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

WP07 Data Report - Opportunistic Groundwater Sampling for IG_BH04

APM-REP-01332-0281 **October 2023**

WSP Canada Inc.

NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

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REPORT

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WP07 Data Report - Opportunistic Groundwater Sampling for IG_BH04

Submitted to:

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20253946 (4070)

NWMO Report: APM-REP-01332-0281

October 2023

Distribution List

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WP07 DATA REPORT
OPPORTUNISTIC GROUNDWATER SAMPLING FOR IG_BH04

CLIENT INFORMATION

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

Project Number: 20253946

Client PO Number: 2001102

Document Name: 20253946 (4070) ig_bh04_wp07_report_r2a

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ISSUE/REVISION INDEX

Issue Code	Revision					Revision Details
	No	By	Rev'd.	App.	Date	
RR	R0a	AKV/BT	NAS	KD	1 March 2023	Draft released for review and comment
RI	R1a	AKV/BT	NAS	KD	13 April 2023	Final released for information
RI	R1b	AKV/BT	NAS	KD	12 May 2023	Final released for information
RI	R2a	ML	NAS	KD	27 October 2023	Final released for information

Issue Codes: RR = Released for Review and Comments, RI = Released for Information

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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 for IG_BH04 comprised of a total of eleven work packages, with involvement from a team led by Golder Associates Ltd. (now WSP Canada Inc.) on behalf of the NWMO in nine of these packages. The IG_BH04 program is described in a Borehole Characterization Plan (BCP) for IG_BH04.

This report describes the methodology, activities and results for Work Package 7 (WP07): Opportunistic Groundwater Sampling for IG_BH04, which includes post-drilling identification of permeable intervals during 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_BH04, which describes the water management for plug drilling and flushing activities. For results of opportunistic groundwater sampling carried out during drilling, refer to Wood, 2022.

IG_BH04 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_BH04 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_BH04 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).

