Final Report

Level 1 and Level 2 Groundwater Assessment
Winslow Drive, Upper Tantallon, NS
(PIDs 41277765 and 41277773)

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Preface

Ramar Construction Limited (Ramar) is planning to construct a 31-unit apartment building at the corner of Winslow Drive and Hammonds Plains Road, in Upper Tantallon. The development will occupy 0.776 hectares across two parcels of land, hereinafter referred to as the subject properties. PID 41277765 is situated at civic address 445 Winslow Drive and occupies and an area of approximately 0.405 hectares. The adjacent parcel of land (PID 41277773) has no civic address and occupies an area of 0.371 hectares. Both properties are undeveloped and covered by a mixed growth of coniferous and deciduous forest.

Fracflow Consultants Inc. (Fracflow) was retained by Ramar to conduct a hydrogeological study of the water supply potential of two properties located at the intersection of Winslow Drive and Hammonds Plains Road, in Upper Tantallon. This documents the scope and findings of both the Level 1 desktop review, and the Level 2 drilling and testing program.

The sustainable yield of PW1 is expected to be between 18 Lpm and 20 Lpm, providing between 25,920 Lpd and 28,800 Lpd. Fracflow estimated the potential maximum water demand for the apartment building to be 19,580 Lpd. There is some degree of uncertainty in the demand estimate given that the building is in the early design phase, but the yield of that well has additional capacity.

In Fracflow's opinion, it makes good sense to add a second production well from an aquifer and water supply management point of view. Both production wells would be configured for simultaneous operation, each producing a target flow rate of approximately 7 Lpm (1.85 gpm), for a total flow rate of 14 Lpm (3.7 gpm) entering the new building. That would generate up to 20,160 Lpd to meet the daily water demand of the building. Balancing the withdrawal requirements of the apartment building across both production wells will also minimize the drawdown around any one well, and that will help to minimize impacts to any existing or future wells on adjacent properties.

Chemical parameters that exceeded the Canadian Drinking Water Quality Guidelines after 72-hours of pumping were turbidity, total aluminum, total arsenic, and total manganese. Those water quality issues can be readily addressed by conventional treatment methods. There was no lead-210 detected in the groundwater sample that was analyzed, but the concentration of radon-222 was 3,610 Bq/L, which is considered to be very high. Assuming that a storage reservoir will be constructed in the apartment building to buffer peak water demand, it will be necessary to air sparge the reservoir and exhaust the radon-222 to the outside to avoid lead-210 formation in the water supply. Further, a sub-slab ventilation system will be necessary to prevent the build up of radon-222 gas inside the building.

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Glossary of Key Hydrogeological Terms[1]

Aquifer	A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.
Aquifer Test	An aquifer test, which is sometimes referred to as a pump test, is a test involving the withdrawal of measured quantities of water from a well and the measurement of the resulting changes in water level or hydraulic head in the aquifer during and after the period of discharge.
Confined Aquifer	A formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geological formations.
Leaky Aquifer	A formation that is partially confined.
Unconfined Aquifer	An aquifer where the water table is exposed to the atmosphere through pore spaces in the overlying materials.
Hydraulic Head	Energy contained in a water mass, produced by elevation, pressure or velocity.
Head Loss	That part of head energy that is lost as a result of friction as water flows.
Hydraulic Conductivity, K	The rate of flow of water through a cross-section of 1 square metre of aquifer under a unit of hydraulic gradient. K can be expressed as $m^3/day/m^2$, which is equivalent to m/day. K can also be expressed in m/min or m/s. The latter is used here.
Hydraulic Gradient	The rate of change in total head per unit of distance of flow in a given direction, either horizontal or vertical.
Specific Capacity	The rate of discharge of a water well per unit of drawdown, expressed here as litres per minute of flow per metre of drawdown (Lpm/m).

1 ***After Driscoll, 1986.***

Transmissivity, T	The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Transmissivity is expressed as cubic metres per day through a vertical section of an aquifer that is 1 m wide under a hydraulic gradient of 1 (i.e., $m^3/d/m$ or simply m^2/d). T is also equal to K multiplied by the aquifer thickness, b. In this report, units of m^2/s are used.
Storativity, S	The amount of water an aquifer either releases from storage, or takes into storage, per unit surface area of the aquifer per unit change in head, expressed as a dimensionless fraction. An unconfined typically has an S value of greater than 0.001, while a confined aquifer has an S value smaller than 0.001.

1.0 INTRODUCTION

Fracflow Consultants Inc. (Fracflow) was retained by Ramar Construction Limited (Ramar) to conduct a hydrogeological study of the water supply potential of two properties located at the intersection of Winslow Drive and Hammonds Plains Road, in Upper Tantallon. This report documents the scope and findings of the Level 1 desktop study, as well as the Level 2 drilling and testing program.

1.1 Site Location

The two subject properties are located at the intersection between Winslow Drive and Hammonds Plains Road, in Upper Tantallon, as shown in **Figure 1**. That figure and all others referenced herein are presented in **Appendix 1**.

PID 41277765 is situated at civic address 445 Winslow Drive and occupies and an area of approximately 0.405 hectares (1 acre). The adjacent parcel of land (PID 41277773) has no civic address and occupies an area of 0.371 hectares (0.918 acres). Both properties are undeveloped and covered by a mixed growth of coniferous and deciduous forest.

1.2 Objectives

A Groundwater Assessment Report is required as part of the Development Agreement (DA) and Subdivision Approval processes for Open Space Design Developments in the Halifax Regional Municipality (HRM), where they are to be serviced by groundwater. While the proposed development is not an Open Space Design, completion of a groundwater assessment, in accordance with HRM's *Guidelines for Groundwater Assessment and Reporting*, is an essential part of the DA negotiation process.

1.2.1 Level 1 Objectives

The purpose of a Level 1 Groundwater Assessment is not to provide a guarantee that future home owners will have an adequate supply of potable water, but rather to provide a qualified opinion about the likelihood of obtaining an adequate supply of potable water for the proposed development without impacting other users in the area. The objectives as outlined in Part 2, Sections 2.1 and 2.2, of the HRM Guidelines, are as follows:

1. To identify and minimize potential impacts of the proposed development on existing groundwater users and sensitive features (e.g. groundwater recharge areas, wetlands, and groundwater fed streams); and

2. To help ensure that future owners of homes and lots in areas that are not serviced with central municipal water have a high probability of obtaining adequate quantities of potable water for domestic consumption over both the short and long-term.

1.2.2 Level 2 Objectives

HRM required that additional information be collected as part of a Level 2 (site-specific) hydrogeological assessment in order to advance the DA process with Ramar. The Level 2 objectives as outlined in Section 2.3 of HRM's Guidelines are summarized as follows:

a) Test Well Installation

The objective of this component of work under the HRM guidelines is to:

1. Locate and construct suitable test wells for aquifer testing, including pumping tests and water quality analyses. The minimum number of test wells for a development area of less than 15 hectares is three, but that typically applies to planning for new subdivisions;

2. The test wells must be located such that the hydrogeological conditions across the site are adequately represented;

3. The test wells will be located and constructed to permit the prediction of the quality and quantity of groundwater supplies, as required to supply the proposed development; and

4. Test well construction must comply, at a minimum, with Provincial Regulations. More stringent standards, such as increased casing length and full annular space grouting of casing, may be necessary in some cases; and test well installation should be fully supervised by a Qualified Person, and detailed information on the site geology should be collected and recorded during the test well installation program.

b) Water Quantity Test

The objective of this component of work under the HRM guidelines is to perform pumping tests and collect groundwater samples for the purpose of:

1. Calculating aquifer properties, such as transmissivity and storativity;

2. Identifying the type of aquifer and aquifer boundaries;

3. Determining the sustainable yield;

4. Determining the potential for interference to existing groundwater users and sensitive features; and

5. Assessing water quality and requirements for water treatment where applicable.

1.3 Scope of Work

The following is a summary list of activities that were completed by Fracflow as part of the Level 1 and Level 2 groundwater assessment.

1. Reviewed relevant background information on topography, soil types and distribution, surficial and bedrock geology, and hydrogeology at or near the subject properties.

2. Reviewed well logs for water supply wells located in Upper Tantallon, and the communities of Hammonds Plains, Upper Hammonds Plains, and Upper Sackville. Those well logs were obtained from the latest version of Nova Scotia Environment and Climate Change's (ECC) Well Logs Database (ECC, 2020). That database contained information on general stratigraphy, depths to water, well and casing depths, and estimated well yields. Those data were supplemented with in-house reports prepared by Fracflow for other development sites with similar geology.

3. Reviewed ECC's Pumping Test Database (2021), which contained a summary of aquifer tests that were carried out by various entities on a variety of private, commercial and institutional water supply wells. Data included aquifer properties such as transmissivity, hydraulic conductivity and storativity, as well as long-term safe yields that were reported for the wells that were tested.

4. Drilled and constructed one 121.9 m (400 feet) deep production well, with 12.1 m (40 feet) of casing sealed with bentonite grout from shoe to surface. Also drilled two observation wells, each constructed with 6.1 m (20 feet) of casing and ending at a total depth of 30.5 m (100 feet).

5. Completed a step drawdown test, 72-hour aquifer test, and recovery test on production well PW1. Water samples were collected after 1-hour, 24-hours and 72-hours for analysis of standard water chemistry and total metals. One sample was collected after 48 hours for total coliform and E. Coli determinations. The 72-hour sample was also analyzed for dissolved metals, radon-222 and lead-210.

6. Prepared this report to document the findings and recommendations arising from the desktop review and the drilling and testing program.

1.4 Report Organization

The components of the **Level 1 Groundwater Assessment** are presented in the following chapters:

Chapter 1: This introduction.

Chapter 2: Reviews the general environmental setting of Upper Tantallon and what is known about the local subsurface conditions in the area;

Chapter 3: Presents information about the potential water demand of the proposed development; and

Chapter 4: Discusses options for water supply development.

The components of the **Level 2 Groundwater Assessment** are presented in the following chapters:

Chapter 5: Presents the pumping test information.

Chapter 6: An evaluation of groundwater quality and discussion of water treatment options.

Chapter 7: Description of potential impacts of groundwater withdrawal on the environment; and

Chapter 8: An outline of the monitoring and contingency plans, which are required components of an application to Nova Scotia Environment and Climate Change for a Groundwater Withdrawal Approval.

1.5 Statement of Limitations

This hydrogeological assessment was conducted by Glenn Bursey, M.Sc., P.Geo. Glenn is a Senior Hydrogeologist and Principal of Fracflow Consultants Inc. and a Qualified Person recognized by ECC. He has 34 years of post-graduate consulting experience, he is a registered Professional Geoscientist with the Association of Professional Geoscientists of Nova Scotia and a Certified Environmental Site Assessor with the Auditing Association of Canada. Technical and engineering guidance was provided by Dr. John Gale, P.Eng., P.Geo., a Senior Hydrogeologist and Geological Engineer with more than 50 years of post-graduate experience, a Principal of Fracflow Consultants Inc., and a Qualified Person recognized by ECC. John is also registered as a professional engineer with the Association of Professional Engineers of Nova Scotia.

This report has been prepared for use by Ramar and other team members working on this design and construction project. Information contained in this report is part of Fracflow's instruments of service, and Fracflow shall retain ownership thereof. Such information shall not be used for any purpose other than for matters related to this project. Any other use, reuse or modification of this document without Fracflow's prior written consent will be at the recipient's sole risk and without liability or legal exposure to Fracflow.

The findings and conclusions presented herein are probabilities based on professional judgement of the significance of those data gathered, and do not constitute scientific certainties. The results are based on data collected by Fracflow, as well as other referenced information, which are specific to the testing that was carried out at the locations specified in this report.

Fracflow has attempted to predict the effects of groundwater withdrawal by testing one production well and monitoring the response to pumping at two observation wells that were constructed on the subject properties, using appropriate scientific and engineering methods. The reader should note that predicted aquifer responses, both physical and chemical, can vary in both time and space and are not warranted.

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2.0 ENVIRONMENTAL SETTING

2.1 Climate

Weather normals recorded by Environment and Climate Change Canada (ECCC) at its regional recording station at Halifax Stanfield International Airport, for the period from 1981 to 2010, show that the monthly temperatures varied between a daily minimum of -10.4°C in January, to a daily maximum of 23.8°C in July, averaging 6.6°C (**Figure 2**). The months of December through March experienced average daily temperatures that were below freezing. Normal precipitation varied from a low of 93.5 mm in August, to a high of 154.2 mm in November, with the normal annual precipitation being 1,396.2 mm (**Figure 2**).

2.2 Geology

2.2.1 Surficial Geology

The site is located on soils of the Gibraltar Series (MacDougall and Cann, 1963). Those soils are reported to be shallow, extremely stony, porous, and have low moisture-holding capacity. The typical soil profile consists of a friable and porous, brown sandy loam, which is friable and porous, near the surface, changing with depth to a dark brown, sandy loam that is strongly cemented and stony. This soil is derived from a pale brown, coarse sandy loam glacial till that in turn is derived from granite.

The glacial till is part of a stony till plain (**Figure 3**) that is derived from local bedrock sources (Stea, et. al., 1992). The matrix material is sandy becoming more silty where drumlin facies are present. The till plain can vary in thickness from 2 to 20 m, but likely does not exceed 6 m in thickness in the study area.

2.2.2 Bedrock Geology

The subject properties and areas west are situated on bedrock of two granitic types (**Figure 4**). The Tantallon plaza to the west is mainly underlain by the Halifax Peninsula Leucomonzogranite, according to 1:50,000 scale geological mapping by the Department of Natural Resources (DNR) (MacDonald and Horne, 1987). This unit is characteristically a light whitish-grey to buff or pinkish, medium to predominantly coarse grained rock containing variable granitic mineralogy (biotite, cordierite, muscovite, and alkali feldspar megocrysts). The most distinguishing features of the rock are its coarse grain size and low biotite content, which is generally five percent.

Areas to the east of Hammonds Plains Road are underlain by a fine-grained variety of leucomonzogranite. This bedrock unit, referred to as the Tantallon Leucomonzogranite, is generally described as a buff-orange, fine-to-medium grained equigranular to porphyritic two-mica leucomonzogranite according to DNR (MacDonald and Horne, 1987). This type of rock is characterized by a predominance of felsic minerals, with less than six percent mafic minerals. This granitic rock is coincident with areas of high equivalent uranium and high equivalent thorium, based on radiometric surveys completed by the Geological Survey of Canada in 1979 and reported by DNR (MacDonald and Horne, 1987). The specific variety of granitic rock that occurs at the site is a medium grey porphyry with phenocrysts of quartz, alkali feldspar, plagioclase, cordierite, and biotite. The physical contact between these two types of granitic bedrock is reported to be sheared and intensely fractured.

2.2.3 Structural Geology

Fracflow previously mapped several fractures in outcrop exposures along Westwood Boulevard, Hemlock Drive, Winslow Drive, and the dirt access road to the north of St. Margaret's Centre Arena. Those roads provided an ideal opportunity to objectively map, in three-dimensional space, a sampling of the fracture orientations in the area. The dip of most of the fracture sets in the area are vertical to near-vertical, while the predominant strike is northwest-southeast. That is consistent with the general fracture patterns mapped by MacDonald and Horne (1987).

2.3 Topography

Ground elevations on the subject properties vary from approximately 75 m at Hammonds Plains Road on the south side, to 80 m at Winslow Drive on the north side (**Figure 5**). The properties are situated at the base of a prominent hill that rises in excess of 120 m to the northwest, which is the inferred recharge area for the local flow system.

The average direction of groundwater flow can be inferred from surface topography, where the shape of the water table tends to be a subdued reflection of that topography. Hilltops and areas of high elevation usually coincide with areas of recharge, while valleys and low-lying areas usually coincide with areas of groundwater discharge. In the area of the subject properties, local and shallow groundwater flow is expected to be toward the southeast.

2.4 Watersheds, Drainage Patterns and Recharge

The subject properties are located in the East/Indian River primary watershed (1EH), which has a surface area of 777.6 km^2. Those properties are also located within the East River secondary watershed (1EH-1), which has an area of 36.8 km^2, and a tertiary watershed designated 1EH-1-E, which has an area of 21.9 km^2. Drainage from those watersheds is south through Stillwater Lake, Flat Lake, Hubley Mill Lake and into St. Margaret's Bay (**Figure 6**). There is a partially infilled wetland located immediately behind the Tantallon shopping plaza and a small pond, known as Dauphinees Pond. The pond and wetland are drained by Dauphinees Brook.

In the Atlantic Region, it has been estimated that the average annual value for runoff is 1,018 mm per year (Environment Canada, 1991). Evapotranspiration, which includes direct evaporation from soil and water bodies combined with transpiration from vegetation, varies between 200 mm and 400 mm per year across the province (Nova Scotia Museum, 1996). When those values are added to the runoff rate, it indicates that only a small percentage of the total precipitation infiltrates groundwater aquifers. Within the East/Indian River primary watershed (1EK), the amount of precipitation that recharges the ground surface was estimated to be 16 percent, which is equivalent to 224 mm per year (Kennedy et al., 2010).

Recharge amounts will vary locally, depending on vegetation, topography, soil types and thickness, etc. In Fracflow's experience, anywhere between 10 and 25 percent of the total precipitation will infiltrate ground surfaces that are similar to those on the subject properties and be available as recharge to the overburden and fractured-bedrock aquifers.

2.5 Known Wells and Estimated Well Yields

2.5.1 Yields from Dug Wells

Construction of a dug well requires a sufficient thickness of saturated overburden materials and a sufficient permeability to support an adequate well yield. In Fracflow's experience, the hydraulic conductivity of glacial till can vary anywhere between 1×10^{-6} m/s for the more sandy varieties of till to a low of 1×10^{-10} m/s when the till is comprised largely of dense, silt and clay.

Fracflow identified only fourteen (14) dug wells in the communities of Upper Hammonds Plains, Hammonds Plains, Upper Tantallon, and Upper Sackville. Reported well yields varied between 54.5 litres per minute (Lpm) and 1,298 Lpm, averaging 510 Lpm and having a median yield of 159 Lpm. One of those wells is in operation at St. Margaret's Centre. It was commissioned by

Fracflow in 2004 and has operated continuously since then. The results are summarized in **Table 1**. That table and all others referenced herein are presented in **Appendix 2**.

The reported well yields for dug wells are much higher than those reported for drilled wells. However, the reported yields of dug well yields are unlikely to reflect long-term sustainable yields and are more likely to reflect pumping from storage for short periods of time. In Fracflow's experience, a dug well that is pumped to dryness in silty/clay glacial till will recover at a rate that is typically in the order of 5 Lpm to 10 Lpm.

ECC's Pumping Test Database (ECC, 2021) has more than twelve hundred entries that represent the results of one-to-three day aquifer tests on water supply wells throughout the province. Those data provide a much better indication of the realistic, long-term sustainable yields of the tested wells compared with the air-lift test results reported on driller's well logs. There were two test results identified for dug wells in Upper Tantallon. Their reported safe yields were 4.5 Lpm and 7.3 Lpm.

Due to the relatively thin nature of overburden that is expected across the subject properties, it is unlikely that dug wells will be a viable option for the new apartment building.

2.5.2 Yields from Drilled Wells

Well construction details for drilled wells completed in the communities of Upper Hammonds Plains, Hammonds Plains, Upper Tantallon, and Upper Sackville were compiled to provide representative data for wells in the primary watershed area. A statistical summary was prepared, by community, for a total of 2,837 wells that were found in the provincial database.

Table 2 presents a summary of well construction details for Upper Hammonds Plains. Those wells were completed in metasandstone, slate and granite. Well yields varied from 0.3 Lpm to 90.8 Lpm, averaging 17.4 Lpm, and having a median value of 11.4 Lpm.

Table 3 presents a summary of well construction details for Hammonds Plains. Those wells were completed largely in granitic rocks. Well yields ranged between 0.3 Lpm and 454 Lpm, averaging 30 Lpm, and having a median value of 13.6 Lpm.

Table 4 presents a summary of well construction details for Upper Tantallon. Those wells were completed largely in granitic rocks. Well yields ranged between 0.9 Lpm and 518 Lpm, averaging 19.7 Lpm, and having a median value of 10.2 Lpm.

Table 5 presents a summary of well construction details for Upper Sackville. Those wells were completed largely in metasandstone and slate. Well yields ranged between 0.5 Lpm and 272 Lpm, averaging 30.1 Lpm, and having a median value of 18.2 Lpm.

The mean well yields for each community described above were associated with large standard deviations that were greater than the average and median values. That observation reflects the dependence of yield on the number of water-bearing features intersected by each well. Some wells are unknowingly drilled into massive rock with few water-bearing fractures.

Spatial variability in well yield on and around Winslow Drive is illustrated in **Figure 7**. One can plainly see that those well yields, estimated by drillers, can vary significantly over short distances. Those estimates are derived from short-term airlift tests of approximately 1 hour duration, and may overestimate the long-term sustainable yield of any given well by 50 percent or more.

ECC's Pumping Test Database (2021) recorded the results from fourteen (14) pump tests for wells constructed in Upper Tantallon, in granitic rock similar to those present on the subject properties. Results are summarized in **Table 6** and are considered more reliable than estimates from air lift testing on the same wells because they are usually conducted over one-to-three day periods. Sustainable or safe yields (Q_{20}) ranged from 5.4 Lpm to 114 Lpm, averaged 29.6 Lpm (St. Dev. 32.2 Lpm), and had a median yield of 20.0 Lpm. As noted earlier, the wide range in yield reflects the three-dimensional geometry and connectivity of fractures within the rock mass and the number of water-bearing features intersected by each vertical well.

2.5.3 NS Observation Well 079

The Lewis Lake (079) observation well is located in the Jerry Lawrence Provincial Park near the community of Lewis Lake, in HRM. The well was constructed in 1969 as a water supply for the park and was converted to an observation well in 2008 to expand the Groundwater Observation Well Network (ECC, 2015).

The observation well was completed in a granite aquifer and is 77 m deep with 7.6 m of casing. A 3-hour pumping test (i.e., step-test) was conducted at this well in 2008 (Kennedy et al., 2009). The results indicated a transmissivity of 1.53 m^2/day, hydraulic conductivity of 2.7×10^{-9} m/day and an estimated safe yield of 57.31 m^3/day (8.8 Igpm).

Water levels were downloaded from ECC's website and are presented in **Figure 8**. The last complete year of posted water-level data was 2020 and those levels remained within the trends for historically high and low water levels. The average groundwater elevation was 69.3 m above mean sea level, which corresponds to an average depth below ground surface of 2.5 m.

A groundwater sample collected from Well 079 in 2008. The results indicate that health-based drinking water guidelines were exceeded for arsenic and fluoride, and aesthetic drinking water guidelines were exceeded for manganese. VOCs and pesticides were not detected (ECC, 2015).

2.5.4 Wells on Winslow Drive

The subject properties are not yet developed and there were no pre-existing wells on those properties at the start of this project. Winslow Drive is a developing residential neighbourhood, but building density is buffered by a parcel of undeveloped Crown Land to the north of the subject properties.

There are ten known wells located within a 250 m radius of the subject properties: four are on Stillwater Lane; one is on Flat Lake Drive; and five are on Westwood Boulevard (including three at St. Margaret’s Centre). Overburden thickness for those wells ranged from 1 m to 9.4 m, and one dug well exists at St. Margaret’s Centre. The other wells that are drilled wells have depths between 30 m and 121.9 m. One well had no measurable yield and the maximum reported well yield was 136 Lpm. The average well yield was 24.6 Lpm, the median well yield was 11.4 Lpm, and the standard deviation was 40.1 Lpm.

3.0 SITE LAYOUT AND ESTIMATED WATER DEMAND

3.1 Site Development

The apartment building that is being planned for construction on the subject properties is expected to have a footprint of 1,094 m^2, representing approximately 14 percent of the total available land area. The building design calls for a three-storey structure that will contain the following:

- 1 unit with one-bedroom;
- 10 units with one bedroom and a den;
- 6 units with two bedrooms; and
- 14 units with two bedrooms and a den.

The north side of the apartment building is reserved for a paved parking area that will occupy approximately 915 m^2 and accommodate fourteen parking stalls. Approximately 360 m^2 of land to the south of the building is reserved for a septic field that will parallel Hammonds Plains Road.

There are two high voltage transmission lines located on the north and west sides of the subject properties, which required consideration when planning the drilling program.

3.2 Water Demand (Preliminary Outlook)

According to a municipal water survey completed by Environment Canada (2011), residential water use averaged 292 litres per person per day based on a national survey of single-family and multi-family homes in 2009. More recently, average daily municipal water use in Nova Scotia was reported to be 170 litres per person per day (Statistics Canada, 2022). That estimate was based on populations served by municipal water supply systems that are metered. Actual daily water use by private residents in rural and suburban areas is expected to be higher because home owners that obtain water from their own private wells are not subject to metering charges and, therefore, tend to be less concerned about water conservation. Some residents of older residential homes intentionally keep their taps running in winter to prevent freeze-ups.

According to Statistics Canada (2007), the average number of people per household in Nova Scotia was 2.4. That number increased to 2.7 according to the latest available census for 2019 (Statista, 2021), which would place the average water demand per household at approximately

459 litres per day (Lpd) (170 litres per person per day × 2.7 people). That demand is considered to be the lower limit for a rural home. The total water demand for private residences will exceed that estimate depending on the size of the family, the age of the home and the types of water fixtures in use (low flow or not), and the presence and type of water treatment systems that are in use.

Based on a minimum occupancy of one person per bedroom for the 31 units that are planned, the **potential minimum estimated water demand is** calculated as 170 Lpd/person × (11 units × 1 bedroom) + (20 units ×2 bedrooms), yielding **8,670 Lpd**. For two people per bedroom, that demand would double to 17,340 Lpd.

Equating the estimated design sewage flow to the total water demand per household offers another approach to estimate the maximum water demand of the planned apartment building. Design sewage flow has yet to be calculated by the project engineers. In general terms, the design sewage baseflow for a residential structure in Nova Scotia, having three bedrooms and low-flow fixtures, is set at 1,000 Lpd (ECC, 2022). Each additional bedroom with low-flow fixtures in a multi-residential unit is to be designed with an additional flow of 350 Lpd (see Table 1 in ECC, 2022). **The estimated design sewage flow for a 31-unit apartment building with 51 bedrooms is 17,800 Lpd** [(1,000 Lpd baseflow for 3 bedrooms) + (350 Lpd × 48 additional bedrooms)]. Keep in mind that the size and nature of the water treatment system has to be factored into the demand estimate. When multi-component treatment is required (e.g., sand filtration, iron removal, arsenic removal, water softening), the daily backwash requirements may increase the demand by another 10 percent or more. Therefore, the **potential water demand could rise to 19,580 Lpd**.

If the actual demand exceeds 23,000 Lpd, it will be necessary to apply for and obtain a Groundwater Withdrawal Approval (ECC, 2010). Ramar understands that there is uncertainty in the demand estimate and, therefore, will plan to install a flow meter and monitor the actual consumption for several months. If actual consumption is found to exceed the trigger value or 23,000 Lpd, then an application will be submitted to ECC for an Approval.

Regardless of demand, it will also be necessary to register the water supply as a Public Drinking Water Supply with ECC.

3.3 Lot Water Balance

Using the Lot Water Balance Calculator in the Groundwater Assessments for Subdivision Developments Toolkit (ECC, 2011), available groundwater recharge across the surface of the subject properties (7,760 m^2), prior to development, would be approximately 7,682 Lpd, assuming 16 percent recharge (224 mm/year), 99 percent permeable surfaces, and a reserve of 50 percent for ecological support. If, after development, roughly half of the precipitation that falls on impermeable surfaces (roof top, paved surfaces) is diverted offsite as storm water runoff, available recharge is reduced to 3,841 Lpd. That simple calculation is not intended for water-supply design, but it does demonstrate that groundwater required to supply the apartment building will be derived from recharge outside the boundaries of the subject properties.

Additional developments in Upper Tantallon are expected in the future. Those developments will replace natural vegetation with impermeable surfaces such as rooftops, driveways, and parking areas, and that will increase runoff and reduce recharge to the fractured-bedrock aquifer. Ramar should ensure that excess capacity is available from its production well(s) because the water table will likely fall, and well yields will likely decline over time. A large parcel of Crown Land present to the north of the subject properties (PID 41033242) will provide a buffer zone between the subject properties and future developments, as long as that Crown Land remains undeveloped.

3.4 Intended Water Use

Groundwater from Production Well PW1 is intended to meet a portion of the water demand of the planned apartment building. It is expected that a second production well will be needed to meet the total demand. Both wells will be operated at moderate flow rates (i.e., below their maximum capacities) to limit the drawdown in each well and minimize the potential for off-site impacts.

3.5 Description of Previous or Existing Withdrawal Approvals

There is one known user of groundwater in the area that extracts groundwater at the rate of more than 23,000 litres per day (Lpd). St. Margaret's Centre, which is located 300 m west-northwest on Westwood Boulevard. That facility extracts groundwater in excess of 23,000 Lpd from two drilled wells and one dug well in accordance with Approval no. is 2004-043390-R01. Fracflow developed that water supply and has been actively working with the owner to manage its supply in a sustainable manner since 2004. Groundwater withdrawal is supplemented by a rainwater collection system for non-potable water use (Fracflow/Dumaresq, 2005).

3.6 Need for a Groundwater Withdrawal Approval

Fracflow developed an estimate of the water demand for the subject property to determine if a Groundwater Withdrawal Approval would be required. An Approval is needed when the daily rate of groundwater extraction exceeds 23,000 Lpd.

The potential water demand of the planned apartment building is estimated to be 19,580 Lpd and it appears that Ramar will not need to make application to ECC for an Approval to extract groundwater at that rate. However, Ramar understands that there is uncertainty in the demand estimate and will plan to install a flow meter and monitor the actual consumption for several months. If actual consumption is found to exceed the trigger value of 23,000 Lpd, then an application will be submitted to ECC for an Approval. This report has been formatted to meet the submission requirements in accordance with the checklist in **Appendix 3**, should a future application be necessary.

4.0 WATER SUPPLY DEVELOPMENT

4.1 General Aquifer Characteristics

4.1.1 Overburden Aquifer

Depths to bedrock for drilled wells in Upper Tantallon, shown in **Table 4**, provide a good indicator of overburden thickness. The inferred thickness of overburden is between 0.2 m and 39.6 m, averaging 4.6 m (St. Dev. 3.7 m) and having a median value of 3.7 m. The average and median depths to static water that was reported for dug wells in all communities that were queried, in **Table 1**, was 3.7 m (St. Dev. 1.8 m). Those data suggested that the thickness of saturated overburden materials on the subject properties is unlikely to be adequate to support the construction and development of dug wells, or drilled wells that are screened in overburden. The one exception is a dug well at St. Margaret’s Centre.

4.1.2 Fractured-Bedrock Aquifer

The underlying bedrock aquifer is generally considered to be unconfined or semi-confined as a result of the thin overburden cover, the predominance of vertical fracturing in the bedrock, and the hydraulic response observed during pump tests conducted by Fracflow at St. Margaret’s Centre, Sir John A. MacDonald High School (now Bay View High School), the Tantallon plaza, and at the RCMP Detachment. Yields of individual wells in the Upper Tantallon area are highly variable and typical of fractured-rock aquifers. The estimated yields ranged from 0.9 to 272 Lpm (one anomalous result of 518 Lpm). In Fracflow’s experience, driller’s estimates tend to overestimate the long-term sustainable yields of those wells.

