturated with the drill cuttings as drilling progressed, which caused a gradual change of the drill fluid parameters with each run. Turbidity was not an indicator of permeable intervals since the measurements were above the Horiba multi-probe's measurement range for the majority of the program (turbidity was greater than 1000 NTU).

Fluorescein concentration was found to generally decrease in the system as drilling progressed and cuttings were removed from the drill fluid with the centrifuge. Therefore, the drill water required the addition of fluorescein by directly mixing the fluorescein into the drill tank to bring the concentration back to the desired range. The system was also required to be topped up with fresh, traced water as the volume of the hole increased and drill fluid was lost to the rock formation. These two actions required time for the system to equalize and mix, which caused fluorescein concentration changes above or below the trigger threshold to be observed occasionally. Further trends related to the drill fluid parameters are discussed in the WP02 report (WSP Golder, 2022a).

A total of eight (8) water samples were submitted for laboratory analyses for IG_BH05. Of these, seven (7) were water source samples (one WS sample having been transferred from IG_BH06), supplied from the Town of Ignace municipal water supply. One (1) water source sample (IG_BH05_WS002) included flocculant additive in the sample, resulting in differences in chemical composition relative to other water source samples (Section 4.2). One (1) sample of drill water was collected after a drilling additive was added to the drill fluid. There were no OGW or associated QA/QC samples collected.

Analytical in-field parameter measurements included alkalinity, total dissolved sulfide, DO (colorimetric method) and ferrous iron, with results recorded in the corresponding data tabs of the DQC workbooks, as well as the acQuire DE-07 Groundwater Sample object. The field procedures for these in-field analyses can be found in Appendix B.

Complete analytical results of the water source and drill water samples are presented in Table A-3 (Appendix A). Calculated values for ferric iron (via subtraction of field measured ferrous iron concentrations from laboratory reported dissolved iron concentrations) are not presented due to dissolved iron concentrations below detection limit in all samples. Fluorescein concentrations were measured in field but not in the laboratory because no commercial laboratory was identified that was able to complete this analysis. Sulphide concentrations were reported below detection limit in all field and laboratory measurements; accordingly, calculated values for hydrogen sulphide and bisulphide are not presented.

4.1 Interval Selection and Purging

Attempted Sample Interval 1 (17.57 – 19.60 mbgs)

During core run CR11, from 16.60 to 19.60 mbgs (along hole), a volume loss of 152 L was observed, along with several fractures in the drill core indicating a possible location for collecting an OGW sample. A reduction in torque to 500 PSI at a depth of approximately 18.60 mbgs was observed before returning to 2000 PSI. This was communicated to the WSP work package Lead and the decision was confirmed with the NWMO to isolate the interval and assess the achievable purge rate.

The drill string was pulled up, with the bit positioned at 16.42 mbgs (along hole), to position the single packer above the suspected water bearing fractures and isolate the interval from 17.57 to 19.60 mbgs (along hole).

With a system volume of approximately 91 litres, the minimum purge rate required to achieve 10 system volumes in 72 hours was 0.21 litres per minute (L/min). The constant rate step test indicated an insufficient available flow rate from the interval and the sample attempt was abandoned. The packers were removed from the borehole and drilling resumed.

Attempted Sample Interval 2 (155.87 – 160.59 mbgs)

During core run CR62, from 157.58 to 160.59 mbgs (along hole), a volume loss of 155 L was observed, with a 25% decrease in fluorescein concentration, along with a slickensided fault with surface coating in the drill core indicating a possible location for collecting an OGW sample. This was communicated to the WSP work package Lead and the decision was confirmed with the NWMO to isolate the interval and assess the achievable purge rate.

The drill string was pulled up, with the bit positioned at 154.57 mbgs (along hole), to position the single packer above the suspected water bearing fractures and isolate the interval from 155.87 to 160.59 mbgs (along hole).

With a system volume of approximately 742 litres, the minimum purge rate required to achieve 10 system volumes in 72 hours was 1.72 litres per minute (L/min). The constant rate step test indicated an insufficient available flow rate from the interval and the sample attempt was abandoned. The packers were removed from the borehole and drilling resumed

Attempted Sample Interval 3 (338.54 – 343.32 mbgs)

During core run CR126, from 340.59 to 343.32 mbgs (along hole), a volume loss of 134 L was observed along with a hematite and chlorite infilled structure in the drill core, indicating a possible location for collecting an OGW sample. This was communicated to the WSP work package Lead and the decision was confirmed with the NWMO to isolate the interval and assess the achievable purge rate.

The drill string was pulled up, with the bit positioned at 337.61 mbgs (along hole), to position the single packer above the suspected water bearing fractures and isolate the interval from 338.54 to 343.32 mbgs (along hole).

With a system volume of approximately 1568 litres, the minimum purge rate required to achieve 10 system volumes in 72 hours was 3.63 litres per minute (L/min). The constant rate step test indicated a potentially feasible OGW sample interval. During the purging, the interval was pumped dry several times before the attempt was abandoned. The packers were removed from the borehole and drilling resumed.

4.2 Water Source Samples

Water source samples are generally of relatively consistent composition over the duration of WP07, which is expected given that the samples are taken from municipal water supply for drinking water. Ignace’s municipal water is sourced from Michel Lake, with water supply for IG_BH05 collected from the municipal source from May 9, 2021 to October 25, 2021. The results are summarized as follows:

- Field pH ranged from 5.63 to 7.23;
- Total alkalinity ranged from 8.0 to 31 mg/L $CaCO_3$ in-field measured values, and ranged from 1.2 to 16 mg/L $CaCO_3$ in laboratory measured values;
- Sulphate ranged from 1.5 to 20 mg/L;
- Total dissolved sulphide was below the method detection limit in in-field measured samples, as well as below the method detection limit (<0.02 mg/L) in all laboratory measured samples;
- Dissolved oxygen concentration measured by Hach meter ranged from 8.1 to 9.6 mg/L, and ranged from 4.3 to 10.6 mg/L in samples measured by the Horiba probe;
- Oxygen-18 ($\delta^{18}O$) ranged from -7.81 to -6.74 ‰ VSMOW;
- Deuterium ($\delta^{2}H$) ranged from -67.0 to -61.6 ‰ VSMOW;
- $\delta^{13}C$-DIC ranged from -10 to -6.8 ‰ PDB;
- ^{14}C-DIC ranged from 27.9 to 100.5 percent Modern Carbon (pMC) or 10,200 to 0 years before present (BP). The minimum result is considered suspect given the surface water origin of the sample and younger ages reported for all other samples. Present is defined as the year 1950 and years BP is calculated by the analytical laboratory according to the formula:

$$Years\ BP = -8033 \times \ln\frac{pMC}{100}$$

- ^{3}H ranged from 6.0 to 9.5 TU; and
- $^{87}Sr/^{86}Sr$ ratio ranged from 0.720 to 0.730.