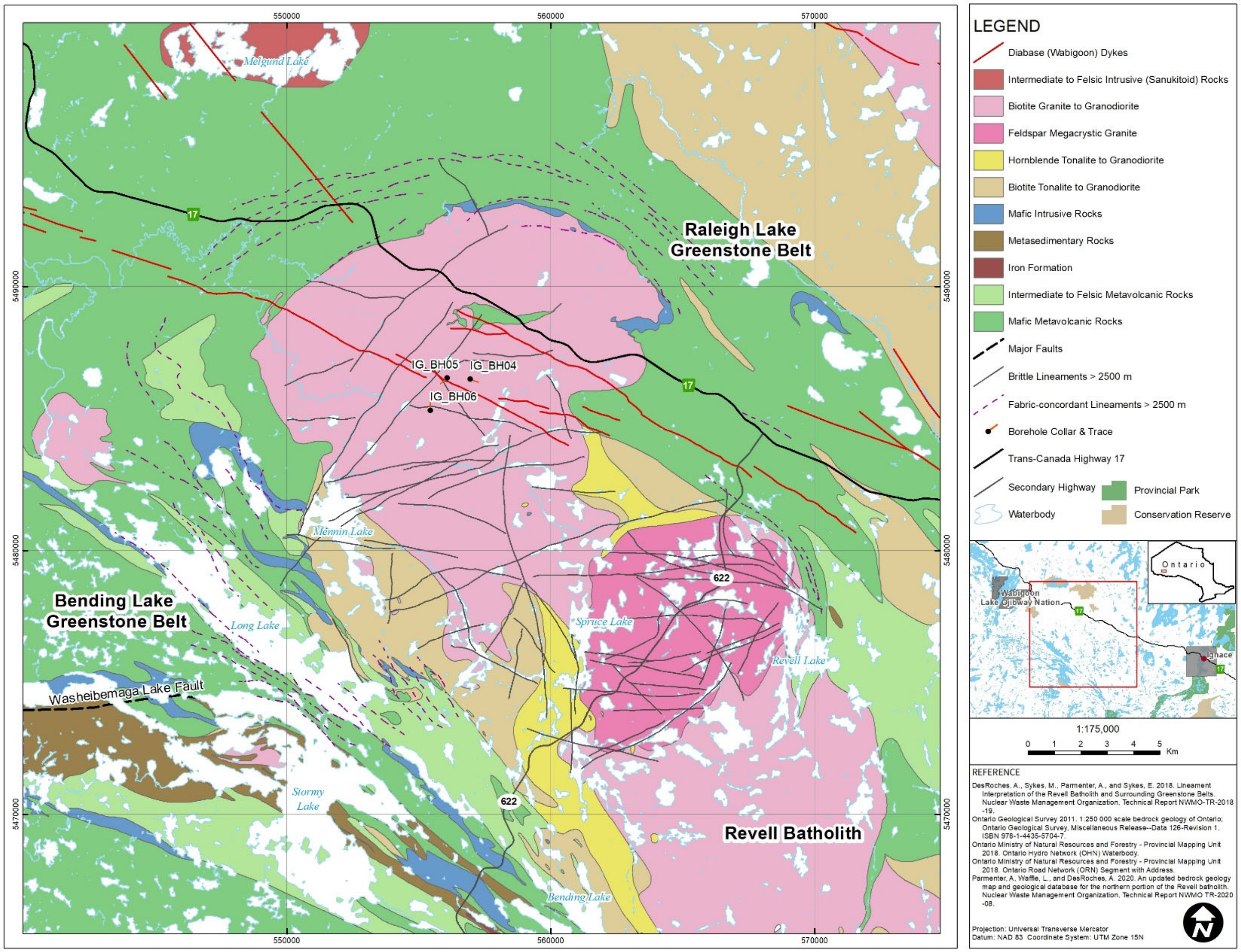

Figure 1: Geological Setting and Location of Boreholes IG_BH04, IG_BH05, and IG_BH06 in the Northern Portion of the Revell Batholith