Quality of groundwater in some areas of Upper Tantallon tend to be very good when first drilled, but generally deteriorate over time mainly due to increasing salt, iron, manganese, arsenic, and elevated radiological parameters (radon-222 and lead-210). Previous investigations by Fracflow for the province and for two commercial clients showed that there was a general decrease in the peak chloride concentrations from Westwood Boulevard toward Highway 103. Fracflow is also aware of a well-defined inverse correlation between chloride and pH in groundwater samples from the area, such that the higher the chloride concentration the lower the pH. An increase in the concentration of salt in the groundwater occurs at the expense of alkalinity, thereby lowering the buffering capacity of the water and the pH. A reduction in pH increases the solubility and mobility of many trace elements such that high concentrations of iron, manganese, arsenic and other metals have been associated with high concentrations of chloride. It stands to reason that if the concentration of chloride in general can be reduced and managed, then one could expect a concomitant reduction in metals concentrations and an improvement in the potable water characteristics. Depending on the actual reduction in concentrations that can be achieved, the scale of a groundwater treatment system can be downsized accordingly.

Drilling and construction of open bedrock wells in the fractured-bedrock aquifer appeared to be the only viable option for development of a groundwater supply for the planned apartment building. Considerations for well placement and design are described below.

4.2 Potential Number of Wells Required

A histogram of estimated well yields (Lpm) for 782 open bedrock wells in Upper Tantallon, as extracted from the NS Well Logs Database (ECC, 2020), is presented in **Figure 9**. The histogram shows a skewed data set where approximately 72 percent of known drilled wells had estimated yields of 20 Lpm or less. The average value of 19.1 Lpm for this dataset is biased high because of several outliers. Fifty (50) percent of the spread in well yield is represented by the Interquartile Range (IQR). The IQR is the difference between the lower or first quartile (4.8 Lpm), the value under which 25 percent of well yields were found, and the value of the upper or third quartile (22.7 Lpm), the value under which 75 percent of well yields were found. Based on the IQR, the equivalent daily yield varies between 6,912 Lpd and 32,688 Lpd. A daily yield based on the median value of 10.1 Lpm would be 14,544 Lpd.

Given the estimated water demand for the planned apartment building, it seemed possible to meet the total demand using one production well but, from a statistical perspective, it was more likely that two production wells would be required. Even if the capacity of one well was found to be sufficient to meet the demand, a second production well is always recommended for a multi-unit complex to maintain a high degree of water security. The total demand should be balanced across two wells, to minimize the pumping rates in the individual wells and reduce drawdown and stress on the aquifer. Further, with two production wells and a domestic storage tank, one well can be shut down to perform routine maintenance with minimal interruption to building operations.

4.3 Selection of Test Well Locations

Fracflow's Senior Hydrogeologist conducted an initial site inspection of the subject property on April 2, 2024 to select the location for the first production well, and to consider the location for the second well. It was important to locate that well in an area where construction and operation of the planned apartment building would not negatively impact the quality and quantity of groundwater from the water supply well. Key factors that were considered in locating the water supply well are listed below.

1. It is important to maximize the separation distances between operating production wells to minimize the effects of well interference. Where possible, production wells constructed in the fractured-bedrock aquifer should be separated by as much as 150 m to 200 m to minimize the risk of significant hydraulic interference. The size of the subject properties will only provide for a maximum separation of 100 m.

2. Production wells are required to be located a minimum of 15.2 m away from any new proposed septic field, as per the *Nova Scotia Well Construction Regulations* to minimize the risk of possible bacterial and chemical contamination associated with septic effluent. In Fracflow's opinion, that generic separation of 15.2 m should be expanded to the maximum allowable, based on site constraints, because of the nature of the fractured-bedrock aquifer. The septic system should also be located hydraulically down-gradient from the production wells, which is the case for the preliminary site design.

3. When possible, production wells should be located hydraulically up-gradient from other potential sources of contamination on developed lots, including heating oil tanks, and roadways, parking and driveways to minimize potential impacts from leaking fuel, leaking fluids from vehicles, and deicing chemicals.

4. Production wells should not be drilled near any areas where blasting may occur as part of site construction. Energy waves from a blast can propagate considerable distances and could alter the natural fracture geometry and well yield.

5. There are two high voltage transmission lines located adjacent to the subject properties. Consultation with a Planner from Nova Scotia Power (NSP) was required to confirm that drilling could be conducted safely along the western and northern boundaries of the subject properties. <u>Fracflow also obtained confirmation from NSP that herbicides are not used along the transmission lines for vegetation control because of well-water usage</u>.

Fracflow concluded that the size of the subject properties and the footprints of the planned apartment building, parking areas, and septic tank and field, will not accommodate the ideal separations distances between production wells. Therefore, it was important to evaluate and understand the local aquifer characteristics when planning and designing the production wells.

One pumping well and two observation wells were needed to properly assess the aquifer characteristics. The drawdown cone or radius of hydraulic influence around any pumping well in fractured bedrock is often elliptical in shape, with the long axis aligned in the direction of highest permeability. By pumping one well and monitoring drawdown in two observation wells, Fracflow expected to be able to estimate the orientation of the long axis of the drawdown cone. The second production well should not be drilled along that long axis, otherwise well interference may significantly reduce the yield of both wells. The second well should be drilled along the short axis of an elliptical-shaped drawdown cone.

The other reason for using observation wells is to determine aquifer storativity. That will help determine if the aquifer is confined, leaky or unconfined. One needs to know the nature of the aquifer in order to assess sustainable yield, and evaluate the vulnerability of the aquifer to near-surface sources of contamination, such as septic fields and brine discharge from water softeners on surrounding properties. The final well layout for the Level 2 assessment is presented in **Figure 10**.

4.4 Production and Observation Wells - Design and Construction

Figure 11 shows that there is a negative correlation (R^2 0.26) between well depth and well yield for wells constructed in Upper Tantallon. A histogram of reported well depths for open bedrock wells in Upper Tantallon is presented in **Figure 12**. The histogram shows a near-normal distribution with similar mean (72.8 m) and median (68.6 m) values for well depth. The value of the upper or third quartile, under which 75 percent of well depths were found, was 91.4 m (300 feet), and that was the target depth for the planned production well on the subject properties.

4.4.1 Production Well PW1

One 152 mm (6-inch) diameter open bedrock well was constructed by DJ’s Well Drilling on May 1 and 2, 2024. That production well, designated as PW1, was completed using 12.2 m (40 feet) of steel casing and a continuous grout seal, injected in the annular space between the casing and the borehole wall, to help protect against sources of near-surface contamination, such as road salt on Winslow Drive. It was necessary to install a temporary surface casing, 254 mm (10-inch) in diameter, to prevent overburden from collapsing into the well bore during grout injection. The well was airlifted periodically as its depth progressed. Airlifting, once the well reached 91.4 m (300 feet), revealed an estimated yield of less than 2 Lpm. With approval from Ramar, the well was advanced to a depth of 121.9 m (400 feet) and the estimated yield was unchanged. Well construction details are summarized in **Table 7**. A copy of the driller's well log is presented in **Appendix 4**.

Rather than deepening the well, Fracflow and DJ's Well Drilling decided to surge the well. A solid surge block, equipped with rubber wipers, was pushed into the well from top of casing to a depth of 116 m. Water was added when needed to keep the water level at the top of the casing. The surge block was extracted and the drill rods were lowered back into the well for airlifting. The estimated short-term well yield was increased more than 10-fold, from under 2 Lpm to approximately 20 Lpm.

4.4.2 Observation Well OW1

Observation well OW1was drilled and constructed by DJ's Well Drilling on May 3, 2024. That well was constructed with the minimum required casing length of 6.1 m (20 feet), and was completed to a final depth of 30.4 m (100 feet). The estimated well yield was 2.3 Lpm. Well construction details are summarized in **Table 7**. A copy of the driller's well log is presented in **Appendix 4**.

4.4.3 Observation Well OW2

Observation well OW2 was drilled and constructed by DJ's Well Drilling on May 3, 2024. That well was constructed with the minimum required casing length of 6.1 m (20 feet), and was completed at a final depth of 30.4 m (100 feet). There was no measurable yield from the well when first airlifted after drilling. The well was surged and the yield increased to 1.1 Lpm. Well construction details are summarized in **Table 7**. A copy of the driller's well log is presented in **Appendix 4**.

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5.0 PUMPING TEST INFORMATION

Fracflow staff conducted the step drawdown test, aquifer test and recovery test on production well PW1 between May 20 and 25, 2024. All physical and chemical data that were collected are presented, interpreted and discussed below. Recommended capacities and depth settings for the submersible pump, and sustainable pumping rate are also provided.

5.1 General Procedures

A Franklin Electric, 240V single-phase, 0.75 hp, 10 gpm submersible pump was installed on May 18, 2024 in Production Well PW1 to a depth of 79.2 m (260 feet) below ground surface by a licensed pump installer from D.J.'s Well Drilling. The pump was operated using a portable, King Canada, 12,000W gasoline-powered generator supplied by DJ's Well Drilling.

A 1.25-inch (0.031) diameter poly pipe was connected to the pump. At surface, there was a 1-inch return line, control valves and a 1-inch E-series flow meter with digital readout supplied by Fracflow. Flow rates were also measured at the end of the discharge line using a calibrated bucket to verify the flow rate being reported by the flow meter.

Discharge water was carried away from the well head through 61 m (200 feet) of 0.05 m (2-inch) lay-flat hose. The point of release of the discharge water was into the gully that is situated between the west property boundary and the power transmission line. There was active groundwater seepage and flow in the gully near Winslow Drive, becoming more disconnected and forming pools of water in the gully approaching Hammonds Plains Road. The presence of active seepage suggested a constant-head boundary condition, which is normally a good location to discharge water from the production well and prevent artificial recharge.

A 0.025 m (1-inch) diameter stilling tube was installed above the top of the pump by Fracflow. The stilling tube was assembled using 1.5 m lengths of flush-threaded PVC pipe, with slotted sections in the lower 20 m. The tube was suspended from a foot clamp mounted on top of the casing with a security rope attached and anchored to the casing. A dedicated Solinst LT datalogger was installed in that stilling tube to monitor temperature (T) and level (L). A redundant set of water levels were also recorded manually using a Solinst electronic water level tape. Given that the pump capacity was larger than the well capacitiy, flow and pressure control required recirculation of excess water back into the pumping well. As drawdown increased, the rate of recirculation was progressively reduced until there was zero return water at 3,415 minutes.

Observation wells OW1 and OW2 were monitored for drawdown while production well PW1 was being tested. Observation well data were required in order to calculate aquifer storativity. Water levels in each observation well were monitored using a dedicated Solinst LT datalogger coupled with a redundant set of manual measurements.

Water quality monitoring was conducted at a sampling port near the well head, immediately downstream from the flow meter. Every several hours, the temperature, pH, specific conductance, and dissolved oxygen content of the discharge water were measured. Water samples were collected for chemical analysis after 1 hour, 24 hours and 72 hours of pumping. Samples for total coliform and *E. Coli* determinations were collected after 48 hours of continuous pumping, on a Thursday, and delivered immediately to the laboratory. Thursday sampling was necessary because of the 24-hour holding time for microbiology, and because samples would not be accepted for coliform determinations on a Friday without a significant surcharge being applied to the cost of analysis.

Once the 72-hour aquifer test was complete, the pump was stopped and water-level recovery was monitored in the pumping well until 97 percent recovery was achieved, which occurred in less than 2 hours. Recovery in the observation wells was monitored for as long as was practicable, continuing into the following day, 26 hours after the pump was shut down.

5.2 Theoretical Concepts

Step and aquifer test data were analyzed with AquiferTest Version 3.01 software (Waterloo Hydrogeologic, 2001) and used to estimate specific capacity, well efficiency, transmissivity (T), hydraulic conductivity (K) and storativity (S). For the sake of brevity in the main body of this report, those theoretical concepts are discussed in some detail in **Appendix 5**.

5.3 Test Results for Production Well PW1

Results from the step drawdown test, aquifer test, and recovery test at production well PW1 are presented in separate sections below. Note that in the following discussion, units of flow will be presented as Litres per minute (Lpm) or US gallons per minute (gpm).

5.3.1 Step Drawdown Test

The step drawdown test involved operating the submersible pump from a depth of 79.2 m (260 feet) below ground surface and monitoring the water level in the production well during six steps. Each step lasted between 60 and 90 minutes. Step test data are summarized in **Table 8**. Time versus drawdown (DD) data are plotted in **Figure 13**.

Flow control during each step was maintained by balancing the valve on the discharge line with the valve on the return line, while keeping the back pressure on the pump at or below 65 psi. The return line was closed at the end of Step 6, as flow increased and pressure dropped. Average flow rate and total drawdown measured after each step were as follows:

- Step 1: 3.93 Lpm - Drawdown 1.98 m
- Step 2: 7.85 Lpm - Drawdown 5.81 m
- Step 3: 11.5 Lpm - Drawdown 11.2 m
- Step 4: 15.4 Lpm - Drawdown 18.6 m
- Step 5: 19.3 Lpm - Drawdown 28.3 m
- Step 6: 23.3 Lpm - Drawdown 43.0 m

The total volume of groundwater removed during the step drawdown test was 7,156 L.

5.3.2 Well Efficiency

The efficiency of production well PW1 was estimated by plotting flow rate (Q) *versus* specific capacity (flow rate divided by drawdown) in **Figure 14**. The concept of well efficiency is rooted in the assumption that flow to a well is laminar, which is not the case when dealing with a fractured-bedrock aquifer. If the well was 100 percent efficient, which means the water level in the well would be equal to the water level in the aquifer during pumping, then data points in **Figure 14** would define a horizontal line. Those data points actually follow a linear trend with a negative slope that reflects the decreasing efficiency of the well as the pumping rate increased. For example, at the flow rate of 7.85 Lpm in Step 2, the specific capacity was 1.35 Lpm per metre of drawdown. At a flow rate of 23.3 Lpm in Step 6, the specific capacity was only 0.54 Lpm per metre of drawdown. PW1 is not an efficient well and, for that reason, one can expect the measured drawdown in the well, at relatively high flow rates, to be much greater than the actual drawdown in the aquifer beyond the well bore.

Based on the well response during the step test, a pumping rate of approximately 20 Lpm was selected for the aquifer test. The predicted drawdown in an equivalent porous media at that pumping rate would be 32.15 m (121.5 feet). The actual drawdown in the fractured-bedrock aquifer was expected to be larger because of its relatively small storage capacity relative to porous media.

5.3.3 Aquifer Test

The aquifer test at PW1 was performed at a constant discharge rate of 20.5 Lpm (5.4 gpm) for a period of 4,320 minutes, or 72 hours. The well was actually pumped for an additional 8.3 hours during the step drawdown test. Total groundwater removed during the 72-hour aquifer test was 84,025 L (22,229 gallons). Water levels were monitored at the pumping well throughout the test, as were the temperature, pH, electrical conductivity and dissolved oxygen content of the discharge water.

Water samples for laboratory chemical analysis were collected after 1 hour, 24 hours, and 72 hours of pumping for analysis of standard water chemistry and total metals. Aliquots of the 72-hour sample were also submitted for radon-222 and lead-210 analysis, and another portion was field-filtered and submitted for dissolved metals analysis. A sample for total coliform and *E. Coli* analysis was collected after 48 hours of pumping.

5.3.4 Transmissivity

Theis and Cooper-Jacob Straight Line analyses were performed using data from pumping well PW1 to estimate the transmissivity (T) and hydraulic conductivity (K) of the fractured-bedrock aquifer. Data from observation well OW1 was used to determine Storativity (S) of the aquifer. The calculations were completed using the Aquifer Test software developed by Waterloo Hydrogeologic (2001). Copies of the Theis and Cooper-Jacob Analysis reports are presented in **Appendix 6**.

Saturated aquifer thickness is a key input parameter when calculating T and K values. The convenient and standard approach would be to assume the aquifer thickness extends from the end of the casing (11.3 m or 37 feet below ground) to the end of the well bore (121.9 m or 400 feet below ground). However, permeable zones created by open fractures in hard rock such as granite typically represent only 0.1 percent of the rock mass or less. Therefore, Fracflow calculated T and K values for 0.1 percent of the open well bore (0.1106 m) to estimate the physical properties of the main water-bearing fracture zones.

Figure 15 presents a log-log plot of time *versus* drawdown that was used for the Theis analysis. Drawdown never reached a steady-state condition. It reached 37 m after 2,850 minutes of pumping and continued to increase after that, albeit at a very slow rate. The final drawdown after 4,350 minutes of pumping was 37.9 m. The calculated values for T and K are presented in **Table 9** for a fully penetrating well in a confined aquifer having a thickness of 0.1106 m.

Figure 16 presents a semi-log plot of time *versus* drawdown that was used for the Cooper-Jacob Straight Line Analysis. Similar features observed in the log-log plot for the Theis analysis are apparent here, although perhaps more well-defined. Flow rate is also shown in this figure. The calculated values for T and K are presented in **Table 9**.

5.3.5 Recovery Data

Figure 17 presents a log-log plot of water-level recovery *versus* time. Approximately 97 percent recovery was realized in 97 minutes. The calculated values for T and K are presented in **Table 9**. The response during recovery is consistent with a leaky confined aquifer.

5.3.6 Observation Well Data

Observation wells OW1 and OW2 were monitored during the aquifer test at production well PW1. **Figure 18** illustrates the hydraulic response that developed at both wells during the step drawdown test, aquifer test and recovery test at PW1.

OW1, which is located approximately 30 m east-northeast of PW1, showed a weak response to pumping at PW1. The maximum drawdown at OW1 was 0.283 m. Recovery of OW1, after the aquifer test at PW1 was completed, was very slow. OW1 recovered only 16 percent after 26 hours of recovery time.

OW2, which is located approximately 30 m southeast of PW1, showed a relatively rapid and pronounced response to pumping at PW1. The maximum drawdown of 0.958 m occurred after only 1,080 minutes of pumping, but then OW2 recovered during the remainder of the aquifer test, reaching a final static water level that was 0.3 m above its initial static water level.

Fracflow can confirm that the recovery at OW2 was not due to recirculation of discharge water from the pumping well. That water was piped 61 m southeast of PW1, in the down-gradient direction, before it was released to surface. From there it flowed as interflow, below the root mat, toward Hammonds Plains Road, emerged in the drainage ditch and flowed toward the intersection of Winslow Drive and Hammonds Plains Road.

Water-level recovery at OW2 is believed to be due to fracture deformation in response to increased effective stress caused by reduced pore water pressure. Fractures open and close due to changes in pore pressure within the fracture planes, which affects the applied normal and shear stresses. The original fracture permeability is controlled by the properties of the fracture plane and the overall fracture geometry. Fluids moving through a fracture plane over long periods of time create a network of open pore space and contact points or asperities that are in meta-stable equilibrium under the applied stresses. Decreases in the applied stress due to increases in pore-water pressures will cause the fractures to open and increase fracture permeability. Conversely, increases in the applied stress due to decreases in pore-water pressures will cause the fractures to close and decrease permeability, crushing the asperities and producing a permanent change in the fracture permeability (Gale and Seok, 2013).

The shape of the drawdown cone has been inferred in **Figure 19**. The cone appears to be nearly concentric because of the relatively small values of drawdown that were recorded at OW1 and OW2, compared with the drawdown recorded in production well PW1. However, the larger and mor rapid drawdown that developed at OW2, before it began to recover, suggests the direction of highest permeability is aligned in a northwest-southeast direction.

Data from observation well OW1 and OW2 were also processed in AquiferTest and used to calculate values of T, K and S for the fractured-bedrock aquifer (see **Table 3**). Theis analysis of drawdown data from an observation well provides the only reliable value for S because there is no excess drawdown created, as is caused by head losses in a pumping well (i.e., drawdown in the well reflects drawdown in the aquifer). The average calculated value of S was 4.5×10^{-4} (**Table 3**). That value is consistent with the hydraulic properties of a confined or leaky confined aquifer. Confined aquifers typically have an S value of between 5×10^{-5} and 5×10^{-3}, while unconfined aquifers typically have an S value between 0.01 and 0.3 (Freeze and Cherry, 1979). The shape of the drawdown curve in Theis space combined with the S value suggests the aquifer is best characterized as a leaky confined aquifer.

Confined and leaky confined aquifers release water due to a reduction in pressure, not by gravity drainage of the pore spaces. For that reason, the zone of influence of a pumping well in a confined aquifer can be quite large compared with an unconfined aquifer. Leaky aquifers can have a more subdued zone of influence, compared with fully confined aquifers, depending on the degree of leakage. The zone of influence also tends to be elliptical in shape in fractured-bedrock aquifers, with the long axis of the ellipse aligned in the direction of highest permeability.

5.3.7 Estimation of Safe Yield

Estimates of safe and sustainable yield for PW1 are presented in **Table 3**. $Q_{(safe)}$ was calculated by multiplying specific capacity (20.5 Lpm/m) by the maximum recommended drawdown (40 m), as per Equation 8 in **Appendix 5**. The value of $Q_{(safe)}$ was 21.6 Lpm. Estimates of Q_{20} were derived by using the average value of T for the pumping well, and for each observation well, multiplied by the constant, the recommended drawdown, and the factor of safety presented in Equation 9 in **Appendix 5**. The value of Q_{20} was 3.1 Lpm using the pumping well data, and 833 Lpm using data from observation well OW1 and 105 Lpm using data from OW2. Each of those values for Q_{20} are considered to be unrealistic. The value of Q_{20} is low when using pumping well data from a fractured-bedrock well because the excess drawdown associated with head losses (low well efficiency) results in lower calculated values for T. The value of Q_{20} is high when using observation well data if the observation well is not in direct hydraulic communication with the pumping well (i.e., not situated along the major axis of an elliptical-shaped drawdown cone that is aligned parallel with the direction of highest permeability). It is Fracflow's opinion that observation well OW1 is aligned along the minor axis of an elliptical-shaped drawdown cone centred on pumping well PW1. That minor axis is aligned parallel with the direction of lowest permeability, resulting in a relatively small drawdown being detected at OW1. A small drawdown yields a higher calculated value of T, and a higher value for Q_{20}. It is also Fracflow's opinion that observation well OW2 is proximal to the major axis of an elliptical shaped drawdown cone centred on pumping well PW1.

In Fracflow's professional opinion, the sustainable yield of PW1 is between 18 Lpm and 20 Lpm, provided that the average drawdown does not exceed 40 m. That will provide between 25,920 Lpd and 28,800 Lpd of groundwater.

Normally, new construction in a developing community replaces large amounts of natural vegetation with impermeable surfaces that will include rooftops, roads, driveways, parking areas, and ditches. Such features increase runoff and reduce recharge to the fractured-bedrock aquifer. The properties at the corner of Winslow Drive and Hammonds Plains Road are well situated in that they are adjacent to existing power transmission lines with wide easements, and a large parcel of undeveloped crown land to the north. If those areas remain as they are, there should be no significant alteration of the current water balance, not withstanding the long-term effects of climate change.

5.3.8 Need for a Second Production Well

As noted in the preceding section of this report, the sustainable yield of PW1 is expected to be between 18 Lpm and 20 Lpm, providing between 25,920 Lpd and 28,800 Lpd. Fracflow estimated the potential maximum water demand for the apartment building to be 19,580 Lpd, but there is some uncertainty in that estimate given that the building is in the early design phase.

A second production well (PW2) is recommended for the location shown in **Figure 19**. Two production wells make good sense from an aquifer and water supply management point of view. Both production wells would be configured for simultaneous operation, each producing a target flow rate of approximately 7 Lpm (1.85 gpm), for a total flow rate of 14 Lpm (3.7 gpm) entering the new building. That would generate up to 20,160 Lpd to meet the daily water demand of the building. It is expected that both wells will have the additional capacity, coupled with storage tanks, to buffer peak demands.

Pumping at low flow rates for longer periods of time, rather than pumping at high flow rates for shorter periods of time, will minimize groundwater velocities through discrete fractures and help to prevent damage to those fracture planes, and prevent spalling of rock off the walls of the well bores. Loose rock breaking of the walls of the well bore can become lodged in the annular space between the walls of the well bore and the submersible pump. If the pump fails and can't be recovered and replaced, the well has to be abandoned and replaced.

Balancing the withdrawal requirements of the apartment building across both production wells will also minimize the drawdown around any one well, and that will help to minimize impacts to any existing or future wells on adjacent properties. Either well should be able to manage the total flow rate, and act as a backup well for several hours, when one well is taken off line for routine maintenance. The use of a recommended VFD drive will allow either well to adjust to the higher or lower pumping rates, as needed, while the other well is being serviced.

Another reason to design for excess capacity by using two production wells is because the water table will likely fall, and well yields will likely decline over time. A large parcel of Crown Land present to the north of the subject properties (PID 41033242) will provide a buffer zone between the subject properties and future developments, as long as that Crown Land remains undeveloped.

5.4 Submersible Pump, Plumbing and Settings

Final selection of the submersible pump should be done by the mechanical engineer to be sure the flow, power and pressure requirements are all compatible with the building design. Based on the aquifer properties and response to pumping during the aquifer test, it is likely that a pump having a 10 gpm capacity and a 0.75 hp motor should be adequate for production well PW1. The use of a Variable Frequency Drive (VFD) to regulate pump flow is recommended.

Recommended depth below ground surface for pump placement is 50 m (164 feet), to accommodate a maximum drawdown of 40 m below the static level of 10.6 m. The pump should be hung from a pitless adaptor that is 1.2 m (4 feet) below the existing ground surface, and also attached to a security wire that is connected to an eye bolt near the top of the well casing. The pump discharge should be connected to a 0.03175 m (1.25 inch) inside diameter poly pipe (Blue PE-4710, SIDR-9 Series or equivalent) that has at least a 200 psi burst pressure. That diameter pipe is preferred over a smaller diameter pipe to minimize head losses, and to accommodate some potential scale build-up, which would reduce the effective diameter of the poly pipe during long-term operation.

Water levels and flow rate will need to be monitored in the production well(s) to confirm that the actual demand does not exceed the trigger value of 23,000 Lpd, above which a Groundwater Withdrawal Approval becomes necessary. A dedicated flow meter will be required on the incoming raw water line that enters the new building. A pressure transducer should be installed in PW1 to permit remote logging of water levels by the Building's Automation System (BAS), if present. Otherwise, some other method of data logging will be necessary (e.g., manual readings entered into Excel). Pump operation will require Warrick-type low-level and high-level electrodes to maintain and control drawdown within a specified range. Low-level and high-level electrodes should be set at the respective depths of 45 m and 15 m below ground surface. In case of electrode failure, a pump protection device (Pumptec or equivalent) should be used to monitor and diagnose motor loads and prevent damage to either the pump or pump motor.

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6.0 WATER QUALITY AND WATER TREATMENT

Raw groundwater quality from production well PW1 was chemically characterized using groundwater samples that were collected during the aquifer test. Field and analytical data are presented below, along with a recommended treatment train for potable water.

6.1 Analytical Laboratories

Bureau Veritas Laboratories (BVL), in Bedford, provided the analytical services for this project. BVL is accredited to perform the analyses that were requested.

6.2 Raw Water Quality

6.2.1 Field-Measured Values

Groundwater quality was periodically monitored during the aquifer test. Calibrated, hand-held meters were used to measure temperature, pH, specific conductance and dissolved oxygen (DO) concentrations. Readings collected during the aquifer test are illustrated in **Figure 20**.

Temperature varied between 9.0°C and 11.7° in response to variable degrees of daily heating and cooling of the surface plumbing. The pH fluctuated throughout the test, varying between 6.37 and 7.33. Specific conductance increased from 121.6 µS/cm, at the start of pumping, to 124.5 µS/cm at the end of pumping. DO content generally decreased from 6.03 mg/L to 3.68 mg/L. Some of the measurable DO was likely associated with aeration in the well bore while returning some water to the well during the first two days of pumping.

6.2.2 Analytical Chemistry

Groundwater samples were collected for standard water chemistry and total metals analysis after 1 hour, 24 hours and 72 hours of pumping. The 72-hour sample was also collected for analysis of dissolved metals, radon-222 and lead-210. One additional sample was collected after 48 hours of pumping for total coliform and *E. Coli* analysis. The results are summarized in **Table 10** and **Table 11**. All analytical data were compared to the Canadian Drinking Water Quality (CDWQ) guidelines for Maximum Acceptable Concentrations (MAC), Aesthetic Objectives (AO) and Operational Guidelines (OG). A copy of the analytical reports are presented in **Appendix 8**.

Raw groundwater quality improved with increased well development and pumping time. The final sample that was collected after 72-hours of pumping was classified, using AquaChem (Waterloo Hydrogeologic, 2006), as a sodium-calcium-chloride-bicarbonate type water with relatively low alkalinity (26 mg/L) and low hardness (23 mg/L). There was good agreement between the field-measured pH (7.12) and laboratory-measured pH (7.17) of the 72-hour sample, reported by BVL. Field-measured pH is normally considered to be more reliable since the APHA standard requires pH to be recorded within 15 minutes, which is not possible when storing and transporting samples to the laboratory.

The raw water is also expected to be chemically aggressive/corrosive based on the negative values of the Langlier Saturation Index (-1.93 to -2.18), and will tend to leach any sources of copper and lead that may be present in the new water supply and distribution system. For that reason, pH conditioning may need to become part of the water treatment plan.

Chemical parameters that exceeded a CDWQ guideline after 72-hours of pumping were:

- Turbidity was 1.7 NTUs compared with an OG of 1 NTU for groundwater. Turbidity decreased during the aquifer test and further reductions are possible as the well continues to develop after it is commissioned.

- Total aluminum was 140 µg/L. That concentration is below the MAC of 2,900 µg/L, but above the OG of 100 µg/L. Total aluminum decreased during the aquifer test and further reductions are possible as the well continues to develop after it is commissioned.

- Total arsenic was 11 µg/L compared with an MAC of 10 µg/L. Total arsenic decreased from 20 µg/Lto 11 µg/L after 24 hours of pumping, but remained at 11 µg/L after 72-hours of pumping. <u>Arsenic reduction should be part of the water treatment plan</u>.

- Total manganese was 34 µg/L, compared with an AO of 20 µg/L to prevent staining of plumbing. Total manganese varied little during the aquifer test and may remain above the AO for the long term. Given that dissolved oxygen (DO) concentrations decreased from 6.03 mg/L to 3.68 mg/L over 72-hours, lower DO concentrations are possible during long-term pumping. Therefore, one should assume that some of the manganese exists in a chemically-reduced form and will be subject to oxidation and precipitation, causing staining of plumbing and fixtures. <u>Total manganese reduction should be part of the water treatment plan</u>.

There were no total coliform or *E. Coli* detected in the sample that was collected after 48 hours of pumping.

The 72-hour sample showed little difference between the total concentrations of metals and their respective dissolved metals concentrations (**Table 6**), with the exception of total aluminum. Those data reveal that most metals, in the samples that were collected, exist in dissolved (not suspended) form, which is consistent with the relatively low turbidity (1.7 NTUs). Metals in dissolved form cannot be removed by simple filtration alone. Aluminum is the one metal that could be removed by simple filtration because its concentration in total form was 140 µg/L, while its dissolved concentration was not detectable (< 5 µg/L).

6.2.3 Radiological Parameters

The leucomonzogranite, of Upper Tantallon, is a well known source of radon-222 in groundwater. Radon-222 is a chemically-inert gas that is formed by the radioactive decay of radium-226, which is part of the uranium-238 decay series. Radon-222 has a half-life of 3.82 days and its decay products form a series of short-lived radionuclides that decay within hours to lead-210 (Health Canada, 2009).

The 72-hour sample of groundwater was analyzed for radon-222 and lead-210. The results are presented in **Table 10**. There was no lead-210 detected in the sample that was analyzed, but the concentration of radon-222 was 3,610 Bq/L, which is considered to be very high. Since it is likely that a storage reservoir will be constructed in the apartment building to buffer peak water demand, it will be necessary to air sparge the reservoir and exhaust the radon-222 to the outside to avoid lead-210 formation in the water supply. Further, a sub-slab ventilation system will be necessary to prevent the build up of radon-222 gas inside the building.

6.2.4 Herbicides

As part of Fracflow's request to Nova Scotia Power (NSP) to provide a safe clearance report prior to drilling, Fracflow asked NSP if herbicides are used for vegetation control along the two power transmission lines that border the north and west sides of the subject properties. NSP advised that herbicides are not being used in the area because Upper Tantallon is not serviced by municipal water and relies on groundwater for potable use.

