Appendix F.2

Groundwater Modelling Report - Part 1 of 3

Groundwater Modelling Report

Goldboro Gold Project

Anaconda Mining

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The Power of Commitment

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1. Introduction

1.1 Background

GHD Limited (GHD) was retained by Anaconda Mining Inc. (Anaconda) to develop a three-dimensional (3D) groundwater flow and fate/transport model to assess groundwater quality and quantity impacts for the Goldboro Gold Project (the Project). The Project is located approximately 175 kilometres (km) northeast of Halifax, 60 km southeast of Antigonish, and 1.6 km northeast of the community of Goldboro on the eastern shore of Isaacs Harbour, in Guysborough County, Nova Scotia, Canada ("Goldboro Mine Site" or "Site"). The Project location is presented on Figure 1.1.

Following the discovery of gold at the Goldboro Mine Site in 1861, there have been several attempts to develop and mine the area. Several mine sites including Boston-Richardson mine, East and West Gold Brook mines, Orex Mine workings, upper seal Harbour and Dolliver Mountain mine, have been developed historically at or near the proposed open pits. The location of the proposed pits relative to the historical Boston-Richardson mine, West Gold Brook mine, East Gold Brook mine, and Orex workings is presented on Figure 1.2.

Anaconda acquired Orex Exploration in 2017 along with the properties owned by Orex including the Boston-Richardson Mine, West Gold Brook Mine, and East Gold Brook Mine. Anaconda proposes to develop the Project as an approximately 4,000-tonne per day mine including associated processing facilities. The mine plan includes two surface extraction areas (open pits), an ore processing facility, a lined tailings management facility (TMF), waste rock storage areas (WRSAs), overburden and organic stockpiles, support buildings including an employee accommodation building, and associated infrastructure (see Figure 1.1 for significant Site features with respect to groundwater flow and fate/transport). The anticipated mine life for extraction of ore is approximately 11 years.

1.2 Purpose

The purpose of this Report is to document GHD's development of a numerical 3D groundwater flow model to represent the hydrogeologic conditions observed at the Project and surrounding area. Model development was based on available site-specific and regional hydrologic, geologic, and hydrogeologic data. The model was used to predict groundwater flow, groundwater/surface water interactions, and constituent of concern (COC)[1] migration during three key stages of Project development. Specifically, the groundwater flow model was applied to evaluate groundwater quantity and quality conditions at three key stages of mine operations. These key stages include:

- **East Pit End-of-Mine (EOM)**: Full extraction of the east pit and partial extraction of the west pit, corresponding to approximately year eight of operations
- **West Pit EOM**: Full extraction of the west pit and partial filling of the fully extracted east pit with water, corresponding to approximately year 11 of operations
- **Post-closure (PC)**: Reclamation of the Project area, including fully filling the east and west pits with water

The groundwater flow, groundwater/surface water interactions, and COC migration predictions at each of these three key stages included:

- Groundwater inflow rates to the open pits
- Groundwater drawdown
- Changes in groundwater discharge to/from surface water bodies

[1] COCs include aluminium, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, uranium, vanadium, zinc, ammonia (as N), unionized ammonia, nitrite (as N), and nitrate (as N).

– Potential COC migration from mine features into the surrounding environment applicable regulatory criteria

1.3 Scope of Work

GHD developed the groundwater flow model based on site-specific and available regional data including surface water features, topography, water well records, and geologic information.

The scope of work completed by GHD to develop the groundwater flow model and apply the model to evaluate potential impacts to groundwater and surface water flow regimes included the following:

– Compiled, reviewed, and interpreted the hydrologic, geologic, and hydrogeologic data available for the Goldboro Mine Site and surrounding area
– Developed a conceptual site model (CSM) for the Goldboro Mine Site and surrounding area based on available regional and site-specific data
– Constructed a 3D groundwater flow model based on the CSM to represent the existing conditions that incorporated the hydrogeological understanding of the study area
– Calibrated the groundwater flow model under steady-state conditions to match measured groundwater elevations and estimated baseflow values
    - Model calibration included an evaluation model input parameter sensitivity
– Applied the calibrated groundwater flow model to evaluate potential changes in groundwater quantity and quality conditions with respect to groundwater flow, groundwater/surface water interactions, and COC migration at the Goldboro Mine Site at East Pit EOM, West Pit EOM, and PC
– Evaluated the prediction sensitivity/uncertainty related to model input parameters
– Documented the groundwater flow model development and its application in this Report

To summarize, the groundwater flow model was calibrated to provide a reasonable representation[2] of groundwater elevations and estimated baseflow values. The calibrated model then was used to simulate groundwater flow, groundwater/surface water interactions, and COC migration at the Goldboro Mine Site at East Pit EOM, West Pit EOM, and PC. During each of the model calibration and application stages, GHD evaluated model sensitivity to input parameters to better understand the uncertainty associated with model predictions.

1.4 Limitations

This report: has been prepared by GHD for Anaconda Mining and may only be used and relied on by Anaconda Mining for the purpose agreed between GHD and Anaconda Mining as set out in Section 1 of this report.

GHD otherwise disclaims responsibility to any entity other than Anaconda Mining arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

[2] A reasonable representation means that the difference between observed and simulated groundwater elevations and baseflow values is within industry standards based on literature, published guidelines, and a qualitative and quantitative assessment of the sensitivities.

1.5 Report Organization

This Report is organized as follows:

- **Section 1 – Introduction:** Presents the introduction, purpose, and scope of work of the hydrogeologic modelling conducted for the Goldboro Mine Site
- **Section 2 – Summary of Hydrologic, Geologic, and Hydrogeologic Conditions:** Presents a summary of observed regional and site-specific hydrologic, geologic, and hydrogeologic conditions at the Goldboro Mine Site
- **Section 3 – Hydrogeologic Conceptual Site Model:** Presents the CSM developed for the Goldboro Mine Site that forms the basis for the construction of the numerical groundwater flow model
- **Section 4 – Simulation Program Selection:** Presents a description of the simulation programs selected to conduct the hydrogeologic modelling
- **Section 5 – Groundwater Flow Model Construction:** Presents details regarding construction of the numerical groundwater flow model to represent the key components of the CSM
- **Section 6 –Groundwater Flow Model Calibration:** Presents the calibration of the numerical groundwater flow model to observed groundwater flow conditions at the Goldboro Mine Site and the sensitivity analysis of model calibration to variations in model input parameters
- **Section 7 – Groundwater Flow Model Application:** Presents the application of the calibrated groundwater flow model to evaluate potential impacts to the groundwater and surface water flow regimes at the Goldboro Mine Site at East and West Pit EOM and PC and the accompanying sensitivity analyses
- **Section 8 – Summary and Conclusions:** Presents a summary of the hydrogeologic modelling conducted at the Goldboro Mine Site and the conclusions obtained
- **Section 9 – References:** Lists the references cited in this Report

2. Summary of Hydrologic, Geologic, and Hydrogeologic Conditions

GHD reviewed the regional and site-specific hydrologic, geologic, and hydrogeologic conditions at the Goldboro Mine Site. This analysis forms the basis for developing a comprehensive CSM that characterizes key groundwater flow conditions, including groundwater sinks (i.e., conditions that remove groundwater from the groundwater flow system) and groundwater sources (i.e., conditions that introduce/recharge groundwater into the groundwater flow system) near the Project. Understanding these groundwater flow conditions allows for the development of a groundwater flow model that can be applied to make predictions of groundwater flow, groundwater/surface water interactions, and COC migration. The details of the regional and site-specific hydrologic, geologic, and hydrogeologic conditions are summarized below.

2.1 Hydrologic Conditions

The hydrologic conditions at the Goldboro Mine Site are affected by regional physiography, topography, and surface water features. Each of these are briefly described in the following sections.

2.1.1 Physiography

The Goldboro Mine Site is located in the Atlantic Uplands division of the Appalachian physiographic province of Canada (Williams et al., 1972). The Atlantic Upland spans approximately 450 km from Cape Canso, past Halifax to Cape Sable and then continues northward approximately 100 km from Port Yarmouth to St. Mary Bay (Goldthwait, 1924). The Atlantic Upland appears in low islands and capes along the Atlantic coast, rising inland at a gradient of approximately 3 m/km, reaching an altitude of approximately 180 to 220 m above mean sea level (AMSL) in the center of the Nova Scotia peninsula. The Atlantic Upland is characterized by rolling hills, drumlin fields, and smooth ridges with intervening lakes, streams, and muskegs.

Physiographic sections can often be subdivided into hydrologic units (basins) of common drainage areas. The Goldboro Mine Site is located in New Harbour (HBR)/Salmon Basin and adjacent to the divide of the Country Harbour Basin. New HBR/Salmon basin occupies approximately 527 square kilometers in Nova Scotia. The New HBR/Salmon Basin discharges to the Atlantic Ocean. Gold Brook Lake, located within the New HBR/Salmon Basin, is the dominant physiographic feature near the Goldboro Mine Site (Figure 2.1).

2.1.2 Topography

Regionally, the topography surrounding the Goldboro Mine Site slopes gently from a maximum level of approximately 110 m AMSL northeast of the Goldboro Mine Site towards sea level to the southeast of the Goldboro Mine Site. Locally, the Goldboro Mine Site is in an area of low topographic relief at approximately 60 m AMSL. The Goldboro Mine Site topography under current conditions (i.e., pre-mining) is presented on Figure 2.1.

Throughout mining operations, the local topography will be altered by the construction of major mine features including the open pit, till stockpiles, and waste stockpiles. The anticipated mine life for extraction of ore is approximately 11 years. In the final year of operation, the open pits are expected to be mined to an elevation of approximately -184 m AMSL and -128 m AMSL for the West and East pits, respectively, while the largest waste stockpiles are expected to reach an elevation of approximately 165 m AMSL and 150 m AMSL.

2.1.3 Surface Water Features

Figure 2.1 presents the surface water features surrounding the Goldboro Mine Site. Regional surface water drainage is predominantly to the southeast along several stream channels and shallow lakes, and there are several low-lying wetlands across the Goldboro Mine Site. The most significant surface water body in the Goldboro Mine Site area is Gold Brook Lake. The southern end of Gold Brook Lake is located approximately 100 m north of the proposed mine pits. Gold Brook Lake drains southeastward to Seal Harbour Lake and finally discharges to the Atlantic Ocean. Gold Brook Lake likely is a location of groundwater discharge (i.e., a groundwater sink).

In addition to Gold Brook Lake, the most significant surface water bodies near the Goldboro Mine Site include Rocky Lakes, Oak Hill Lake, Ocean Lake, and Meadow Lake.

2.2 Geologic Conditions

The geology near the Project generally consists of a cobbly, silty sand glacial till (overburden), overlaying bedrock of the sand-rich turbidites of the Goldenville formation comprised of mainly argillite and greywacke. Sections 2.2.1 and 2.2.2 provide descriptions of the overburden and bedrock geology, respectively.

The information presented below focuses on geologic conditions pertinent to understanding groundwater flow conditions at the Goldboro Mine Site. Regional geologic conditions were inferred from monitoring well installation borehole records, exploratory geologic drillhole records, regional well records, and regional geology reports.

2.2.1 Overburden Geology

The overburden at the Goldboro Mine Site consists of glacial till deposits of varying thickness and occasional shallow peat bogs. Stea and Fowler (1979) described the overburden as a blue-greenish-grey, loose, cobbly silt-sand till that will grade into a sandier, coarser till, sometimes with red clay inclusions. Site-specific grain size analysis indicates variable grain size distribution in the samples with the average grain size of approximately 25 to 60 percent gravel, 20 to 45 percent sand, 10 to 25 percent silt and clay (WSP, 2019a).

Drainage can be limited by factors such as topography, silt content of the soil, and degree of compactness of the underlying glacial till. Variable drainage conditions that exist in the study area have resulted in the development of different soil types from the glacial till (Figure 2.2). For example, significant peat deposits have developed in poorly drained topographic depressions located on the northwestern shore of Gold Brook Lake, to the west and east of the mine site, and within the flood plain of Gold Brook. The previous study by Orex (1990) noted that the silt and clay content of the till typically increases with depth, as the contact with the bedrock surface is approached.

Overburden thickness was estimated by first interpolating top of bedrock elevations then subtracting these elevations from ground surface elevations. Interpolating top of bedrock elevations was accomplished using kriging with locally varying mean methodologies as implemented in Stanford Geostatistical Modeling Software (SGeMS)/PyKrige/Surfer Version 20.1.195/Leapfrog 2021.2.4 (Remy et al, 2009). This method involves implementing a regression function relating ground surface elevations with top of bedrock elevations. Regionally, the till deposit has a thickness ranging from approximately 2 m to 20 m (Stea et al., 1992). At the Goldboro Mine Site, the glacial till deposits are on average approximately 6.5 meters thick and range from 0.5 m to over 18 m. Figure 2.3 shows the interpolated overburden thickness generated based on the publicly available historical exploratory drillhole records, Nova Scotia Well Logs database of drilled and dug wells, exploratory drillhole data provided by Anaconda, and recently drilled groundwater monitoring, and geotechnical well records.

2.2.2 Bedrock Geology

2.2.2.1 Regional Geology

Nova Scotia is divided into two distinct geologic regions, the Avalon Terrane to the north and the Meguma Terrane to the south. The two terranes are separated by the Minus Geofracture (commonly referred to as the Cobequid-Chedabucto Fault System). The Project is located within the southern Meguma Terrane. The oldest known rocks of the Meguma Terrane are the greywackes and argillites of the Cambrian to Ordovician aged Meguma Group, which were intruded by granitic plutons during the Devonian Acadian Orogeny (Sangster and Smith, 2007).

The Paleozoic turbiditic metasedimentary sequence of the Meguma Group consists of two major stratigraphic units: the basal greywacke dominated Goldenville Formation; and the overlying, finer-grained, argillite-dominated Halifax Formation. The Goldenville Formation is estimated to be approximately 6.7 km thick with an unknown base, while the overlaying Halifax Formation is approximately 4.4 km thick in the northwest of Nova Scotia and to 0.5 km thick to the south (Malcom, 1929; Taylor, 1967; Sangster and Smith, 2007). In one section near Halifax, the Halifax formation is 11.8 km thick (Sangster and Smith, 2007)

During the Acadian Orogeny, approximately 400 million years ago, the sediments of the Goldenville and Halifax Formations were deformed, uplifted, metamorphosed into greenschist-amphibolite faces grade and were subsequently intruded by granitic plutons during the during the mid-Devonian to Carboniferous age 50 to 375 million years ago. The main feature of the deformational history is a series of major east-west trending upright to slightly reclined asymmetric folds (Duncan, 1987). Regional geologic conditions depicting the approximate locations of the Goldenville and Halifax formations are presented on Figure 2.4.

2.2.2.2 Local Geology

The proposed pits are located within the Goldenville Formation of the Meguma Group. A small band of the Halifax Formation crosses the Project area north of Gold Brook Lake. The Goldenville formation is sedimentologically monotone (i.e., there is not significant variation in the depositional environment in which the sediments were deposited), consisting of greywackes, argillite, mudstone, and slate/shale. Rocks of Meguma group are folded into a series of parallel regional folds (synclines and anticlines).

The Project area lies on the Seal Harbour Anticline which strikes approximately east west and can be traced for more than 13 kilometers. The anticline plunges gently to the east and passes beneath the southern-most tip of Gold Brook Lake (WSP, 2019a).

Locally, structural geology is relatively complex. The bedrock is highly to intensely fractured near surface, with quartz vein intrusions along fault shear zones which crosscut the greywacke and slate strata. Three main faults have been identified and mapped in the study area as shown on Figure 2.5. Some faults are highly brecciated. Observations within historical mine workings have shown that some large faults have been made impervious by breccia fines and therefore will not conduct groundwater.

2.3 Hydrogeologic Conditions

Groundwater flow systems in Nova Scotia are relatively shallow, with the majority of groundwater flow occurring in the upper 150 m. Large-scale groundwater flow between watersheds has not been observed, likely due to the geology present throughout the province (i.e., low permeability faulted/folded bedrock) that does not lend itself to the development of large regional aquifer systems (Kennedy et al., 2010).

The water table at Goldboro Mine Site typically is close to ground surface (i.e., averaging 1.9 m below ground surface, in shallow monitoring wells measured in 2021). The bedrock forms a fractured rock aquifer system, which is overlain by a thin overburden aquifer. The groundwater flow system is strongly influenced by topography such that recharge occurs in areas of high elevation and discharge is to low lying streams, rivers, and bogs. Interpreted groundwater elevation contours are presented on Figure 2.6 for the overburden/shallow bedrock flow system. Groundwater elevations were interpolated using kriging with locally varying mean methodologies in a manner similar to top of bedrock elevation interpolations. Figure 2.6 shows that in general groundwater elevations mimic topographic relief and locally groundwater discharges to low-lying surface water features. Gold Brook Lake is likely the most significant surface water body receiving groundwater discharge.

Regional groundwater flow in the fractured crystalline bedrock is controlled by secondary permeability and fracturing. The rock matrix permeability is believed to be generally low. Fracture density is high in the weathered shallow bedrock and decreases with depth (WSP, 2019a). Therefore, the majority of bedrock flow is expected to occur in shallower depth intervals and will decrease with depth, consistent with the understanding presented by Kennedy et al (2010). Regionally groundwater flow is expected to be towards the Atlantic Ocean; however, groundwater flow at depth is likely minimal due to the low permeability of the deeper bedrock.

2.3.1 Hydrostratigraphic Units and Hydraulic Properties

Two major hydrostratigraphic units are defined near the Goldboro Mine Site consisting of the overburden and weathered bedrock hydrostratigraphic units. The overburden is further divided into two main units. These include the upper unit, which is more transmissive to groundwater, and the lower silt-dominated unit, which is less transmissive to groundwater. The identified faults are not considered separate hydrostratigraphic units as discussed below. The hydraulic properties (i.e., hydraulic conductivity) of each of these major aquifer units are summarized below. Hydraulic conductivity values are based on a pumping test conducted by WSP (2019), packer tests and slug tests conducted by WSP, and packer tests analysed by GHD. These tests and the corresponding hydraulic conductivity values are summarized in Tables 2.1 and 2.2. The spatial distribution of the tests conducted at the study area are illustrated in Figure 2.7.

2.3.1.1 Overburden

WSP conducted slug testing in three monitoring well nests having screens installed in the overburden, at the contact between till, and fractured bedrock, and in the fractured bedrock (WSP 2019a). The upper till layer identified at MW17-03S had a hydraulic conductivity of 3×10^{-6} m/s. MW17-03S has greater amounts of gravel in the till matrix that likely contributed to the relatively transmissive hydraulic conductivity value. The lower till unit had a hydraulic conductivity of 6×10^{-7} m/s (average of two tests in MW17-1) (WSP, 2019a). The slug tests results are presented in Table 2.1. Table 2.1 includes slug test results for MW17-03D and MW17-02, which are screened in fractured bedrock and in the fractured bedrock/till interface, respectively and as such are not summarized in this section.

2.3.1.2 Bedrock

Measured hydraulic conductivities in the bedrock are presented in Tables 2.1 and 2.2. As presented in Table 2.2, bedrock hydraulic conductivity at the Goldboro Mine Site has been observed to decrease with depth consistent with the observation of weathered fractured bedrock at shallow depths grading into less fractured and more competent bedrock at depth. In general, the highest hydraulic conductivity values, on the order of 1×10^{-6} m/s to 1×10^{-3} m/s occur within the upper 30 m of bedrock while hydraulic conductivity values on the order of 1×10^{-8} m/s to 1×10^{-6} m/s occur at depths greater than 30 m below the top of bedrock. Several empirical equations have been developed by researchers to describe this trend. One of the most frequently-used equations is the model developed by Wei et al. (1995).

$$K = K_i \left[\frac{1 - Z}{58 + 1.02 \times Z}\right]^3 \qquad \text{Equation 2.1}$$

Where:

Z = Depth below ground surface (m)

K_i = Hydraulic conductivity near ground surface

Figure 2.8 illustrates the hydraulic conductivity values measured at the Site, from Table 2.2, compared to measurement depth. The hydraulic conductivity versus depth relationship developed using Equation 2.1 is also shown on Figure 2.8. As illustrated on Figure 2.8, Equation 2.1 provides a reasonable representation of the observed pattern in measured hydraulic conductivity values with increasing depth. It should be noted that the packer tests were typically selected at the intervals with perceived higher fracture densities and secondary permeabilities (which would correspond with greater hydraulic conductivity values) based on the Rock Quality Designation (RQD) of each interval. Consequently, the estimated hydraulic conductivity values, especially at depth, were biased towards higher values and representative of zones conducting groundwater flow. In general, groundwater flow in the bedrock is controlled by the fracturing and secondary permeability, which is greater in the shallow zones and decreases with depth.

2.3.1.3 Faults

As described in Section 2.2.2.2, three main faults have been identified in the Project area. Some of these large faults have been observed to be filled will breccia fines, indicating that they will likely not conduct water. Packer testing and pumping testing in borehole BR-17-MET-1, which appears to intercept the New Belt Fault, showed that the fault had low hydraulic conductivity compared to other bedrock zones (WSP, 2019a). This is consistent with observations made at other gold deposits within the Meguma group where large faults were filled with breccia fines or a clay like gouge and demonstrated similar permeability to the surrounding formation (Jacques and Whitford, 1986). Therefore, the faults observed in the Project area are assumed to behave similarly to the surrounding bedrock formation and are not considered as a distinct hydrostratigraphic unit.

2.3.2 Groundwater Sinks

A groundwater sink is any feature that removes groundwater from the groundwater flow system. Within the Project area, the primary groundwater sinks correspond to groundwater discharge to surface water features. Groundwater discharge to surface water features is discussed in more detail in the following section.

2.3.2.1 Discharge to Surface Water Features

Locally, groundwater flow typically follows topographic relief, moving towards surface water features and low-lying areas. During some times of the year, when surface water stage elevations are lower than surrounding groundwater elevations, the linear/flowing surface water features (i.e., rivers, creeks, and channels) presented on Figure 2.1 will receive groundwater discharge as baseflow. On an average annual basis, baseflow within the primary watersheds containing the Project is estimated to range from approximately 17 to 21 percent of average annual precipitation (Kennedy et al, 2010).

The proposed open pits are located approximately 100 m south of Gold Brook Lake. Gold Brook Lake is the primary surface water feature in the area and is likely an area of groundwater discharge. Gold Brook Lake is approximately 1,700 m long with a maximum width of approximately 790 m at it northern end and 110 m at its southern end. Gold Brook Lake has a maximum depth of approximately 3 m and a mean depth of 1.7 m. Gold Brook Lake is drained from its southern end by Gold Brook which flows in a southerly to southeasterly direction ultimately discharging into Isaacs Harbour and the Atlantic Ocean.

The proposed open pits will also act as a groundwater sink both when dewatered during operations and once full during reclamation.

2.3.3 Groundwater Sources

A groundwater source is any feature that contributes water to the groundwater flow system. At the Project, the primary groundwater source is from groundwater recharge through precipitation infiltration. In some areas it is expected that groundwater will receive recharge from surface water features; however, surface water features overall are expected to receive net discharge from the groundwater flow system.

2.3.3.1 Recharge Through Precipitation Infiltration

Groundwater near the Project area receives precipitation at a reported average annual rate of approximately 1,409.2 mm/yr (GHD, 2022a). The amount of precipitation reaching the groundwater table is typically considered to range from approximately 10 to 40 percent of the average annual precipitation (Arnold et al., 2000; and Rushton and Ward, 1979).

Site-specific average baseflow was estimated using the chloride mass-balance (CMB) method (Healy, 2010) for the Site. The CMB method is widely used to estimate groundwater recharge. In this method, groundwater recharge is estimated using the following equation:

$$R = \frac{Cl_p}{Cl_{gw}} \times P \qquad \text{Equation 2.2}$$

Where R is recharge in mm, Cl_p is chloride concentration in precipitation, Cl_{gw} is chloride concentration in groundwater, and P is average annual precipitation. Chloride concentration in groundwater was estimated from 4 monitoring wells (MW17-1, MW17-2, MW17-3D, and MW173S) at the Site. GHD estimated the precipitation chloride concentration from the publicly available data for Sherbrook Station (approximately 27 km east of the site) collected from 2008 to 2018. GHD estimated that the site specific average annual recharge is 18.5 percent of average annual precipitation or approximately 260 mm/year. The lower and upper quartiles of the percentages of precipitation contributing to recharge are 17 and 23 percent, respectively. The Site-specific average groundwater recharge estimates of 17 to 23 percent of average annual precipitation corresponds well with the estimated baseflow range of 17 to 21 percent of average annual precipitation presented by Kennedy et al (2010).

Baseflow is often used to estimate recharge rates, with the caveats that: 1) baseflow probably represents some amount less than that which recharges the aquifer; and 2) baseflow is best applied to provide a reasonable estimate of recharge occurring over long time periods (1 year or more) (Risser et al., 2005). Therefore, the recharge estimates developed by Kennedy et al (2010) through annual baseflow analysis and those developed by GHD using the CMB method are applicable to determine the potential range of groundwater recharge values for the Project Area. As such the average annual recharge within the Project area likely ranges from approximately 220 to 340 mm/yr.

During construction, a geomembrane liner will be placed at the bottom of the TMF and will remain in place through closure. During closure, the TMF will be covered by a geomembrane as well. It is anticipated that the geomembrane liner, and the geomembrane cover will reduce infiltration of precipitation over the TMF area.

2.3.3.2 Recharge from Surface Water Features

While surface water features are expected to be a net groundwater sink, there will be losing reaches (i.e., sections where surface water recharges groundwater) along some surface water features. Surface water features will recharge groundwater in areas where groundwater levels fall below adjacent surface water elevations.