One (1) water source sample (IG_BH05_WS002) included flocculant additive in the sample, resulting in differences in chemical composition relative to other water source samples. These differences are responsible for a lower minimum value for total alkalinity and a higher maximum value for sulphate in the above ranges than applies to the remainder of the water source sample range. Relative results of key major ions are presented in a piper plot in Figure 4. Water source samples, other than IG_BH05_WS002, are clustered and demonstrate that the major ion composition is generally consistent. The major ion chemistry of the water source samples is represented by similar proportions of calcium and sodium, with lesser concentrations of magnesium and potassium, and a higher proportion of bicarbonate relative to other anions.

Oxygen-18 and deuterium results are presented in Figure 5 and are compared to the Global Meteoric Water Line (GMWL) and Local Meteoric Water Line (LMWL). The LMWL presented is for Atikokan, Ontario (Fritz et al., 1987). This LMWL is considered a reasonable representation (based on distance) of the LMWL for Ignace, Ontario, for which a closer published LMWL has not been identified. All water source samples plot below and to the right of the LMWL and GMWL.

Water source samples are collected from the municipal water supply, which is sourced from a local lake, therefore it is known that the samples are primarily composed of modern precipitation. Tritium results are consistent with this origin.

4.3 Drill Water Samples

A single drill water additive sample was collected for IG_BH05, IG_BH05_DW003. The drill water sample is a mixture of source water, drilling additives, inputs from rock flour (from the drilling process) and groundwater. High turbidity was observed in the drill water sample. Sample IG_BH05_DW003 is associated with the Pure-Vis™drill additive used throughout the drilling process. The results are summarized as follows:

- Field pH of 11.8;
- Total alkalinity of 374 mg/L as $CaCO_3$ in field measured values and 260 mg/L $CaCO_3$ in laboratory measured values;
- Sulphate of 28 mg/L;
- Total dissolved sulphide was below the method detection limit;
- Dissolved oxygen concentration measured by the Horiba probe was 8.26 mg/L;
- Oxygen-18 (δ18O) was -7.11 ‰ VSMOW;
- Deuterium (δ2H) was -64.2 ‰ VSMOW;
- δ13C-DIC was -29.6 ‰ PDB;
- 14C-DIC was 92.38 % modern carbon or 637 years BP;
- 3H was 9.0 TU; and
- 87Sr/86Sr ratio was 0.723.

Relative results of key major ions are presented in a piper plot in Figure 4. Total cation and anion concentrations in drill water are approximately one order-of-magnitude greater than those reported in water source samples.

The major ion composition is dominated by sodium, calcium, and hydroxide (note that hydroxide is not among the major ion species presented Figure 4). The drill water sample represents drill water with longer drilling exposure time and elevated values of sodium, calcium, potassium, and bicarbonate concentrations are assumed to be a result of the drilling process. Potential mechanisms for changes to drill water composition other than additive include influence from groundwater or dissolution of rock flour produced during the drilling process. As the composition of water influenced by dissolution of drill cuttings was not independently assessed, nor were groundwater samples collected, the relative contribution of these influences cannot be confirmed.

Oxygen-18 and deuterium results are presented in Figure 5, and all drill water samples plot below and to the right of the LMWL.

Drill water samples are derived from the water source, which is collected from the municipal water supply. This water is sourced from Lake Michel, therefore it is known that the samples are primarily comprised of modern precipitation. Tritium results are consistent with this origin.