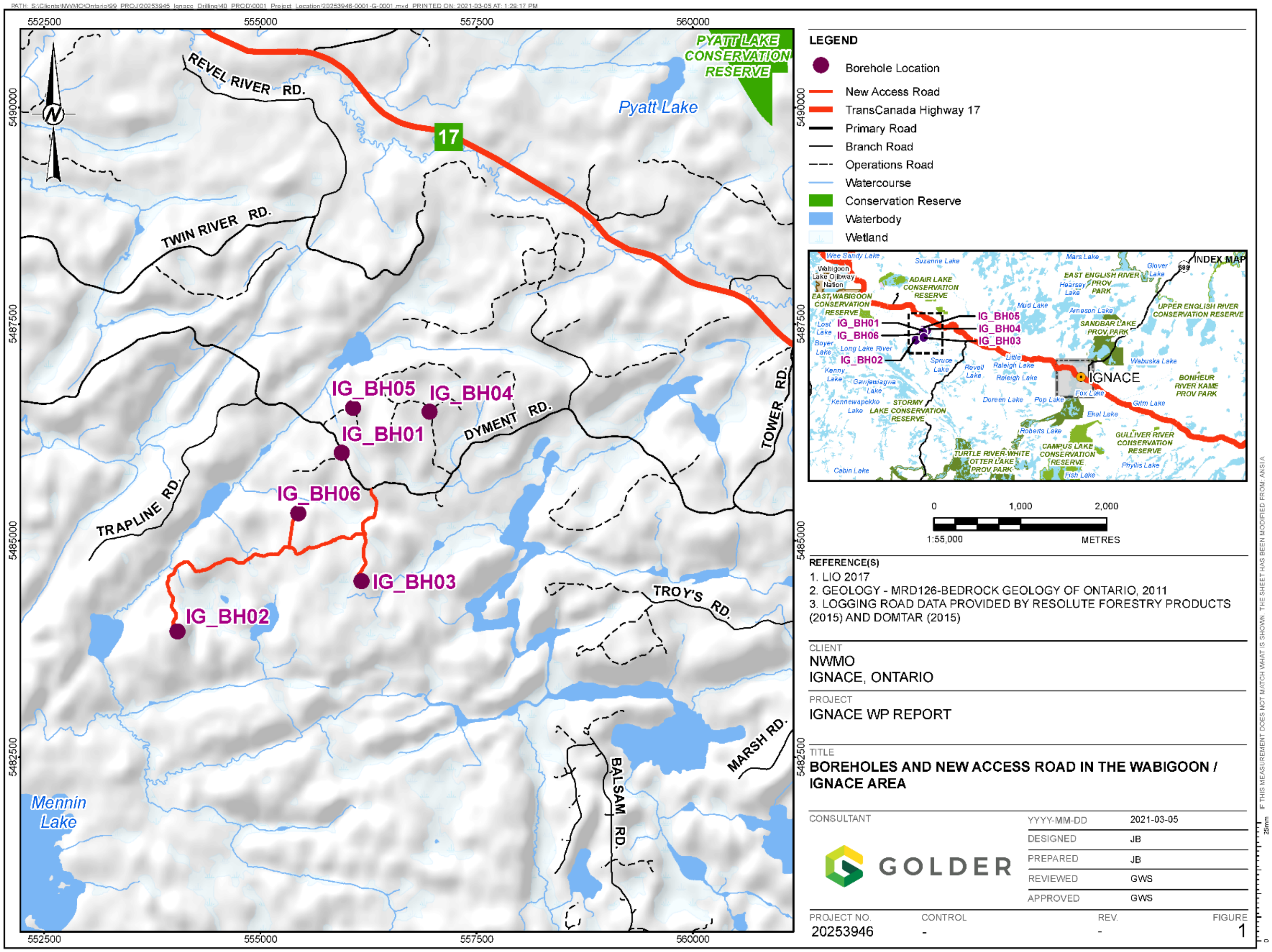

Figure 2: Location of IG_BH04 in Relation to the Ignace Area

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 post-drilling under WP02 to characterize the source water prior to introducing it to the drill system. They were denoted IG_BH04_WSXXX (“water source”) and included laboratory analyses, in-field parameters, and in-field geochemistry analyses.
- No viable Opportunistic Groundwater samples were collected post-drilling and therefore no associated drill water samples for QAQC or microbiology were collected.
- No post-drilling groundwater 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_BH04 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 hydraulic testing (WP06), of permeable intervals for collecting OGW samples;
- Collection and preservation of OGW sample volumes for geochemical analysis;
- 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.

3.3 Methodology

3.3.1 Roles and Responsibilities

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

- 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 Golder 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 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; 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 (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 Golder WP02 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 approximately 50 m intervals, starting at approximately 390 m. This data is presented in the WP02 Data Report. As described in the WP02 report (WSP Golder, 2022a), monitoring of the drill fluid volume changes was not required, since the main objective of the drilling and flushing was to prepare the borehole for the proceeding Work Packages. 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 Flushing Report (WSP Golder, 2022a).

3.3.3 Interval Selection

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 QA/QC

A Data Quality Confirmation (DQC) workbook was filled out for each fluid sample collected (water source, drill fluid or groundwater) for IG_BH04. As no opportunistic groundwater sample attempts were made during post-drilling activities for IG_BH04, no associated DQC workbooks were populated. For the water source 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 samples. 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.

Equipment Decontamination

As there were no opportunistic groundwater sample attempts carried out during post-drilling activities for IG_BH04, no equipment decontamination was required.

Field Blanks and Duplicates

No QA/QC samples were collected during post-drilling activities for IG_BH04.

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 1, 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 1: 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)

Parameter Group	Parameter List	Bottle Type Requirement	Sample Volume Requirement	Field Filtering Requirement	Preservative Requirement	Analytical Laboratory
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 & Beta, ^{210}Po, ^{210}Pb, ^{90}Sr		5 X 1 L	Yes, 0.45 µm filter	Trace grade nitric acid	
Stable Isotopes	$\delta^{18}O$, 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	

Parameter Group	Parameter List	Bottle Type Requirement	Sample Volume Requirement	Field Filtering Requirement	Preservative Requirement	Analytical Laboratory
	$\delta^{13}C$ 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	

3.3.5 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

Potential sample intervals were expected to be identified during WP06 activities. During the hydraulic testing of IG_BH04, there were no intervals encountered where assessments of the hydraulic conductivity indicated that there would be sufficient inflow into the borehole to attempt a purge rate assessment, and therefore no purge rate assessments were carried out and no opportunistic groundwater samples were collected.

A total of three (3) water source samples are presented in this report as follows:

- IG_BH04_WS016: This water source sample was collected from the initial batch of fresh water used for plug drilling and flushing activities at IG_BH04 and was submitted for laboratory analyses under WP07 for IG_BH04.
- IG_BH04_WS017: This water source sample represents IG_BH05_WS001, of which some volume was transferred from the IG_BH05 drill site for use during testing activities at IG_BH04. This sample was submitted for laboratory analyses under WP07 for IG_BH05, with the results presented here under the corresponding IG_BH04 sample ID.
- IG_BH04_WS018: This water source sample represents IG_BH05_WS004, of which some volume was transferred from the IG_BH05 drill site for use during testing activities at IG_BH04. This sample was submitted for laboratory analyses under WP07 for IG_BH05, with the results presented here under the corresponding IG_BH04 sample ID.

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 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

There were no opportunistic groundwater sample attempts carried out during plug drilling or post-drilling testing of IG_BH04.