3. Hydrogeologic Conceptual Site Model (CSM)

Understanding the hydrologic, geologic, and hydrogeologic conditions at the Goldboro Mine Site, as described in Section 2, forms the basis for developing a conceptual understanding of the groundwater flow system. This conceptual understanding is the hydrogeologic CSM and it facilitates selecting model domain limits for the numerical groundwater flow model, as well as hydrostratigraphic unit representation and boundary conditions taking into consideration the observed Site-specific and regional hydrogeologic conditions.

3.1 General Hydrogeologic Characteristics

Understanding the general hydrogeologic characteristics of the groundwater flow system for the Goldboro Mine Site is fundamental to developing a representative CSM and guides the development of the numerical groundwater flow model. Based on the available regional and site-specific information, the hydrogeologic characteristics presented in Section 2 are summarized as follows:

- Based on the available monitoring well installation borehole records, exploratory geologic drillhole records, regional well records, and regional geology reports the geologic conditions at the Goldboro Mine Site consist of fractured interbedded argillite and greywacke bedrock overlain by a thin till overburden layer. The overburden consists of a silty sand and gravel containing cobbles and boulders.
- Groundwater flow at the Goldboro Mine Site occurs primarily in the till overburden layer and the shallow weathered fractured bedrock zone. Bedrock permeability decreases with depth indicating that groundwater flow rates also are expected to decrease with depth.
- Groundwater flow directions in the till overburden typically follow topographic relief, and the groundwater table is expected to mimic ground surface, with recharge occurring in upland areas, and discharge occurring to surface water bodies in low lying areas.
- Groundwater flow in the bedrock is controlled by secondary permeability and fracturing, and more so in the weathered shallow bedrock than in the more competent deep bedrock. Hydraulic conductivity in the bedrock declines with depth.
- Identified faults have a similar hydraulic conductivity to the surrounding bedrock formation
- The linear surface water features near Goldboro Mine Site predominantly are groundwater sinks, removing water from the groundwater flow system
  - Water from losing reaches of the linear surface water features may contribute to the groundwater flow system as groundwater sources.
- Regionally, groundwater discharges to Goldbrook Lake, Ocean Lake, and Isaacs Harbour.
- At depth within the deep bedrock, the permeability becomes sufficiently low such that vertical groundwater flow is negligible.

4. Simulation Program Selection

The simulation program selection to develop the numerical groundwater flow model for the Goldboro Mine Site was based on the following considerations:

- The ability of the program to represent the key components of the CSM;
- The demonstrated verification that the program correctly represents the hydrogeologic processes being considered;
- The proven acceptance of the program by regulatory agencies and the scientific/engineering community;

- The ability of the program to represent the proposed mine design; and
- The ability of the program to provide a reasonable numerical solution in consideration of the complexity of the hydrogeological conditions at the Goldboro Mine Site.

4.1 Groundwater Flow Model

As described in Section 2.3.1.2 groundwater flow through bedrock tends to occur through fractures and secondary permeability. When there is sufficient connection between the fractures and secondary permeability at the scale of interest, as is the case near the Site, groundwater flow can be approximated as occurring through an equivalent porous medium (EPM) and the flow equations can be solved using finite-difference methodologies.

MODFLOW-NWT (Niswonger et al., 2011), developed by the United States Geological Survey (USGS), can simulate steady-state or transient groundwater flow in two or three dimensions. MODFLOW-NWT uses a finite-difference method leading to a numerical approximation that allows for a description of and solution to complex groundwater flow problems. A rectangular grid is superimposed over the study area to horizontally subdivide the region of interest into a number of rectangular cells, and then the study area is subdivided vertically using model layers. Hydraulic properties are assigned to the model cells consistent with the hydrogeologic unit that falls within each model cell. Groundwater flow is formulated as a differential water balance for every model cell and hydraulic head is solved at the center of every model cell. MODFLOW-NWT allows for the specification of flows associated with wells, areal groundwater recharge, rivers, drains, streams, and other groundwater sources/sinks.

MODFLOW-NWT was selected to simulated groundwater flow for this modelling study due to its ability to efficiently solve complex groundwater flow simulations characterized by drying and rewetting of model cells such as that encountered in the simulation of dewatering scenarios. MODFLOW-NWT is a standalone version of MODFLOW-2005 (Harbaugh, 2005), which is an update to the original MODFLOW (McDonald and Harbaugh, 1988) and MODFLOW-2000 (Harbaugh et al., 2000). MODFLOW has been extensively verified and is readily accepted by many regulatory agencies throughout North America and Europe. MODFLOW-NWT can represent the hydrogeologic components of the CSM for the Goldboro Mine Site including flow through bedrock using the assumption that flow through bedrock can be treated as an EPM. The Newton Solver (NWT) and the Upstream Weighting (UPW) package included in MODFLOW-NWT were employed to solve the groundwater flow equation. For convergence, the solution technique required the satisfaction of both hydraulic head and flow residual criteria providing a rigorous and reliable simulated water balance throughout the model domain.

4.2 Parameter Estimation

The calibration of the groundwater flow model was aided using the parameter estimation program PEST, which is an acronym for Parameter Estimation (Watermark Numerical Computing, 2016). PEST is a model-independent parameter estimator that has become a groundwater industry standard for groundwater flow model calibration. It has a powerful inversion engine, which provides the ability to set bounds on model input parameters such as hydraulic conductivity and groundwater recharge. PEST conveys to MODFLOW-NWT input parameter values that vary within their specified bounds with the objective of establishing optimal input parameter values that minimize the error between observed and simulated calibration targets. For each run of input parameters, PEST calculates objective function values (OFVs) at each model calibration target location. OFVs represent the error between calculated versus measured values at each calibration target location. PEST automatically makes changes to the input parameter values (within their specified bounds) to reduce OFVs, selecting the run that exhibits the lowest overall OFVs as the optimal solution.

4.3 Contaminant Transport Model

Contaminant (metals) transport was simulated using MT3D-USGS (Bedekar et al., 2016). MT3D-USGS, an update to MT3DMS (Zheng and Wang, 1999), includes new transport modelling capabilities to accommodate flow terms calculated by MODFLOW packages that previously were unsupported by MT3DMS and to provide greater flexibility in the simulation of solute transport and reactive solute transport. MT3D-USGS also includes the capability to route a solute through dry model cells that may be simulated in MODFLOW-NWT. MT3D-USGS is a reactive transport model that, when integrated with MODFLOW-NWT, can simulate multispecies transport in one, two, or three dimensions, and is able to simulate transport processes that are applicable to the Goldboro Mine Site, including advection, biodegradation (or decay), adsorption and dispersion in groundwater flow systems. MT3D-USGS is commonly used by the industry and accepted by regulatory agencies throughout North America and Europe.

4.4 Graphical User Interface

The graphical user interface (GUI) Groundwater Vistas (Rumbaugh, 2020) was used as the interface between the assembled hydrogeologic data and the required MODFLOW-NWT and MT3D-USGS input files. The GUI facilitates pre- and post-processing of MODFLOW-NWT and MT3DMS input/output files.

5. Groundwater Flow Model Construction

Groundwater flow model construction is the process of developing the horizontal and vertical discretization of the selected model domain, specifying hydraulic properties consistent with the hydrostratigraphic units, and implementing boundary conditions consistent with the CSM. The groundwater flow model construction relative to these aspects is presented in the following sections.

5.1 Groundwater Flow Model Spatial Domain and Discretization

5.1.1 Groundwater Flow Model Spatial Domain

A groundwater flow model domain should extend to where reasonably defensible boundary conditions can be established. Model domain limits, and the associated boundary conditions, should be based on regional-scale natural hydrogeologic features where possible. The model domain limits and the associated boundary conditions should be selected to minimize bias in model predictions over the area of interest within the interior of the model domain.

GHD selected a model domain and associated boundary conditions representative of observed conditions at the Goldboro Mine Site and reasonably expected conditions regionally. The selected model domain and boundary conditions assigned at the model domain limits are illustrated on Figure 5.1, and are described in general terms as follows:

- North: The northern model domain limit is aligned with an expected groundwater flow divide located near the New Harbour Salmon basin watershed divide and along topographic highs from Meadow Lake towards the watershed divide near Oak Hill Lake. A no-flow boundary condition is assigned to the nodes along this limit of the model.
- West: The western model domain boundary was selected to correspond with surface water bodies along Meadow Lake, Isaacs Harbour River, and Isaacs Harbour. Constant head boundary conditions are assigned to represent these surface water bodies.
- South and Southeast: The southeastern model domain limit corresponds to groundwater flow divides along topographic highs and the flow lines adjacent to three creeks that have been crossed by the model domain. It is assumed that water flows from the high lands toward these creeks. This boundary condition was selected to be a sufficient distance from the Project area to avoid undue bias on predictive simulations while maintaining a reasonable model size to maintain computational efficiency. A no flow boundary condition is assigned to all the nodes along this boundary.
- Northeast: The northeastern boundary condition corresponds to surface water along the margins of Ocean Lake. Constant head boundary conditions were assigned to simulate the interaction between lake water and groundwater.

As presented on Figure 5.1, the model domain extends approximately 7 km in the north-south direction and 8 km in the east-west direction. Details on implementing the boundary conditions described above at the model domain limits are provided in Section 5.2. Additional river boundary conditions on the interior of the model domain corresponding to surface water bodies discussed in Section 2 and are further described in Section 5.2.

Vertically, the model domain extends from ground surface, where a recharge boundary condition is applied, to approximately 600 m below the bottom of bedrock surface where a horizontal no-flow boundary is inferred. At this depth, the permeability of the deep bedrock becomes sufficiently low such that active vertical groundwater flow is considered negligible. The bottom of the model domain was also set to provide sufficient vertical separation between the bottom of the model domain and the proposed open pits to avoid unduly biasing predictive simulations.

5.1.2 Groundwater Flow Model Discretization

Horizontally, the model domain is discretized into rows and columns using a rectangular finite-difference grid. The finite-difference grid is extended over the model domain described in Section 5.1.1. The finite-difference grid is presented on Figure 5.2. A minimum finite-difference grid spacing of 10 m was applied over the area of interest as defined by the preliminary mine layout. Beyond the area of interest, the grid spacing progressively increases to a maximum of 44 m at the edge of the model domain. The model domain is discretized horizontally into 395 rows and 420 columns.

Vertically, the model domain extends from ground surface to 600 m below top of the bedrock where a vertical no-flow boundary is inferred as described in Section 5.1.1. Ground surface elevations over the model domain were generated using the LiDAR imagery data for the Goldboro Mine Site. The vertical discretization of the model domain consists of 24 model layers to capture major changes in hydrostratigraphy at the study area. Model Layer 1 represents the upper and generally higher conductive overburden. Model Layer 2 represents the lower overburden which has been interpreted to have a lower conductivity than the shallow overburden. It is assumed that Model Layers 1 and 2 have equal thicknesses that vary from approximately 0.25 m to 7 m. Therefore, the variable overburden thickness presented on Figure 2.3 was divided equally to define the top and bottom of Layers 1 and 2. Figure 5.3 presents the vertical discretization of Model Layers 3 to 24 representing the bedrock. Figure 5.3 includes the hydraulic conductivity testing results, empirical model of hydraulic conductivity values based on Wei et al., (1995), and geometric mean of the measured hydraulic conductivity values in the upper three bedrock zones, where there is sufficient information to estimate this value. These layers are coloured on Figure 5.2 to represent the hydraulic conductivity transition with depth to lower conductivity values. As shown on Figure 5.3, Model Layers 3 to 19 are assigned a uniform thickness of 15 m to provide sufficient grid refinement to represent the Project features and to incorporate the observed decrease in hydraulic conductivity with depth. The bottom five layers, where the bedrock conductivity is interpreted to vary by less than an order of magnitude, are assigned a variable thickness increasing with depth. The bottom five layers have thickness of approximately 23, 36, 57, 89 and 139 m, respectively.

5.2 Flow Model Boundary Conditions

As described in Section 5.1.1 and shown on Figures 5.1 and 5.2, the boundary conditions for the groundwater flow model consist of:

- River boundary conditions to represent inner surface water features that potentially could receive groundwater discharge or potentially could recharge groundwater (e.g., Gold Brook Lake, Rocky Lakes, Oak Hill Lake, etc.).
- Constant head boundary conditions to represent surface water features along the outer edge of the model (Isaacs Harbour, Ocean Lake, Meadow Lake, and Isaacs Harbour River).
- No-flow boundary conditions to represent anticipated flow divides located along watershed boundaries and between topographic highs along the model domain limits.
- Recharge over the top of the model domain to represent precipitation infiltration.
- Vertical no-flow boundary condition at depth corresponding to the inferred base of the active groundwater flow system within deep bedrock.

With respect to the predictive simulations of the open pit mine and pit filling the following additional boundary condition type is used:

– A drain boundary condition is specified to represent surface water features that are considered to represent a point of groundwater discharge only. This includes the seepage face of the open pit mine; and
– A constant head boundary condition is also applied to represent the full pit lake and the varying stage of the pit lake for the simulation of pit infilling.

The implementation of these boundary conditions in the model is described in further detail below.

5.2.1 River Boundary Condition

A river boundary can simulate the interaction between surface water and groundwater. It can represent both groundwater discharge to surface water (i.e., a gaining stream) and groundwater recharge from surface water (i.e., a losing stream). If a specified river stage elevation is lower than the simulated groundwater elevation, the river boundary receives discharge from groundwater. If the specified river stage elevation is higher than the simulated groundwater elevation, the river boundary serves as a recharge to groundwater. The quantity of surface and groundwater exchange is equal to the difference between the simulated groundwater elevation within the river cell and the specified head within the river cell multiplied by a conductance term. The conductance term reflects the relative ease of groundwater flow through sediments or bedding material that form the base of the surface water body.

As shown on Figure 5.1, river boundary conditions were assigned to represent natural surface water features located within the active model domain. The river cell stage elevations were assigned based on ground surface elevations minus the depth to water interpolated between surface water gauge locations. Where no gauging station is available it is assumed that the stage elevation is 0.2 m above ground surface for rivers and streams and 0.5 m above ground surface for lakes. The conductance term for the river cells was estimated using:

$$C_{River} = \frac{K \times A}{M} \qquad \text{Equation 5.1}$$

Where:

C_{River}	=	river cell conductance (square metres per day [m^2/d])
K	=	hydraulic conductivity of streambed sediments (m/d)
A	=	area of the river cell (square metres [m^2])
M	=	thickness of the river bed material (m)

For larger surface water bodies (i.e., lakes) that encompass multiple model cells, the river cell area was calculated as the model cell area or the portion of the surface water body contained by the river cell. For narrow surface water bodies (i.e., streams), the river cell area was calculated as the length of the stream within the river cell multiplied by stream width estimated from satellite imagery. The streambed sediment thickness was assumed to be 0.1 m. The hydraulic conductivity of the streambed sediments was adjusted during model calibration.

5.2.2 No-Flow Boundary Condition

No-flow boundary conditions were applied where negligible groundwater flow across a model boundary can reasonably be expected. No-flow boundary conditions are specified along watershed divides and between adjacent topographic highs where groundwater is expected to flow downslope creating a groundwater flow divide with negligible groundwater flow across the divide (the divide is assumed to correspond to a line drawn on topographic highs or assumed flow line). At the bottom of the model domain (600 m below the top of bedrock), it is assumed that the permeability of the deep bedrock becomes sufficiently low that active groundwater flow, and vertical groundwater flow in particular, is considered negligible. Therefore, a no-flow boundary condition is specified across the bottom of the model domain.

5.2.3 Recharge

Recharge from precipitation infiltration was applied as the top model domain. As discussed in Section 2.3.3.1, regional and Site-specific estimates indicate that average annual groundwater recharge near in the Project area ranges from 220 to 340 mm/yr. To account for recharge variation across the model domain, GHD subdivided the model domain into 5 different recharge zones corresponding to either rapid, imperfect, poor, excessive, or inundated drainage. All but the inundated drainage patterns are shown on Figure 2.2. Inundated areas corresponded to large surface water features and were assigned a lower recharge rate corresponding to leakage from those features. A single recharge value is applied for each zone. The recharge magnitude at each zone was estimated during model calibration. The average recharge rate assigned over the model domain is compare against the range in recharge values developed by Kenney et al. (2010) and Site-specific range estimated by GHD using the CBM method to ensure that the calibrated recharge range is within or near the estimated average annual recharge rate of 220 to 340 mm/yr.

5.2.4 Drain Boundary Condition

A drain boundary condition simulates groundwater/surface water interactions by removing groundwater from the groundwater flow system. Unlike a river boundary condition, a drain boundary condition cannot represent a losing stream condition where surface water recharges groundwater. The drain boundary condition is active if the specified drain stage elevation is lower than the simulated groundwater elevation, and inactive when the specified drain stage elevation is higher than the simulation groundwater elevation. Similar to river cells, the quantity of groundwater discharge to the drain boundary is equal to the difference between the simulated groundwater elevation within the drain cell and the specified drain stage elevation multiplied by a conductance term.

A drain boundary condition was applied along the open pit wall to simulate the open pit above specified pit lake stage elevations. The drain stage elevations representing of the open faces of the pit were set based on the elevation of the proposed pit walls. The drain conductance was set to a high value of 1,000 m^2/d to represent low resistance to seepage at the pit walls.

A drain boundary condition was also applied to simulate old mine workings at the site. The conductance term in this scenario has been calculated at each drain cell. The conductance was assumed to be proportional to the relative volume of each computational grid that has been occupied by the mine workings. The hydraulic conductivity of the drain boundary condition is assumed to be equal to average conductivity of the bedrock. This method accounts for the resistance of groundwater entering the mine workings due to the relatively larger finite-difference model cell size compared to the size of the mine workings.

5.3 Hydraulic Conductivity Distribution

The hydraulic conductivity zones were assigned in the model to represent each of the major hydrogeologic units identified in the CSM: the overburden unit and the bedrock unit. The overburden unit is further subdivided into an upper and lower overburden unit, represented by Model Layers 1 and 2, respectively. The upper overburden unit is subdivided into five hydraulic conductivity zones based on the surficial geology presented on Figure 2.2. A single hydraulic conductivity value is assigned to Layer 2, representative of the lower overburden unit. Model Layers 3 to 24 represent bedrock. Bedrock is subdivided into five different conductivity zones based on observed hydraulic conductivity values and the relationship defining the decrease of hydraulic conductivity values with depth as described in Section 2.3.1.2. The hydraulic conductivity zones specified in Model Layers 3 to 24 are presented on Figure 5.2 along with hydraulic conductivity testing results and the calculated geometric mean of the hydraulic conductivity test results within each hydraulic conductivity zone. As shown on Figure 5.3, five hydraulic conductivity zones are assigned to represent the bedrock and the geometric mean of the hydraulic conductivity decreases with the depth of each hydraulic conductivity zone. The hydraulic conductivity value for each hydraulic conductivity zone was adjusted within reasonable bounds during model calibration. The ranges of the reasonable bounds were assessed based on the results of the hydraulic conductivity testing within each hydrogeologic unit, as well as published literature values. A summary of initial (i.e., geometric mean where available) and upper and lower hydraulic conductivity bounds used for all the zones are presented in the Table 5.1.

6. Groundwater Flow Model Calibration

Groundwater flow model calibration is the process of adjusting model input parameter and boundary conditions such that simulated results provide a reasonable representation of observed groundwater flow conditions at the Goldboro Mine Site. The objective is to determine a unique combination of input parameters to produce a numerical solution that best matches the observed groundwater elevations at the Goldboro Mine Site.

6.1 Calibration Targets

Selection of steady-state model calibration target datasets normally considers whether the available groundwater elevation monitoring captures the following:

– Represents the average groundwater flow conditions;
– Groundwater stresses/boundary conditions represent the range of conditions affecting groundwater elevations and flow directions;
– Provides spatial coverage of the model domain with measurements at all the available monitoring well locations; and
– Includes the key area of interest within the model domain.

The monitoring network includes monitoring wells and boreholes within the Project area. Groundwater elevations have been measured at 62 boreholes, 5 monitoring wells installed by WSP in 2017, and 34 monitoring wells installed by Terrane Geoscience (Terrane) in 2021 and 2022. A single round of groundwater elevation measurements was conducted by WSP at the borehole locations. Multiple rounds of groundwater elevation monitoring have been completed at an irregular frequency at the 5 monitoring well locations installed by WSP including monitoring events in December 2017 and June 2019, and ongoing monthly monitoring since October 2019. Transducers are installed in the 34 monitoring well locations installed by Terrane and water levels are measured manually on approximately a quarterly basis corresponding with transducer data downloads. To develop the groundwater calibration dataset, GHD considered all available groundwater elevation monitoring data to provide the greatest spatial coverage over the Project area. GHD selected groundwater elevations measured at the 62 borehole locations and 5 monitoring well locations collected in June 2019. GHD supplemented the borehole water level and WSP monitoring well groundwater elevation data with averaged groundwater elevations collected at the 34 monitoring locations installed in 2021 and 2022. Supplementing the largest available synoptic round of groundwater elevation measurements collected in June 2019 with available monitoring well data collected in 2021 and 2022 provides the greatest coverage of the project area based on available groundwater elevation monitoring data. The estimated static water levels are presented in Table 6.1. The layer that these monitoring wells are assigned in the model are also presented in Table 6.1. Since the boreholes are open holes drilled in the bedrock, GHD assumed that the groundwater elevation measured at open boreholes represents the most conductive bedrock layer (fractured bedrock). It is expected that that water level measured at these locations have higher uncertainty, or are of lower quality, than groundwater elevations measured at the monitoring locations. The location of boreholes and monitoring wells are presented on Figure 6.1.

In addition to estimated static water levels, GHD calibrated the model to estimated baseflow to surface water bodies. As described in Section 2.3.2.1, average annual baseflow is estimated to vary between 17 to 23 percent of average annual precipitation and estimated average annual recharge based on baseflow estimates is 220 to 340 mm/yr. Therefore, applied recharge rates and simulated baseflow to surface water bodies are compared against the estimated baseflow range to confirm that simulated baseflow is representative of Project conditions.

6.2 Calibration Methodology

The groundwater flow field throughout the model domain was simulated under steady-state conditions for the calibration target dataset. The solution to the groundwater flow equation was obtained using a numerical solver with specified convergence criteria. As described in Section 4.1, the NWT solver and the UPW package implemented in MODFLOW-NWT were used. The convergence criteria between successive solver iterations were specified as 0.0001 m for the maximum hydraulic head change, and 100 m^3/d for the maximum flow residual throughout the model domain.

Model calibration was performed in an iterative manner by adjusting the hydraulic conductivity values per geologic unit, recharge rate, and the hydraulic conductivity of the streambed sediments for river cell boundary conditions. PEST was applied to aid the model calibration process as an automated means to optimize model input parameter values within reasonable ranges.

The model calibration was evaluated both qualitatively and quantitatively. Qualitative evaluations included visually comparing the simulated versus observed groundwater elevations and groundwater flow directions, as well as the spatial distribution of calibration residuals. Calibration residuals are calculated as the observed groundwater elevation minus the simulated groundwater elevation at each calibration target location. A negative residual value indicates that the observed groundwater elevation is over-predicted, and a positive residual value indicates that the observed groundwater elevation is under-predicted. Focused areas of largely over- or under-predicted groundwater elevations would indicate spatial bias in the calibration results, and adjustments to model input parameters are made to minimize this bias.

The quantitative assessment of the calibration was conducted by examining the calibration residual statistics. Statistics such as the mean residual, absolute mean residual, sum of the residual values squared (referred to as the residual sum of squares), and residual standard deviation, were calculated to quantify an overall measure of the discrepancy between observed and simulated groundwater elevations provided by the calibrated model. The objective of the model calibration is to minimize these residual statistics.

Another quantitative assessment of the calibration was conducted by comparing the difference between observed and simulated total baseflow for the model domain and the difference between the observed and simulated inflow into the Boston-Richardson mine workings, with the goal of minimizing this difference.

A further quantitative measure of the calibration was provided by the simulated volumetric water budget report by MODFLOW-NWT, indicating the quantities of flow into and out of the model domain via specified groundwater flow boundary conditions. The volumetric budget was reviewed to ensure that the total inflows and outflows were consistent with the CSM, and to ensure that the discrepancy between simulated inflows and outflows is less than 1 percent, indicating that a satisfactory numerical convergence was obtained for the solution of the groundwater flow equation.

6.3 Groundwater Flow Model Calibration Results

Calibration residuals at each target locations are shown in Table 6.2. The locations of all calibration targets are presented on Figure 6.1. The spatial distribution of calibration residuals is presented on Figure 6.2. Figure 6.2 provides a qualitative evaluation of the model calibration and demonstrate that there is reasonably good agreement between the simulated and observed groundwater elevations. The residual values at each target location that are presented on Figures 6.2 demonstrates that the GW model slightly underpredicts the water level elevations; however, over- and under-predictions of observed groundwater elevations have a reasonably random distribution throughout the Goldboro Mine Site and surrounding area. This supports that there is limited spatial bias in areas of over- or under-predicted groundwater elevations.

Scatter plots of observed versus simulated groundwater elevations are presented on Figure 6.3. Figure 6.3 illustrates that underprediction tends to occur in the lower quality borehole targets while the distribution of over- and under-predicted targets is more even distributed for the higher quality monitoring well targets. The residual statistics for the base case calibrated model are summarized on Figure 6.3. The calibrated model provides a residual mean of 0.44 m, an absolute residual mean of 1.32 m, a residual sum of squares of 341.8 m^2, and residual standard deviation of 1.78 m. These residual statistics were minimized during the model calibration process while maintaining a reasonable representation of observed groundwater flow directions consistent with the CSM.

The residual standard deviation for the base case calibrated model is 3 percent of the range of measured groundwater elevations, as indicated on Figure 6.3. Spitz and Moreno (1996) suggest that the residual standard deviation should be less than about 10 percent of the range in measured target groundwater elevations. The residual standard deviation for the calibrated model lies below this metric. This result, combined with the residual mean and the absolute mean being less than 1.5 m, indicates that the calibrated model provides a reasonably good match to the measured groundwater elevations.