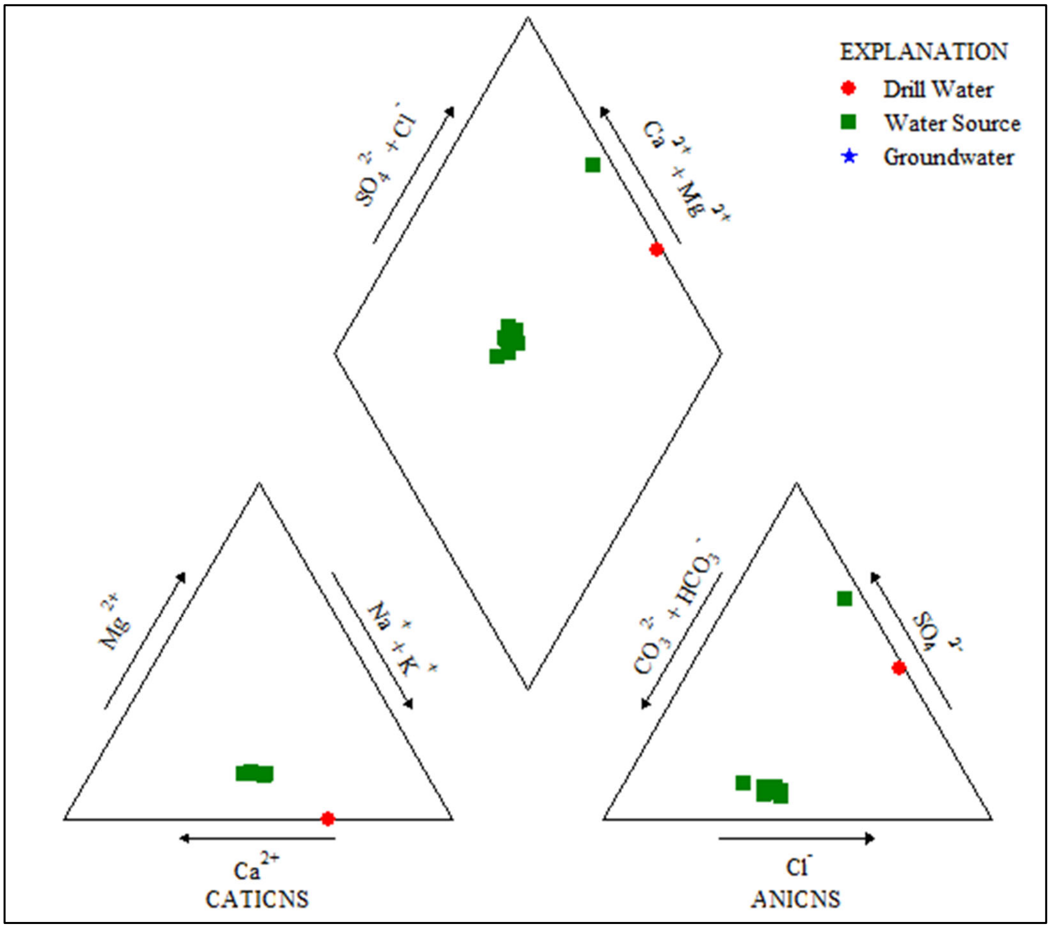

Figure 4: Piper plot of select WP07 water samples

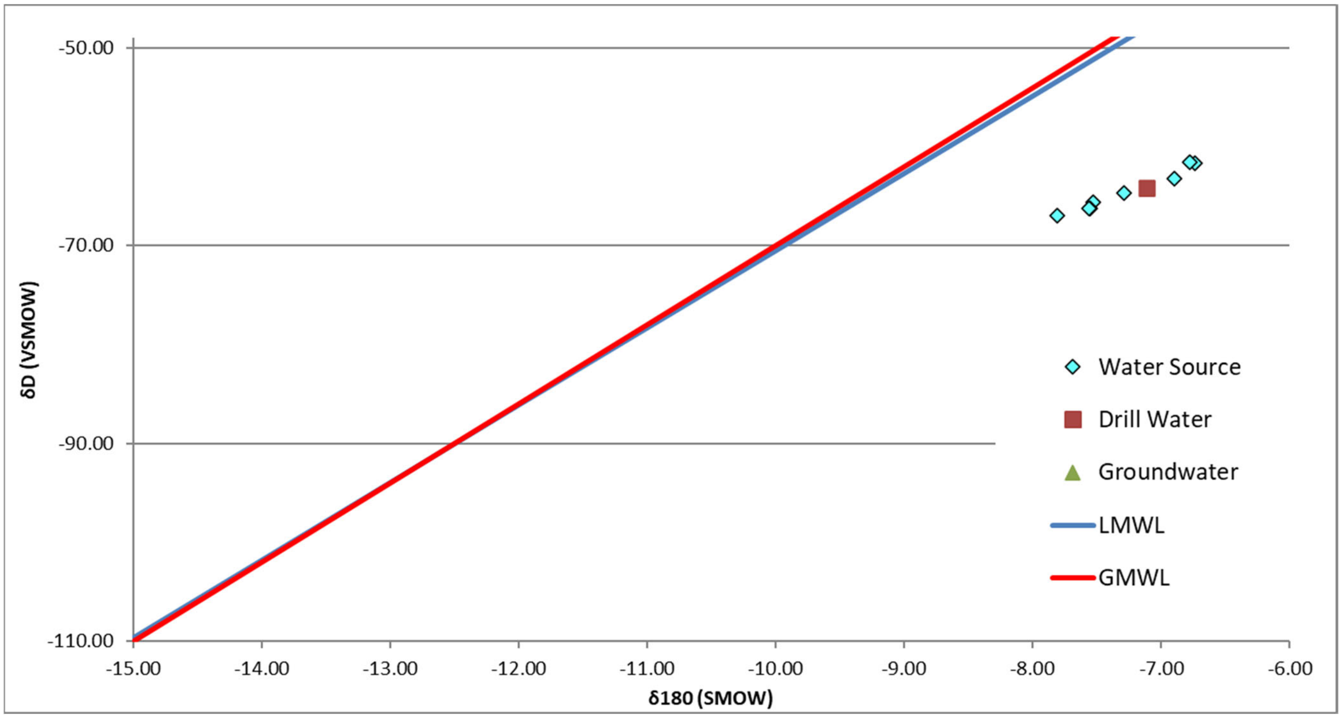

Figure 5: Oxygen (δ18O) - Deuterium (δ2H) plot of WP07 water samples. Local Meteoric Water Line for Atikokan, Ontario (Fritz et al., 1987).

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APPENDIX A

Table A-1: Sample Summary Description for IG_BH05 Fluid Samples

Table A-2: Laboratory Analytical Methodology

Table A-3: Water Source and Drill Water Sample Results

Sample ID	Date Collected	Time Collected	Depth		Bottle Sets for Laboratory Analysis																					In-Field Geochemistry				In-Field Measurements[1]	Microbiology[5]			Purpose of Sample
					Major Elements & Metals[2]	Trace Elements, Anions and Nutrients[2]							Physical-Chemical[2]	Rare Earth Elements[2]	Radioisotopes[2]	Stable Isotopes[3]				Radioisotopes[3]				Noble Gas Concentration & Isotopic Ratios[4]		Sulphide	Dissolved Oxygen	Ferrous Iron	Alkalinity		PLFA	DNA	Cell Count	
			From (mbgs)	To (mbgs)	Na, K, Ca, Mg, Sr, Li, Si, Al, B, S_{Total}, $Fe_{TotalDiss}$ (Dissolved Metals by ICPMS)	SiO_2 & I	S^{2-}_{Total}	Cu, Ni, Zn, Pb, Cd, Al, As, Se, Bi, U, Cs, Rb, Ba, Cr, Co, Th, Zr	NH_4+NH_3 (total ammonia), NH_4 (ammonium)	N_{total}, P_{total}, TOC	DOC	Br, F, Cl, I, SO_4, PO_4, NO_3, NO_2, HCO_3	pH, Alkalinity, TIC	Ce to Y	^{238}U, ^{234}U, ^{40}K, ^{222}Rn, ^{223}Ra, ^{224}Ra, ^{226}Ra, ^{228}Ra, ^{227}Th, ^{232}Th, ^{230}Th, Gross Alpha & Beta, ^{210}Po, ^{210}Pb, ^{90}Sr	δ^{18}O, δ^{2}H	^{87}Sr/^{86}Sr	δ^{13}C DIC	^{37}Cl	^{36}Cl	^{129}I	^{14}C-DIC	E^{3}H	He, Ne, Ar	^{3,4}He, ^{20,22}Ne, ^{21,22}Ne, ^{40,36}Ar									
IG_BH05_DW001	19-May-21	9:30	49.65	52.58																										✓				50m Drill Fluid Archive
IG_BH05_DW002	21-May-21	14:30	97.60	100.57																										✓				100m Drill Fluid Archive
IG_BH05_DW003	28-May-21	14:40	100.57	100.57	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓[6]	✓[6]	✓	✓	✓	✓	✓				8L of Pure-Vis added to drilling water following cementing of Surface Casing
IG_BH05_DW004	3-Jun-21	2:00	148.63	151.65																										✓				150m Drill Fluid Archive
IG_BH05_DW005	7-Jun-21	22:40	196.62	199.64																										✓				200m Drill Fluid Archive
IG_BH05_DW006	11-Jun-21	4:00	250.63	253.66																										✓				250m Drill Fluid Archive
IG_BH05_DW007	15-Jun-21	9:45	298.66	301.65																										✓				300m Drill Fluid Archive
IG_BH05_DW008	25-Jun-21	11:10	346.64	349.62																										✓				350m Drill Fluid Archive
IG_BH05_DW009	29-Jun-21	10:25	397.66	400.55																										✓				400m Drill Fluid Archive
IG_BH05_DW010	2-Jul-21	10:01	448.60	451.53																										✓				450m Drill Fluid Archive
IG_BH05_DW011	4-Jul-21	2:10	499.62	502.65																										✓				500m Drill Fluid Archive
IG_BH05_DW012	6-Jul-21	4:45	547.63	550.65																										✓				550m Drill Fluid Archive
IG_BH05_DW013	9-Jul-21	5:45	598.65	601.62																										✓				600m Drill Fluid Archive
IG_BH05_DW014	12-Jul-21	13:00	649.53	652.51																										✓				650m Drill Fluid Archive
IG_BH05_DW015	15-Jul-21	15:40	700.60	703.56																										✓				700m Drill Fluid Archive
IG_BH05_DW016	19-Jul-21	11:40	748.73	751.55																										✓				750m Drill Fluid Archive
IG_BH05_DW017	22-Jul-21	22:45	799.53	802.64																										✓				800m Drill Fluid Archive
IG_BH05_DW018	26-Jul-21	1:19	847.66	850.65																										✓				850m Drill Fluid Archive
IG_BH05_DW019	28-Jul-21	22:00	898.53	901.65																										✓				900m Drill Fluid Archive
IG_BH05_DW020	1-Aug-21	10:20	949.64	952.63																										✓				950m Drill Fluid Archive
IG_BH05_DW021	6-Aug-21	21:09	997.63	1000.63																										✓				1000m Drill Fluid Archive
IG_BH05_WS001	9-May-21	7:30	0.00	0.00	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
IG_BH05_WS002	21-May-21	16:10	100.57	100.57	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Fresh source water sampled prior to drilling with the addition of flocculant additive
IG_BH05_WS003	26-May-21	12:45	100.57	100.57	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
IG_BH05_WS004	4-Jun-21	13:45	160.59	160.59	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
IG_BH05_WS005	28-Jun-21	13:45	391.60	391.60	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
IG_BH05_WS006	30-Jul-21	10:04	913.65	916.62	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
IG_BH05_WS007	30-Aug-21	14:40	1000.63	1000.63	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample transferred from IG_BH06 for testing activities; original sample ID is IG_BH06_WS001
IG_BH05_WS008	25-Oct-21	14:08	1000.63	1000.63	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				

