PHASE 2 INITIAL BOREHOLE DRILLING AND TESTING, IGNACE AREA

Westbay Fluid Pressure Monitoring and Groundwater Sampling in Ignace Boreholes

2020 Annual Report

APM-REP-01332-0296 **October 2022**

GEOFIRMA

NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Nuclear Waste Management Organization
22 St. Clair Avenue East, 4th Floor
Toronto, Ontario
M4T 2S3
Canada

Tel: 416-934-9814
Web: www.nwmo.ca

Westbay Fluid Pressure Monitoring and Groundwater Sampling in Ignace Boreholes

2020 Annual Report

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Prepared for:

Nuclear Waste Management Organization
22 St. Clair Avenue East. 4th Floor
Toronto, ON, M4T 2S3

Prepared by:

GEOFIRMA
ENGINEERING
1 Raymond St. Suite 200, Ottawa, Ontario K1R 1A2
☎ 613.232.2525 613.232.7149 geofirma.com

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Prepared by:	Amy Cartier, G.I.T. and Chris Morgan, M.A.Sc., P.Geo.	
Reviewed by:	Kenneth Raven, P.Eng., P.Geo.	
Approved by:	Sean Sterling Sean Sterling, M.Sc, P.Eng., P.Geo. – Project Manager - Principal	

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1 INTRODUCTION

Geofirma Engineering Ltd. has been retained by the Nuclear Waste Management Organization (NWMO) to complete long-term monitoring of Westbay multi-level systems that are installed in deep bedrock boreholes near Ignace, Ontario.

The purpose of this project is to measure groundwater pressures and temperatures and to collect groundwater samples for geochemical analysis from Westbay systems installed in boreholes at Ignace. Measuring fluid pressures in each of the monitoring intervals of a single Westbay multilevel system is referred to as pressure profiling. Data obtained from this project will be used to evaluate the groundwater system at the site.

The scope of work includes pressure profiling and groundwater sampling and analysis in four Westbay systems installed in Ignace boreholes: IG_BH01, IG_BH03, IG_BH05 and IG_BH06. Pressure measurements will be taken at each sampling port and selected intervals will be targeted for groundwater sampling. Specific intervals targeted for groundwater sampling will be selected based on the interval hydraulic properties and the likelihood of collecting a groundwater sample that is representative of pre-drilling conditions for the target bedrock interval.

The fluid pressure monitoring and groundwater sampling program was initiated in November 2020 and is expected to continue quarterly until at least the end of 2023. An annual technical report (this report) will be prepared by Geofirma to describe all work activities completed each year including all pressure profiling, groundwater sampling, and laboratory analysis.

This 2020 Annual Report is the first report prepared by Geofirma. The report describes the field activities and results from a single monitoring event completed in November 2020 in IG_BH01 and IG_BH03. Earlier monitoring events in 2020 were cancelled due to the ongoing COVID 19 pandemic.

Work described in this technical report was carried out in accordance with *Test Plan: Fluid Pressure Monitoring and Groundwater Sampling in Ignace Boreholes* (Geofirma Engineering Ltd., 2020a), *Project Quality Plan: Fluid Pressure Monitoring and Groundwater Sampling in Ignace Boreholes* (Geofirma Engineering Ltd., 2020b), and *Health, Safety, and Environment Plan: Fluid Pressure Monitoring and Groundwater Sampling in Ignace Boreholes* (Geofirma Engineering Ltd., 2020c).

2 BACKGROUND

2.1 NWMO APM Program

The NWMO is implementing Adaptive Phased Management (“APM”), Canada’s plan for the long-term management of the nations’ used nuclear fuel. APM includes the emplacement of the used nuclear fuel in an underground deep geological repository (DGR). The initial borehole drilling and testing project at Ignace, Ontario is part of the Phase 2 geoscientific preliminary field investigations in the NWMO’s APM site selection process.

This Phase 2 project involves the drilling and testing of multiple deep boreholes in a potential repository area (PRA) located within the northwestern portion of the Revell Batholith, approximately 50 km west of Ignace, Ontario. All boreholes are being drilled using HQ3 wireline coring equipment that produces a 96 mm nominal diameter borehole to depths of approximately 1000m along borehole length. As of Dec 31, 2020, four boreholes had been drilled in Ignace, Ontario. The first borehole, IG_BH01, was drilled vertically; the others were drilled at an inclined angle of 70° from horizontal. The inclination of the boreholes varied slightly during drilling, resulting in borehole true vertical depths ranging from approximately 883 to 1,000 metres below ground surface (mBGS).

Westbay multilevel monitoring systems (MP38) have been installed in two of the boreholes completed by the end of 2020 (IG_BH01 and IG_BH03), designed with 20 and 21 discrete monitoring intervals, respectively. Borehole IG_BH02 has been temporarily sealed using five bridge plug-style packers to minimize vertical borehole fluid cross connections. Borehole IG_BH04 will also be temporarily sealed using bridge plugs.

2.2 Work Location

Ignace is located approximately 250 km northwest of Thunder Bay along the Trans-Canada Highway (HWY 17). Figure 1 shows the locations of all six boreholes planned for drilling and testing as part of the APM Phase 2 geoscientific preliminary field investigation program. All fieldwork described in this report was completed by Geofirma at boreholes IG_BH01 and IG_BH03.

2.3 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 recent geophysical modelling, the batholith has a relatively flat base that extends to depths of nearly 4 km in some regions (Sanders Geophysics Limited [SGL], 2020). The batholith is surrounded by supracrustal rocks of the Raleigh Lake (to the north and east) and Bending Lake (to the southwest) greenstone belts (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 2). 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 condition (Blackburn and Hinz, 1996; Stone et al., 1998). In some locations, primary features, such as pillow basalt or bedding in sedimentary rock units is 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).

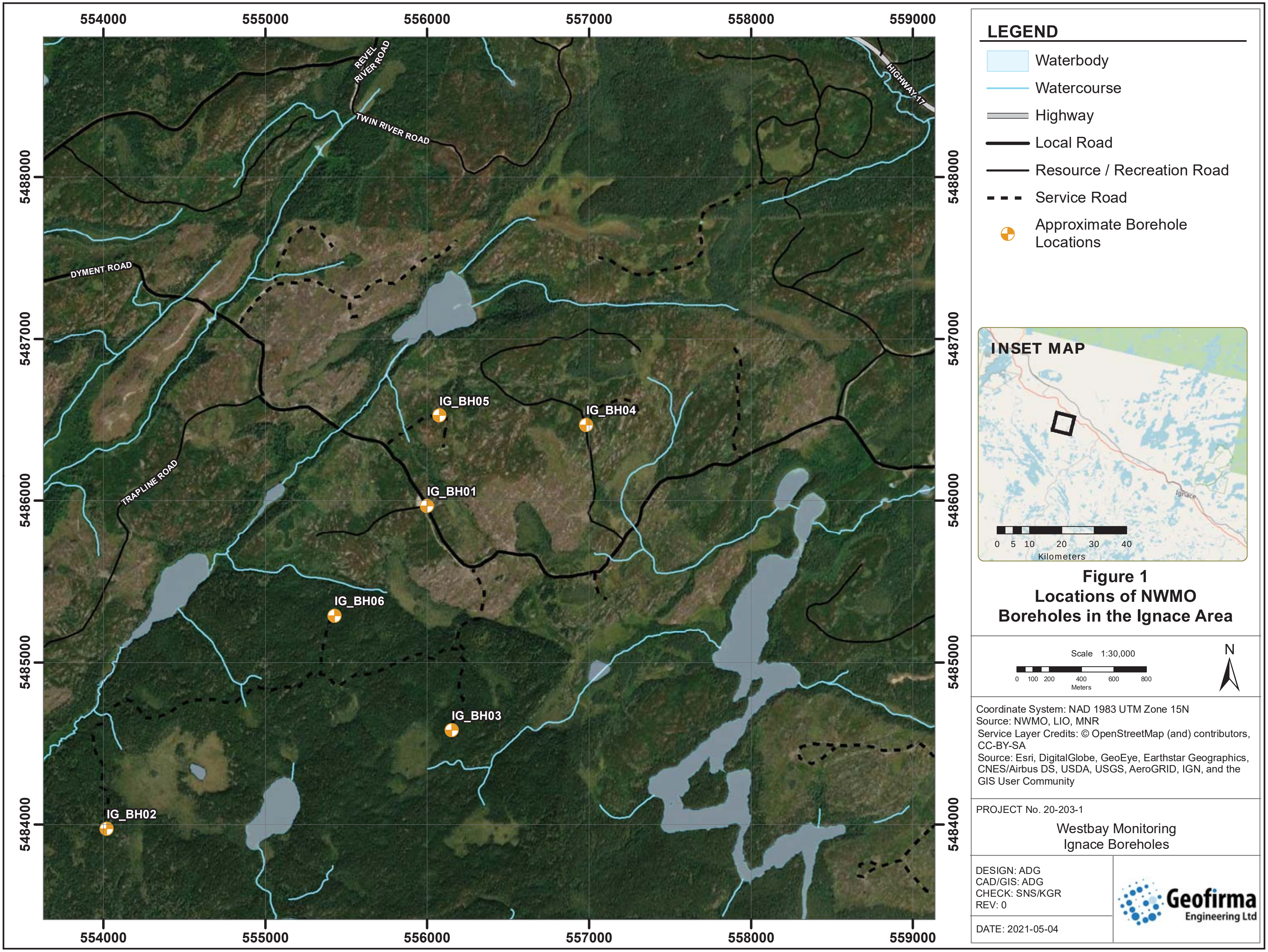
Three main suites of plutonic rock are recognized in the Revell batholith (Figure 2), including, from oldest to youngest: a Biotite Tonalite to Granodiorite suite, a Hornblende Tonalite to Granodiorite suite, and a Biotite Granite to Granodiorite suite. Plutonic rocks of the Biotite Tonalite to Granodiorite 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. This suite includes the oval-shaped potassium-feldspar megacrystic granite body in the central portion of the Revell batholith. One sample of coarse-grained, pink, massive potassium feldspar megacrystic biotite granite produced a U-Pb age of 2694.0+/-0.9 Ma (Stone et al., 2010).

Boreholes IG_BH01 to IG_BH06 are located in the northern portion of the Revell batholith (Figure 2). Bedrock exposure in this part of the batholith is generally very good due to minimal overburden, few water bodies, and relatively recent forestry activities. The bedrock surrounding IG_BH01-06 is composed mainly of massive to weakly foliated felsic intrusive rocks that vary in composition between granodiorite and tonalite. 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 southeast of the investigation area. The granite is observed to intrude into the granodiorite-tonalite bedrock, indicating that it is a distinct, younger intrusion (Golder and PGW, 2017).

A west-northwest trending mafic dyke interpreted from aeromagnetic data and observed during detailed mapping to be approximately 15-20 m wide, extends across the northern portion of the batholith (Figure 2; Golder and PGW, 2017). This dyke is associated with several other similarly-oriented mafic dykes that stretch across the northern portion of the Revell batholith and into the surrounding greenstone belts. 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 northwest of in the area of IG_BH01-06 (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 east of IG_BH02 hosts a more continuous, un-named water body that flows to the sout. The linear and segmented nature of this waterbody's shorelines may also represent the surface expression of structural features that extend into the bedrock (Figure 2; DesRoches et al., 2018).

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 trending northeast and northwest (SRK and Golder, 2015; Golder and PGW, 2017). Interpreted bedrock lineaments generally follow these same dominant orientations in the northern portion of the Revell batholith (DesRoches et al., 2018). Minor subhorizontal 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 2). Additional details of the lithological units and structures found at surface in the northern portion of the Revell batholith are provided in Golder and PGW (2017).



LEGEND

- Waterbody
- Watercourse
- Highway
- Local Road
- Resource / Recreation Road
- Service Road
- Approximate Borehole Locations

Figure 1
Locations of NWMO Boreholes in the Ignace Area

Scale 1:30,000

0 100 200 400 600 800
Meters

N

Coordinate System: NAD 1983 UTM Zone 15N
Source: NWMO, LIO, MNR
Service Layer Credits: © OpenStreetMap (and) contributors, CC-BY-SA
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

PROJECT No. 20-203-1

Westbay Monitoring
Ignace Boreholes

DESIGN: ADG
CAD/GIS: ADG
CHECK: SNS/KGR
REV: 0

Geofirma
Engineering Ltd

DATE: 2021-05-04

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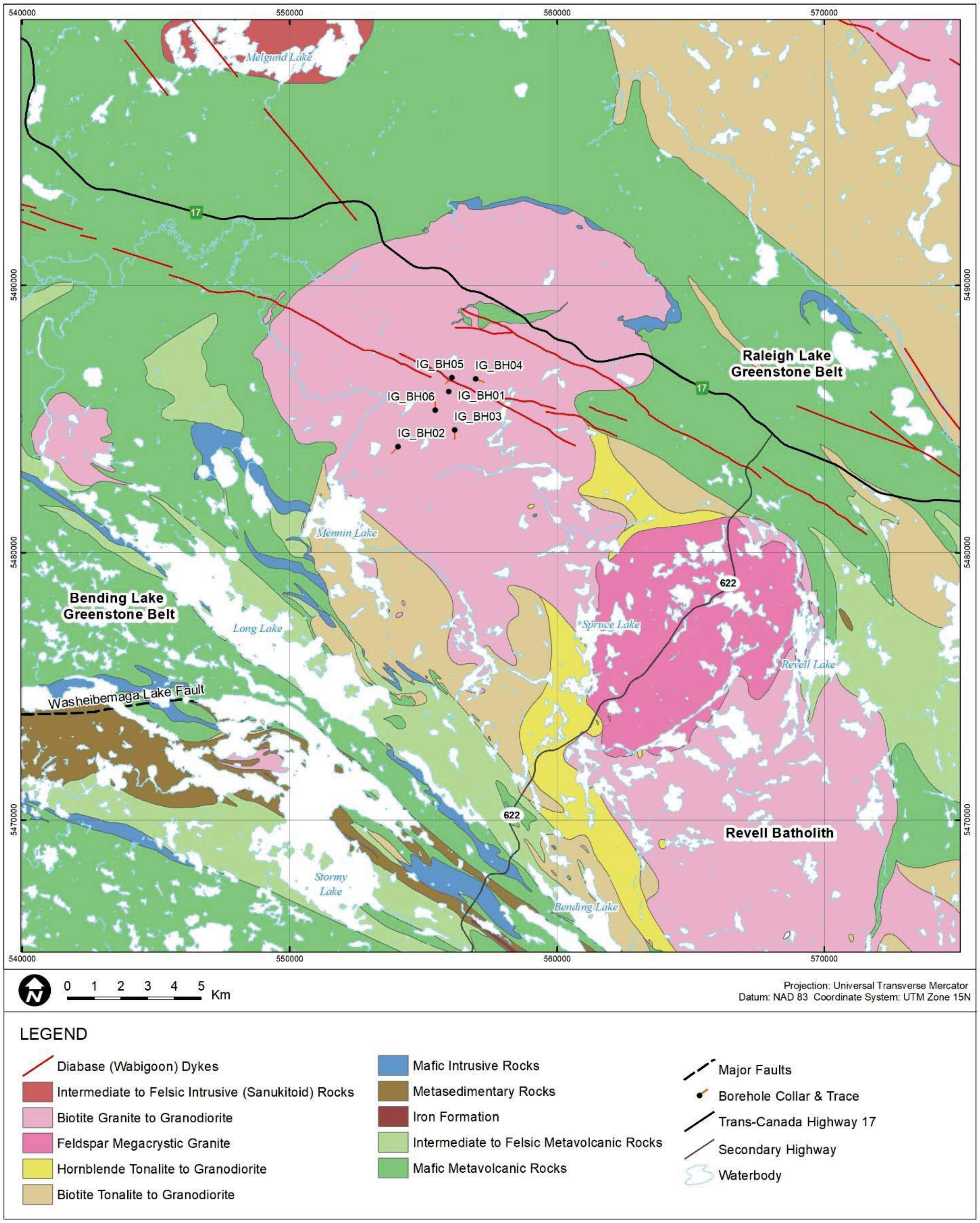
Figure 2 Bedrock Geology of the Ignace Area



3 METHODS

3.1 Quarterly Monitoring Events

In a typical year, Geofirma expects to complete a total of four quarterly monitoring events at the Ignace site. First, second and third quarter (Q1-Q3) monitoring events in 2020 were cancelled due to the ongoing COVID-19 pandemic. The fourth quarter (Q4) monitoring event was completed by Geofirma in November 2020. Details of the work activities completed for each monitoring event are summarized in Table 1.

Table 1 Summary of 2020 Field Activities for Ignace Westbay Monitoring

Monitoring Event	Field Work Dates	Work Activities Completed
Q1	--	No Q1 quarterly monitoring event due to COVID pandemic
Q2	--	No Q2 quarterly monitoring event due to COVID pandemic
Q3	--	No Q3 quarterly monitoring event due to COVID pandemic
Q4	Nov 25-30	• Mobilization to Ignace from Ottawa • Handover of NWMO owned Westbay equipment • Pressure/temperature profiling at IG_BH01 • Pressure/temperature profiling at IG_BH03 • Purging and sampling from IG_BH01_T_INT_009

3.2 Fluid Pressure and Temperature Profiling

Fluid pressure and temperature profiling was completed in the Westbay MP38 systems according to the methodology outlined in the test plan (Geofirma Engineering Ltd., 2020a). All fluid pressure and temperature measurements from the Westbay systems were collected using NWMO-owned Westbay equipment (MOSDAX, MAGI, etc.).

Prior to the start of each pressure profile, Geofirma field staff completed a series of measurements and QA/QC procedures. A barometric logger (Solinst Barologger) was installed to record barometric pressure throughout the pressure profiling. Atmospheric pressure was monitored at 60 second frequency throughout the profiling event. Before lowering the MOSDAX probe into the well, a surface inspection and function checks were also completed. Manual water level measurements from within the MP casing were recorded for each borehole and used to assess the calibration of the MOSDAX probe when the probe was submerged to a known depth (e.g., magnetic collar).

Pressure and temperature profiling was completed from the deepest to the shallowest sampling ports at each borehole. At each sampling port, the following measurements were collected: start profile time, landed pressure inside of the MP38 casing, opening sampling port, interval pressure and temperature, landed pressure inside the MP38 casing after closing pumping port, and end profile time.

All field measurements and records of Westbay equipment operation during pressure and temperature profiling were recorded on purpose-built field data sheets within the Data Quality Confirmation (DQC) Workbook (Appendix D). Any additional field notes not captured in the DQC workbook were recorded in a field notebook.

Visual QA/QC of pressure/temperature data was performed at each port, ensuring that values were acceptable when compared to data from previous monitoring round(s). Anomalous values were noted in the DQC workbook and confirmed by a second pressure measurement at the same location.

3.3 Groundwater Purging

3.3.1 Interval Selection for Groundwater Purging and Sampling

Monitoring intervals selected for purging and groundwater sampling were selected by NWMO. In 2020, only one interval IG_BH01_T_INT_009 was selected for purging and sampling. Geofirma completed purging and sampling of the ninth interval (IG_BH01_T_INT_009), at 540.2 m BGS (540.2 m BGS TDV) of IG_BH01, during the Q4 (November 2020) monitoring event.

3.3.2 Interval Purging

Operation of the Westbay equipment for purging activities was completed by Geofirma staff according to procedures outlined in the test plan (Geofirma Engineering Ltd., 2020a) and Westbay procedures. All water generated during purging was collected in 20 L plastic buckets and removed from site. NWMO personnel disposed of water generated during purging at the Ignace landfill. Details for each purging event are described below.

3.3.2.1 Purging - IG_BH01_T_INT_009 (Q4)

Due to the low transmissivity of the targeted interval (IG_BH01_T_INT_009), NWMO personnel completed purging activities prior to arrival of Geofirma staff at the site. On November 27, 2020, Geofirma completed a final 24-hour purge of IG_BH01_T_INT_009. For this interval, purging was completed through the MOSDAX sampler probe, which was affixed to the measurement port with the sample valve open.

Purging by Geofirma was completed using two methods. Initially, Waterra ½ inch HDPE tubing with inertial foot valve was used to recover 18 L from within the MP casing. While purging, the foot valve accidentally disconnected from the HDPE tubing which required removing the Westbay sampler probe to retrieve. Subsequently, alternate equipment was used to complete purging using a Solinst double valve pump (Model 408) lowered into the MP casing. 18 L were purged using the double valve pump, resulting in a total purge volume of 36 L over the 24-hour period.

