Appendix G

Water Resources Baseline Study

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Water Resources Baseline Study

Kami Iron Ore Mine and Rail Infrastructure Project

Prepared for

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1.0 INTRODUCTION

Alderon Iron Ore Corp. (Alderon) is proposing to develop an iron ore mine in western Labrador, and build associated infrastructure at the Pointe-Noire Terminal in the Port of Sept-Îles, Québec. The mine Property is located south of the towns of Wabush and Labrador City in Newfoundland and Labrador and east of Fermont, Québec (Figure 1.1). The Kami Iron Ore Mine and Rail infrastructure is located entirely within Labrador, and includes construction, operation, and rehabilitation and closure of an open pit, waste rock disposal areas, processing infrastructure, a tailings management facility (TMF), ancillary infrastructure to support the mine and process plant, and a rail transportation component. The mine will have a nominal capacity of 16 million metric tonnes of iron ore concentrate per year. Concentrate will be transported by existing rail to the Pointe-Noire Terminal at the Port of Sept-Îles, where Project-related components will be located on land within the jurisdiction of the Port Authority of Sept-Îles.

A groundwater and surface water study was required to provide input to the geotechnical evaluation of the Project, to provide information on potential freshwater inflows and other hydrogeological concerns related to the Project, and as a supporting document for the environmental assessment. This assessment includes a review of the existing information related to the topography, geology, hydrogeology and hydrology of the area, conclusions on how these may impact the project, provides an overview of work that has been completed to date (April 2012) and includes recommendations for future monitoring.

1.1 Project Overview

The Kami Iron Ore Project in Labrador includes construction, operation, and closure / decommissioning of the following primary components (Figure 1.2):

- Open pit (Rose Pit);
- Waste rock disposal areas (Rose North and Rose South);
- Processing infrastructure includes crushing, grinding, spiral concentration, magnetic separation, and tailings thickening areas;
- Tailings management facility (TMF);
- Effluent treatment facility;
- Ancillary infrastructure to support the mine and process plant (gate and guardhouse, reclaim water pumphouse, truck wash bay and shop, electrical substation, explosives magazine storage, administration / office buildings, maintenance offices, warehouse area and employee facilities, conveyors, load-out silo, stockpiles, sewage and water treatment units, mobile equipment, access road and transmission lines);
- A rail transportation component to connect the mine site to the Québec North Shore & Labrador (QNS&L) Railway; and
- Electrical transmission line from terminal to be located by Nalcor Energy to the mine site.

1.2 Study Team

The Freshwater Quality and Quantity (Groundwater and Surface Water) Baseline Study was completed by a diverse Stantec team comprised of engineers, scientists, technicians, administrators and senior reviewers from across North America. The majority of the work pertaining to groundwater was completed in the St. John's, Newfoundland and Labrador office and the Dartmouth, Nova Scotia office, while the majority of the surface water work was completed in the Markham, Ontario office.

1.2.1 Groundwater

The groundwater team was comprised of water resource scientists and engineers, including the following:

- Robert Macleod, M.Sc., P.Geo. – Team Lead, Hydrogeologist
- David MacFarlane, M.Sc., P.Geo. – Sr. Hydrogeologist
- Carolyn Anstey Moore, M.Sc., M.ASc., P.Geo. – Env. Geochemist, Hydrogeologist
- Jim Slade, P.Eng., P.Geo. – Geological Engineer
- Andrew Sullivan, M.Eng., – Environmental Engineer
- Peter Fleming, B.Sc., CET – Sr. Technologist

1.2.2 Surface Water

The surface water team was comprised of water resource scientists and engineers, including the following:

- Sheldon Smith MES P.Geo. – Team Lead, Hydrologist
- Andres Rodrigues M.Sc.E., P.Eng. – Water Resources Engineer
- Sundar Premisari Ph.D. P.Eng. – Water Resources Engineer
- Celia Fan M.Sc.E., P.Eng. –Water Resources Technician
- Maria Ma M.Sc., EIT – Water Resources Technician

1.3 Report Structure

The Report discusses existing environment conditions for freshwater quality and quantity (groundwater and surface water). Section 4.30 of the Draft EIS Guidelines for the Project prescribes the Baseline Study format. As such, the Report structure includes study rationale and objectives, provides an overview of the study area, describes methods used in groundwater and surface water assessment, and presents results, conclusions and recommendations.