Prepared By: NAS
Checked By: ML
Reviewed By: KDV

Notes
IG_BH05_GWxxx indicates a groundwater sample
IG_BH05_DWxxx indicates a drill water sample
IG_BH05_WSxxx indicates a water source (fresh water supply) sample

[1] In-field measurements include the fluorescein concentration measured with an Aqualuor Fluorometer, and the following parameters measured with a Horiba U52-2 Multiprobe: temperature, pH, electrical conductivity, ORP, turbidity and dissolved oxygen, and density measurements using a hydrometer.

[2] Laboratory analyses completed by Bureau Veritas (BV)

[3] Laboratory analyses completed by Isotope Tracer Technologies (IT2)

[4] Laboratory analyses completed by University of Ottawa (UofO)

[5] Microbiology analyses completed by University of Waterloo; no samples analyzed for microbiology for IG_BH05

[6] IG_BH05_DW003 submitted for Noble Gas analyses, however analyses not performed due to high turbidty of sample

Parameter	Units	Method	Method Detection Limit or Standard Deviation (where noted with ±1 σ)
Major Elements and Metals			
Sodium	mg/L	ICP/MS (CAM SOP-00447)	0.1
Potassium	mg/L	ICP/MS (CAM SOP-00447)	0.2
Calcium	mg/L	ICP/MS (CAM SOP-00447)	0.2
Magnesium	mg/L	ICP/MS (CAM SOP-00447)	0.05
Strontium	mg/L	ICP/MS (CAM SOP-00447)	0.001
Lithium	mg/L	ICP/MS (CAM SOP-00447)	0.005
Silicon	mg/L	ICP/MS (CAM SOP-00447)	0.05
Aluminum	ug/L	ICP/MS (CAM SOP-00447)	4.9
Boron	ug/L	ICP/MS (CAM SOP-00447)	10
Sulphur	mg/L	ICP/MS (CAM SOP-00447)	0.05
Iron	mg/L	ICP/MS (CAM SOP-00447)	0.1
Trace Elements, Anions & Nutrients			
Copper	µg/L	ICP/MS (CAM SOP-00447)	0.50
Nickel	µg/L	ICP/MS (CAM SOP-00447)	1.0
Zinc	µg/L	ICP/MS (CAM SOP-00447)	5.0
Lead	µg/L	ICP/MS (CAM SOP-00447)	0.50
Cadmium	µg/L	ICP/MS (CAM SOP-00447)	0.090
Aluminum	µg/L	ICP/MS (CAM SOP-00447)	4.9
Arsenic	µg/L	ICP/MS (CAM SOP-00447)	1.0
Selenium	µg/L	ICP/MS (CAM SOP-00447)	2.0
Bismuth	µg/L	ICP/MS (CAM SOP-00447)	1.0
Uranium	µg/L	ICP/MS (CAM SOP-00447)	0.10
Cesium	µg/L	ICP/MS (CAM SOP-00447)	0.20
Rubidium	µg/L	ICP/MS (CAM SOP-00447)	0.20
Barium	µg/L	ICP/MS (CAM SOP-00447)	2.0
Chromium	µg/L	ICP/MS (CAM SOP-00447)	5.0
Cobalt	µg/L	ICP/MS (CAM SOP-00447)	0.50
Thorium	µg/L	ICP/MS (CAM SOP-00447)	2.0
Zirconium	µg/L	ICP/MS (CAM SOP-00447)	1.0
Silica	mg/L	KONE (AB SOP-00011)	0.05
Sulphide	mg/L	ISE (CAM SOP-00455)	0.02
Ammonium	as N mg/L	Calculated	0.00061
Total Ammonia	as N mg/L	Colourimetry (CAM SOP-00441)	0.05
Total Nitrogen	mg/L	Calculated	0.1
Total Kjeldahl Nitrogen	mg/L	SKAL (CAM SOP-00938)	0.1
Total Phosphorus	mg/L	Colourimetry (CAM SOP-00407)	0.02
Total Organic Carbon	mg/L	CAM SOP-00446	0.40
Dissolved Organic Carbon	mg/L	CAM SOP-00446	0.40
Bromide	mg/L	Ion Chromatography (CAM SOP-00435)	1.0
Chloride	mg/L	Ion Chromatography (CAM SOP-00435)	1.0
Iodide	mg/L	Ion Chromatography (CAL SOP-00057)	0.1
Fluoride	mg/L	Potentiometry - ISE (CAM SOP-00449)	0.1
Sulphate	mg/L	Automated Colourimetry	1.0
Orthophosphate	mg/L	KONE (CAM SOP-00461)	0.01
Nitrite	as N mg/L	Colourimetry (CAM SOP-00440)	0.01
Nitrate	as N mg/L	Colourimetry (CAM SOP-00440)	0.1
Bicarbonate	mg/L as $CaCO_3$	CAM SOP-00102	1.0
Physical-Chemical			
pH	-	CAM SOP-00413	-
Total Alkalinity	mg/L as $CaCO_3$	CAM SOP-00448	1.0
TIC	mg/L	CAM SOP-00433	1.0