Prior to the main groundwater sampling, a confirmatory sample was collected using the Westbay MOSDAX sampler to measure fluorescein concentration. The measured fluorescein concentration, of 8.719 ppb, was discussed with the NWMO to confirm the initiation of sample collection for IG_BH01_T_INT_009. The fluorescein concentration was measured using a Turner Designs Aquafluor fluorometer, which was calibrated prior to use. Records of the purging volumes, fluorescein measurements, and equipment calibration were recorded in the Field Parameter Measurement/Testing Field Data Sheet and the Equipment Calibration Tracking Sheet of the DQC workbook.

3.4 Groundwater Sampling

Groundwater sampling was performed by Geofirma staff using a NWMO-owned Westbay MOSDAX sampler probe and accessories. All sampling was completed in accordance with the test plan (Geofirma Engineering Ltd., 2020a) and Westbay sampling procedures. A summary of the field procedures for groundwater sampling is provided in the following sections.

3.4.1 Samples Collected in 2020

Only one set of samples was collected in 2020. The groundwater sample, with a full suite of duplicates and QA/QC samples was collected from IG_BH01_T_INT_009 during the Q4 (November 2020) monitoring event. A list of all samples collected in 2020 is provided in Table 2.

Table 2 Groundwater Sampling Summary - 2020 Monitoring Events

Monitoring Event	Intervals Sampled	Associated Sample IDs
Q1	--	No Q1 quarterly monitoring event due to COVID pandemic
Q2	--	No Q2 quarterly monitoring event due to COVID pandemic
Q3	--	No Q3 quarterly monitoring event due to COVID pandemic
Q4	IG_BH01_T_INT_009	• Sample: IG_BH01_GW017 • Rinsate Blank: IG_BH01_GW018 • Field Blank: IG_BH01_GW019 • Duplicate: IG_BH01_GW020

3.4.1.1 Sampling - IG_BH01_T_INT_009 (Q4)

The IG_BH01_T_INT_009 sample and duplicate were collected from the monitoring interval with the MOSDAX probe attached to the sampling port. Sample collection from IG_BH01_T_INT_009 was completed between November 28-30, 2020.

Approximately 5.0 L of water was required to meet the sampling objectives, with an additional 1.0-1.5 L required to complete field parameter measurements. A full suite of QA/QC and duplicate samples were also collected, requiring an additional 5.0 L of water. Fourteen sampling runs were required to collect sufficient water to meet these requirements, including two runs for noble gas sampling.

3.4.2 Equipment Decontamination

Prior to sample collection, all sampling equipment (MOSDAX probe, stainless steel sample bottles, fittings) was decontaminated by Geofirma field staff. All equipment decontamination was recorded in the DQC workbook and followed the procedure described below:

1. Put on new, powder-free nitrile gloves. Remove potential clothing that may contaminate field equipment.
2. Wipe off visible loose contamination (e.g., dirt) using a brush or paper towel.
3. Wash equipment with solution made of laboratory grade non-phosphate, non-perfumed detergent (e.g., Alconox) and water. Use a brush to apply detergent. For internal mechanisms or items that

cannot be washed using a brush, flush two system volumes of the cleaning solution though the system.

4. Rinse the equipment using deionized or distilled water and allow the equipment to air dry. Try to place equipment in a location that minimizes potential of airborne contamination (e.g., dust) during drying.
5. Purge rinse water from MOSDAX sampling probe using compressed nitrogen. Compressed nitrogen is applied to the inlet port using sampling tubing and flushed through the open port at the bottom of the tool.
6. Contain all water generated during decontamination procedures and dispose of it along with the purge water.
7. If a duplicate sample is being collected (as described in Section 3.3.4), collect a rinsate sample after decontamination is complete by running deionized or distilled water through the Westbay MOSDAX sampler probe.

Purge water generated during the purging and sampling was contained in plastic buckets and disposed by NWMO at the Ignace landfill. Rinsate water and water containing laboratory standards and solutions was contained in a plastic bucket and transported offsite by Geofirma for offsite disposal.

3.4.3 Groundwater Sample Collection

Sample collection was completed using NWMO-owned Westbay MOSDAX sampling equipment. Four stainless steel sample containers (0.25 L each) were connected in series and attached to the bottom of the MOSDAX sampler probe. Prior to lowering the sample bottles into the borehole, the four containers were flushed with high-purity nitrogen (N_2) and then evacuated using a hand-held vacuum pump.

Once lowered and connected to the sampling port, the valve on the MOSDAX sampler was opened so that groundwater could fill the vacated stainless-steel containers. The pressure in the MOSDAX sampler probe was monitored during sampling to ensure that the sample containers were filled (approximately 5-30 minutes). Once the bottles were filled, the valve on the MOSDAX sampler was closed, and all the bottles were retrieved.

Function tests of the Westbay equipment and the sampling sequence for each sampling run were documented in the Groundwater Sampling Field Data Sheet of the DQC Workbook.

3.4.4 Field Parameter Measurements and Transfer of Water to Laboratory Bottles

Sample water collected with the MOSDAX sampler probe was used to fill laboratory bottles, completed field parameter measurements, and field analytical testing as outlined in Table 3. Calibration of the measurement equipment and completion of field testing (e.g., alkalinity) was completed following manufacturer-provided instructions.

To minimize exposure to the atmosphere, sample water used for field parameter measurements was kept in Westbay sample bottles and released only in the quantity required to perform each test. Polyethylene tubing was used to transfer the water directly from the stainless-steel sample bottles into the Horiba flow-through cell, eliminating the exposure to the atmosphere.

Water collected for laboratory analysis was decanted from the stainless-steel sample bottles into laboratory provided bottles. All bottles were placed in coolers on ice and shipped/delivered to the analytical laboratories under chain of custody (COC) procedures.

Table 3 Field Parameter Measurement and Field Analytical Testing Methods

Parameter	Volume Required	Field-Measurement Method
Fluorescein	250 mL	Handheld Fluorometer (Turner Designs Aquafluor™)
Turbidity	500 mL	In sealed flow-through cell (i.e., Horiba Flow Chamber) with inserted water quality multi-probe (Horiba-U52/U50)
Dissolved Oxygen (DO)		
Electrical Conductivity		
Temperature		
Oxidation-Reduction Potential (ORP)		
pH		
Fluid Density		HACH™ Hydrometer (SG > 1.0)
Dissolved Total Sulphide [S^{2-}_{Total}]	25 mL	Dissolved total sulphide by methylene blue method and colorimeter (Hach DR900Multiparameter Colorimeter)
Ferrous Iron [Fe^{2+}]	10 mL	1-10 Phenanthroline Method using portable colorimeter (Hach DR900Multiparameter Colorimeter)
Dissolved Oxygen	50 mL	Indigo Camine method using portable colorimeter (Hach DR900) for concentrations < 1mg/L and Horiba-U52/50 for concentrations > 1 mg/L
Alkalinity	100 mL	Hach™ Alkalinity Test Kit, digital titration method using sulphuric acid (H_2SO_4), phenolphthalein indicator, and bromcresol green-methyl red indicator; hydroxide, carbonate and bicarbonate alkalinities can be determined

3.4.5 Sampling Procedure for Noble Gas Samples

Water samples for noble gases (He, Ar, Ne) were collected using 3/8-inch copper tubing connected to the Westbay MOSDAX sampler. A train of three 0.3 m long copper tubes were connected MOSDAX sampler using a 250 mL stainless-steel Westbay sample bottle between the probe and the copper tubes. Prior to sampling, the copper tubing, sample bottle, and sampler probe were flushed with high purity nitrogen and then evacuated using a hand-held vacuum pump.

Once connected to the sampling port, the valve on the MOSDAX probe was opened, and groundwater filled the sample container and copper tubing. The pressure in the MOSDAX sampler probe was monitored to determine when the sample containers were full (approximately 6-8 minutes). When the containers were full, the sampler probe was retrieved.

Upon retrieval to the surface, refrigeration clamps were used to seal off both ends of each 0.3 m long copper tubing segment. By sealing each segment, triplicate samples were collected. After clamping, the noble gas samples were wrapped in bubble wrap and placed in a rigid-sided cooler for transport.

After clamping of the copper tubing for noble gas sample IG_BH01_GW017_1, Geofirma noticed a minor leak at the closed end. The leak was likely caused by pressure build up at the end of clamping. Upon completion of clamping, the Westbay sample bottle was opened and was still under pressure, suggesting that very little pressure was lost.

3.4.6 Collection of QA/QC Samples

QA/QC samples were collected in 2020 as part of the Q4 monitoring event. Three types of QA/QC samples were collected, including:

- *Rinsate blank* - to test the sampling equipment after decontamination for equipment impacts;
- *Field blank* - tritium-free blanks to assess atmospheric contamination during sample collection and transport; and,
- *Duplicate samples* – complete set of duplicate samples.

The rinsate blank was collected by running deionized/distilled water through the Westbay MOSDAX sampler probe and sampler containers after completion of decontamination activities, prior to sample collection. Sufficient water was run through the sampling equipment to fill laboratory-provided sample bottles for major elements and metals, trace elements, and anions.

A tritium-free “field” blank was collected to assess atmospheric contamination of groundwater samples. Tritium-free water was provided in bottles by the University of Ottawa. These bottles were stored on-site and left exposed to the atmosphere for the same duration as the tritium and ^{14}C-DIC samples. During sampling, the tritium-free water was decanted into sample bottles identical to the ones used for tritium and ^{14}C-DIC analyses. The field blank was analyzed for tritium and ^{14}C-DIC at the same time as the corresponding groundwater sample.

A full suite of duplicates was also collected in 2020 during the Q4 monitoring event. Duplicate samples were collected at the same time as the primary/original sample, on a bottle-by-bottle basis. For example, both the original and duplicate tritium bottles were filled before filling the next bottle type.

3.5 Laboratory Analyses

Samples collected during the monitoring event(s) were shipped/delivered to analytical laboratories under chain of custody procedures. All samples were transported in rigid-sided coolers with bubble wrap to prevent damage during transport. Except for the noble gas samples, all other samples were transported on ice to maintain a temperature below 10 degrees C during transport.

Laboratory analysis of groundwater samples was completed by Bureau Veritas, Isotope Tracer Technologies (IT2), and the University of Ottawa. A complete list of analytes analyzed by laboratories as part of the monitoring program is provided in Table 4.

Bureau Veritas (formerly Maxxam Analytics Inc) completed laboratory analyses of the non-isotopic parameters listed, which included listed major elements and metals, trace elements, anions and nutrients. Bureau Veritas is accredited through CALA, Standards Council of Canada and MOE licenses for the listed analytes.

Isotope Tracer Technologies Inc. (IT2), of Waterloo, Ontario completed all the listed stable and radioactive isotope analyses, except for ^{36}Cl and ^{129}I. Analysis for noble gas isotopes and ^{129}I was completed by the University of Ottawa. The analysis of ^{36}Cl was subcontracted by the University of Ottawa (UofO) to ETH Zurich, Switzerland. Geofirma reviewed and accepted IT2 and UofO quality management systems (QMSs) in June 2019 and August 2019 as part of proposal preparation for lab analytical work at Ignace and at South Bruce.

IT2 follow protocols to conform with ISO 17025:2005; National Institute of Standards and Technology (NIST) and International Atomic Energy Agency (IAEA) Standard Reference Materials (SRM); participation in all International Atomic Energy Agency inter-comparison studies (e.g., TRIC, WICO and TEL). UofO, including the laboratories of the Advanced Research Complex (e.g., A. E. Lalonde AMS Laboratory, Hydrogeochemistry Laboratory), similarly follow protocols to conform with ISO 17025:2005. Both IT2 and UoO have historically met NWMO project quality documentation requirements for the stable and radioactive isotope analyses discussed here. In October 2017 UofO Hydrogeochemistry Laboratory successfully passed a NWMO quality audit. UoO has reviewed and accepted ETH Zurich QMS. ETH Zurich is a world leader in ^{36}Cl AMS analyses and administers international inter-laboratory comparison studies of ^{36}Cl analyses including some joint testing with UoO on ^{36}Cl AgCl sample preparation.

Table 4 Completed Laboratory Analyses, by Analytical Lab

Analytes	Analytical Lab or Storage
Major and Trace Elements and Metals (Na, K, Ca, Mg, Sr, Li, Si, Al, B, Cu, Ni, Zn, Pb, Cd, As, Se, Bi, U, Cs, Rb, Ba, Cr, Co, Th, Zr)	Bureau Veritas
Total Dissolved Sulphur, Total Dissolved Iron	
Ruthenium (Ru)	
Reactive Silica (SiO_2)	
Sulphide (S^{2-}) (by zinc acetate ppt)	
Anions (Br, Cl, SO_4, PO_4, I, NO_2, NO_3)	
pH	
Total Alkalinity as $CaCO_3$	
Fluoride (F)	

Analytes	Analytical Lab or Storage
Total Inorganic Carbon (TIC)	
Carbonate, Bicarbonate (CO_3, HCO_3)	
Total Ammonia (NH_4+NH_3)	
Total Nitrogen	
Total Organic Carbon (TOC)	
Total Phosphorus	
Dissolved Organic Carbon (DOC)	
$\delta^{18}O$, $\delta^{2}H$, ^{3}H (enriched, saline sample)	Isotope Tracer Tech. (IT2)
$^{87}Sr/^{86}Sr$	
$\delta^{37}Cl$	
$\delta^{13}C$-DIC	
^{14}C-DIC	
^{129}I, ^{36}Cl	University of Ottawa
^{3}He, ^{4}He, ^{20}Ne, ^{21}Ne, ^{22}Ne, ^{36}Ar, ^{40}Ar, Kr (total), Xe (total)	
Archive	NWMO Ignace Office

4 RESULTS AND ANALYSIS

Analysis of field data and results from the 2020 quarterly monitoring event are presented in the following sections. Groundwater pressures and calculation of hydraulic heads are presented in Section 4.1. Chemistry results from groundwater sampling are presented in Section 4.2.

4.1 Groundwater Pressures and Hydraulic Heads

4.1.1 Conversion of Absolute Pressure Fluid Profile

The Westbay MOSDAX pressure probe measures absolute pressure in the packer-isolated borehole intervals outside the MP38 casing, which is considered the formation pressure (P_f). Pressures measured by this equipment are total/absolute pressures, expressed in metric (SI) units of kilopascal (kPa), which include the water pressure and atmospheric pressure (P_a). The effect of atmospheric pressure ($P_{a)}$ was addressed by measuring the P_a at ground surface and subtracting the P_a from the formation pressure. For pressure data presented in this report, the averaged P_a measured at the start and end of a given pressure profile was used to correct all measurements collected during the profile. A separate P_a was used for each quarterly pressure profile at each borehole.

4.1.2 Calculation of Equivalent Freshwater and Environmental Hydraulic Heads

Formation fluid pressures measured in variable-density groundwater systems are commonly expressed as freshwater hydraulic heads and environmental hydraulic heads. Equivalent freshwater heads assume a constant fluid density with depth across the entire length of the measured profile.

The data required to complete these calculations are depth/elevations of MP measurement ports, measured formation fluid pressures, and the reference formation fluid density profile. Hydraulic head (H) is the sum of the elevation head (Z) and the pressure head (ψ).

Equivalent freshwater hydraulic heads are calculated from measured formation pressures and MP system measurement port elevations as:

$$H_f = Z + \psi = Z + \frac{P_f - P_a}{\rho_f g} \qquad [1]$$

Where: H_f = equivalent freshwater hydraulic head [mASL];

Z = elevation of MP pressure measurement port [mASL];

P_f = formation pressure measured in MP measurement port [Pa or kg/ms^2];

P_a = averaged atmospheric pressure measured at ground surface [Pa or kg/ms^2];

ρ_f = density of freshwater [1000 kg/m^3 at ambient temperatures]; and

g = gravitational acceleration [9.8065 m/s^2].

Note: for head calculations, ground surface elevations were assumed to be 442.02 mASL (IG_BH03) and 430.72 mASL (IG_BH01).

Environmental hydraulic heads are determined from calculated freshwater heads and a reference formation fluid density profile as:

$$H_e = H_f - \left(\frac{\rho_f - \rho_a}{\rho_f}\right)(Z - Z_r) \qquad [2]$$

Where: H_e = environmental hydraulic head [m ASL]

Z_r = elevation of reference point below which an average fluid density is determined [i.e., top of the groundwater system as represented by ground surface]; and

ρ_a = average density of water between Z and Z_r defined as:

$$\rho_a = \frac{1}{Z_r - Z}\int_{Z}^{Z_r} \rho(z)dz \qquad [3]$$

Fluid density profile functions ($\rho(z)$) can be determined from compilations of measured fluid densities of porewater and groundwater samples from different depths at a given site.

4.1.3 Calculated Hydraulic Heads

Calculated equivalent freshwater hydraulic heads from the 2020 monitoring event are plotted in meters above mean sea level (m ASL) with true vertical depths (TVD) below ground surface (Figure 3). Appendix A provides tables showing the measured formation pressures and calculated equivalent freshwater hydraulic heads from Q4 pressure profiling in IG_BH01 and IG_BH03. No calculation of environmental heads was performed in this annual report as fluid density profiles for IG_BH01 and IG_BH03 have not yet been determined.

Head profiles in IG_BH01 and IG_BH03 for the Q4 (November 2020) monitoring round were generally consistent with data from previous pressure profiling that was provided by the NMWO. The relatively low formation pressure and head observed in IG_BH01 interval 9 (540.2 m BGS) was likely caused by ongoing purging of that port by NMWO in preparation for groundwater sampling.

4.2 Groundwater Chemistry

A set of the water chemistry results from the 2020 sampling event is provided in Appendix B. Since only one monitoring event was completed in 2020, all results that are presented in this report are from the November 2020 (Q4) monitoring event.

Geofirma technical staff completed a review of the laboratory reported results. Unless otherwise noted in the discussion below, the water chemistry results are considered acceptable based on Geofirma's review. Since previous sampling from the Westbay system was not completed prior to the Q4 2020 monitoring event, discussion of results is limited to QA completed by Geofirma. Records of Geofirma's review of laboratory results are included in the DQC workbook.

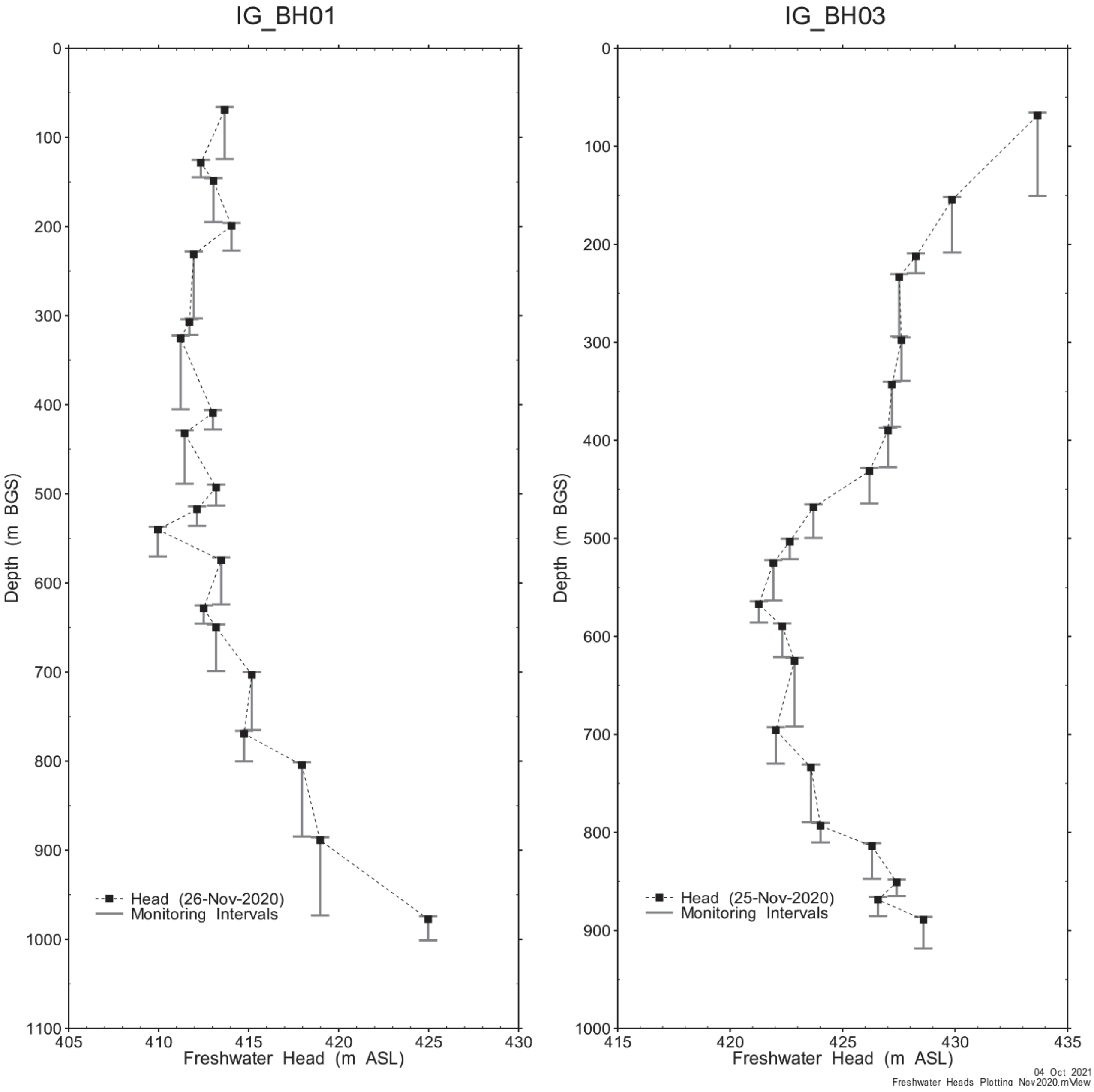


Figure 3 Vertical Depth Profiles of Equivalent Freshwater Hydraulic Heads

4.2.1 Field Measurements

The only field measurements completed by Geofirma in 2020 were from water sampled from IG_BH01_T_INT_009. A summary of the field measurements and field analytical test results are provided below in Table 5 and Table 6.