The Freshwater Quality and Quantity (Groundwater and Surface Water) section of the EIS is structured to allow for an easy distinction between groundwater and surface water components. Separate sub-sections within the Methods, Study Outputs, Conclusions and Recommendations sections are supplemented with an examination of how they influence and interact with each other.

Much of the data collected is presented as summary tables and illustrations in appendices and is referenced within the report. The report is organized to provide an overview of the methods used in data collection and then present the information as it was interpreted and analyzed. Finally, conclusions and recommendations are made for both groundwater and freshwater monitoring plans moving forward.

2.0 RATIONALE / OBJECTIVES

A Baseline Study for freshwater quality and quantity (groundwater and surface water) is specified in Section 4.30 of the Draft EIS Guidelines for the Project and prescribed in accordance with section 12 of the *Newfoundland and Labrador Environmental Assessment Regulations, 2003*. A Baseline Study (Study) is required for groundwater and surface water quality and quantity because these environmental features are Valued Ecosystem Components (VEC) that requires "additional data for use in determining the potential for significant effects on a VEC due to the proposed undertaking, and to provide the necessary baseline information for monitoring programs". This VEC includes stream and lake sediment quality.

Objectives of the Study include:

- Delineation and presentation of Study area(s) of adequate scales for groundwater and surface water baseline investigations from which to subsequently assess comprehensively the Project effects on the VEC;
- Present the methods used to describe and characterize the existing environment for the VEC;
- Present the results of background information review of local to regional groundwater and surface water quality and quality to provide context to Project investigations;
- Present the Study Area field monitoring plans and activities;
- Present the findings and results of field monitoring;
- Present the findings and results of VEC modeling undertaken to better understand VEC normals, variability, range, and scale so that the range of environmental conditions that may be anticipated over the Project life cycle can be qualified and quantified;
- Provide Study conclusions reviewing the VEC constraints and opportunities specifically in relation to Project - VEC interactions such as Project water demand, effluent discharge and other mechanisms for contaminants to enter the VEC environment; and
- Provide recommendations for further monitoring and follow up.

The purpose of this report is to address the guidelines as laid out in the EIS Draft Guidelines (section 4.18) prepared by the Canadian Environmental Assessment Agency and the Newfoundland and Labrador Department of Environment and Conservation. In addition to satisfying these regulatory requirements, it is aimed to fulfill the recommendations laid out in the Baseline Hydrogeology and Hydrology Scoping Studies prepared by Stantec (2011*a,b*).

A complete conceptual hydrogeological model of the site was developed by following the three staged approach recommended in the Scoping Study. These stages included; 1) detailed review, 2) groundwater level monitoring, and 3) site investigations. Each of these three stages has been completed to a certain extent, and the information gathered helps to build the hydrogeological model. The conceptual hydrogeological model presented in the Scoping Study will be built upon to allow for a more accurate picture of the freshwater quality and quantity on site to be developed. New information gained over the following year through the baseline monitoring programs will be used to update, and where relevant, to revise the understanding presented herein.

3.0 STUDY AREA

The Kami Property is located in western Labrador approximately 10 km from the iron-mining towns of Wabush, NL, and Labrador City, NL, and 5.5 km north east of the town of Fermont, QC (Figure 3.1). The mine property is located 6 km south of the Wabush Mines mining lease, owned by Cliffs Natural Resources Inc. (Cliffs). The Kami Property is comprised of 7,625 hectares located in Labrador and 125 hectares located in Quebec, with the entirety of project development activities taking place within Labrador.

The Project area that will be developed (Figure 3.2) includes an open pit, waste rock disposal area, processing infrastructure, TMF, ancillary infrastructure and a rail transport component. These developments will take place in a regional setting comprised of a series of north-south trending elongated lakes amongst rolling hills and valleys with local elevations ranging from 594 m to 700 m.