6.2.5 Temperature and Conductivity Profiles at PW1

While pumping PW1, the temperature and specific conductance of the water column was profiled to the depth of the pump using a Solinst TLC meter. The profile is shown in **Figure 21**. The specific conductance began to increase and fluctuate below 47 m, suggesting zones of active inflow were present below that depth.

6.2.6 Temperature and Conductivity Profiles at OW1

While pumping PW1, the temperature and specific conductance of the water column at observation well OW1 was profiled with depth using a Solinst TLC meter. The profile is shown in **Figure 22**. The increase in specific conductance below 22 m suggests active inflow was occurring below that depth.

6.2.7 Temperature and Conductivity Profiles at OW2

While pumping PW1, the temperature and specific conductance of the water column at observation well OW2 was profiled with depth using a Solinst TLC meter. The profile is shown in **Figure 23**. The increase in specific conductance at 30 m, which was close to the end of the well, suggests either active inflow at that depth or the presence of highly conductive drill cuttings that were not removed by airlifting.

6.3 Recommended Water Treatment Process

Raw groundwater from production well PW1 will require treatment for potable use. In Fracflow’s professional opinion, the treatment train should consist of equipment that can perform the following processes in the ordered sequence given below:

(1) Oxidation/filtration media (Filox-R) to reduce and maintain the concentration of manganese at or below the AO value of 20 µg/L.
(2) Adsorption media (MetSorb HMRG) to reduce and maintain total arsenic at or below the MAC of 10 µg/L.
(3) Chlorine disinfection of water entering the storage reservoir, by chemical injection, to prevent bacterial growth in the reservoir. UV disinfection will also work, but chlorine is

preferred because it provides continued disinfection after the injection point, as long as a residual concentration remains.

(4) Air sparging in the storage reservoir to exhaust radon-222 and prevent the formation of lead-210.

(5) A second chlorine disinfection station before distribution of treated water throughout the building (chlorine will be volatilized in the storage tank by air sparging).

Determining factors in the selection of the treatment process are described below. Media tank sizes can be varied based on the preferences and requirements of the mechanical engineer and the water treatment contractor. It will be critical to follow the recommended service flow rates specified by the media manufacturers in order to achieve the necessary minimum contact times for all media. A duplex alternating design is recommended for all media tanks for redundancy, and to ensure continuous operation during backwash cycles.

6.3.1 Oxidation/Filtration to Remove Manganese (Filox-R)

An oxidation/filtration process should be utilized to lower the concentrations of manganese. Most media types are not effective at removing all manganese when some or all of the manganese is present in reduced (Mn^{2+}) form. Manganese is also very slow to oxidize unless the pH is greater than 9.5. Filox-R is the recommended media for this site. Filox-R utilizes an oxidation-reduction reaction and filtration process similar to Greensand Plus, but at a higher level of performance. An important factor to note is that Filox-R media is dense, having a reported bulk density of 1,826 kilograms per cubic metre (kg/m^3), or 114 pounds per cubic foot (lbs/ft^3). It will require a relatively high rate of flow for backwashing, in the order of 16 and 30 gpm/ft^2.

6.3.2 Adsorption Media to Reduce Arsenic (MetSorb)

An arsenic adsorption media will be required to lower the concentration of arsenic, but the effectiveness of the adsorption process is sensitive to variety of factors including oxidation state of the arsenic, pH of raw water, and Empty Bed Contact Time (EBCT).

- Oxidation state - Most adsorption media are not effective at removing all arsenic when some or all of the arsenic is present in reduced (As^{3+}) form. Since it is not known if As^{3+} is present in the raw water, Fracflow recommends that space be reserved for a liquid sodium hypochlorite (i.e., bleach) injection system to pre-oxidize the arsenic, in case it is deemed necessary after commissioning and performance testing.

- pH of raw water - The effectiveness of arsenic removal tends to diminish with increasing pH.

- EBCT - an important factor that will control the physical requirements of the arsenic removal system. EBCT is a measure of the time that raw water is in contact with the adsorption media in the tank, assuming that all raw water passes through that tank at the same velocity.

There are several types of arsenic adsorption media available. MetSorb HMRG media is the preferred choice for raw groundwater conditions at this site. According to the manufacturer, Graver Technologies, MetSorb HMRG media consists largely of titanium dioxide (TiO_2) having an adsorptive capacity that is between 7 grams (g) and 12 g of arsenic per kilogram (kg) of media. Its reported bulk density is 650 kg/m^3, or 40 lbs/ft^3, and it can be backwashed at a rate of between 3 and 5 US gpm/ft^2.

6.3.3 Disinfection by Chemical Injection (Chlorination)

Chlorine disinfection of treated water is recommended over UV light for disinfection because a residual concentration of chlorine will be carried through the plumbing to the point-of-use. Disinfection is recommended before and after the storage tank because of the requirement for air sparging to remove radon (see next section). A Stenner pump model 85MHP40, or equivalent, is likely to provide an acceptable range of injection rates (5 to 105 mL/min). The injection rate will need to be balanced and optimized with the solution strength at the time of commissioning and probably on a seasonal basis thereafter. A large solution tank (378 L or 100 USG) will reduce the frequency of mixing new batches of solution.

Trihalomethanes (THMs) are a byproduct of disinfection by chlorination in the presence of natural organic carbon. There was no detectable total organic carbon (TOC) present in any samples from PW1 and, therefore, THM formation is not expected to be of concern.

6.3.4 Air Sparging to Remove Radon-222

Radon should be actively removed from water stored in the potable water supply tank by air sparging. Equip the tank with a 0.5-inch diameter perforated pipe, anchored across the base of the tank, and connect to a floor-mounted air compressor that generates approximately 1.24 CFMs at 30 psi. Pipe the vent for the tank to an exhaust fan. That fan will pull radon from the tank and release it through a vented pipe attached to the outside of the building. That vent will need to be screened and inverted to prevent contamination from bird droppings, etc.

As noted earlier, there is the potential for residual chlorine in the potable water storage tank to be volatilized as a result of air sparging to remove radon. Drinking water that exits the potable tank has to be chlorinated a second time before being distributed throughout the building.

6.4 Commissioning and Monitoring

Characterization of raw water quality and flow conditions is an essential pre-requisite for design of an effective treatment system. Sufficient chemical data were collected during Level 2 for conceptual design of the treatment train, but one must understand that changes in raw water quantity and quality can occur during long-term pumping. Adjustments and/or equipment additions to the treatment train may become necessary after commissioning. For example, the raw water is expected to be somewhat chemically aggressive/corrosive based on the negative values of the Langlier Saturation Index (-1.93 to -2.18), and will tend to leach any sources of copper and lead that may be present in the new water supply and distribution system. For that reason, pH conditioning may need to become part of the water treatment plan.

It is not possible to confidently predict time to failure for the Filox-R and MetSorb media. Raw and treated water quality will need to be monitored on a regular basis at key points within the treatment system and correlated with recorded cumulative flow meter readings to develop breakthrough curves, especially for arsenic. That will require a flow meter to be installed on the incoming raw water line and sampling ports to be installed after each major component of the treatment system.

Quarterly monitoring of chemical quality for at least one year will be necessary and data should be reviewed by a qualified professional during that period. Adjustments to flow rates and backwash frequencies will likely be necessary to fine tune the operation of the treatment system as monitoring results become available. Once breakthrough curves are available, a schedule for media replacement can be developed and the monitoring frequency can be scaled back.

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7.0 EVALUATION OF POTENTIAL IMPACTS

It appears that a Groundwater Withdrawal Approval will not be required given that the estimated demand of the apartment building is less than 23,000 Lpd. In the event that flow meter records show the actual demand to be in excess of that threshold value, an Approval will be required.

An evaluation of the potential impacts of groundwater withdrawal is part of the reporting process when applying for a Groundwater Withdrawal Approval. Nova Scotia Environment and Climate Change's (ECC) Guide to Groundwater Withdrawal Approvals (NSE, 2010) requires that the potential effects of groundwater withdrawal be evaluated from three key perspectives: sustainable yield, well interference and water quality. The scope of this hydrogeological study was designed to permit characterization of the aquifer properties at a level sufficient to render a qualified opinion on the likelihood that groundwater from as many as two production wells can supply a sustainable quantity of groundwater to meet the demand of the apartment building, without causing significant impact to the aquifer, the environment, or other groundwater users in the area.

7.1 Well Interference and Sustainable Yield

As discussed in Chapter 5 of this report, aquifer test data collected from PW1 suggest that the fractured-bedrock aquifer is a leaky confined aquifer. Confined and leaky confined aquifers release water due to a reduction in pressure, not by gravity drainage of the pore spaces. For that reason, the radius of influence of a pumping well in a confined aquifer can be quite large compared with an unconfined aquifer. Leaky aquifers can have a more subdued radius of influence, compared with fully confined aquifers, depending on the degree of leakage.

Some degree of hydraulic interference should be expected between production well PW1 and a second production well (PW2) that will likely be required. In fact, any other well within a 250 m radius of PW1 could experience a measurable or incremental drawdown. That drawdown is likely to be quite small and is expected to be relatively more pronounced in the northwest-southeast direction, following the inferred direction of highest permeability. There was less than 1 m of drawdown recorded in observation wells OW1 and OW2 during the aquifer test at PW1.

Given the calculated transmissivity of the fractured-bedrock aquifer, extraction of up to 19,580 Lpd of groundwater by the apartment building, from two production wells, is unlikely to cause significant harm to other users in Fracflow's current opinion.

7.2 Water Quality and the Receiving Environment

Section 2.4 of the Guide to Groundwater Withdrawal Approvals requires the applicant to evaluate any condition that has the potential to impact the environment. Fracflow does not anticipate any issues, however, careful consideration needs to be given to disposal of backwash from the water treatment system. It should not be released into the on-site septic system. ECC will require it to be released in an area, and in a manner, that will not impact the existing wells or off-site properties.

The current location of the proposed disposal field overlaps with an inferred fracture zone at the south end of the property, where induced infiltration of effluent could impact groundwater quality. Fracflow recommends that the disposal field be shifted northeast and, if possible, wrap around the corner so that a portion of the disposal field parallels Winslow Drive.

7.3 Seawater Intrusion

The potential for seawater intrusion on the subject property is negligible given its inland location at elevations of between 75 and 80 m, The expected drawdown that will develop in both production wells (maximum 40 m) is expected to keep the pumping levels in each well to above 35 m above mean sea level.

7.4 Groundwater-Surface Water Interaction

As noted earlier in this report, it is Fracflow’s professional opinion that the main water-bearing zone or zones represent a leaky confined aquifer. Groundwater consumption by the apartment building is unlikely to have any significant effect on the water balance of surface water bodies in the area, but the cumulative effect of development pressures in Upper Tantallon will depressurize the aquifer and continue to lower the potentiometric surface over the long-term. The best that can be done is to ensure sound water management and conservation practices are adopted by all water users.

8.0 MONITORING AND CONTINGENCY PLANS

The owner of the apartment building will be expected to operate its well field in accordance with the following provisions:

- Environment Act S.N.S. 1994-1995, c.1, s.1 as amended from time to time, with the latest updates issued in 2018;
- Regulations pursuant to the aforementioned Act;
- Related standards adopted by the Nova Scotia Department of Environment and Climate Change, including the Guide to Groundwater Withdrawal Approvals, the Well Construction Regulations of Nova Scotia, and the Water Well Decommissioning Guidelines; and
- Specific terms and conditions that could be prescribed in a Water Withdrawal Approval.

8.1 Monitoring Plan

The owner of the apartment building will need to closely monitor the operation of its production wells and thereby ensure that it operates in compliance with the regulations and any approvals that may be issued. The scope of the monitoring program will focus on withdrawal rates, water levels, and raw and treated water quality.

It is Fracflow's expectation that a digital flow meter will be installed on the discharge lines from each well pump. Those meters should be tied into the Building Automation System (BAS), if a BAS is to be used, and track daily consumption. All data should be copied tand backed up in a spreadsheet program and compared with approved limits for water withdrawal. Pump operations should be controlled using a dedicated Variable Frequency Drives (VFD). VFDs are normally programmed to shut the submersible pumps down if there is a rapid increase in amperage, signalling the loss of water above the pump.

Raw and treated groundwater samples will need to be collected on a quarterly basis and analyzed for total coliform and *E. Coli*. Raw and treated groundwater samples will also need to be collected for chemical analysis once every two years at a minimum, although quarterly sampling is recommended for the first year.

8.2 Contingency Plan

A Contingency Plan is normally required for large well fields where impacts on neighbouring water wells is known and/or expected to occur. Significant impacts to wells neighbouring the subject property are not expected because of the relatively low sustainable yield of production well PW1, compared with the capacity of the aquifer.

If water levels and well yields in private wells on adjacent properties begin to decline, a Professional Hydrogeologist should be retained to review all operational data for the production well and the impacted well(s). Depending on the extent of any such impacts that are either identified or predicted to occur, the Professional Hydrogeologist will work with the owner of the apartment building to develop an appropriate Contingency Plan.

8.3 Other Requirements

8.3.1 Water Well Survey

A survey of private wells in the area is sometimes required as part of a Water Approval process. However, it is Fracflow's opinion that a survey is not warranted at this time.

8.3.2 Property Ownership and Site Plan

Proof of ownership and a plan of the entire subject property is documentation that is required to support an application for a Groundwater Withdrawal Approval. Those documents will be supplied to ECC under a separate cover, if and when an application for a Groundwater Withdrawal Approval becomes a requirement.

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APPENDIX 1

Figures

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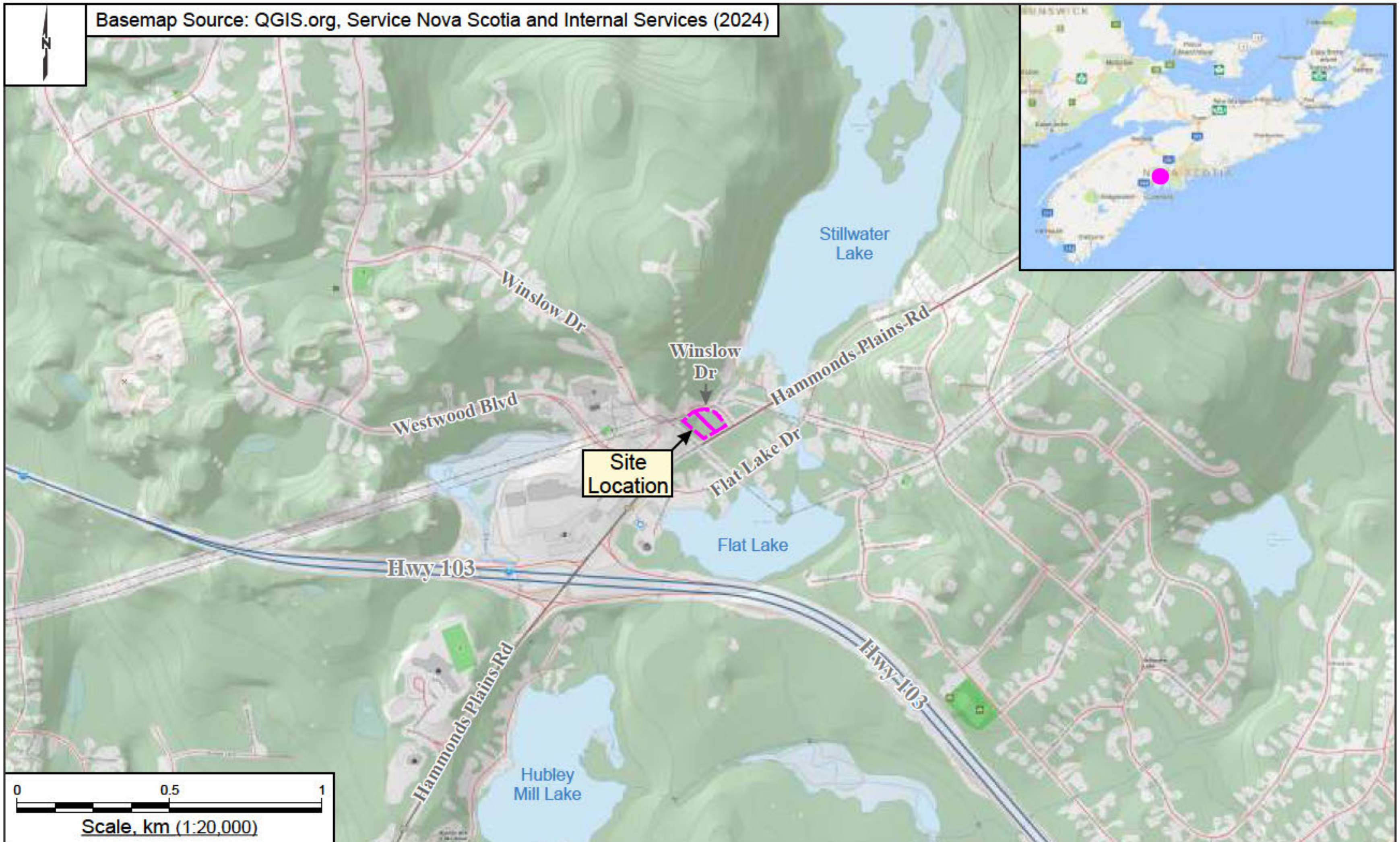

Figure 1 General location map.

Project No.	Scale
879	As Shown
Location	Date
Upper Tantallon, NS	July 2024

FFC

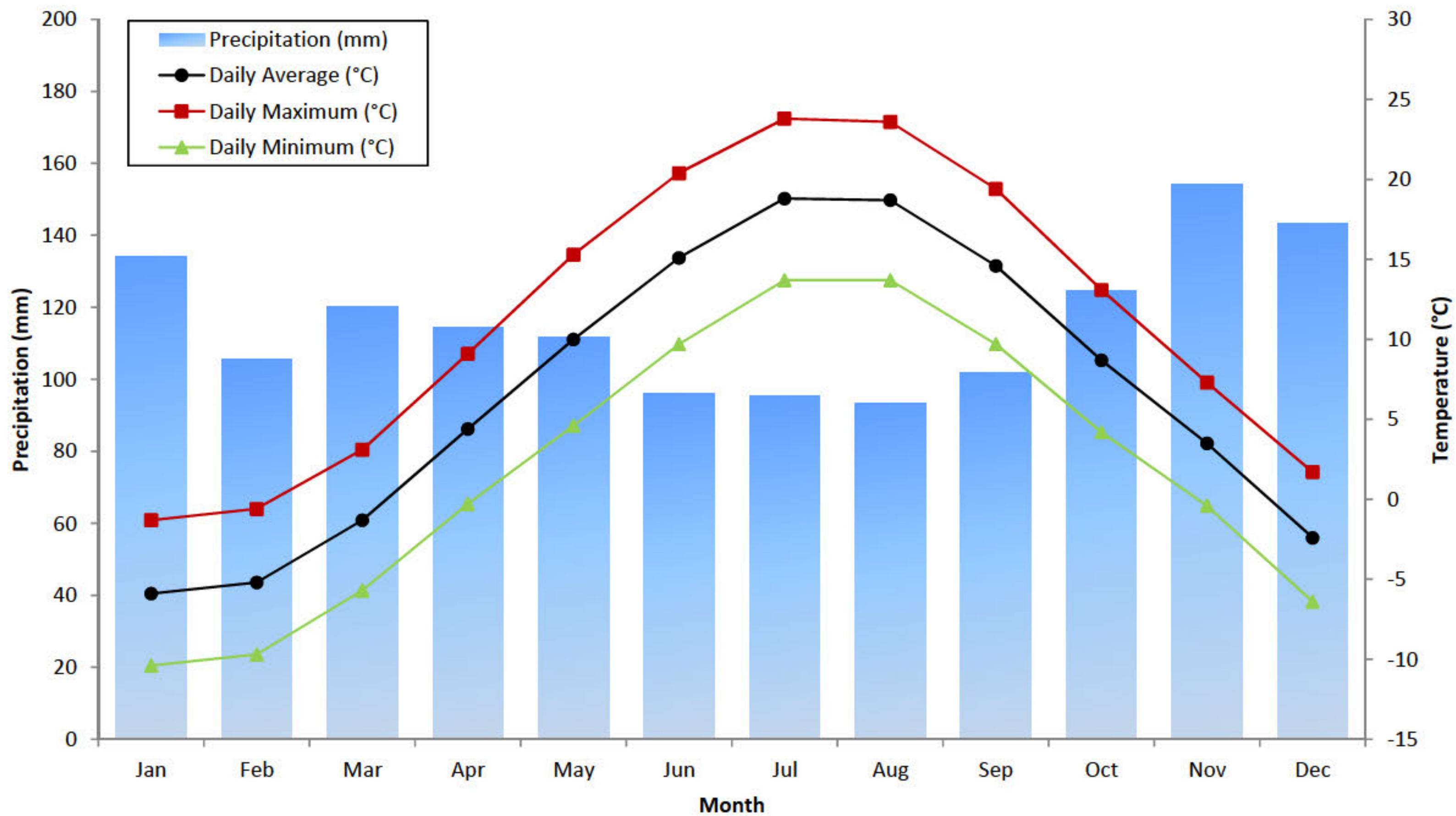

Figure 2	Temperature and precipitation, Canadian Climate Normals recorded at Halifax Stanfield International Airport (1981-2010) (ECCC, 2019).	Project No. 879	Scale As Shown
		Location Upper Tantallon	Date July 2024

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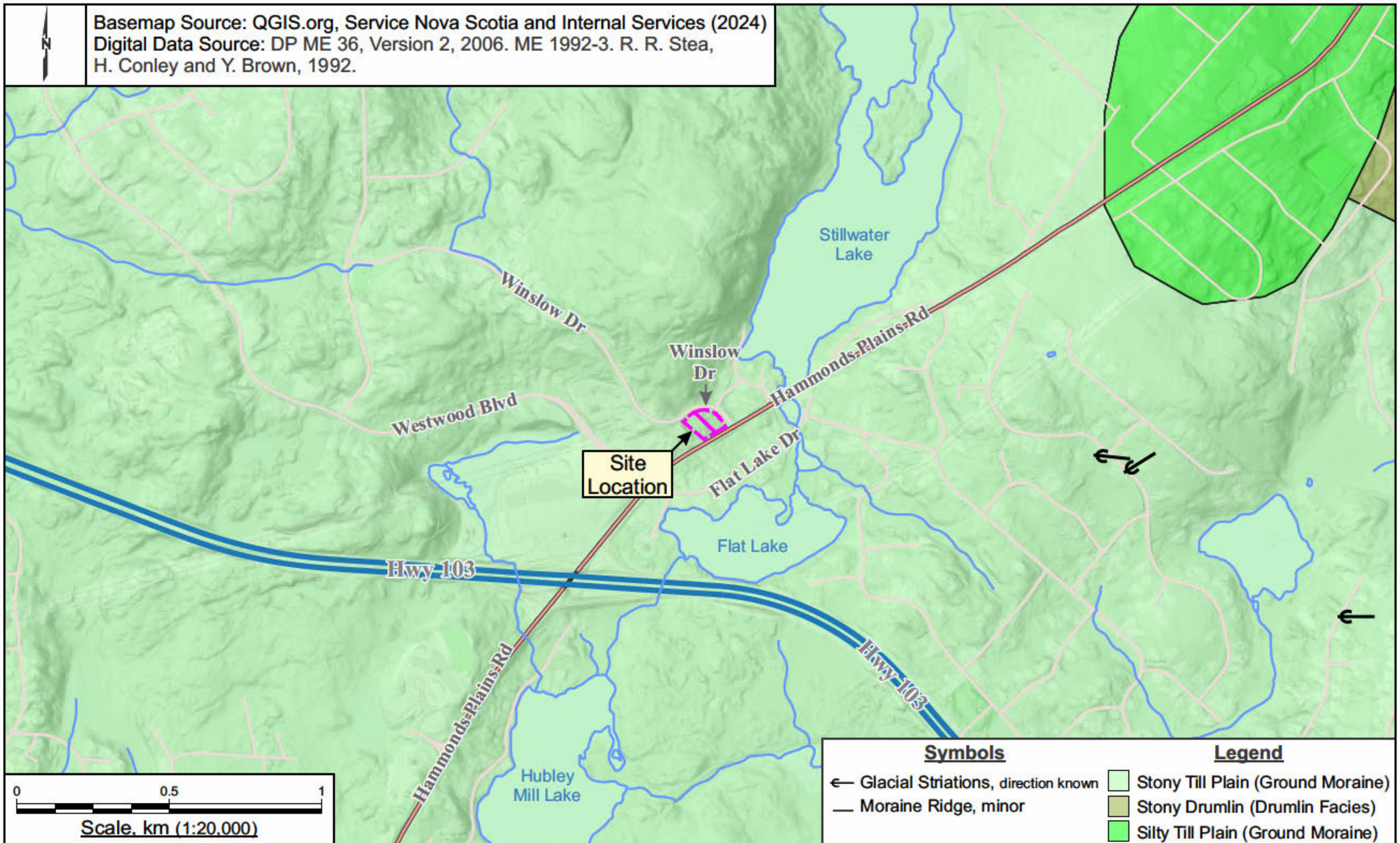

Figure 3 Surficial Geology.

Project No.	Scale
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Location	Date
Upper Tantallon, NS	March 2024

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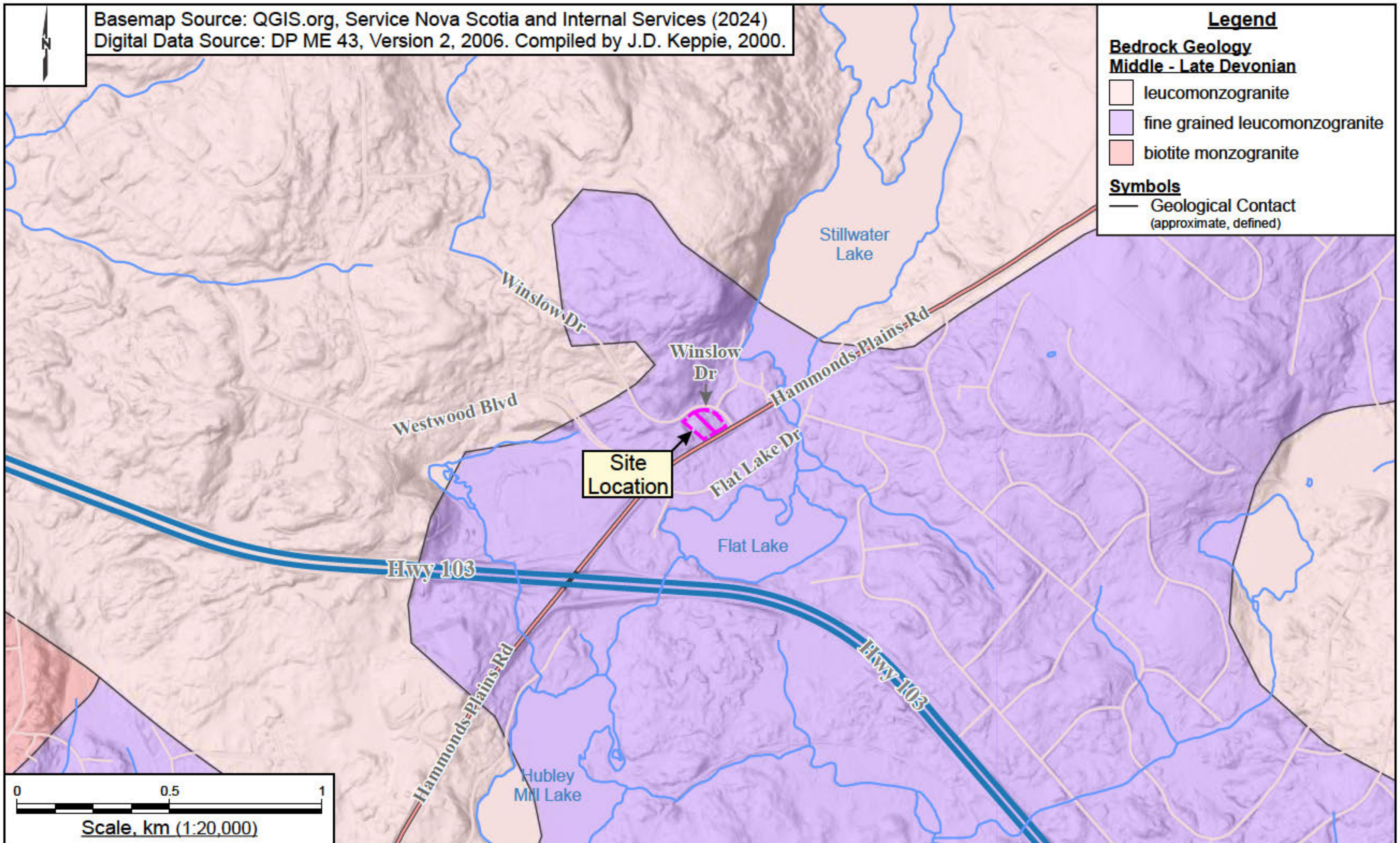

Figure 4 Bedrock Geology.

Project No.	Scale
879	As Shown
Location	Date
Upper Tantallon, NS	July 2024

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Figure 5 Topography of the study area.

Project No.	Scale
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Location	Date
Upper Tantallon, NS	July 2024

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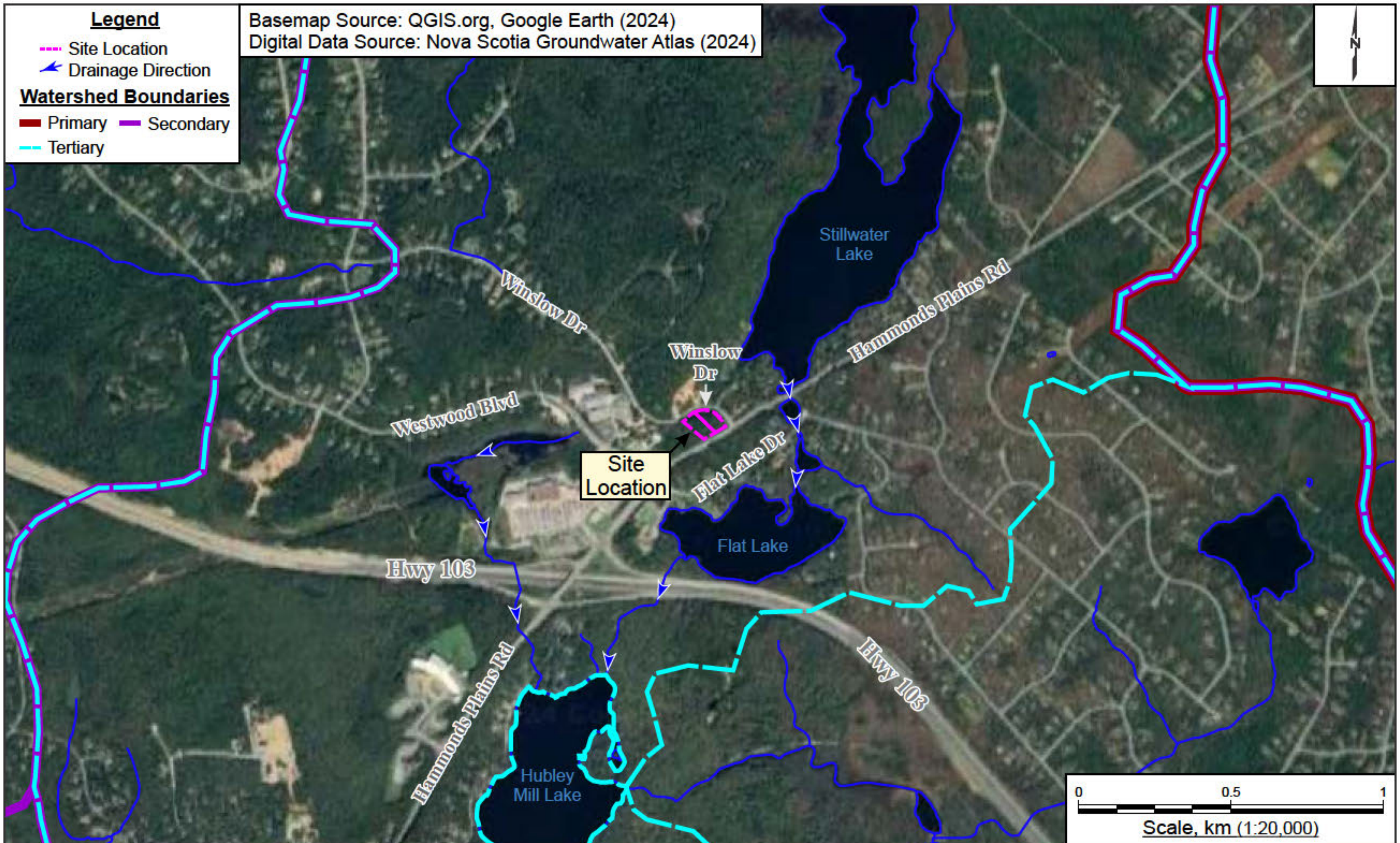

Figure 6 Watershed boundaries and water courses.