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_BH04 collected from the municipal source from April 18, 2021 to June 4, 2021. The results are summarized as follows:

- Field pH ranged from 6.92 to 7.23;
- Total alkalinity ranged from 15 to 17 mg/L $CaCO_3$ in-field measured values, and ranged from 15 to 16 mg/L $CaCO_3$ in laboratory measured values;
- Sulphate ranged from 1.9 to 2.7 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 6.87 to 12.1 mg/L in samples measured by the Horiba probe;
- Oxygen-18 ($\delta^{18}O$) ranged from -7.81 to 7.56 ‰ VSMOW;
- Deuterium ($\delta^{2}H$) ranged from -67.5 to -66.3 ‰ VSMOW;
- $\delta^{13}C$-DIC ranged from -8.5 to -5.4 ‰ PDB;
- ^{14}C-DIC ranged from 96.4 to 98.2 percent Modern Carbon (pMC) or 147 to 291 years before present (BP). 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 6.6 to 9.5 TU; and
- $^{87}Sr/^{86}Sr$ ratio ranged from 0.727 to 0.729.

Relative results of key major ions are presented in a piper plot in Figure 3. Water source samples 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 a higher proportion of bicarbonate relative to other anions.

Oxygen-18 and deuterium results are presented in Figure 4 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.