The Study area for surface water is defined as the Project Regional Study Area (RSA). Project effects on water resources are derived from sources within the Project Development Area (PDA). The PDA defines the major project component areas and surface activities. The effects on surface water will be specifically assessed in the EIS at the PDA and Local Study Area (LSA) scales.

The LSA encompasses the PDA and includes the areas downstream from the PDA within which direct Project surface water effects may be measured and quantified. Project surface water effects at the boundary of the LSA are considered to be residual effects, which are defined as the net residual effects after effects mitigation has been incorporated into the assessment. The Regional Study Area (RSA) defines the Project effects measurement boundary, where Project residual effects are assessed with those of other known or anticipated sources in a cumulative effects assessment. As such the surface water study area is the RSA.

With respect to groundwater, potential Project-related effects will be limited to the PDA and the LSA. Due to the topography, drainage, anticipated short local groundwater flow pathways and groundwater-surface water interactions, no effects on groundwater resources are anticipated within the RSA.

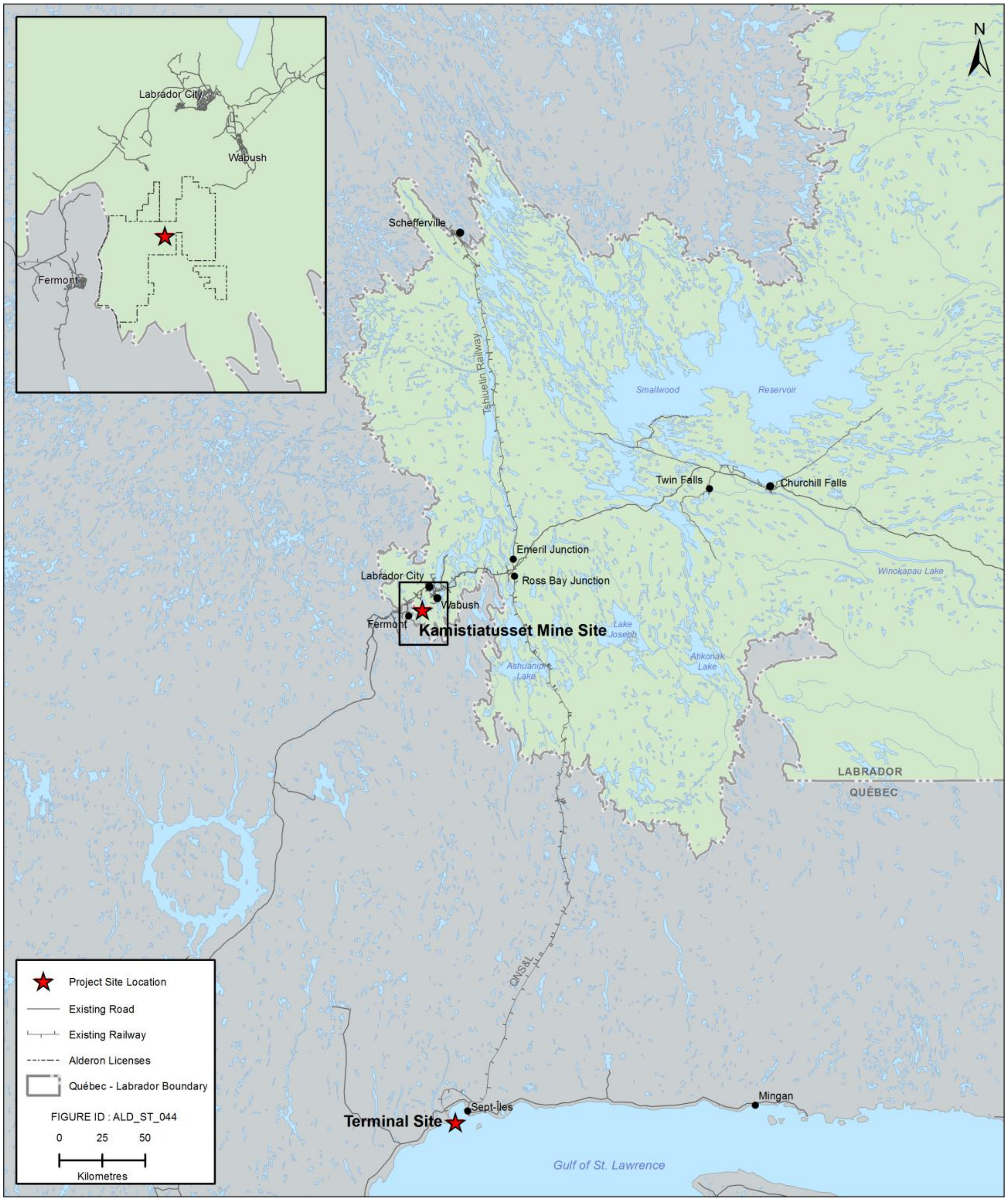
Watershed Characteristics