Project No.	Scale
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Location	Date
Upper Tantallon, NS	July 2024

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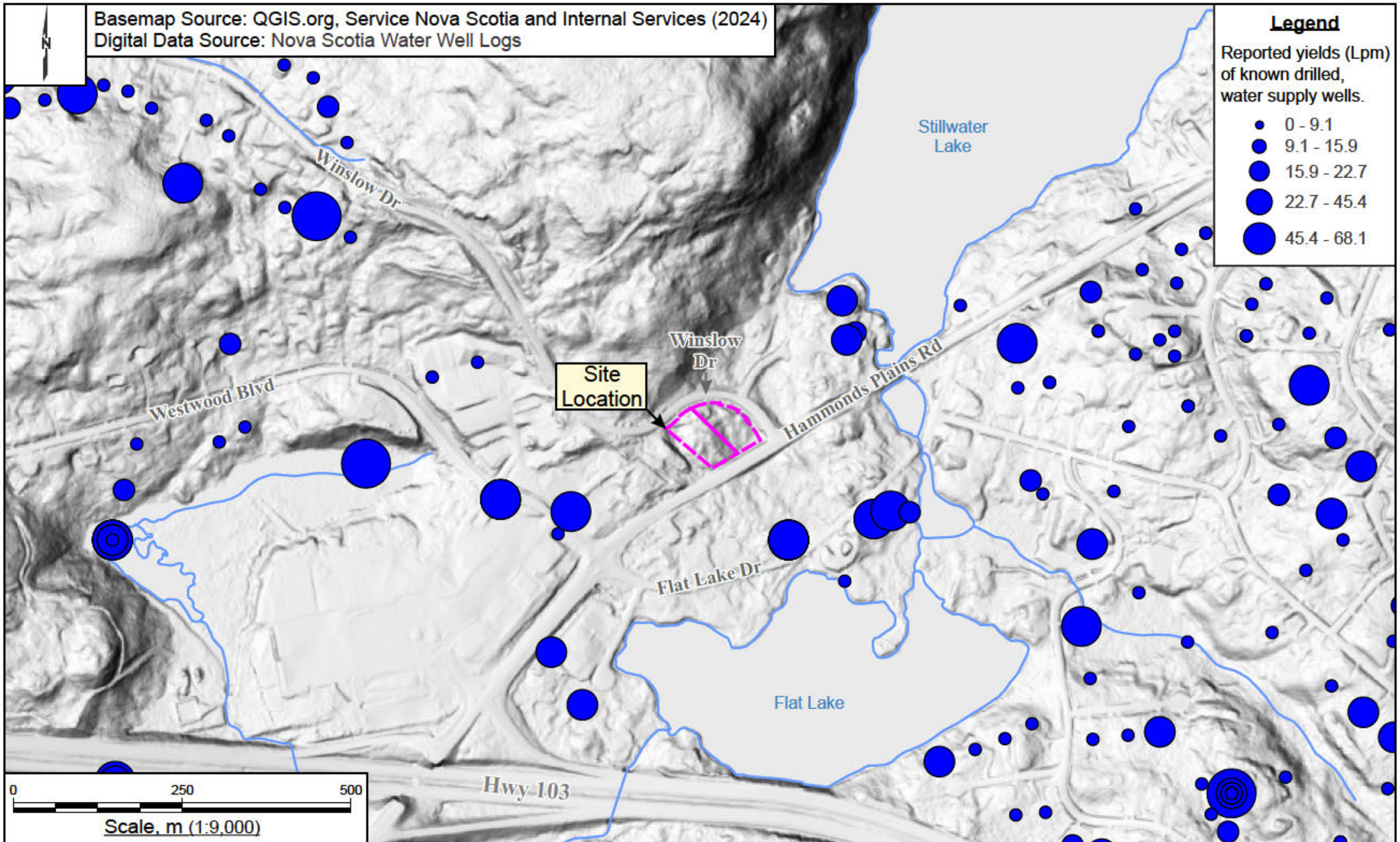

Figure 7 Known drilled wells and reported yields (Lpm) in Upper Tantallon.

Project No.	Scale
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Location	Date
Upper Tantallon, NS	July 2024

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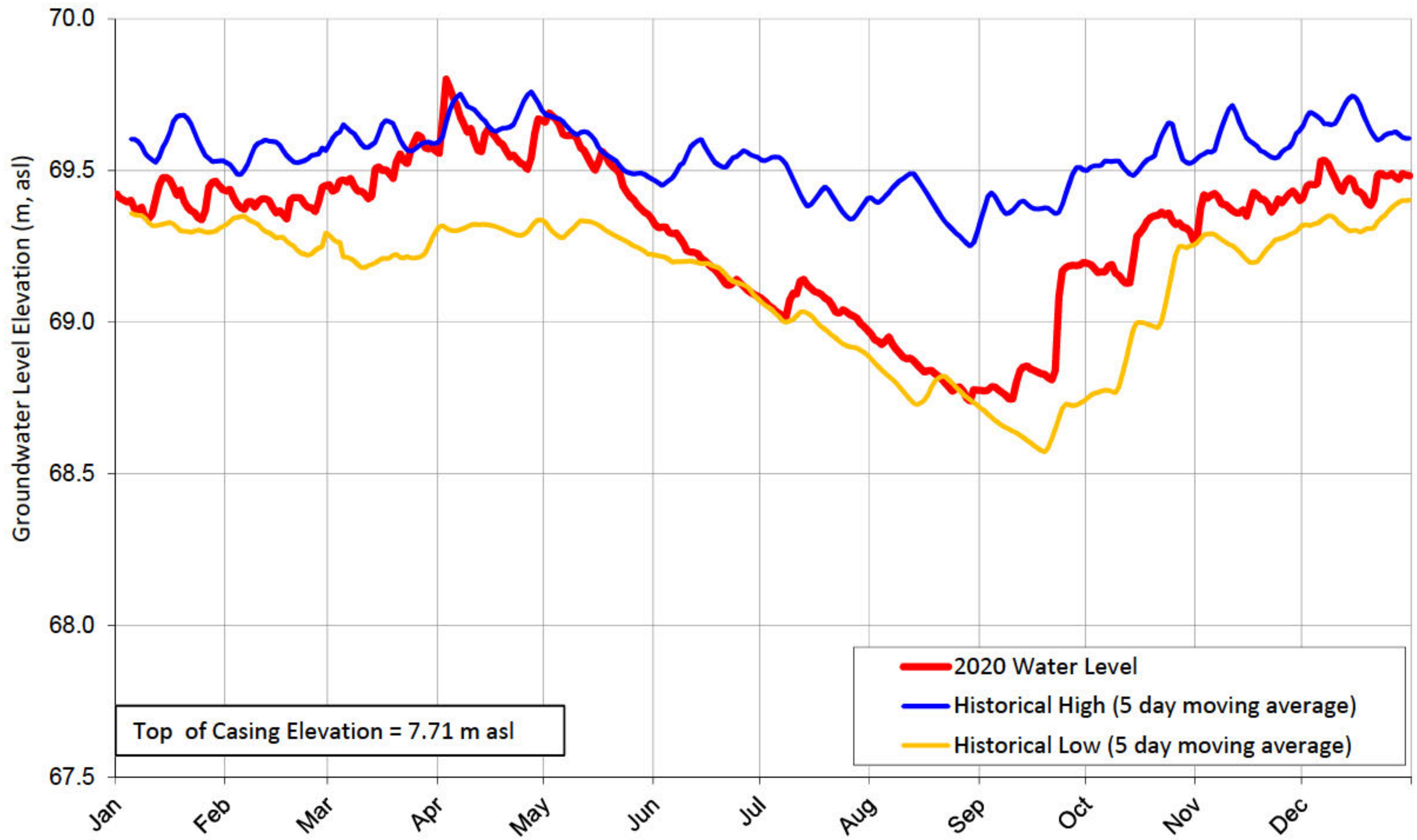

Figure 8 Water level data for Nova Scotia Observation Well 079 (Lewis Lake) for the period 2009-2020 (source: ECC).

Project No.	Scale
879	As Shown
Location	**Date**
Upper Tantallon	July 2024

FFC

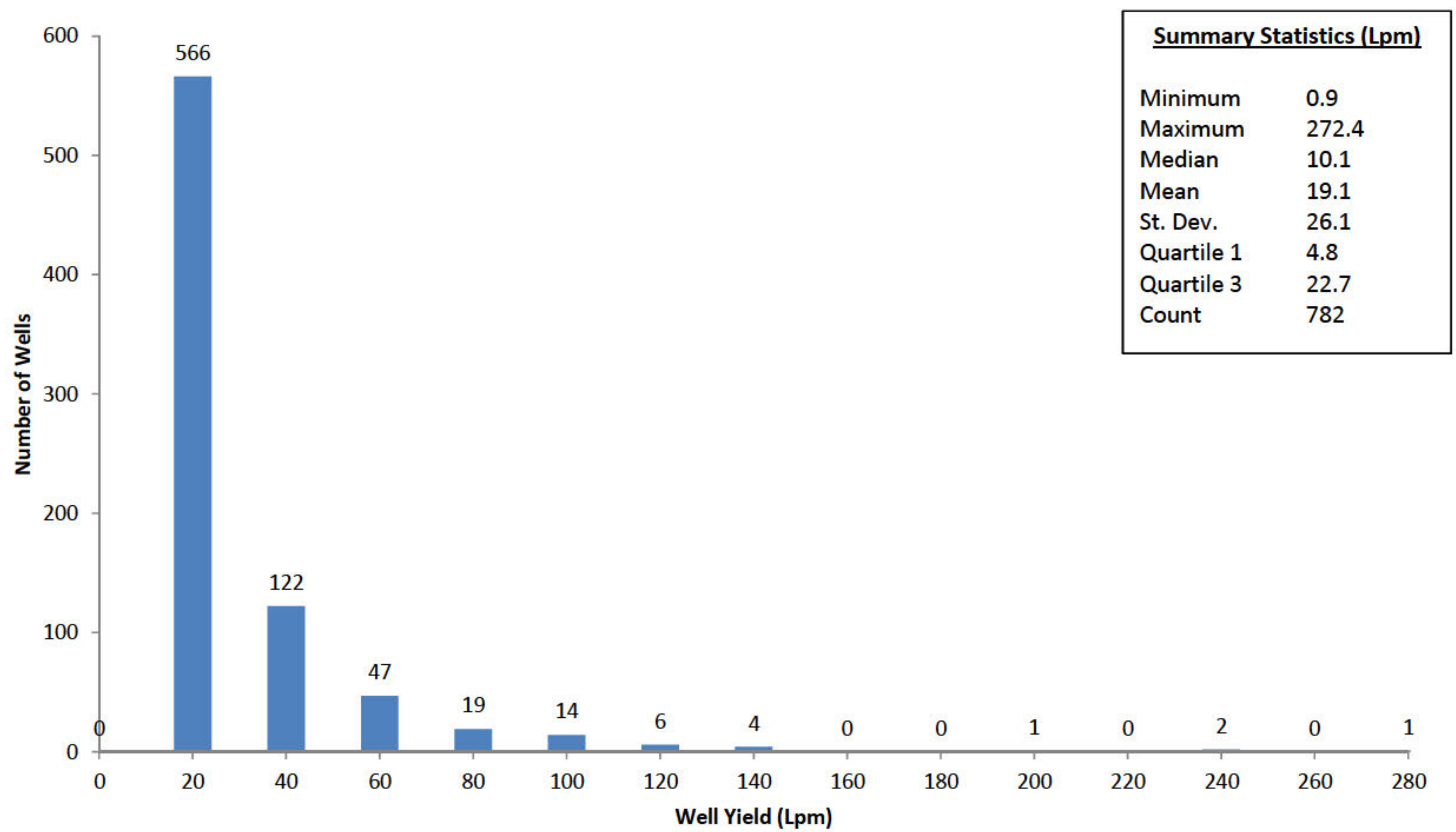

Figure 9 Histogram of well yields for bedrock wells identified in Upper Tantallon.

Project No.	Scale
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Location	Date
Upper Tantallon	July 2024

FFC

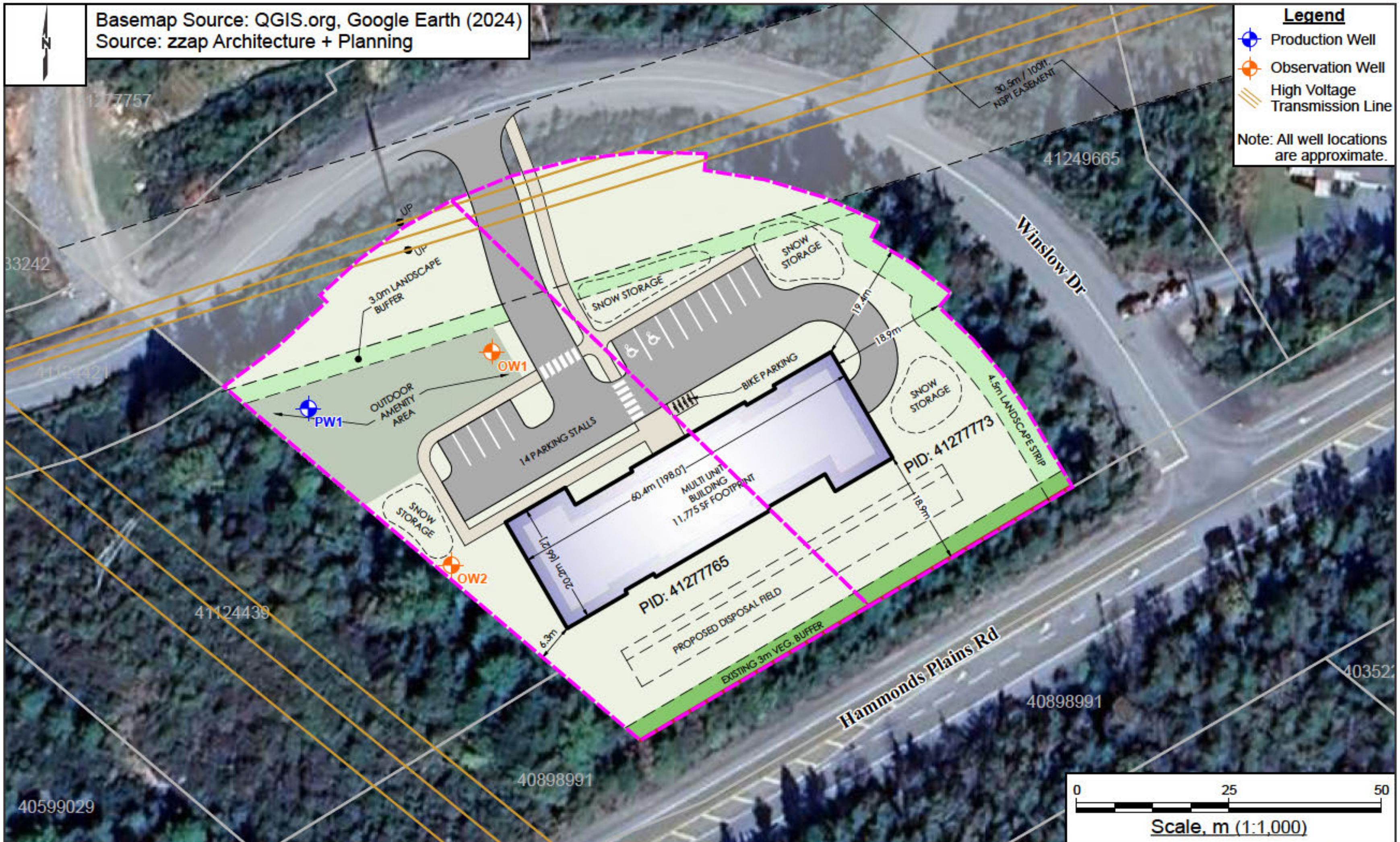

Figure 10 Development plan and well location map.

Project No.	Scale
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Location	Date
Upper Tantallon, NS	July 2024

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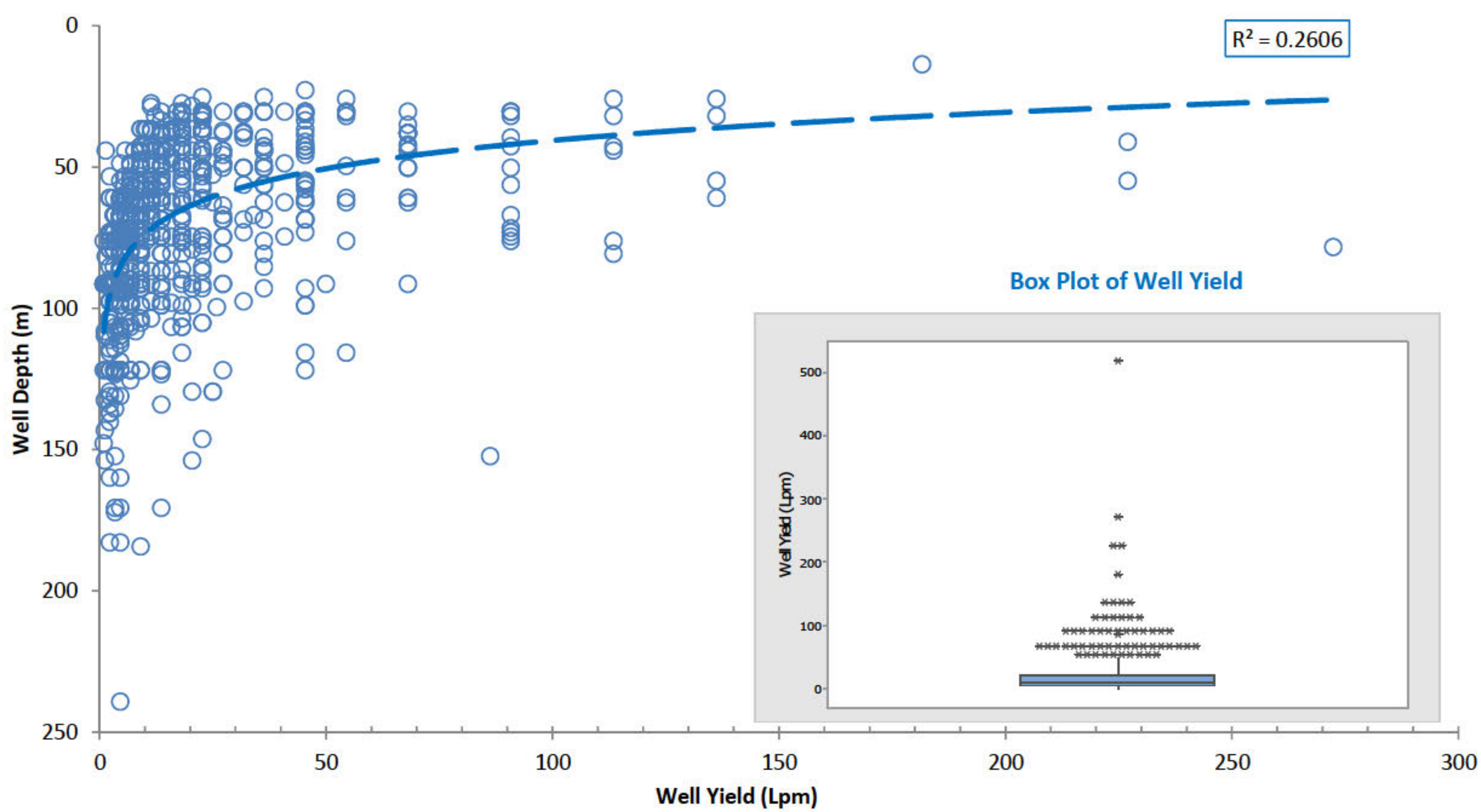

Figure 11 Well yield versus well depth for the list of bedrock wells identified in Upper Tantallon.	Project No. 879	Scale As Shown
	Location Upper Tantallon	Date July 2024

FFC

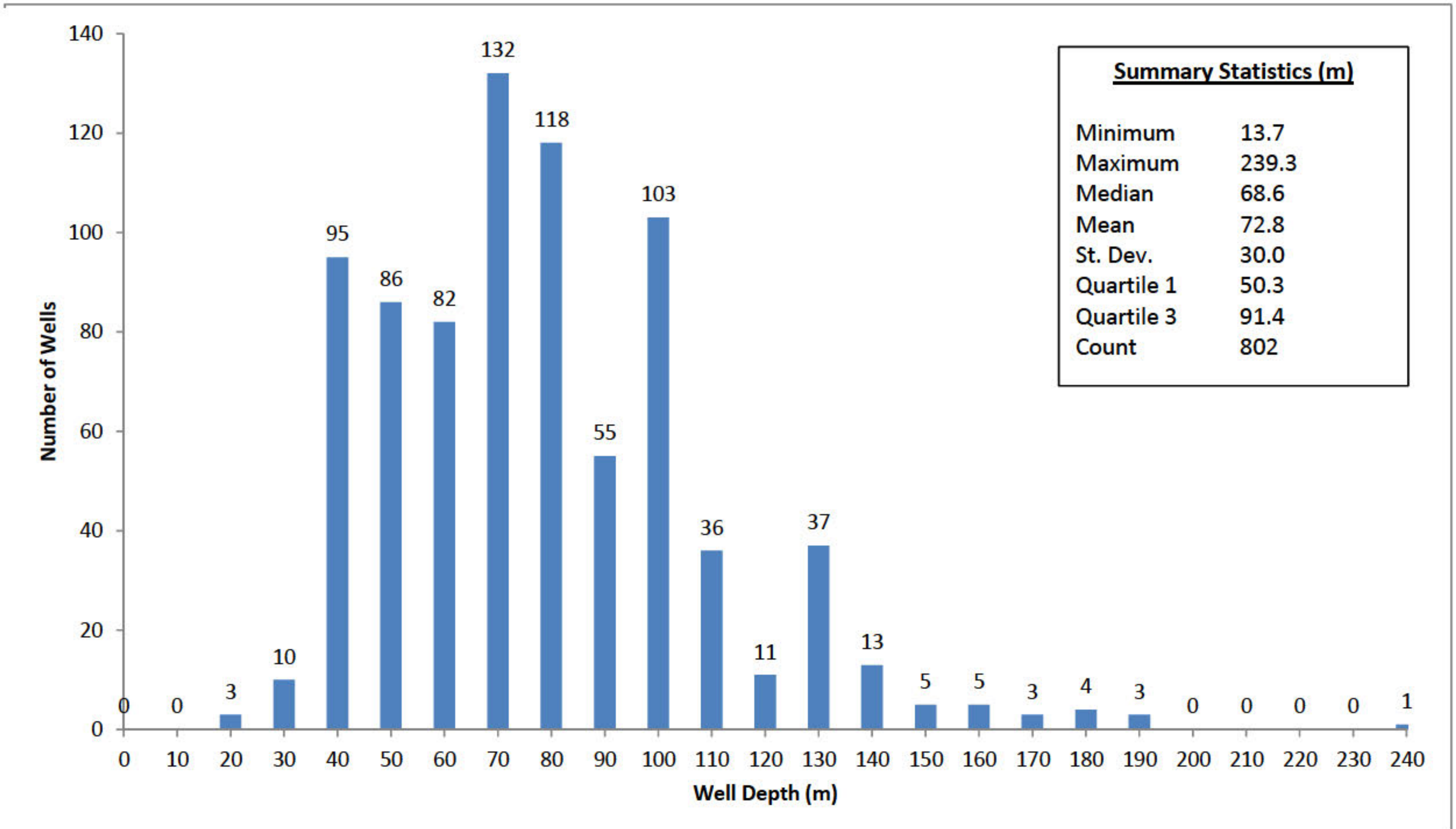

Figure 12 Histogram of well depths for the list of bedrock wells identified in Upper Tantallon.

Project No.	Scale
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Location	**Date**
Upper Tantallon	July 2024

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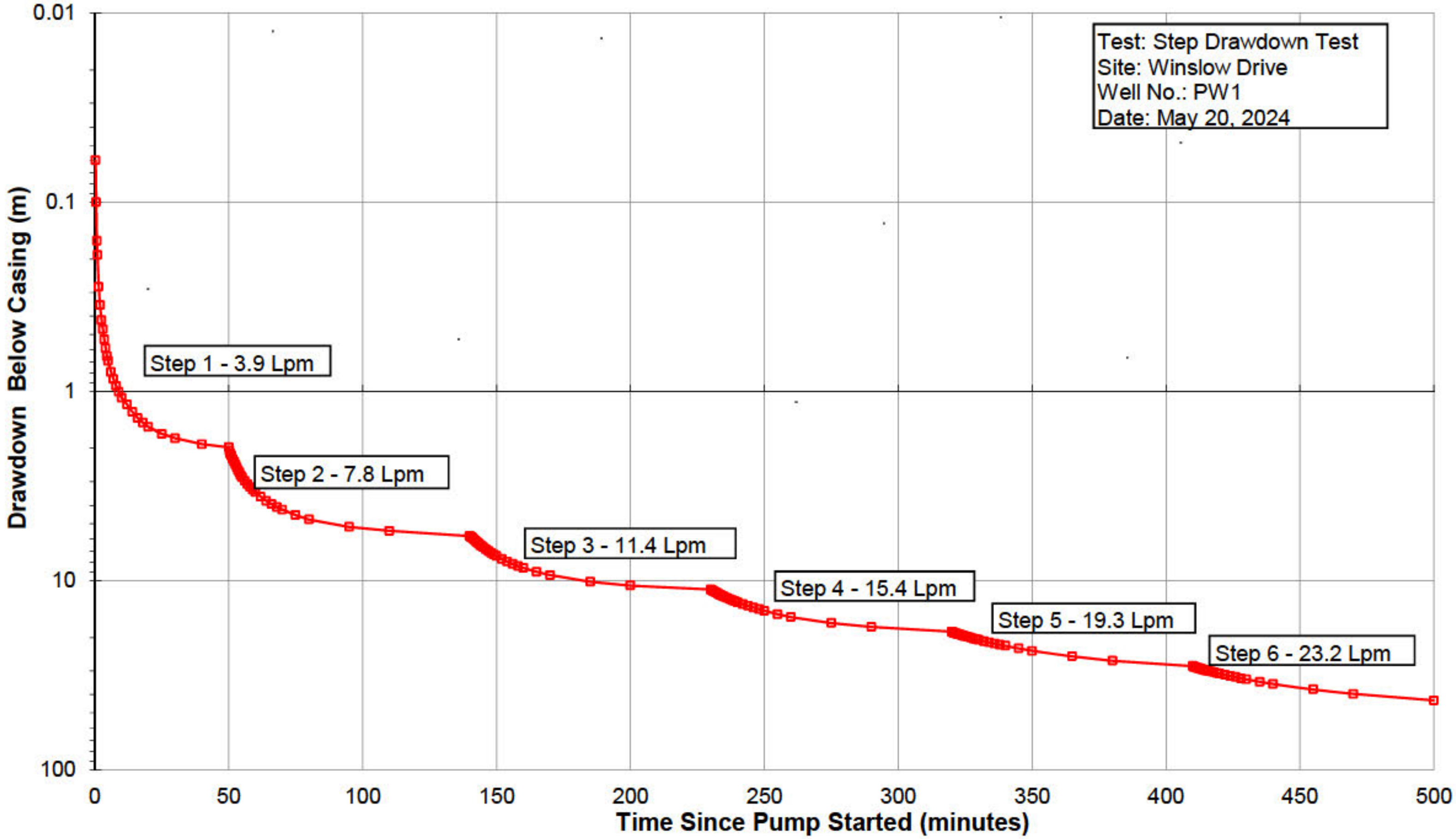

Figure 13 Time versus drawdown for the step drawdown test at PW1.

Project No.	Scale
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Location	Date
Winslow Drive	July 2024

FFC

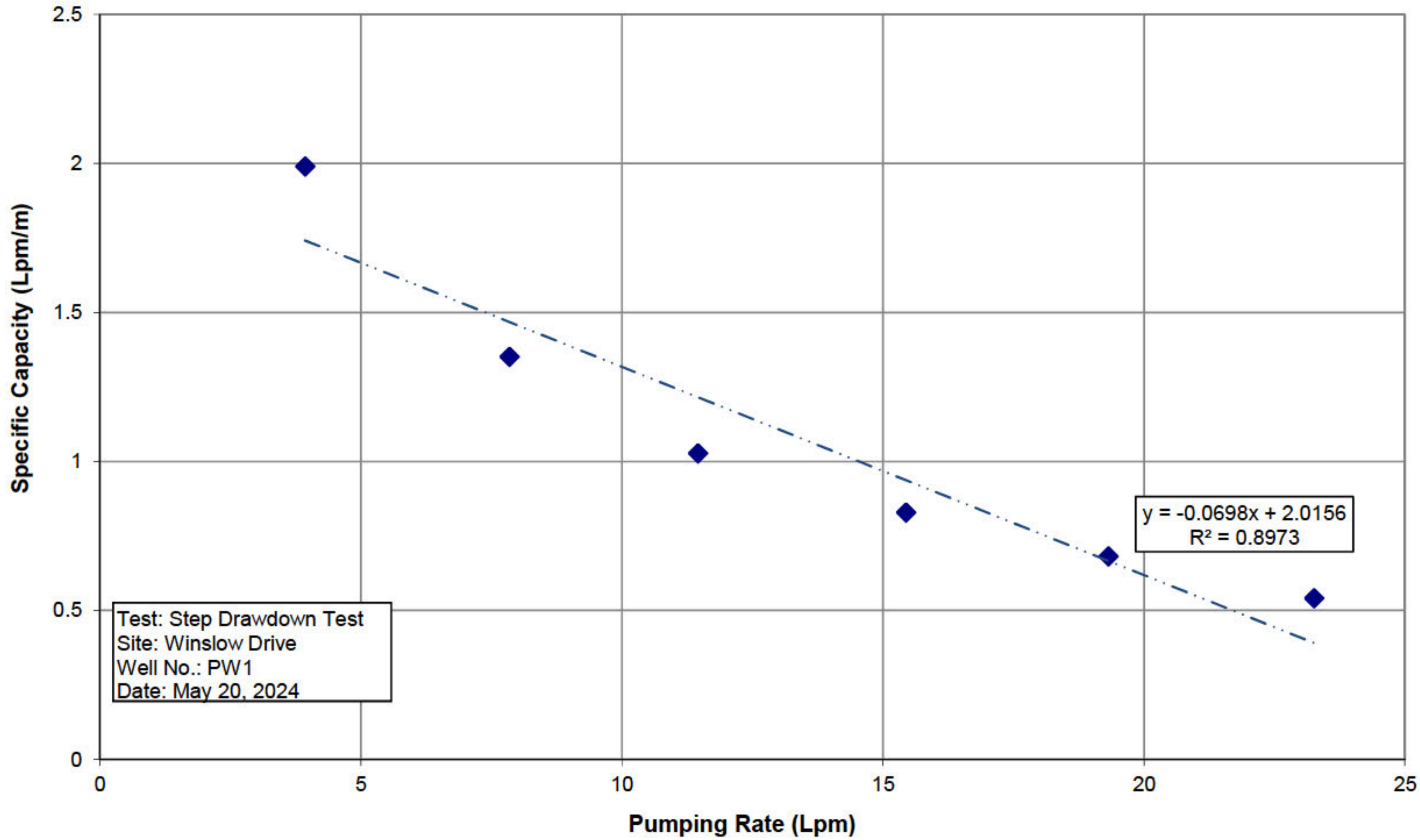

Figure 14 Plot of pumping rate versus specific capacity for PW1.