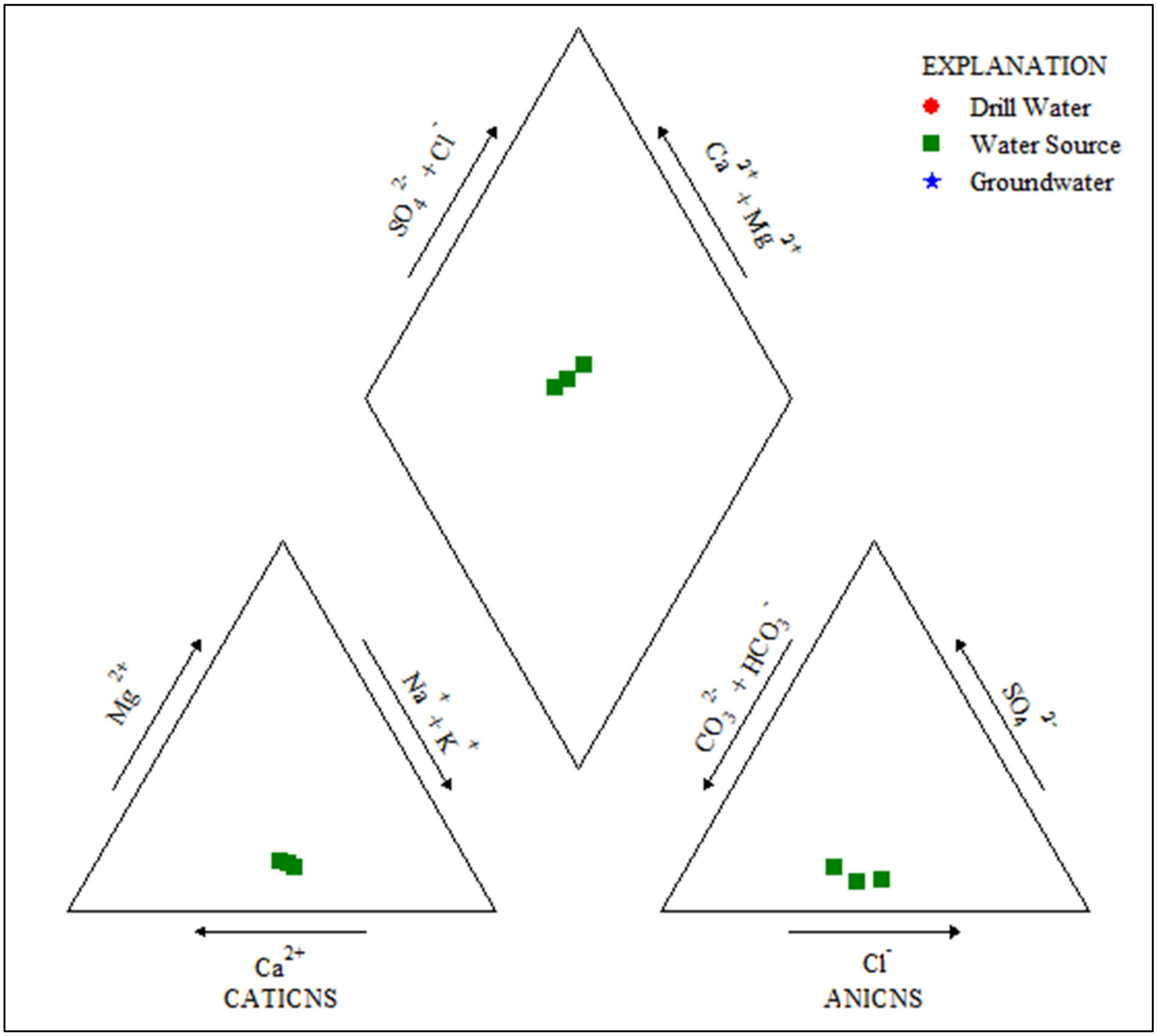

Figure 3: Piper plot of select WP07 water samples

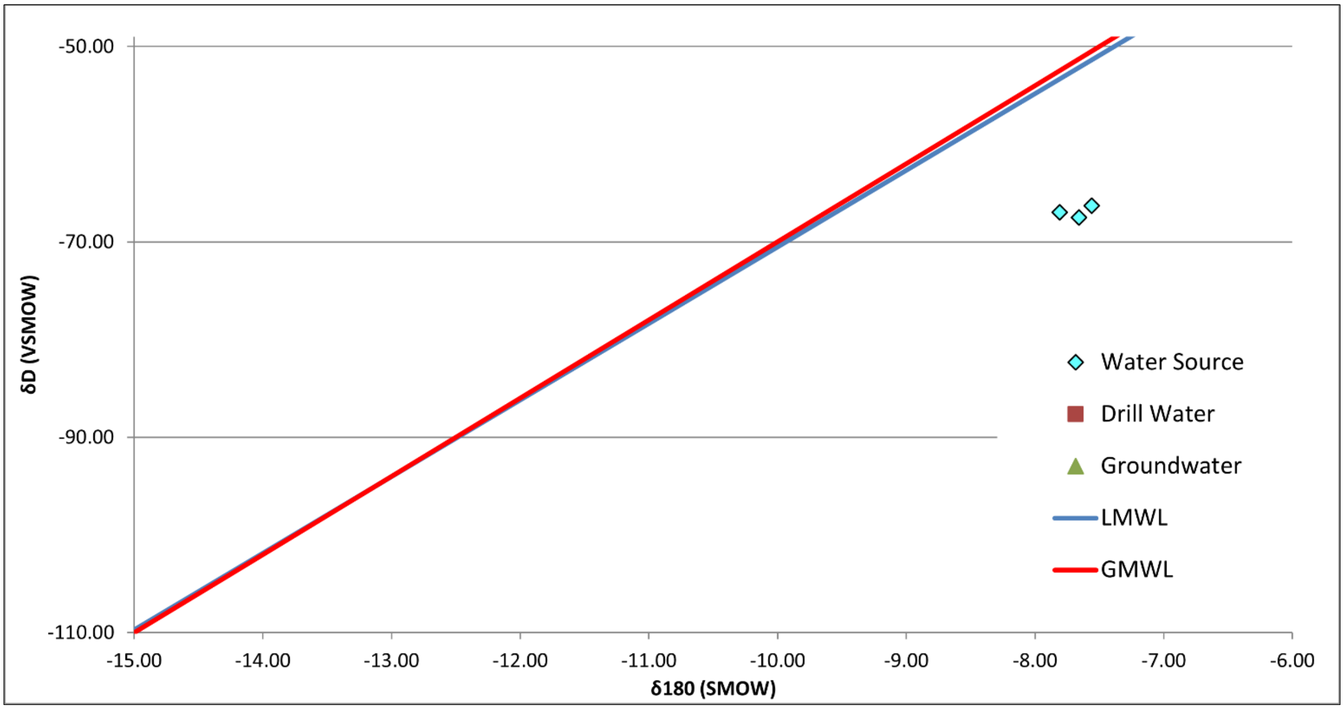

Figure 4: Oxygen (δ18O) - Deuterium (δ2H) plot of WP07 water samples. Local Meteoric Water Line for Atikokan, Ontario (Fritz et al., 1987).

4.3 Drill Water Samples

No drill water samples were collected during plug drilling or post-drilling testing of IG_BH04.

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APPENDIX A

Table A-1: Sample Summary Description for IG_BH04 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										
					Major Elements & Metals[2]	Trace Elements, Anions and Nutrients[2]							Physical-Chemical[2]	Rare Earth Elements[2]	Radioisotopes[2]
			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
IG_BH04_WS016	18-Apr-21	9:00	1000.20	1000.20	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IG_BH04_WS017	9-May-21	7:30	1000.36	1000.36	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IG_BH04_WS018	04-Jun-21	13:45	1000.36	1000.36	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Sample ID	Bottle Sets for Laboratory Analysis										In-Field Geochemistry				In-Field Measurements[1]	Microbiology[5]			Purpose of Sample
	Stable Isotopes[3]				Radioisotopes[3]				Noble Gas Concentration & Isotopic Ratios[4]		Sulphide	Dissolved Oxygen	Ferrous Iron	Alkalinity		PLFA	DNA	Cell Count	
	$\delta^{18}O$, $\delta^{2}H$	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ 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_BH04_WS016	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample for drilling of plugs and borehole flushing
IG_BH04_WS017	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample transferred from IG_BH05 for testing activities; original sample ID is IG_BH05_WS001
IG_BH04_WS018	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				Water source sample transferred from IG_BH05 for testing activities; original sample ID is IG_BH05_WS004