Surface water hydrology is important to mining as a source of mine water supply, discharge dilution and assimilative capacity and, as mine site drainage works, can affect the quantity and quality of local surface water and groundwater. Changes to the hydrological regime can affect fish, fish habitat, as well as other aquatic and terrestrial resources and ecosystems. Minimizing hydrological effects is a key criterion in obtaining environmental permits to mine.

The study area encompasses several sub-watersheds of the Churchill River, including Mills Lake, Long Lake, Riordan Lake, Waldorf River, Pike Lake South, Wabush Lake, and several unnamed brooks and lakes. This region hosts mining operations which cumulatively could affect regional groundwater and surface water resources.

Figure 3.1 presents the Project Site location in western Labrador. Figure 3.2 presents the surface water study area.

Figure 3.1 Project Location for the Kami Iron Ore Mine and Rail Infrastructure Project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Smallwood
Reservoir
Twin Falls
Churchill Falls
Emeril Junction
Ross Bay Junction
Labrador City
Wabush
Fermont
Kamistiatusset Mine Site
Lake Joseph
Ashuanipi Lake
Atikonak Lake
Winokapau Lake
LABRADOR
QUÉBEC
QNS&L
Mingan
Sept-Îles
Terminal Site
Gulf of St. Lawrence
Project Site Location
Existing Road
Existing Railway
Alderon Licenses
Québec - Labrador Boundary
FIGURE ID : ALD_ST_044
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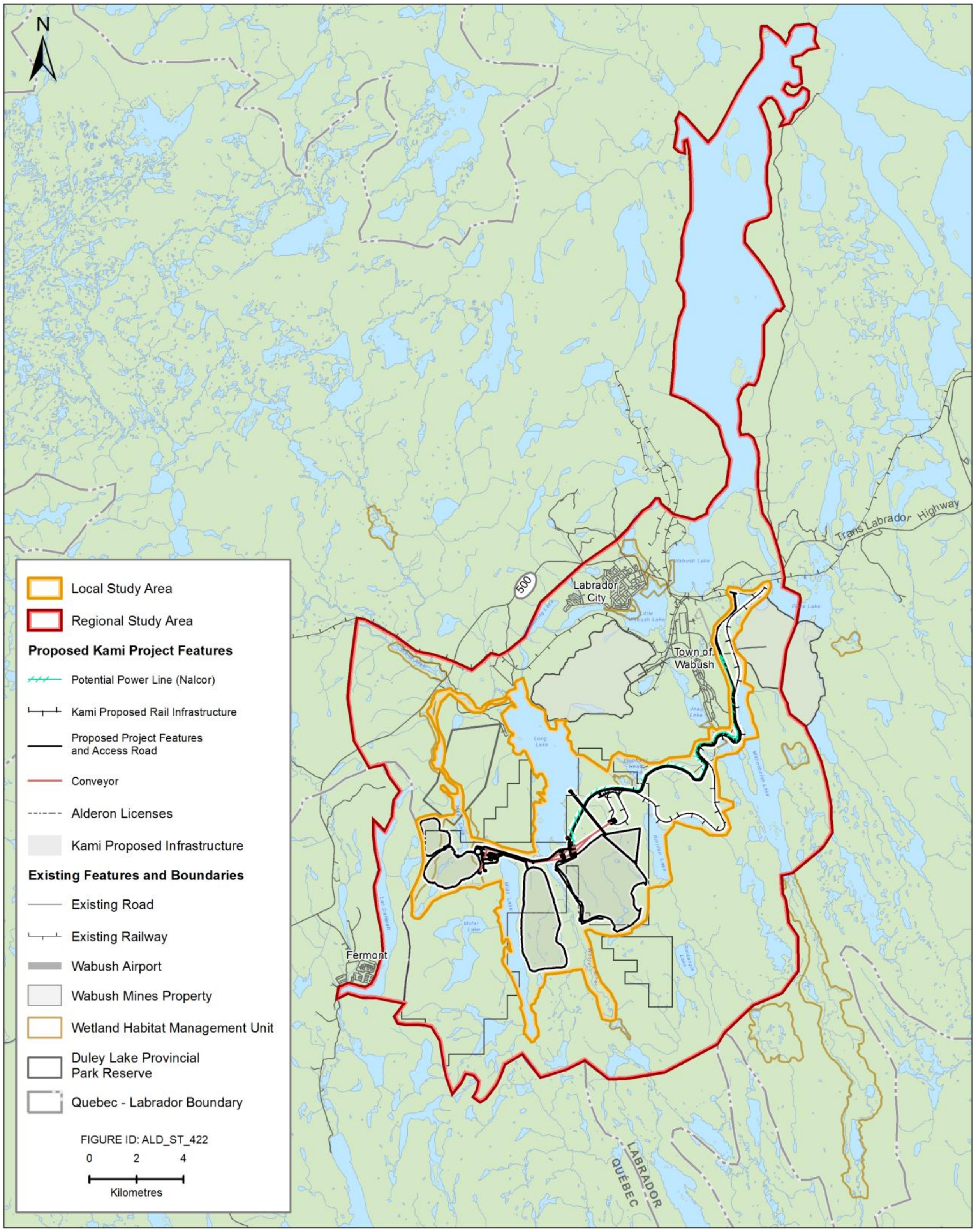
Kilometres