Project No.	Scale
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Location	**Date**
Winslow Drive	July 2024

FFC

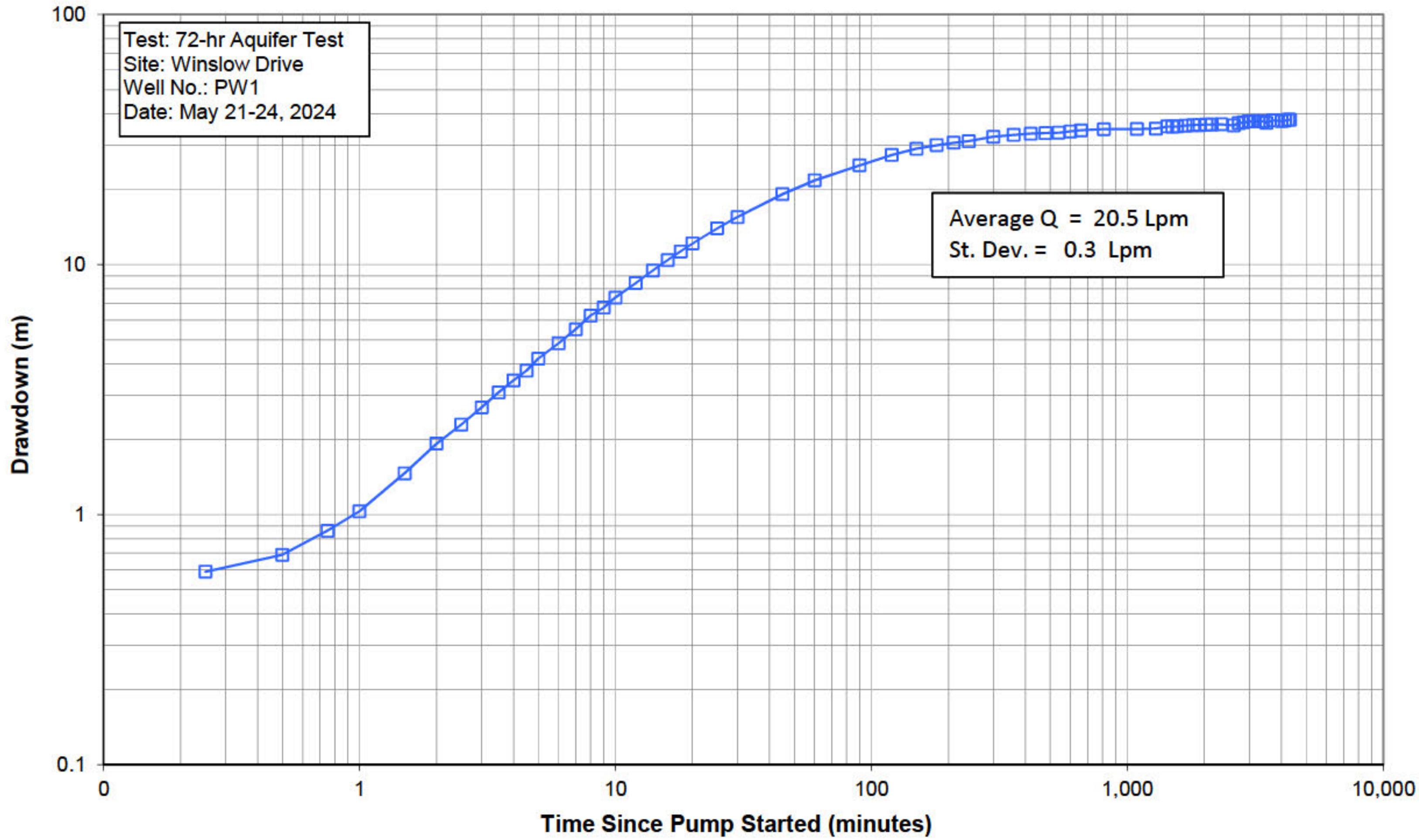

Figure 15 Log-log plot of time versus drawdown (Theis Method) for the aquifer test at PW1.

Project No.	Scale
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Location	Date
Winslow Drive	July 2024

FFC

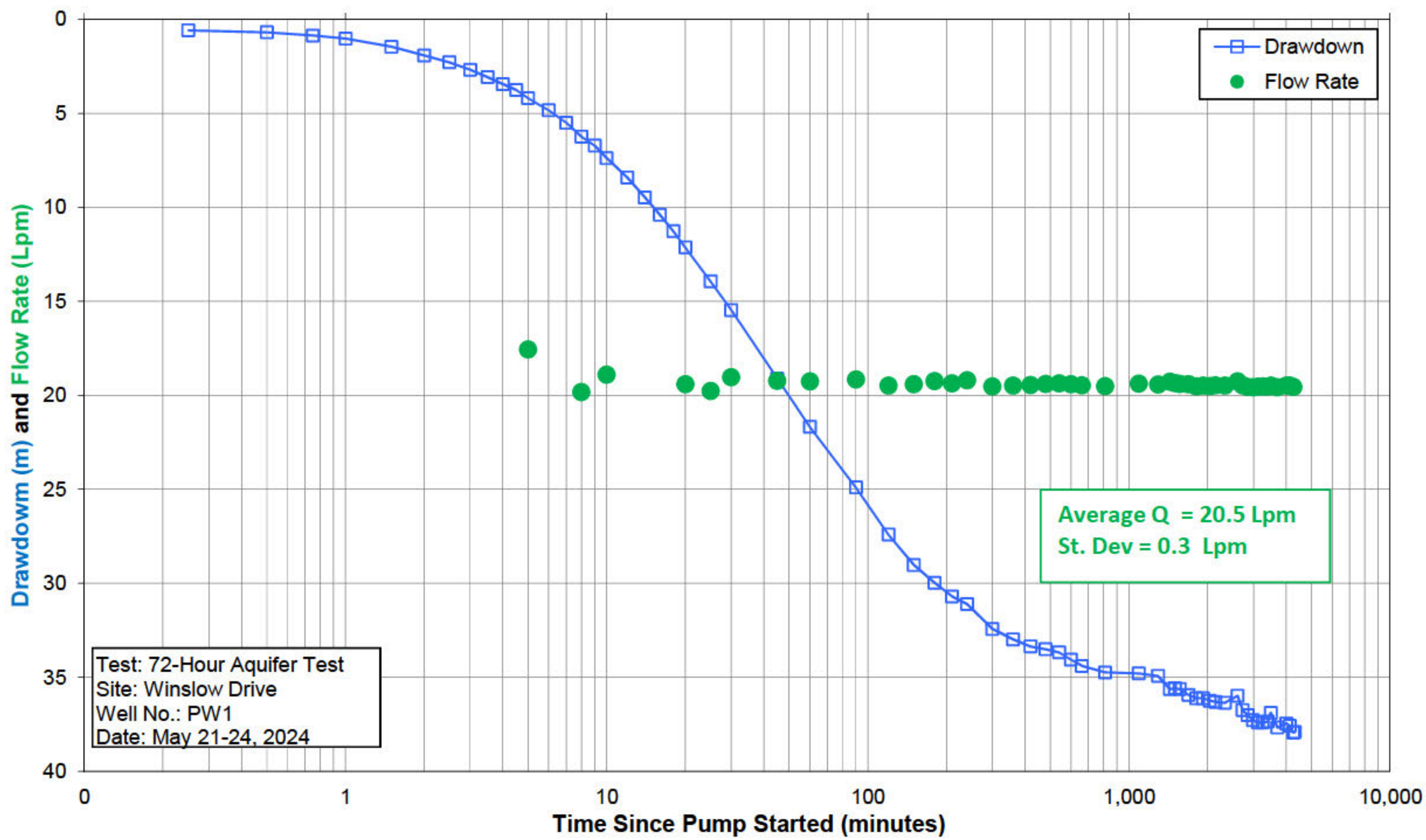

Figure 16 Semi-log plot (Cooper-Jacob straight-line method) of time versus drawdown and flow rate for the aquifer test at PW1.

Project No.	Scale
879	As Shown
Location	Date
Winslow Drive	July 2024

FFC

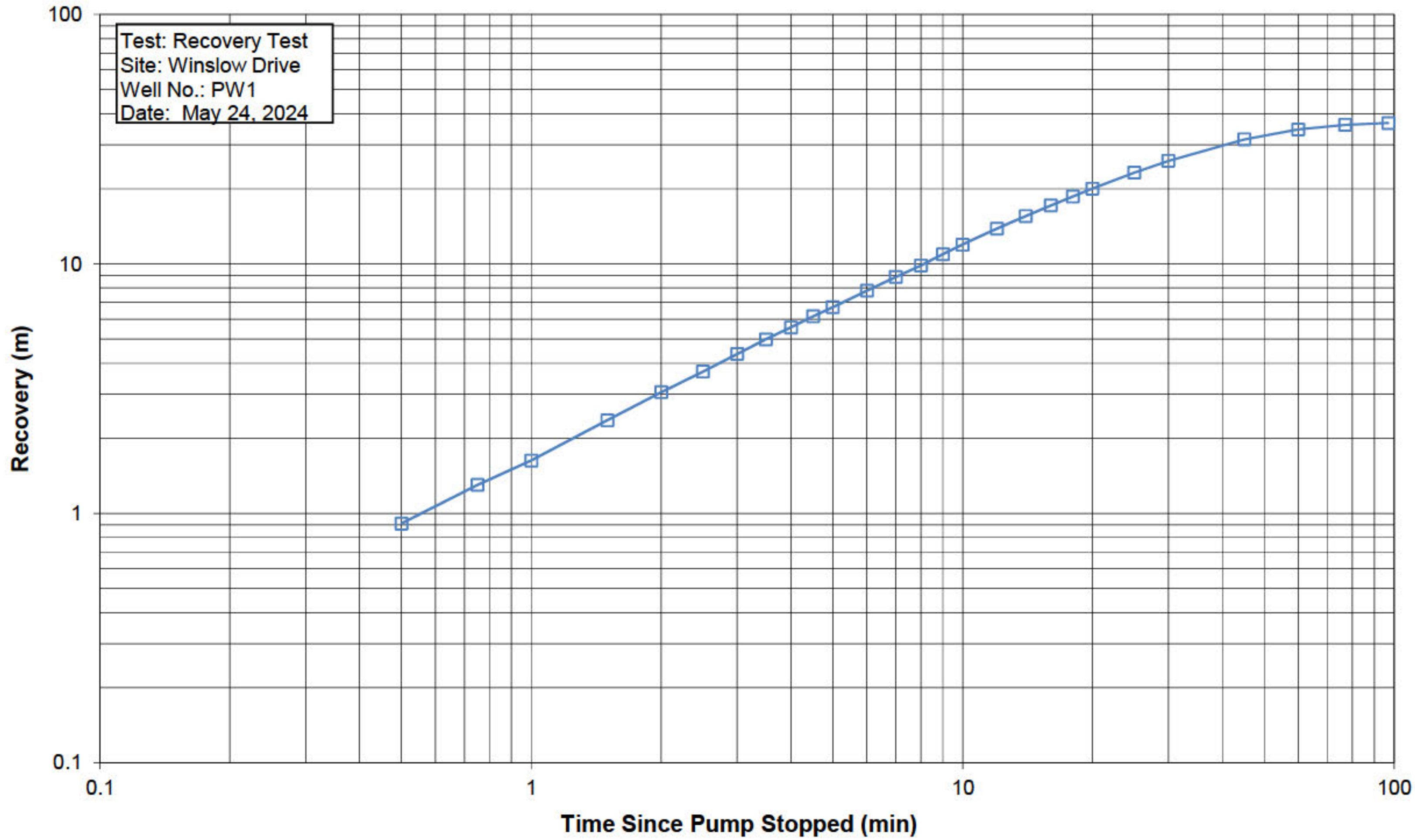

Figure 17 Log-log plot of recovery data for PW1 after the termination of the aquifer test.

Project No.	Scale
879	As Shown
Location	**Date**
Winslow Drive	July 2024

FFC

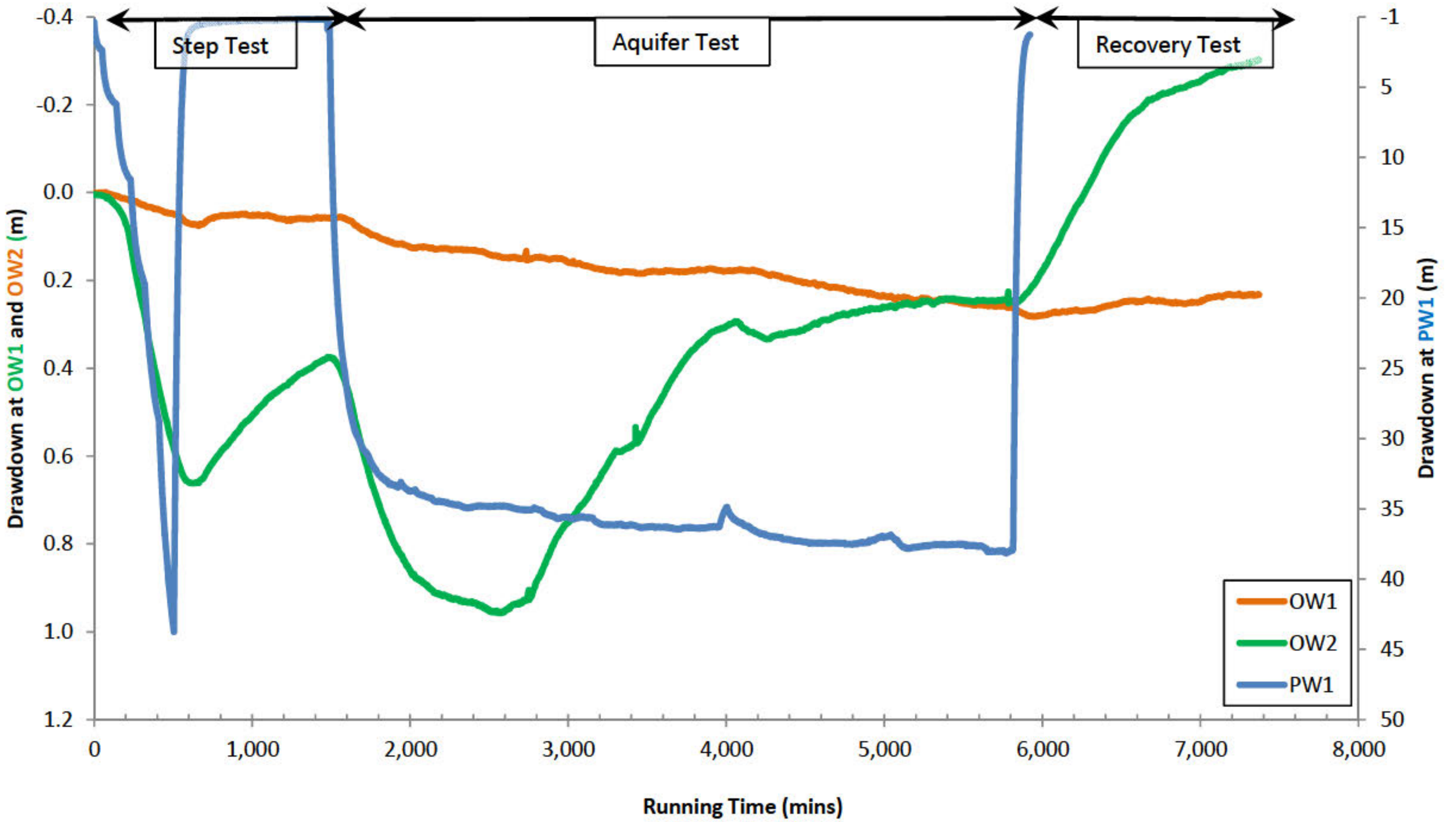

Figure 18 Water level trends at observation wells OW1 and OW2 during the step drawdown test, aquifer test and recovery test at PW1.

Project No.	Scale
879	As Shown
Location	Date
Winslow Drive	July 2024

FFC

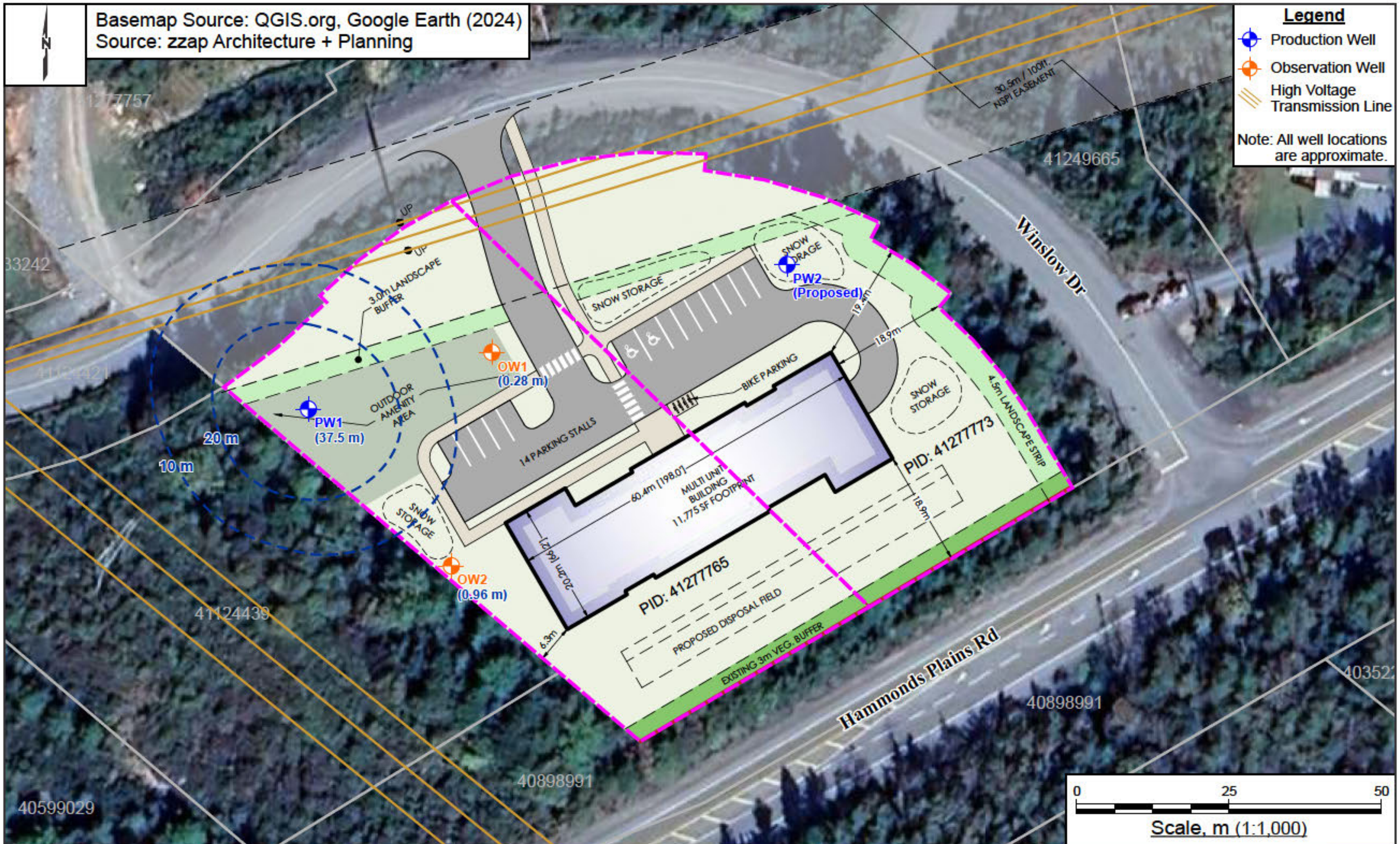

Figure 19 Inferred shape of the drawdown cone around PW1 after 2,500 minutes of pumping, and proposed location for PW2.

Project No.	Scale
879	As Shown
Location	**Date**
Upper Tantallon, NS	July 2024

FFC

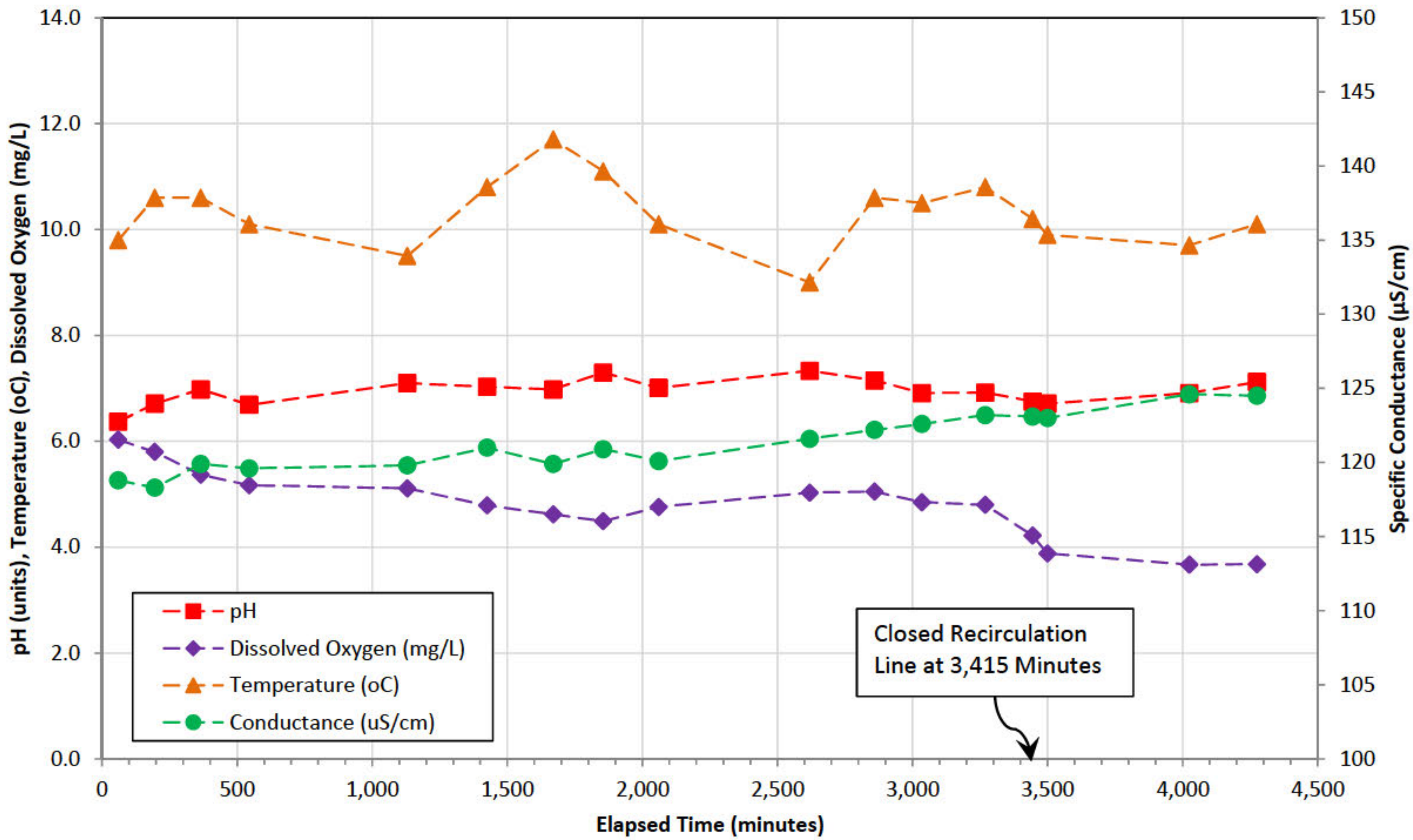

Figure 20 Field-measured water quality of groundwater discharge from PW1 during the aquifer test.

Project No.	Scale
879	As Shown
Location	**Date**
Winslow Drive	July 2024

FFC

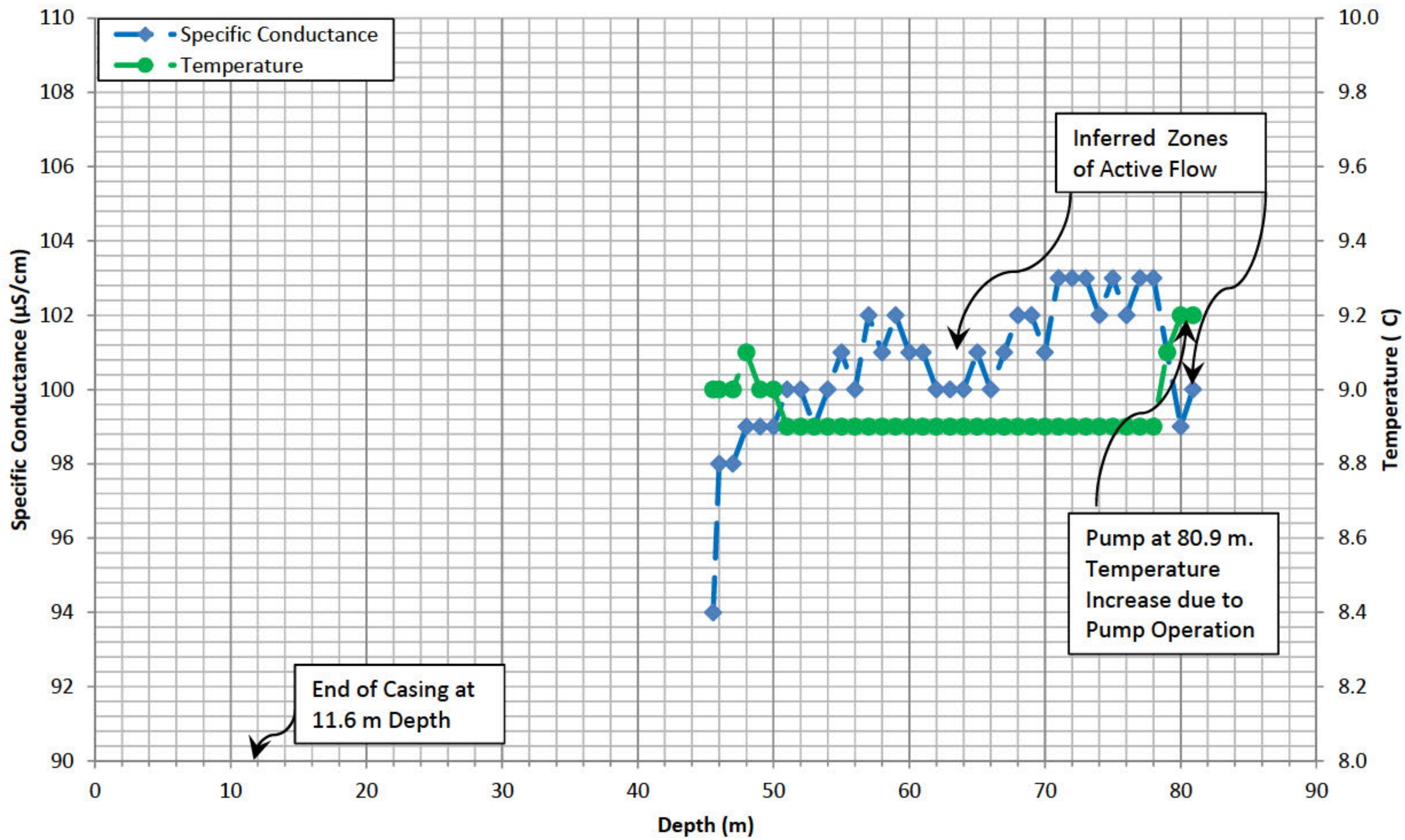

Figure 21 Temperature and conductivity profile of production well PW1 during the aquifer test.

Project No.	Scale
879	As Shown
Location	**Date**
Winslow Drive	July 2024

FFC

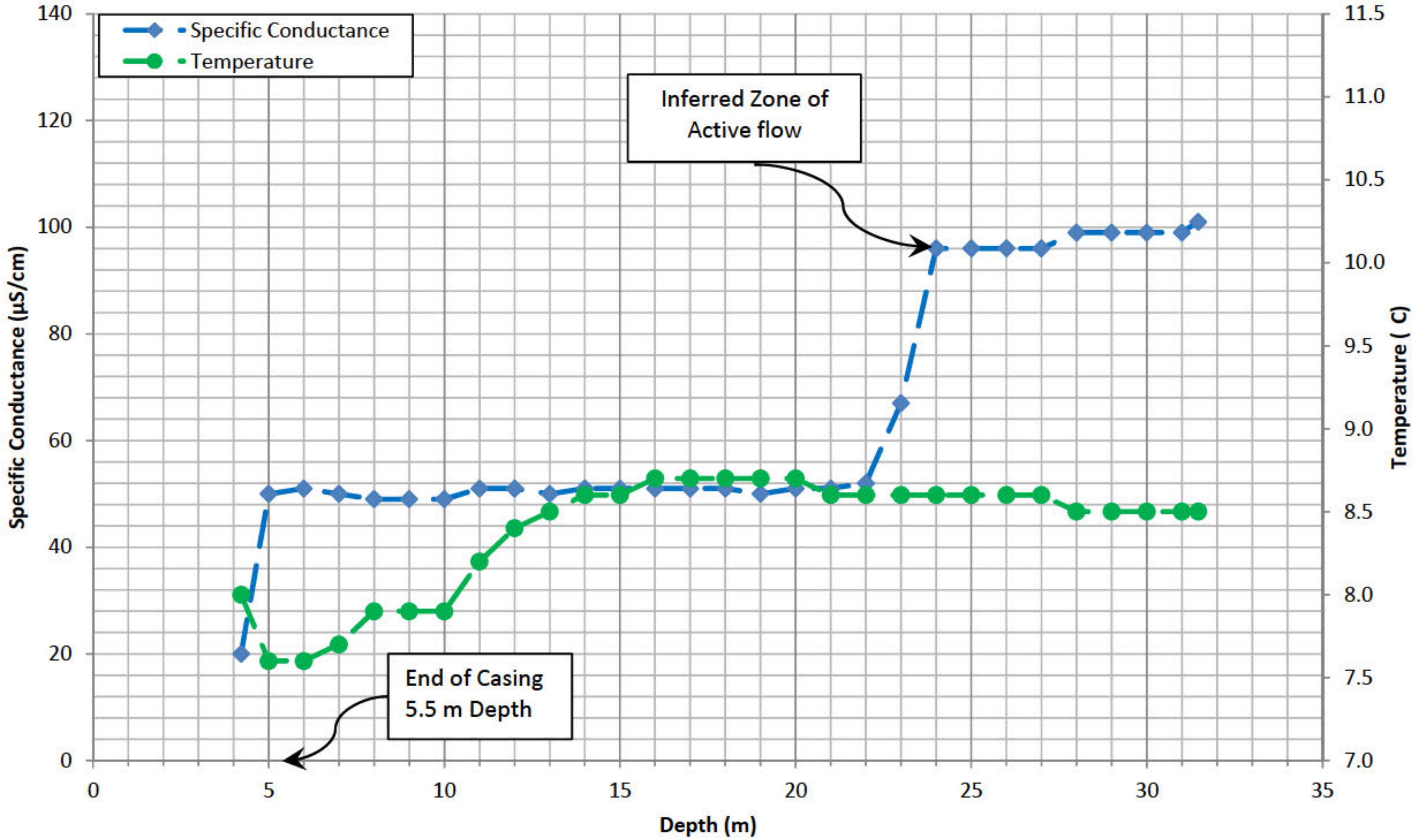

Figure 22 Temperature and conductivity profile of observation well OW1 during the aquifer test at PW1.	Project No. 879	Scale As Shown
	Location Winslow Drive	Date July 2024

FFC

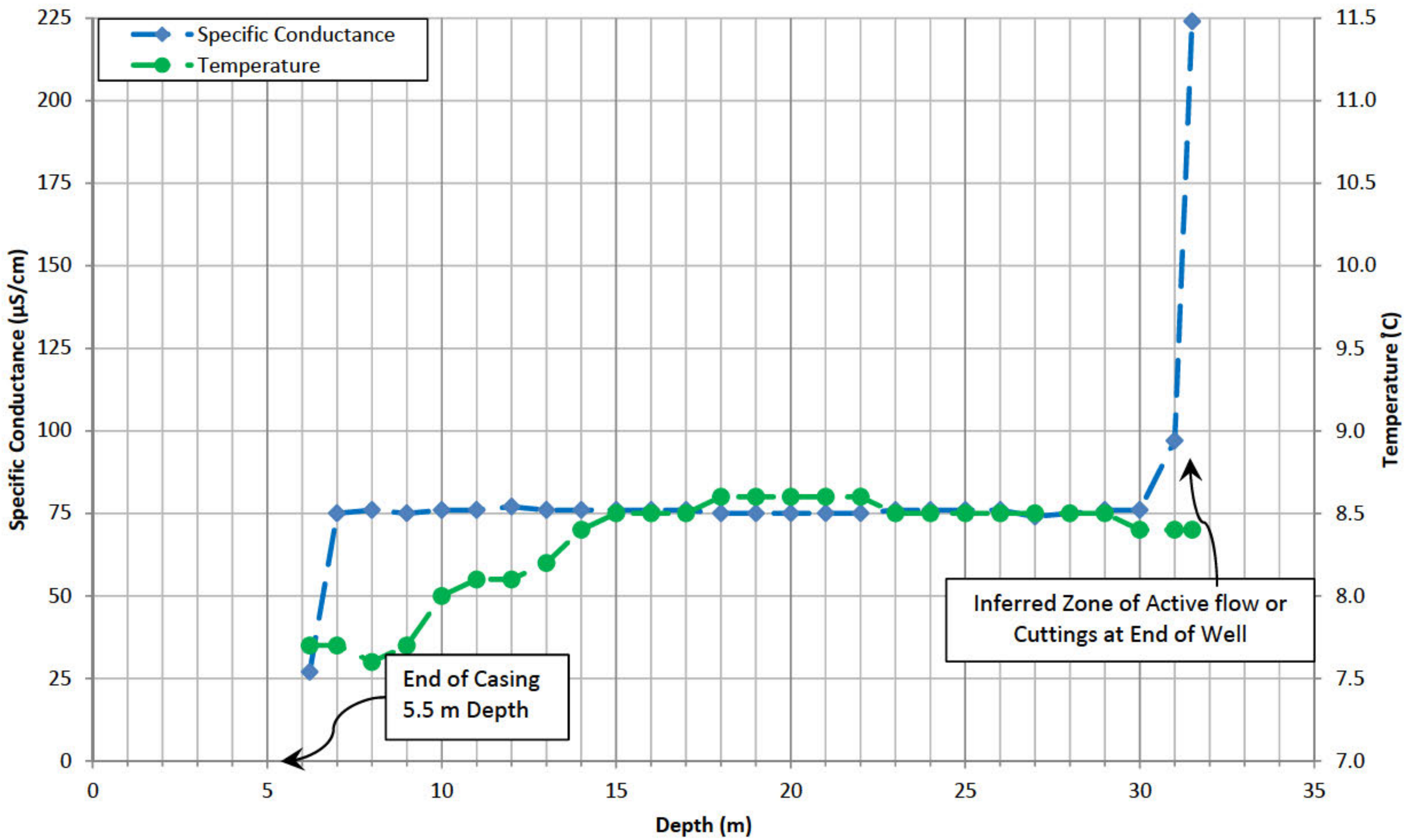

Figure 23 Temperature and conductivity profile of observation well OW2 during the aquifer test at PW1.