Notes
IG_BH04_GWxxx indicates a groundwater sample
IG_BH04_DWxxx indicates a drill water sample
IG_BH04_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_BH04

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

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			
$\delta^{18}O$	VSMOW	Cavity Ring Down Spectroscopy	±0.1‰ (±1 σ)
$\delta^{2}H$	VSMOW	Cavity Ring Down Spectroscopy	±1‰ (±1 σ)
$^{87}Sr/^{86}Sr$	ratio	Thermal Ionization Mass Spectrometry	±0.0001 (±1 σ)
$\delta^{13}C$ 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^3STP/g	Helix SFT Noble Gas Mass Spectrometer	± 1.91E-13 (±1 σ)
^{4}He	cm^3STP/g	Helix SFT Noble Gas Mass Spectrometer	± 1.50E-07 (±1 σ)
^{20}Ne	cm^3STP/g	Helix SFT Noble Gas Mass Spectrometer	± 3.23E-07 (±1 σ)
^{21}Ne	cm^3STP/g	Helix SFT Noble Gas Mass Spectrometer	± 9.52E-10 (±1 σ)
^{22}Ne	cm^3STP/g	Helix SFT Noble Gas Mass Spectrometer	± 3.26E-08 (±1 σ)
^{36}Ar	cm^3STP/g	Helix SFT Noble Gas Mass Spectrometer	± 5.79E-07 (±1 σ)
^{40}Ar	cm^3STP/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		
Sample Date and Time		2021-04-18 9:00	2021-05-09 7:30	2021-06-04 13:45
Sample ID		IG_BH04_WS016 [1]	IG_BH04_WS017 [2]	IG_BH04_WS018 [3]
GENERAL PARAMETERS				
pH (field)	-	6.97	7.23	6.92
Temperature (field)	°C	8.13	11.52	22.43
Density (field)	g/cm^3	1	1	1
ORP (field)	mV	640	426	503
EC (field)	(ms/cm)	0.064	0.059	0.05
Turbidity (field)	NTU	7.8	0	4.9
Fluorescein (field)	ppb	0	0	0
Dissolved Oxygen (field-Horiba)	mg/L	12.1	7.34	6.87
Dissolved Oxygen (field-Hach) [5]	mg/L		9.6	8.1
Sulphide (field)	mg/L		BDL	BDL
Ferrous Iron (field)	mg/L		BDL	BDL
Total Alkalinity (Lab)	mg/L $CaCO_3$	15	16	15
Total Alkalinity (Field) [6]	mg/L $CaCO_3$	17	17	15
Total Alkalinity (for calc)	mg/L $CaCO_3$	15	16	15
Total Alkalinity [4]	mg/L HCO_3-	18	20	18
Hydroxide Alkalinity (speciated)	mg/L $CaCO_3$	0	0	0
Hydroxide Alkalinity (speciated)	mg/L OH-	0	0	0
Carbonate Alkalinity (speciated)	mg/L $CaCO_3$	0	0	0
Carbonate Alkalinity (speciated)	mg/L $CO_3$2-	0	0	0
Bicarbonate Alkalinity (speciated)	mg/L $CaCO_3$	15	16	15
Bicarbonate Alkalinity (speciated)	mg/L HCO_3-	18	19	18
GENERAL CHEMISTRY (LABORATORY)				
pH-Lab	units	7.45	7.36	7.57
Alkalinity-Bicarbonate	mg/L	15	16	14
Alkalinity-Carbonate	mg/L			<1.0
Alkalinity-Hydroxide	mg/L			<1.0
Alkalinity Total as $CaCO_3$	mg/L	15	16	15
Total Ammonia as N (NH_4+NH_3)	mg/L	<0.050	<0.050	<0.050
Bromide (Br)	mg/L	<1.0	<1.0	<1.0
Chloride (Cl)	mg/L	9.4	5.9	7.3
Fluoride (F)	mg/L	<0.10	<0.10	<0.10
Iodide (I)	mg/L	<0.10	<0.10	<0.10
Nitrate (NO_3)	mg/L	<0.10	<0.10	<0.10
Nitrite (NO_2)	mg/L	<0.010	<0.010	<0.010
Nitrate + Nitrite	mg/L	<0.10	<0.10	<0.10
Total Kjeldahl Nitrogen	mg/L	0.31	<0.10	0.18
Total Nitrogen	mg/L			
OrthoPhosphate (PO_4)	mg/L	<0.010	<0.010	<0.010
Total Phosphorus (P_{tot})	mg/L	0.022	<0.020	<0.020
Sulphate (SO_4)	mg/L	2.2	2.7	1.9
Sulphide as S	mg/L	<0.020	<0.020	<0.020
Sulphide as H_2S	mg/L			
Dissolved Organic Carbon (DOC)	mg/L	3.2	2.7	2.8
Total Inorganic Carbon (TIC)	mg/L	3	3	3
Total Organic Carbon (TOC)	mg/L	3.2	2.6	2.9
Reactive Silica (SiO_2)	mg/L	2.8	3	3