Parameter	Units	Method	Method Detection Limit or Standard Deviation (where noted with ±1 σ)
Rare Earth Elements			
Cerium	µg/L	ICP/MS (STL SOP-00071)	0.6
Dysprosium	µg/L	ICP/MS (STL SOP-00071)	4.0
Erbium	µg/L	ICP/MS (STL SOP-00071)	4.0
Europium	µg/L	ICP/MS (STL SOP-00071)	0.8
Gadolinium	µg/L	ICP/MS (STL SOP-00071)	4.0
Holmium	µg/L	ICP/MS (STL SOP-00071)	0.8
Lanthanum	µg/L	ICP/MS (STL SOP-00071)	1.0
Lutetium	µg/L	ICP/MS (STL SOP-00071)	2.0
Neodymium	µg/L	ICP/MS (STL SOP-00071)	6.0
Praseodymium	µg/L	ICP/MS (STL SOP-00071)	0.8
Ruthenium	µg/L	ICP/MS (STL SOP-00071)	4.0
Samarium	µg/L	ICP/MS (STL SOP-00071)	4.0
Scandium	µg/L	ICP/MS (STL SOP-00071)	10
Terbium	µg/L	ICP/MS (STL SOP-00071)	2.0
Thulium	µg/L	ICP/MS (STL SOP-00071)	0.8
Ytterbium	µg/L	ICP/MS (STL SOP-00071)	4.0
Yttrium	µg/L	ICP/MS (STL SOP-00071)	4.0
Stable Isotopes			
δ^{18}O	VSMOW	Cavity Ring Down Spectroscopy	±0.1‰ (±1 σ)
δ^{2}H	VSMOW	Cavity Ring Down Spectroscopy	±1‰ (±1 σ)
^{87}Sr/^{86}Sr	ratio	Thermal Ionization Mass Spectrometry	±0.0001 (±1 σ)
δ^{13}C DIC	PDB	Finnigan MAT, DeltaPlus XL IRMS	±0.2‰ (±1 σ)
^{37}Cl	per mil SMOC	Isotope Ratio Mass Spectrometry	±0.15‰ (±1 σ)
Radioisotopes			
Potassium-40 (^{40}K)	Bq/kg	Gamma Spectrometry (BQL SOP-00007)	50
Radon-222 (^{222}Rn)	Bq/kg	Gamma Spectrometry (BQL SOP-00007)	10
Total alpha activity	Bq/kg	GFPC (BQL SOP-00008)	0.1
Total beta activity	Bq/kg	GFPC (BQL SOP-00008)	0.1
Lead-210 (^{210}Pb)	Bq/kg	GFPC (BQL SOP-00008)	0.1
Polonium-210 (^{210}Po)	Bq/kg	Alpha Spectrometry (BQL SOP-00006)	0.01
Radium-223 (^{223}Ra)	Bq/kg	Gamma Spectrometry (BQL SOP-00007)	0.5
Radium-224 (^{224}Ra)	Bq/kg	Gamma Spectrometry (BQL SOP-00007)	0.5
Radium-226 (^{226}Ra)	Bq/kg	Gamma Spectrometry (BQL SOP-00007)	1.0
Radium-228 (^{228}Ra)	Bq/kg	Gamma Spectrometry (BQL SOP-00007)	0.5
Uranium-234 (^{234}U)	Bq/kg	Alpha Spectrometry (BQL SOP-00006)	0.01
Uranium-238 (^{238}U)	Bq/kg	Alpha Spectrometry (BQL SOP-00006)	0.01
Thorium-227 (^{227}Th)	Bq/kg	Neutron Activation (BQL SOP-00001)	0.5
Thorium-230 (^{230}Th)	Bq/kg	Neutron Activation (BQL SOP-00001)	5.0
Thorium-232 (^{232}Th)	Bq/kg	Neutron Activation (BQL SOP-00001)	0.01
Strontium-90 (^{90}Sr)	Bq/kg	GFPC (BQL SOP-00008)	0.1
^{36}Cl	ratio	Accelerator Mass Spectrometry	± 8.31E-14 (±1 σ)
^{129}I	atoms/kg	Accelerator Mass Spectrometry	± 1.97E+07 - 5.75E+07 (±1 σ)
^{14}C-DIC	years BP	Accelerator Mass Spectrometry	± 5 - 10% (±1 σ)
^{3}H	TU	Liquid Scintillation Counting	± 0.5 - 1.1 (±1 σ)
Noble Gas Concentrations & Isotopic Ratios			
^{3}He	cm^{3}STP/g	Helix SFT Noble Gas Mass Spectrometer	± 1.91E-13 (±1 σ)
^{4}He	cm^{3}STP/g	Helix SFT Noble Gas Mass Spectrometer	± 1.50E-07 (±1 σ)
^{20}Ne	cm^{3}STP/g	Helix SFT Noble Gas Mass Spectrometer	± 3.23E-07 (±1 σ)
^{21}Ne	cm^{3}STP/g	Helix SFT Noble Gas Mass Spectrometer	± 9.52E-10 (±1 σ)
^{22}Ne	cm^{3}STP/g	Helix SFT Noble Gas Mass Spectrometer	± 3.26E-08 (±1 σ)
^{36}Ar	cm^{3}STP/g	Helix SFT Noble Gas Mass Spectrometer	± 5.79E-07 (±1 σ)
^{40}Ar	cm^{3}STP/g	Helix SFT Noble Gas Mass Spectrometer	± 1.73E-04 (±1 σ)

Notes:

1) Detection limits are not applicable to isotopes as measurement is relative to a standard rather than absolute.

2) When a sample required dilution, the detection limit is adjusted accordingly. Adjusted detection limits are specified in the Laboratory Certificates of Analyses (COAs) for BV included in the data deliverable.

3) Calculated standard deviation values for Noble Gases, ^{3}H, ^{36}Cl, ^{37}Cl and ^{129}I based on results of samples from IG_BH04, IG_BH05 and IG_BH06. All other standard deviation values as reported by laboratories.