Project No. 879	Scale As Shown
Location Winslow Drive	Date July 2024

FFC

APPENDIX 2

Tables

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Table 1 Statistical summary of known dug wells in the communities of Hammonds Plains, Upper Hammonds Plains, Upper Tantallon, and Upper Sackville.

Statistical Parameter	Well Depth (m)	Length of Casing (m)	Depth to Bedrock (m)	Static Water Level (m)	Estimated Well Yield (Lpm)
Average	6.6	6.4	---	3.7	510
Median	6.9	6.9	---	3.7	159
Minimum	3.0	0.8	---	0.2	54.5
Maximum	8.4	8.4	---	6.1	1,298
St. Dev.	1.4	2.0	---	1.8	612
Count	14	13	---	11	6.00

Table 2 Summary of drilled wells in the community of Upper Hammonds Plains.

Statistical Parameter	Well Depth (m)	Length of Casing (m)	Depth to Bedrock (m)	Static Water Level (m)	Estimated Well Yield (Lpm)
Average	96.7	11.2	4.7	5.2	17.4
Median	99.1	12.2	3.7	4.6	11.4
Minimum	25.9	5.8	0.3	1.5	0.3
Maximum	165	24.4	19.8	12.2	90.8
St. Dev.	30.1	3.5	3.7	1.8	18.4
Count	118	117	116	83	114

Table 3 Summary of drilled wells in the community of Hammonds Plains.

Statistical Parameter	Well Depth (m)	Length of Casing (m)	Depth to Bedrock (m)	Static Water Level (m)	Estimated Well Yield (Lpm)
Average	69.8	14.3	9.4	6.8	30.0
Median	62.5	12.2	6.1	6.1	13.6
Minimum	3.0	0.6	0.3	0.2	0.3
Maximum	191	58.8	55.5	69.5	454
St. Dev.	31.8	9.1	9.0	5.4	43.0
Count	1,024	976	930	623	998

Table 4 Summary of drilled wells in the community of Upper Tantallon.

Statistical Parameter	Well Depth (m)	Length of Casing (m)	Depth to Bedrock (m)	Static Water Level (m)	Estimated Well Yield (Lpm)
Average	72.8	9.0	4.6	7.1	19.7
Median	68.6	7.0	3.7	6.1	10.2
Minimum	13.7	0.6	0.2	0.6	0.9
Maximum	239	183	39.6	76.2	518
St. Dev.	30.0	7.4	3.7	6.9	31.6
Count	802	772	737	526	783

Table 5 Summary of drilled wells in the community of Upper Sackville.

Statistical Parameter	Well Depth (m)	Length of Casing (m)	Depth to Bedrock (m)	Static Water Level (m)	Estimated Well Yield (Lpm)
Average	54.5	12.4	8.7	6.4	30.1
Median	48.8	8.5	5.2	4.6	18.2
Minimum	7.9	1.5	0.3	0.3	0.5
Maximum	192	66.4	65.5	39.6	272
St. Dev.	23.0	9.2	9.3	6.1	33.3
Count	951	895	837	559	942

Table 6 Summary of pump test data for wells in Upper Tantallon.

Pump Test ID	Test For	Community	Rock Type	Well Type	Well Number	Well Depth (m)	Well Diameter (mm)	Casing Length (m)	Start Date	End Date	Duration (Hours)	Pumping Rate (m^3/day)	Static Water Level (m)	Maximum Drawdown (m)	T (m^2/day)	SC (m^2/day)	K (m/day)	Q_{20} (Lpm)
HAL-51	Digital Components Ltd., John Creighton	Hammonds Plains	Plutonic	Drilled	742261	131.1	152.4	12.8	10-Jan-75	13-Jan-75	72	39.3	14.3	50.0	0.5	0.8	4.50E-03	18.2
HAL-106	Sobeys Commercial Development (Well TW1)	Upper Tantallon	Plutonic	Drilled	930469	76.2	152.4	6.1	20-Apr-93	23-Apr-93	72	28.8	7.0	15.1	0.7	1.9	9.68E-03	20.0
HAL-122	Atlantic Superstore, Loblaws Property Group	Upper Tantallon	Plutonic	Drilled	20919	93.0	152.4	18.3	26-Jul-02	29-Jul-02	72	50.7	6.5	38.0	0.7	1.3	8.41E-03	22.7
HAL-133	Sir John A. MacDonald High School, Nova Scotia Department of Transportation and Public Works	Upper Tantallon	Plutonic	Drilled	40295	91.4	152.4	18.3	16-Aug-04	19-Aug-04	73	47.0	10.6	7.1	5.2	6.6	7.43E-02	85.7
HAL-136	St. Margarets Centre	Upper Tantallon	Plutonic	Drilled	881977	90.0	152.4	6.1	31-Jul-04	05-Aug-04	132	19.6	13.4	37.3	0.3		4.01E-03	10.7
HAL-150	Village Station Townhomes Ltd.	Upper Tantallon	Plutonic	Drilled	110081	121.9	152.4	12.2	19-Mar-11	22-Mar-11	72	19.3	1.7	60.7	0.3	0.3	3.00E-03	
HAL-163	Cobalt Properties Limited	Upper Tantallon	Plutonic	Drilled	940883	123.4	152.4	6.1	30-Apr-12	03-May-12	72	56.2	6.1	69.0	0.8	0.8	6.83E-03	21.1
HAL-169	St. Margarets Square, WM Fares Group	Upper Tantallon	Plutonic	Drilled	121184	93.0	152.4	12.2	20-Nov-12	23-Nov-12	72	33.3	5.4	46.9	0.5	0.7	5.71E-03	21.3
HAL-173	Eleanor Hubley Villa (NS Dept. of Housing)	Upper Tantallon	Plutonic	Drilled	921780	76.8	152.4	7.3	20-Jan-93	23-Jan-93	72	23.1	1.8	49.9	0.3	0.4		8.2
HAL-176.1	W.M. Fares Architects/3283920 Nova Scotia Limited	Upper Tantallon	Plutonic	Drilled		62.5	152.0	14.3	29-Feb-16	03-Mar-16	72	46.5	4.1	39.7	1.2	1.2	2.04E-02	16.7
HAL-176.2	W.M. Fares Architects/3283920 Nova Scotia Limited	Upper Tantallon	Plutonic	Drilled		93.0	152.0	15.8	29-Feb-16	03-Mar-16	72	34.0	5.6	21.6	1.1	1.6	2.45E-01	28.0
HAL-31	Tantallon Junior High School, Municipality of the County of Halifax School Board	Upper Tantallon	Plutonic	Drilled	700630	91.4	152.4	3.7	05-Jan-71	08-Jan-71	72	42.1	2.2	74.0	0.2	0.6	1.84E-03	5.4
HAL-62	Maritime Resource Management Services (MRMS) Information Centre	Upper Tantallon	Plutonic	Drilled	752759	85.3	152.4	7.3	20-Jun-75	23-Jun-75	72	163.6	2.6	2.8	9.3	57.5	3.08E-01	113.6
HAL-74	Tantallon Junior High School, Municipality of the County of Halifax School Board	Upper Tantallon	Plutonic	Drilled	700630	91.4	152.4	3.7	07-Oct-77	10-Oct-77	72	44.0	5.8	57.8	0.5	0.8	5.52E-03	13.6
Statistical Summary for Drilled Wells											**Average**	**46.3**	**6.2**	**40.7**	**1.5**	**5.7**	**5.4E-02**	**29.6**
											Median	**40.7**	**5.7**	**43.3**	**0.6**	**0.8**	**6.8E-03**	**20.0**
											Minimum	**19.3**	**1.7**	**2.8**	**0.2**	**0.3**	**1.8E-03**	**5.4**
											Maximum	**163.6**	**14.3**	**74.0**	**9.3**	**57.5**	**3.1E-01**	**114**
											St. Dev.	**35.7**	**4.0**	**22.2**	**2.6**	**15.6**	**1.0E-01**	**32.2**
											Count	**14**	**14**	**14**	**14**	**13**	**1.3E+01**	**13**

Table 7 Summary of well construction details.

Parameter	Units	Production Well PW1	Observation Well OW1	Observation Well OW2
Northing	**m**	4,950,069	4,950,669	4,950,643
Easting	**m**	432,332	432,352	432,352
Top of Casing Elevations (Benchmark Elevation at PW1 is Assumed)	**m**	80.9	81.8	81.4
Relative Ground Elevations (Benchmark Elevation at PW1 is Assumed)	**m**	80.0	81.2	80.8
Intended Use	---	Potable Water Supply	Observation Well	Observation Well
Well Type	---	Open Bedrock Well	Open Bedrock Well	Open Bedrock Well
Date Drilled	---	May-24	May-24	May-24
Diameter	**mm**	152	152	152
Depth to Bedrock	**m**	0.9	1.5	0.6
Length of Casing (below ground surface)	**m**	11.3	6.1	6.1
Screened Section	**m**	Not Applicable	Not Applicable	Not Applicable
Well Depth	**m**	121.9	30.5	30.5
Overburden Type	---	Silty Sand with Gravel, Cobbles and Boulders	Silty Sand with Gravel, Cobbles and Boulders	Silty Sand with Gravel, Cobbles and Boulders
Bedrock Type	---	Leucomonzogranite	Leucomonzogranite	Leucomonzogranite
Depth of Primary Water-Bearing Zones	**m**	Not Identified	Not Identified	Not Identified
Hydro-Frac Zones	**m**	None (Well was Surged)	None	None (Well was Surged)
Static Water Level (May 20, 2024)	**m btoc**	10.69	4.115	5.355
Yield from Final Air Lift Test	**Lpm**	22.7	2.3	1.1
Pumping Rate During Aquifer Test	**Lpm / Time**	20.5 / 72-hours	---	---
Depth of Pump for Aquifer Test	**m**	71.6	---	---
Pump Size, Capacity for Aquifer Test	**Hp / USGpm**	0.75 / 10	---	---

Table 8 Step test data and calculated values of specific capacity for production well PW1.

Well ID	**Step**	**Step Duration (mins)**	**Flow Rate (Lpm)**	**Maximum Depth to Water (m btoc)**	**Drawdown (m)**	**Specific Capacity (Lpm/m)**
PW1	1	50	3.9	13.04	1.98	1.99
	2	90	7.9	16.87	5.81	1.35
	3	90	11.5	22.22	11.16	1.03
	4	90	15.4	29.70	18.64	0.83
	5	90	19.3	39.39	28.33	0.68
	6	90	23.3	54.06	43.00	0.54

Note: 'm btoc' means metres below top of casing.

Table 9 Calculated aquifer properties and theoretical yield of production well PW1.

Data Set Used	**Test Method**	**Specific Capacity (m^2/min) or (L/min/m)**	**Transmissivity (m^2/s)**	**Hydraulic Conductivity (m/s)**	**Storativity (Dimensionless)**	**Maximum Recommended Drawdown (m)**	**Theoretical Yield (Lpm)**	
							Q_{safe}	**Q_{20}**
Production Well PW1	Theis	0.00054 (0.54)	3.26E-06	3.27E-05	---	40	21.6	3.1
	Cooper-Jacob		3.23E-06	3.24E-05	---			
	Theis Recovery		1.66E-06	1.66E-05	---			
Observation Well OW1	Theis	0.00054 (0.54)	7.18E-04	7.18E-03	3.75E-04	40	21.6	833
	Cooper-Jacob		7.34E-04	7.35E-03	---			
Observation Well OW2	Theis	0.00054 (0.54)	9.04E-05	9.04E-04	5.30E-04	40	21.6	105
	Cooper-Jacob		9.19E-05	9.19E-04	---			
	Average Values	**---**	**2.35E-04**	**2.35E-03**	**4.53E-04**	**---**	**---**	---

Notes:

1. Recommended depth for the pump is 50 m (164 feet) below ground surface. The maximum recommended drawdown is 40 m (131.2 feet) below top of casing.

2. Specific capacity is calculated as the test flow rate (0.0205 m^3/min) divided by the maximum observed drawdown in the pumping well (37.9 m).

3. Q20 is calculated using the average value of transmissivity for the pumping well (PW1), and using the average value of transmissivity for each observation well (OW1 and OW2).

Table 10 Standard water chemistry, total metals, radiological parameters, and microbiology of groundwater samples from production well PW1.

Parameter	Unit	Canadian Drinking Water Quality Guidelines			Field ID	Aquifer Test			
					Field ID	879-PW1-1HR	879-PW1-24HRS	879-PW1-48HRS	879-PW1-72 HRS
					Date	21-May-24	22-May-24	23-May-24	24-May-24
					Lab	Bureau Veritas	Bureau Veritas	Bureau Veritas	Bureau Veritas
		MAC	AO	Other Value	Lab ID	ZFV108	ZFV110	ZFV111	ZGG270
Major Ion, Physical and Calculated Values									
pH				7.0-10.5		6.93	6.98	---	7.17
Reactive Silica as SiO2	mg/L					21	24	---	24
Chloride	mg/L		250			19	17	---	19
Fluoride	mg/L	1.5				---	---	---	0.45
Sulphate	mg/L		500			7.7	7.6	---	7.9
Alkalinity	mg/L					22	25	---	26
True Colour	TCU		15			<5	<5	---	7.1
Turbidity (Groundwater Source)	NTU			1		16	3.4	---	1.7
Electrical Conductivity	µS/cm					150	150	---	160
Nitrate + Nitrite as N	mg/L					0.12	0.08	---	0.077
Nitrate as N	mg/L	10				0.12	0.18	---	0.077
Nitrite as N	mg/L	1				<0.01	<0.01	---	<0.01
Ammonia as N	mg/L					<0.05	<0.05	---	<0.05
Total Organic Carbon	mg/L					<0.5	<0.5	---	<0.5
Ortho-Phosphate as P	mg/L					0.073	0.12	---	0.12
Total Sodium	mg/L		200			20	18	---	20
Total Potassium	mg/L					1.9	1.4	---	1.4
Total Calcium	mg/L					5.7	6.8	---	7.2
Total Magnesium	mg/L					1.5	1.5	---	1.6
Bicarb. Alkalinity (as CaCO3)	mg/L					22	25	---	26
Carb. Alkalinity (as CaCO3)	mg/L					<1	<1	---	<1
Calculated TDS	mg/L		500			91	92	---	95
Hardness	mg/L					21	23	---	23
Langelier Index (@20C)	NA					-2.32	-2.12	---	-1.93
Langelier Index (@ 4C)	NA					-2.57	-2.38	---	-2.18
Saturation pH (@ 20C)	NA					9.24	9.1	---	9.1
Saturation pH (@ 4C)	NA					9.49	9.35	---	9.35
Anion Sum	me/L					1.13	1.14	---	1.26
Cation sum	me/L					1.35	1.29	---	1.23
% Difference/ Ion Balance	%					8.87	6.17	---	1.20
Total Metals									
Aluminum	µg/L	2,900		100		1,700	220	---	140
Antimony	µg/L	6				<1	<1	---	<1
Arsenic	µg/L	10				20	11	---	11
Barium	µg/L	1,000				9.5	10	---	10
Beryllium	µg/L					0.6	0.25	---	0.22
Bismuth	µg/L					<2	<2	---	<2
Boron	µg/L	5,000				<50	<50	---	<50
Cadmium	µg/L	5				0.09	0.014	---	0.012
Chromium	µg/L	50				<1	<1	---	<1.0
Cobalt	µg/L					0.97	<0.40	---	<0.4
Copper	µg/L	2,000	1,000			19	3.1	---	2.3
Iron	µg/L		300			850	200	---	140
Lead	µg/L	5				3	0.61	---	<0.5
Manganese	µg/L	120	20			38	32	---	34
Molybdenum	µg/L					<2	<2	---	<2
Nickel	µg/L					2.6	<2	---	<2
Phosphorous	µg/L					150	150	---	160
Selenium	µg/L	50				<0.5	<0.5	---	<0.5
Silver	µg/L					<0.1	<0.1	---	<0.1
Strontium	µg/L	7,000				63	79	---	81
Thallium	µg/L					<0.1	<0.1	---	<0.1
Tin	µg/L					<2	<2	---	<2
Titanium	µg/L					5.3	<2	---	<2
Uranium	µg/L	20				12	5.1	---	4.1
Vanadium	µg/L					<2	<2	---	<2
Zinc	µg/L		5,000			99	12	---	11
Radiological Parameters									
Lead-210	Bq/L	0.2				---	---	---	<0.1
Radon-222	Bq/L					---	---	---	3,610
Micro-Biology									
Total Coliforms	CFU/100 mL	0				---	---	<2	---
E. Coli	CFU/100 mL	0				---	---	<2	---
Field Measurements									
Temperature	°C					9.8	10.8	10.6	10.1
pH	Std. Units			7.0-10.5		6.37	7.03	7.15	7.12
Dissolved Oxygen	mg/L					6.03	4.79	5.05	3.68
Specific Conductance	µS/cm					119	121	122	125

Notes:

1. MAC is Maximum Acceptable Concentration. Values in excess of MAC are shaded in blue.

2. AO is Aesthetic Objective. Values in excess of AO are shaded in green.

3. OG is Operational Guidance. Values in excess of OG are shaded in orange.

Table 11 Dissolved and total metals in groundwater samples from production well PW1.

Parameter	Unit	Field ID	Aquifer Test	
		Field ID	879-PW1-72 HRS	
		Date	24-May-24	
		Lab ID	ZGG270	
		Type	Total Metals	Dissolved Metals
Aluminum (see Note 1)	µg/L		140	<5
Antimony	µg/L		<1	<1
Arsenic	µg/L		11	10
Barium	µg/L		10	9.5
Beryllium	µg/L		0.22	0.2
Bismuth	µg/L		<2	<2
Boron	µg/L		<50	<50
Cadmium	µg/L		0.012	0.017
Chromium	µg/L		<1.0	<1
Cobalt	µg/L		<0.4	<0.4
Copper	µg/L		2.3	3.0
Iron (see Note 1)	µg/L		140	110
Lead	µg/L		<0.5	0.53
Manganese (see Note 2)	µg/L		34	31
Molybdenum	µg/L		<2	<2
Nickel	µg/L		<2	<2
Phosphorous	µg/L		160	140
Selenium	µg/L		<0.5	<0.5
Silver	µg/L		<0.1	<0.1
Strontium	µg/L		81	73
Thallium	µg/L		<0.1	<0.1
Tin	µg/L		<2	<2
Titanium	µg/L		<2	<2
Uranium	µg/L		4.1	3.4
Vanadium	µg/L		<2	<2
Zinc	µg/L		11	17

Notes:

1. Similar concentrations of total and dissolved metals show that most metal exist in dissolved form and cannot be removed by physical filtration. Aluminum is the exception.

2. MAC is Maximum Acceptable Concentration. Values in excess of MAC are shaded in blue.

3. AO is Aesthetic Objective. Values in excess of AO are shaded in green.

4. OG is Operational Guidance. Values in excess of OG are shaded in orange.

APPENDIX 3

Submission Checklist

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Nova Scotia Environment and Climate Change
Submission Checklist for Hydrogeological Studies

Hydrogeological Study - General Requirements			
Task	**Sub-Task**	**Included in Report**	**Report Page No.**
Site Description	Site Description	Yes	3-1
	Well Field Description	Yes	4-4
	Description of Intended Water Use	Yes	3-3
	Groundwater Withdrawal Details	Yes	3-4
	Description of Existing and Previous Water Withdrawal Approvals	Yes	3-3
Description of Hydrogeology	Regional and Local Hydrogeology and Surface Water Features	Yes	2-1
Pumping Test Information	Pumping Test Analysis	Yes	5-1
	Water Quality Analysis	Yes	6-1
Evaluation of Potential Impacts	Sustainable Yield	Yes	5-7
	Well Interference Effects	Yes	7-1
	Water Quality Effects	Yes	7-2
	Seawater Intrusion	Yes	7-2
	Groundwater-Surface Water Interaction	Yes	7-2
Supporting Figures and Data	Site Location Map and Site Plan	Yes	Appendix 1
	Well Logs	Yes	Appendix 4
	Pumping Test Data and Graphs	Yes	Appendix 6
	Laboratory Reports	Yes	Appendix 7

Notes on General Requirements
Withdrawal Approvals and Hydrogeological Studies are required for groundwater withdrawals greater than 23,000 L/day.
Hydrogeological Studies must be signed by a qualified hydrogeologist.
Reports and data must be submitted in both hard copy and electronic formats.
A 72-hour pumping test and analysis is required for each pumping well included in the application.
Production well(s) must be pump tested at a rate greater than or equal to the requested withdrawal rate.
Well interference effects should be evaluated for wells within 500 m or greater from production well(s).
Seawater intrusion effects should be evaluated if the production well is within 500 m of sea water.
Groundwater-surface water interaction effects should be evaluated if the production well is within 60 m of a surface water body.
Other information may be required for large groundwater supplies. See main text for guide.

APPENDIX 4

Well Logs

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Print | Clear Form

NOVA SCOTIA

Drilled Well Report

NSE Well No. ____________ (Departmental use)

Certified Well Contractor

Name *Arthur Jefferson*

Certificate No. *781*

Company *DJ's Well Drilling*

Address *1508 Palmer Drive, PO Box 385, Kingston, NS, B0P1R0*

Helpers Name(s) *Josh Bohaker*

Well Owner/Contractor Information

Well drilled for: Owner *Ramar Construction Limited PW1*

or Contractor/Builder/Consultant/etc. *Fracflow Consultants*

Civic Address of well *Winslow Drive*

Lot No. and Subdivision of well ____________

County *Halifax* Postal Code ______ Phone ______

Nearest Community in: ☐ NS Atlas ☑ NS Map Book *Upper Tantallon*

Stratigraphic Log

Depth in feet From	To	Colour	General Description of Overburden/Bedrock	Water Found	Well Sketch
0	3	brown	till	N	
3	40	grey	granite	N	
40	400	red &	granite	Y	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	

Attach Another Sheet if Needed

Well Location

Property (PID) ____________

GPS (WGS84 UTM) Northing *4950667* m

Easting *432334* m

☐ NS Atlas ☐ NS Map Book

Page Column Row

Roamer Letter Roamer Number

Well Location Sketch

Well Construction Information

Total depth below surface *400* ft

Depth to bedrock *3* ft

Water bearing fractures encountered *40-400* ft

____ ft ____ ft ____ ft ____ ft

Well Casing

Outer Casing

From *+3* To *37* ft

Diameter *6* in

Wall Thickness *0.188* in

Material: ☑ steel or ______

ASTM spec. *A589*

Inner Casing

From ____ To ____ ft

Diameter ____ in

Wall Thickness ____ in

Material: ☐ steel or ______

ASTM spec. ______

Length of casing above ground *1* ft *6* in

☑ driveshoe: type *heavy rotary*

☑ grout: type *bentonite* ☐ packer: type ______

Well Finish

☑ open hole ☐ slotted casing ☐ screen ☐ gravel pack

Screens: make ______ material ______

length ____ ft from ____ to ____ ft slot size ____

length ____ ft from ____ to ____ ft slot size ____

Gravel pack: size ______ from ____ to ____ ft

Clearance Distance to Nearest

Oil tank *N/A* ft

Roadway outer boundary *>50* ft

Road name *Winslow Drive*

On-site sewage system *N/A* ft

Off-site sewage system *N/A* ft

Cesspool or other potential source of contamination ____ ft (please identify source)

______

Watercourse ____ ft Well ____ ft

Water Yield

Method: ☑ Air blown ☐ Bail ☐ Pump

Rate *5* igpm Duration *1* hrs

Test depth *400* ft

Depth to water at end of test *400* ft

Total drawdown *360* ft

Water level recovered to *40* ft

by *12* hrs ____ mins after test ended.

Depth to static level *40* ft

☐ Overflow

Water Quality

Colour *clear* Taste *none* Odour *none* Other ______

Final Status of Well

☑ Water supply
☐ Observation Well
☐ Test Hole
☐ Recharge Well
☐ Abandoned, insufficient supply
☐ Abandoned, poor quality
☐ Abandoned, salt water
☐ Unfinished
☐ Other ______

Water Use

☑ Domestic
☐ Industrial
☐ Commercial
☐ Municipal
☐ Irrigation
☐ Public Supply
☐ Agricultural
☐ Heat Pump
☐ Other ______

Method of Drilling

☑ Rotary
☐ Cable Tool
☐ Jet
☐ Other ______

☐ Drilling Fluids

Type: ______

Driller's Comments

Well Drilled on Empty Lot

Certification

I certify this well has been constructed in accordance with the *Nova Scotia Environment Act and Well Construction Regulations.*

Date Well completed *02-May-2024*

Signature [redacted]

Date Signed *02-May-2024*

Mail to:

Nova Scotia Department of Environment
30 Damascus Road, Suite 115
Bedford, Nova Scotia B4A 0C1

Important Home Owner's Document - Safeguard with legal documents.
Original to NSE Copy to Customer Copy to Contractor

Rev 08/13

Print Clear Form

NOVA SCOTIA

Drilled Well Report

NSE Well No. ____________ (Departmental use)

Certified Well Contractor

Name *Arthur Jefferson*

Certificate No. *781*

Company *DJ's Well Drilling*

Address *1508 Palmer Drive, PO Box 385, Kingston, NS, B0P1R0*

Helpers Name(s) *Josh Bohaker*

Well Owner/Contractor Information

Well drilled for: Owner *Ramar Construction Limited OW1*

or Contractor/Builder/Consultant/etc. *Fracflow Consultants*

Civic Address of well *Winslow Drive*

Lot No. and Subdivision of well ____________

County *Halifax* Postal Code ________ Phone ________

Nearest Community in: ☐ NS Atlas ☑ NS Map Book *Upper Tantallon*

Stratigraphic Log

Depth in feet From	To	Colour	General Description of Overburden/Bedrock	Water Found	Well Sketch
0	*5*	*brown*	*till & clay*	Y ☑N	
5	*100*	*grey*	*granite*	☑Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	
				Y N	

Attach Another Sheet if Needed

Well Location

Property (PID) ____________

GPS (WGS84 UTM) Northing *4950677* m

Easting *432359* m

☐ NS Atlas ☐ NS Map Book

Page Column Row

Roamer Letter Roamer Number

Well Location Sketch

Well Construction Information

Total depth below surface *100* ft

Depth to bedrock *5* ft

Water bearing fractures encountered *20-100* ft

____ ft ____ ft ____ ft ____ ft

Well Casing

Outer Casing

From *+2* To *18* ft

Diameter *6* in

Wall Thickness *0.188* in

Material: ☑ steel or ________

ASTM spec. *A589*

Inner Casing

From ____ To ____ ft

Diameter ____ in

Wall Thickness ____ in

Material: ☐ steel or ________

ASTM spec. ________

Length of casing above ground *1* ft *6* in

☑ driveshoe: type *heavy rotary*

☑ grout: type *bentonite* ☐ packer: type ________

Well Finish

☑ open hole ☐ slotted casing ☐ screen ☐ gravel pack

Screens: make ________ material ________

length ____ ft from ____ to ____ ft slot size ____

length ____ ft from ____ to ____ ft slot size ____

Gravel pack: size ________ from ____ to ____ ft

Clearance Distance to Nearest

Oil tank *N/A* ft

Roadway outer boundary *>50* ft

Road name *Winslow Drive*

On-site sewage system *N/A* ft

Off-site sewage system *N/A* ft

Cesspool or other potential source of contamination ____ ft (please identify source)

Watercourse ____ ft Well ____ ft

Water Yield

Method: ☑ Air blown ☐ Bail ☐ Pump

Rate *.5* igpm Duration *1* hrs

Test depth *100* ft

Depth to water at end of test *100* ft

Total drawdown *80* ft

Water level recovered to *20* ft

by *12* hrs ____ mins after test ended.