Sample Type		Water Source		
Sample Date and Time		2021-04-18 9:00	2021-05-09 7:30	2021-06-04 13:45
Sample ID		IG_BH04_WS016 [1]	IG_BH04_WS017 [2]	IG_BH04_WS018 [3]
Aluminum (Al) diss.	mg/L	0.0076	0.02	0.025
Antimony (Sb) diss.	mg/L			
Arsenic (As) diss.	mg/L	<0.001	<0.001	<0.001
Barium (Ba) diss.	mg/L	0.005	0.0031	0.0038
Beryllium (Be) diss.	mg/L			
Bismuth (Bi) diss.	mg/L	<0.001	<0.001	<0.001
Boron (B) diss.	mg/L	<0.01	<0.01	<0.01
Cadmium (Cd) diss.	mg/L	<0.00009	<0.00009	<0.00009
Calcium (Ca) diss.	mg/L	4.9	4.1	4.7
Cesium (Cs) diss.	mg/L	<0.0002	<0.0002	<0.0002
Chromium (Cr) diss.	mg/L	<0.005	<0.005	<0.005
Cobalt (Co) diss.	mg/L	<0.0005	<0.0005	<0.0005
Copper (Cu) diss.	mg/L	0.0015	<0.0009	0.0016
Iron (Fe) diss.	mg/L	<0.1	<0.1	<0.1
Lead (Pb) diss.	mg/L	<0.0005	<0.0005	<0.0005
Lithium (Li) diss.	mg/L	<0.005	<0.005	<0.005
Magnesium (Mg) diss.	mg/L	0.86	0.78	0.86
Manganese (Mn) Diss.	mg/L			
Molybdenum (Mo) diss.	mg/L			
Nickel (Ni) diss.	mg/L	<0.001	<0.001	<0.001
Phosphorus (P) diss	mg/L			
Potassium (K) diss.	mg/L	0.44	0.41	0.46
Rubidium (Rb) diss.	mg/L	0.001	0.0011	0.0013
Ruthenium (Ru) diss.	mg/L			
Selenium (Se) diss.	mg/L	<0.002	<0.002	<0.002
Silicon (Si) diss	mg/L	1.3	1.3	1.4
Silver (Ag) diss	mg/L			
Sodium (Na) diss.	mg/L	6.2	4.4	5.5
Strontium (Sr) diss.	mg/L	0.011	0.012	0.012
Sulfur (S) diss	mg/L	0.63	0.65	0.7
Tellurium (Te) diss	mg/L			
Thallium (Tl) diss	mg/L			
Thorium (Th) diss.	mg/L	<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
Vanadium (V) diss.	mg/L			
Zinc (Zn) diss.	mg/L	0.025	0.0071	0.027
Zirconium (Zr) diss.	mg/L	<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	%	-1.6	-7.6	0.5