Prepared By: NAS
Checked By: ML
Reviewed By: KDV

Sample Type		Water Source								Drill Water
Sample Date and Time		2021-05-09 7:30	2021-05-21 16:10	2021-05-26 12:45	2021-06-04 13:45	2021-06-28 13:45	2021-07-30 10:04	2021-08-30 14:40	2021-10-25 14:08	2021-05-28 14:40
Sample ID		IG_BH05_WS001	IG_BH05_WS002	IG_BH05_WS003	IG_BH05_WS004	IG_BH05_WS005	IG_BH05_WS006	IG_BH05_WS007 [1]	IG_BH05_WS008	IG_BH05_DW003
GENERAL PARAMETERS										
pH (field)	-	7.23	5.63	6.76	6.92	5.66	6.84	7.05	6.76	11.76
Temperature (field)	°C	11.52	25.25	12.9	22.43	18.77	17.03	17.68	13.69	18.02
Density (field)	g/cm^3	1	1	1	1	1.02	1.01	1	1	1
ORP (field)	mV	426	361	334	503	334	343	337	764	74
EC (field)	(ms/cm)	0.059	0.088	0.071	0.05	0.05	0.066	0.051	0.061	1.36
Turbidity (field)	NTU	0	6.4	1	4.9	19.1	0	0	7.4	1000
Fluorescein (field)	ppb	0	0	0	0			0	0	79.48
Dissolved Oxygen (field-Horiba)	mg/L	7.34	4.3	9.12	6.87	7.33	10.63	6.86	5.92	8.26
Dissolved Oxygen (field-Hach) [3]	mg/L	9.6	9	9.3	8.1	8.7	8.6	9.5	9.6	-[5]
Sulphide (field) [3]	mg/L	0	0	0	0	0	0	0	0	-[5]
Ferrous Iron (field) [3]	mg/L	0	0.06	0	0	0	0.05	0	0.03	-[5]
Total Alkalinity (Lab)	mg/L $CaCO_3$	16	1.2	12	15	14	13	13	14	260
Total Alkalinity (Field) [4]	mg/L $CaCO_3$	16.6	7.95	30.7	14.5	31.2	15.45	14	18.27	374.2
Total Alkalinity [2]	mg/L HCO_3-	20	1	15	18	17	16	16	17	317
Hydroxide Alkalinity (speciated)	mg/L $CaCO_3$	0	0	0	0	0	0	0	0	205
Hydroxide Alkalinity (speciated)	mg/L OH-	0	0	0	0	0	0	0	0	70
Carbonate Alkalinity (speciated)	mg/L $CaCO_3$	0	0	0	0	0	0	0	0	54
Carbonate Alkalinity (speciated)	mg/L $CO_3$2-	0	0	0	0	0	0	0	0	32
Bicarbonate Alkalinity (speciated)	mg/L $CaCO_3$	16	1	12	15	14	13	13	14	1
Bicarbonate Alkalinity (speciated)	mg/L HCO_3-	19	2	15	18	17	16	16	17	1
GENERAL CHEMISTRY (LABORATORY)										
pH-Lab	units	7.36	6.15	7.15	7.57	7.19	7.38	7.07	7.39	11.4
Alkalinity-Bicarbonate	mg/L	16	1.2	12	14	14	13	13	14	6.2
Alkalinity-Carbonate	mg/L				<1.0					
Alkalinity-Hydroxide	mg/L				<1.0					
Alkalinity Total as $CaCO_3$	mg/L	16	1.2	12	15	14	13	13	14	260
Total Ammonia as N (NH_4+NH_3)	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	1.1
Bromide (Br)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Chloride (Cl)	mg/L	5.9	6.7	7.2	7.3	6.8	7.2	7.8	7.2	25
Fluoride (F)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.22
Iodide (I)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Nitrate (NO_3)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Nitrite (NO_2)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.016
Nitrate + Nitrite	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Kjeldahl Nitrogen	mg/L	<0.10	0.47	0.1	0.18	0.12	0.22	0.12	<0.10	14
Total Nitrogen	mg/L						0.22	0.12	<0.10	
OrthoPhosphate (PO_4)	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<1.0
Total Phosphorus (P_{tot})	mg/L	<0.020	<0.020	<0.020	<0.020	0.025	<0.020	<0.020	<0.020	<0.40
Sulphate (SO_4)	mg/L	2.7	20	1.5	1.9	2.4	2.3	2.1	2	28
Sulphide as S	mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Sulphide as H_2S	mg/L									
Dissolved Organic Carbon (DOC)	mg/L	2.7	2.8	2.5	2.8	2.5	2.7	3.1	2.3	83
Total Inorganic Carbon (TIC)	mg/L	3	1	3	3	4	3	3	3	<10
Total Organic Carbon (TOC)	mg/L	2.6	3.2	2.5	2.9	2.6	3	3	2.4	270
Reactive Silica (SiO_2)	mg/L	3	3.1	2.8	3	3.4	3.9	4.9	5.3	30
Aluminum (Al) diss.	mg/L	0.02	0.57	0.011	0.025	0.013	0.0088	0.02	0.0089	1.3
Antimony (Sb) diss.	mg/L									
Arsenic (As) diss.	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium (Ba) diss.	mg/L	0.0031	0.0094	0.0024	0.0038	0.005	0.0044	0.0042	0.0037	0.011
Beryllium (Be) diss.	mg/L									
Bismuth (Bi) diss.	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (B) diss.	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.014
Cadmium (Cd) diss.	mg/L	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009	<0.00009
Calcium (Ca) diss.	mg/L	4.1	5.6	4	4.7	4.6	4.3	4.6	4.3	39
Cesium (Cs) diss.	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.00053
Chromium (Cr) diss.	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.025
Cobalt (Co) diss.	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Copper (Cu) diss.	mg/L	<0.0009	0.0023	0.0074	0.0016	<0.0009	0.0012	0.0013	0.0015	0.016
Iron (Fe) diss.	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Lead (Pb) diss.	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Lithium (Li) diss.	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.02
Magnesium (Mg) diss.	mg/L	0.78	0.96	0.8	0.86	0.84	0.82	0.89	0.8	<0.05
Manganese (Mn) Diss.	mg/L									
Molybdenum (Mo) diss.	mg/L									
Nickel (Ni) diss.	mg/L	<0.001	0.0019	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Phosphorus (P) diss	mg/L									
Potassium (K) diss.	mg/L	0.41	0.44	0.41	0.46	0.44	0.46	0.46	0.44	25
Rubidium (Rb) diss.	mg/L	0.0011	0.0014	0.0012	0.0013	0.0015	0.0012	0.0013	0.0013	0.071
Ruthenium (Ru) diss.	mg/L									
Selenium (Se) diss.	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silicon (Si) diss	mg/L	1.3	1.5	1.3	1.4	1.5	1.5	2.1	2.3	15
Silver (Ag) diss	mg/L									
Sodium (Na) diss.	mg/L	4.4	5.1	4.9	5.5	4.7	4.3	5.1	4.6	81
Strontium (Sr) diss.	mg/L	0.012	0.022	0.011	0.012	0.013	0.012	0.013	0.012	0.14
Sulfur (S) diss	mg/L	0.65	6.4	0.66	0.7	0.64	0.68	0.7	0.65	7.5
Tellurium (Te) diss	mg/L									
Thallium (Tl) diss	mg/L									
Thorium (Th) diss.	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Tin (Sn) diss	mg/L									
Titanium (Ti) diss.	mg/L									
Tungston (W) diss.	mg/L									
Uranium (U) diss.	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium (V) diss.	mg/L									
Zinc (Zn) diss.	mg/L	0.0071	0.023	<0.005	0.027	0.022	0.019	0.0064	0.0052	<0.005
Zirconium (Zr) diss.	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Calcium (Ca) unfiltered	mg/L									
Iron (Fe) unfiltered	mg/L									
Lithium (Li) unfiltered	mg/L									
Magnesium (Mg) unfiltered	mg/L									
Potassium (K) unfiltered	mg/L									
Silicon (Si) unfiltered	mg/L									
Sodium (Na) unfiltered	mg/L									
Strontium (Sr) unfiltered	mg/L									
Charge Balance Error	%	-7.6	-3.7	1	0.5	-1.4	-3.5	0.7	-3.7	-3.1