The volumetric water budget for the calibrated model was examined for the model calibration. A discrepancy of close to zero occurs in the water budget between the simulated inflow and outflows, which demonstrates that good numerical convergence was achieved throughout the model domain. The calibrated model estimated that the total recharge over the entire model domain is equal to 252 mm/year which is comparable with the estimated recharge in the area (253 mm/year).

Table 6.3 shows the calibrated parameter values and the corresponding boundaries applied during model calibration. In general, the bounds for hydraulic conductivity values were determined from the hydraulic conductivity values obtained from the slug tests, packer tests conducted at the Goldboro Mine Site, and literature values (see Section 2.3.1). The recharge bounds were set based on the expected recharge value described in Section 5.2.3.

As shown in Table 6.3, the calibrated hydraulic conductivity for the shallow bedrock is 3.6×10^{-8} m/s. The calibrated hydraulic conductivity for deep bedrock zones ranges from 2×10^{-8} to 1×10^{-7} m/s.

A horizontal to vertical hydraulic conductivity anisotropy ratio of 10:1 was applied in the overburden to represent horizontal stratification of the different soil types (clay, silty, sand, and gravel/cobbles) that make up the overburden. A horizontal to vertical hydraulic conductivity anisotropy ratio of 1:1 was applied in bedrock to represent the relatively uniform vertical to horizontal hydraulic characteristics of the folded and fractured bedrock.

The calibrated hydraulic conductivity values are generally consistent with the measured hydraulic conductivity values obtained from slug tests and packer tests conducted at the Goldboro Mine Site. The calibrated hydraulic conductivity for the bedrock fractured bedrock tended towards a higher value (3.59×10^{-7} m/s), while the calibrated hydraulic conductivity for the deep bedrock tended towards a lower value (1.61×10^{-8} m/s), which is consistent with the CSM of reduced permeability with depth in the bedrock, as presented in Section 3.3.1.2.

The calibrated recharge rates vary between 100 and 450 mm/yr. As in Section 6.3 the average recharge rate (252 mm/year) over the entire model domain based on the volumetric water budget is comparable with the estimated baseflow (253 mm/year) of the study area.

6.4 Model Evaluation

Orex reported that inflow rates into mine workings during dewatering activities in 1990 ranged from 18.5 to 21.1 liters per second (L/s) (Orex, 1990); however, there is limited technical data available pertaining to the area pumped, the extent of the workings dewatered, or the water level measurements in shafts or other observation points. GHD used this limited available data to evaluate the calibrated model.

To estimate the groundwater inflow rate into historical mine working using the calibrated model, GHD assumed that the entire Orex and Boston Richardson mine workings were dewatered during the dewatering work in 1990. In the next step, all the model cells that are intercepted by these historical mine workings were assigned as drain cells. The conductance term of the drain cells that are not completely taken by mine working were corrected to account for the pressure loss through the portion of the computational cell that is occupied by the bedrock.

In order calculate the conductance term, GHD assumed that the mine working is located at the center of the computational cell (Figure 6.4). The conductivity of the aquifer material at the computational cell then can be used to account for the aquifer head loss inside the computational drain cell. The drain bed thickness was calculated for all of the drain cells. The conductance of the drain BC then was calculated based on the hydraulic conductivity of the cell, cell geometry and the drain bed thickness.

The calibrated model then was run under steady-state conditions and the total mine workings drain volumetric water budget/discharge rate was evaluated. Discharge to the mine workings under calibrated conditions is 22.8 L/s. This value is slightly higher than the reported value of mine working inflow (18.1 to 21.1 L/s). The slight overestimation of seepage into the historical mine working is conservative with respect to the simulation of pit inflow volumes and changes in baseflow.

The model evaluation has provided further evidence that the calibrated model is capable of simulating groundwater condition in the study area.

6.5 Sensitivity Analysis

Composite sensitivity evaluates the sum of changes in simulated groundwater elevations at each calibration target location that result from changes in calibration parameter values. An individual sensitivity value is calculated as the ratio of change in simulated value per unit change in parameter value. The composite sensitivity is the sum of individual sensitivities. Composite sensitivities are summarized in Table 6.4 and shown on Figure 6.5. As shown on Figure 6.5, in order of most to least sensitive, the four most sensitive parameters are the recharge for areas with imperfect drainage, areas with rapid drainage, areas with poor drainage, and areas with excessive drainage. Since the applied recharge rate directly impacts simulated water levels it follows that recharge rates are the most sensitive parameters. Areas with imperfect drainage cover the majority of the Project area, with rapidly draining areas covering the next largest area within the Project. This supports that the identification of sensitive model parameters is consistent with the hydrogeologic understanding of the Project area. Overall, the conductivity of streambed sediments shows the least impact on the observations.

7. Groundwater Flow Model Application

As described in Section 1.2, the primary objectives of this modelling effort include simulating the predictive scenarios to estimate the following:

1. Groundwater inflow rates into the open pit mine at East Pit EOM and West Pit EOM, and into the pit lakes at PC
2. Groundwater drawdown at East Pit EOM, West Pit EOM, and PC
3. Change in groundwater discharge to/from surface water bodies at East Pit EOM, West Pit EOM, and PC
4. Transport of COCs from mine features into the surrounding environment at East Pit EOM, West Pit EOM, and PC

GHD implemented the East Pit EOM, West Pit EOM, and PC scenarios in the calibrated model to simulate potential impacts of the Project development. As described in Section 1.2, East Pit EOM corresponds to the condition where the east pit is fully extracted and the west pit is partially extracted, and West Pit EOM corresponds to the condition where the east pit is partially filled with water and the west pit is fully extracted. East Pit EOM and West Pit EOM were selected as they correspond to the worst-case scenarios with respect to simulated baseflow reduction, drawdown, and pit inflow rates. PC was selected for evaluation as it corresponds to the long-term reclamation condition and will represent the worst case with respect to the extent of COC migration from the WRSAs. Where appropriate, predictive simulation results are compared against spatial boundaries and regulatory guidelines to assess the extent and significance of potential impacts. The implementation of the East Pit EOM, West Pit EOM, and PC scenarios in the calibrated groundwater flow model is described in Section 7.1. Section 7.2 presents the definition of spatial boundaries and applied regulatory criteria to assess the potential impacts at the East Pit EOM, West Pit EOM, and PC scenarios. The predictive simulation results are summarized in Section 7.3 and the sensitivity/uncertainty analysis of the predictive results is present in Section 7.4.

7.1 Scenario Implementation

7.1.1 Estimation of Groundwater Inflow Rates at East Pit and West Pit EOM, and PC

East Pit EOM and West Pit EOM are simulated by incorporating the proposed open West and East pits and associate Project infrastructure into the calibrated model. The proposed open pits are represented by specifying drain cells along the perimeter of the pits and setting internal model cells within the proposed pits to no-flow boundaries. For West Pit EOM, where the east pit is partially filled, constant head cells were specified below an elevation of 32 m AMSL representing the partially filled pit. A PC, constant head cells were specified below an elevation of 50.24 m AMSL for the east pit and below 51.7 m AMSL for the west pit. As discussed in Section 5.2.4, a high conductance value of 1,000 m^2/d is assigned to the drain cells such that water entering a drain cell will discharge to the open pit without resistance when the groundwater elevation is above the drain stage elevation. The simulated volumetric flow of water entering the pit drain cells is summed over the entire West and East pit to estimate the total groundwater inflow rate into the pits at East Pit and West Pit EOM under the average annual conditions.

7.1.2 Estimation of Drawdown at East Pit EOM, West Pit EOM, and PC

Simulated drawdown is estimated by comparing simulated groundwater elevation contours under the calibrated baseline conditions against groundwater elevations simulated at East Pit EOM, West Pit EOM, and PC. Each comparison was completed assuming steady-state conditions to simulate the maximum potential drawdown under each scenario. Steady-state conditions are conservative for East Pit EOM and West Pit EOM because the actual drawdown may not reach steady-state conditions during operations and subsequent filling of the pits. To estimate drawdown for each condition, simulated groundwater elevation contours at East Pit EOM, West Pit EOM, or PC were subtracted from simulated groundwater elevation contours for the calibrated baseline model. The extent of drawdown was compared against the project area (PA), local assessment area (LAA), and regional assessment area (RAA) boundaries shown on Figure 7.1.

7.1.3 Simulated Change in Groundwater Discharge to/from Surface Water Bodies

GHD applied the numerical groundwater flow model to predict potential changes in groundwater discharge to/from surface water bodies (i.e., baseflow) that may occur resulting from Project development at East Pit EOM, West Pit EOM, and PC. Simulated baseflow is calculated through a mass balance of river boundary conditions representing lakes, streams, and wetlands within the model domain boundaries (i.e., baseflow is equal to the simulated groundwater recharge from surface water bodies minus groundwater discharge to surface water bodies). Simulated baseflow at East Pit EOM, West Pit EOM, and PC is subtracted from the simulated baseflow for the calibrated model representing baseline conditions to estimate the potential change in baseflow. The change in baseflow is calculated to estimate a potential range in baseflow impacts moving from the current condition (the calibrated model under baseline conditions) to East Pit EOM, West Pit EOM, and then to PC condition. The calibrated baseflow estimates are estimated and reported for surface water assessment points shown on Figure 7.1.

7.1.4 COC Transport

The development of the Goldboro Mine Site has the potential to degrade groundwater and surface water quality within and surrounding the Project. Water that migrates through the waste rock may have associated COC concentrations that could migrate into the surrounding environment. Therefore, GHD developed a contaminant transport model to simulate the potential migration of COCs at the Goldboro Mine Site at East Pit EOM, West Pit EOM, and PC.

Three naturally occurring transport mechanism zones were specified, corresponding to the overburden, shallow bedrock, and deep bedrock. The transport mechanism zones reflect the difference in transport parameters representative of the geologic/lithologic material of each zone. Effective porosity values of 0.15, 0.1 and 0.02 were assigned to the overburden, fractured bedrock, and bedrock respectively, consistent with the range of literature values presented in Freeze and Cherry (1979) and Spitz and Moreno (1996).

The COCs are treated as a conservative tracer using a constant unit concentration specified within each source zone. Sorption/retardation and reactions along the groundwater flow path, which may reduce COC concentrations, are conservatively assumed to be negligible and therefore were not simulated. The COC transport mechanisms implemented in each zone include advection and dispersion only, which are discussed in Sections 7.1.5.1 and 7.1.5.2, respectively.

COC migration is simulated using MT3DM-USGS For each potential source zone that may have a unique source concentration (i.e., WRSAs, overburden and organic stockpiles), an independent transport simulation was conducted. COC migration is simulated for eight and 11 years for East Pit EOM and West Pit EOM, respectively. It is conservatively assumed that the waste rock stockpiles are fully constructed and that COCs are leaching into groundwater at year 0 of each simulation. For PC contaminant transport is simulated for 500 years to approximate steady-state conditions and provide a conservative estimate of maximum concentrations at potential receptors (i.e., the nearby surface water bodies of concern and residential water well locations). The concentrations simulated at each receptor were multiplied by the source concentrations for each potential COC source, owing to the linear nature of the 3D contaminant transport equation. Using the principle of superposition[3] concentrations were summed across each transport simulation (i.e., NE WRSA, till stockpile, and organics stockpile) to estimate the total COC concentrations at potential receptors. Source concentrations are presented in Table 7.1, 7.2, and 7.3 for East Pit EOM, West Pit EOM, and PC, respectively. It should be noted that the same source concentrations are applied for both East Pit EOM and West Pit EOM. The base case source concentration represents the median predicted source concentration while the upper case source concentration represents the 90th percentile predicted source concentration.

7.1.4.1 Advection

Advection, the bulk movement of a fluid through a geologic medium, is the primary transport mechanism at the Goldboro Mine Site. The advection mechanism is governed by Darcy's Law, which determines the groundwater flow velocity, accounting for the hydrogeologic characteristics (hydraulic gradients, hydraulic conductivity, and porosity), of the aquifer. Groundwater flow conditions simulated by MODFLOW-NWT represent advection throughout the entire model domain. MT3D-USGS uses the groundwater flow field simulated by MODFLOW-NWT as input for solving the advection-dispersion transport equation.

7.1.4.2 Dispersion

Dispersion is a transport mechanism by which a solute spreads along the groundwater flow path. Dispersion results from two basic processes: molecular diffusion; and mechanical mixing. Molecular diffusion is a process where solutes move from zones of higher concentrations to zones of lower concentrations. The driving force of this movement is kinetic activity at the molecular level. Mechanical dispersion occurs due to the variability (i.e., heterogeneity) in pore-space groundwater velocities that act to spread or mix a solute in an aquifer. The primary aquifer characteristics that cause this mixing are variable frictional forces in pore channels, variations in pore channel geometry, and pore channel branching.

Dispersion/spreading of solutes during groundwater flow results in dilution of solute pulses and attenuation of concentration peaks. This dilution/attention affect is accounted for in the transport equation by applying longitudinal, transverse, and vertical dispersivity coefficients in a 3D domain.

Obtaining field measurements of the dispersivity is impracticable. However, simple estimate techniques, based on the length of plume or distance to the measured point (″scale″), are available by compiling field data. It is noted that researchers indicate dispersivity values can range over two to three orders of magnitude for a given value of plume

[3] The principle of superposition states that for a linear problem (i.e., the 3D contaminant transport equation), the net response caused by two or more stimuli (e.g., contaminant sources) is the sum of the responses that are caused by each stimulus individually. Therefore, each source zone can be simulated independently and summed together to estimate the total combined impact of all sources at a given receptor.

length or distance to a measurement point (Gelhar et al., 1992). Empirical relationships of dispersivity versus plume length (L_P) are provided by Al-Suwaiyan (1996) and Xu and Eckstein (1995), as follows:

$$\alpha_L = 0.82\left(\log_{10}(L_P)\right)^{2.446} \qquad \text{Equation 7.1}$$

Where:

α_L = is the longitudinal dispersivity in m

L_P = is the estimated plume length (m)

The plume length or scale is assumed to be 200 m, roughly corresponding to the maximum distance from a potential source zone (i.e., the waste rock piles) to a potential groundwater receptor (i.e., Goldboro Lake). Using an assumed plume length of 200 m, an estimated longitudinal dispersivity value of 6.2 m was calculated. The horizontal transverse dispersivity was specified to be 1/10 of the longitudinal dispersivity and the vertical transverse dispersivity was assumed to be 1/100 of the longitudinal dispersivity, as suggested by Gelhar et al. (1992) and Spitz and Moreno (1996).

7.2 Spatial Boundaries

The spatial boundaries considered in the evaluation of potential groundwater impacts resulting from the Goldboro Mine Site development are the PA, LAA, and RAA. The PA, LAA, and RAA boundaries are presented on Figure 7.1. The PA encompasses the Project infrastructure including the west and east pits, WRSAs, mill infrastructure and TMF. The LAA encompasses a 500 m buffer surrounding the PA or to the extents to the groundwater flow model domain where the groundwater flow model domain is located within 500 m of the PA. The LAA was selected encompass expected direct or indict impacts between the PA and nearest identified residential well. The boundary of the LAA is located over 250 m from the nearest identified residential well. The RAA aims to account for the maximum extent of potential groundwater quality and quantity impacts and roughly corresponds to the extent of the groundwater flow model domain. As an additional assessment, groundwater impacts are also compared against the locations of the nearest residential dwellings that potentially have potable wells.

7.3 Regulatory Guidelines

Potential groundwater quality impacts should be compared against appropriate groundwater quality guidelines. While there are no potable groundwater uses within the PA, a portion of the Project is located on Crown land and potentially could be considered potable in the future. Therefore, simulated COC concentrations are compared against lower of the Nova Scotia Environment (NSE) Tier 1 Environmental Quality Standards (EQS) for potable coarse-grained soil for agricultural/residential use and maximum acceptable concentrations (MAC) specified under the Guidelines for Canadian Drinking Water Quality (GCDWQ), herein referred to as Potable Criteria. It is recognized that some COCs, including arsenic and manganese, are naturally present in groundwater at concentrations that exceed NSE Tier 1 EQS or MACs specified under the GCDWQ. Simulated COC concentrations are also compared against the fresh water Nova Scotia (NS) Tier II Pathway-Specific Standards (PSS) for groundwater discharging to surface water (> 10m).

7.4 Scenario Simulation Results

7.4.1 Simulated Groundwater Inflow Rates at East Pit EOM, West Pit EOM, and PC

Groundwater inflow rates into the open pit are simulated at East Pit EOM, West Pit EOM, and PC. The simulated volumetric flow from the pit drain cells is summed over the entire west and east open pits to estimate the potential groundwater inflow rates into the open pits. At East Pit EOM the simulated groundwater inflow rates are 1,811 and 1,874 m^3/day for the east and west pits, respectively. At West Pit EOM the simulated groundwater inflow rates are 950 and 2,168 m^3/day for the east and west pits, respectively. At PC, the simulated groundwater inflow rates are 474 and 524 m^3/day, for the east and west pits, respectively.

7.4.2 Simulated Drawdown

Figures 7.2, 7.3, and 7.4 show simulated drawdown at East Pit EOM, West Pit EOM, and PC. As shown on Figures 7.2 and 7.3, the greatest extent of drawdown is simulated at West Pit EOM and East Pit EOM. This is expected as West Pit EOM and East Pit EOM correspond to the maximum extraction and dewatering of the west and east pits, respectively. Maximum simulated extent of drawdown at East Pit EOM and West Pit EOM is contained inside the PA. There is also groundwater table drawdown simulated under the TMF which is due to a reduction in groundwater recharge associated with lining the TMF facility. Figure 7.4 shows that simulated drawdown decreases at PC relative to East Pit EOM and West Pit EOM. Under all three scenarios, East Pit EOM, West Pit EOM, and PC, the predicted drawdown or radius of influence does not reach the nearest residential water well. The maximum predicted extent of drawdown, defined as 0.5 m of drawdown, extends approximately 500 m from the open pits, and the nearest residential water well is located approximately 1.5 km from the pits.

7.4.3 Simulated Change in Baseflow

GHD applied the numerical groundwater flow model to simulate potential changes in baseflow that may occur within and surrounding the Project area under East Pit EOM, West Pit EOM, and PC conditions. The simulated change in baseflow is assessed for select assessment points downgradient of Gold Brook Lake. The simulated changes in baseflow at surface water assessment points located downstream of Gold Brook Lake are presented in Table 7.4.

GBL-Outlet, located downstream of Gold Brook Lake (see Figure 7.1) measures surface water runoff and baseflow from Gold Brook and its tributaries. Each assessment point downstream of GBL-Outlet represents the Gold Brook watershed area between the assessment point and GBL-Outlet. For example, GB-DS1 represents the Gold Brook watershed area between GBL-Outlet and GB-DS1, and GB-DS6 represents the Gold Brook watershed area between GBL-Outlet and GB-DS6. Assessment point GBL-Outlet includes the simulated change in baseflow for Gold Brook Lake and all contributing drainage areas upstream of Gold Brook Lake. As shown in Table 7.4, the simulated baseflow reduction ranges from 53 to 320 percent at East Pit EOM, from 50 to 254 percent at West Pit EOM, and from 34 to 86 percent at PC. It should be noted that at PC, baseflow to the filled pit lakes is not included as baseflow within the watersheds and including that baseflow would result in a negligible impact at PC. Simulated changes in baseflow are incorporated into the site water balance assessment (GHD, 2022a) to assess the impact of baseflow change on surface water flows. During mine operations, all groundwater discharge to the open pit mine and to the surface water management ditches will be managed and ultimately discharged to Gold Brook Lake and Gold Brook. Once the east pit lake has reached 50.24 m AMSL and West pit has reached 51.74 m AMSL the pit lakes will naturally discharge to Gold Brook.

7.4.4 Simulated COC Transport

GHD conducted COC transport simulations to estimate the location and significance of potential COC impacts to surface water and the extent of impacts to groundwater quality. Simulated COC mass loadings from groundwater to surface water are presented in Table 7.5, 7.6, and 7.7 for East Pit EOM, West Pit EOM, and PC, respectively. Simulated COC mass loadings are assessed at four assessment points downstream of Gold Brook Lake, GBL-Outlet, GB-DS2, GB-DS4, and GB-DS6. Simulated COC mass loadings at each assessment point are incorporated into the predictive water quality assessment (GHD, 2022b) to predict the potential cumulative impact, from groundwater discharge and surface water runoff, of the Project on surface water quality.

Simulated unit concentration contours presented on Figures 7.5 through 7.9 for East Pit EOM. Figure 7.10 to 7.14 illustrates the unit concentration for West Pit EOM. The simulated unit concentrations for PC are shown on Figure 7.15 to 7.17. These figure show that the maximum unit concentration simulated to discharge to a natural surface water body occurs around Gold Brook Lake and to Gold Brook and are captured by the assessment points downstream of Gold Brook Lake and along Gold Brook.

To assess the potential impact of the Project on groundwater quality, the predicted concentrations for each COC using upper case source concentrations are compared against Potable Criteria for East Pit EOM, West Pit EOM and PC are illustrated on Figure 7.18 to 7.35. In these figures a predicted exceedance of Potable Criteria is indicated in red. The results show that with the exception of arsenic at PC, any predicted increase in COC concentrations above potable criteria is contained within the PA at East Pit EOM, West Pit EOM, and PC condition. The predicted increase in arsenic concentrations above Potable Criteria only extends a small distance (approximately 100 m) southeast of the PA and is within the range in arsenic concentrations observed in monitoring wells installed within the PA. Predicted COC concentration increases above Potable Criteria do not extend to within 1 km of the nearest residential well.

To aid in the assessment of wetland and fish and fish habitat assessments, GHD also compared simulated COC concentrations using upper case source concentrations against NS Tier II PSS for groundwater discharging to surface water (>10 m). Figures 7.36 through 7.57 present the comparison of simulated COC concentrations against NS Tier II PSS for groundwater discharging to surface water (>10 m). Figures 7.36 through 7.57 are provided as input for the wetland and fish and fish habitat assessment.

7.5 Scenario Simulation Sensitivity/Uncertainty Analysis

As identified in the sensitivity analysis of calibrated model parameter values presented in Section 6.5, recharge from precipitation infiltration is the most sensitive parameter for model calibration. It is also anticipated that changes in recharge rates due to seasonality or variability between years would impact predicted inflow rates into the open pits and potentially the predicted change in baseflow as well. Changes in recharge rates are less likely to impact predicted COC concentrations at groundwater receptors due to the slow migration of groundwater through the subsurface which will occur over several years and is thus well represented on an average annual basis. Therefore, GHD conducted a sensitivity/uncertainty analysis on the predicted pit inflow rates and changes in baseflow under wet and dry conditions to consider potential seasonal variations in recharge rates and surface water elevations. Section 7.5.1 and 7.5.2 present the sensitivity/uncertainty analysis of pit inflow rates and changes in baseflow under wet and dry seasons conditions, respectively.

7.5.1 Wet Conditions Sensitivity/Uncertainty Analysis

GHD estimated that during wet seasons the precipitation increases by 19 percent from the average annual precipitation over the study area (GHD 2022a). It is also estimated that the average Gold Brook Lake elevation is 51.92 m AMSL during wet seasons and the average water level in creeks and wetlands rises 0.22 m during wet seasons (GHD 2022c).

GHD assumed that percent increase in recharge during wet seasons is the same as the percent increase in precipitation during wet seasons. Therefore, GHD increased recharge over the model domain by 19 percent to represent wet season groundwater recharge. GHD also increased the surface water elevation of Gold Brook Lake to 51.92 m AMSL and increased the surface water elevations of creeks and wetlands by 0.22 m to represent the wet season condition. Sections 7.5.1.1 and 7.5.1.2 presented the estimation of pit inflow rates and changes in baseflow, respectively, under the wet season condition.

7.5.1.1 1.4 Inflow

Simulated groundwater inflow rates under the wet season condition at East Pit EOM are 1,867 and 1,935 m^3/day (3.1 and 3.2 percent increase from the average annual conditions) for the east and west pits, respectively. The simulated groundwater inflow rates under the wet season condition at West Pit EOM are 993 and 2,228 m^3/day (4.5 and 2.8 percent increase from the average annual conditions) for the east and west pits, respectively. The simulated groundwater inflow rates under the wet season condition at PC are 514 and 561 m^3/day (8.4 and 7.0 percent increase from average conditions) for the east and west pits, respectively.

7.5.1.2 Baseflow

The simulated baseflow reduction under the wet season condition is presented in Table 7.8. Table 7.8 also presents the percent change from the average condition. The percent change is calculated by subtracting percent change from baseline conditions in wet seasons from percent change from baseline in average condition divided by the percent change from baseline in the average condition. Table 7.8 demonstrates that the percent change from baseline conditions decreases under wet conditions. Therefore, the precent change in baseflow is predicted to decrease during wet seasons for East Pit EOM, West Pit EOM, and PC.

7.5.2 Dry Conditions Sensitivity/Uncertainty Analysis

GHD estimated that during wet seasons the precipitation decreases by 9 percent over the study area (GHD 2022a). GHD also estimated that the average Gold Brook Lake elevation is 51.1 m AMSL during dry seasons and that the average water level at creeks and wetlands decreases 0.14 m during Dry seasons (GHD 2022c).

Using the same approach as was applied for the wet season condition, GHD decreased recharge over the model domain by 9 percent, set the elevation of Gold Brook Lake to 51.1 m AMSL and decreased the surface water elevations of creeks and streams by 0.14 m to represent the dry seasons condition. Sections 7.5.2.1 and 7.5.2.2 presented the estimation of pit inflow rates and changes in baseflow, respectively, under the dry season condition.