Table 5 Field Parameter Measurements - Results

Sample Interval	Sample Date/Time	pH	Temperature (Degrees C)	EC (mS/cm)	ORP (mV)	DO (mg/L)	Turbidity (NTU)	TDS (g/L)
IG_BH01_T_INT_009	28-Nov-20 16:00	5.12	5.67	8.61	4	1.5	3.5	5.26
IG_BH01_T_INT_009	28-Nov-20 16:30	5.08	5.61	8.47	82	1.4	4.5	5.36

EC = Electrical Conductivity
ORP = Oxidation Reduction Potential
TDS = Total Dissolved Solids

Table 6 Field Analytical Testing - Results

Sample Interval	Sample Date/Time	Fluorescein (ppb)	Specific Gravity	DO (mg/L)	Ferrous Iron Fe2+ (mg/L)	Sulphide (mg/L)	Total Alkalinity (mg/L as CaCO3)
IG_BH01_T_INT_009	28-Nov-20 14:00	9.048	1.001	>1	0.603	0.00	14
IG_BH01_T_INT_009	30-Nov-20 13:30	8.184	Not measured	>1	0.450	0.00	11

Issues with the pH measurements and dissolved oxygen (DO) were indicated at the time of sampling. Despite field calibration using a laboratory-provided single standard, pH measurements recorded with the multimeter probe (Horiba U52) were between 5.08-5.12. These field measurements of pH were lower than anticipated and below the laboratory reported values of 6.76 and 6.96. Based on these results, Geofirma intends to perform future field calibrations of the Horiba U52 for pH using a 2-point calibration, rather than the singe standard solution used in Q4 2020.

Field measurements of dissolved oxygen (DO) were also outside of the anticipated range (0 to <1 mg/L) for water samples from 540 mBGS. DO was measured using two different methods, both providing DO values that exceeded 1 mg/L.

The first method was to push sample water directly from the nitrogen-flushed and evacuated Westbay sample bottles into the flow-through cell using ¼ inch polyethylene tubing. Measurements of DO collected with the Horiba multimeter in the flow-through cell were between 1.4-1.5 mg/L after flushing approximately 1.75 L (two sampling runs) through the cell. After each liter was flushed, the cell had to be disconnected to retrieve another sampling run (1 L of water). Since the water stayed stagnant for ~45 min after each liter flushed, it was difficult to have DO stabilize to within the anticipated range.

The second DO method was completed by directing sample water from the Westbay sample bottles into a small cup using ¼ inch polyethylene tubing. Once the water was overflowing from the cup, an AccuVac snap-sampler was used to sample water from the bottom of the overflowing cup and was immediately analyzed using the HACH DR900 (Inigo Carmine Method 8316). Samples collected using this method exceeded the method range (>1mg/L DO).

Improved DO measurements may be possible by measuring directly from the discharge line during the final 24-hour purge. It is recommended that the discharge from the purge line (Waterra or double valve pump) be connected directly to the flow through cell.

4.2.2 General Chemistry

General chemistry results are summarized in Appendix B, with the associated laboratory report from Bureau Veritas (BV) provided in Appendix C.

Discussion of QA samples, including rinsate samples and duplicates are provided in section 5.2.1.

4.2.3 Isotopes

Isotope results are summarized in Appendix B, with the associated laboratory reports from the University of Ottawa and IT2 provided in Appendix C. Isotopic results in the appendix are raw, as delivered, from the laboratory. ^{14}C results will need to be corrected for drill water contamination and interpreted. This interpretation is outside the scope of this report and will be done as part of the DGSM (Descriptive Geological Site Model report).

Discussion of QA samples, including field blank samples and duplicates are provided in section 5.2.2

4.2.4 Noble Gases

Noble gas results are summarized in Appendix B, with the associated laboratory report from the University of Ottawa in Appendix C.

Discussion of QA samples are provided in section 5.2.3.

5 DATA QUALITY

Overall quality management of the activities performed at each quarterly monitoring event, and represented in this report, are consistent with the Test Plan (Geofirma, 2020) and Project Quality Plan (Geofirma, 2020).

5.1 In-Field Data Quality Assurance

Each quarterly monitoring event has a designated Data Quality Confirmation Workbook (DQC). The DQC was completed by field staff each day throughout the monitoring event to ensure quality of data collected, following the data deliverable verification procedures outlined in the Test Plan (Geofirma, 2020). A copy of the completed workbook can be found in Appendix D.

As discussed in section 4.2.1, Geofirma noted issues with the pH and dissolved oxygen (DO) field measurements at the time of sampling. Field recorded pH measurements were between 5.08 - 5.12, these field measurements were lower than anticipated and below the laboratory reported values of 6.76 and 6.96. Similarly, the field DO measurements were above of the anticipated range (0 to 1 mg/L). Although these field measurements are valid, they are likely unreliable.

5.2 Laboratory Data Quality

Three types of QA/QC samples were collected as part of the groundwater sampling event for laboratory quality assurance:

- Rinsate Blank – to test sampling equipment for impacts after decontamination
- Field Blank – tritium-free blanks to assess atmospheric contamination during sample collection and transport; and
- Duplicate Sample – complete set of duplicate samples for comparison

5.2.1 General Chemistry

Comparison of the BV laboratory results for the original sample (IG_BH01_GW017) and the duplicate sample (IG_BH01_GW020) show only minor changes in values on an analyte basis. The high degree of consistency between the original and duplicate sample indicates that the BV results have acceptable precision. Additionally, the calculated charge-balance error of <10% for the analyses provided by BV, confirms the acceptable precision of the results.

Results for the rinsate blank sample (IG_BH01_GW018) collected prior to sampling shows mostly non-detects, except for low concentrations of calcium (Ca), copper (Cu), nickel (Ni), sodium (Na), strontium (Sr) and chloride (Cl). The laboratory reported rinsate concentrations for Cl, Ca, Na, and Sr were orders of magnitude lower than the associated sample concentrations. The rinsate concentrations for Cu ($1x10^{-3}$ mg/L) and Ni ($1.2x10^{-3}$ mg/L), which were not detected in the groundwater samples, were just above laboratory detection limits of $9x10^{-4}$ mg/L and $1x10^{-3}$ mg/L, respectively. These results from the rinsate blank confirm that the decontamination procedure and sampling equipment had negligible impact on the reported values for the associated original (IG_BH01_GW017) and duplicate (IG_BH01_GW020) groundwater samples.

All laboratory analyses completed by BV Labs, excluding pH and dissolved organic carbon (DOC), were extracted, or analysed within the given holding times. Although, the samples were delivered to the lab within Geofirma's optimal holding time of two (2) days after collection, BV was unable to analyse pH and DOC within the set laboratory holding times of four (4) and five (5) days, respectively and have noted these analyses to be potentially biased.

BV labs reported dilution of samples was required for reactive silica (Si02) and therefore the detection limit was adjusted accordingly.

5.2.2 Isotopes

Geofirma compared the IT2 Laboratory results for the original sample (IG_BH01_GW017) and the duplicate sample (IG_BH01_GW020). The results for ^{37}Cl, ^{13}C and ^{14}C were flagged by Geofirma as they were outside of the expected range. The lab was contacted by Geofirma to re-check and confirm the results. The lab re-issued the final report confirming the results for ^{37}Cl and ^{14}C, and correcting the reporting error of the ^{13}C results for sample IG_BH01_GW017. As discussed in Section 4.2.3, ^{14}C results will need to be corrected for drill water contamination and interpreted. This interpretation is outside the scope of this report and will be done as part of the DGSM (Descriptive Geological Site Model report).

A low concentration of tritium (1.5 TU) was detected in the primary sample, IG_BH01_GW017. Since tritium levels were below the laboratory detection limit (<0.8 TU) in the duplicate sample and associated field blank, the low concentration reported for IG_BH01_GW017 may indicate potential atmospheric contamination during sample collection, transport, and analysis. The most probable source of tritium exposure would be during field filtering, where samples are filtered using syringe filters from the Westbay sample bottle into the laboratory-provided bottle. Higher capacity filters attached directly to the Westbay sample bottles may reduce potential for atmospheric exposure for future sampling events.

The ^{129}I and ^{36}Cl results from the University of Ottawa Radiohalide laboratory were evaluated by Geofirma. Comparison of the original sample (IG_BH01_GW017) with the duplicate sample (IG_BH01_GW020) results demonstrated minor changes for each analyte, this consistency shows acceptable precision of the results.

5.2.3 Noble Gases

Geofirma evaluated the results from the University of Ottawa AMS laboratory of the primary sample (IG_BH01_GW017) with the duplicate sample (IG_BH01_GW020). Comparison of the helium and neon results show only minor changes in values for each analyte. The high degree of consistency between the original and duplicate sample indicates that the He and Ne results have acceptable precision.

The lab was unable to report any results for Ar, Kr and Xe of sample IG_BH01_GW020 (duplicate). The lab states that the sample was leaking and therefore deemed it compromised and unable to analyze. As described in section 3.4.5., noble gas samples are collected in three (3) sections of Cu tubes and sealed on each end using mechanical threaded compression clamps, two of the tubes had been used for He and Ne analysis and the third was deemed compromised. The lab speculates that the leak may have been caused by corrosion of the Cu tubes. Notwithstanding the absence of duplicate results to compare with, Geofirma evaluated the Ar, Kr and Xe results received for sample IG_BH01_GW017 (primary) alongside the labs QA procedures and have deemed them acceptable.

6 DATA DELIVERY

6.1 Data Deliverables

As part of the data delivery schedule prescribed in the project test plan (Geofirma Engineering Ltd., 2020a), Geofirma provided NWMO with the following items for each quarterly monitoring event:

- Data Quality Confirmation (DQC) Workbook
- Photographs of field activities
- Completed import templates for data entry into acQuire by NWMO:
    - IMP-15 – BV Groundwater Chemistry Results
    - IMP-15 – University of Ottawa Groundwater Chemistry Results
    - IMP-15 – IT2 Groundwater Chemistry Results
    - IMP-22 – Port Pressure Measurements for IG_BH01
    - IMP-22 – Port Pressure Measurements for IG_BH03

  - IMP-DE07 – Groundwater Field Parameter Measurements
- Barometric Pressure Data

Table 7 provides a summary of data delivery by quarterly monitoring event.

Table 7 Data Delivery, by Quarterly Monitoring Event

Monitoring Event	Data Delivery Date	Comments
Q1	--	No Q1 quarterly monitoring event due to COVID pandemic
Q2	--	No Q2 quarterly monitoring event due to COVID pandemic
Q3	--	No Q3 quarterly monitoring event due to COVID pandemic
Q4	September 21, 2022	Revised data delivery.

7 CONCLUSIONS

Geofirma Engineering Ltd. was retained by the Nuclear Waste Management Organization (NWMO) to complete quarterly monitoring of Westbay multi-level systems that are installed in deep bedrock boreholes near Ignace, Ontario. No quarterly monitoring was completed by Geofirma during the first three quarters (Q1-Q3) of 2020 due to the ongoing COVID 19 pandemic.

The Q4 monitoring event was completed by Geofirma between November 25-30, 2020, including pressure profiling at IG_BH01 and IG_BH03, and collection of a water sample from IG_BH01_T_INT_009. A full suite of duplicates, a field blank, and a rinsate blank were also collected during sampling of IG_BH01_T_INT_009. Field parameter measurements and field analytical testing were completed while sampling IG_BH01_T_INT_009.

The water samples from IG_BH01_T_INT_009 were analyzed for a large suite of conventional laboratory analyses at Bureau Veritas Laboratories. Isotope and noble gas analysis were completed at the University of Ottawa and Isotope Tracer Technologies (IT2).

Measured formation pressures and calculated equivalent freshwater heads for IG_BH01 and _IG_BH03 from the Q4 monitoring event were consistent with previous pressure profiles collected by the NWMO. Low formation pressure observed in SB_BH01 interval 9 (540.2 m BGS) was caused by ongoing purging of that port by NMWO in preparation for groundwater sampling. Calculation of environmental heads was not completed as fluid density profiles for IG_BH01 and IG_BH03 have not been provided to Geofirma by the NWMO.

Groundwater chemistry results from Bureau Veritas, IT2, and the University of Ottawa were reviewed and accepted by Geofirma. Results have been provided to NWMO for all listed analysis, excluding Ar, Xe and Kr results for sample IG_BH01_GW020 which was unable to be analyzed due the sample being compromised as a result of a leaking Cu tube.

Issues with the pH measurements and dissolved oxygen (DO) were indicated at the time of sampling. The pH measurements recorded in the field (5.08-5.12) were out of the expected range and below the laboratory reported values (6.76-6.96). DO measurements collected at the time of sampling using the multiparameter probe and with colorimetric kits exceeded the anticipated value (1 mg/L DO). Following a review of the field and laboratory data, Geofirma concluded that the field measurements for pH and DO are likely unreliable. An improved pH calibration method for the field multimeter probe will be implemented by Geofirma for future monitoring events. Improved DO measurements may be possible by measuring DO directly from the discharge line during the final 24-hour purge.

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Appendix A

Fluid Pressures, Calculated Pressure Heads and Calculated Freshwater Heads

Table A.1 – Fluid Pressure, Calculated Pressure Head and Calculated Freshwater Head for IG_BH01
Table A.2 - Fluid Pressure, Calculated Pressure Head and Calculated Freshwater Head for IG_BH03

Table A.1 - Fluid Pressure, Calculated Pressure Head(Ψ)and Calculated Freshwater Head (H*f*) for IG_BH01

Port No.	Port Depth (m BGS)	2020 - Q4 (Nov-20)			
		Fluid Pressure (kPa)	Ψ (m)	Water Level (m BGS)	H*f* (m)
1	977.3	9623.97	971.56	5.74	424.98
2	888.8	8697.2	877.05	11.75	418.97
3	804.4	7859.64	791.64	12.76	417.96
4	769.3	7483.93	753.33	15.97	414.75
5	703.1	6838.95	687.56	15.54	415.18
6	649.8	6296.8	632.27	17.53	413.19
7	628.4	6080.18	610.18	18.22	412.50
8	574.4	5560.18	557.16	17.24	413.48
9	540.2	5190.3	519.44	20.76	409.96
10	517.4	4988.05	498.82	18.58	412.14
11	493	4759.2	475.48	17.52	413.20
12	432.1	4144.78	412.83	19.27	411.45
13	409.3	3936.62	391.60	17.70	413.02
14	325.6	3098.23	306.11	19.49	411.23
15	307.3	2923.52	288.29	19.01	411.71
16	231.2	2179.65	212.43	18.77	411.95
17	199.2	1886.43	182.53	16.67	414.05
18	149	1384.3	131.33	17.67	413.05
19	128.5	1176.38	110.13	18.37	412.35
20	69.1	606.85	52.05	17.05	413.67

Notes for Calculation:	**Q4 2020**
P_{atm} (average), kPa	96.41
Ground Surface Elevation, mASL	430.72

Table A.2 - Fluid Pressure, Calculated Pressure Head(Ψ)and Calculated Freshwater Head (H*f*) for IG_BH03

Port No.	True Port Depth (m BGS)	Nov-20			
		Fluid Pressure (kPa)	Ψ (m)	Water Level (m BGS)	H*f* (m ASL)
1	889.02	8683.48	875.59	13.43	428.59
2	868.72	8464.55	853.27	15.45	426.57
3	851.01	8299.04	836.39	14.62	427.40
4	814.02	7925.53	798.30	15.72	426.30
5	793.33	7700.23	775.33	18.00	424.02
6	733.71	7111.38	715.28	18.43	423.59
7	695.74	6723.73	675.75	19.99	422.03
8	624.95	6037.68	605.79	19.16	422.86
9	589.73	5686.94	570.03	19.70	422.32
10	567.23	5456.11	546.49	20.74	421.28
11	525.1	5049.26	505.00	20.10	421.92
12	503.37	4843.32	484.00	19.37	422.65
13	468.38	4510.5	450.06	18.32	423.70
14	431.35	4171.75	415.52	15.83	426.19
15	390.08	3775.15	375.08	15.00	427.02
16	343.28	3317.9	328.45	14.83	427.19
17	297.88	2876.85	283.47	14.41	427.61
18	233.35	2243.05	218.84	14.51	427.51
19	212.2	2042.9	198.43	13.77	428.25
20	154.48	1492.65	142.32	12.16	429.86
21	68.62	687.96	60.27	8.35	433.67

Notes for Calculation:	**Q4 2020**
P_{atm} (average), kPa	96.96
Ground Surface Elevation, mASL	442.02

Appendix B

Groundwater Chemistry Results

Table B.1 – Analytical Results of Groundwater Sample – *Field Parameters*
Table B.2 – Analytical Results of Groundwater Sample – *Inorganics*
Table B.3 – Analytical Results of Groundwater Sample – *Metals*
Table B.4 – Analytical Results of Groundwater Sample – *Isotopes*
Table B.5 – Analytical Results of Groundwater Sample – *Noble Gases*

Table B.1 - Analytical Results of Groundwater Samples - Field Parameters

	Units	IG_BH01	
Port:		BH01_T_INT_009	
Ground Surface Elevation:	mASL	430.72	
Depth:	mBGS	540.2	
Sample ID:		**IG_BH01_GW017**	**IG_BH01_GW020**
Sample Type:		Primary	Duplicate
Field Parameters			
pH	--	5.12	5.08
Temp	°C	5.67	5.61
EC	mS/cm	8.61	8.47
ORP	mV	4	82
DO	mg/L	1.5	1.4
Turbidity	NTU	3.5	4.5
TDS	mg/L	5260	5360
Total Alkalinity as CaCO3	mg/L	14	11
Fluorescein	ppb	9.048	8.184
Density	g/cm^3	1.001	--
Colorimetric			
DO (low range)	mg/L	>1.0	>1.0
Dissolved Ferrous Iron (Fe2+)	mg/L	0.603	0.45
Total Dissolved Sulphide (S2-)	mg/L	0.0	0.0