Figure 3.2 Surface Water Study Area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Labrador City
Wabush Lake
Little Wabush Lake
Town of Wabush
Flora Lake
Long Lake
Jean Lake
Elephant Head Lake
Wahnahnish Lake
Riordan Lake
Mills Lake
Molar Lake
Waldorf River
Rectangle Lake
Fermont
LABRADOR
QUÉBEC
Local Study Area
Regional Study Area
Proposed Kami Project Features
Potential Power Line (Nalcor)
Kami Proposed Rail Infrastructure
Proposed Project Features and Access Road
Conveyor
Alderon Licenses
Kami Proposed Infrastructure
Existing Features and Boundaries
Existing Road
Existing Railway
Wabush Airport
Wabush Mines Property
Wetland Habitat Management Unit
Duley Lake Provincial Park Reserve
Quebec - Labrador Boundary
FIGURE ID: ALD_ST_422
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4.0 METHODS

4.1 Groundwater

4.1.1 Approach and Rationale

The aim of the groundwater investigations completed to date has been to develop a site-wide characterization of both the quality and quantity of the groundwater. The water levels, seasonal water level fluctuations, flow directions and patterns and the hydraulic properties of overburden and bedrock were all considered to help develop an understanding of how groundwater might interact with the project, and how the project might in turn interact with the natural hydrogeological-hydrologic cycle.

Investigation into specific groundwater characteristics focused on areas that will be developed during the project including: Main Plant site, TMF, Waste Rock areas, Access Road, Rail Line and Power Transmission Lines and the Rose Pit area. Field investigations were broadly divided into two sections: the site wide areas (all areas outside the Rose Pit) which were done through the “BH-GE” borehole series, and the Rose Pit area which was investigated through the “ROB” borehole series along with selected Alderon exploration “K” borehole series. The locations of these different series of boreholes can be seen in Figures A.2 (Rose Pit) and A.3 (East Areas).