7.5.2.1 1.4 Inflow

Simulated groundwater inflow rates under the dry season condition at East Pit EOM are 1,781 and 1,843 m^3/day (1.6 and 1.7 percent decrease from average conditions) for the east and west pits, respectively. The simulated groundwater inflow rates under the dry season condition at West Pit EOM are 925 and 2,137 m^3/day (2.6 and 1.4 percent decrease from average conditions) for the east and west pits, respectively. The simulated groundwater inflow rates under the dry season condition at PC are 474 and 524 m^3/day (4.7 and 3.7 percent decrease from average conditions) for the east and west pits, respectively.

7.5.2.2 Baseflow

The simulated baseflow reduction under the dry season condition is presented in Table 7.9. Table 7.9 also presents the percent change from the average condition. Table 7.9 shows that the percent baseflow reduction in dry seasons is predicted to increase by up to 8 percent from average annual conditions at East Pit EOM and up to 7 percent from average annual conditions at West Pit EOM. Predicted baseflow reductions increase up to 3.4 percent from average annual conditions at PC. The simulated change in baseflow reduction under the dry season condition is generally insignificant in comparison to the total baseflow reduction simulated under the average annual condition.

8. Summary and Conclusions

GHD developed a 3D numerical groundwater flow model to represent the geologic and hydrogeologic conditions within the overburden and bedrock observed at the Project and surrounding area. The 3D groundwater flow model is based on a hydrogeological CSM GHD developed for the Project area to facilitate representation of the observed hydrogeological conditions. The groundwater flow model was developed using the USGS's MODFLOW-NWT groundwater flow computer program. GHD calibrated the groundwater flow model to provide a reasonable representation of observed groundwater elevations and estimated baseflow (i.e., groundwater discharge to surface water). GHD further evaluated the calibrated model against observed inflow rates into the historical Orex and Boston-Richardson mine workings. The inflow rate predicted by the calibrated model is comparable with the inflow rates reported for the Orex and Boston-Richardson mine workings. The model input parameters (e.g., hydraulic conductivity and recharge) applied in the calibrated model are consistent with observed Project conditions. The model calibration, evaluation, and application of parameter values consistent with observed parameter value ranges demonstrates that the calibrated model is suitable for the application of predicting Project impacts to groundwater impacts relative to simulated baseline Project conditions. To address potential uncertainty in the model calibration dataset, a sensitivity analysis was conducted to identify sensitive model parameters and inform the uncertainty analysis of model predictions.

Using the calibrated model, GHD estimated the pits inflow rates. At East Pit EOM the simulated groundwater inflow rates range from 1,781 to 1,867 m^3/day for the east pit and from 1,843 to 1,935 m^3/d for the west pit. At West Pit EOM the simulated groundwater inflow rates range from 925 to 993 m^3/day for the east pit and from 2,137 to 2,228 m^3/d for the west pit. At PC, the simulated groundwater inflow rates range from 474 to 514 m^3/day for the east pit and from 524 to 561 m^3/d for the west pit.

GHD applied the calibrated model to predict potential groundwater quantity impacts at East Pit EOM, West Pit EOM, and PC. Simulated drawdown of 0.5 m extends approximately 500 m from the proposed pits and does not extend beyond the PA for East Pit EOM and West Pit EOM. Simulated drawdown decreases in PC once the east and west pits have filled. Drawdown of the groundwater table is not predicted to reach the nearest residential water well located over 1.5 km from the pits. The simulated reduction in baseflow ranged from 53 to 320 percent at East Pit EOM, from 50 to 254 percent at West Pit EOM, and from 34 to 86 percent at PC for Gold Brook Lake and downstream assessment points located along Gold Brook. Simulated changes in baseflow are incorporated into the site water balance assessment (GHD, 2022a) to assess the impact of baseflow change on surface water flows. GHD conducted an uncertainty analysis on predicted changes in baseflow to assess potential impacts of seasonality on baseflow predictions. The uncertainty analysis demonstrates that the percent change in baseflow from baseline conditions will decrease in wet seasons and will increase in dry seasons by up to 8 percent at East Pit EOM, 7 Percent at West Pit EOM and 3.4 percent at PC.

GHD also applied the calibrated groundwater model to simulate potential COC impacts to surface water bodies surrounding the Goldboro Mine Site. Simulated mass loadings of COCs from groundwater to surface water were provided as input to the Predictive Water Quality Assessment (GHD, 2022b) to assess the cumulative impact of the Project on surface water quality as a result of predicted changes in groundwater quality and the discharge of surface water runoff collected within the PA. GHD also provided a comparison of predicted COC concentration increases in groundwater against NS Tier II PSS criteria to identify potential locations of impacts to surface water features including streams and wetlands. The comparison of predicted COC concentration increases in groundwater against Tier 2 PSS criteria is incorporated into the wetlands and fish and fish habitat assessments to determine the significance of potential impacts of groundwater discharge on wetlands and fish and fish habitat. Finally, GHD compared predicted COC concentrations in groundwater against Potable Criteria to assess the extent of potential groundwater COC impacts and to determine if water quality at residential water well locations could potentially be impacted by the Project. With the exception of arsenic, the predicted increase in COC concentrations above portable criteria does not extend beyond the PA. The predicted increase in arsenic concentration above Potable Criteria only extends a small distance (~100m) beyond the PA and is within the range in arsenic concentrations observed in monitoring wells installed within the PA. Predicted COC concentration increases above Potable Criteria do not extend to within 1 km of the nearest residential well.

Model development and predictive scenario analysis is based on data available at the time of model development.

9. References

Azam, S., Wilson, G. W., Fredlund, D. G., & Van Zyl, D. (2011). Geotechnical characterization of mine waste rock. In Proceedings of the 17th International Conference on Soil Mechanics and Geotechnical Engineering: 5-9 October 2009, Alexandria, Egypt (volume 5) (pp. 3421-3425). IOS Press.

Arnold, J.G., R.S. Muttiah, R. Srinivasan, and P.M. Allan, 2000. Regional Estimation of Base Flow and Groundwater Recharge in the Upper Mississippi River Basin, Journal of Hydrology, 227, pp. 21 40.

Bedekar, V., E.D. Morway, C.D. Langevin and M. Tonkin, 2016. MT3D-USGS Version 1: A U.S. Geological Survey Release of MT3DMS Updated with New and Expand Transport Capabilities for Use with MODFLOW: U.S. Geological Survey Techniques and Methods 6-A53, 69 p, http://dx.doi.org/10.3133/tm6A53.

Duncan, D.R., 1987. Assessment Report on 1987 Exploration Programme on Development License 0078, Halifax County, Nova Scotia, MTS 11E/2. Nova Scotia Department of Natural Resources Assessment Report AR ME 1987 117.

Freeze, R.A., and Cherry, J.A., 1979. Groundwater: Englewood Cliffs, NJ, Prentice-Hall, 604 p.

GHD, 2022a. Water Balance Analysis Summary Report. Ref No. 11222385 Report 6. April.

GHD, 2022b. Predictive Water Quality Assessment. Ref No. 11222385 Report 7. April.

GHD, 2022c. 2021 Surface Water Monitoring Report. Ref No. 1222385 Report 4, March.

Goldthwait, J.W., 1924. Physiography of Nova Scotia, Department of Mines, Geological Survey of Canada. Memoir 140, No. 122, Geological Series.

GoldSim Technology Group (2021), GoldSim User's Guide (Version 4.0), https://www.goldsim.com/Web/Customers/Education/Documentation/, October 2021.

Harbaugh, A.W. 2005. MODFLOW 2005, The U.S. Geological Survey Modular Ground Water Model the Ground Water Flow Process, Chapter 16 of Book 6. Modeling Techniques, Section A. Ground Water. U.S. Geological Survey Techniques and Methods 6 A16.

Harbaugh, A.W., R. Banta, M. Hill, and M.G. McDonald, 2000. MODFLOW 2000, The U.S. Geological Survey Modular Ground Water Model — User Guide To Modularization Concepts And The Ground Water Flow Process, United States Geological Survey Open File Report 0092, Reston, Virginia.

Healy, R.W., 2010. Estimated Groundwater Recharge, Cambridge University Press.

Jacques, Whitford & Associates Ltd. (JWA), 1986. Environmental Assessment of Gold Mining Exploration Beaver Dam, Nova Scotia.

Kennedy, G.W., K.G. Garroway and D.S. Finlayson-Bourque, 2010. Estimation of Regional Groundwater Budget in Nova Scotia, Nova Scotia Department of Natural Resource, Open File Illustration ME 2010-2.

Malcom, W., 1929, Gold fields of Nova Scotia,Geol. Surv. Can., Mem. 156, 253 p.

McDonald, M.G. and A.W. Harbaugh, 1988. A Modular Three Dimensional Finite Difference Ground Water Flow Model. Techniques of Water Resources Investigations of the United States Geological Survey, Book 6, Survey Open File Report 83 875.

Momeyer, S. A. (2014). Hydrologic processes in unsaturated waste rock piles in the Canadian subarctic (Doctoral dissertation, University of British Columbia).

MRB & Associates (2004). Technical Report, Goldboro Property, Guysborough County, Nova Scotia.

Niswonger, R.G., 2011. MODFLOW NWT, A Newton Formulation for MODFLOW 2005, Chapter 37 of Section A, Groundwater Book 6, Modeling Techniques and Methods 6 A37.

Orex, 1990. Environmental Assessment Report for a Proposed Gold Mine Project at GoldBoro, Guysborough County, Nova Scotia, Nolan, David & Associates.

Remy, N., Boucher, A., & Wu, J. (2009). Applied Geostatistics with SGeMS: A user's guide. Cambridge University Press.

Risser, D.W., Gburek, W.J., and Folmar, G.J., 2005, Comparison of methods for estimating ground water recharge and base flow at a small watershed underlain by fractured bedrock in the eastern United States: U.S. Geological Survey Scientific Investigations Report 2005–5038, 31 p.

Rumbaugh, J.O. and D.B. Rumbaugh, 2020. Guide to Using Groundwater Vistas, Version 8, Environmental Simulations, Inc., Leesport, Pennsylvania.

Sangster, A.L. and P.K. Smith, 2007. Metallogenic Summary of the Meguma Gold Deposits, Nova Scotia. In Goodfellow, W.D., ed., Mineral Deposits of Canada: A Synthesis of Major Deposit Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods: Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5, p. 723 732.

Spitz, K., and J. Moreno, 1996. A Practical Guide to Groundwater And Solute Transport Modeling, John Wiley & Sons, Inc., Toronto, ON, pp. 461.

Stea, R., H. Conley, and Y. Brown, 1992. Surficial Geology of the Province of Nova Scotia Map 92-3.

Stea, R., and T., 1979, Fowler, Minor and Trace Element Variations in Winconsinan Tills, Eastern Shore Region, Nova Scotia, NSDME Paper No. 79-4.

Taylor, F.C., 1967, Reconnaissance geology of Shelburne map-area. Queens, Shelburne, and Yarmouth Counties, Nova Scotia, Geol. Surv. Can., Mem. 349, 83 p.

Watermark Numerical Computing, 2016. PEST, Model Independent Parameter Estimation User Manual Part I: PEST, SENSAN and Global Optimizers, 6th Edition, Watermark Numerical Computing, Brisbane, Australia, April.

Wei, Z.Q., Egger, P. and Descoeudres, F. (1995) ‘Permeability predictions for jointed rock masses’, *International Journal of Rock Mechanics, Mineral Science and Geomechanics*, 32, pp. 251–26l.

Williams, H., M.J. Kennedy and E, R, W. Neale, 1972, The Appalachian Structural Province, p. 182 261. In Price, R.A., and R. J. W. Douglas (ed.). Variations in Tectonic Styles in Canada. Geol. Assoc. Can. Spec. Pap. 11: 181 261.

WSP, 2019a. Hydrogeological Investigation-Updated, GoldBoro Project, Anaconda Mining Inc.

WSP, 2019b. Hydrogeological Modeling Study, GoldBoro Project, Anaconda Mining Inc.

Zheng, C., and P.P. Wang, 1999. "MT3DMS: A Modular Three Dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide", U.S. Army Corps of Engineers, Washington, DC, Contract Report SERDP 99 1, December.

Table 2.1

Slug Test Results
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

ID	Monitoring Well	Hydraulic Conductivity (m/s)	Analysis Method	Slug Test Method	Lithology
1	MW 17-01	9.00E-07	Hvorslev	Falling Head	Till (SM) (80%) and Bedrock (fractured greywacke) (20%)
2	MW 17-01	5.00E-07	Hvorslev	Rising Head	Till (SM) (80%) and Bedrock (fractured greywacke) (20%)
3	MW 17-02	5.00E-06	Hvorslev	Falling Head	Bedrock (fractured greywacke) (80%) and Till (SM) (20%)
4	MW 17-02	6.00E-06	Hvorslev	Rising Head	Bedrock (fractured greywacke) (80%) and Till (SM) (20%)
5	MW 17-02	6.00E-06	Hvorslev	Rising Head	Bedrock (fractured greywacke) (80%) and Till (SM) (20%)
6	MW 17-03D	8.00E-06	Hvorslev	Falling Head	Bedrock (fractured greywacke)
7	MW 17-03D	8.00E-06	Hvorslev	Rising Head	Bedrock (fractured greywacke)
8	MW 17-03S	3.00E-06	Hvorslev	Falling Head	Till (SM)

Table 2.2

Bedrock Hydraulic Conductivity Testing Results
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Borehole ID	Hydraulic Conductivity (m/s)	Test Midpoint Below Top of Bedrock (m)	Hydraulic Test Method/Type	Overburden Thickness (m)
MW17-02	6.00E-06	1.00	Slug test rising head	6.0
MW17-03D	8.00E-06	1.00	Slug test rising head	9.0
BR-17-MET-2	9.00E-07	4.00	Packer test	7.8
MW42B	2.73E-06	4.03	Packer test	5.0
MW51B	9.38E-06	4.21	Packer test	5.2
MW21B	1.15E-05	4.49	Packer test	4.7
MW23B	1.30E-05	4.98	Packer test	11.7
MW7B	1.43E-05	5.95	Packer test	3.8
MW5B	9.94E-08	6.02	Packer test	4.0
MW6B	4.56E-08	6.06	Packer test	2.7
BR-17-MET-2	7.00E-08	7.00	Packer test	7.8
MW16B	5.85E-06	8.89	Packer test	9.5
MW1B	4.59E-05	9.13	Packer test	1.6
MW15B	2.89E-06	12.81	Packer test	7.0
BR-17-MET-2	1.00E-07	13.00	Packer test	7.8
MW20B	6.09E-08	14.36	Packer test	4.0
MW21B	3.23E-05	14.98	Packer test	4.7
BR-17-MET-2	9.00E-08	15.00	Packer test	7.8
MW26B	1.72E-06	15.57	Packer test	2.5
MW56B	8.05E-05	15.84	Packer test	0.7
MW23B	1.12E-05	16.00	Packer test	11.7
MW42B	6.66E-06	17.27	Packer test	5.0
MW16B	1.83E-05	17.88	Packer test	9.5
MW46B	5.70E-07	19.12	Packer test	1.8
MW51B	4.65E-06	19.19	Packer test	5.2
MW1B	2.82E-04	19.62	Packer test	1.6
MW7B	2.62E-06	19.67	Packer test	3.8
MW5B	9.99E-08	19.77	Packer test	4.0
BR-17-MET-3	1.00E-06	20.00	Packer test	9.0
MW26B	7.37E-06	21.57	Packer test	2.5
MW15B	6.16E-06	21.96	Packer test	7.0
BR-17-MET-2	8.00E-08	23.00	Packer test	7.8
MW6B	2.26E-07	23.30	Packer test	2.7
BR21-270	3.10E-07	25.06	Packer test	3.9
MW56B	2.12E-04	26.30	Packer test	0.7
BR21-274	4.21E-07	28.61	Packer test	2.6
BR21-271	8.29E-07	32.71	Packer test	7.5
BR-17-MET-3	9.50E-07	37.00	Pumping Test	9.0
BR-17-MET-3	2.00E-07	39.00	Packer test	9.0
BR-17-MET-2	6.00E-08	40.00	Packer test	7.8
BR-17-MET-2	2.00E-08	44.00	Packer test	7.8
BR-17-MET-3	3.00E-07	48.00	Packer test	9.0
BR-17-MET-1	5.00E-08	51.62	Pumping Test	7.1
BR21-273	2.44E-07	52.51	Packer test	2.5
BR-17-MET-2	1.00E-07	64.00	Packer test	7.8
BR21-274	2.72E-07	85.61	Packer test	2.6
BR-17-MET-2	9.00E-08	88.00	Packer test	7.8
BR21-270	1.99E-07	94.07	Packer test	3.9
BR-17-MET-2	7.00E-08	100.00	Packer test	7.8
BR21-272	1.88E-07	100.51	Packer test	2.4
BR21-274	4.33E-07	109.61	Packer test	2.6
BR-17-MET-5	1.80E-07	114.91	Pumping Test	12.6
BR21-272	2.39E-07	115.51	Packer test	2.4
BR21-270	1.82E-07	123.46	Packer test	3.9
BR21-271	2.14E-07	134.71	Packer test	7.5
BR21-273	2.34E-07	148.51	Packer test	2.5
BR21-271	9.61E-08	149.71	Packer test	7.5
BR21-272	1.99E-07	166.51	Packer test	2.4
BR21-271	3.54E-07	179.71	Packer test	7.5
BR-17-MET-2	3.00E-08	189.00	Pumping Test	7.8
BR21-272	2.56E-07	193.51	Packer test	2.4
BR21-273	1.02E-07	193.51	Packer test	2.5
BR21-270	9.43E-08	199.06	Packer test	3.9
BR21-273	2.26E-07	217.51	Packer test	2.5
BR21-271	3.04E-07	218.71	Packer test	7.5
BR21-272	1.09E-07	223.51	Packer test	2.4

Table 5.1

Hydraulic Conductivity Zones
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Zone Number	Description	Model Layer	Hydraulic Conductivity			Anisotropy		
			Initial Estimate (m/s)	Lower Bound (m/s)	Upper Bound (m/s)	Initial Estimate (-)	Lower Bound (-)	Upper Bound (-)
1	Upper Till Excessive Drainage	1	1.50E-05	3.00E-06	1.50E-04	10	1	100
2	Upper till Rapid drainage	1	1.00E-05	2.00E-06	1.00E-04	10	1	100
3	Upper till Imperfect drainage	1	6.80E-06	1.40E-06	6.80E-05	10	1	100
4	Upper till Poor drainage	1	4.50E-06	9.00E-07	4.50E-05	10	1	100
5	Upper till Inundated	1	6.00E-07	1.20E-07	6.00E-06	10	1	100
6	Lower till	2	6.00E-07	1.20E-07	6.00E-06	10	1	100
7	Fractured bedrock (depth 0-30 meters)	3-4	1.80E-06	4.56E-08	1.83E-05	5	1	10
8	Competent bedrock (depth 30-120 meters)	5-10	3.80E-07	2.00E-08	8.30E-07	5	1	10
9	Competent bedrock (depth 120-255 meters)	11-19	1.80E-07	3.60E-08	9.00E-07	5	1	10
10	Competent bedrock (depth 255-372 meters)	20-22	5.40E-08	1.10E-08	2.70E-07	5	1	10
11	Competent bedrock (depth 372-600 meters)	23-24	1.70E-08	3.40E-09	8.60E-08	5	1	10

Table 6.1

Estimated Static Water Levels at Boreholes and Monitoring Wells
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

ID	Name	Water Level (m)	Model Layer
1	BR_91_110	58.63	3
2	BR_95_124	61.8	3
3	BR_18_47	62.95	3
4	BR_88_45	58.95	3
5	BR_18_45	58.78	3
6	BR_18_46	61.47	3
7	BR_18_43	68.58	3
8	BR_18_44	55.23	3
9	BR_18_48	52.04	3
10	BR_18_49	63.24	3
11	BR_18_50	76.88	3
12	BR_18_51	76.23	3
13	BR_18_52	76.84	3
14	BR_18_53	77.13	3
15	BR_18_54	74.99	3
16	BR_18_55	74.93	3
17	BR_18_56	71.26	3
18	BR_18_57	73.37	3
19	BR_18_58	73.02	3
20	BR_18_59	75.39	3
21	BR_18_60	73.39	3
22	BR_18_61	71.44	3
23	BR_18_62	75.49	3
24	BR_18_63	76.3	3
25	BR_18_64	61.31	3
26	BR_18_65	65.97	3
27	BR_18_66	63.68	3
28	BR_18_67	63.92	3
29	BR_18_68	51.94	3
30	BR_18_71	51.99	3
31	BR_19_100	56.48	3
32	BR_19_101	63.87	3
33	BR_19_102	66.76	3
34	BR_19_72	66.31	3
35	BR_19_73	68.25	3
36	BR_19_74	66.4	3
37	BR_19_75	66.73	3
38	BR_19_76	61.25	3
39	BR_19_87	51.47	3
40	BR_19_93	57.19	3
41	BR_19_94	59.5	3
42	BR_19_95	62.55	3
43	BR_19_96	65.81	3
44	BR_19_97	65.56	3
45	BR_19_98	52.83	3
46	BR-17-MET-1	64.07	3
47	BR-17-MET-2	64.72	3
48	BR-17-MET-3	62.24	3
49	BR-17-MET-4	51.47	3
50	BR-17-MET-5	55.06	3
51	BR-17-MET-6	54.54	3
52	BR-17-MET-7	54.24	3
53	BR-17-MET-8	54.85	3

Table 6.1

Estimated Static Water Levels at Boreholes and Monitoring Wells
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

ID	Name	Water Level (m)	Model Layer
54	BR-17-MET-9	54.81	3
55	BR-17-MET-10	58.6	3
56	BR-17-MET-11	60.1	3
57	BR_18_69	52	3
58	BR_18_70	52.21	3
59	BR_19_88	64.41	3
60	BR_19_91	54.7	3
61	BR_19_92	54.56	3
62	BR_19_99	54	3
63	MW17-01	59.29	2
64	MW17-02	52.11	3
65	MW17-02S	50.21	1
66	MW17-03D	50.43	3
67	MW17-03S	52.41	1
68	MW15-C	75.61025	15
69	MW15-B	79.675	4
70	MW15-A	79.782	1
71	MW7-B	84.52525	4
72	MW7-A	85.0045	3
73	MW20-B	70.68025	4
74	MW20-A	70.994	2
75	MW20-C	69.39175	9
76	MW46-C	71.87725	10
77	MW46-A	75.519	3
78	MW46-B	74.959	4
79	MW26-A	71.34	3
80	MW26-B	70.969	4
81	MW21-A	58.552	3
82	MW21-B	58.457	4
83	MW43-B	58.7285	3
84	MW43-A	59.913	3
85	MW5-A	57.72875	2
86	MW5-B	57.365	4
87	MW30-A	65.9625	3
88	MW30-C	57.1615	16
89	MW30-B	57.4625	4
90	MW6-A	62.2645	3
91	MW6-B	58.91975	4
92	MW29-B	55.066	3
93	MW29-A	55.159	2
94	MW23-A	55.691	2
95	MW23-B	55.214	4
96	MW54-A	57.081	2
97	MW54-B	56.965	3
98	MW55-B	68.45	3
99	MW55-A	69.607	2
100	MW1-A	110.256	3
101	MW1-B	104.777	4

Table 6.2

Model Calibration Targets and Residuals
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Monitoring Well ID	Model Layer	Observed GW Elevation (m AMSL)	Simulated GW Elevation (m AMSL)	Residual[1] (m)
BR-91-110	3	58.63	62.44	-3.81
BR-95-124	3	61.80	60.62	1.18
BR-18-47	3	62.95	62.47	0.48
BR-88-45	3	58.95	58.72	0.23
BR-18-45	3	58.78	57.92	0.86
BR-18-46	3	61.47	60.54	0.93
BR-18-43	3	68.58	67.57	1.01
BR-18-44	3	55.23	54.70	0.53
BR-18-48	3	52.04	51.31	0.73
BR-18-49	3	63.24	62.03	1.21
BR-18-50	3	76.88	76.58	0.30
BR-18-51	3	76.23	76.05	0.18
BR-18-52	3	76.84	76.73	0.11
BR-18-53	3	77.13	77.17	-0.04
BR-18-54	3	74.99	74.28	0.71
BR-18-55	3	74.93	74.28	0.65
BR-18-56	3	71.26	71.02	0.24
BR-18-57	3	73.37	72.99	0.38
BR-18-58	3	73.02	72.20	0.82
BR-18-59	3	75.39	75.02	0.37
BR-18-60	3	73.39	73.59	-0.20
BR-18-61	3	71.44	69.30	2.14
BR-18-62	3	75.49	74.75	0.74
BR-18-63	3	76.30	77.94	-1.64
BR-18-64	3	61.31	60.83	0.48
BR-18-65	3	65.97	65.13	0.84
BR-18-66	3	63.68	62.20	1.48
BR-18-67	3	63.92	64.02	-0.10
BR-18-68	3	51.94	51.46	0.48
BR-18-71	3	51.99	51.28	0.71
BR-19-100	3	56.48	53.44	3.04
BR-19-101	3	63.87	63.48	0.39
BR-19-102	3	66.76	66.89	-0.13
BR-19-72	3	66.31	66.83	-0.52
BR-19-73	3	68.25	67.28	0.97
BR-19-74	3	66.40	65.90	0.50
BR-19-75	3	66.73	66.87	-0.14
BR-19-76	3	61.25	60.47	0.78
BR-19-87	3	51.47	54.05	-2.58
BR-19-93	3	57.19	57.31	-0.12
BR-19-94	3	59.50	58.33	1.17
BR-19-95	3	62.55	61.10	1.45
BR-19-96	3	65.81	62.57	3.24
BR-19-97	3	65.56	63.32	2.24
BR-19-98	3	52.83	55.49	-2.66
BR-17-MET-1	3	64.07	63.74	0.33
BR-17-MET-2	3	64.72	63.53	1.19
BR-17-MET-3	3	62.24	62.45	-0.21

Table 6.2

Model Calibration Targets and Residuals
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Monitoring Well ID	Model Layer	Observed GW Elevation (m AMSL)	Simulated GW Elevation (m AMSL)	Residual[1] (m)
BR-17-MET-4	3	51.47	51.25	0.22
BR-17-MET-5	3	55.06	53.37	1.69
BR-17-MET-6	3	54.54	51.85	2.69
BR-17-MET-7	3	54.24	53.59	0.65
BR-17-MET-8	3	54.85	52.68	2.17
BR-17-MET-9	3	54.81	52.81	2.00
BR-17-MET-10	3	58.60	53.91	4.69
BR-17-MET-11	3	60.10	55.36	4.74
BR-18-69	3	52.00	51.31	0.69
BR-18-70	3	52.21	51.25	0.96
BR-19-88	3	64.41	62.68	1.73
BR-19-91	3	54.70	50.57	4.13
BR-19-92	3	54.56	50.57	3.99
BR-19-99	3	54.00	51.50	2.50
MW17-01	2	59.29	59.23	0.06
MW17-02	3	52.11	52.43	-0.32
MW17-02S	1	50.21	52.51	-2.30
MW17-03D	3	50.43	50.07	0.36
MW17-03S	1	52.41	50.34	2.07
MW15-C	15	75.61	78.73	-3.12
MW15-B	4	79.68	80.26	-0.58
MW15-A	1	79.78	80.45	-0.67
MW7-B	4	84.53	83.92	0.61
MW7-A	3	85.00	84.08	0.92
MW20-B	4	70.68	70.70	-0.02
MW20-A	2	70.99	70.92	0.07
MW20-C	9	69.39	70.11	-0.72
MW46-C	10	71.88	71.55	0.33
MW46-A	3	75.52	73.33	2.19
MW46-B	4	74.96	73.22	1.74
MW26-A	3	71.34	69.77	1.57
MW26-B	4	70.97	69.69	1.28
MW21-A	3	58.55	59.11	-0.56
MW21-B	4	58.46	58.92	-0.46
MW43-B	3	58.73	58.83	-0.10
MW43-A	3	59.91	58.84	1.07
MW5-A	2	57.73	57.92	-0.19
MW5-B	4	57.37	57.95	-0.58
MW30-A	3	65.96	63.39	2.57
MW30-C	16	57.16	63.00	-5.84
MW30-B	4	57.46	62.77	-5.31
MW6-A	3	62.26	61.19	1.07
MW6-B	4	58.92	61.04	-2.12
MW29-B	3	55.07	54.44	0.63
MW29-A	2	55.16	54.44	0.72
MW23-A	2	55.69	53.24	2.45
MW23-B	4	55.21	53.32	1.89
MW54-A	2	57.08	59.16	-2.08

Table 6.2

Model Calibration Targets and Residuals
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Monitoring Well ID	Model Layer	Observed GW Elevation (m AMSL)	Simulated GW Elevation (m AMSL)	Residual[(1)] (m)
MW54-B	3	56.97	59.27	-2.30
MW55-B	3	68.45	68.41	0.04
MW55-A	2	69.61	68.69	0.92
MW1-A	3	110.26	109.77	0.49
MW1-B	4	104.78	109.45	-4.67

Notes:

m	Metres
m AMSL	Metres above mean sea level
0.58	Positive groundwater elevation residual - over prediction of observed groundwater elevation
-1.58	Negative groundwater elevation residual - under prediction of observed groundwater elevation
(1)	Residual is calculated as observed groundwater elevation minus the simulated groundwater elevation.