Sample Type		Water Source								Drill Water
Sample Date and Time		2021-05-09 7:30	2021-05-21 16:10	2021-05-26 12:45	2021-06-04 13:45	2021-06-28 13:45	2021-07-30 10:04	2021-08-30 14:40	2021-10-25 14:08	2021-05-28 14:40
Sample ID		IG_BH05_WS001	IG_BH05_WS002	IG_BH05_WS003	IG_BH05_WS004	IG_BH05_WS005	IG_BH05_WS006	IG_BH05_WS007[1]	IG_BH05_WS008	IG_BH05_DW003
Rare Earth Elements and Isoptopes (Laboratory)										
Cerium (Ce)	µg/L	<0.60	<0.48	<0.48	<0.48	<0.48	<0.30	<0.30	<0.30	<0.48
Praesedymium (Pr)	µg/L	<0.80	<0.64	<0.64	<0.64	<0.64	<0.40	<0.40	<0.40	<0.64
Neodymium (Nd)	µg/L	<6.0	<4.8	<4.8	<4.8	<4.8	<3.0	<3.0	<3.0	<4.8
Samarium (Sm)	µg/L	<4.0	<3.2	<3.2	<3.2	<3.2	<2.0	<2.0	<2.0	<3.2
Europium (Eu)	µg/L	<0.80	<0.64	<0.64	<0.64	<0.64	<0.40	<0.40	<0.40	<0.64
Gadolinium (Gd)	µg/L	<4.0	<3.2	<3.2	<3.2	<3.2	<2.0	<2.0	<2.0	<3.2
Terbium (Tb)	µg/L	<2.0	<1.6	<1.6	<1.6	<1.6	<1.0	<1.0	<1.0	<1.6
Disprosium (Dy)	µg/L	<4.0	<3.2	<3.2	<3.2	<3.2	<2.0	<2.0	<2.0	<3.2
Holmium (Ho)	µg/L	<0.80	<0.64	<0.64	<0.64	<0.64	<0.40	<0.40	<0.40	<0.64
Erbium (Er)	µg/L	<4.0	<3.2	<3.2	<3.2	<3.2	<2.0	<2.0	<2.0	<3.2
Lanthanum (La)	µg/L	<1.0	<0.8	<0.8	<0.8	<0.8	<0.5	<0.5	<0.5	<0.8
Lutetium (Lu)	µg/L	<2.0	<1.6	<1.6	<1.6	<1.6	<1.0	<1.0	<1.0	<1.6
Thulium (Tm)	µg/L	<0.8	<0.64	<0.64	<0.64	<0.64	<0.40	<0.40	<0.40	<0.64
Yttrium	µg/L	<4.0	<3.2	<3.2	<3.2	<3.2	<2.0	<2.0	<2.0	<3.2
Ytterbium (Yb)	µg/L	<4.0	<3.2	<3.2	<3.2	<3.2	<2.0	<2.0	<2.0	<3.2
Potassium-40 (^{40}K)	Bq/kg	<50	<50	<50	<50	<50	<50	<50	<50	<50
Radon-222 (^{222}Rn)	Bq/kg	<100	<100	<100	<10	<10	<10	<10	<10	
Total alpha activity	Bq/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total beta activity	Bq/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	0.87
Lead-210 (^{210}Pb)	Bq/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<1.0
Polonium-210 (^{210}Po)	Bq/kg	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Radium-223 (^{223}Ra)	Bq/kg	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Radium-224 (^{224}Ra)	Bq/kg	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Radium-226 (^{226}Ra)	Bq/kg	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<0.010	<1.0
Radium-228 (^{228}Ra)	Bq/kg	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Uranium-234 (^{234}U)	Bq/kg	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Uranium-238 (^{238}U)	Bq/kg	<0.010	<0.01	<0.010	<0.010	0.02	<0.010	<0.010	<0.010	<0.010
Thorium-227 (^{227}Th)	Bq/kg	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Thorium-230 (^{230}Th)	Bq/kg	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Thorium-232 (^{232}Th)	Bq/kg	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Strontium-90 (^{90}Sr)	Bq/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Oxygen-18 of water (δ^{18}O)	per mil VSMOW	-7.81	-7.53	-7.55	-7.56	-7.29	-6.9	-6.74	-6.78	-7.11
Deuterium of water (δ^{2}H)	per mil VSMOW	-67	-65.6	-66.3	-66.3	-64.7	-63.2	-61.7	-61.6	-64.2
Deuterium-excess	per mil									
Tritium (^{3}H)	TU	7.1	6	7.1	9.5	8.9	9	8.4	8	9
Carbon-13 of DIC (δ^{13}C-DIC)	per mil VPDB	-7.8	-8.7	-8.6	-8.5	-10	-6.8	-7.4	-8.4	-29.6
Carbon-14 of DIC (^{14}C-DIC)	pmC	96.44	77.24	100.54	96.91	27.96	96.22	94.74	97.59	92.38
Chlorine-37 (δ^{37}Cl)	per mil SMOC	-1.86	0.35	0.76	0.64	0.61	2.27	-0.02	0.02	0.46
Chlorine-36 (^{36}Cl/Cl)	-	4.4E-13	4.34E-13	3.96E-13	3.9E-13	3.83E-13	3.5E-13	3.67E-13	3.32E-13	-[6]
Iodine-129 (^{129}I)	atoms/kg	9.42E+08	8.99E+08	8.10E+08	8.35E+08	9.36E+08	9.60E+08	1.16E+09	1.14E+09	7.51E+08
Stronium isotope ratio (^{87}Sr/^{86}Sr)	-	0.7275	0.71959	0.72965	0.7287	0.72287	0.72587	0.72852	0.72904	0.72311
Helium-4	cm^{3}STP/g	6.21E-08	6.82E-08	1.11E-07	3.64E-08	3.33E-07	9.22E-08	1.01E-07	3.96E-07	-[6]
Helium-3	cm^{3}STP/g	9.42E-14	9.01E-14	1.58E-13	4.64E-14	3.95E-13	1.06E-13	1.27E-13	5.21E-13	-[6]
Helium isotope ratio (^{3}He/4He)	-									
Neon	cm^{3}STP/g									
Neon-20	cm^{3}STP/g	1.50E-07	2.47E-07	4.47E-07	1.26E-07	9.22E-07	3.41E-07	3.60E-07	7.29E-07	-[6]
Neon-21	cm^{3}STP/g	4.41E-10	7.32E-10	1.33E-09	3.71E-10	2.73E-09	1.01E-09	1.07E-09	2.13E-09	-[6]
Neon-22	cm^{3}STP/g	0.000000015	2.53E-08	4.59E-08	1.28E-08	9.38E-08	3.48E-08	3.68E-08	7.27E-08	-[6]
Neon isotope ratio (^{20}Ne/^{22}Ne)	-									
Argon	cm^{3}STP/g									
Argon-36	cm^{3}STP/g	5.85E-07	9.53E-07	1.40E-06	3.95E-07	4.23E-07	1.01E-06	1.16E-06	4.11E-07	-[6]
Argon-40	cm^{3}STP/g	1.74E-04	2.85E-04	4.16E-04	1.17E-04	1.25E-04	2.95E-04	3.47E-04	1.19E-04	-[6]
Argon isotope ratio (^{40}Ar/^{36}Ar)	-									
Krypton	cm^{3}STP/g									
Krypton-184	cm^{3}STP/g									
Xenon	cm^{3}STP/g									
Xenon-132	cm^{3}STP/g									

Notes:

[1] Data corresponds to that originally reported for IG_BH06_WS001.

[2] Total Alkalinity as HCO3^{-} calculated based on laboratory reported alkalinity result. Where only a field reported alkalinity result was available, the field value was used.

[3] Hach model DR2800 Spectrophotometer used for field readings.

[4] Alkalinity kit model 10-400 mg/L Model AL-DT used for field titration.

[5] Sulphide, DO and Ferrous Iron were over the measurement range of the Hach Spectrophotometer and not reported.

[6] IT2 had insuffient sample to run the ^{36}Cl/Cl analysis. Noble gas analyses not performed due to high turbidity of sample .