Depth to static level *20* ft

☐ Overflow

Water Quality

Colour *clear* Taste *none* Odour *none* Other ____

Final Status of Well

- ☐ Water supply
- ☑ Observation Well
- ☐ Test Hole
- ☐ Recharge Well
- ☐ Abandoned, insufficient supply
- ☐ Abandoned, poor quality
- ☐ Abandoned, salt water
- ☐ Unfinished
- ☐ Other ____

Water Use

- ☑ Domestic
- ☐ Industrial
- ☐ Commercial
- ☐ Municipal
- ☐ Irrigation
- ☐ Public Supply
- ☐ Agricultural
- ☐ Heat Pump
- ☐ Other ____

Method of Drilling

- ☑ Rotary
- ☐ Cable Tool
- ☐ Jet
- ☐ Other ____
- ☐ Drilling Fluids

Type: ____

Driller's Comments

Well Drilled on Empty Lot

Certification

I certify this well has been constructed in accordance with the *Nova Scotia Environment Act and Well Construction Regulations.*

Date Well completed *03-May-2024*

Signature [redacted]

Date Signed *03-May-2024*

Mail to:

Nova Scotia Department of Environment
30 Damascus Road, Suite 115
Bedford, Nova Scotia B4A 0C1

Important Home Owner's Document - Safeguard with legal documents.

Original to NSE Copy to Customer Copy to Contractor

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Print | Clear Form

NOVA SCOTIA

Drilled Well Report

NSE Well No. ____________ (Departmental use)

Certified Well Contractor

Name: Arthur Jefferson

Certificate No.: 781

Company: DJ's Well Drilling

Address: 1508 Palmer Drive, PO Box 385, Kingston, NS, B0P1R0

Helpers Name(s): Josh Bohaker

Well Owner/Contractor Information

Well drilled for: Owner: Ramar Construction Limited OW2

or Contractor/Builder/Consultant/etc.: Fracflow Consultants

Civic Address of well: Winslow Drive

Lot No. and Subdivision of well: ____________

County: Halifax   Postal Code: ______   Phone: ______

Nearest Community in: ☐ NS Atlas ☑ NS Map Book: Upper Tantallon

Stratigraphic Log

Depth in feet From	To	Colour	General Description of Overburden/Bedrock	Water Found	Well Sketch
0	2	brown	till & rocks	☐ Y ☑ N	
2	100	red &	granite	☑ Y ☐ N	
				☐ Y ☐ N	
				☐ Y ☐ N	
				☐ Y ☐ N	
				☐ Y ☐ N	
				☐ Y ☐ N	
				☐ Y ☐ N	
				☐ Y ☐ N	
				☐ Y ☐ N	
				☐ Y ☐ N	
				☐ Y ☐ N	
				☐ Y ☐ N	

Attach Another Sheet if Needed

Well Location

Property (PID): ____________

GPS (WGS84 UTM) Northing: 4950647 m

Easting: 432344 m

☐ NS Atlas ☐ NS Map Book

Page ____ Column ____ Row ____

Roamer Letter ____ Roamer Number ____

Well Location Sketch

Well Construction Information

Total depth below surface: 100 ft

Depth to bedrock: 2 ft

Water bearing fractures encountered: 20-100 ft

____ ft ____ ft ____ ft ____ ft

Well Casing

Outer Casing

From: +2 To: 18 ft

Diameter: 6 in

Wall Thickness: 0.188 in

Material: ☑ steel or ____________

ASTM spec.: A589

Inner Casing

From: ____ To: ____ ft

Diameter: ____ in

Wall Thickness: ____ in

Material: ☐ steel or ____________

ASTM spec.: ____________

Length of casing above ground: 1 ft 6 in

☑ driveshoe: type: heavy rotary

☑ grout: type: bentonite   ☐ packer: type: ____________

Well Finish

☑ open hole ☐ slotted casing ☐ screen ☐ gravel pack

Screens: make ____________ material ____________

length ____ ft from ____ to ____ ft slot size ____

length ____ ft from ____ to ____ ft slot size ____

Gravel pack: size ____________ from ____ to ____ ft

Clearance Distance to Nearest

Oil tank: N/A ft

Roadway outer boundary: >50 ft

Road name: Winslow Drive

On-site sewage system: N/A ft

Off-site sewage system: N/A ft

Cesspool or other potential source of contamination ____ ft (please identify source) ____________

Watercourse ____ ft   Well ____ ft

Water Yield

Method: ☑ Air blown ☐ Bail ☐ Pump

Rate: .25 igpm   Duration: 1 hrs

Test depth: 100 ft

Depth to water at end of test: 100 ft

Total drawdown: 80 ft

Water level recovered to: 20 ft

by 12 hrs ____ mins after test ended.

Depth to static level: 20 ft

☐ Overflow

Water Quality

Colour: clear   Taste: none   Odour: none   Other: ____

Final Status of Well

- ☐ Water supply
- ☑ Observation Well
- ☐ Test Hole
- ☐ Recharge Well
- ☐ Abandoned, insufficient supply
- ☐ Abandoned, poor quality
- ☐ Abandoned, salt water
- ☐ Unfinished
- ☐ Other ____________

Water Use

- ☑ Domestic
- ☐ Industrial
- ☐ Commercial
- ☐ Municipal
- ☐ Irrigation
- ☐ Public Supply
- ☐ Agricultural
- ☐ Heat Pump
- ☐ Other ____________

Method of Drilling

- ☑ Rotary
- ☐ Cable Tool
- ☐ Jet
- ☐ Other ____________

☐ Drilling Fluids

Type: ____________

Driller's Comments

Well Drilled on Empty Lot

Certification

I certify this well has been constructed in accordance with the *Nova Scotia Environment Act and Well Construction Regulations.*

Date Well completed: 03-May-2024

Signature: [redacted]

Date Signed: 03-May-2024

Mail to:

Nova Scotia Department of Environment
30 Damascus Road, Suite 115
Bedford, Nova Scotia B4A 0C1

Important Home Owner's Document - Safeguard with legal documents.
Original to NSE   Copy to Customer   Copy to Contractor

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APPENDIX 5

Theoretical Concepts

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A5.1 Theoretical Concepts

Step and aquifer test data were analyzed with AquiferTest Version 3.01 software (Waterloo Hydrogeologic, 2001) and used to estimate specific capacity, well efficiency, transmissivity (T), hydraulic conductivity (K) and storativity (S). Each of those theoretical concepts are discussed in some detail below.

A4.1.1 Well Efficiency and Specific Capacity

The purpose of a step-drawdown test is two-fold:

1) Evaluate the efficiency of the test well; and

2) Select the pumping rate for the constant-rate pump test.

Each step of the step-drawdown test was conducted over a period of 60 to 120 minutes, with each step representing a successively higher pumping rate.

Drawdown in a pumping well can be described by Equation 1 below:

$$s = BQ + CQ^2 \qquad \textbf{(1)}$$

where,

s = drawdown,
Q = pumping rate,
B = coefficient for the laminar component of drawdown (intercept), and
C = coefficient for the turbulent component of drawdown (slope).

Well efficiency, E_w, is then defined by Equation 2 below:

$$E_w = \frac{BQ}{BQ + CQ^2}. \qquad \textbf{(2)}$$

The efficiency of the well was analyzed by plotting s/Q versus Q. If a well is 100 percent efficient, which means the water level in the well is equal to the water level in the formation during pumping, then the data points on the plot would define a horizontal line. If an impermeable boundary condition was encountered, or if the well showed decreasing efficiency, then the data points would define a line that was sloping upward. When data points define a line with a negative slope, which is indicative of progressive development, well efficiency cannot be calculated. It is also important to note that the theory of well efficiency was developed with the assumption that flow to the well is laminar (i.e., as would occur in porous media, not fractured rock).

Specific capacity (SC) is the production rate of a well divided by the maximum drawdown observed at the end of each step (S_{max}) and is mathematically expressed by Equation 3:

$$SC = \frac{Q}{S_{max}}. \qquad \textbf{(3)}$$

SC is reported here in units of litres per minute per metre (Lpm/m).

A4.1.2 Transmissivity, Conductivity and Storativity

Data collected during each aquifer test were evaluated using two different analytical methods. AquiferTest software, Version 3.01 (Waterloo Hydrogeologic, 2001) was used to assist with the computations and plotting routines associated with the Theis and Cooper-Jacob methods. Both methods are based on the principles of flow through porous media and one must broadly assume that the hydraulic characteristics of fractured-bedrock aquifers approximate those of porous media if those methods are being applied to a fractured-bedrock aquifer. The proper application of those analytical solutions relies heavily on the expertise of the hydrogeologist to understand the effect of that limiting assumption, as well as other specific assumptions that are inherent to each method.

Three key properties of an aquifer that one attempts to calculate using aquifer test data are transmissivity (T), hydraulic conductivity (K) and storativity (S). K describes the ease through which water can move through pores spaces or fractures, and in this report K is expressed in units of metres per second (m/s). T is a measure of how much water can be transmitted horizontally through an aquifer and is defined as K multiplied by the aquifer thickness, b, and is expressed in this report in units of square metres per second (m^2/s). S is the Storativity of an aquifer and it is a dimensionless parameter than relates to the volume of water that can be released from storage, per unit surface area, per unit change in hydraulic head. Values of S for confined aquifers are usually 0.005 or less, while the value of S for unconfined aquifers ranges from 0.02 to 0.3 (Fetter, 1980). Calculation of S requires that drawdown data from an observation well be used.

Theis Method (Confined Aquifer): Field measurements are plotted as log-log values for time divided by the radius of the pumping well (t/r^2) on the X-axis versus drawdown (s) on the Y-axis. Plotted data are compared to the standard Theis curve which is a theoretical relationship in log-log space for values of 1/*u* on the X-axis versus W(*u*) on the Y-axis where *u* is a calculated value and W(*u*) is the integral of the dimensionless parameter, *u*. The following equation is used to calculate *u*:

$$u = r^2S/4Tt \qquad \textbf{(4)}$$

where r is the radius of the pumping well, S is storativity, T is transmissivity, and t is time. The assumptions are that the aquifer is confined and of infinite extent, the aquifer is also homogeneous, isotropic and of uniform thickness. It is also assumed that the well is fully penetrating and pumped at a constant rate and that well storage is small.

Cooper-Jacob Time-Drawdown Method (Confined Aquifer): This is a simplification of the Theis Method. Field measurements are plotted in semi-log space with time on the X-axis and drawdown on the Y-axis. The same assumptions described above for the Theis Method are applicable here. The equations for T and S are as follows:

$$T = 2.3Q/4\pi\Delta s \qquad \textbf{(5)}$$

where Q = rate of discharge from the pumping well and Δs is the change in drawdown over one log cycle;

$$S = 2.25Tt_o/r^2 \qquad \textbf{(6)}$$

where t_o is the time at which the straight-line fit intersects the time axis. Again, as with the Theis analysis, the calculation of S requires that drawdown data from an observation well is used.

A4.1.3 Sustainable Well Yield

There are two methods available that are often used to estimate safe or sustainable yield of an aquifer. The first is the specific capacity (SC) method or Q_{safe}. The other is the Q_{20} method. Both methods were developed based on groundwater flow theories in porous media and were never intended for application to fractured-bedrock aquifers. The results from those calculations are not definitive and need to be interpreted with caution.

The following formula is used to calculate $Q_{safe:}$

$$Q_{safe} = SC \times \text{Useable Drawdown} \qquad \textbf{(7)}$$

The specific capacity is calculated as follows:

$$SC = Q_{test} / S_{max} \qquad \textbf{(8)}$$

where, Q_{test} is the pumping rate used during the aquifer test and S_{max} is the maximum drawdown observed in the pumping well during the aquifer test.

Using the Q_{20} method (NSE, 2011b), the safe yield is calculated as follows:

$$Q_{20} = (0.683 \times T) \times H \times S_f \qquad \textbf{(9)}$$

where, T is the transmissivity of the well, H is the useable drawdown in the well, and S_f is the factor of safety, which is normally set at 0.7. This is considered to be a relatively conservative method of calculating the long-term safe yield of a well constructed in porous media.

APPENDIX 6

AquiferTest Analysis Reports

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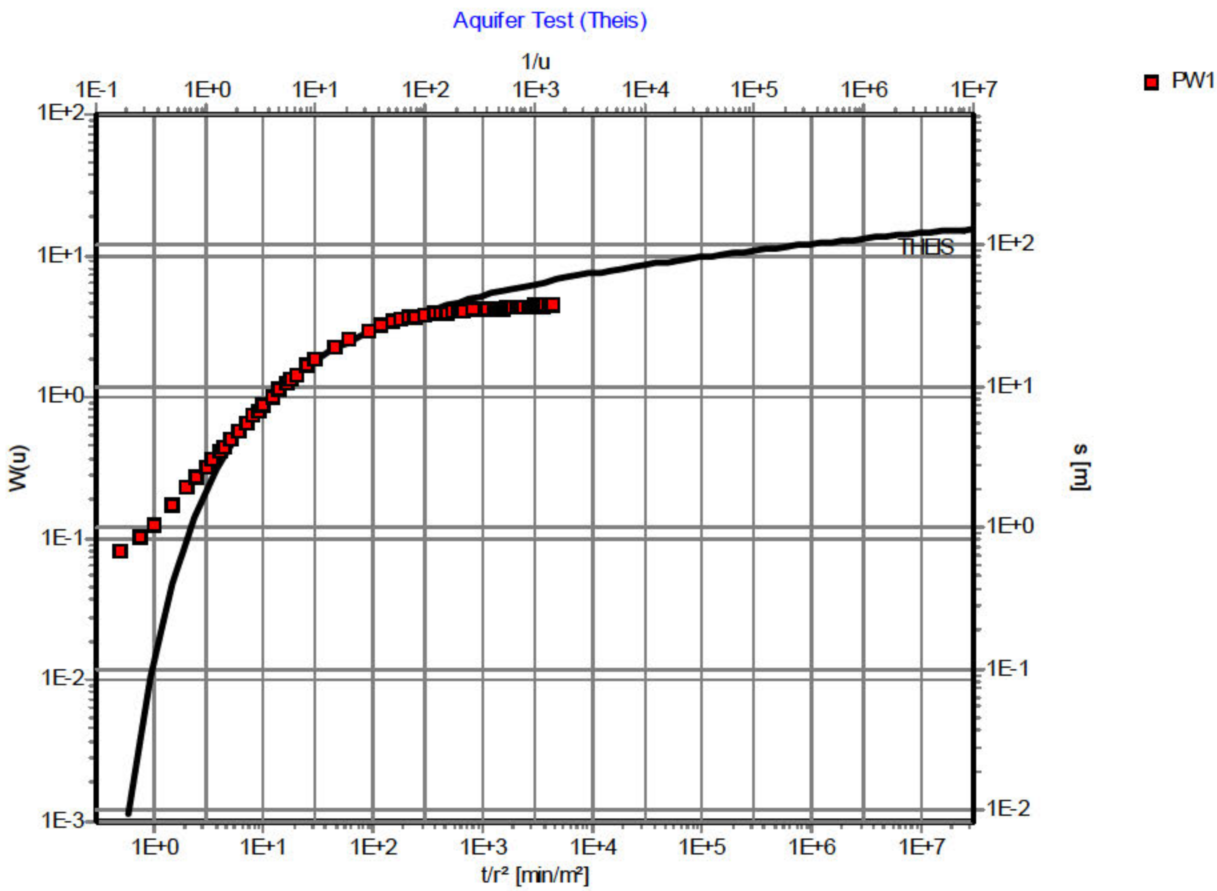
Fracflow Consultants Inc.
2 Fielding Avenue, Suite D
Dartmouth, NS B3B 1E1
Tel: (902) 468-1317; Fax: (902) 468-4704

Analysis Report	
Project:	Winslow Drive
No:	879
Client:	Ramar Developments Limited

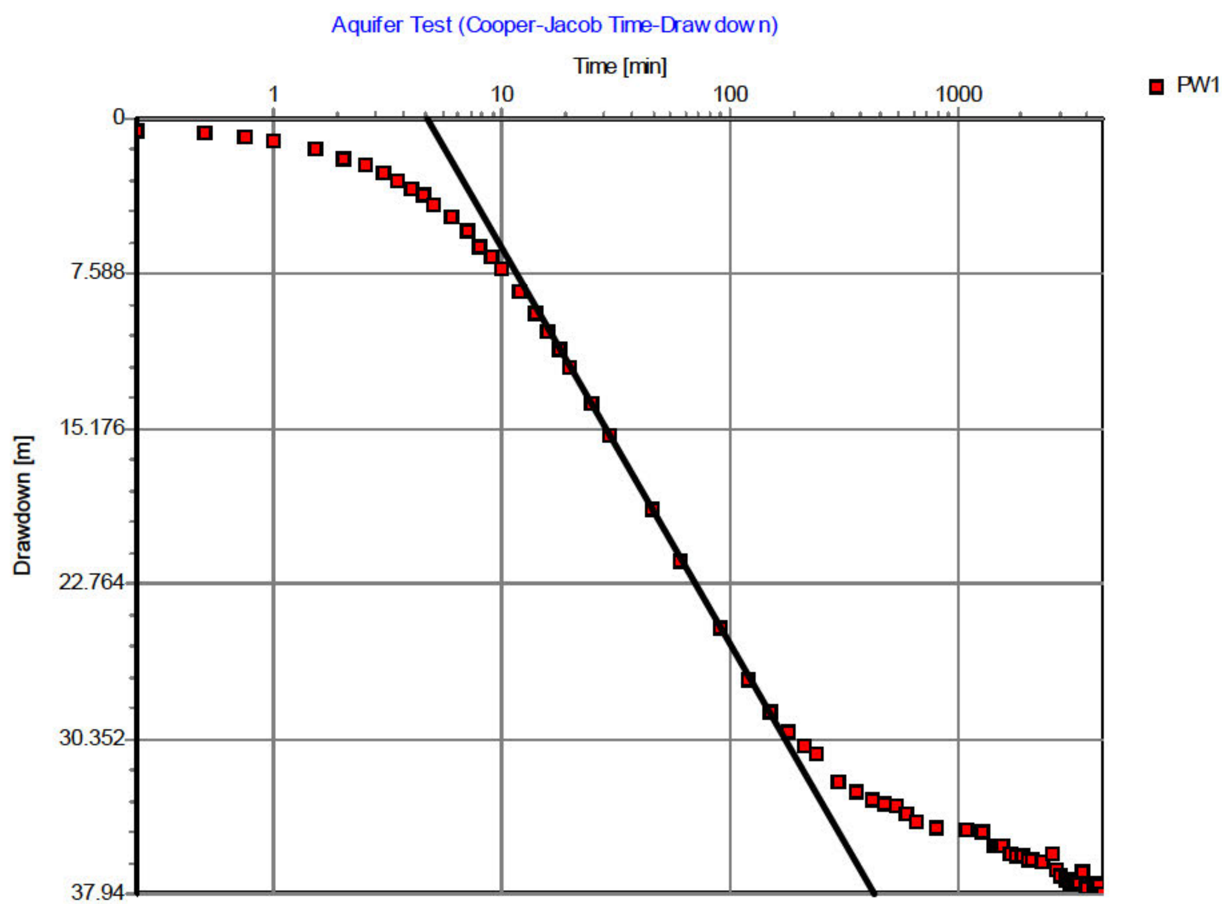


Test name:	**Aquifer Test**			
Analysis method:	**Theis**			
Analysis results:	Transmissivity:	3.26E-6 [m²/s]	Conductivity:	3.27E-5 [m/s]
	Storativity:	2.35E-3		
Test parameters:	Pumping well:	PW1	Aquifer thickness:	0.09991 [m]
	Screen radius:	0.076 [m]	Confined aquifer	
	Screen length:	110.6 [m]		
	Casing radius:	0.076 [m]		
	Discharge rate:	0.000342 [m³/s]		

Comments:

Evaluated by: Fracflow
Date: 6/1/2024

Fracflow Consultants Inc. 2 Fielding Avenue, Suite D Dartmouth, NS B3B 1E1 Tel: (902) 468-1317; Fax: (902) 468-4704	**Analysis Report** Project: Winslow Drive No: 879 Client: Ramar Developments Limited



Test name: **Aquifer Test**

Analysis method: **Cooper-Jacob Time-Drawdown**

Analysis results:	Transmissivity:	3.23E-6 [m²/s]	Conductivity:	3.24E-5 [m/s]
Test parameters:	Pumping well:	PW1	Aquifer thickness:	0.09991 [m]
	Screen radius:	0.076 [m]	Confined aquifer	
	Screen length:	110.6 [m]		
	Casing radius:	0.076 [m]		
	Discharge rate:	0.000342 [m³/s]		

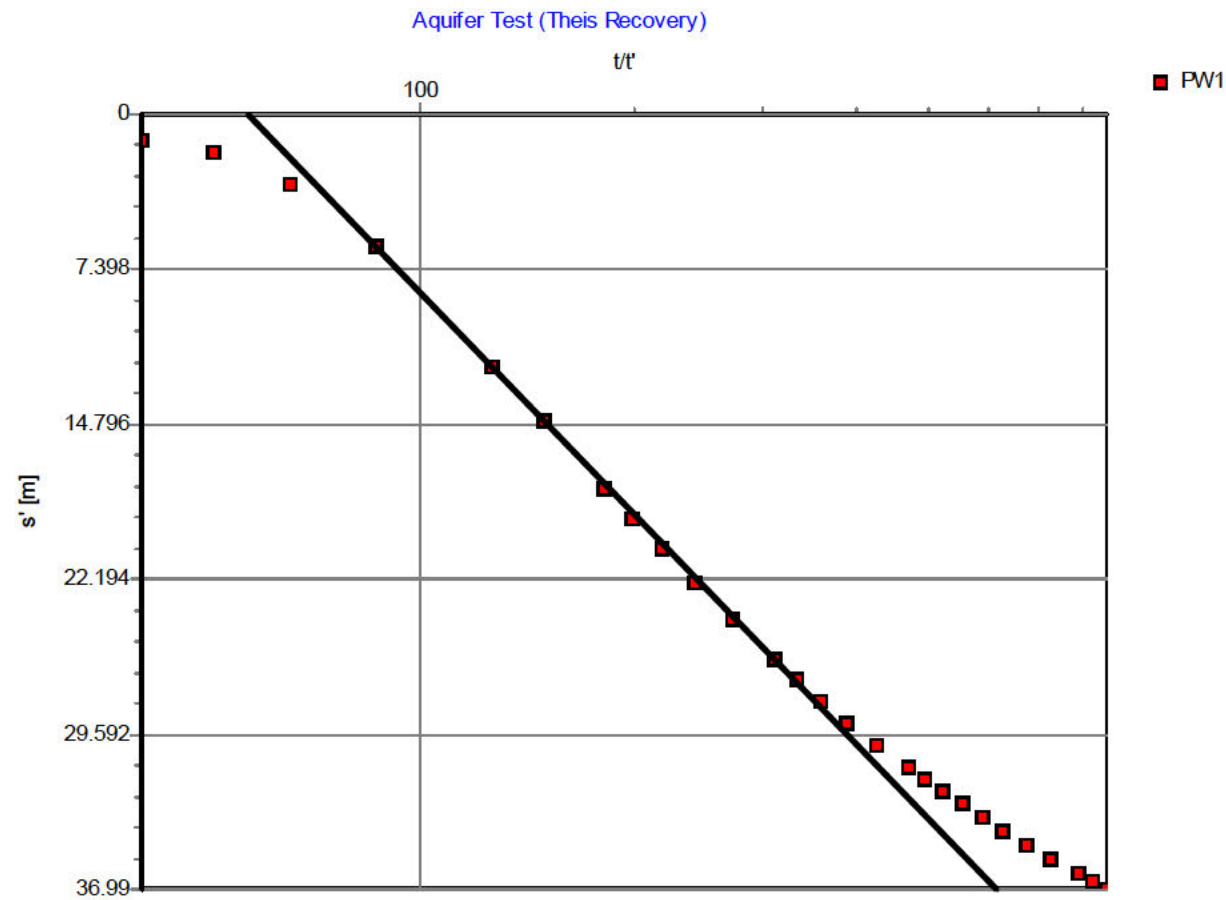
Comments:

Evaluated by:

Date: 6/1/2024

Fracflow Consultants Inc.
2 Fielding Avenue, Suite D
Dartmouth, NS B3B 1E1
Tel: (902) 468-1317; Fax: (902) 468-4704

Analysis Report	
Project:	Winslow Drive
No:	879
Client:	Ramar Developments Limited



Test name: **Aquifer Test**

Analysis method: **Theis Recovery**

Analysis results:	Transmissivity:	1.66E-6 [m²/s]	Conductivity:	1.66E-5 [m/s]

Test parameters:	Pumping well:	PW1	Aquifer thickness:	0.09991 [m]
	Screen radius:	0.076 [m]	Confined aquifer	
	Screen length:	110.6 [m]		
	Casing radius:	0.076 [m]		
	Discharge rate:	0.000342 [m³/s]		
	Pump Time	4320 [min]		

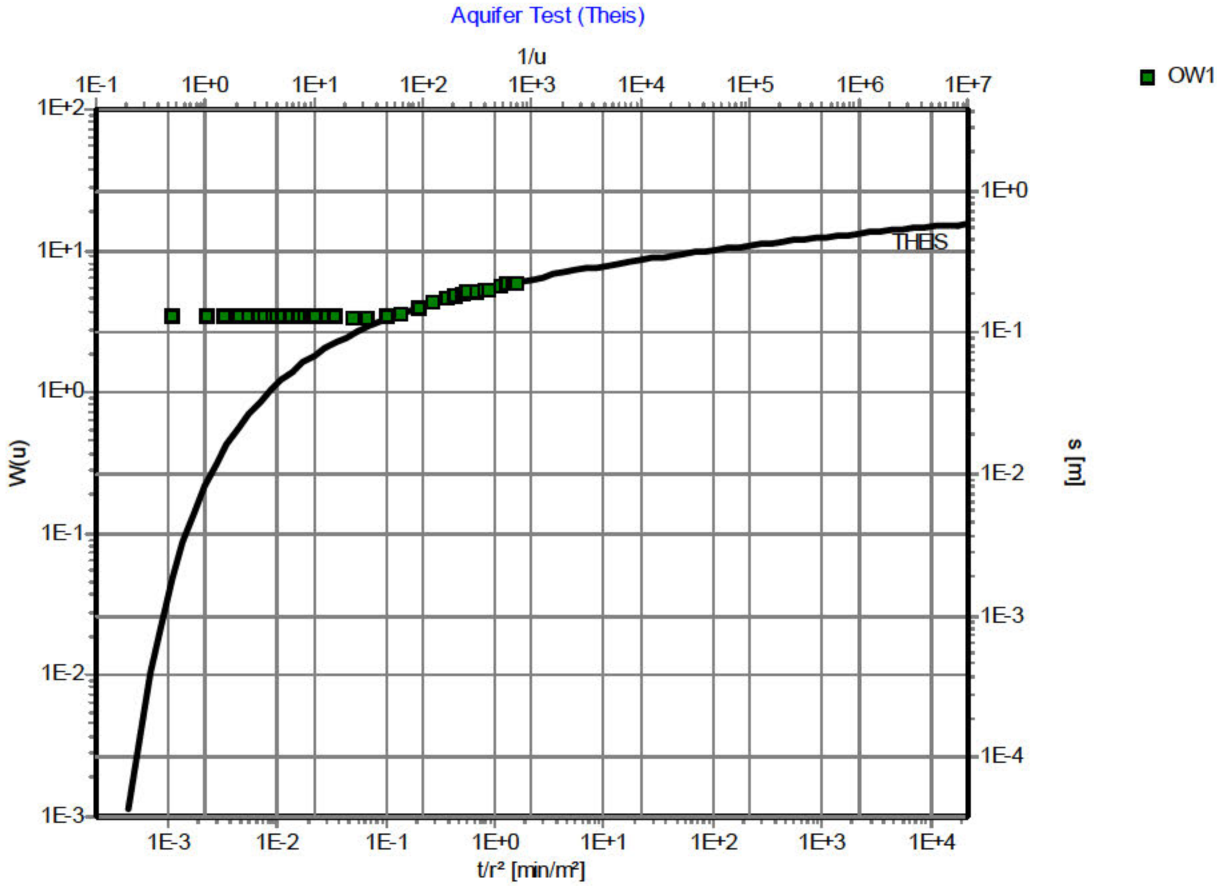
Comments:

Evaluated by:

Date: 6/1/2024

Fracflow Consultants Inc.
2 Fielding Avenue, Suite D
Dartmouth, NS B3B 1E1
Tel: (902) 468-1317; Fax: (902) 468-4704

Analysis Report	
Project:	Winslow Drive
No:	879
Client:	Ramar Developments Limited



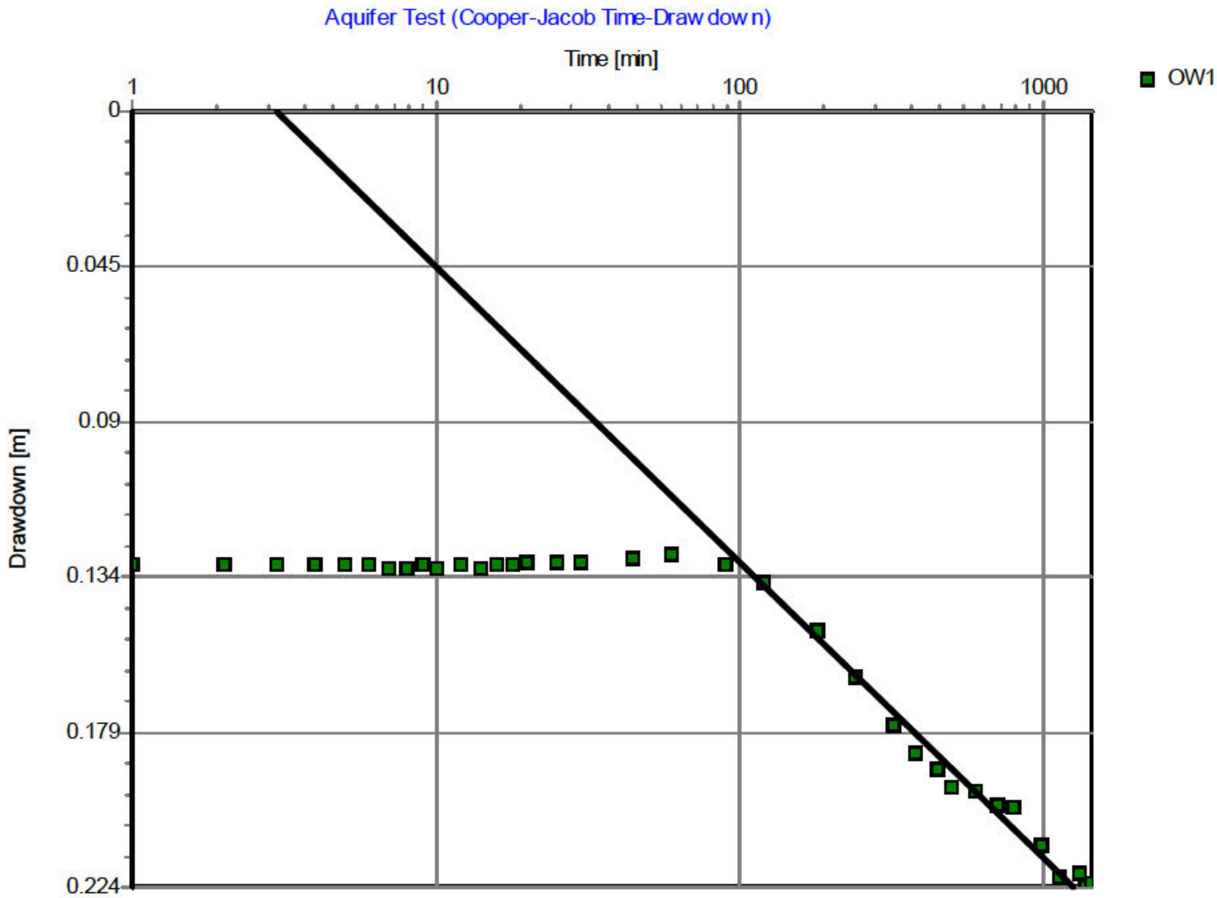
Test name:	**Aquifer Test**			
Analysis method:	**Theis**			
Analysis results:	Transmissivity:	7.18E-4 [m²/s]	Conductivity:	7.18E-3 [m/s]
	Storativity:	3.75E-4		
Test parameters:	Pumping well:	PW1	Aquifer thickness:	0.09991 [m]
	Screen radius:	0.076 [m]	Confined aquifer	
	Screen length:	110.6 [m]		
	Casing radius:	0.076 [m]		
	Discharge rate:	0.000342 [m³/s]		