Understanding the groundwater characteristics of the Kami Property was done through the collection and analysis of physical data (water levels, hydraulic conductivity, and water quality) and through the review of available information on the local hydrological and hydrogeological environment.

4.1.2 Information review

4.1.2.1 On-site Sources

On-site activities began with a Stantec site visit in March 2011 to get an overview of the Kami Property and to discuss the current state of the project. Available mapping, exploration drilling and conceptual stratigraphy and ore body information was provided by Project personnel. During this visit, a preliminary understanding of the site’s spatial characteristics, geology and topography was gained to help develop the next steps of the project. Subsequent to the initial site visit, more extensive investigations have been carried out both in the Rose Pit area and across the Kami Property to provide more detailed information on area specific hydrogeological features; this work is on-going. More details on the site investigations will be provided in Section 4.1.3.

4.1.2.2 Off-Site Sources

Information gathered from off-site sources was primarily composed of a review of relevant reports and documents. An extensive literature review was conducted for the *Baseline*

Hydrogeology Scoping Study, completed in June 2011 by Stantec. The document review concluded that a report completed by Watts, Griffis and McOuat titled *'A Technical Report on the Kamistiatusset Property*' held the most relevant information. The 2011 information review, along with communication with Alderon, helped to develop a conceptual hydrogeological model and to guide the development of the geotechnical and hydrogeological field investigation programs currently being carried out.

4.1.2.3 Identified Knowledge Gaps

Due to the climate in the Project area, with temperatures below 0^{o}C for much of October through to May, some substantial gaps exist in the information collected to date from the field investigation program. A total of eleven (11) wells were found to be frozen in the March 2012 field program alone, leading to gaps in both groundwater quality and groundwater level data. Automated water level data loggers were installed in early 2012, and provide a partial record covering a few months in the winter; monitoring over the course of at least one year is recommended to get a more complete idea of groundwater trends. An intensive program of geotechnical drilling and sampling will continue during the summer of 2012. The on-going groundwater program is concurrent with the geotechnical work, and it is intended that this baseline document and associated databases will be updated as the new information becomes available.

4.1.3 Geotechnical and Hydrogeological Investigations

4.1.3.1 Previous Work

Previous geotechnical work includes developing a preliminary geotechnical understanding of the Project site in the 2011 Scoping Study (Stassinu Stantec, 2011*a*) which also presented a plan for further investigative work to be carried out. Portions of this investigative field program have been completed and information gathered from this work has been considered in the preparation of this EIS. Stantec has completed a number of other studies that have also influenced the field investigation program, including;

- Environmental Study (Stantec 2011);
- Tailings Management Study (Stantec 2011);
- Waste Rock Management Study (Stantec 2011);
- Hydrologic Study - Kami Site (Stantec 2011);
- Baseline Hydrogeology Scoping Study - Kami Site (Stantec 2011);
- Site Wide Geotechnical Study - Kami Site (Stantec 2011); and
- Rehabilitation & Closure Report (Stantec 2011).

Previous hydrogeological work included the June 2011 '*Baseline Hydrogeology Scoping Study*' (Stassinu Stantec, 2011b) which aimed to develop a conceptual hydrogeological model for the site and provide guidance on future work. A number of subsequent studies, as listed above, have helped to develop the hydrogeological investigation program.

The Baseline hydrogeological Scoping Study laid out the proposed hydrogeological work plan in three distinct stages, of which stage one has been completed while stage two and three are ongoing;

1. **Detailed Review**: Reviewing existing data, collecting additional geotechnical data from overburden samples and bedrock cores and collaborating with Alderon geologists to prioritize major structural interpretation.
2. **Site Investigations**: The geotechnical drilling programs were sub-divided into overburden (ROB) and bedrock (RBR) drilling in the Rose Pit area, and the BH-series drilling in other areas of the Project site. Groundwater monitoring standpipes or piezometers were installed concurrent with the geotechnical program and selected wells were subsequently sampled and hydraulically tested.
3. **Groundwater Level Monitoring**: Recording of static levels during site visits as well as deploying water level data loggers to record water levels every six hours. This provides insight on groundwater fluctuation patterns over time.