Table 6.3

Calibrated Model Parameter Values
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Parameter	Units	Calibrated Value	Lower Bound	Upper Bound	Geometric Mean of Observed Values
Hydraulic Conductivity					
Upper Till Poor Drainage	(m/s)	4.09E-05	3.00E-06	1.50E-04	3.00E-06
Upper Till Imperfect Drainage	(m/s)	9.31E-06	3.00E-06	1.00E-04	3.00E-06
Upper Till Rapid Drainage	(m/s)	9.25E-06	3.00E-06	6.80E-05	3.00E-06
Upper Till Excessive Drainage	(m/s)	4.96E-06	3.00E-06	4.50E-05	3.00E-06
Upper Till Inundated	(m/s)	6.03E-07	1.20E-07	6.00E-06	3.00E-06
Lower Till	(m/s)	7.77E-07	1.20E-07	6.00E-06	7.00E-07
Fractured Bedrock (depth 0-30 meters)	(m/s)	3.59E-07	4.56E-08	1.83E-05	6.52E-07
Competent Bedrock (depth 30-120 meters)	(m/s)	1.06E-07	2.00E-08	8.30E-07	3.77E-07
Competent Bedrock (depth 120-255 meters)	(m/s)	8.92E-08	3.60E-08	9.00E-07	1.79E-07
Competent Bedrock (depth 255-372 meters)	(m/s)	4.66E-08	1.10E-08	2.70E-07	--(2)
Competent Bedrock (depth 372-600 meters)	(m/s)	1.61E-08	3.40E-09	8.60E-08	--(2)
Anisotropy					
Upper Till Poor Drainage	-	10	1	100	--(2)
Upper Till Imperfect Drainage	-	10	1	100	--(2)
Upper Till Rapid Drainage	-	10	1	100	--(2)
Upper Till Excessive Drainage	-	10	1	100	--(2)
Upper Till Inundated	-	10	1	100	--(2)
Lower Till	-	10	1	100	--(2)
Fractured Bedrock (depth 0-30 meters)	-	1	1	10	--(2)
Competent Bedrock (depth 30-120 meters)	-	1	1	10	--(2)
Competent Bedrock (depth 120-255 meters)	-	1	1	10	--(2)
Competent Bedrock (depth 255-372 meters)	-	1	1	10	--(2)
Competent Bedrock (depth 372-600 meters)	-	1	1	10	--(2)
Streambed Sediments Hydraulic Conductivity					
Creeks	(m/s)	3.91E-06	1.20E-07	1.50E-04	--(2)
Wetlands	(m/s)	8.00E-05	1.20E-07	1.50E-04	--(2)
Lakes	(m/s)	3.20E-05	1.20E-07	1.50E-04	--(2)
Recharge					
Upper Till Poor Drainage	mm/yr	250	--(1)	--(1)	--(2)
Upper Till Imperfect Drainage	mm/yr	100	--(1)	--(1)	--(2)
Upper Till Rapid Drainage	mm/yr	402	--(1)	--(1)	--(2)
Upper Till Excessive Drainage	mm/yr	450	--(1)	--(1)	--(2)

Notes:

(1) The average recharge rate over the entire model domain is compared to the literature range of recharge rates from 220 to 340 mm/yr. Individual recharge zones are may be above or below this range.
(2) Observed values are not available to calculate the geometric mean.

Table 6.4

Parameter Composite Sensitivity Values
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Parameter	Units	Calibrated Value	Composite Sensitivity[(1)]
Hydraulic Conductivity			
Upper Till Poor Drainage	(m/s)	4.09E-05	4.18E-02
Upper Till Imperfect Drainage	(m/s)	9.31E-06	9.86E-02
Upper Till Rapid Drainage	(m/s)	9.25E-06	8.34E-02
Upper Till Excessive Drainage	(m/s)	4.96E-06	2.10E-02
Upper Till Inundated	(m/s)	6.03E-07	1.45E-03
Lower Till	(m/s)	7.77E-07	3.20E-02
Fractured Bedrock (depth 0-30 meters)	(m/s)	3.59E-07	9.45E-02
Competent Bedrock (depth 30-120 meters)	(m/s)	1.06E-07	8.57E-02
Competent Bedrock (depth 120-255 meters)	(m/s)	8.92E-08	4.16E-02
Competent Bedrock (depth 255-372 meters)	(m/s)	4.66E-08	1.16E-02
Competent Bedrock (depth 372-600 meters)	(m/s)	1.61E-08	5.52E-03
Streambed Sediments Hydraulic Conductivity			
Creeks	(m/s)	3.91E-06	5.34E-03
Wetlands	(m/s)	8.00E-05	2.54E-05
Lakes	(m/s)	3.20E-05	2.86E-05
Recharge			
Upper Till Poor Drainage	mm/yr	250	4.69E+01
Upper Till Imperfect Drainage	mm/yr	100	1.86E+02
Upper Till Rapid Drainage	mm/yr	402	1.16E+02
Upper Till Excessive Drainage	mm/yr	450	9.98E+00

Note:

(1) The composite sensitivity is unitless.

Table 7.1

East Pit EOM Source Concentrations
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Constituent of Concern	Source Zone Concentrations							
	NW Waste Rock Stockpile		SE Waste Rock Stockpile		NE Waste Rock Stockpile		Organics	Till
	Base Case (µg/l)	Upper Case (µg/l)	Base Case (µg/l)	Upper Case (µg/l)	Base Case (µg/l)	Upper Case (µg/l)	(µg/l)	(µg/l)
Aluminum	23.89	63.73	24.79	66.11	25.47	67.92	809.11	148.27
Antimony	6.75	13.50	6.94	13.89	7.07	14.15	0.90	0.90
Arsenic	154.34	394.50	163.06	416.79	168.73	431.27	7.21	2.50
Barium	8.55	17.11	8.55	17.11	8.55	17.11	38.00	10.65
Beryllium	0.50	1.00	0.50	1.00	0.50	1.00	0.12	0.04
Cadmium	0.04	0.08	0.04	0.08	0.04	0.08	0.18	0.04
Chromium	1.00	2.00	1.00	2.00	1.00	2.00	2.09	2.83
Cobalt	2.50	5.01	2.50	5.01	2.50	5.01	1.18	0.53
Copper	0.60	0.93	0.62	0.95	0.63	0.97	7.90	2.60
Iron	120.02	240.07	120.02	240.07	120.02	240.07	420.03	352.49
Lead	1.06	2.12	1.06	2.12	1.06	2.12	11.40	1.20
Manganese	140.03	280.10	140.03	280.10	140.03	280.10	92.31	21.95
Mercury	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
Nickel	22.46	62.03	21.50	62.03	21.12	62.03	3.10	1.05
Selenium	0.50	1.00	0.50	1.00	0.50	1.00	0.97	1.21
Silver	0.10	0.20	0.10	0.20	0.10	0.20	0.05	0.05
Thallium	0.10	0.20	0.10	0.20	0.10	0.20	0.21	0.03
Uranium	1.57	3.14	1.57	3.14	1.57	3.14	0.21	0.11
Vanadium	4.79	9.57	5.02	10.03	5.17	10.35	3.57	1.50
Zinc	17.76	67.49	18.13	68.90	18.37	69.84	163.99	33.00
Ammonia (N)	310	550	370	650	370	660	1400	300
Unionized Ammonia	3.038	5.39	3.626	6.37	3.626	6.468	13.72	2.94
Nitrite (N)	170	300	200	350	200	360	30	30
Nitrate (N)	19000	34000	23000	41000	23000	41000	620	350

Table 7.2

West Pit EOM Source Concentrations
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Constituent of Concern	Source Zone Concentrations							
	NW Waste Rock Stockpile		SE Waste Rock Stockpile		NE Waste Rock Stockpile		Organics	Till
	Base Case (µg/l)	Upper Case (µg/l)	Base Case (µg/l)	Upper Case (µg/l)	Base Case (µg/l)	Upper Case (µg/l)	(µg/l)	(µg/l)
Aluminum	23.89	63.73	24.79	66.11	25.47	67.92	809.11	148.27
Antimony	6.75	13.50	6.94	13.89	7.07	14.15	0.90	0.90
Arsenic	154.34	394.50	163.06	416.79	168.73	431.27	7.21	2.50
Barium	8.55	17.11	8.55	17.11	8.55	17.11	38.00	10.65
Beryllium	0.50	1.00	0.50	1.00	0.50	1.00	0.12	0.04
Cadmium	0.04	0.08	0.04	0.08	0.04	0.08	0.18	0.04
Chromium	1.00	2.00	1.00	2.00	1.00	2.00	2.09	2.83
Cobalt	2.50	5.01	2.50	5.01	2.50	5.01	1.18	0.53
Copper	0.60	0.93	0.62	0.95	0.63	0.97	7.90	2.60
Iron	120.02	240.07	120.02	240.07	120.02	240.07	420.03	352.49
Lead	1.06	2.12	1.06	2.12	1.06	2.12	11.40	1.20
Manganese	140.03	280.10	140.03	280.10	140.03	280.10	92.31	21.95
Mercury	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
Nickel	22.46	62.03	21.50	62.03	21.12	62.03	3.10	1.05
Selenium	0.50	1.00	0.50	1.00	0.50	1.00	0.97	1.21
Silver	0.10	0.20	0.10	0.20	0.10	0.20	0.05	0.05
Thallium	0.10	0.20	0.10	0.20	0.10	0.20	0.21	0.03
Uranium	1.57	3.14	1.57	3.14	1.57	3.14	0.21	0.11
Vanadium	4.79	9.57	5.02	10.03	5.17	10.35	3.57	1.50
Zinc	17.76	67.49	18.13	68.90	18.37	69.84	163.99	33.00
Ammonia (N)	310	550	370	650	370	660	1400	300
Unionized Ammonia	3.038	5.39	3.626	6.37	3.626	6.468	13.72	2.94
Nitrite (N)	170	300	200	350	200	360	30	30
Nitrate (N)	19000	34000	23000	41000	23000	41000	620	350

Table 7.3

PC Source Concentrations
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Constituent of Concern	Source Zone Concentrations					
	NW Waste Rock Stockpile		SE Waste Rock Stockpile		NE Waste Rock Stockpile	
	Base Case (µg/l)	Upper Case (µg/l)	Base Case (µg/l)	Upper Case (µg/l)	Base Case (µg/l)	Upper Case (µg/l)
Aluminum	15.36	40.96	16.04	42.78	16.41	43.76
Antimony	6.69	13.38	6.88	13.76	7.01	14.02
Arsenic	99.06	253.21	104.49	267.07	107.21	274.03
Barium	8.55	17.11	8.55	17.11	8.55	17.11
Beryllium	0.50	1.00	0.50	1.00	0.50	1.00
Cadmium	0.04	0.08	0.04	0.08	0.04	0.08
Chromium	1.00	2.00	1.00	2.00	1.00	2.00
Cobalt	2.50	5.01	2.50	5.01	2.50	5.01
Copper	0.51	0.79	0.52	0.81	0.53	0.82
Iron	120.02	240.07	120.02	240.07	120.02	240.07
Lead	1.06	2.12	1.06	2.12	1.06	2.12
Manganese	140.03	280.10	140.03	280.10	140.03	280.10
Mercury	0.01	0.01	0.01	0.01	0.01	0.01
Nickel	27.48	62.03	27.99	62.03	28.54	62.03
Selenium	0.50	1.00	0.50	1.00	0.50	1.00
Silver	0.10	0.20	0.10	0.20	0.10	0.20
Thallium	0.10	0.20	0.10	0.20	0.10	0.20
Uranium	1.57	3.14	1.57	3.14	1.57	3.14
Vanadium	3.38	6.76	3.54	7.09	3.64	7.28
Zinc	17.90	68.02	18.29	69.52	18.55	70.51

Table 7.4

Simulated Baseflow
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Mining Stage	Unit	GBL-Outlet	GB-DS1	GB-DS2	GB-DS3	GB-DS4	GB-DS5	GB-DS6
Baseline Pre-Mining	m^3/day	-4,932	-215	-550	-341	-1,084	-1,645	-1,990
East Pit EOM	m^3/day	-2,344	472	553	65	444	-115	-458
	% change from baseline	-52%	-320%	-201%	-119%	-141%	-93%	-77%
West Pit EOM	m^3/day	-2,450	331	226	-36	7	-552	-897
	% change from baseline	-50%	-254%	-141%	-90%	-101%	-66%	-55%
PC	m^3/day	-3,233	-31	-185	-241	-617	-1,177	-1,522
	% change from baseline	-34%	-86%	-66%	-29%	-43%	-28%	-24%

Table 7.5

Estimated East Pit EOM Groundwater Loading for Assessment Points Downstream of Goldboro Lake
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Constituent of Concern	GBL-Outlet		GB-DS2		GB-DS4		GB-DS6	
	Base Case (kg/month)	Upper Case (kg/month)	Base Case (kg/month)	Upper Case (kg/month)	Base Case (kg/month)	Upper Case (kg/month)	Base Case (kg/month)	Upper Case (kg/month)
Aluminum	749.41	881.52	252.21	257.12	137.57	159.34	14.13	37.68
Antimony	23.26	45.44	1.49	2.32	3.90	7.56	3.96	7.92
Arsenic	526.06	1334.43	22.22	52.37	87.16	220.78	92.93	237.54
Barium	60.57	87.93	14.68	15.70	10.90	15.40	4.87	9.75
Beryllium	1.71	3.31	0.11	0.17	0.28	0.55	0.29	0.57
Cadmium	0.27	0.39	0.06	0.07	0.05	0.07	0.02	0.04
Chromium	6.09	9.29	2.06	2.18	1.21	1.74	0.57	1.14
Cobalt	9.13	17.14	0.83	1.13	1.55	2.87	1.43	2.85
Copper	9.06	10.13	3.12	3.16	1.71	1.89	0.35	0.54
Iron	862.66	1246.53	289.99	304.25	168.75	231.98	68.40	136.82
Lead	12.41	15.80	3.17	3.29	2.18	2.74	0.60	1.21
Manganese	526.58	974.45	47.75	64.39	88.70	162.46	79.80	159.63
Mercury	0.04	0.06	0.01	0.01	0.01	0.01	0.00	0.01
Nickel	72.18	201.13	3.77	8.58	11.87	33.21	12.25	35.35
Selenium	2.89	4.49	0.90	0.96	0.57	0.83	0.29	0.57
Silver	0.38	0.70	0.05	0.06	0.07	0.12	0.06	0.11
Thallium	0.49	0.81	0.07	0.08	0.08	0.14	0.06	0.11
Uranium	5.23	10.25	0.29	0.48	0.87	1.70	0.89	1.79
Vanadium	19.36	35.36	2.14	2.74	3.32	5.96	2.86	5.72
Zinc	195.12	357.27	54.24	60.27	35.22	61.96	10.33	39.27
Ammonia (N)	2279.97	3137.79	498.33	531.60	416.76	564.22	210.88	370.45
Unionized Ammonia	22.34	30.75	4.88	5.21	4.08	5.53	2.07	3.63
Nitrite (N)	634.32	1104.25	46.02	63.84	113.58	192.58	113.98	199.47
Nitrate (N)	68612.00	121999.66	3049.27	5187.92	12243.15	21722.61	13108.23	23366.84

Table 7.6

Estimated West Pit EOM Groundwater Loading for Assessment Points Downstream of Goldboro Lake
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Constituent of Concern	GBL-Outlet		GB-DS2		GB-DS4		GB-DS6	
	Base Case (kg/month)	Upper Case (kg/month)	Base Case (kg/month)	Upper Case (kg/month)	Base Case (kg/month)	Upper Case (kg/month)	Base Case (kg/month)	Upper Case (kg/month)
Aluminum	838.26	991.48	299.98	315.02	140.27	167.08	16.64	44.37
Antimony	27.07	52.78	3.24	5.77	4.76	9.26	4.66	9.32
Arsenic	610.34	1548.30	62.59	154.98	107.08	271.69	109.44	279.73
Barium	69.47	101.15	18.71	21.83	11.95	17.50	5.74	11.48
Beryllium	1.98	3.83	0.24	0.42	0.35	0.67	0.34	0.67
Cadmium	0.31	0.45	0.08	0.10	0.05	0.08	0.03	0.05
Chromium	7.45	11.16	2.40	2.76	1.35	1.99	0.67	1.34
Cobalt	10.59	19.87	1.50	2.41	1.85	3.48	1.68	3.36
Copper	10.43	11.66	3.67	3.79	1.79	2.01	0.41	0.64
Iron	1036.63	1481.26	339.04	382.76	184.65	262.54	80.55	161.13
Lead	13.78	17.71	4.02	4.41	2.30	2.99	0.71	1.42
Manganese	607.49	1126.25	86.82	137.83	105.79	196.66	93.98	187.99
Mercury	0.05	0.07	0.01	0.02	0.01	0.01	0.00	0.01
Nickel	83.49	232.94	9.20	23.95	14.50	40.79	14.43	41.63
Selenium	3.51	5.36	1.07	1.25	0.63	0.96	0.34	0.67
Silver	0.45	0.82	0.08	0.11	0.08	0.14	0.07	0.13
Thallium	0.56	0.93	0.11	0.14	0.10	0.16	0.07	0.13
Uranium	6.07	11.88	0.69	1.26	1.06	2.08	1.05	2.11
Vanadium	22.48	41.05	3.55	5.38	3.93	7.19	3.37	6.73
Zinc	220.56	408.50	67.11	85.60	37.38	70.32	12.17	46.24
Ammonia (N)	2601.89	3599.15	660.92	762.88	461.60	643.26	248.33	436.26
Unionized Ammonia	25.50	35.27	6.48	7.48	4.52	6.30	2.43	4.28
Nitrite (N)	740.52	1287.03	96.45	151.07	138.12	235.44	134.23	234.91
Nitrate (N)	79787.52	141845.21	8722.06	15276.66	15053.48	26731.58	15436.63	27517.47

Table 7.7

Estimated PC Groundwater Loading for Assessment Points Downstream of Goldboro Lake
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Constituent of Concern	GBL-Outlet		GB-DS2		GB-DS4		GB-DS6	
	Base Case (kg/month)	Upper Case (kg/month)	Base Case (kg/month)	Upper Case (kg/month)	Base Case (kg/month)	Upper Case (kg/month)	Base Case (kg/month)	Upper Case (kg/month)
Aluminum	120.55	321.51	15.39	41.04	24.53	65.43	37.10	98.95
Antimony	52.00	104.01	6.60	13.21	10.53	21.05	15.92	31.84
Arsenic	782.67	2000.53	100.25	256.24	159.81	408.48	241.67	617.72
Barium	64.97	129.97	8.20	16.41	13.08	26.16	19.78	39.56
Beryllium	3.80	7.60	0.48	0.96	0.76	1.53	1.16	2.31
Cadmium	0.29	0.58	0.04	0.07	0.06	0.12	0.09	0.18
Chromium	7.60	15.20	0.96	1.92	1.53	3.06	2.31	4.63
Cobalt	19.02	38.04	2.40	4.80	3.83	7.66	5.79	11.58
Copper	3.96	6.10	0.50	0.77	0.80	1.23	1.21	1.86
Iron	911.88	1824.06	115.15	230.33	183.56	367.19	277.59	555.27
Lead	8.06	16.11	1.02	2.03	1.62	3.24	2.45	4.91
Manganese	1063.91	2128.15	134.35	268.73	214.17	428.41	323.87	647.85
Mercury	0.05	0.10	0.01	0.01	0.01	0.02	0.02	0.03
Nickel	212.67	471.28	26.85	59.51	42.81	94.87	64.74	143.46
Selenium	3.80	7.60	0.48	0.96	0.76	1.53	1.16	2.31
Silver	0.76	1.52	0.10	0.19	0.15	0.31	0.23	0.46
Thallium	0.76	1.52	0.10	0.19	0.15	0.31	0.23	0.46
Uranium	11.93	23.87	1.51	3.01	2.40	4.80	3.63	7.27
Vanadium	26.63	53.27	3.40	6.80	5.42	10.85	8.20	16.40
Zinc	138.40	525.99	17.55	66.70	27.98	106.33	42.31	160.79