Table B.2 Analytical Results of Groundwater Samples - Inorganics

	Units		**IG_BH01**		
Port:			BH01_T_INT_009		
Ground Surface Elevation:	mASL		430.72		
Depth:	mBGS		540.2		
Sample ID:			**IG_BH01_GW017**	**IG_BH01_GW020**	**IG_BH01_GW018**
Sample Type:			Primary	Duplicate	Rinsate
Calculated Parameters	**Units**	**RDL**			
Ammonium (NH4)	mg/L	0.05	0.12	0.12	--
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	1.00	9.0	7.3	--
Carb. Alkalinity (calc. as CaCO3)	mg/L	1.00	BDL	BDL	--
Total Nitrogen (N)	mg/L	0.10	0.27	0.28	--
Inorganics					
Total Ammonia-N	mg/L	0.05	0.095	0.096	--
Fluoride (F-)	mg/L	0.10	0.49	0.50	BDL
Total Inorganic Carbon (C)	mg/L	1.00	2	2	--
Dissolved Iodide	mg/L	0.10	0.25	0.28	BDL
Total Kjeldahl Nitrogen (TKN)	mg/L	0.10	0.27	0.28	--
Dissolved Organic Carbon (DOC)	mg/L	0.40	0.76	0.77	--
Total Organic Carbon (TOC)	mg/L	0.40	0.87	0.81	--
Orthophosphate (P)	mg/L	0.01	BDL	BDL	0.030
pH	pH	--	6.96	6.76	--
Total Phosphorus	mg/L	0.02	0.033	0.026	--
Reactive Silica (SiO2)	mg/L	0.50	9.1 (1)	8.5 (2)	--
Sulphide	mg/L	0.02	ND	ND	--
Alkalinity (Total as CaCO3)	mg/L	1.00	9.1	7.3	--
Nitrite (N)	mg/L	0.01	BDL	BDL	BDL
Dissolved Chloride (Cl-)	mg/L	50	4700	4600	5.2
Nitrate (N)	mg/L	0.10	BDL	BDL	BDL
Nitrate + Nitrite (N)	mg/L	0.10	BDL	BDL	BDL
Dissolved Bromide (Br-)	mg/L	50	BDL	BDL	BDL
Dissolved Sulphate (SO4)	mg/L	50	BDL	BDL	BDL

Notes:

RDL = Reportable detection limits

BDL = Below detectable limit

Table B.3 - Analytical Results of Groundwater Samples - Metals

	Units		IG_BH01		
Port:			BH01_T_INT_009		
Ground Surface Elevation:	mASL		430.72		
Depth:	mBGS		540.2		
Sample ID:			**IG_BH01_GW017**	**IG_BH01_GW020**	**IG_BH01_GW018**
Sample Type:			Primary	Duplicate	Rinsate
Metals	**Units**	**RDL**			
Total Ruthenium (Ru)	mg/L	2.0E-03	BDL	BDL	BDL
Dissolved Aluminum (Al)	mg/L	4.9E-03	BDL	BDL	5.30E-03
Dissolved Arsenic (As)	mg/L	1.0E-03	BDL	BDL	BDL
Dissolved Barium (Ba)	mg/L	2.0E-03	0.26	0.26	BDL
Dissolved Bismuth (Bi)	mg/L	1.0E-03	BDL	BDL	BDL
Dissolved Boron (B)	mg/L	1.0E-02	0.24	0.24	BDL
Dissolved Cadmium (Cd)	mg/L	9.0E-05	BDL	BDL	BDL
Dissolved Calcium (Ca)	mg/L	1.0	1700	1800	2
Dissolved Cesium (Cs)	mg/L	2.0E-04	BDL	BDL	BDL
Dissolved Chromium (Cr)	mg/L	5.0E-03	BDL	BDL	BDL
Dissolved Cobalt (Co)	mg/L	5.0E-04	BDL	BDL	BDL
Dissolved Copper (Cu)	mg/L	9.0E-04	BDL	BDL	1.00E-03
Dissolved Iron (Fe)	mg/L	0.10	0.72	0.73	BDL
Dissolved Lead (Pb)	mg/L	5.0E-04	BDL	BDL	BDL
Dissolved Lithium (Li)	mg/L	5.0E-03	3.80E-02	3.80E-02	BDL
Dissolved Magnesium (Mg)	mg/L	5.0E-02	3.00	3.00	BDL
Dissolved Nickel (Ni)	mg/L	1.0E-03	BDL	BDL	1.20E-03
Dissolved Potassium (K)	mg/L	0.20	11	11	BDL
Dissolved Rubidium (Rb)	mg/L	2.0E-04	1.20E-02	1.20E-02	BDL
Dissolved Selenium (Se)	mg/L	2.0E-03	BDL	BDL	BDL
Dissolved Silicon (Si)	mg/L	5.0E-02	4.60	4.80	BDL
Dissolved Sodium (Na)	mg/L	0.10	580	600	1.1
Dissolved Strontium (Sr)	mg/L	1.0E-03	21	21	2.10E-02
Dissolved Thorium (Th)	mg/L	2.0E-03	BDL	BDL	BDL
Dissolved Uranium (U)	mg/L	1.0E-04	BDL	BDL	BDL
Dissolved Zirconium (Zr)	mg/L	1.0E-03	BDL	BDL	BDL

Notes:

RDL = Reportable detection limits

BDL = Below detectable limit

Table B.4 - Analytical Results of Groundwater Samples - Isotopes

		Units	**IG_BH01**		
	Port:		BH01_T_INT_009		
	Elevation:	mASL	430.72		
	Depth:	mBGS	540.2		
	Sample ID:		**IG_BH01_GW017**	**IG_BH01_GW020**	**IG_BH01_GW019**
	Sample Type:		Primary	Duplicate	Field Blank
Isotopes					
$\delta^{18}O$	Avg	VSMOW	-12.08	-12.10	-13.10
	StDv		0.01	0.02	0.04
$\delta^{2}H$	Avg	VSMOW	-82.4	-82.7	-86.9
	StDv		0.2	0.1	0.3
^{3}H	Result	TU	1.5	<0.8	<0.8
	± 1σ		0.2	0.2	0.5
$\delta^{37}Cl$	Result	SMOC	0.48	-0.37	--
	StDv		0.14	0.05	--
^{36}Cl	Result	36Cl/Cl	1.56E-14	1.69E-14	--
$\delta^{13}C$ (DIC)	Result	PDB	-10.4	-10.3	-11.6
$\delta^{14}C$ (DIC)	Result	14C yr BP	7892	8109	7620
		±	99	96	78
		F14C	0.3744	0.3644	0.3873
		±	0.0046	0.0043	0.0037
$^{87}Sr/^{86}Sr$	Ratio		0.72042	0.72011	--
	StdErr (abs)		1.280E-05	1.109E-05	--
	StdDv		1.378E-04	1.189E-04	--
$^{129}I/^{127}I$	Ratio		66.6E-14	61.2E-14	--
	StdDv		2.20E-14	1.50E-14	--
^{129}I	Conc	$x10^{6}$ atoms/g	3.05E-02	2.87E-02	--
	StdDv		1.01E-03	6.93E-04	--

Notes:

TU (Tritium Units)

1TU = 3.221 Picocurries/L per IAEA, 2000 Report.

1TU = 0.11919 Becquerels/L per IAEA, 2000 Report.

Table B.5 - Analytical Results of Groundwater Samples - Noble Gases

	Units	IG_BH01	
Port:		BH01_T_INT_009	
Ground Surface Elevation:	mASL	430.72	
Depth:	mBGS	540.2	
Sample ID:		**IG_BH01_GW017**	**IG_BH01_GW020**
Sample Type:		Primary	Duplicate
Noble Gas			
^{3}He	cm^3 STP/g	1.16E-10	3.05E-10
	±	3.42E-12	3.38E-12
^{4}He	cm^3 STP/g	1.16E-03	6.22E-03
	±	2.32E-06	6.22E-07
^{20}Ne	cm^3 STP/g	7.66E-07	9.78E-07
	±	2.45E-09	1.27E-09
^{21}Ne	cm^3 STP/g	2.31E-09	3.19E-09
	±	3.70E-12	2.55E-12
^{22}Ne	cm^3 STP/g	7.68E-08	9.83E-08
	±	2.61E-10	7.87E-11
^{36}Ar	cm^3 STP/g	1.70E-07	ND (2)
	±	5.086E-09	
^{40}Ar	cm^3 STP/g	1.97E-04	ND (2)
	±	5.89E-06	
$Kr_{(Total)}$	cm^3 STP/g	2.04E-08	ND (2)
	±	1.019E-09	
$Xe_{(Total)}$	cm^3 STP/g	5.37E-09	ND (2)
	±	2.685E-10	

Notes:

ND = No data

ND (1) : He measurements not possible due to He abundance exceeding inlet capacity of mass spectrometer

ND (2): Sample leaking during extraction, likely due to corrosion from high salinity. Could not be run for Ar, Kr, Xe.

Appendix C

Laboratory Reports

Your Project #: P020-203
Site#: IG-BH01
Site Location: 20-203
Your C.O.C. #: C#800970-01-01

Attention: Chris Morgan

Geofirma Engineering Ltd
1 Raymond St
Suite 200
Ottawa, ON
CANADA K1R 1A2

Report Date: 2020/12/23
Report #: R6460992
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C0W4852
Received: 2020/12/02, 09:30

Sample Matrix: Water
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Alkalinity	2	N/A	2020/12/08	CAM SOP-00448	SM 23 2320 B m
Carbonate, Bicarbonate and Hydroxide	2	N/A	2020/12/09	CAM SOP-00102	APHA 4500-CO2 D
Anions	3	N/A	2020/12/09	CAM SOP-00435	SM 23 4110 B m
Dissolved Organic Carbon (DOC) (3)	2	N/A	2020/12/08	CAM SOP-00446	SM 23 5310 B m
Fluoride	3	2020/12/07	2020/12/08	CAM SOP-00449	SM 23 4500-F C m
Dissolved Metals by ICPMS	3	N/A	2020/12/09	CAM SOP-00447	EPA 6020B m
Iodide, Thiosulphate, Thiocyanate (1)	3	N/A	2020/12/11	CAL SOP-00057	Dionex #034035 R09 m
Total Extractable Elements by ICP-MS (2, 4)	3	2020/12/18	2020/12/21	STL SOP-00071	MA.200–Mét. 1.2 R5 m
Silica (Reactive) (1)	2	N/A	2020/12/11	AB SOP-00011	EPA370.1 R1978 m
Ammonium as NH4+	2	N/A	2020/12/23		
Total Ammonia-N	2	N/A	2020/12/10	CAM SOP-00441	USGS I-2522-90 m
Nitrate (NO3) and Nitrite (NO2) in Water (5)	3	N/A	2020/12/09	CAM SOP-00440	SM 23 4500-NO3I/NO2B
pH	2	2020/12/07	2020/12/08	CAM SOP-00413	SM 4500H+ B m
Field Measured pH (6)	2	N/A	2020/12/02		Field pH Meter
Orthophosphate	3	N/A	2020/12/09	CAM SOP-00461	EPA 365.1 m
Sulphide	2	N/A	2020/12/08	CAM SOP-00455	SM 23 4500-S G m
Field Temperature (6)	2	N/A	2020/12/02		Field Thermometer
Total Inorganic Carbon (TIC)	2	N/A	2020/12/09	CAM SOP-00433	SM 23 5310 m
Total Kjeldahl Nitrogen in Water	2	2020/12/08	2020/12/08	CAM SOP-00938	OMOE E3516 m
Total Nitrogen (calculated)	2	N/A	2020/12/09		
Total Organic Carbon (TOC) (7)	2	N/A	2020/12/08	CAM SOP-00446	SM 23 5310B m
Total Phosphorus (Colourimetric)	2	2020/12/08	2020/12/09	CAM SOP-00407	SM 23 4500 P B H m

Remarks:

Bureau Veritas Laboratories are accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by BV Labs are based upon recognized Provincial, Federal or US method compendia such as CCME, MELCC, EPA, APHA.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in BV Labs profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and BV Labs in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been

Your Project #: P020-203
Site#: IG-BH01
Site Location: 20-203
Your C.O.C. #: C#800970-01-01

Attention: Chris Morgan

Geofirma Engineering Ltd
1 Raymond St
Suite 200
Ottawa, ON
CANADA K1R 1A2

Report Date: 2020/12/23
Report #: R6460992
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BV LABS JOB #: C0W4852
Received: 2020/12/02, 09:30

accounted for when stating conformity to the referenced standard.

BV Labs liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. BV Labs has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by BV Labs, unless otherwise agreed in writing. BV Labs is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested. When sampling is not conducted by BV Labs, results relate to the supplied samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix “m” indicates test methods incorporate validated modifications from specific reference methods to improve performance.
(1) This test was performed by BVLabs Calgary via Mississauga
(2) This test was performed by BVLab Montreal via Mississauga
(3) Dissolved Organic Carbon (DOC) present in the sample should be considered as non-purgeable DOC.
(4) Non-accredited test method
(5) Values for calculated parameters may not appear to add up due to rounding of raw data and significant figures.
(6) This is a field test, therefore, the results relate to items that were not analysed at Bureau Veritas Laboratories.
(7) Total Organic Carbon (TOC) present in the sample should be considered as non-purgeable TOC.

Encryption Key

AUTHORIZED REPORT
RAPPORT AUTORISÉ

Bureau Veritas Laboratories
23 Dec 2020 13:15:01

Please direct all questions regarding this Certificate of Analysis to your Project Manager.
Katherine Szozda, Project Manager
Email: Katherine.Szozda@bvlabs.com
Phone# (613)274-0573 Ext:7063633
==
This report has been generated and distributed using a secure automated process.
BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total Cover Pages : 2

RESULTS OF ANALYSES OF WATER

BV Labs ID		OIR406			OIR406			OIR407		
Sampling Date		2020/12/02 09:30			2020/12/02 09:30			2020/12/02 09:30		
COC Number		C#800970-01-01			C#800970-01-01			C#800970-01-01		
	UNITS	**IG-BH01-GW017**	**RDL**	**QC Batch**	**IG-BH01-GW017 Lab-Dup**	**RDL**	**QC Batch**	**IG-BH01-GW020**	**RDL**	**QC Batch**
Calculated Parameters										
Ammonium (NH4)	mg/L	0.12	0.05	7096433				0.12	0.05	7096433
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	9.0	1.0	7096432				7.3	1.0	7096432
Carb. Alkalinity (calc. as CaCO3)	mg/L	<1.0	1.0	7096432				<1.0	1.0	7096432
Total Nitrogen (N)	mg/L	0.27	0.10	7096435				0.28	0.10	7096435
Field Measurements										
Field Temperature	Celsius	5.67	N/A	ONSITE				5.67	N/A	ONSITE
Field Measured pH	pH	5.12		ONSITE				5.12		ONSITE
Inorganics										
Total Ammonia-N	mg/L	0.095	0.050	7097268				0.096	0.050	7097268
Fluoride (F-)	mg/L	0.49	0.10	7094661				0.50	0.10	7094661
Total Inorganic Carbon (C)	mg/L	2	1	7097489				2	1	7097489
Dissolved Iodide	mg/L	0.25	0.10	7106036				0.28	0.10	7106036
Total Kjeldahl Nitrogen (TKN)	mg/L	0.27	0.10	7097633				0.28	0.10	7097633
Dissolved Organic Carbon	mg/L	0.76	0.40	7097228				0.77	0.40	7097228
Total Organic Carbon (TOC)	mg/L	0.87	0.40	7097260				0.81	0.40	7097260
Orthophosphate (P)	mg/L	<0.010	0.010	7094660				<0.010	0.010	7094660
pH	pH	6.96		7094662				6.76		7094662
Total Phosphorus	mg/L	0.033	0.020	7097236				0.026	0.020	7097236
Reactive Silica (SiO2)	mg/L	9.1 (1)	0.50	7106048	9.1	0.50	7106048	8.5 (2)	0.50	7106048
Sulphide	mg/L	<0.020	0.020	7097796				<0.020	0.020	7097796
Alkalinity (Total as CaCO3)	mg/L	9.1	1.0	7096254				7.3	1.0	7096254
Nitrite (N)	mg/L	<0.010	0.010	7097495				<0.010	0.010	7097495
Dissolved Chloride (Cl-)	mg/L	4700	50	7098538				4600	50	7098538
Nitrate (N)	mg/L	<0.10	0.10	7097495				<0.10	0.10	7097495
Nitrate + Nitrite (N)	mg/L	<0.10	0.10	7097495				<0.10	0.10	7097495
Dissolved Bromide (Br-)	mg/L	<50	50	7098538				<50	50	7098538
Dissolved Sulphate (SO4)	mg/L	<50	50	7098538				<50	50	7098538

RDL = Reportable Detection Limit

QC Batch = Quality Control Batch

Lab-Dup = Laboratory Initiated Duplicate

N/A = Not Applicable

(1) Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

Matrix spike exceeds acceptance limits due to probable matrix interference.

(2) Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

RESULTS OF ANALYSES OF WATER

BV Labs ID		OIR406			OIR406			OIR407		
Sampling Date		2020/12/02 09:30			2020/12/02 09:30			2020/12/02 09:30		
COC Number		C#800970-01-01			C#800970-01-01			C#800970-01-01		
	UNITS	**IG-BH01-GW017**	**RDL**	**QC Batch**	**IG-BH01-GW017 Lab-Dup**	**RDL**	**QC Batch**	**IG-BH01-GW020**	**RDL**	**QC Batch**
Metals										
Total Ruthenium (Ru)	ug/L	<2.0	2.0	7122590				<2.0	2.0	7122590

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch
Lab-Dup = Laboratory Initiated Duplicate

BV Labs ID		OIR408		
Sampling Date		2020/12/02 09:30		
COC Number		C#800970-01-01		
	UNITS	**IG-BH01-GW018**	**RDL**	**QC Batch**
Inorganics				
Fluoride (F-)	mg/L	<0.10	0.10	7094661
Dissolved Iodide	mg/L	<0.10	0.10	7106036
Orthophosphate (P)	mg/L	0.030	0.010	7094660
Nitrite (N)	mg/L	<0.010	0.010	7097495
Dissolved Chloride (Cl-)	mg/L	5.2	1.0	7098538
Nitrate (N)	mg/L	<0.10	0.10	7097495
Nitrate + Nitrite (N)	mg/L	<0.10	0.10	7097495
Dissolved Bromide (Br-)	mg/L	<1.0	1.0	7098538
Dissolved Sulphate (SO4)	mg/L	<1.0	1.0	7098538
Metals				
Total Ruthenium (Ru)	ug/L	<2.0	2.0	7122590

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

BV Labs ID		OIR406	OIR407		OIR408		
Sampling Date		2020/12/02 09:30	2020/12/02 09:30		2020/12/02 09:30		
COC Number		C#800970-01-01	C#800970-01-01		C#800970-01-01		
	UNITS	**IG-BH01-GW017**	**IG-BH01-GW020**	**RDL**	**IG-BH01-GW018**	**RDL**	**QC Batch**
Metals							
Dissolved Aluminum (Al)	ug/L	<4.9	<4.9	4.9	5.3	4.9	7097207
Dissolved Arsenic (As)	ug/L	<1.0	<1.0	1.0	<1.0	1.0	7097207
Dissolved Barium (Ba)	ug/L	260	260	2.0	<2.0	2.0	7097207
Dissolved Bismuth (Bi)	ug/L	<1.0	<1.0	1.0	<1.0	1.0	7097207
Dissolved Boron (B)	ug/L	240	240	10	<10	10	7097207
Dissolved Cadmium (Cd)	ug/L	<0.090	<0.090	0.090	<0.090	0.090	7097207
Dissolved Calcium (Ca)	ug/L	1700000	1800000	1000	2100	200	7097207
Dissolved Cesium (Cs)	ug/L	<0.20	<0.20	0.20	<0.20	0.20	7097207
Dissolved Chromium (Cr)	ug/L	<5.0	<5.0	5.0	<5.0	5.0	7097207
Dissolved Cobalt (Co)	ug/L	<0.50	<0.50	0.50	<0.50	0.50	7097207
Dissolved Copper (Cu)	ug/L	<0.90	<0.90	0.90	1.0	0.90	7097207
Dissolved Iron (Fe)	ug/L	720	730	100	<100	100	7097207
Dissolved Lead (Pb)	ug/L	<0.50	<0.50	0.50	<0.50	0.50	7097207
Dissolved Lithium (Li)	ug/L	38	38	5.0	<5.0	5.0	7097207
Dissolved Magnesium (Mg)	ug/L	3000	3000	50	<50	50	7097207
Dissolved Nickel (Ni)	ug/L	<1.0	<1.0	1.0	1.2	1.0	7097207
Dissolved Potassium (K)	ug/L	11000	11000	200	<200	200	7097207
Dissolved Rubidium (Rb)	ug/L	12	12	0.20	<0.20	0.20	7097207
Dissolved Selenium (Se)	ug/L	<2.0	<2.0	2.0	<2.0	2.0	7097207
Dissolved Silicon (Si)	ug/L	4600	4800	50	<50	50	7097207
Dissolved Sodium (Na)	ug/L	580000	600000	500	1100	100	7097207
Dissolved Strontium (Sr)	ug/L	21000	21000	1.0	21	1.0	7097207
Dissolved Thorium (Th)	ug/L	<2.0	<2.0	2.0	<2.0	2.0	7097207
Dissolved Uranium (U)	ug/L	<0.10	<0.10	0.10	<0.10	0.10	7097207
Dissolved Zirconium (Zr)	ug/L	<1.0	<1.0	1.0	<1.0	1.0	7097207