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Where blanks appear throughout this table, no results are available.
For Charge Balance, Total Alkalinity and speciated value calculations, see Calculations spreadsheet as part of the Data Deliverable
"BDL": Result below method detection limit.

APPENDIX B

Analytical In-field Analysis Procedures

1.0 ANALYTICAL IN-FIELD PARAMETER MEASUREMENTS

The sample analyses for alkalinity, total sulfide, dissolved oxygen and ferrous iron can be impacted by contact with the atmosphere. The fresh water used for borehole drilling and flushing purposes, sampled as water source (WS), was collected from a municipal source, and transferred to holding tanks using a water truck with pumps and hoses, and was therefore in continuous contact with the atmosphere. The in-field analyses described in this appendix were therefore carried out without preventing contact to the atmosphere. No opportunistic groundwater (OGW) samples were collected and only the procedures used for water source sample analyses are described.

Alkalinity

Alkalinity of the WS sample was measured in the field using a titration method that determines the phenolphthalein and total alkalinities. The titration method consists of incremental addition of sulphuric acid (H_2SO_4), while using phenolphthalein and bromcresol green-methyl red indicators to visually identify key endpoints in the titration. Once the phenolphthalein and total alkalinities were determined, the proportion of the phenolphthalein alkalinity relative to the total alkalinity was used to estimate the hydroxide, carbonate and bicarbonate alkalinities.

The WS sample for alkalinity analysis was first collected by passing the sample through a 0.45 µm groundwater filter and into a clean flask (rinsed with nanopure deionized water). Next, a Hach kit and digital titrator was used to complete alkalinity measurements.

Sulphide

Total sulphide (S^{2-}_{Total}) was measured in the field after sample collection using the Methylene Blue Method. Hach sulphide reagents and spectrophotometer was used to carry out the analysis in the field. First, two standard Hach reagents, referred to as Sulphide 1 Reagent and Sulphide 2 Reagent, were readied by loading two separate 1 mL syringes (fitted with a hypodermic needle) with 0.5 mL of each reagent with no headspace. A blank was prepared with 25 mL nanopure deionized water in a Hach spectrophotometer sample cell; the blank was used to zero the Hach spectrophotometer before reading the WS sample. The Hach spectrophotometer was turned on and readied, as it needs time to warm-up prior to use. These steps were completed first to minimize the time between the WS sample preparation and the analysis.

Next, a glass syringe was used to extract about 25 mL of the sample and then any air was removed with some of the sample; this was to ensure there was no headspace. Once the 25 mL sample was attained, the syringe had the tip capped with a rubber septum. If there were air bubbles present after attaching the rubber septum, additional sample was collected and the process repeated. The syringe with 0.5 mL of Sulphide 1 Reagent was then immediately inserted through the rubber septum into the glass syringe and the first reagent was then injected into the WS sample. The syringe with 0.5 mL of Sulphide 2 Reagent was then immediately inserted through the rubber septum into the glass syringe and the second reagent was then injected into the WS sample. The reagents also needed to be added to the blank in the same sequence immediately after adding to the WS sample: 0.5 mL of Sulphide 1 Reagent, then 0.5 mL of Sulphide 2 Reagent. The timer on the Hach spectrophotometer was then started for a 5 minimum reaction time. Once the 5-minute reaction time was complete, the blank was inserted into the Hach spectrophotometer to zero the instrument. The sample in the glass syringe was then injected into a sample cell and inserted into the Hach spectrophotometer for an immediate sample reading; the reading value was recorded directly into the AcQuire groundwater sampling data entry object. If there is dissolved sulphide in the WS sample, the sample will turn a blue colour during the reaction time; therefore, the colour of the WS sample was recorded in field notes as a qualitative indicator of presence/absence of sulphide. Given the importance of the potential presence of dissolved sulphide on the long-term chemical stability of some of the barrier components associated with the deep geological repository, this procedure was repeated twice to attain a duplicate in-field measurement of total sulphide (S^{2-}_{Total}).

Prior to collecting the WS sample, a series of five sulphide standards were prepared using a sulphide stock standard solution (Radiello™ Methylene Blue Calibration Standard). Using the stock standard solution, five standards were prepared at different concentrations that are expected to encompass the range of sulphide concentrations in a potential OGW sample (0.01 mg/L to 1 mg/L). The known concentrations of the standards can be compared to the values measured using the Hach spectrophotometer to determine a sample-specific correction factor. Preparation and analysis of standards were completed prior to the start of, and during, field work as a QA check on the operation of the Hach spectrophotometer and recorded in the Data Quality Confirmation Workbook.

The concentrations of hydrogen sulphide (H_2S) and unionized hydrogen sulphide (or bisulphide ion, HS^-) were calculated using the total sulphide (S^{2-}_{total}) concentration and pH. Concentration of S^{2-} ions will not be measured or calculated, given that the concentrations of S^{2-} ions under natural conditions are negligible.

Dissolved Oxygen

Dissolved oxygen (DO) was measured in the field after sample collection using the Indigo Carmine Method. Hach AccuVac Ampuls and spectrophotometer were used to carry out the analysis in the field. The Hach AccuVac Ampuls are glass cells pre-loaded with reagent and under a vacuum so that the sample is sucked into the ampul without exposure to atmospheric conditions. The DO results were compared to the DO measured using the multiprobe; all values were recorded in the Data Quality Confirmation Workbook.

Ferrous Iron

Ferrous iron (Fe^{2+}) was measured in the field after sample collection using the 1-10 Phenanthroline Method. Hach Ferrous Iron Reagent powder pillows and spectrophotometer were used to carry out the analysis in the field. A Ferrous Iron Reagent powder pillow was added to 25 mL of sample and then inverted to mix the contents. The timer on the Hach spectrophotometer was then started for a 3 minimum reaction time. A blank was then prepared using 10 mL of nanopure deionized water. Once the 3-minute reaction time was complete, the blank was inserted into the Hach spectrophotometer to zero the instrument. This method is only applicable for concentrations up to 3 mg/L; in the case when samples contain concentrations of ferrous iron greater than 3 mg/L, the sample would need to be diluted with nanopure deionized water (attained from a laboratory) to bring the concentration within the detection range of the method. The concentration would then be corrected by the dilution factor.

Similar to the hydrogen sulphide analysis, a series of five ferrous iron standards were prepared using ferrous ammonium sulfate, hexahydrate ($Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$). These standards were prepared at different concentrations, which are expected to encompass the range of ferrous iron concentrations in a potential OGW sample; in this case, it was expected that the concentrations will be relatively low (<1 mg/L). The standards were analysed using the 1-10 Phenanthroline Method and the known concentrations of the standards can be compared to the values measured using the Hach spectrophotometer to determine a sample-specific correction factor. Preparation and analysis of standards were completed prior to the start of, and during field work as a QA check on the operation of the Hach spectrophotometer and recorded in the Data Quality Confirmation Workbook.

2.0 SAMPLE COLLECTION FOR MICROBIOLOGY RESEARCH AND DEVELOPMENT

No Opportunistic Groundwater Samples (OGW) were collected, and therefore, no corresponding microbiology samples were collected.

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