Table 7.8

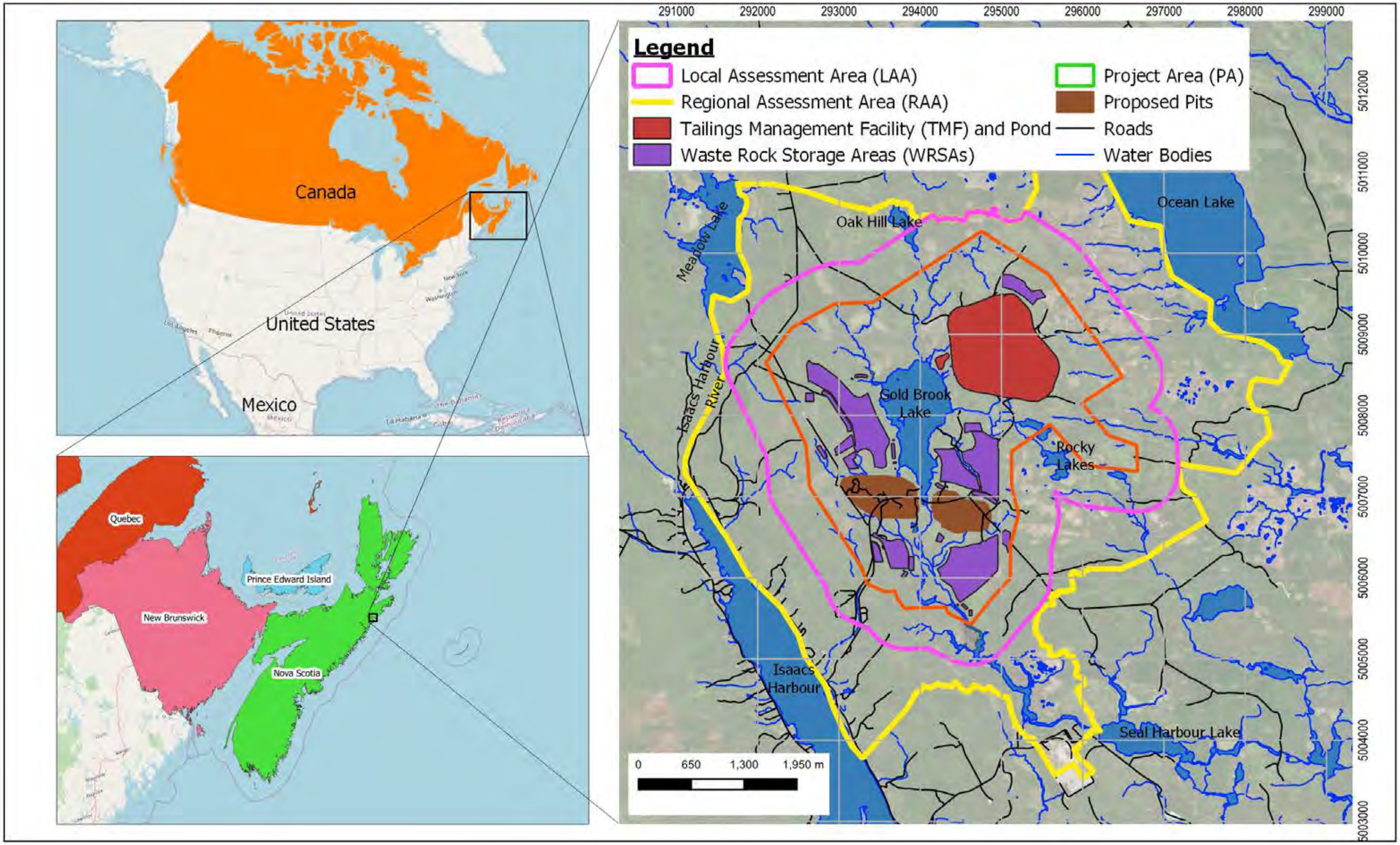
Wet Season Simulated Baseflow
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Mining Stage	Unit	GBL-Outlet	GB-DS1	GB-DS2	GB-DS3	GB-DS4	GB-DS5	GB-DS6
Baseline	m^3/day	-6088	-259	-675	-408	-1329	-2031	-2441
	% change from average conditio	23.4%	20.5%	22.7%	19.6%	22.6%	23.5%	22.7%
East Pit EOM	m^3/day	-3,139	459	467	16	257	-443	-852
	% change from average conditio	-7.7%	-13.3%	-15.7%	-12.8%	-15.3%	-16.0%	-15.4%
	% change from baseline	-48.5%	-277.2%	-169.2%	-103.8%	-119.3%	-78.2%	-65.1%
West Pit EOM	m^3/day	-3,244	319	142	-86	-179	-880	-1,290
	% change from average conditio	-7.2%	-12.3%	-14.3%	-11.9%	-14.0%	-14.7%	-14.1%
	% change from baseline	-46.7%	-222.9%	-121.0%	-79.0%	-86.5%	-56.7%	-47.2%
PC	m^3/day	-4,028	-44	-268	-291	-802	-1,503	-1,914
	% change from average conditio	-1.7%	-2.9%	-9.0%	-2.8%	-8.0%	-8.7%	-8.1%
	% change from baseline	-33.9%	-83.2%	-60.3%	-28.5%	-39.7%	-26.0%	-21.6%

Table 7.9

Dry Season Simulated Baseflow
Anaconda Mining Inc
Goldboro Gold Project
Goldboro, Guysborough County, Nova Scotia

Mining Stage	Unit	GBL-Outlet	GB-DS1	GB-DS2	GB-DS3	GB-DS4	GB-DS5	GB-DS6
Baseline	m^3/day	-4489	-198	-501	-315	-991	-1498	-1817
	% change from average conditio	-9.0%	-7.9%	-8.9%	-7.6%	-8.6%	-8.9%	-8.7%
East Pit EOM	m^3/day	-2,044	473	581	82	508	4	-314
	% change from average conditio	3.8%	6.1%	7.7%	5.9%	7.4%	7.8%	7.5%
	% change from baseline	-54.5%	-339.2%	-216.0%	-126.0%	-151.3%	-100.3%	-82.7%
West Pit EOM	m^3/day	-2,150	333	254	-18	71	-434	-753
	% change from average conditio	3.5%	5.5%	6.8%	5.2%	6.5%	6.9%	6.6%
	% change from baseline	-52.1%	-268.2%	-150.7%	-94.2%	-107.2%	-71.0%	-58.6%
PC	m^3/day	-2,932	-29	-158	-223	-552	-1,059	-1,378
	% change from average conditio	0.7%	-0.3%	3.4%	-0.3%	2.7%	3.0%	2.8%
	% change from baseline	-34.7%	-85.4%	-68.5%	-29.2%	-44.3%	-29.3%	-24.2%



Paper Size ANSI A

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GHD

SIGNAL GOLD INC.
GOLDBORO GOLD PROJECT, GOLDBORO,
GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

STUDY AREA EXTENT

Project No. **11222385**
Revision No. **-**
Date. **April 2022**

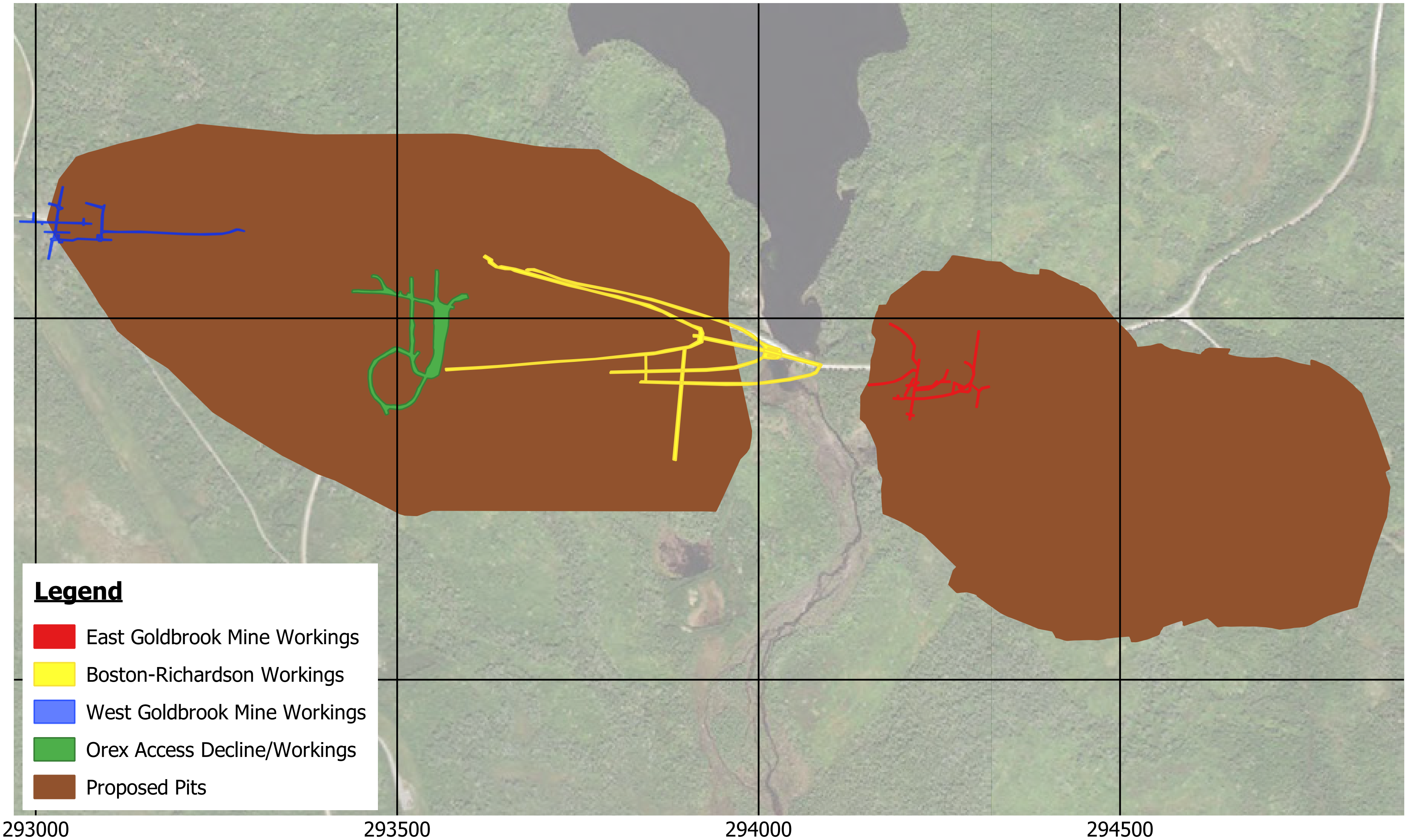
FIGURE 1.1

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 1.qgz

Data Source: Bing Aerial (http://ecn.t3.tiles.virtualearth.net/tiles/a{q}.jpeg?g=1)

Print Date: 2022/04/07

Created By: Amir Niazi



Paper Size ANSI A

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Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

N

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

LOCATION OF HISTORICAL MINE WORKINGS AND PROPOSED PITS

Project No. **11222385**
Revision No. **-**
Date. **April 2022**

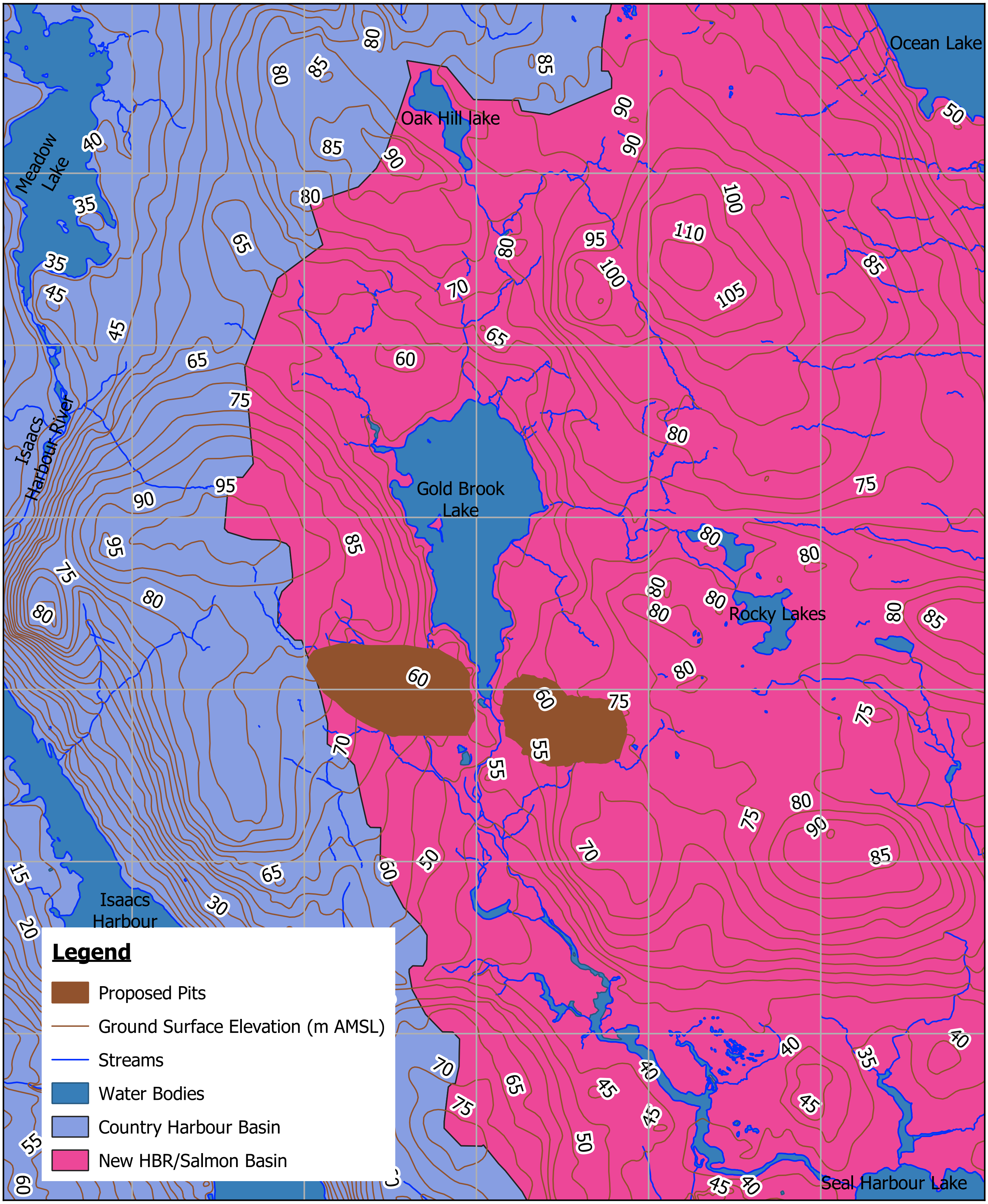
FIGURE 1.2

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 1.qgz

Data Source: Bing Aerial (http://ecn.t3.tiles.virtualearth.net/tiles/a{q}.jpeg?g=1)

Print Date: 2022-05-04

Created By: Amir Niazi



Paper Size ANSI A

0 0.3 0.6 0.9 km

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

N

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

SITE TOPOGRAPHY AND DRAINAGE BASINS

Project No.	**11222385**
Revision No.	**-**
Date.	**April 2022**

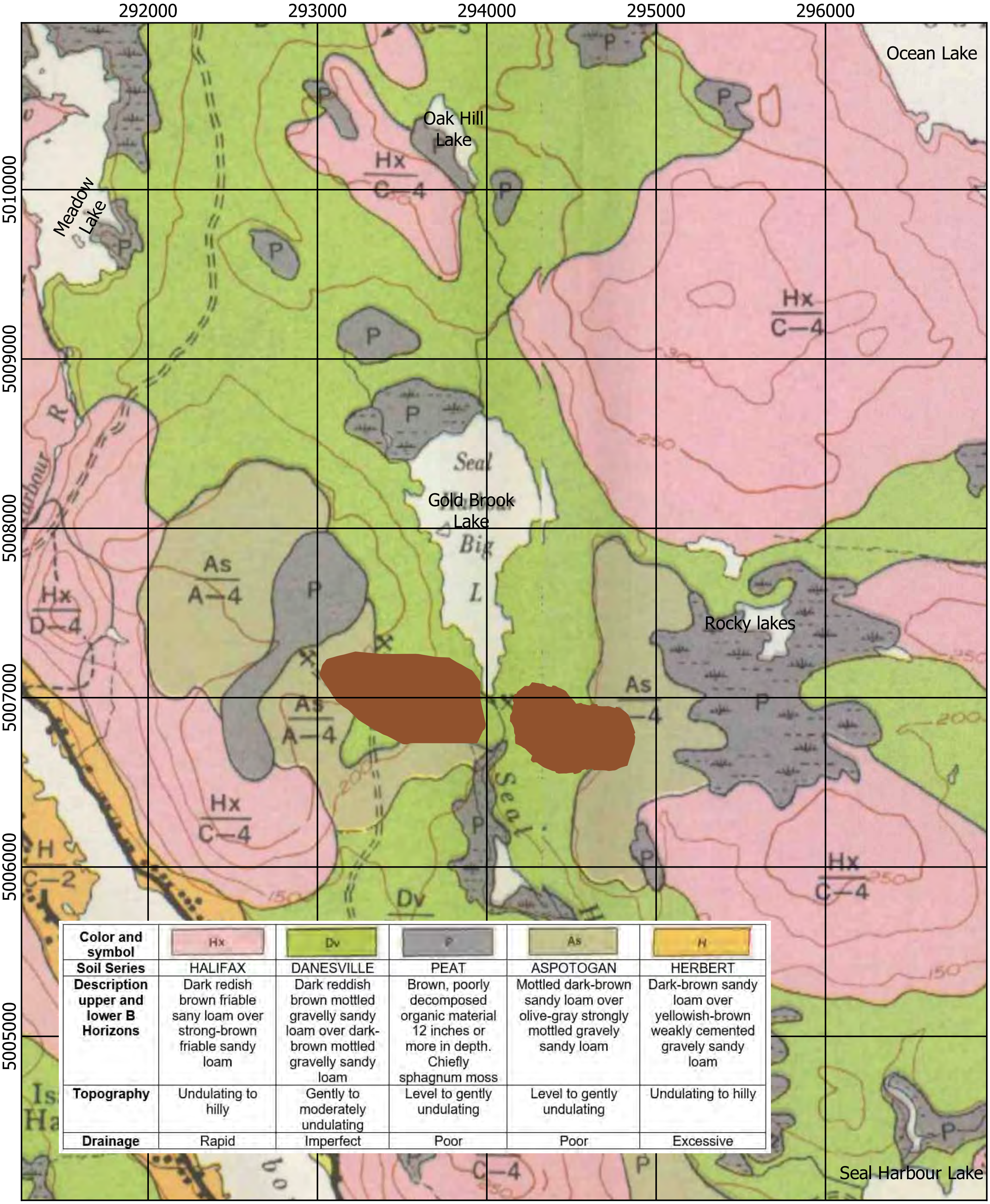
FIGURE 2.1

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 1.qgz

Data Source: 1:10,000 watersheds for Nova Scotia. primary watersheds. https://data.novascotia.ca/Environment-and-Energy/1-10-000-Nova-Scotia-Primary-Watersheds/569x-2wnq

Print Date: 2022-05-03

Created By: Amir Niazi



Color and symbol	Hx	Dv	P	As	H
Soil Series	HALIFAX	DANESVILLE	PEAT	ASPOTOGAN	HERBERT
Description upper and lower B Horizons	Dark redish brown friable sany loam over strong-brown friable sandy loam	Dark reddish brown mottled gravelly sandy loam over dark-brown mottled gravelly sandy loam	Brown, poorly decomposed organic material 12 inches or more in depth. Chiefly sphagnum moss	Mottled dark-brown sandy loam over olive-gray strongly mottled gravely sandy loam	Dark-brown sandy loam over yellowish-brown weakly cemented gravely sandy loam
Topography	Undulating to hilly	Gently to moderately undulating	Level to gently undulating	Level to gently undulating	Undulating to hilly
Drainage	Rapid	Imperfect	Poor	Poor	Excessive

Paper Size ANSI A

0 0.3 0.6 0.9 km

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

N

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

SURFICIAL GEOLOGY

Project No. **11222385**
Revision No. **-**
Date. **April 2022**

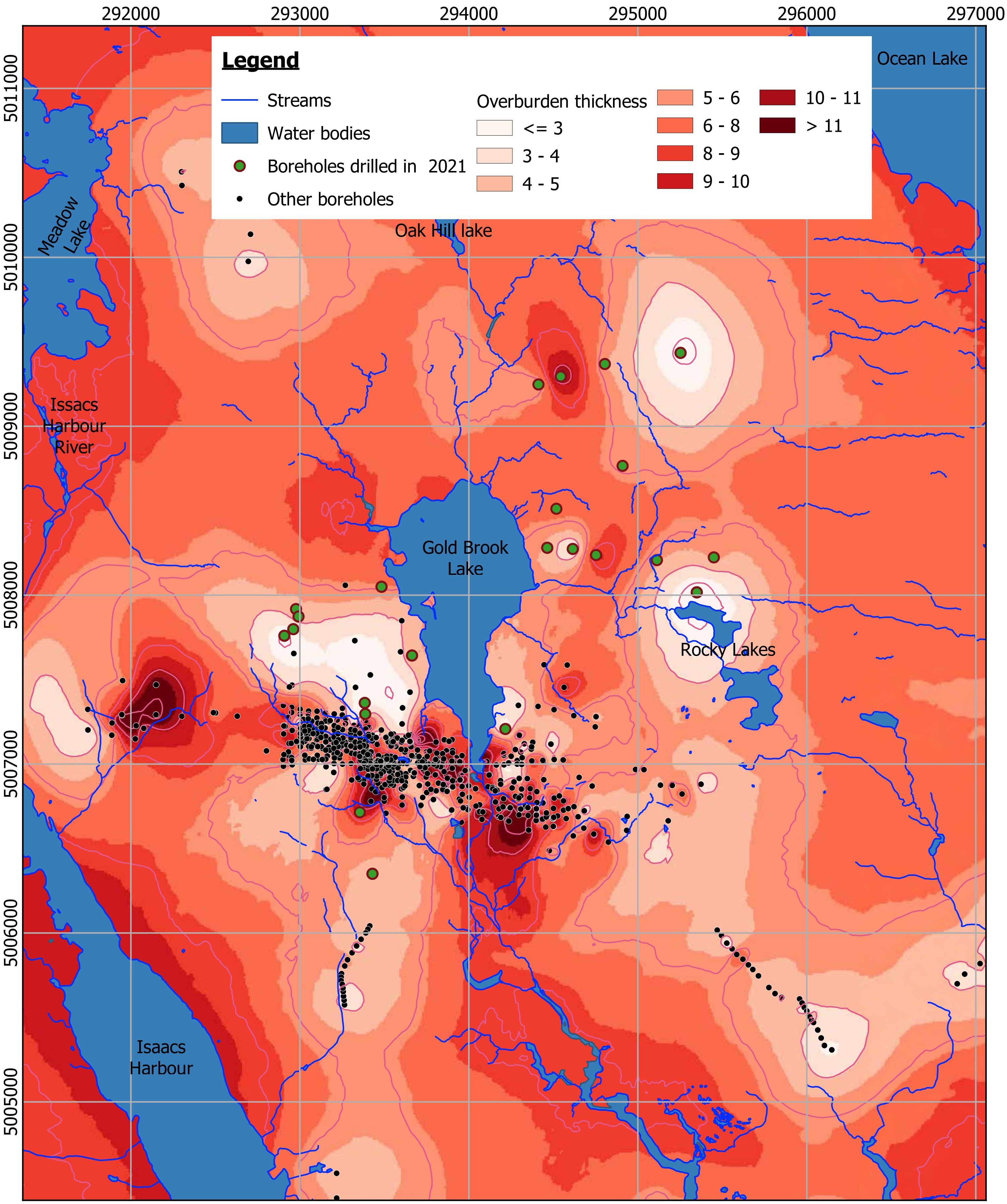
FIGURE 2.2

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 1.qgz

Data Source: Soil Map of Guysborough County, Soil Research Institute, Ottawa, 1963

Print Date: 2022-05-03

Created By: Amir Niazi



Paper Size ANSI A

0 0.3 0.6 0.9 Km

N

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

GHD

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

OVERBURDEN THIKNESS

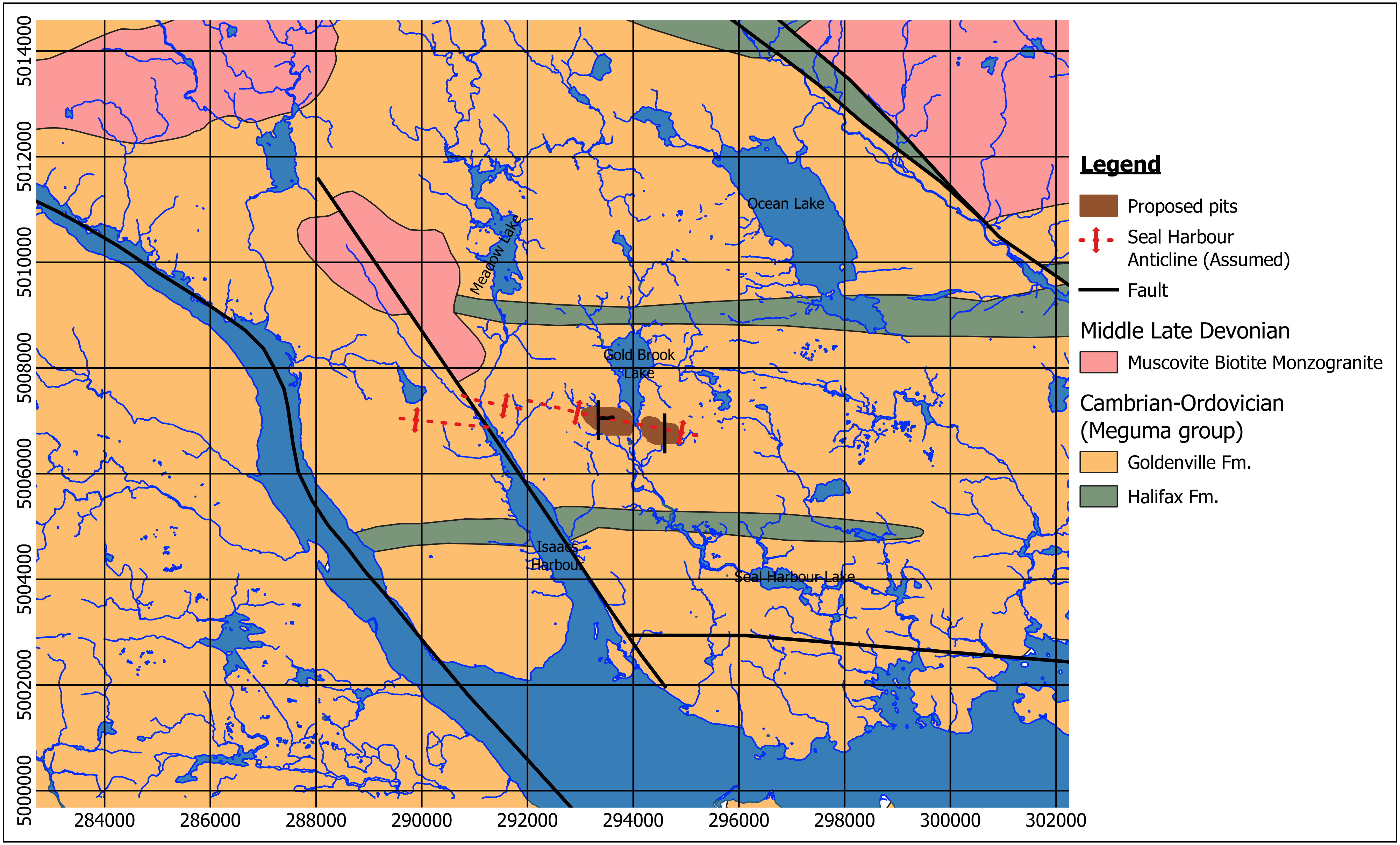
Project No. **11222385**
Revision No. **-**
Date. **April 2022**