RDL = Reportable Detection Limit
QC Batch = Quality Control Batch

TEST SUMMARY

BV Labs ID: OIR406
Sample ID: IG-BH01-GW017
Matrix: Water

Collected: 2020/12/02
Shipped:
Received: 2020/12/02

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Alkalinity	AT	7096254	N/A	2020/12/08	Surinder Rai
Carbonate, Bicarbonate and Hydroxide	CALC	7096432	N/A	2020/12/09	Automated Statchk
Anions	IC	7098538	N/A	2020/12/09	Fari Dehdezi
Dissolved Organic Carbon (DOC)	TOCV/NDIR	7097228	N/A	2020/12/08	Chandra Nandlal
Fluoride	ISE	7094661	2020/12/07	2020/12/08	Surinder Rai
Dissolved Metals by ICPMS	ICP/MS	7097207	N/A	2020/12/09	Arefa Dabhad
Iodide, Thiosulphate, Thiocyanate	IC/EC	7106036	N/A	2020/12/11	Coralynn Topping
Total Extractable Elements by ICP-MS	ICP/MSMS	7122590	2020/12/18	2020/12/21	Nicholas Ethier
Silica (Reactive)	KONE	7106048	N/A	2020/12/11	Craig Choquette
Ammonium as NH4+	CALC/NH3	7096433	N/A	2020/12/23	Automated Statchk
Total Ammonia-N	LACH/NH4	7097268	N/A	2020/12/10	Amanpreet Sappal
Nitrate (NO3) and Nitrite (NO2) in Water	LACH	7097495	N/A	2020/12/09	Chandra Nandlal
pH	AT	7094662	2020/12/07	2020/12/08	Surinder Rai
Field Temperature	PH	ONSITE	N/A	2020/12/02	Katherine Szozda
Orthophosphate	KONE	7094660	N/A	2020/12/09	Deonarine Ramnarine
Sulphide	ISE/S	7097796	N/A	2020/12/08	Neil Dassanayake
Field Temperature	PH	ONSITE	N/A	2020/12/02	Katherine Szozda
Total Inorganic Carbon (TIC)	TOCV/NDIR	7097489	N/A	2020/12/09	Nimarta Singh
Total Kjeldahl Nitrogen in Water	SKAL	7097633	2020/12/08	2020/12/08	Rajni Tyagi
Total Nitrogen (calculated)	CALC	7096435	N/A	2020/12/09	Automated Statchk
Total Organic Carbon (TOC)	TOCV/NDIR	7097260	N/A	2020/12/08	Chandra Nandlal
Total Phosphorus (Colourimetric)	LACH/P	7097236	2020/12/08	2020/12/09	Shivani Shivani

BV Labs ID: OIR406 Dup
Sample ID: IG-BH01-GW017
Matrix: Water

Collected: 2020/12/02
Shipped:
Received: 2020/12/02

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Silica (Reactive)	KONE	7106048	N/A	2020/12/11	Craig Choquette

BV Labs ID: OIR407
Sample ID: IG-BH01-GW020
Matrix: Water

Collected: 2020/12/02
Shipped:
Received: 2020/12/02

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Alkalinity	AT	7096254	N/A	2020/12/08	Surinder Rai
Carbonate, Bicarbonate and Hydroxide	CALC	7096432	N/A	2020/12/09	Automated Statchk
Anions	IC	7098538	N/A	2020/12/09	Fari Dehdezi
Dissolved Organic Carbon (DOC)	TOCV/NDIR	7097228	N/A	2020/12/08	Chandra Nandlal
Fluoride	ISE	7094661	2020/12/07	2020/12/08	Surinder Rai
Dissolved Metals by ICPMS	ICP/MS	7097207	N/A	2020/12/09	Arefa Dabhad
Iodide, Thiosulphate, Thiocyanate	IC/EC	7106036	N/A	2020/12/11	Coralynn Topping
Total Extractable Elements by ICP-MS	ICP/MSMS	7122590	2020/12/18	2020/12/21	Nicholas Ethier
Silica (Reactive)	KONE	7106048	N/A	2020/12/11	Craig Choquette

TEST SUMMARY

BV Labs ID: OIR407
Sample ID: IG-BH01-GW020
Matrix: Water

Collected: 2020/12/02
Shipped:
Received: 2020/12/02

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Ammonium as NH4+	CALC/NH3	7096433	N/A	2020/12/23	Automated Statchk
Total Ammonia-N	LACH/NH4	7097268	N/A	2020/12/10	Amanpreet Sappal
Nitrate (NO3) and Nitrite (NO2) in Water	LACH	7097495	N/A	2020/12/09	Chandra Nandlal
pH	AT	7094662	2020/12/07	2020/12/08	Surinder Rai
Field Temperature	PH	ONSITE	N/A	2020/12/02	Katherine Szozda
Orthophosphate	KONE	7094660	N/A	2020/12/09	Deonarine Ramnarine
Sulphide	ISE/S	7097796	N/A	2020/12/08	Neil Dassanayake
Field Temperature	PH	ONSITE	N/A	2020/12/02	Katherine Szozda
Total Inorganic Carbon (TIC)	TOCV/NDIR	7097489	N/A	2020/12/09	Nimarta Singh
Total Kjeldahl Nitrogen in Water	SKAL	7097633	2020/12/08	2020/12/08	Rajni Tyagi
Total Nitrogen (calculated)	CALC	7096435	N/A	2020/12/09	Automated Statchk
Total Organic Carbon (TOC)	TOCV/NDIR	7097260	N/A	2020/12/08	Chandra Nandlal
Total Phosphorus (Colourimetric)	LACH/P	7097236	2020/12/08	2020/12/09	Shivani Shivani

BV Labs ID: OIR408
Sample ID: IG-BH01-GW018
Matrix: Water

Collected: 2020/12/02
Shipped:
Received: 2020/12/02

Test Description	Instrumentation	Batch	Extracted	Date Analyzed	Analyst
Anions	IC	7098538	N/A	2020/12/09	Fari Dehdezi
Fluoride	ISE	7094661	2020/12/07	2020/12/08	Surinder Rai
Dissolved Metals by ICPMS	ICP/MS	7097207	N/A	2020/12/09	Arefa Dabhad
Iodide, Thiosulphate, Thiocyanate	IC/EC	7106036	N/A	2020/12/11	Coralynn Topping
Total Extractable Elements by ICP-MS	ICP/MSMS	7122590	2020/12/18	2020/12/21	Nicholas Ethier
Nitrate (NO3) and Nitrite (NO2) in Water	LACH	7097495	N/A	2020/12/09	Chandra Nandlal
Orthophosphate	KONE	7094660	N/A	2020/12/09	Deonarine Ramnarine

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	5.0°C

Anions Analysis: Due to the sample matrix, sample required dilution. Detection limits were adjusted accordingly.

Results relate only to the items tested.

QUALITY ASSURANCE REPORT

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
7094660	DRM	Matrix Spike	Orthophosphate (P)	2020/12/09		105	%	75 - 125
7094660	DRM	Spiked Blank	Orthophosphate (P)	2020/12/09		97	%	80 - 120
7094660	DRM	Method Blank	Orthophosphate (P)	2020/12/09	<0.010		mg/L	
7094660	DRM	RPD	Orthophosphate (P)	2020/12/09	2.8		%	25
7094661	SAU	Matrix Spike	Fluoride (F-)	2020/12/08		102	%	80 - 120
7094661	SAU	Spiked Blank	Fluoride (F-)	2020/12/08		100	%	80 - 120
7094661	SAU	Method Blank	Fluoride (F-)	2020/12/08	<0.10		mg/L	
7094661	SAU	RPD	Fluoride (F-)	2020/12/08	13		%	20
7094662	SAU	Spiked Blank	pH	2020/12/08		102	%	98 - 103
7094662	SAU	RPD	pH	2020/12/08	0.45		%	N/A
7096254	SAU	Spiked Blank	Alkalinity (Total as CaCO3)	2020/12/08		95	%	85 - 115
7096254	SAU	Method Blank	Alkalinity (Total as CaCO3)	2020/12/08	<1.0		mg/L	
7096254	SAU	RPD	Alkalinity (Total as CaCO3)	2020/12/08	1.1		%	20
7097207	ADA	Matrix Spike	Dissolved Aluminum (Al)	2020/12/08		106	%	80 - 120
			Dissolved Arsenic (As)	2020/12/08		99	%	80 - 120
			Dissolved Barium (Ba)	2020/12/08		100	%	80 - 120
			Dissolved Bismuth (Bi)	2020/12/08		90	%	80 - 120
			Dissolved Boron (B)	2020/12/08		91	%	80 - 120
			Dissolved Cadmium (Cd)	2020/12/08		101	%	80 - 120
			Dissolved Calcium (Ca)	2020/12/08		NC	%	80 - 120
			Dissolved Cesium (Cs)	2020/12/08		94	%	80 - 120
			Dissolved Chromium (Cr)	2020/12/08		93	%	80 - 120
			Dissolved Cobalt (Co)	2020/12/08		96	%	80 - 120
			Dissolved Copper (Cu)	2020/12/08		95	%	80 - 120
			Dissolved Iron (Fe)	2020/12/08		96	%	80 - 120
			Dissolved Lead (Pb)	2020/12/08		88	%	80 - 120
			Dissolved Lithium (Li)	2020/12/08		95	%	80 - 120
			Dissolved Magnesium (Mg)	2020/12/08		NC	%	80 - 120
			Dissolved Nickel (Ni)	2020/12/08		90	%	80 - 120
			Dissolved Potassium (K)	2020/12/08		106	%	80 - 120
			Dissolved Rubidium (Rb)	2020/12/08		97	%	80 - 120
			Dissolved Selenium (Se)	2020/12/08		95	%	80 - 120
			Dissolved Silicon (Si)	2020/12/08		111	%	80 - 120
			Dissolved Sodium (Na)	2020/12/08		NC	%	80 - 120
			Dissolved Strontium (Sr)	2020/12/08		NC	%	80 - 120
			Dissolved Thorium (Th)	2020/12/08		96	%	80 - 120
			Dissolved Uranium (U)	2020/12/08		95	%	80 - 120
			Dissolved Zirconium (Zr)	2020/12/08		110	%	80 - 120
7097207	ADA	Spiked Blank	Dissolved Aluminum (Al)	2020/12/08		97	%	80 - 120
			Dissolved Arsenic (As)	2020/12/08		100	%	80 - 120
			Dissolved Barium (Ba)	2020/12/08		98	%	80 - 120
			Dissolved Bismuth (Bi)	2020/12/08		99	%	80 - 120
			Dissolved Boron (B)	2020/12/08		93	%	80 - 120
			Dissolved Cadmium (Cd)	2020/12/08		103	%	80 - 120
			Dissolved Calcium (Ca)	2020/12/08		98	%	80 - 120
			Dissolved Cesium (Cs)	2020/12/08		98	%	80 - 120
			Dissolved Chromium (Cr)	2020/12/08		94	%	80 - 120
			Dissolved Cobalt (Co)	2020/12/08		99	%	80 - 120
			Dissolved Copper (Cu)	2020/12/08		93	%	80 - 120
			Dissolved Iron (Fe)	2020/12/08		99	%	80 - 120
			Dissolved Lead (Pb)	2020/12/08		96	%	80 - 120

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
			Dissolved Lithium (Li)	2020/12/08		96	%	80 - 120
			Dissolved Magnesium (Mg)	2020/12/08		99	%	80 - 120
			Dissolved Nickel (Ni)	2020/12/08		98	%	80 - 120
			Dissolved Potassium (K)	2020/12/08		97	%	80 - 120
			Dissolved Rubidium (Rb)	2020/12/08		100	%	80 - 120
			Dissolved Selenium (Se)	2020/12/08		100	%	80 - 120
			Dissolved Silicon (Si)	2020/12/08		98	%	80 - 120
			Dissolved Sodium (Na)	2020/12/08		100	%	80 - 120
			Dissolved Strontium (Sr)	2020/12/08		100	%	80 - 120
			Dissolved Thorium (Th)	2020/12/08		99	%	80 - 120
			Dissolved Uranium (U)	2020/12/08		99	%	80 - 120
			Dissolved Zirconium (Zr)	2020/12/08		102	%	80 - 120
7097207	ADA	Method Blank	Dissolved Aluminum (Al)	2020/12/08	<4.9		ug/L	
			Dissolved Arsenic (As)	2020/12/08	<1.0		ug/L	
			Dissolved Barium (Ba)	2020/12/08	<2.0		ug/L	
			Dissolved Bismuth (Bi)	2020/12/08	<1.0		ug/L	
			Dissolved Boron (B)	2020/12/08	<10		ug/L	
			Dissolved Cadmium (Cd)	2020/12/08	<0.090		ug/L	
			Dissolved Calcium (Ca)	2020/12/08	<200		ug/L	
			Dissolved Cesium (Cs)	2020/12/08	<0.20		ug/L	
			Dissolved Chromium (Cr)	2020/12/08	<5.0		ug/L	
			Dissolved Cobalt (Co)	2020/12/08	<0.50		ug/L	
			Dissolved Copper (Cu)	2020/12/08	<0.90		ug/L	
			Dissolved Iron (Fe)	2020/12/08	<100		ug/L	
			Dissolved Lead (Pb)	2020/12/08	<0.50		ug/L	
			Dissolved Lithium (Li)	2020/12/08	<5.0		ug/L	
			Dissolved Magnesium (Mg)	2020/12/08	<50		ug/L	
			Dissolved Nickel (Ni)	2020/12/08	<1.0		ug/L	
			Dissolved Potassium (K)	2020/12/08	<200		ug/L	
			Dissolved Rubidium (Rb)	2020/12/08	<0.20		ug/L	
			Dissolved Selenium (Se)	2020/12/08	<2.0		ug/L	
			Dissolved Silicon (Si)	2020/12/08	<50		ug/L	
			Dissolved Sodium (Na)	2020/12/08	<100		ug/L	
			Dissolved Strontium (Sr)	2020/12/08	<1.0		ug/L	
			Dissolved Thorium (Th)	2020/12/08	<2.0		ug/L	
			Dissolved Uranium (U)	2020/12/08	<0.10		ug/L	
			Dissolved Zirconium (Zr)	2020/12/08	<1.0		ug/L	
7097207	ADA	RPD	Dissolved Arsenic (As)	2020/12/09	NC		%	20
			Dissolved Barium (Ba)	2020/12/09	1.6		%	20
			Dissolved Boron (B)	2020/12/09	1.8		%	20
			Dissolved Cadmium (Cd)	2020/12/09	NC		%	20
			Dissolved Chromium (Cr)	2020/12/09	NC		%	20
			Dissolved Cobalt (Co)	2020/12/09	2.1		%	20
			Dissolved Copper (Cu)	2020/12/09	1.4		%	20
			Dissolved Lead (Pb)	2020/12/09	NC		%	20
			Dissolved Nickel (Ni)	2020/12/09	3.2		%	20
			Dissolved Selenium (Se)	2020/12/09	NC		%	20
			Dissolved Sodium (Na)	2020/12/09	2.5		%	20
			Dissolved Uranium (U)	2020/12/09	4.8		%	20
7097228	C_N	Matrix Spike	Dissolved Organic Carbon	2020/12/08		98	%	80 - 120
7097228	C_N	Spiked Blank	Dissolved Organic Carbon	2020/12/08		101	%	80 - 120

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
7097228	C_N	Method Blank	Dissolved Organic Carbon	2020/12/08	<0.40		mg/L	
7097228	C_N	RPD	Dissolved Organic Carbon	2020/12/08	4.6		%	20
7097236	SSV	Matrix Spike	Total Phosphorus	2020/12/08		NC	%	80 - 120
7097236	SSV	QC Standard	Total Phosphorus	2020/12/08		100	%	N/A
7097236	SSV	Spiked Blank	Total Phosphorus	2020/12/08		101	%	80 - 120
7097236	SSV	Method Blank	Total Phosphorus	2020/12/08	<0.020		mg/L	
7097236	SSV	RPD	Total Phosphorus	2020/12/08	0.16		%	20
7097260	C_N	Matrix Spike	Total Organic Carbon (TOC)	2020/12/08		99	%	80 - 120
7097260	C_N	Spiked Blank	Total Organic Carbon (TOC)	2020/12/08		99	%	80 - 120
7097260	C_N	Method Blank	Total Organic Carbon (TOC)	2020/12/08	<0.40		mg/L	
7097260	C_N	RPD	Total Organic Carbon (TOC)	2020/12/08	0.24		%	20
7097268	ASP	Matrix Spike	Total Ammonia-N	2020/12/10		103	%	75 - 125
7097268	ASP	Spiked Blank	Total Ammonia-N	2020/12/10		99	%	80 - 120
7097268	ASP	Method Blank	Total Ammonia-N	2020/12/10	<0.050		mg/L	
7097268	ASP	RPD	Total Ammonia-N	2020/12/10	0.61		%	20
7097489	NS3	Matrix Spike	Total Inorganic Carbon (C)	2020/12/09		84	%	80 - 120
7097489	NS3	Spiked Blank	Total Inorganic Carbon (C)	2020/12/09		92	%	80 - 120
7097489	NS3	Method Blank	Total Inorganic Carbon (C)	2020/12/09	<1		mg/L	
7097489	NS3	RPD	Total Inorganic Carbon (C)	2020/12/09	0.13		%	20
7097495	C_N	Matrix Spike	Nitrite (N)	2020/12/09		102	%	80 - 120
			Nitrate (N)	2020/12/09		101	%	80 - 120
7097495	C_N	Spiked Blank	Nitrite (N)	2020/12/09		100	%	80 - 120
			Nitrate (N)	2020/12/09		104	%	80 - 120
7097495	C_N	Method Blank	Nitrite (N)	2020/12/09	<0.010		mg/L	
			Nitrate (N)	2020/12/09	<0.10		mg/L	
7097495	C_N	RPD	Nitrite (N)	2020/12/09	NC		%	20
			Nitrate (N)	2020/12/09	NC		%	20
7097633	RTY	Matrix Spike	Total Kjeldahl Nitrogen (TKN)	2020/12/08		106	%	80 - 120
7097633	RTY	QC Standard	Total Kjeldahl Nitrogen (TKN)	2020/12/08		98	%	80 - 120
7097633	RTY	Spiked Blank	Total Kjeldahl Nitrogen (TKN)	2020/12/08		97	%	80 - 120
7097633	RTY	Method Blank	Total Kjeldahl Nitrogen (TKN)	2020/12/08	<0.10		mg/L	
7097633	RTY	RPD	Total Kjeldahl Nitrogen (TKN)	2020/12/08	NC (1)		%	20
7097796	NYS	Matrix Spike	Sulphide	2020/12/08		85	%	80 - 120
7097796	NYS	Spiked Blank	Sulphide	2020/12/08		88	%	80 - 120
7097796	NYS	Method Blank	Sulphide	2020/12/08	<0.020		mg/L	
7097796	NYS	RPD	Sulphide	2020/12/08	NC		%	20
7098538	FD	Matrix Spike	Dissolved Chloride (Cl-)	2020/12/09		98	%	80 - 120
			Dissolved Bromide (Br-)	2020/12/09		112	%	80 - 120
			Dissolved Sulphate (SO4)	2020/12/09		98	%	80 - 120
7098538	FD	Spiked Blank	Dissolved Chloride (Cl-)	2020/12/09		96	%	70 - 130
			Dissolved Bromide (Br-)	2020/12/09		111	%	80 - 120
			Dissolved Sulphate (SO4)	2020/12/09		98	%	80 - 120
7098538	FD	Method Blank	Dissolved Chloride (Cl-)	2020/12/09	<1.0		mg/L	
			Dissolved Bromide (Br-)	2020/12/09	<1.0		mg/L	
			Dissolved Sulphate (SO4)	2020/12/09	<1.0		mg/L	
7098538	FD	RPD	Dissolved Chloride (Cl-)	2020/12/09	5.2		%	20
7106036	CT6	Matrix Spike	Dissolved Iodide	2020/12/11		105	%	80 - 120
7106036	CT6	Spiked Blank	Dissolved Iodide	2020/12/11		107	%	80 - 120
7106036	CT6	Method Blank	Dissolved Iodide	2020/12/11	<0.10		mg/L	
7106036	CT6	RPD	Dissolved Iodide	2020/12/11	NC		%	20
7106048	CCQ	Matrix Spike [OIR406-02]	Reactive Silica (SiO2)	2020/12/11		260 (2)	%	80 - 120

QUALITY ASSURANCE REPORT(CONT'D)

QA/QC Batch	Init	QC Type	Parameter	Date Analyzed	Value	Recovery	UNITS	QC Limits
7106048	CCQ	Spiked Blank	Reactive Silica (SiO2)	2020/12/11		108	%	80 - 120
7106048	CCQ	Method Blank	Reactive Silica (SiO2)	2020/12/11	<0.050		mg/L	
7106048	CCQ	RPD [OIR406-02]	Reactive Silica (SiO2)	2020/12/11	0.011		%	20
7122590	NET	Spiked Blank	Total Ruthenium (Ru)	2020/12/21		88	%	70 - 130
7122590	NET	Method Blank	Total Ruthenium (Ru)	2020/12/21	<2.0		ug/L	

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

(1) Due to a high concentration of NOx, the sample required dilution. The detection limit was adjusted accordingly.