Sample Type		Water Source		
Sample Date and Time		2021-04-18 9:00	2021-05-09 7:30	2021-06-04 13:45
Sample ID		IG_BH04_WS016 [1]	IG_BH04_WS017 [2]	IG_BH04_WS018 [3]
Rare Earth Elements and Isotopes (Laboratory)				
Cerium (Ce)	ug/L	<0.60	<0.60	<0.48
Praesedymium (Pr)	ug/L	<0.80	<0.80	<0.64
Neodymium (Nd)	ug/L	<6.0	<6.0	<4.8
Samarium (Sm)	ug/L	<4.0	<4.0	<3.2
Europium (Eu)	ug/L	<0.80	<0.80	<0.64
Gadolinium (Gd)	ug/L	<4.0	<4.0	<3.2
Terbium (Tb)	ug/L	<2.0	<2.0	<1.6
Disprosium (Dy)	ug/L	<4.0	<4.0	<3.2
Holmium (Ho)	ug/L	<0.80	<0.80	<0.64
Erbium (Er)	ug/L	<4.0	<4.0	<3.2
Lanthanum (La)	ug/L	<1.0	<1.0	<0.80
Lutetium (Lu)	ug/L	<2.0	<2.0	<1.6
Thulium (Tm)	ug/L	<0.80	<0.80	<0.64
Yttrium	ug/L	<4.0	<4.0	<3.2
Ytterbium (Yb)	ug/L	<4.0	<4.0	<3.2
Potassium-40 (^{40}K)	Bq/kg	<50	<50	<50
Radon-222 (^{222}Rn)	Bq/kg	180	<100	<10
Total alpha activity	Bq/kg	<0.10	<0.10	<0.10
Total beta activity	Bq/kg	<0.10	<0.10	<0.10
Lead-210 (^{210}Pb)	Bq/kg	<0.10	<0.10	<0.10
Polonium-210 (^{210}Po)	Bq/kg	<0.010	<0.010	<0.010
Radium-223 (^{223}Ra)	Bq/kg	<0.50	<0.50	<0.50
Radium-224 (^{224}Ra)	Bq/kg	<0.50	<0.50	<0.50
Radium-226 (^{226}Ra)	Bq/kg	<1.0	<1.0	<1.0
Radium-228 (^{228}Ra)	Bq/kg	<0.50	<0.50	<0.50
Uranium-234 (^{234}U)	Bq/kg	<0.010	<0.010	<0.010
Uranium-238 (^{238}U)	Bq/kg	<0.01	<0.010	<0.010
Thorium-227 (^{227}Th)	Bq/kg	<0.50	<0.50	<0.50
Thorium-230 (^{230}Th)	Bq/kg	<5.0	<5.0	<5.0
Thorium-232 (^{232}Th)	Bq/kg	<0.01	<0.01	<0.01
Strontium-90 (^{90}Sr)	Bq/kg	<0.10	<0.10	<0.10
Oxygen-18 of water ($\delta^{18}O$)	per mil VSMOW	-7.66	-7.81	-7.56
Deuterium of water ($\delta^{2}H$)	per mil VSMOW	-67.5	-67.0	-66.3
Deuterium-excess	per mil			
Tritium (^{3}H)	TU	6.6	7.1	9.5
Carbon-13 of DIC ($\delta^{13}C$-DIC)	per mil VPDB	-5.4	-7.8	-8.5
Carbon-14 of DIC (^{14}C-DIC)	pmC	0.9818	0.9644	0.9691
Chlorine-37 ($\delta^{37}Cl$)	per mil SMOC	1.08	-1.86	0.64
Chlorine-36 ($^{36}Cl/Cl$)	-	3.02E-13	4.40E-13	3.90E-13
Iodine-129 (^{129}I)	atoms/kg	1.20E+09	9.42E+08	8.35E+08
Stronium isotope ratio ($^{87}Sr/^{86}Sr$)	-	0.72682	0.7275	0.7287
Helium-4	cm^3STP/g	6.21E-08	3.64E-08	1.46E-08
Helium-3	cm^3STP/g	9.42E-14	4.64E-14	2.11E-14
Helium isotope ratio ($^{3}He/4He$)	-			
Neon	cm^3STP/g			

Sample Type		Water Source		
Sample Date and Time		**2021-04-18 9:00**	**2021-05-09 7:30**	**2021-06-04 13:45**
Sample ID		**IG_BH04_WS016 [1]**	**IG_BH04_WS017 [2]**	**IG_BH04_WS018 [3]**
Neon-20	cm^3STP/g	1.50E-07	0.000000126	6.37E-08
Neon-21	cm^3STP/g	4.41E-10	3.71E-10	1.91E-10
Neon-22	cm^3STP/g	1.50E-08	1.28E-08	6.50E-09
Neon isotope ratio ($^{20}Ne/^{22}Ne$)	-			
Argon	cm^3STP/g			
Argon-36	cm^3STP/g	5.85E-07	3.95E-07	2.49E-07
Argon-40	cm^3STP/g	1.74E-04	1.17E-04	7.34E-05
Argon isotope ratio ($^{40}Ar/^{36}Ar$)	-			
Krypton	cm^3STP/g			
Krypton-184	cm^3STP/g			
Xenon	cm^3STP/g			
Xenon-132	cm^3STP/g			

Notes:

[1] WS016: In-field analyses for sulphide, DO and ferrous iron not reported due to delay in field measurements.

[2] Data corresponds to that originally reported for IG_BH05_WS001.

[3] Data corresponds to that originally reported for IG_BH05_WS004.

[4] 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.

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

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

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.

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

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

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