FIGURE 2.3

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 1.qgz

Print Date: 2022-05-03Print Date: $CURRENT_DATE(yyyy-MM-dd)

Created By: Amir Niazi



Paper Size ANSI A

0 1 2 3 km

N

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS UTM Zone 20N

GHD

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

REGIONAL BEDROCK GEOLOGY

Project No. **11222385**
Revision No. **-**
Date. **April 2022**

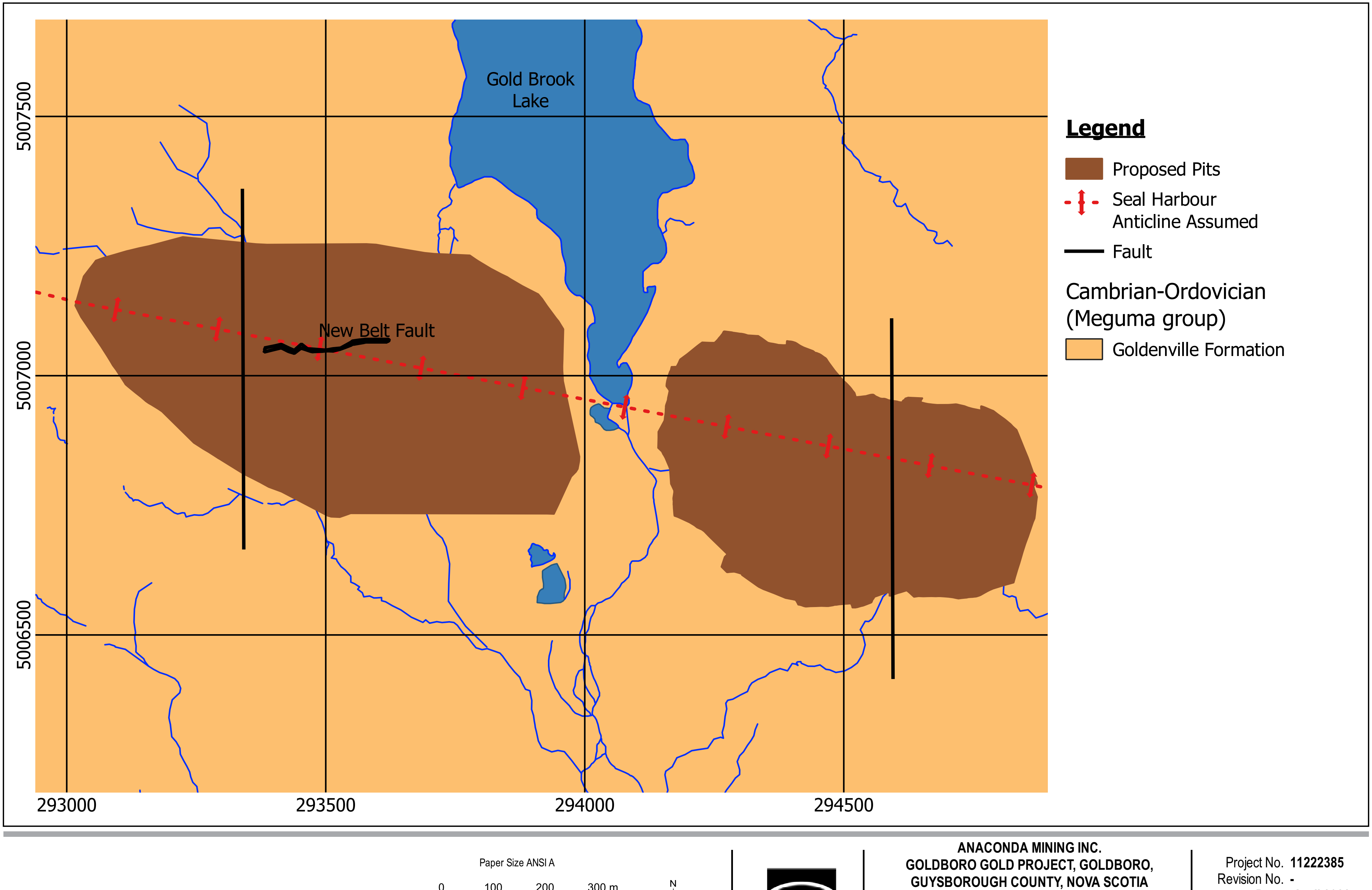
FIGURE 2.4

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 1.qgz

Print Date: 2022-05-03

Data Source: DP ME 43, Version 2, 2006. Digital Version of Nova Scotia Department of Natural Resources Map ME 2000-1, Geological Map of the Province of Nova Scotia, Scale 1:500 000
Local structural data: WSP (2018)

Created By: Amir Niazi



Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

GHD

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

Project No. **11222385**
Revision No. **-**
Date. **April 2022**

LOCAL BEDROCK GEOLOGY

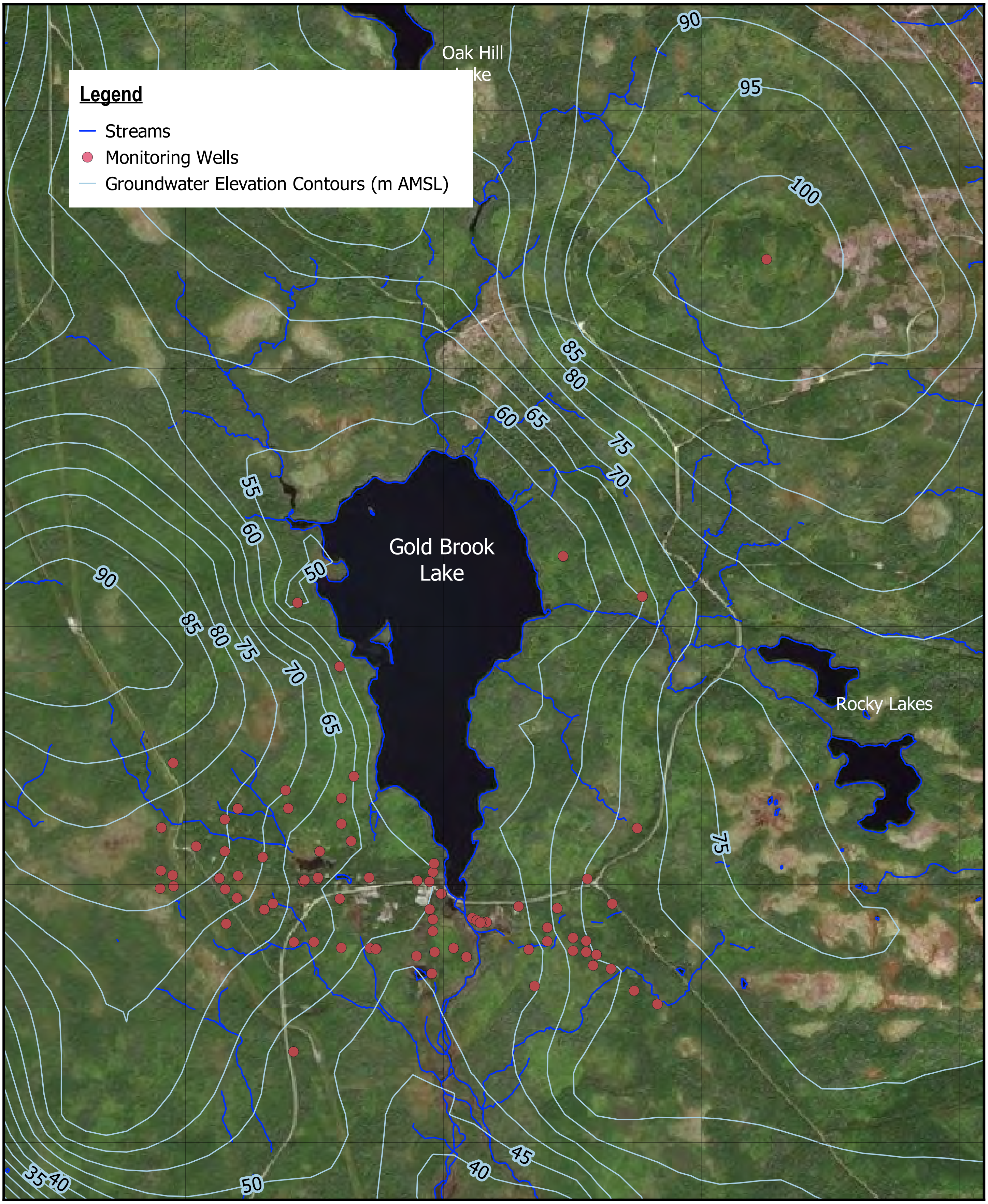
FIGURE 2.5

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 1.qgz

Print Date: 2022-05-03

Data Source: DP ME 43, Version 2, 2006. Digital Version of Nova Scotia Department of Natural Resources Map ME 2000-1, Geological Map of the Province of Nova Scotia, Scale 1:500 000
Local structural data: WSP (2018), 3D geological model

Created By: Amir Niazi



Paper Size ANSI A

0 0.2 0.4 0.6 km

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

N

GHD

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

OBSERVED GROUNDWATER ELEVATION CONTOURS

Project No. **11222385**
Revision No. **-**
Date. **April 2022**

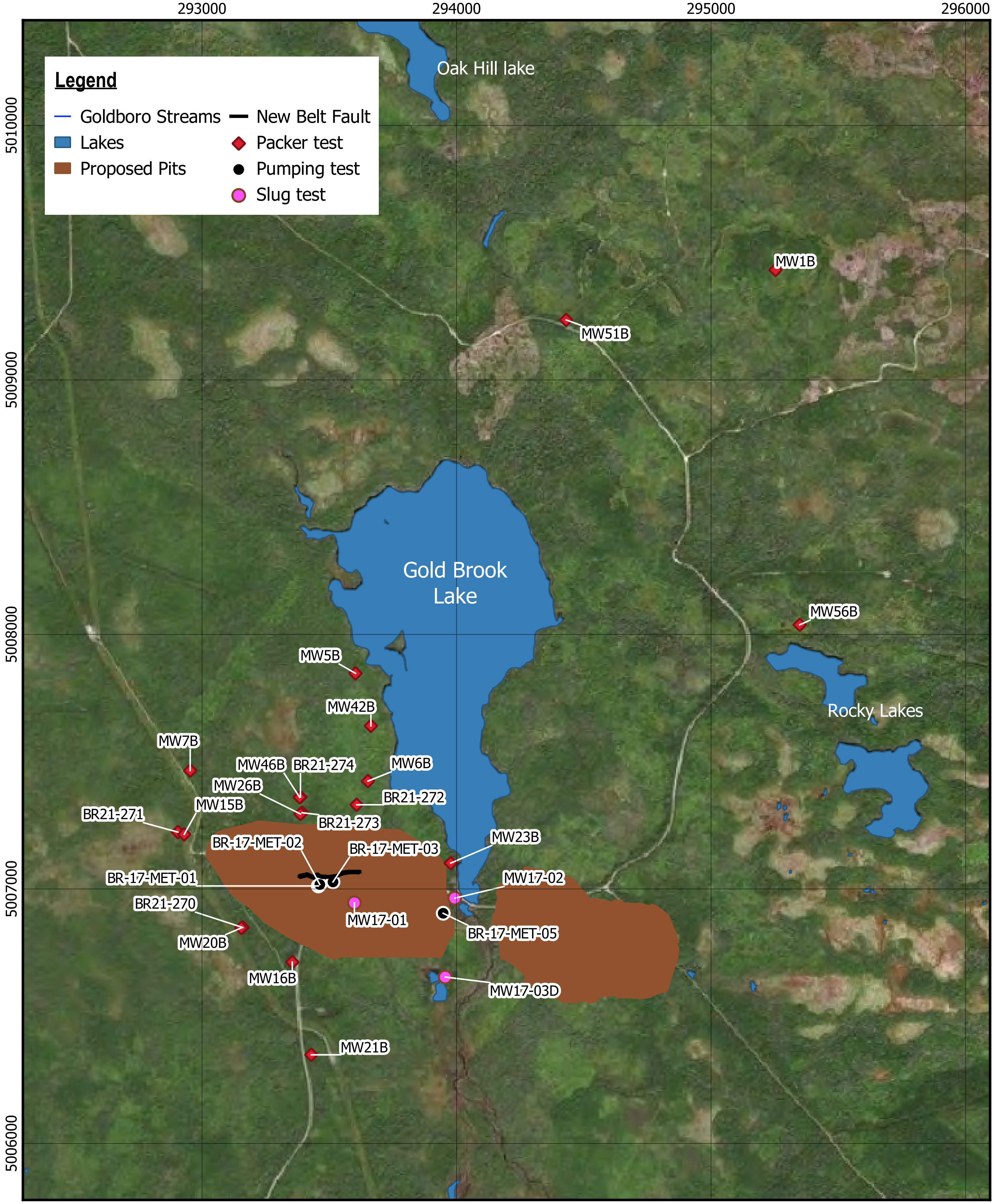
FIGURE 2.6

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 1.qgz

Data Source: Bing Aerial (http://ecn.t3.tiles.virtualearth.net/tiles/a{q}.jpeg?g=1)

Print Date: 2022-05-30

Created By: Amir Niazi



Paper Size ANSI A

0 200 400 600 m

N

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

GHD

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

SPATIAL DISTRIBUTION OF HYDRAULIC CONDUCITIVITY TESTS

Project No. 11222385
Revision No. -
Date. April 2022

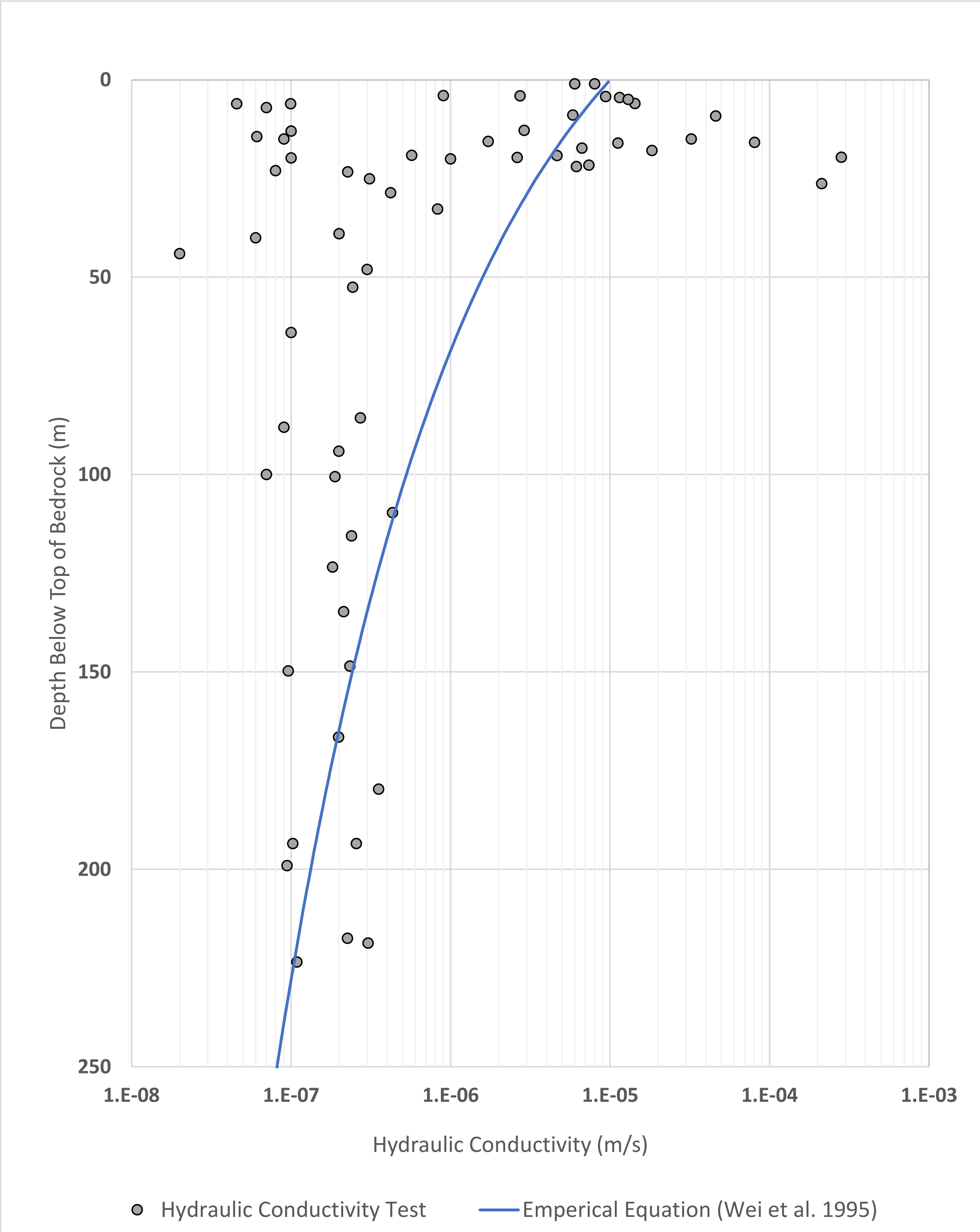
FIGURE 2.7

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 1.qgz

Data Source: Bing Aerial (http://ecn.t3.tiles.virtualearth.net/tiles/a{q}.jpeg?g=1)

Print Date: 2022-05-30

Created By: Amir Niazi



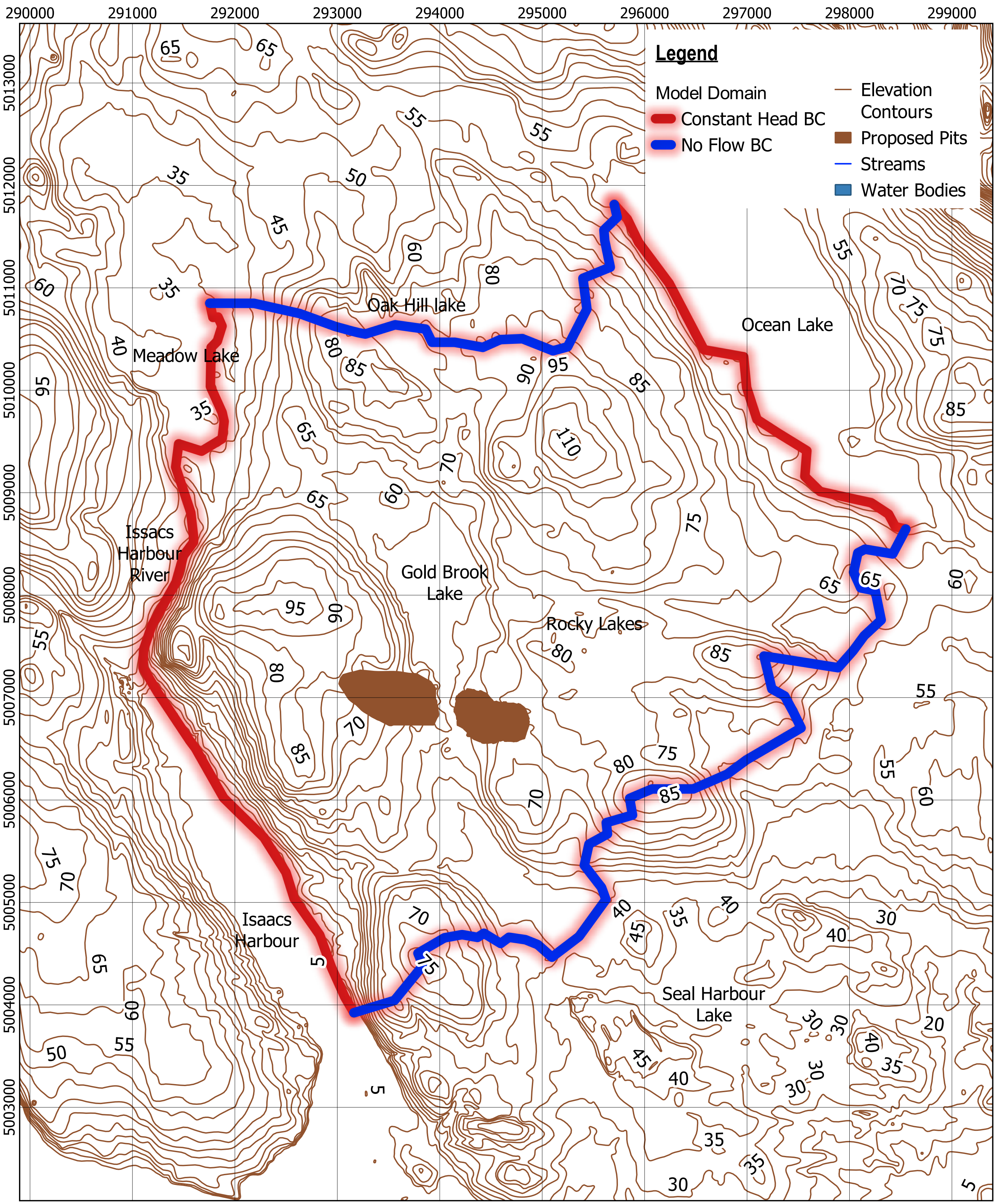
ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

HYDRULIC CONDUCTIVITY VERSUS DEPTH

Project No. **11222385**
Date **May 2022**

FIGURE 2.8

Filename: Z:\HEG\11222385\Documentation\MOD\EA\Excel\New folder\Figure 2.7.xlsx
Plot Date: 3 May 2022 04:17 PM



Paper Size ANSI A

0 0.5 1 1.5 km

N

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

GHD

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

GROUNDWATER MODEL DOMAIN

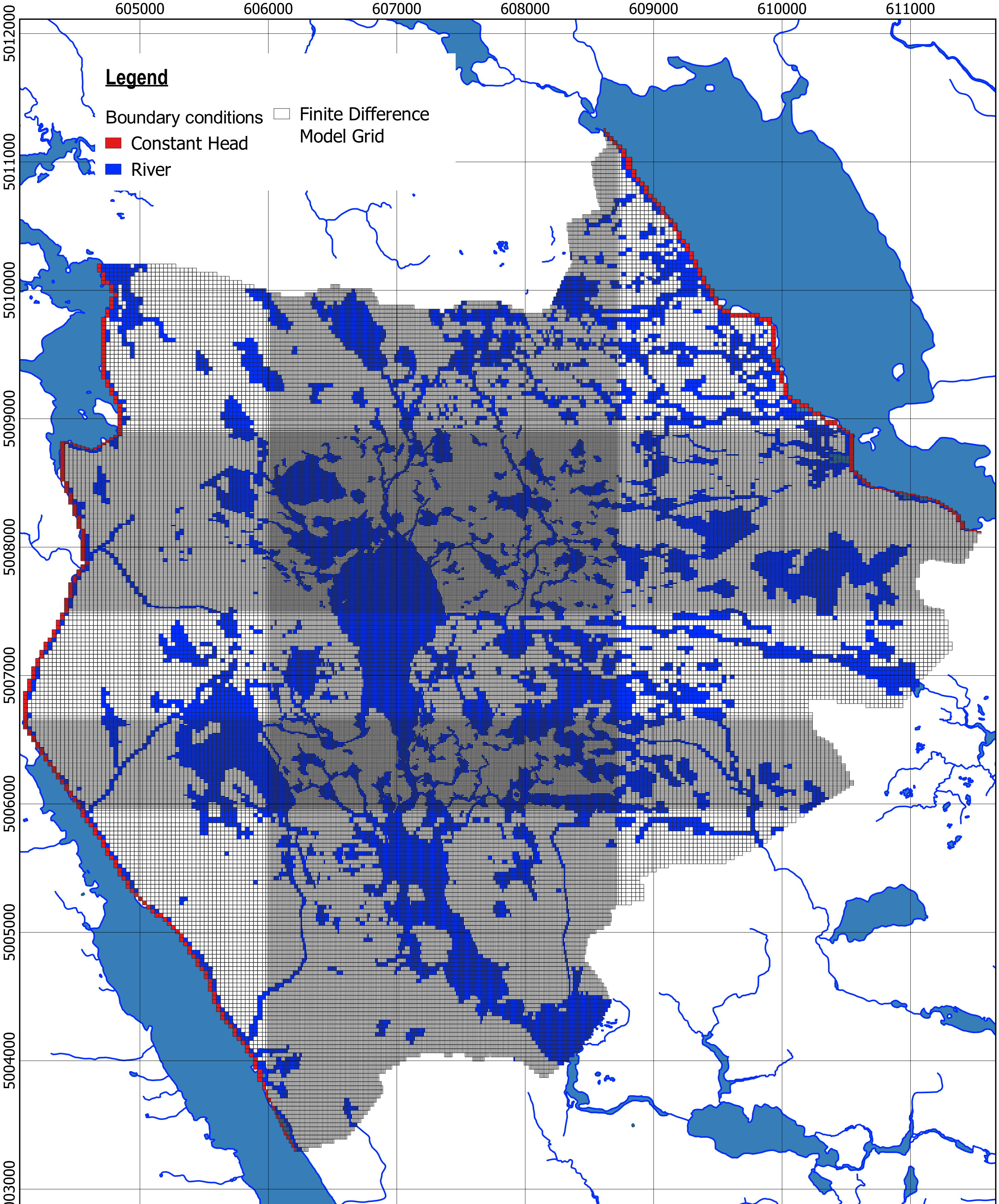
Project No. **11222385**
Revision No. **-**
Date. **April 2022**