(2) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).

Anastassia Hamanov, Scientific Specialist

Eva Pranjic

Ewa Pranjic, M.Sc., C.Chem, Scientific Specialist

Katherine Szozda

Katherine Szozda, Project Manager

Sandy (Wei) Yuan, M.Sc., QP, Scientific Specialist

Shu Yang
2008-014

Shu Yang

Shu Yang, Analyst 2

BV Labs has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports.
For Service Group specific validation please refer to the Validation Signature Page.

IMMEDIATE

Bureau Veritas Laboratories
6740 Campobello Road, Mississauga, Ontario Canada L5N 2L8 Tel (905) 817-5700 Toll-free 800-563-6266 Fax (905) 817-5777 www.bvlabs.com

CHAIN OF CUSTODY RECORD

Page of

INVOICE TO:		REPORT TO:		PROJECT INFORMATION:		Laboratory Use Only:	
Company Name:	#12078 Geofirma Engineering Ltd	Company Name:	Geofirma Engineering	Quotation #:	C00845	BV Labs Job #:	Bottle Order #:
Attention:	Accounts Payable	Attention:	Chris Morgan	P.O. #:			800970
Address:	1 Raymond St Suite 200	Address:		Project:	PO20-203	COC #:	Project Manager:
	Ottawa ON K1R 1A2			Project Name:	20-203	C#800970-01-01	Katherine Szozda
Tel:	(613) 232-2525 Fax: (613) 232-7149	Tel:	613402 1701 Fax:	Site #:	IG-BH01		
Email:	accountspayable@geofirma.com	Email:	cmorgan@geofirma.com	Sampled By:	CAM, AMSC		

MOE REGULATED DRINKING WATER OR WATER INTENDED FOR HUMAN CONSUMPTION MUST BE SUBMITTED ON THE BV LABS DRINKING WATER CHAIN OF CUSTODY

Regulation 153 (2011)
☒ Table 1 ☐ Res/Park ☐ Medium/Fine
☐ Table 2 ☐ Ind/Comm ☐ Coarse
☐ Table 3 ☐ Agri/Other ☐ For RSC
☐ Table

Other Regulations
☐ CCME ☐ Sanitary Sewer Bylaw
☐ Reg 558 ☐ Storm Sewer Bylaw
☐ MISA Municipality
☐ PWQO ☐ Reg 406 Table
☐ Other

Special Instructions

Include Criteria on Certificate of Analysis (Y/N)? X

ANALYSIS REQUESTED (PLEASE BE SPECIFIC)

	Sample Barcode Label	Sample (Location) Identification	Date Sampled	Time Sampled	Matrix	Field Filtered (please circle): [✓ Metals] / Hg / Cr VI	Dissolved Metals by ICPMS	Metals-Ruthenium (Not filtered)	Metals - Total Sufur/Iron	Silica (Reactive)	Anions - Br, CL, SO4, PO4, I, NO2/NO3/F	Alkalinity, Carbonate/Bicarbonate, pH, Sulphide	DOC, TOC & TIC	Total Ammonia-N, Total Nitrogen	Total Phosphorus (Colourmetric)		# of Bottles	Comments
1		IG_BH01_GW017	Nov 28-30 2020	Varies	GW	X	X	X		X	X	X	X	X	X		8	See bottles for specific dates / times
2		IG_BH01_GW020	↓	↓	GW	X	X	X		X	X	X	X	X	X		8	↓
3		IG_BH01_GW018	↓	↓	GW	X	X	X			X						2	Use gen. Chem bottle for Ru analysis
4																		Received in Sudb
5																		Note:
6																		COC ID:
7																		Geofirma_BVL_0001
8																		
9																		
10																		

02-Dec-20 09:30
Katherine Szozda
C0W4852
ZPK ENV-1231

Turnaround Time (TAT) Required:
Please provide advance notice for rush projects

Regular (Standard) TAT: ☒
(will be applied if Rush TAT is not specified):
Standard TAT = 5-7 Working days for most tests.
Please note: Standard TAT for certain tests such as BOD and Dioxins/Furans are > 5 days - contact your Project Manager for details.

Job Specific Rush TAT (if applies to entire submission)
Date Required: Time Required: ☐
Rush Confirmation Number: *(call lab for #)*

* RELINQUISHED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	RECEIVED BY: (Signature/Print)	Date: (YY/MM/DD)	Time	# jars used and not submitted
Chris Morgan	20/12/02	7:30	Julie Clement	20/12/02	9:30	
				20/12/02	09:10	

Laboratory Use Only				
Time Sensitive	Temperature (°C) on Recei	Custody Seal	Yes	No
	5/3/7 4/5/5	Present	✓	
		Intact	✓	

White: BV Labs Yellow: Client

SAMPLES MUST BE KEPT COOL (< 10° C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BV LABS

* UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO BV LABS' STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS WHICH ARE AVAILABLE FOR VIEWING AT WWW.BVLABS.COM/TERMS-AND-CONDITIONS.

* IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

** SAMPLE CONTAINER, PRESERVATION, HOLD TIME AND PACKAGE INFORMATION CAN BE VIEWED AT WWW.BVLABS.COM/RESOURCES/CHAIN-OF-CUSTODY-FORMS.

ISOTOPE TRACER
TECHNOLOGIES INC

Isotope Analyses for:
Geofirma Engineering LTD

IT^2 FILE
200234

2021-02-22

Approved by:

Orfan S-Stash

Orfan Shouakar-Stash, PhD
Director
Isotope Tracer Technologies Inc.
695 Rupert St. Unit B, Waterloo, ON, N2V 1Z5
Tel: 519-886-5555 | Fax: 519-886-5575
Email: orfan@it2isotopes.com
Website: www.it2isotopes.com

Reported: 2021-02-22

ISOTOPE TRACER
TECHNOLOGIES INC

Client: Geofirma Engineering LTD
Address: 1 RAYMOND ST. SUITE 200
Ottawa, ON. K1R 1A2
Tel.: (613)402-1701
Attn.: Chris Morgan
E-mail: cmorgan@geofirma.com

File Number: 200234
Project Number: # 20-203

#	Client ID	Sample #	Sampling		$\delta^{18}O$	Aver	Stdv	$\delta^{2}H$	Aver	Stdv
			Date	Time	H_2O	VSMOW		H_2O	VSMOW	
1	IG-BH01-GW017	65670	2020-11-24	N/A	X	-12.08	0.01	X	-82.4	0.2
2	IG-BH01-GW020	65671	2020-11-29	N/A	X	-12.10	0.02	X	-82.7	0.1
3	IG-BH01-GW019	65672	2020-11-29	N/A	X	-13.10	0.04	X	-86.9	0.3

^{18}O & ^{2}H (CRDS)

Instrument Used: Cavity Ring Down Spectroscopy (CRDS)
CRDS (Model L2130-i) (Picarro, California, USA).

Standard Used:
IT2-11B / IT2-12C / IT2-13B Calibrated with IAEA Standards (V-SMOW, SLAP, and GISP)

Typical Standard deviation:
(^{18}O ±0.1‰) (^{2}H ± 1‰)

Approved by:

Orfan Shouakar-Stash, PhD
Director
Isotope Tracer Technologies Inc.
695 Rupert St. Unit B, Waterloo, ON, N2V 1Z5
Tel: 519-886-5555 | Fax: 519-886-5575
Email: orfan@it2isotopes.com
Website: www.it2isotopes.com

Updated: 2021-03-19

ISOTOPE TRACER
TECHNOLOGIES INC

Client: Geofirma Engineering LTD
Address: 1 RAYMOND ST. SUITE 200
Ottawa, ON. K1R 1A2
Tel.: (613)402-1701
Attn.: Chris Morgan
E-mail: cmorgan@geofirma.com

File Number: 200234
Project Number: # 20-203

#	Client ID	Sample #	Sampling		E^3H	Result	± 1σ
			Date	Time			
1	IG-BH01-GW017	65670	2020-11-24	N/A	X	1.5	0.2
2	IG-BH01-GW020	65671	2020-11-29	N/A	X	< 0.8	0.2
3	IG-BH01-GW019	65672	2020-11-29	N/A	X	< 0.8	0.5

E^3H ANALYSES

Result added Mar.19, 2021

Tritium is reported in Tritium Units.
1TU = 3.221 Picocurries/L per IAEA, 2000 Report.
1TU = 0.11919 Becquerels/L per IAEA, 2000 Report.

Approved by:

Orfan S-Stash

Orfan Shouakar-Stash, PhD
Director
Isotope Tracer Technologies Inc.
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Tel: 519-886-5555 | Fax: 519-886-5575
Email: orfan@it2isotopes.com
Website: www.it2isotopes.com

Reported: 2021-02-22

ISOTOPE TRACER
TECHNOLOGIES INC

Client: Geofirma Engineering LTD
Address: 1 RAYMOND ST. SUITE 200
Ottawa, ON. K1R 1A2
Tel.: (613)402-1701
Attn.: Chris Morgan
E-mail: cmorgan@geofirma.com

File Number: 200234
Project Number: # 20-203

#	Client ID	Sample #	Sampling		$^{87}Sr/^{86}Sr$	Result	StdErr (abs)	StdDev (abs)
			Date	Time				
1	IG-BH01-GW017	65670	2020-11-24	N/A	X	0.72042	1.280E-05	1.378E-04
2	IG-BH01-GW020	65671	2020-11-29	N/A	X	0.72011	1.109E-05	1.189E-04
3	IG-BH01-GW019	65672	2020-11-29	N/A				

$^{87}Sr/^{86}Sr$ ANALYSES

Instrument Used:

Thermal Ionization Mass Spectrometry (TIMS), TI-Box, spectromat, Germany

Standard Used:

NIST-987

Typical Standard deviation:

±0.0001

Approved by:

Orfan Shouakar-Stash, PhD
Director
Isotope Tracer Technologies Inc.
695 Rupert St. Unit B, Waterloo, ON, N2V 1Z5
Tel: 519-886-5555 | Fax: 519-886-5575
Email: orfan@it2isotopes.com
Website: www.it2isotopes.com

Reported: 2021-02-22

ISOTOPE TRACER
TECHNOLOGIES INC

Client: Geofirma Engineering LTD
Address: 1 RAYMOND ST. SUITE 200
Ottawa, ON. K1R 1A2
Tel.: (613)402-1701
Attn.: Chris Morgan
E-mail: cmorgan@geofirma.com

File Number: 200234
Project Number: # 20-203

#	Client ID	Sample #	Sampling		$\delta^{37}Cl$	Result	Stdv
			Date	Time			
1	IG-BH01-GW017	65670	2020-11-24	N/A	X	0.48	0.14
2	IG-BH01-GW020	65671	2020-11-29	N/A	X	-0.37	0.05
3	IG-BH01-GW019	65672	2020-11-29	N/A			

^{37}Cl ANALYSES

Instrument Used:

Isotope Ratio Mass Spectrometry (IRMS) - MAT 253, Thermo Scientific, Germany
Coupled with an Agilent 6890 Gas Chromatograph (GC)

Standard Used:

SMOC

Typical Standard deviation:

± 0.15‰

Approved by:

Orfan S-Stash

Orfan Shouakar-Stash, PhD
Director
Isotope Tracer Technologies Inc.
695 Rupert St. Unit B, Waterloo, ON, N2V 1Z5
Tel: 519-886-5555 | Fax: 519-886-5575
Email: orfan@it2isotopes.com
Website: www.it2isotopes.com

Client: Geofirma Engineering LTD
Address: 1 RAYMOND ST. SUITE 200
Ottawa, ON. K1R 1A2
Tel.: (613)402-1701
Attn.: Chris Morgan
E-mail: cmorgan@geofirma.com

ISOTOPE TRACER
TECHNOLOGIES INC

File Number: 200234
Project Number: # 20-203

#	Client ID	Sample #	Sampling		δ^{13}C	Result	^{14}C	Result			
			Date	Time	DIC	PDB	DIC	14C yr BP	±	F14C	±
1	IG-BH01-GW017	65670	2020-11-24	N/A	X	-10.4	X	7892	99	0.3744	0.0046
2	IG-BH01-GW020	65671	2020-11-29	N/A	X	-10.3	X	8109	96	0.3644	0.0043
3	IG-BH01-GW019	65672	2020-11-29	N/A	X	-11.6	X	7620	78	0.3873	0.0037

DATA Revised Feb.26, 2021

^{13}C DIC Analyses

Instrument Used:

Finnigan MAT, Delta^{Plus} XL IRMS, Germany.

Standard Used: IT2-27 / IT2-34/ NBS-18/ NBS-19

Typical Standard deviation: ± 0.2 ‰

^{14}C DIC Analyses

Instrument Used:

AMS (Accelerator Mass Spectrometry)

Standard Used:

OX1: 1.05 x e-10
OX2: 1.35 x e-10
C6: 1.5 x e-10
C7: 0.5 x e-10

Typical Standard deviation:

5 to 10% of Standard values listed above

Approved by:

Orfan Shouakar-Stash, PhD
Director
Isotope Tracer Technologies Inc.
695 Rupert St. Unit B, Waterloo, ON, N2V 1Z5
Tel: 519-886-5555 | Fax: 519-886-5575
Email: orfan@it2isotopes.com
Website: www.it2isotopes.com

Reporting of Data

In this analysis report, we have followed the conventions recommended by Millard (2014).

Radiocarbon Analysis

Radiocarbon analyses are performed on a 3MV tandem accelerator mass spectrometer built by High Voltage Engineering (HVE). 12,13,14C+3 ions are measured at 2.5 MV terminal voltage with Ar stripping. The fraction modern carbon, F14C, is calculated according to Reimer et al. (2004) as the ratio of the sample 14C/12C ratio to the standard 14C/12C ratio (in our case Ox-II) measured in the same data block. Both 14C/12C ratios are background-corrected and the result is corrected for spectrometer and preparation fractionation using the AMS measured 13C/12C ratio and is normalized to δ13C (PDB). Radiocarbon ages are calculated as -8033ln(F14C) and reported in 14C yr BP (BP=AD 1950) as described by Stuiver and Polach (1977). The errors on 14C ages (1σ) are based on counting statistics and 14C/12C and 13C/12C variation between data blocks. We do not report δ13C as it is measured on the AMS and contains machine fractionation.

D14C (defined as per mil Depletion or Enrichment Relative to Standard Normalized for Isotope Fractionation) are calculated as (F14C – 1) · 1000.

Δ14C (defined as age corrected D14C) are calculated as (F14C·e(1950-y)/8267) – 1) · 1000, where y = year of measurement.

ISOTOPE TRACER
TECHNOLOGIES INC

CHAIN OF CUSTODY / ANALYTICAL SERVICES REQUEST FORM

Page __ of __

Note: all TAT Quoted material is in business days which exclude statutory holidays and weekends.

Specify date required	Service Requested
	[✓ *(regular)*]
	(Rush)

COMPANY NAME Geofirma Engineering
OFFICE ADDRESS 1 Raymond St., Ottawa, ON. K1R 1A2
PROJECT MANAGER: Chris Morgan
PROJECT # 20-203
PHONE 613-402-1701
FAX
PO # 202031-009

REPORT FORMAT/DISTRIBUTION

EMAIL X FAX ________ BOTH ________
SELECT: PDF _____ DIGITAL _____ BOTH _____
EMAIL 1 cmorgan@geofirma.com
EMAIL 2 ______________________________

SAMPLING INFORMATION

ANALYSIS REQUEST

Sample Date/Time		TYPE		MATRIX					ANALYSIS REQUEST										PLEASE INDICATE FILTERED, PRESERVED OR BOTH <----- (F, P, F/P)	
									F	F	F	F	F	F						
Date (YYYY-MM-DD)	Time (24hr) (hh:mm)	COMP	GRAB	WATER	SOIL	OTHER	SAMPLE DESCRIPTION TO APPEAR ON REPORT	NUMBER OF CONTAINERS	^3H	$\delta^{18}O$, ^2H	$^{87}Sr/^{86}Sr$	$\delta^{37}Cl$	$\delta^{13}C$-DIC	14-DIC					COMMENTS	LAB ID
2020-11-29	Various		X	X			IG_BH01_GW017	6	X	X	X	X	X	X						
2020-11-29	Various		X	X			IG_BH01_GW020	6	X	X	X	X	X	X						
2020-11-29	Various		X	X			IG_BH01_GW019	2	X					X						

SUBMISSION #:
ENTERED BY:
DATE/TIME ENTERED:
BIN #:

SPECIAL INSTRUCTIONS/COMMENTS

COCID =
Geofirma_IT2_0001

THE QUESTIONS BELOW MUST BE ANSWERED FORWATER SAMPLES (CHECK Yes OR No)

Are any samples taken from a regulated DW System? Yes ___ No X
If yes, an authorized drinking water COC MUST be used for this submission.
Is the water sampled intended to be potable for human consumption? Yes ___ No X

SAMPLE CONDITION

___ FROZEN
X COLD
___ COOLING INITIATED
___ AMBIENT

Observations

SAMPLED BY: Chris Morgan	DATE & TIME 29/Nov/20	RECEIVED BY: Reception	DATE & TIME Dec. 11, 2020
RELINQUISHED BY: Chris Morgan	DATE & TIME 08/Dec/20	RECEIVED AT LAB BY:	DATE & TIME

1. TAT may vary dependent on complexity of analysis and lab workload at time of submission. Please contact the lab to confirm TATs.

2. Any known or suspected hazards relating to a sample must be noted on the chain of custody in comments section.

Send completed copy/scan of COC to cmorgan@geofirma.com

The André E. Lalonde AMS Laboratory
Noble Gases Laboratory
University of Ottawa, Advanced Research Complex
25 Templeton St
Ottawa ON K1N 6N5 Canada

alapp@uottawa.ca
☎: 613-562-5800 ext: 7981
www.ams.uottawa.ca

Analysis Report

Date: March 16, 2022
Revised: September 20, 2022

Samples Submitted by: Amy Cartier
Report Submitted to: Amy Cartier

Noble Gas Analysis

Light Noble Gas Procedure

Gas extraction from water follows the procedure outlined in Aeschbach-Hertig & Solomon 2013. This involves gas extraction from copper tube water samples under vacuum by water vapour sweep into a stainless steel gas flask. The extracted gases are let into a sample preparation line and cryogenically separated. For light noble gases (He and Ne), standards and samples are introduced into an ultra-high vacuum preparation system where bulk (N2, O2) and trace gases (CO2, Ar) are removed using liquid N2 charcoal traps and two SAES getters, followed by analysis on a Thermo Scientific Helix SFT Noble Gas Mass Spectrometer. Internal standards using precise aliquots from a tank of clean dry atmospheric air are run each morning and during analysis to measure instrument drift and sensitivity. Internal standards of air equilibrated water (AEW) are also run as internal checks on the water extraction procedure and analyses. Following purification, He is separated from Ne using a He cooled cryo trap that cycles down to 5K, before releasing He at 28K and Ne at 70K. He and Ne are introduced separately into the Helix SFT operating under static vacuum. Each analysis undergoes a mass peak center, followed by separate integrations on each mass peak. These integrations generate a linear regression used to calculate peak intensity at time zero (when the sample was released into the mass spectrometer).For Ar, Kr and Xe, gases, residual water vapour was removed cryogenically prior to gettering of reactive gases and cryogenic separation of Kr and Xe from Ar. Abundance analysis was done by quadrupole mass spectrometry at the University of Utah Noble Gas Lab.