Comments:

Evaluated by:
Date: 6/1/2024

Fracflow Consultants Inc.
2 Fielding Avenue, Suite D
Dartmouth, NS B3B 1E1
Tel: (902) 468-1317; Fax: (902) 468-4704

Analysis Report	
Project:	Winslow Drive
No:	879
Client:	Ramar Developments Limited



Test name: **Aquifer Test**

Analysis method: **Cooper-Jacob Time-Drawdown**

Analysis results:	Transmissivity:	7.34E-4 [m²/s]	Conductivity:	7.35E-3 [m/s]

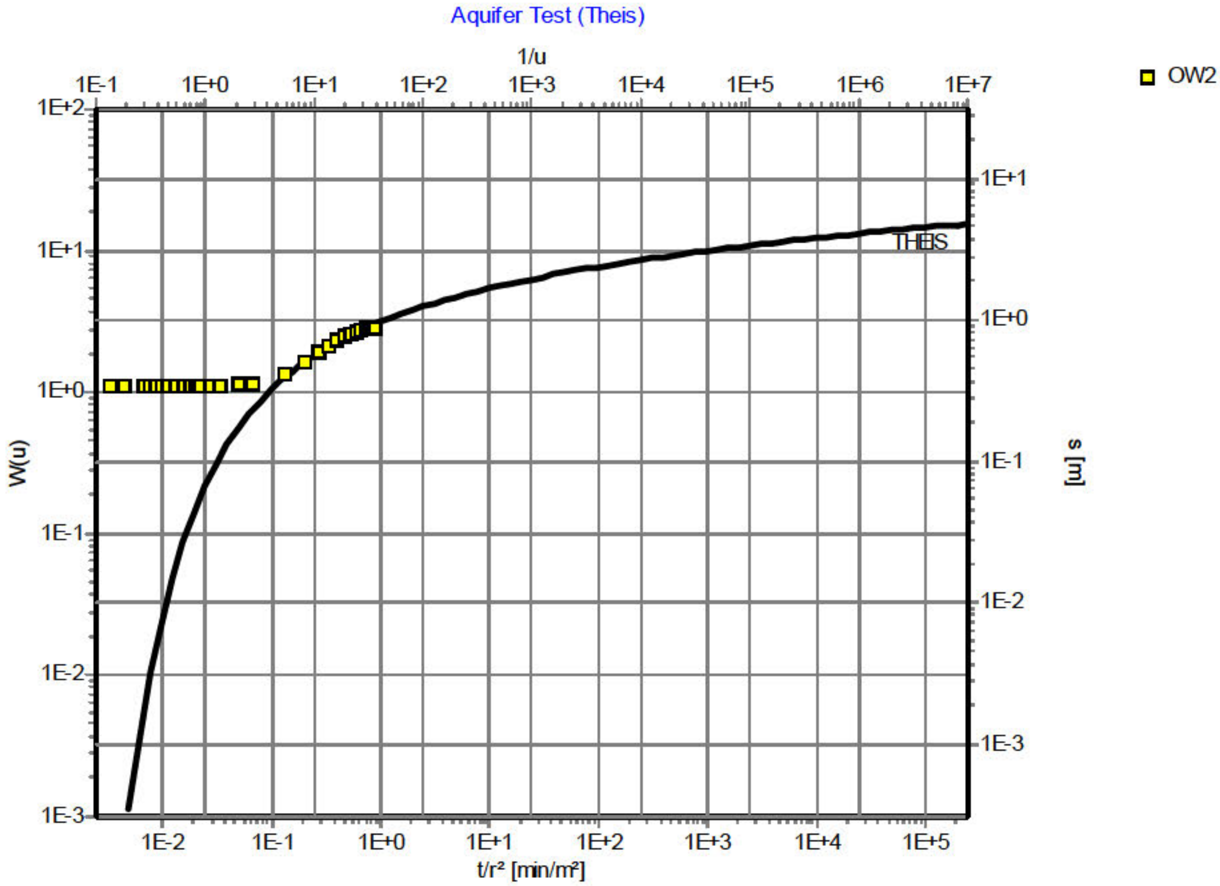
Test parameters:	Pumping well:	PW1	Aquifer thickness:	0.09991 [m]
	Screen radius:	0.076 [m]	Confined aquifer	
	Screen length:	110.6 [m]		
	Casing radius:	0.076 [m]		
	Discharge rate:	0.000342 [m³/s]		

Comments:

Evaluated by: Fracflow
Date: 6/1/2024

Fracflow Consultants Inc.
2 Fielding Avenue, Suite D
Dartmouth, NS B3B 1E1
Tel: (902) 468-1317; Fax: (902) 468-4704

Analysis Report	
Project:	Winslow Drive
No:	879
Client:	Ramar Developments Limited



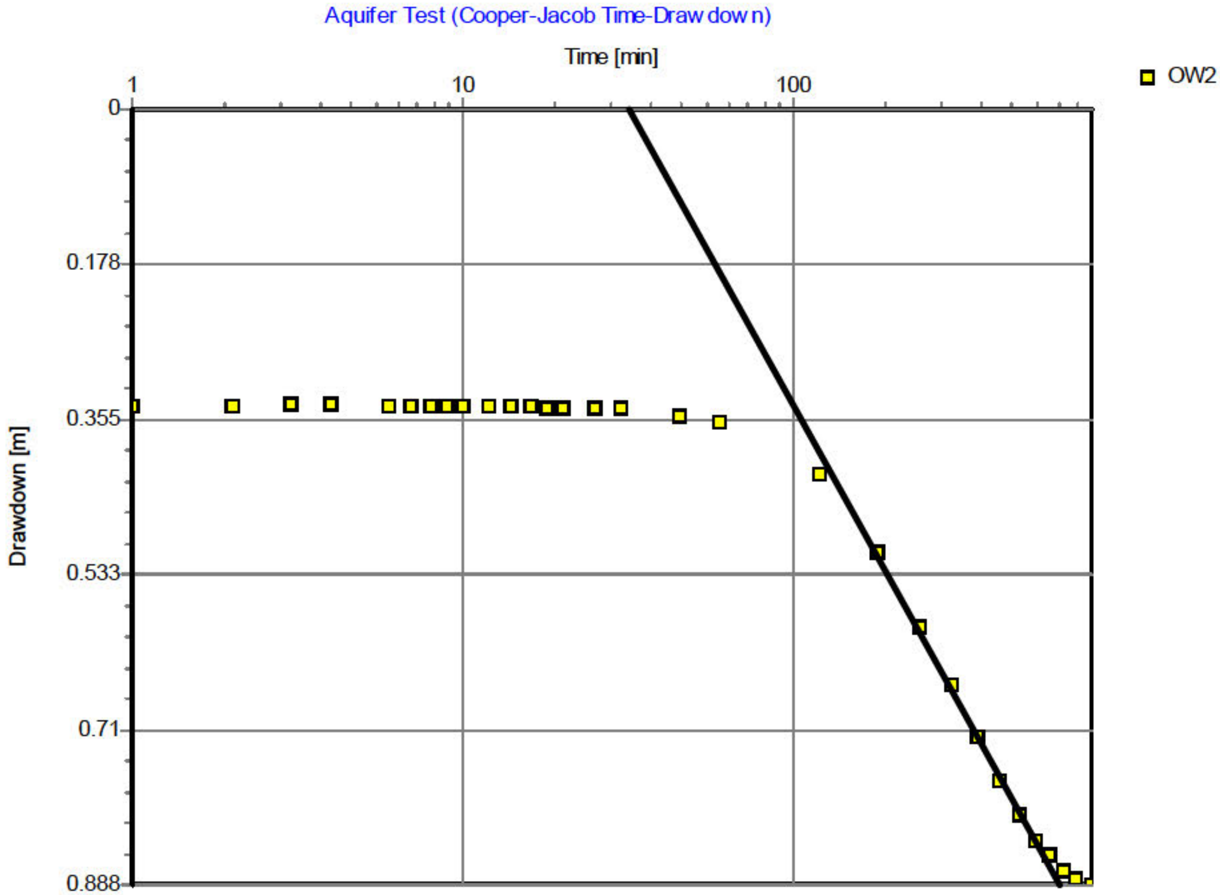
Test name:	**Aquifer Test**			
Analysis method:	**Theis**			
Analysis results:	Transmissivity:	8.83E-5 [m²/s]	Conductivity:	8.84E-4 [m/s]
	Storativity:	5.18E-4		
Test parameters:	Pumping well:	PW1	Aquifer thickness:	0.09991 [m]
	Screen radius:	0.076 [m]	Confined aquifer	
	Screen length:	110.6 [m]		
	Casing radius:	0.076 [m]		
	Discharge rate:	0.000342 [m³/s]		

Comments:

Evaluated by: Fracflow
Date: 6/1/2024

Fracflow Consultants Inc.
2 Fielding Avenue, Suite D
Dartmouth, NS B3B 1E1
Tel: (902) 468-1317; Fax: (902) 468-4704

Analysis Report	
Project:	Winslow Drive
No:	879
Client:	Ramar Developments Limited



Test name: **Aquifer Test**

Analysis method: **Cooper-Jacob Time-Drawdown**

Analysis results:	Transmissivity:	9.19E-5 [m²/s]	Conductivity:	9.19E-4 [m/s]

Test parameters:				
	Pumping well:	PW1	Aquifer thickness:	0.09991 [m]
	Screen radius:	0.076 [m]	Confined aquifer	
	Screen length:	110.6 [m]		
	Casing radius:	0.076 [m]		
	Discharge rate:	0.000342 [m³/s]		

Comments:

Evaluated by: Fracflow
Date: 6/1/2024

APPENDIX 7

Analytical Reports

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Your P.O. #: NS2326
Your Project #: 879
Site Location: WINSLOW
Your C.O.C. #: C#991512-01-01

Attention: Glenn Bursey

Fracflow Consultants Inc
2 Fielding Ave
Suite D
Dartmouth, NS
CANADA B3B 1E1

Report Date: 2024/06/03
Report #: R8174604
Version: 2 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C4F3545
Received: 2024/05/23, 10:14

Sample Matrix: Ground Water
Samples Received: 3

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Carbonate, Bicarbonate and Hydroxide	2	N/A	2024/05/28	N/A	SM 24 4500-CO2 D
Alkalinity	2	N/A	2024/05/27	ATL SOP 00142	SM 24 2320 B
Chloride	2	N/A	2024/05/28	ATL SOP 00014	SM 24 4500-Cl- E m
Coliform MTM in Liquid (MPN/100mL)	1	N/A	2024/05/23	ATL SOP 00067	SM24 9221 A-C m
Colour	2	N/A	2024/05/28	ATL SOP 00020	SM 24 2120C m
Conductance - water	2	N/A	2024/05/27	ATL SOP 00004	SM 24 2510B m
Hardness (calculated as CaCO3)	2	N/A	2024/05/29	ATL SOP 00048	Auto Calc
Metals Water Total MS	2	2024/05/28	2024/05/28	ATL SOP 00058	EPA 6020B R2 m
Ion Balance (% Difference)	2	N/A	2024/05/29	N/A	Auto Calc.
Anion and Cation Sum	2	N/A	2024/05/29	N/A	Auto Calc.
Nitrogen Ammonia - water	2	N/A	2024/05/27	ATL SOP 00015	EPA 350.1 R2 m
Nitrogen - Nitrate + Nitrite	2	N/A	2024/05/28	ATL SOP 00016	USGS I-2547-11m
Nitrogen - Nitrite	2	N/A	2024/05/28	ATL SOP 00017	SM 24 4500-NO2- B m
Nitrogen - Nitrate (as N)	2	N/A	2024/05/28	ATL SOP 00018	ASTM D3867-16
pH (1)	2	N/A	2024/05/27	ATL SOP 00003	SM 24 4500-H+ B m
Phosphorus - ortho	2	N/A	2024/05/28	ATL SOP 00021	SM 24 4500-P E m
Sat. pH and Langelier Index (@ 20C)	2	N/A	2024/05/29	ATL SOP 00049	Auto Calc.
Sat. pH and Langelier Index (@ 4C)	2	N/A	2024/05/29	ATL SOP 00049	Auto Calc.
Reactive Silica	2	N/A	2024/05/28	ATL SOP 00022	EPA 366.0 m
Sulphate	2	N/A	2024/05/28	ATL SOP 00023	ASTM D516-16 m
Total Dissolved Solids (TDS calc)	2	N/A	2024/05/29	N/A	Auto Calc.
Organic carbon - Total (TOC) (2)	2	N/A	2024/05/27	ATL SOP 00203	SM 24 5310B m
Turbidity	2	N/A	2024/05/28	ATL SOP 00011	EPA 180.1 R2 m

Remarks:

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

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas 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

Your P.O. #: NS2326
Your Project #: 879
Site Location: WINSLOW
Your C.O.C. #: C#991512-01-01

Attention: Glenn Bursey

Fracflow Consultants Inc
2 Fielding Ave
Suite D
Dartmouth, NS
CANADA B3B 1E1

Report Date: 2024/06/03
Report #: R8174604
Version: 2 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C4F3545
Received: 2024/05/23, 10:14

Uncertainty has not been accounted for when stating conformity to the referenced standard.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas 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 Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas 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 Bureau Veritas, 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.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) The APHA Standard Method requires pH to be analyzed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the APHA Standard Method holding time.
(2) TOC / DOC present in the sample should be considered as non-purgeable TOC / DOC.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to:
Cynthia Kendall MacKenzie, M.Sc., Project Manager 2
Email:
Phone# (902)420-0203
==
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Bureau Veritas Job #: C4F3545
Report Date: 2024/06/03

Fracflow Consultants Inc
Client Project #: 879
Site Location: WINSLOW
Your P.O. #: NS2326
Sampler Initials: GB

RESULTS OF ANALYSES OF GROUND WATER

Bureau Veritas ID		ZFV108	ZFV110	
Sampling Date		2024/05/21 10:00	2024/05/22 10:00	
COC Number		C#991512-01-01	C#991512-01-01	
	UNITS	**879-PW1-1HR**	**879-PW1-24HR**	**RDL**
Calculated Parameters				
Anion Sum	me/L	1.13	1.14	N/A
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	22	25	1.0
Calculated TDS	mg/L	91	92	1.0
Carb. Alkalinity (calc. as CaCO3)	mg/L	<1.0	<1.0	1.0
Cation Sum	me/L	1.35	1.29	N/A
Hardness (CaCO3)	mg/L	21	23	1.0
Ion Balance (% Difference)	%	8.87	6.17	N/A
Langelier Index (@ 20C)	N/A	-2.32	-2.12	
Langelier Index (@ 4C)	N/A	-2.57	-2.38	
Nitrate (N)	mg/L	0.12	0.080	0.050
Saturation pH (@ 20C)	N/A	9.24	9.10	
Saturation pH (@ 4C)	N/A	9.49	9.35	
Inorganics				
Total Alkalinity (Total as CaCO3)	mg/L	22	25	2.0
Dissolved Chloride (Cl-)	mg/L	19	17	1.0
Colour	TCU	<5.0	<5.0	5.0
Nitrate + Nitrite (N)	mg/L	0.12	0.080	0.050
Nitrite (N)	mg/L	<0.010	<0.010	0.010
Nitrogen (Ammonia Nitrogen)	mg/L	<0.050	<0.050	0.050
Total Organic Carbon (C)	mg/L	<0.50	<0.50	0.50
Orthophosphate (P)	mg/L	0.073	0.12	0.010
pH	pH	6.93	6.98	
Reactive Silica (SiO2)	mg/L	21	24	1.0
Dissolved Sulphate (SO4)	mg/L	7.7	7.6	2.0
Turbidity	NTU	16	3.4	0.10
Conductivity	uS/cm	150	150	1.0

RDL = Reportable Detection Limit
N/A = Not Applicable

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Bureau Veritas Job #: C4F3545
Report Date: 2024/06/03

Fracflow Consultants Inc
Client Project #: 879
Site Location: WINSLOW
Your P.O. #: NS2326
Sampler Initials: GB

ELEMENTS BY ICP/MS (GROUND WATER)

Bureau Veritas ID		ZFV108	ZFV110	
Sampling Date		2024/05/21 10:00	2024/05/22 10:00	
COC Number		C#991512-01-01	C#991512-01-01	
	UNITS	**879-PW1-1HR**	**879-PW1-24HR**	**RDL**
Metals				
Total Aluminum (Al)	ug/L	1700	220	5.0
Total Antimony (Sb)	ug/L	<1.0	<1.0	1.0
Total Arsenic (As)	ug/L	20	11	1.0
Total Barium (Ba)	ug/L	9.5	10	1.0
Total Beryllium (Be)	ug/L	0.60	0.25	0.10
Total Bismuth (Bi)	ug/L	<2.0	<2.0	2.0
Total Boron (B)	ug/L	<50	<50	50
Total Cadmium (Cd)	ug/L	0.090	0.014	0.010
Total Calcium (Ca)	ug/L	5700	6800	100
Total Chromium (Cr)	ug/L	<1.0	<1.0	1.0
Total Cobalt (Co)	ug/L	0.97	<0.40	0.40
Total Copper (Cu)	ug/L	19	3.1	0.50
Total Iron (Fe)	ug/L	850	200	50
Total Lead (Pb)	ug/L	3.0	0.61	0.50
Total Magnesium (Mg)	ug/L	1500	1500	100
Total Manganese (Mn)	ug/L	38	32	2.0
Total Molybdenum (Mo)	ug/L	<2.0	<2.0	2.0
Total Nickel (Ni)	ug/L	2.6	<2.0	2.0
Total Phosphorus (P)	ug/L	150	150	100
Total Potassium (K)	ug/L	1900	1400	100
Total Selenium (Se)	ug/L	<0.50	<0.50	0.50
Total Silver (Ag)	ug/L	<0.10	<0.10	0.10
Total Sodium (Na)	ug/L	20000	18000	100
Total Strontium (Sr)	ug/L	63	79	2.0
Total Thallium (Tl)	ug/L	<0.10	<0.10	0.10
Total Tin (Sn)	ug/L	<2.0	<2.0	2.0
Total Titanium (Ti)	ug/L	5.3	<2.0	2.0
Total Uranium (U)	ug/L	12	5.1	0.10
Total Vanadium (V)	ug/L	<2.0	<2.0	2.0
Total Zinc (Zn)	ug/L	99	12	5.0
RDL = Reportable Detection Limit				

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Bureau Veritas Job #: C4F3545
Report Date: 2024/06/03

Fracflow Consultants Inc
Client Project #: 879
Site Location: WINSLOW
Your P.O. #: NS2326
Sampler Initials: GB

MICROBIOLOGY (GROUND WATER)

Bureau Veritas ID		ZFV111	
Sampling Date		2024/05/23 10:00	
COC Number		C#991512-01-01	
	UNITS	**879-PW1-48HR**	**RDL**
Microbiological			
Total Coliforms	MPN/100mL	<2.0	2.0
Fecal coliform	MPN/100mL	<2.0	2.0
Escherichia coli	MPN/100mL	<2.0	2.0
RDL = Reportable Detection Limit			

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GENERAL COMMENTS

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

Package 1	7.7°C

Sample ZFV108 [879-PW1-1HR] : Poor RCAp Ion Balance due to sample matrix.

Sample ZFV110 [879-PW1-24HR] : RCAp Ion Balance acceptable. Anion/cation agreement within 0.2 meq/L.

Results relate only to the items tested.

Bureau Veritas Job #: C4F3545
Report Date: 2024/06/03

Fracflow Consultants Inc
Client Project #: 879
Site Location: WINSLOW
Your P.O. #: NS2326
Sampler Initials: GB

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

[redacted]

Janah Rhyno, Scientific Specialist

[redacted]

Jason Wang, Microbiology Supervisor

[redacted]

Automated Statchk

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Your P.O. #: NS2326
Your Project #: 879
Site Location: WINSLOW
Your C.O.C. #: N/A

Attention: Glenn Bursey

Fracflow Consultants Inc
2 Fielding Ave
Suite D
Dartmouth, NS
CANADA B3B 1E1

Report Date: 2024/06/12
Report #: R8187731
Version: 3 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C4F5623
Received: 2024/05/24, 13:40

Sample Matrix: Ground Water
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Carbonate, Bicarbonate and Hydroxide	1	N/A	2024/06/03	N/A	SM 24 4500-CO2 D
Alkalinity	1	N/A	2024/05/31	ATL SOP 00142	SM 24 2320 B
Chloride	1	N/A	2024/05/30	ATL SOP 00014	SM 24 4500-Cl- E m
Colour	1	N/A	2024/05/31	ATL SOP 00020	SM 24 2120C m
Conductance - water	1	N/A	2024/05/31	ATL SOP 00004	SM 24 2510B m
Fluoride	1	N/A	2024/06/03	ATL SOP 00043	SM 24 4500-F- C m
Hardness (calculated as CaCO3)	1	N/A	2024/05/30	ATL SOP 00048	Auto Calc
Metals Water Diss. MS (as rec'd)	1	N/A	2024/05/29	ATL SOP 00058	EPA 6020B R2 m
Metals Water Total MS	1	2024/05/29	2024/05/29	ATL SOP 00058	EPA 6020B R2 m
Ion Balance (% Difference)	1	N/A	2024/06/03	N/A	Auto Calc.
Anion and Cation Sum	1	N/A	2024/06/03	N/A	Auto Calc.
Nitrogen Ammonia - water	1	N/A	2024/05/28	ATL SOP 00015	EPA 350.1 R2 m
Nitrogen - Nitrate + Nitrite	1	N/A	2024/05/31	ATL SOP 00016	USGS I-2547-11m
Nitrogen - Nitrite	1	N/A	2024/05/30	ATL SOP 00017	SM 24 4500-NO2- B m
Nitrogen - Nitrate (as N)	1	N/A	2024/05/31	ATL SOP 00018	ASTM D3867-16
pH (2)	1	N/A	2024/05/31	ATL SOP 00003	SM 24 4500-H+ B m
Phosphorus - ortho	1	N/A	2024/05/30	ATL SOP 00021	SM 24 4500-P E m
Lead 210 (1)	1	N/A	2024/06/11	BQL SOP-00008	GFPC
Radon-222 (1, 3)	1	N/A	2024/05/30	BQL SOP-00007	Gamma Spectrometry
Sat. pH and Langelier Index (@ 20C)	1	N/A	2024/06/03	ATL SOP 00049	Auto Calc.
Sat. pH and Langelier Index (@ 4C)	1	N/A	2024/06/03	ATL SOP 00049	Auto Calc.
Reactive Silica	1	N/A	2024/05/30	ATL SOP 00022	EPA 366.0 m
Sulphate	1	N/A	2024/05/30	ATL SOP 00023	ASTM D516-16 m
Total Dissolved Solids (TDS calc)	1	N/A	2024/06/03	N/A	Auto Calc.
Organic carbon - Total (TOC) (4)	1	N/A	2024/05/29	ATL SOP 00203	SM 24 5310B m
Turbidity	1	N/A	2024/05/31	ATL SOP 00011	EPA 180.1 R2 m

Remarks:

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Your P.O. #: NS2326
Your Project #: 879
Site Location: WINSLOW
Your C.O.C. #: N/A

Attention: Glenn Bursey

Fracflow Consultants Inc
2 Fielding Ave
Suite D
Dartmouth, NS
CANADA B3B 1E1

Report Date: 2024/06/12
Report #: R8187731
Version: 3 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C4F5623
Received: 2024/05/24, 13:40

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas 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 accounted for when stating conformity to the referenced standard.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas 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 Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas 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 Bureau Veritas, results relate to the supplied samples tested.
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Reference Method suffix “m” indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) This test was performed by Bureau Veritas Kitimat, 6790 Kitimat Road, Unit 4 , Mississauga, ON, L5N 5L9
(2) The APHA Standard Method requires pH to be analyzed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the APHA Standard Method holding time.
(3) These results have been corrected to show the Radon concentration at the time of sampling.
(4) TOC / DOC present in the sample should be considered as non-purgeable TOC / DOC.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to:
Maryann Comeau, Customer Experience Supervisor/PM
Email: Maryann.COMEAU@bureauveritas.com
Phone# (902)420-0203 Ext:298
==
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Bureau Veritas Job #: C4F5623
Report Date: 2024/06/12

Fracflow Consultants Inc
Client Project #: 879
Site Location: WINSLOW
Your P.O. #: NS2326
Sampler Initials: GB

RESULTS OF ANALYSES OF GROUND WATER

Bureau Veritas ID		ZGG270	
Sampling Date		2024/05/24 10:00	
COC Number		N/A	
	UNITS	**879-PWL-72HR**	**RDL**
RADIONUCLIDE			
Radon-222	Bq/L	3610	10
Calculated Parameters			
Anion Sum	me/L	1.26	N/A
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	26	1.0
Calculated TDS	mg/L	95	1.0
Carb. Alkalinity (calc. as CaCO3)	mg/L	<1.0	1.0
Cation Sum	me/L	1.23	N/A
Hardness (CaCO3)	mg/L	23	1.0
Ion Balance (% Difference)	%	1.20	N/A
Langelier Index (@ 20C)	N/A	-1.93	
Langelier Index (@ 4C)	N/A	-2.18	
Nitrate (N)	mg/L	0.077	0.050
Saturation pH (@ 20C)	N/A	9.10	
Saturation pH (@ 4C)	N/A	9.35	
Inorganics			
Total Alkalinity (Total as CaCO3)	mg/L	26	2.0
Dissolved Chloride (Cl-)	mg/L	19	1.0
Colour	TCU	7.1	5.0
Dissolved Fluoride (F-)	mg/L	0.45	0.10
Nitrate + Nitrite (N)	mg/L	0.077	0.050
Nitrite (N)	mg/L	<0.010	0.010
Nitrogen (Ammonia Nitrogen)	mg/L	<0.050	0.050
Total Organic Carbon (C)	mg/L	<0.50	0.50
Orthophosphate (P)	mg/L	0.12	0.010
pH	pH	7.17	
Reactive Silica (SiO2)	mg/L	24	1.0
Dissolved Sulphate (SO4)	mg/L	7.9	2.0
Turbidity	NTU	1.7	0.10
Conductivity	uS/cm	160	1.0
RADIONUCLIDE			
Lead-210	Bq/L	<0.10	0.10

RDL = Reportable Detection Limit
N/A = Not Applicable

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Bureau Veritas Job #: C4F5623
Report Date: 2024/06/12

Fracflow Consultants Inc
Client Project #: 879
Site Location: WINSLOW
Your P.O. #: NS2326
Sampler Initials: GB

ELEMENTS BY ICP/MS (GROUND WATER)

Bureau Veritas ID		ZGG270	
Sampling Date		2024/05/24 10:00	
COC Number		N/A	
	UNITS	**879-PWL-72HR**	**RDL**
Metals			
Dissolved Aluminum (Al)	ug/L	<5.0	5.0
Total Aluminum (Al)	ug/L	140	5.0
Dissolved Antimony (Sb)	ug/L	<1.0	1.0
Total Antimony (Sb)	ug/L	<1.0	1.0
Dissolved Arsenic (As)	ug/L	10	1.0
Total Arsenic (As)	ug/L	11	1.0
Dissolved Barium (Ba)	ug/L	9.5	1.0
Total Barium (Ba)	ug/L	10	1.0
Dissolved Beryllium (Be)	ug/L	0.20	0.10
Total Beryllium (Be)	ug/L	0.22	0.10
Dissolved Bismuth (Bi)	ug/L	<2.0	2.0
Total Bismuth (Bi)	ug/L	<2.0	2.0
Dissolved Boron (B)	ug/L	<50	50
Total Boron (B)	ug/L	<50	50
Dissolved Cadmium (Cd)	ug/L	0.017	0.010
Total Cadmium (Cd)	ug/L	0.012	0.010
Dissolved Calcium (Ca)	ug/L	6700	100
Total Calcium (Ca)	ug/L	7200	100
Dissolved Chromium (Cr)	ug/L	<1.0	1.0
Total Chromium (Cr)	ug/L	<1.0	1.0
Dissolved Cobalt (Co)	ug/L	<0.40	0.40
Total Cobalt (Co)	ug/L	<0.40	0.40
Dissolved Copper (Cu)	ug/L	3.0	0.50
Total Copper (Cu)	ug/L	2.3	0.50
Dissolved Iron (Fe)	ug/L	110	50
Total Iron (Fe)	ug/L	140	50
Dissolved Lead (Pb)	ug/L	0.53	0.50
Total Lead (Pb)	ug/L	<0.50	0.50
Dissolved Magnesium (Mg)	ug/L	1400	100
Total Magnesium (Mg)	ug/L	1600	100
Dissolved Manganese (Mn)	ug/L	31	2.0
Total Manganese (Mn)	ug/L	34	2.0
Dissolved Molybdenum (Mo)	ug/L	<2.0	2.0
Total Molybdenum (Mo)	ug/L	<2.0	2.0
RDL = Reportable Detection Limit			

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Bureau Veritas Job #: C4F5623
Report Date: 2024/06/12

Fracflow Consultants Inc
Client Project #: 879
Site Location: WINSLOW
Your P.O. #: NS2326
Sampler Initials: GB

ELEMENTS BY ICP/MS (GROUND WATER)

Bureau Veritas ID		ZGG270	
Sampling Date		2024/05/24 10:00	
COC Number		N/A	
	UNITS	**879-PWL-72HR**	**RDL**
Dissolved Nickel (Ni)	ug/L	<2.0	2.0
Total Nickel (Ni)	ug/L	<2.0	2.0
Dissolved Phosphorus (P)	ug/L	140	100
Total Phosphorus (P)	ug/L	160	100
Dissolved Potassium (K)	ug/L	1300	100
Total Potassium (K)	ug/L	1400	100
Dissolved Selenium (Se)	ug/L	<0.50	0.50
Total Selenium (Se)	ug/L	<0.50	0.50
Dissolved Silver (Ag)	ug/L	<0.10	0.10
Total Silver (Ag)	ug/L	<0.10	0.10
Dissolved Sodium (Na)	ug/L	17000	100
Total Sodium (Na)	ug/L	20000	100
Dissolved Strontium (Sr)	ug/L	73	2.0
Total Strontium (Sr)	ug/L	81	2.0
Dissolved Thallium (Tl)	ug/L	<0.10	0.10
Total Thallium (Tl)	ug/L	<0.10	0.10
Dissolved Tin (Sn)	ug/L	<2.0	2.0
Total Tin (Sn)	ug/L	<2.0	2.0
Dissolved Titanium (Ti)	ug/L	<2.0	2.0
Total Titanium (Ti)	ug/L	<2.0	2.0
Dissolved Uranium (U)	ug/L	3.4	0.10
Total Uranium (U)	ug/L	4.1	0.10
Dissolved Vanadium (V)	ug/L	<2.0	2.0
Total Vanadium (V)	ug/L	<2.0	2.0
Dissolved Zinc (Zn)	ug/L	17	5.0
Total Zinc (Zn)	ug/L	11	5.0
RDL = Reportable Detection Limit			

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GENERAL COMMENTS

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

Package 1	4.7°C

RESULTS OF ANALYSES OF GROUND WATER

Radon-222: Radon Result's are decay corrected as per sampling date and time

Results relate only to the items tested.

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

[redacted]

Colleen Acker, B.Sc, Scientific Service Specialist

[redacted]

Steven Simpson, BSc.,MBA,C.Chem,Miss.-Kitimat, Lab Director

[redacted]

Automated Statchk

Bureau Veritas 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 Signatures page if included, otherwise available by request. For Department specific Analyst/Supervisor validation names, please refer to the Test Summary section if included, otherwise available by request. This report is authorized by Suzanne Rogers, General Manager responsible for Nova Scotia Environmental laboratory operations.

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