FIGURE 5.1

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 3.qgz

Print Date: 2022-05-30

Created By: Amir Niazi



Paper Size ANSI A

0 400 800 1,200 m

N

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

GHD

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

HORIZONTAL MODEL DISCRETIZATION AND BOUNDARY CONDITIONS

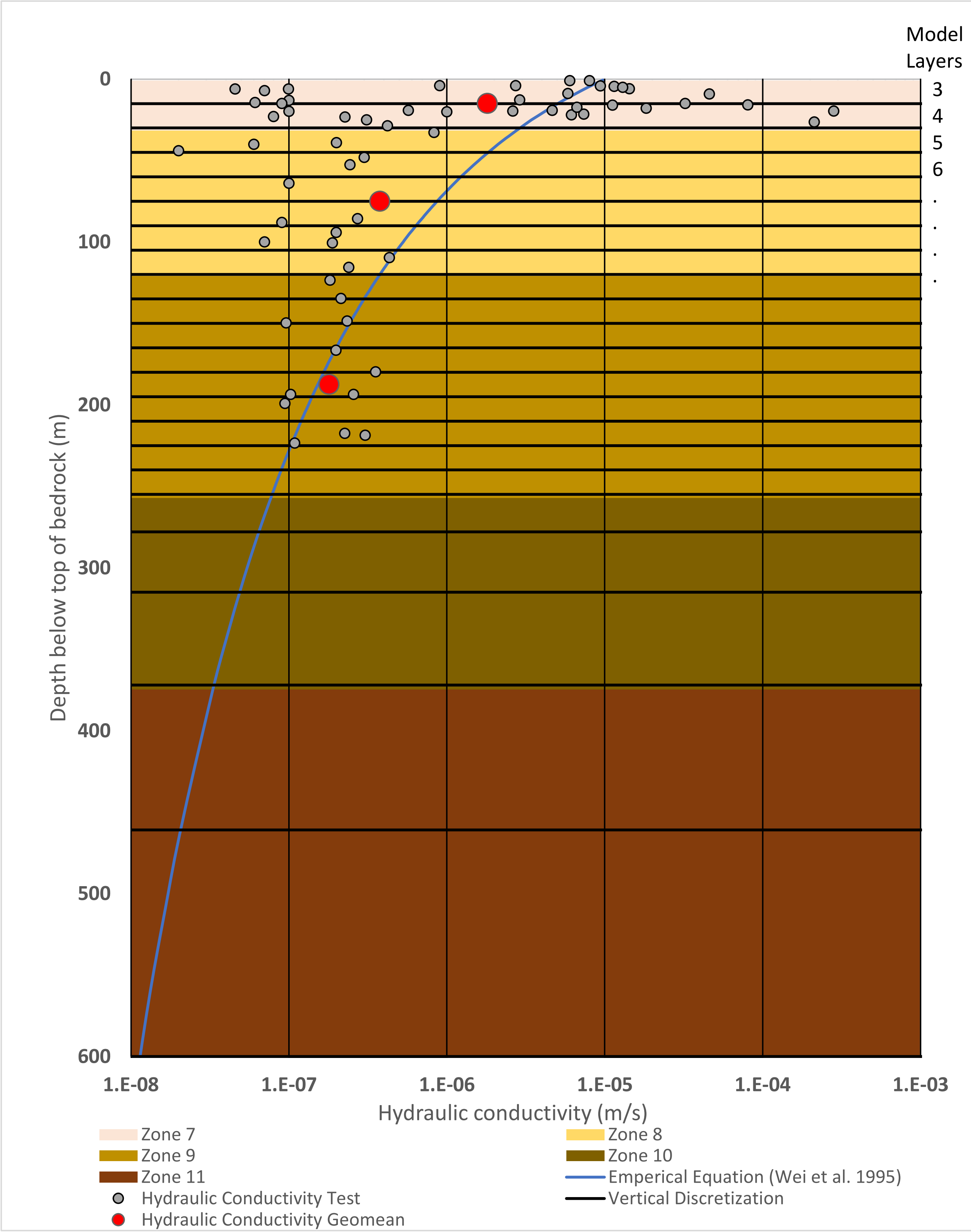
Project No. **11222385**
Revision No. -
Date. **April 2022**

FIGURE 5.2

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 3.qgz

Print Date: 2022-05-30

Created By: Amir Niazi



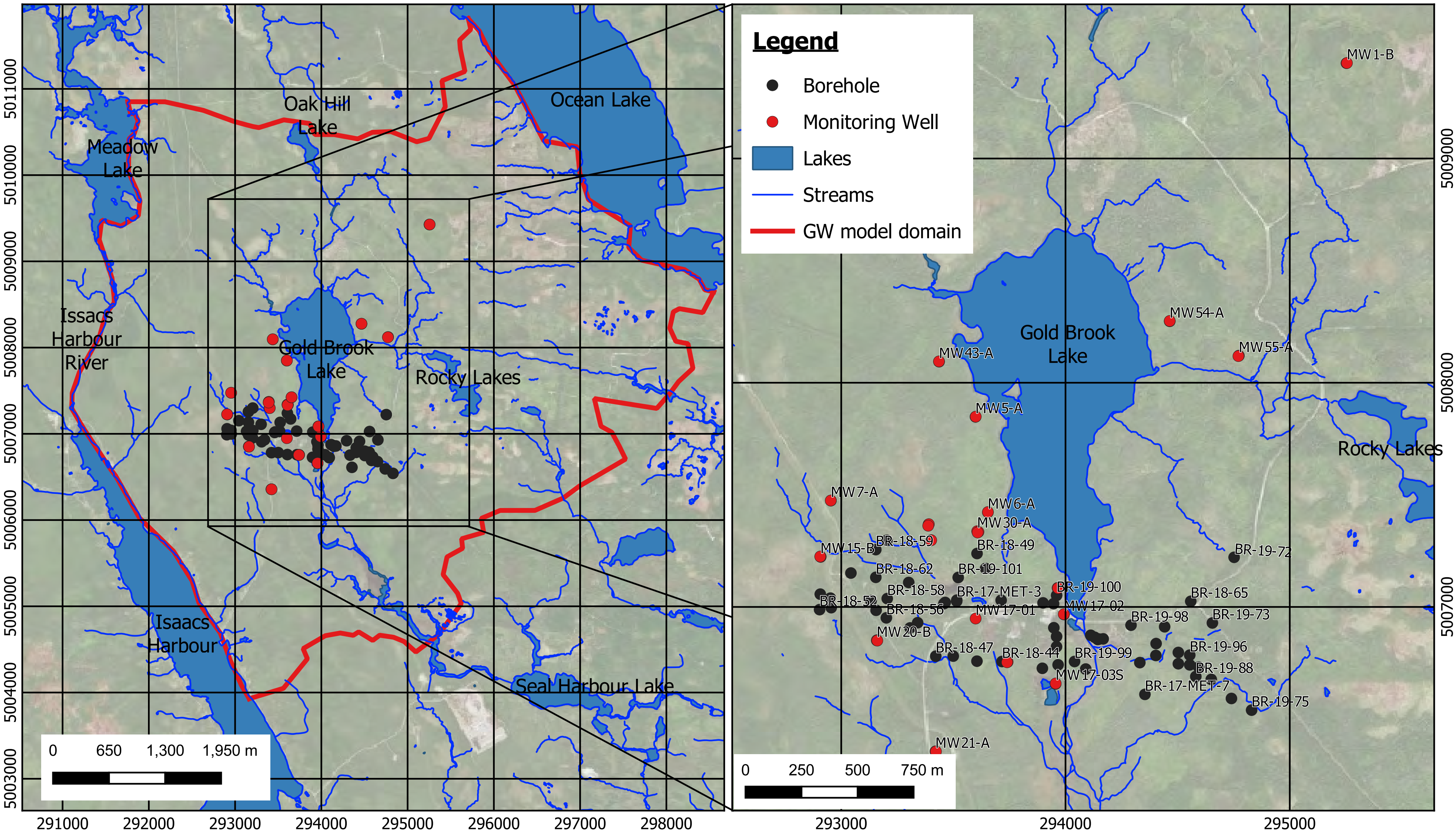
ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

BEDROCK HYDRAULIC CONDUCTIVTIY ZONES

Project No. **11222385**
Date **May 2022**

FIGURE 5.3

Filename: Z:\HEG\11222385\Documentation\MOD\EA\Excel\New folder\Figure 5.2.xlsx
Plot Date: 3 May 2022 04:18 PM



Paper Size ANSI A

N

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

GHD

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

CALIBRATION TARGET LOCATIONS

Project No. **11222385**
Revision No. **-**
Date. **April 2022**

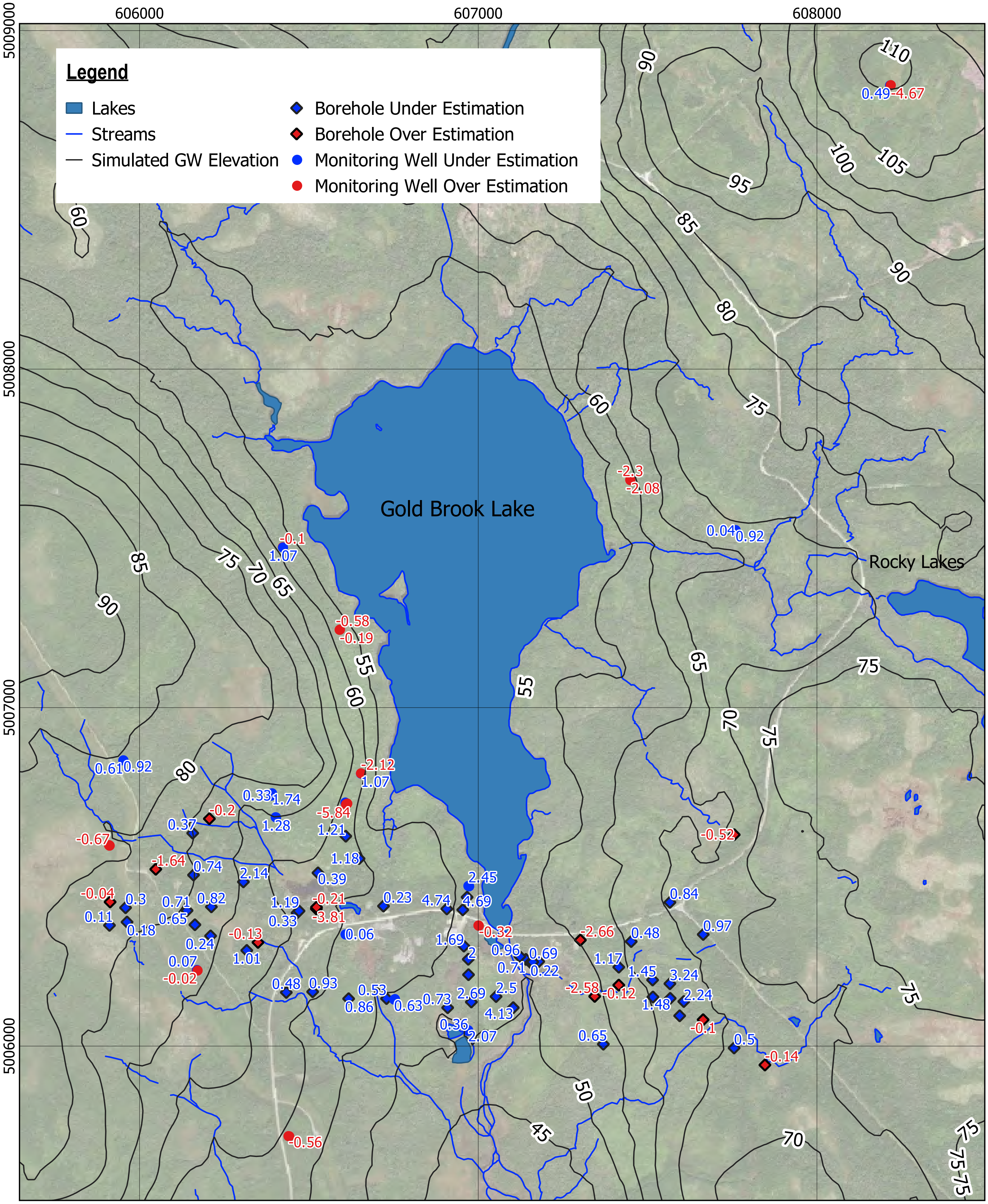
FIGURE 6.1

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 6.qgz

Data Source: Bing Aerial (http://ecn.t3.tiles.virtualearth.net/tiles/a{q}.jpeg?g=1)

Print Date: 2022-05-30

Created By: Amir Niazi



Paper Size ANSI A

0 150 300 450 m

N

Map Projection: Transverse Mercator
Horizontal Datum: North American 1983 CSRS
Grid: NAD 1983 CSRS98 MTM Zone 4

GHD

ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

SIMULATED VERSUS OBSERVED GROUNDWATER ELEVATIONS

Project No. **11222385**
Revision No. **-**
Date. **April 2022**

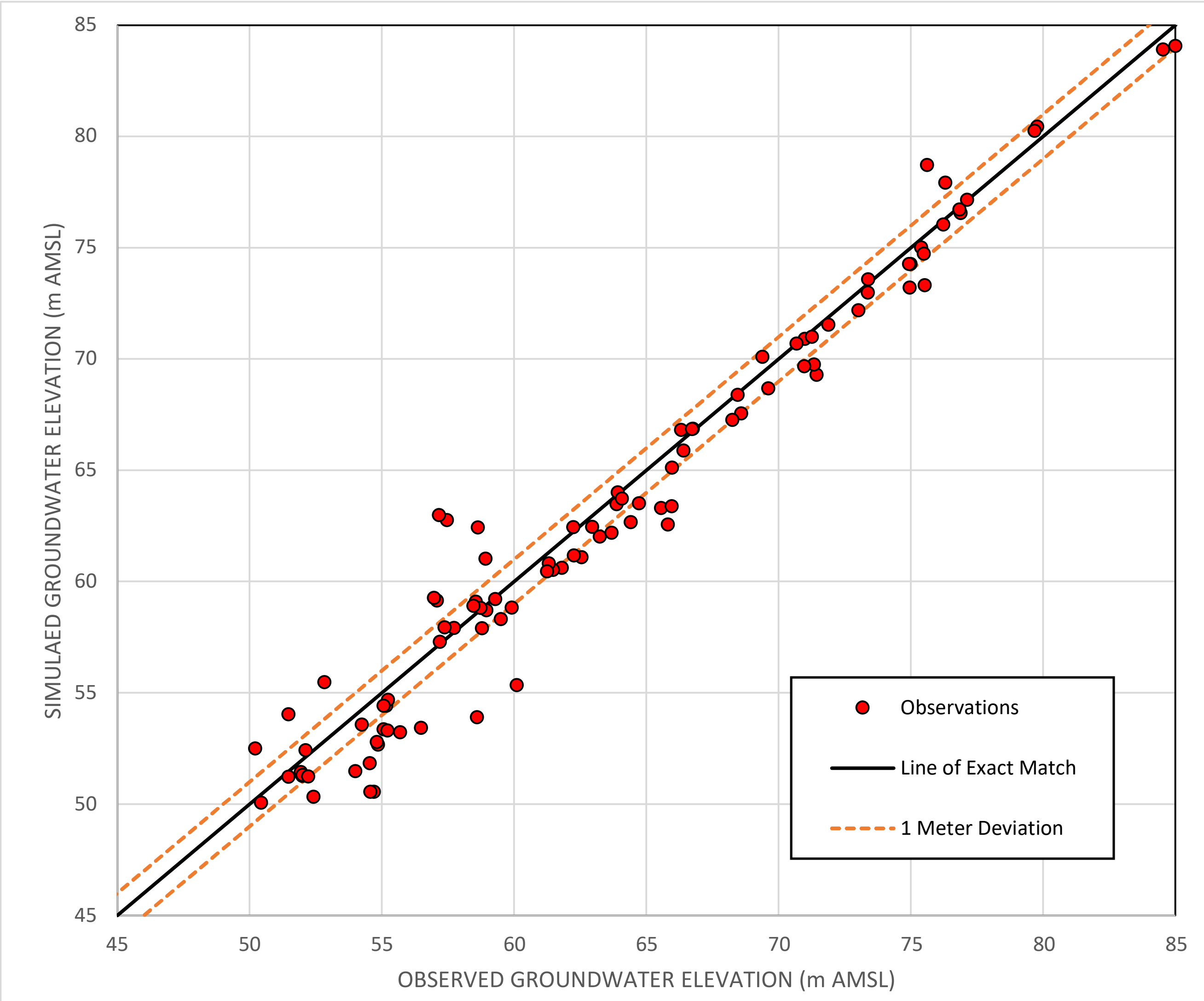
FIGURE 6.2

Document Path: Z:\HEG\11222385\Documentation\MOD\EA\Maps\GIS\Figure 6.qgz

Data Source: Bing Aerial (http://ecn.t3.tiles.virtualearth.net/tiles/a{q}.jpeg?g=1)

Print Date: 2022-05-30

Created By: Amir Niazi



CALIBRATION STATISTICS

NUMBER OF OBSERVATIONS =	101
RESIDUAL MEAN (m) =	0.44
ABSOLUTE RESIDUAL MEAN (m) =	1.32
RESIDUAL STANDARD DEVIATION (m) =	1.78
RESIDUAL SUM OF SQUARES (m^2) =	341.78
MINIMUM RESIDUAL (m) =	-5.84
MAXIMUM RESIDUAL (m) =	4.74
OBSERVED HEAD RANGE (m) =	60.05
STANDARD DEVIATION/HEAD RANGE =	0.03
SCALED RMSE =	0.03

GHD

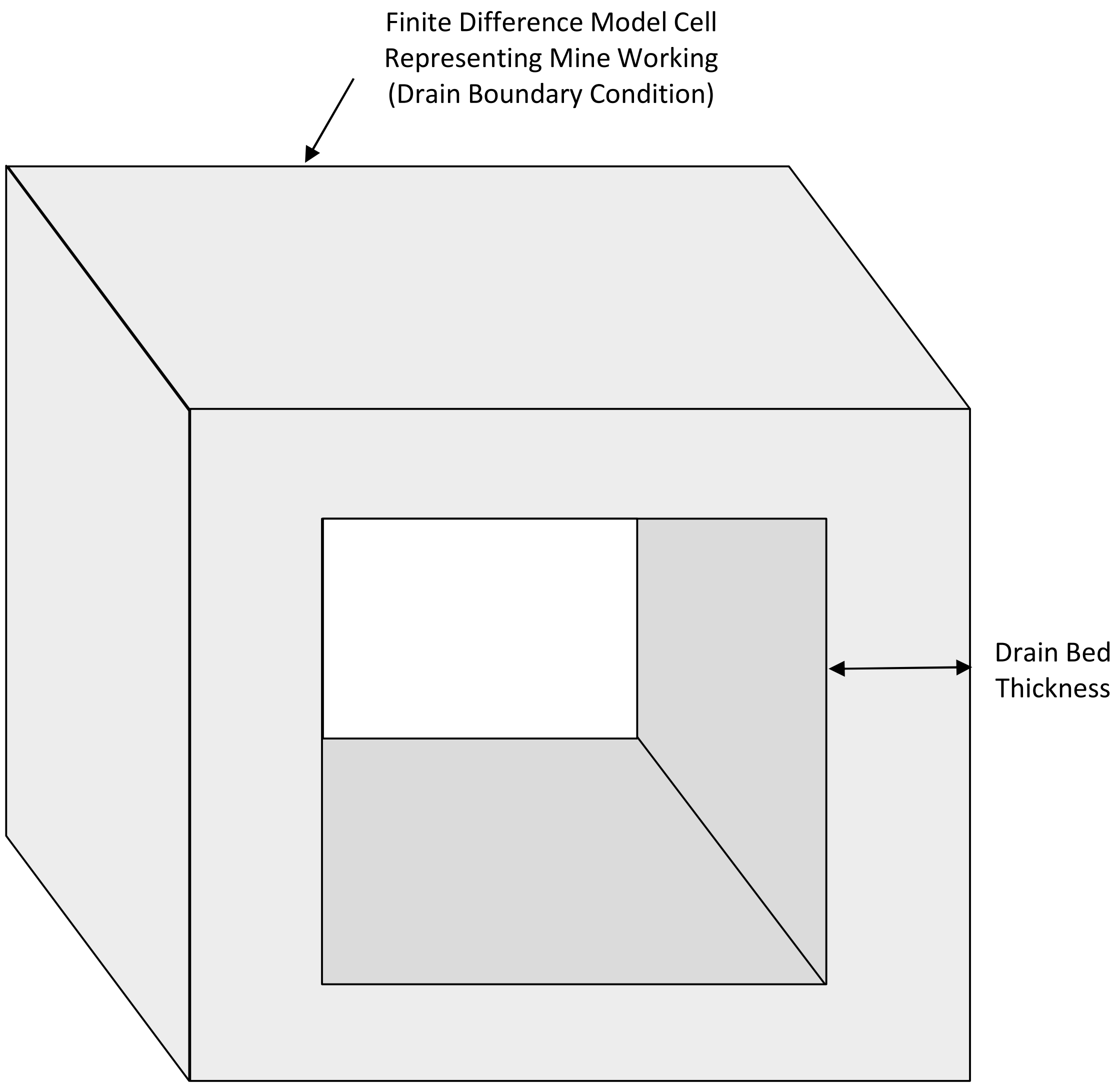
ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

SIMULATED VS. OBSERVED GW ELE.

Project No. **11222385**
Date **May 2022**

FIGURE 6.3

Filename: Z:\HEG\11222385\Documentation\MOD\EA\Excel\New folder\Figure 6.3-2.xlsx
Plot Date: 3 May 2022 04:21 PM



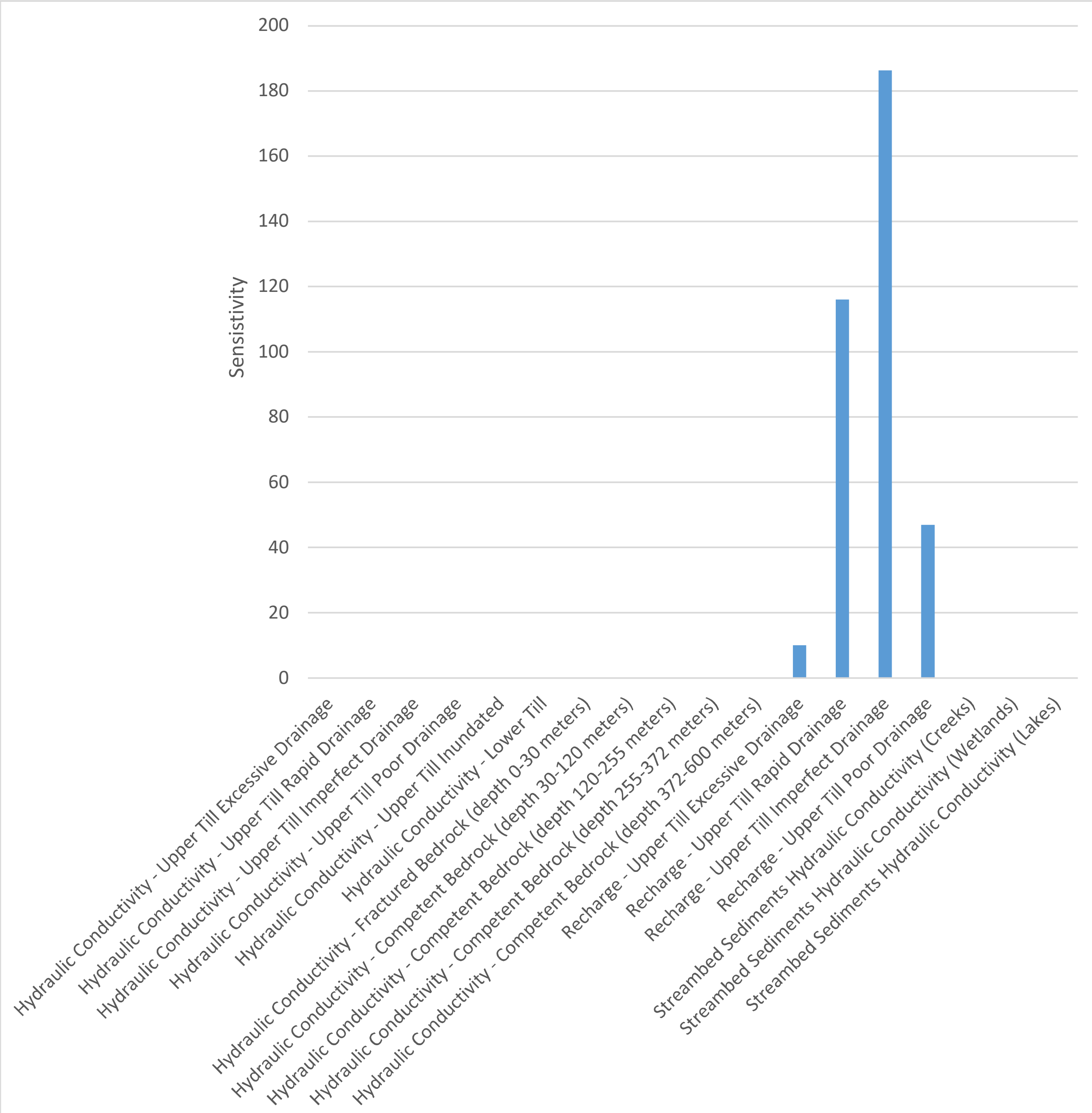
ANACONDA MINING INC.
GOLDBORO GOLD PROJECT, GOLDBORO,
GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

DRAIN CELLS REPRESENTING MINE WORKINGS

Project No. **11222385**
Date **May 2022**

FIGURE 6.4

Filename: Z:\HEG\11222385\Documentation\MOD\EA\Excel\New folder\Figure 6.4.xlsx
Plot Date: 3 May 2022 04:22 PM



ANACONDA MINING INC
GOLDBORO GOLD PROJECT, GOLDBORO, GUYSBOROUGH COUNTY, NOVA SCOTIA
GROUNDWATER MODELLING

COMPOSITE SENSITIVITY RESULTS

Project No. **11222385**
Date **May 2022**

FIGURE 6.5

Filename: Z:\HEG\11222385\Documentation\MOD\EA\Excel\New folder\Figure 6.5.xlsx
Plot Date: 3 May 2022 04:23 PM