Heavy Noble Gas Procedure

Sample collection vessels are placed on an inlet manifold where the sample gas is expanded into an all-metal cleanup system. A water vapor pump is used to sweep the flask volume equivalent to 5 times to ensure that no residual gas is left within the collection vessel. We've tested this method extensively by preforming multiple inlets of a sample volume and this method has repeatedly shown that less than 0.1% of the gas is left in the flask after sweeping. Once the inlet process is completed and the sample has been injected into the cleanup and analysis system, a valve isolating the collection vessel is closed for the remainder of the analysis. Water vapor is then removed from the sample gas using a cold head held at 178K (–95 ˚C). An isotopic standard, referred to as a spike, of 78Kr and 124Xe is also added to the sample gas at this point. The amount of spike delivered through a pipet is extremely small, close to the atmospheric amounts of 84Kr and 132Xe. Once the sample gas has been sufficiently dehydrated (approx. 15 minutes) and the isotopic standard has been added, a total inlet pressure is measured using a Baratron® gauge. The sample is then split into three fractions; each is used to measure 2 specific gases of the original sample. First, a small fraction is split off and used for a bulk gas analysis; this includes quadrupole (Stanford Research Systems (SRS) RGA 300) measurements of N2, O2, Ar, CO2 and CH4. Of these gases only N2 is generally used. The remaining gas is then exposed to a Ti-Zr getter held at 523K (250 ˚C), which removes all reactive gasses (N2, O2, CO2, CH4, etc.). The sample is then exposed to a second Ti-Zr getter held at 298K, which removes hydrogen gas generated by the first getter. The dry cleaned gas is then simultaneously split into the remaining two fractions intended for analysis by first drawing Ar, Kr and Xe onto a nude electro polished stainless steel (SS) trap held at 25K. Once the heavy noble gases have been drawn onto the stainless steel trap the remaining portion (predominantly He and Ne) are exposed to a charcoal trap which is held at <10K (<-263˚C), trapping the remaining gas. After all the gas has been initially trapped onto their respective cold heads, the three cold heads (H2O trap, SS Trap, and Charcoal trap) are warmed and re-cooled to allow for the release of any gas molecules inadvertently trapped within ice during the water vapor pump and dehydration phase of the cleanup process, and also to layer the He, Ne, Ar, Ne, Kr and Xe for measurement. After all of the gases have been trapped and layered onto the cold heads, the analysis phase of the process begins.

First, Ar is released from the SS cold head at 51K and inlet to the quadrupole where both 36Ar and 40Ar are measured statically using the quadrupole MS. Because of low abundances of several isotopes, the RGA is fitted with an electron multiplier to obtain better measurements of 36Ar, 22Ne, and also to obtain a better quantitative measurement of the less abundant isotopes of Kr, and Xe. Next, the stainless steel cold head is cooled back down to 45K and then pumped on with a turbo molecular pump to remove any remaining Ar. This is necessary to reduce the partial pressure of Ar in the RGA so that it will not interfere with Kr and Xe during quadrupole measurement.

References:

Aeschbach-Hertig W., Solomon D.K. (2013) Noble Gas Thermometry in Groundwater Hydrology. In: Burnard P. (eds) The Noble Gases as Geochemical Tracers. Advances in Isotope Geochemistry. Springer, Berlin, Heidelberg

Table 1 – Helium and Neon Isotope Data

Sample ID	UON	3He		4He		Ne20		Ne21		Ne22	
		cc/g	±	cc/g	±	cc/g	±	cc/g	±	cc/g	±
IG_BH01_GW017	UON-964	1.16E-10	3.42E-12	1.16E-03	2.32E-06	7.66E-07	2.45E-09	2.31E-09	3.70E-12	7.68E-08	2.61E-10
IG_BH01_GW020	UON-965	3.05E-10	3.38E-12	6.22E-03	6.22E-07	9.78E-07	1.27E-09	3.19E-09	2.55E-12	9.83E-08	7.87E-11

Table 2 – Argon Isotope, Total Krypton & Total Xenon Data

Sample ID	UON	Ar36		Ar40		KrTotal		XeTotal	
		cc/g	±	cc/g	±	cc/g	±	cc/g	±
IG_BH01_GW017	UON-964	1.70E-07	5.086E-09	1.97E-04	5.896E-06	2.04E-08	1.019E-09	5.37E-09	2.685E-10
IG_BH01_GW020	UON-965	n/a 2		n/a 2		n/a 2		n/a 2	

Remarks: Values are reported as cc gas STP / g water.

[n/a 1] He measurements not possible due to He abundance exceeding inlet capacity of mass spectrometer.

[n/a 2] Sample leaking during extraction, likely due to corrosion from high salinity. Could not be run for Ar, Kr, Xe

André E. Lalonde AMS Laboratory

Radiohalides Laboratory

www.ams.uottawa.ca

Analysis Report

SUBMITTER SUMMARY			
Submitter Name:	Amy Cartier	**Affiliation:**	Geofirma
Submitter Email:	acartier@geofirma.com	**Street Address:**	200-1 Raymond St.
Submitter Phone:	613-232-2525	**City, Province:**	Ottawa, ON
Principal Investigator Name:	Chris Morgan	**Postal Code:**	K1R 1A2
Principal Investigator Email:	cmorgan@geofirma.ca	**Country:**	Canada
Principal Investigator Phone:		**Date Submitted:**	2020-12-09

PROJECT INFORMATION	
Project Title:	20-203-1: NWMO Westbay Monitoring Ignace Boreholes
Country:	Canada
Site Name:	IG_BH01
Collection Date:	Nov 29 2020

SUBMISSION TIMELINE	
Date samples received (YYYY/MM/DD)	Report date (YYYY/MM/DD)
(2020/12/21)	(2021/03/20)

ANALYTICAL NOTES

Notes regarding analysis/sample preparation.

Please note: Unless otherwise specified in the submission form, any remaining sample material will be held for a period of six (6) months, after which time it will be discarded.

CONTACT INFORMATION	
Should you have any questions regarding your data or sample preparation please contact:	
Name:	Monika Wilk
Email:	mwilk@uottawa.ca
Phone:	613-562-5800 ext. 6183

Researchers are asked to report any publications that include data generated at the AEL AMS facility. Publication notifications should be sent to ael-ams@uottawa.ca . Published data should include the unique UO identifier number provided in this analytical report.

Table 1. Analysis Results for Water Samples

uOttawa Number	Submitter's Sample I.D.	Weight of Groundwater Used (*g*)	^{127}I Concentration Measured (ppb)	Mass of Iodide Carrier Added (mg)	^{129}I/^{127}I Ratio Measured (*x10* $^{-14}$) *		^{129}I Concentration (*x10* ^{6} *atoms/g*)	
					Ratio	Standard Deviation	Concentration	Standard Deviation
UOH-3423	IG_BH01_GW017	201.19	324	1.88	66.6	2.2	3.05E-02	1.01E-03
UOH-3424	IG_BH01_GW020	202.87	305	1.94	61.2	1.5	2.87E-02	6.93E-04

Note: ** ^{129}I/^{127}I Ratio Measured includes both sample and carrier added*

The errors represent 68.3% confidence limits, based on 1 measurement each. These measurements were normalized with respect to the ISO-6II reference material for which $^{129}I/^{127}I = (5.72 \pm 0.08)x10^{-12}$, by calibration with the NIST 3230 I and II standard reference material.

The AMS system background was monitored with our standard NaI blank material and found to be normal. No background corrections were applied to these data. A NaI blank measured with this set of samples yielded a $^{129}I/^{127}I$ ratio of (1.13 ± 0.07) $x10^{-14}$.

André E. Lalonde AMS Laboratory

Radiohalides Laboratory

www.ams.uottawa.ca

Analysis Report

SUBMITTER SUMMARY			
Submitter Name:	Amy Cartier	**Affiliation:**	Geofirma
Submitter Email:	acartier@geofirma.com	**Street Address:**	200-1 Raymond St.
Submitter Phone:	613-232-2525	**City, Province:**	Ottawa, ON
Principal Investigator Name:	Chris Morgan	**Postal Code:**	K1R 1A2
Principal Investigator Email:	cmorgan@geofirma.ca	**Country:**	Canada
Principal Investigator Phone:		**Date Submitted:**	2020-12-09

PROJECT INFORMATION	
Project Title:	20-203-1: NWMO Westbay Monitoring Ignace Boreholes
Country:	Canada
Site Name:	IG_BH01
Collection Date:	Nov 29 2020

SUBMISSION TIMELINE	
Date samples received (YYYY/MM/DD)	Report date (YYYY/MM/DD)
spring 2021	(2021/10/16)

ANALYTICAL NOTES
Notes regarding analysis/sample preparation.

Please note: Unless otherwise specified in the submission form, any remaining sample material will be held for a period of six (6) months, after which time it will be discarded.

CONTACT INFORMATION	
Should you have any questions regarding your data or sample preparation please contact:	
Name:	Monika Wilk
Email:	mwilk@uottawa.ca
Phone:	613-562-5800 ext. 6183

Researchers are asked to report any publications that include data generated at the AEL AMS facility. Publication notifications should be sent to ael-ams@uottawa.ca . Published data should include the unique UO identifier number provided in this analytical report.

K210903

Bats version 3.157 (cv 04.04.2019) written by L. Wacker, C. Vockenhuber

sample	ETH label	^{35}Cl LE (µA)	^{37}Cl/^{35}Cl final (%)	σ (%)	^{36}Cl/^{35}Cl final (10^{-12})	stat. err (%)	σ (%)	comment	Cl (mg/L)	^{36}Cl/Cl final (10^{-15})	±	^{36}Cl atoms/L (10^{6})
IG_BH01_GW017	CV4056	6.11	32.47	0.34	0.021	7.4	8.3	prepared at ETH	4700	15.6	1.3	1241
IG_BH01_GW020	CV4057	6.69	32.14	0.26	0.022	8.0	5.7	prepared at ETH	4600	16.9	1.0	1321
IG_BH01_GW021	CV4058	5.87	32.61	0.53	0.023	8.1	7.5	prepared at ETH	3900	17.1	1.3	1130
IG_BH01_GW022	CV4059	6.89	32.82	0.42	0.021	8.3	9.9	prepared at ETH	4000	15.6	1.5	1059
Blank	BLANK1	6.10	32.29	0.29	0.003	18.3	19.6	inhouse machine blank		2.3		
Blank	BLANK2	6.42	32.27	0.18	0.003	17.5	12.6	inhouse machine blank		2.2		
Seawater	Argento et al, 2010								19350	0.5		164

no blank subtraction was applied!

For samples with natural Cl the ^{36}Cl/^{35}Cl ratios can be converted to ^{36}Cl/Cl applying the conversion factor of 0.7577.
The nominal ^{36}Cl/Cl ratio of the internal standard K382/4N is $(17.36 \pm 0.35)\times10^{-12}$.
The internal standard is calibrated against the primary standard KNSTD5000 (nominal ^{36}Cl/Cl ratio $(5.00 \pm 0.10)\times10^{-12}$) by K. Nishizumi.
The half-life of ^{36}Cl is $(3.01 \pm 0.02)\times10^{5}$ years.
A sample scatter of 1% was added to the uncertainty.

The measurement was performed at the 6 MV Tandem accelerator using the GFM method (Vockenhuber et al. 2019).

For samples with natural Cl the ^{36}Cl/^{35}Cl ratios can be converted to ^{36}Cl/Cl applying the conversion factor of 0.7577.

The nominal ^{36}Cl/Cl ratio of the internal standard K382/4N is $(17.36 \pm 0.35)\times10^{-12}$.

The internal standard is calibrated against the primary standard KNSTD5000 (nominal 36Cl/Cl ratio (5.00 ± 0.10)×10-12) by K. Nishizumi.

The half-life of ^{36}Cl is $(3.01 \pm 0.02)\times10^{5}$ years.

A sample scatter of 1% was added to the uncertainty.

The measurement was performed at the 6 MV Tandem accelerator using the GFM method (Vockenhuber et al. 2019).

Appendix D

Data Quality Confirmation (DQC) Workbook(s)

20-203-1: Groundwater Sampling - Field Data Sheet

Well ID:	IG_BH01		**Date:**	26-Nov-20
Westbay Stick Up:	0.58	m AGS	**Weather**	0 Degrees C, Snowy
MP38 Water Level Before:	50.01	m BTOC	**Start Time**	8:30
MP38 Water Level After:	50.165	m BTOC	**End Time:**	11:43
Probe Serial No (Range)	EMS4960 (2000psi)			

Pre-Profile	
Time:	8:52
Pressure (kPa):	96.18
Temp (°C)	12.48

Post-Profile	
Time:	11:43
Pressure (kPa):	96.64
Temp (°C)	5.51

Port #	Port Depth (m BGS)	Start Profile Time	Landed Pressure, MP38 Pre Profile (kPa)	Shoe Out	Interval Measurements			Shoe In	Landed Pressure, MP38 Post Profile (KPa)	Comments
					Pressure (kPa)	Temp. (°C)	Time			
1	977.3	9:43	9310.5	x	9623.97	14.17	9:44	x	9310.44	
2	888.8	9:52	8433.9	x	8697.2	13.58	9:53	x	8433.77	Pressure readings verified by AMSC
3	804.4	9:59	7595.97	x	7859.64	12.73	10:00	x	7596.05	Note: first reading after shoe-in at 6943kPa, likely caused by face seal sticking at port and causing a vaccum when releasing from port
4	769.3	10:10	7247.85	x	7483.93	12.18	10:11	x	7247.92	
5	703.1	10:16	6592.11	x	6838.95	11.51	10:19	x	6592.13	
6	649.8	10:24	6063.25	x	6296.8	11.02	10:26	x	6062.95	
7	628.4	10:29	5851.17	x	6080.18	10.73	10:30	x	5851.36	
8	574.4	10:34	5315.17	x	5560.18	10.25	10:35	x	5315.75	Pressure readings verified by AMSC
9	540.2	10:39	4975.9	x	5190.3	9.83	10:40	x	4975.96	Interval pressure lower than previous round due to recent purging from interval
10	517.4	10:43	4748.85	x	4988.05	9.55	10:44	x	4748.8	
11	493	10:49	4507.05	x	4759.2	9.26	10:50	x	4507.1	
12	432.1	10:55	3902.05	x	4144.78	8.56	10:59	x	3901.95	
13	409.3	11:01	3675.18	x	3936.62	8.35	11:03	x	3675.42	
14	325.6	11:09	2843.49	x	3098.23	7.68	11:09	x	2843.6	
15	307.3	11:11	2662.12	x	2923.52	7.38	11:13	x	2662.25	Pressure readings verified by AMSC
16	231.2	11:17	1906.89	x	2179.65	6.76	11:18	x	1906.78	Shoe'd out twice to confirm reading: second reading 2178.80
17	199.2	11:26	1588.98	x	1886.43	6.12	11:27	x	1588.95	
18	149	11:31	1090.15	x	1384.3	5.87	11:32	x	1090.35	
19	128.5	11:34	887.48	x	1176.38	5.69	11:35	x	887.46	
20	69.1	11:38	298.15	x	606.85	5.51	11:40	x	298.2	Pressure readings verified by AMSC

Completed by:	CAM & AMSC	Verified by:	SNS
Date:	26-Nov-20	Date:	20-Jan-21

20-203-1: Groundwater Sampling - Field Data Sheet

Well ID:	IG_BH03		**Date:**	25-Nov-20
Westbay Stick Up:	0.86	m AGS	**Weather**	0 Degrees C, Cloudy
MP38 Water Level Before:	76.997	m BTOC	**Start Time**	9:05
MP38 Water Level After:	77.225	m BTOC	**End Time:**	13:30
Probe Serial No (Range)	EMS4960 (2000psi)			

Pre-Profile	
Time:	9:10
Pressure (kPa):	97.7
Temp (℃)	7

Post-Profile	
Time:	13:23
Pressure (kPa):	96.21
Temp (℃)	5.47

Port #	**Port Depth (m BHA)**	**Start Profile Time**	**Landed Pressure, MP38 Pre Profile (kPa)**	**Shoe Out**	**Interval Measurements**			**Shoe In**	**Landed Pressure, MP38 Post Profile (KPa)**	**Comments**
					Pressure (kPa)	**Temp. (℃)**	**Time**			
1	967.3	10:16	8183.43	x	8683.48	13.22	10:18	x	8183.31	
2	944.4	10:23	7981.84	x	8464.55	13.14	10:24	x	7981.7	
3	924.5	10:34	7806.81	x	8299.04	12.92	10:36	x	7806.5	
4	883.3	10:42	7441.52	x	7925.53	12.67	10:42	x	7441.56	
5	860.4	10:49	7237.26	x	7700.23	12.35	10:51	x	7237.35	
6	794.8	10:57	6648.18	x	7111.38	11.89	10:58	x	6647.87	
7	753.3	11:05	6272.96	x	6723.73	11.41	11:06	x	6272.96	
8	676.5	11:20	5573.15	x	6037.68	10.66	11:21	x	5573.37	
9	638.3	11:29	5225.38	x	5686.94	10.37	11:30	x	5225.66	
10	613.9	11:34	5003	x	5456.11	10.1	11:35	x	5003.04	Sample outside of 50kpa from previous round. Remeasured to confirm reading at: 5455.89
11	568.2	11:42	4586.69	x	5049.26	9.8	11:44	x	4586.12	
12	544.6	12:01	4372.08	x	4843.32	9.41	12:05	x	4372.18	
13	506.6	12:10	4025.45	x	4510.5	9.13	12:11	x	4025.31	Interval pressure confirmed by second reading at: 4171.80
14	466.4	12:15	3659.86	x	4171.75	8.8	12:17	x	3659.9	
15	421.6	12:21	3252.75	x	3775.15	8.43	12:23	x	3252.51	
16	370.8	12:27	2789.85	x	3317.9	7.95	12:29	x	2789.75	Measurment of interval pressure verified by AMSC
17	321.5	12:34	2341.2	x	2876.85	7.52	12:35	x	2341.72	
18	251.5	12:40	1703.05	x	2243.05	6.93	12:41	x	1704.42	Note: 1.4kPa change pre/post measurement of interval pressure. Pressure in MP casing was
19	228.6	12:48	1495.5	x	2042.9	6.55	12:51	x	1495.5	
20	166.2	12:55	924.85	x	1492.65	6.15	12:57	x	924.82	
21	73.5	13:07	96.95	x	687.96	5.57	13:09	x	96.9	Verified by AMSC

Note: Depths are in meters below ground surface along borehole axis

Completed by:	CAM & AMSC	Verified by:	SNS
Date:	25-Nov-20	Date:	20-Jan-21

20-203-1: Groundwater Sampling - Field Data Sheet

Well ID:	IG_BH01	**Start Time**	12:45 (Nov 26)
MP38 Water Level Before Sampling:	67.32 m BTOC	**Starting Ambient Pressure**	96.64 kPa
MP38 Water Level After Sampling:	68.49 m BTOC	**End Sampling Time**	13:00 (Nov-30)
Probe Serial No. (Pressure Range)	EMS4960 (2000psi)	**Ending Ambient Pressure**	96.82 kPa
Date:	November 26 - 30 , 2020		

Other Notes/Comments: Start of sampling second day, atm pressure 95.74kPa

End of sampling on Nov 28, atm 95.89 kPa

			Function Tests/Preparation							Sampling Sequence										
Sampling Run Start Time	**Port #**	**Run #**	**Shoe-Out**	**Close Valve**	**Vaccum Check**	**Open Valve**	**Evacuate Bottles (<35 kPa)**	**Close Valve**	**Landed Port**	**Landed Westbay MP38 Pressure (pre-sample, kPa)**	**Shoe-Out**	**Zone Pressure (pre-sample, kPa)**	**Open-Valve**	**Stablization Time (sec)**	**Zone Pressure (post-sample kPa)**	**Close Valve**	**Shoe-In**	**Landed Westbay MP38 Pressure (post-sample, kPa)**	**Sampling Run End Time**	**Comments (volume recovered, parameters measured, samples collected, etc)**
Nov26: 12:45	IG_BH01_T_INT_009	1	X	X	X	X	32	X	X	4979	x	5191.75	X	600	5169	X	X	4979.14	13:40	~200 mL recovered, run used for pre-purge fluorescien concentration. Only one bottle used.
Nov28: 10:40	IG_BH01_T_INT_009	2	X	X	X	X	38	X	X	4820.12	X	5177.25	X	1774	5113.25	X	X	4819.98	11:41	First run for GW sampling of IG_BH01_T_INT_009. Used for field parameter measurment and archive sample collection.
Nov 28: 12:38	IG_BH01_T_INT_009	3	X	X	X	X	37	X	X	4819.66	X	5168.83	X	1214	5057.48	X	X	4819.03	13:26	Second run for GW sampling of IG_BH01_T_INT_009. Used to complete field parameter measurements and archive sample collection.
Nov 28: 14:55	IG_BH01_T_INT_009	4	X	X	X	X	38	X	X	4818.87	X	5167.07	x	960	5021.49	X	X	4818.38	15:40	Third run for GW sampling of IG_BH01_T_INT_009. Used for field parameter measurements.
Nov 28: 16:27	IG_BH01_T_INT_009	5	X	X	X	X	34	X	X	4817.88	X	5159.27	X	988	5019.31	X	X	4816.89	17:15	Fouth run for GW sampling of IG_BH01_T_INT_009. Used for lab sample collection.
Nov 29: 8:40	IG_BH01_T_INT_009	6	X	X	X	X	30	X	X	4817.69	x	5182.07	x	1020	5044.95	x	x	4817.49	9:32	Starting amb P: 96.85kPa. Day 2 of GW sampling IG_BH01_T_INT_009. Fifth run used for lab sample collection (129I,36Cl) . Verified by CAM
Nov 29:10:04	IG_BH01_T_INT_009	7	X	X	X	X	29	X	X	4816.64	X	5165.38	X	990	5033.97	X	X	4815.88	10:39	Sixth run for GW sampling of IG_BH01_T_INT_009. Run used for lab sample collection (129I, 36Cl).
Nov 29: 11:17	IG_BH01_T_INT_009	8	X	X	X	X	35	X	X	4815.94	X	5161.18	X	1025	5019.77	X	X	4815.38	11:54	Seventh run for GW sampling of IG_BH01_T_INT_009. Seventh run used for lab sample collection (SiO2, Ammonia, Dissolved metals, Nutritents/total N/ TOC/ Total P).
Nov 29: 12:30	IG_BH01_T_INT_009	9	X	X	X	X	39	X	X	4815.51	X	5154.27	X	1160	5036.94	X	X	4814.95	13:07	Eighth run for GW sampling of IG_BH01_T_INT_009. Run used for lab sample collection (14-DIC). Field blank (IG_BH01_GW019) collected.
Nov 29: 13:45	IG_BH01_T_INT_009	10	X	X	X	X	38	X	X	4814.79	X	5153.32	X	1038	5014.16	X	X	4814.06	14:25	Ninth run for GW sampling of IG_BH01_T_INT_009. Run used for lab sample collection (3H).
Nov 29: 14:52	IG_BH01_T_INT_009	11	X	X	X	X	36	X	X	4814.1	X	5144.4	X	1080	5017.62	X	X	4813.63	15:31	Tenth run for GW sampling of IG_BH01_T_INT_009. Run used for lab sample collection (3H).
Nov 29: 15:56	IG_BH01_T_INT_009	12	X	X	X	X	38	X	X	4813.88	X	5141.35	X	1090	5012.87	X	X	4813.2	16:35	Eleventh run for GW sampling of IG_BH01_T_INT_009. Run used for lab sample collection (3H, DOC, Sulphide, 13-DIC). EOD amb P: 97.00kPa
Nov 30: 9:22	IG_BH01_T_INT_009	13	X	X	X	X	43	X	x	4813.48	X	5181.56	x	948	5025.78	X	X	4812.77	10:03	Starting amb P: 97.77 kPa. Day 3 of GW sampling IG_BH01_T_INT_009. 12th run used for lab sample collection (General Chem)
Nov 30: 10:35	IG_BH01_T_INT_009	14	X	X	X	X	36	X	X	4803.44	X	5163.4	X	430	5083.92	X	X	4803.01	11:00	Thirteenth run for GW sampling of IG_BH01_T_IINT_009. Run used for lab sample collection (unfiltered metals and noble gases). Sample tube for GW017_1 had a minor (<3mL) leak at end of crimping/clamping. Leak only from closed end. Verfied by CAM
Nov 30: 11:31	IG_BH01_T_INT_009	15	X	X	X	X	42	X	x	4802.3	X	5171.13	X	390	5078.8	X	X	4802.21	12:28	Fourteenth run for GW sampling of IG_BH01_T_INT_009. Run used for lab sample collection (noble gases) and field analytics. EOD amb P: 96.82 kPa.

Note: Record field parameter measurements on *20-203-01: Field Parameter Measurement/Testing - Field Data Sheet*

Completed by:	AMSC	Verified by:	SNS
Date:	Nov 30 2020	Date:	January 20, 2021

20-203-1: Groundwater Sampling - Field Data Sheet

Well ID:	IG_BH01	**Multiparameter Probe:**	Horiba U52: SNo. LS7M6AG2	**Other Notes/Comments** pH value seems low, discussed with NWMO, wait to compare to lab values, only single concentration pH used by Horiba as part of autocalibration - consider 2 point calibration in future with additional standards.
Date(s):	Nov 26 - Nov 30, 2020	**Fluorometer:**	Turner Designs: SNo. 807511	
Operator(s):	CAM & AMSC	**Colorimeter:**	HACH DR900: SNo. 200660001027	

Port ID	Cumulative Purge/Sampled Volume (L)	Measurement Date and Time	Multiparameter Probe								Fluorometer		Hydrometer	Colorimetric				Alkalinity		Sample Collected (Y/N)	Comments (sampling run #, sample ID, water colour or odour, etc.)
			Calibrated	pH	Temp (°C)	EC (mS/cm)	ORP (mV)	DO (mg/L)	Turbidity (NTU)	TDS (g/L)	Calibrated	Fluorescein (ppb)	Specific Gravity	Calibrated	Dissolved Oxygen (mg/L)	Dissolved Ferrous Iron Fe^{2+} (mg/L)	Total Dissolved Sulphide S^{2-} (mg/L)	Phenol. (mg/L)	Total as $CaCO_3$ (mg/L)		
IG_BH01_T_INT_009	0	Nov 26, 2020: 13:40									X	8.719	Not recorded							No	Collected to see pre-purging fluorescien concentration, sample field filtered before analysis
IG_BH01_T_INT_009	38	Nov 28, 2020: 14:00									X	9.048 (1)	1.001	X	>1 mg/L	0.603 (3)	0.00	0	14	Yes	Collected after second sampling run for IG_BH01 T_INT_009. DO values exceed 1mg/L limit for low-range colorimeter test
IG_BH01_T_INT_009	39	Nov 28, 2020: 16:00	X	5.12	5.67	8.61	4	1.5	3.5	5.26										Yes	Measured values on third sampling round after running 1.5 L through flow through cell. First 0.5 L was from previous run. Note: DO unstable & trending downwards.
IG_BH01_T_INT_009	39	Nov 28, 2020: 16:30	X	5.08	5.61	8.47	82	1.4	4.5	5.36										Yes	Measured values 30 min after water stopped running through flow through cell (see previous measurments)
IG_BH01_T_INT_009	49.5	Nov 30, 2020: 13:30									x	8.184 (2)	Not recorded	x	>1 mg/L	0.45	0.00	0	11	Yes	Measured values at the end of sampling from IG_BH01_T_INT_009

Notes:

if dissolved oxygen > 1 mg/L use the multiparameter meter for measurement

if dissolved oxygen < 1 mg/L use the colorimeteric method for measurement

(1) Originally reported as 8.902ppb, when compaed to field notes, recording was inaccurate. Average was calculated from field note recordings and updated in DQC

(2) Originally reported as 8.191ppb, when compared to field notes, recording was inaccurate. Average was calculated from field note recordings and updated in DQC

(3) Originally reported as 0.61mg/L, when compared to field notes, recording was inaccurate. Average was calculated from field note recordings and updated in DQC

Completed by:	CAM/ AMSC	**Verified by:**	SNS
Date:	Nov 30 2020	**Date:**	Jan 20 2021

20-203-1: Groundwater Sampling - Field Data Sheet

Date	Time	Personnel	Equipment Type	Serial Number	Calibration Check			Calibration Performed			Comments
					Check Method & Standard(s) Used	Equipment Reading(s)	Calibration Required (Y/N)	Calibration Method & Standard(s) Used	Equipment Reading(s)	Calibration Completed (Y/N)	
25-Nov-20	10:10	CAM	Westbay MOSDAX	EMS 4960	Air pressure check vs solinst barologger	Barologger: 95.85 kPa, MOSDAX: 97.70 kPa	No				
25-Nov-20	13:15	CAM	Westbay MOSDAX	EMS 4960	Water pressure check vs manual water level	Manual WL: 72.57 m BTOC, Westbay: 71.65 m BTOC	No				
26-Nov-20	9:10	CAM	Westbay MOSDAX	EMS 4960	Air pressure check vs solinst barologger	Barologger: 95.46 kPa, MOSDAX: 96.18 kPa	No				
26-Nov-20	9:20	CAM	Westbay MOSDAX	EMS 4960	Water pressure check vs manual water level	Manual WL: 49.43m BTOC, Westbay: 48.78 m BTOC	No				
26-Nov-20	12:00	CAM & AMSC	Turner Designs AquaFluor Fluorometer	807511	N/A	N/A	Yes	3-Point Standard: 0, 10, 100 ppb	Blank=0.18ppb 10ppb=9.51ppb, 100ppb=100.23ppb	Yes	Calibration completed prior to collection of fluoroscien sample
28-Nov-20	9:00	AMSC	Turner Designs AquaFluor Fluorometer	807511	N/A	N/A	Yes	3-Point Standard: 0, 10, 100 ppb	Blank=0.19ppb 10ppb=9.19 ppb, 100ppb=96.32 ppb	Yes	Prior to sample collection from IG_BH01_T_INT_009
28-Nov-20	9:00	AMSC	Horiba U52	LS7M6AG2	N/A	N/A	Yes	Laboratory-provided standard solution (pH=4.00, EC=4.99)	pH=4.02 , EC =4.50 mS/cm	Yes	Prior to sample collection from IG_BH01_T_INT_009
28-Nov-20	9:00	AMSC	HACH DR900	200660001027	Accuracy check for ferrous iron using field-prepared standard	Ferrous Iron: 1.57mg/L	No				
28-Nov-20	9:00	AMSC	HACH DR900	200660001027	Blank check for sulfide & ferrous iron	Sulfide: 0.00mg/L ; Ferrous Iron: 0.00mg/L	No				Prior to sample collection from IG_BH01_T_INT_009
28-Nov-20	16:00	CAM	Horiba U52	LS7M6AG2	N/A	N/A	Yes	Laboratory-provided standard solution (pH=4.00, EC=4.99)	pH=3.99 , EC =4.51 mS/cm	Yes	Prior to sample collection from IG_BH01_T_INT_009
30-Nov-20	13:30	CAM	Turner Designs AquaFluor Fluorometer	807511	N/A	N/A	Yes	3-Point Standard: 0, 10, 100 ppb	Blank=0.19ppb 10ppb=9.52 ppb, 100ppb=98.60 ppb	Yes	Prior to final round of field measurments at end of sampling for IG_BH01_T_INT_009

Completed by:	CAM & AMSC	**Verified by:**	SNS
Date:	Nov 30 2020	**Date:**	20-Jan-21
Revised:	Aug 12 2021 AMSC		

20-203-1: Groundwater Sampling - Field Data Sheet

Borehole ID:	IG_BH01 and IG_BH03	**Comments:**
Date:	Nov 25-28, 2020	
Completed by:	CAM, AMSC	
Sampling Interval:	IG_BH01_INT_T_009	

Equipment	Decon. Date/Time	Decontamination Required (Y/N)	PPE	Decontamination Procedure					Comments
				Loose Contamination Removed	Detergent Wash *(record type of detergent used)*	Dionized Water Rinse	Air Dried (Minimize Dust)	Rinsate Sample Collected (Y/N)	
Electronic Water Level Tape	Nov 25: 10:00	Y	Y	Y	Alconox	Y	N/A	N	Decon before start of program since water level tape was used on previous project
MOSDAX Sampler	Nov 28: 9:00	Y	Y	None	Alconox	Y	10 min	Y	
Westbay Sample Bottles (x4)	Nov 28: 9:00	Y	Y	None	Alconox	Y	10 min	Y	
Westbay Sample Bottles (x4)	Nov 28: 10:00	Y	Y	None	Alconox	Y	30 min	Y	Rinsate sample collected prior to IG_BH01 T_INT_009 Sampling

Completed by: CAM. AMSC	**Verified by:**	SNS
Date: 28-Nov-20	**Date:**	20-Jan-21

20-203-1: Chain of Custody Tracking Sheet

COC Number/ID	Sample ID(s)	Shipping Information						Receiving Information				Comments
		Shipped Date	Shipped Time	Temp. Shipped (deg C)	COC Signed by Geofirma (Y/N)	Shipping Address	Shipping Method	Received Date	Received Time	Temp Received (deg C)	COC Signed By Receiving Lab (Y/N)	
Geofirma_BVL_0001	IG_BH01_GW017, IG_BH01_GW018, IG_BH01_GW020	02-Dec-20	7:30	<10	Yes	434 Westmount Ave., Greater Sudbury ON P3A 5Z8	Hand delivered to Sudbury drop off - then courier	02-Dec-20	9:30	5,3,7	Yes	Main sample (017), duplicate (020), rinstate (018)
Geofirma_IT2_0001	IG_BH01_GW017, IG_BH01_GW019, IG_BH01_GW020	08-Dec-20	--	<10	Yes	695 Rupert St, Waterloo, ON N2V 1Z5	Courier - Purolator	11-Dec-20	10:48	Not recorded	Confirmed by email	Main sample (017), duplicate (020), trip blank (019)
Geofirma_UoO_0001	IG_BH01_GW017, IG_BH01_GW020	09-Dec-20	14:00	<10	Yes	25 Templeton St, Ottawa ON K1N 6N5	Hand Delivered	09-Dec-20	14:00	Not recorded	Yes	Main sample (017), duplicate (020)
Geofirma_NWMO_0001	IG_BH01_GW017, IG_BH01_GW020	28-Nov-20	19:00	5 Deg	Yes	NWMO Ignace Office	Hand delivered	28-Nov-20	19:22	5 Deg	Yes	Main sample (017), duplicate (020), received by Brayden Moore

Completed by: CAM, AMSC	Verified by: SNS
Date: Nov 30 2020	Date: Jan 20 2021

20-203-1: Laboratory Data Quality Confirmation Report

Laboratory Report Date	23-Dec-20
Laboratory Name	Bureau Veritas
Laboratory Report ID (If applicable)	C0W4852
Analyses Completed	Major and Trace Elements and Metals; Total dissolved sulphur; Total dissolved iron; Reactive silica; Sulphide; Anions; pH; Alkalinity; Fluoride; TIC; TOC; DOC; TKN; Total Phosphorus; Total Ammonia; Total Nitrogen; Carbonate, Bicarbonate and Hydroxide

Associated COC #(s)	Geofirma_BVL_0001

Samples Included in Laboratory Report

IG_BH01_GW017; IG_BH01_GW020; IG_BH01_GW018

Quality Check and Verification	Verified By (Initials)	Comments
Results received from laboratory	AMSC	
All samples were tested or accounted for. Justification provided for any untested samples (e.g. spare sample)	AMSC	
Laboratory data report provided with results	AMSC	
Laboratory testing methods/techniques included in data report	AMSC	
Laboratory QA procedures and equipment calibration included in data report	AMSC	Equipment calibration n/a
Laboratory results are within reasonable/expected range	AMSC	Higher detection of P, Al, Cu and Ni in rinsate sample in comparison to sample/duplicate

Other Comments/Notes:

Note: A copy of this form is to be complete for each laboratory data report that is received by Geofirma

Completed by: AMSC	Verified by:	SNS
Date: 6-Jan-2021	Date:	20-Jan-21

20-203-1: Laboratory Data Quality Confirmation Report

Laboratory Report Date	19-Mar-21
Laboratory Name	Isotope Tracer Technologies Inc (IT2)
Laboratory Report ID (If applicable)	200234
Analyses Completed	δ18O, δ2H, 3H, 87Sr/86Sr , δ37Cl, δ13C-DIC , 14C-DIC,

Associated COC #(s)	Geofirma_IT2_0001

Samples Included in Laboratory Report

IG_BH01_GW017; IG_BH01_GW020; IG_BH01_GW019

Quality Check and Verification	Verified By (Initials)	Comments
Results received from laboratory	AMSC	
All samples were tested or accounted for. Justification provided for any untested samples (e.g. spare sample)	AMSC	Missing results for 3H on sample GW0019 on orginal report, lab contacted and ran sample and re-issued report.
Laboratory data report provided with results	AMSC	
Laboratory testing methods/techniques included in data report	AMSC	
Laboratory QA procedures and equipment calibration included in data report	AMSC	
Laboratory results are within reasonable/expected range	AMSC	See comment below

Other Comments/Notes:

Results for 37Cl, 13C and 14C were flagged as results were not in expected range, lab was contacted to re-check and confirm results. There was an error in reporting for 13C in sample GW0017, lab corrected and re-issued report. Reported results for 37Cl and 14C were checked and confirmed.

Note: A copy of this form is to be complete for each laboratory data report that is received by Geofirma

Completed by: AMSC	Verified by: SNS
Date: 26-Apr-21	Date: 27-Apr-21

20-203-1: Laboratory Data Quality Confirmation Report

Laboratory Report Date	19-Sep-22
Laboratory Name	Univeristy of Ottawa Noble Gas Laboratory
Laboratory Report ID (If applicable)	
Analyses Completed	He, Ne, Ar, Kr, Xe

Associated COC #(s)	Geofirma_UoO_0001

Samples Included in Laboratory Report

IG_BH01_GW017; IG_BH01_GW020

Quality Check and Verification	**Verified By (Initials)**	**Comments**
Results received from laboratory	AMSC	
All samples were tested or accounted for. Justification provided for any untested samples (e.g. spare sample)	AMSC	
Laboratory data report provided with results	AMSC	
Laboratory testing methods/techniques included in data report	AMSC	
Laboratory QA procedures and equipment calibration included in data report	AMSC	
Laboratory results are within reasonable/expected range	AMSC	

Other Comments/Notes:

Report for analyses of He, Ne received on Feb 25th 2021. Revision made to the reporting units, revised report received on April 25th 2022.

A secondary report was received on 19 Sep 2022 that includes the results for Ar, Kr and Xe. These analyses were unable to be run at uOttawa, so the lab got a third party to run them, at the same time they ran the samples for He and Ne isotopes. The results for He and Ne from both reports are consistent and acceptable. Both the original lab report (R1) and the secondary one (R2) are included in the data delivery. However, only the results from the second report (R2) will be reported in acquire and technical reports to remain consistent.

Note: A copy of this form is to be complete for each laboratory data report that is received by Geofirma

Completed by:	AMSC	**Verified by:**	SNS
Date:	2021-04-26 / 2022-09-20	**Date:**	2021-04-27 / 2022-09-21

20-203-1: Laboratory Data Quality Confirmation Report

Laboratory Report Date	March 20 2021, October 16 2021
Laboratory Name	University of Ottawa Radiohalides Laboratory
Laboratory Report ID (If applicable)	
Analyses Completed	129I, 36Cl

Associated COC #(s)	Geofirma_UoO_0001

Samples Included in Laboratory Report

IG_BH01_GW017; IG_BH01_GW020

Quality Check and Verification	**Verified By (Initials)**	**Comments**
Results received from laboratory	AMSC	
All samples were tested or accounted for. Justification provided for any untested samples (e.g. spare sample)	AMSC	
Laboratory data report provided with results	AMSC	
Laboratory testing methods/techniques included in data report	AMSC	
Laboratory QA procedures and equipment calibration included in data report	AMSC	
Laboratory results are within reasonable/expected range	AMSC	

Other Comments/Notes:

Original report for 129I was missing Geofirma's sample ID numbers, lab was contacted and re-issued the report. Report for 36-Cl was received in October 2021.

Note: A copy of this form is to be complete for each laboratory data report that is received by Geofirma

Completed by:	AMSC	Verified by:	SNS
Date:	2021-04-26 / 2022-09-20	Date:	2021-04-27 / 2022-09-21