4.1.3.2 Scope of Investigations

The geotechnical and groundwater programs were completed simultaneously, with the groundwater program using the boreholes installed during the geotechnical program. The boreholes were logged to confirm the stratigraphy, geologic and geotechnical properties of the overburden and upper few meters of bedrock. Monitoring wells installed in most boreholes were designed to investigate the hydrogeological properties of overburden and bedrock, including water levels, water quality and hydraulic conductivity. Selected wells were instrumented with automated water level data loggers which provide an indication of seasonal water level fluctuations.

4.1.3.3 Drilling Program

The geotechnical drilling program takes a phased approach, consisting of three main stages;

- Stage 1 – Geotechnical Field Investigation for Preliminary Planning (completed);
- Stage 2 – Geotechnical Field Investigation for Design 2011 and 2012 (ongoing); and
- Stage 3 – Aggregate Sourcing Study (planned).

Stage 1 activities were completed through two separate programs, one for the site wide wells and one for wells located in the Rose Pit. The Rose Pit overburden wells were concentrated around the perimeter and within the footprint of the proposed OPM to develop a good understanding of overburden and shallow bedrock conditions for the pit slope design, labeled as “ROB” wells (Rose Pit Overburden) or “RBR” wells (Rose Pit Bedrock) on Figure A.2. The site wide wells were clustered around areas of proposed infrastructure development, and were distributed across the entire site, labeled as “BH” wells on Figure A.3.

Table B.1 Appendix B summarizes the borehole and monitor well information to date. As of May 2012, a total of twenty-four (24) ROB wells were completed at twenty (20) distinct locations with four (4) nested well pairs; a total of twenty-two (22) BH wells were completed across the remainder of the site. The Rose Pit wells were drilled between September 29, 2011 to April 10, 2012 and range in depth from 5.82 to 60.1 mbg, averaging 22.2 m. The site wide wells were drilled between September 5, 2011 and December 1, 2011 and range in depth from 4.6 to 53.00 mbg (BH-11-11B), averaging 17.0 m. The information gathered in this stage was intended to generally characterize the stratigraphy, hydrogeology and geotechnical properties of the specific areas of interest, and to identify requirements for further investigation and/or special design considerations in subsequent stages. This information is imbedded in the subsequent sections throughout this report. Detailed borehole logs with as-built monitoring well details stratigraphy, water level and locations of geotechnical samples collected are presented in in Appendix C.

Stage 2 work (on-going during the 2012 field work season) is based on the final site development details, and is aimed to provide detailed information for infrastructure and mine design. This stage will consist of approximately four hundred and fifty (450) test locations made up of both test pits and boreholes throughout the footprint of the Project. The Stage 3 work is aimed at identifying suitable aggregate supply sources for site infrastructure construction and includes a desktop study as well as a field investigation program.

All drilling activities were supervised by Stantec and carried out by Lantech Drilling Services Inc. (Lantech). Other sub-contractors were also involved in site preparation including the clearing of trees and the removal of snow. As sites were located in remote locations, with only a few having pre-existing access trails, transportation to and from well sites was facilitated by helicopter (Canadian Helicopters Group). The drill rig was also transported between sites via helicopter.

4.1.3.4 Monitor Well Installation

Monitoring wells were installed at each of the drill sites with a total of forty-five (45) monitoring wells (24 ROB wells and 21 BH wells) installed between the fall of 2011 and the spring of 2012. The well depth varied depending on the depth of overburden and depth to groundwater in certain areas. The time taken to complete each well varied considerably depending on the depth of the well, the material encountered and the local weather conditions.

Monitor Well Locations

Figures 4.1, 4.2 and 4.3, Appendix A show the locations of the monitor wells. The following boreholes and monitor wells were used in this assessment:

The ROB-series wells in the vicinity of the Rose Pit OPM are distributed around the perimeter of the proposed mine (ROB-11-1A/B, 8A/B, 9, 10, 11, 12, 16; and ROB-12-2, 3, 4, 5A/B, 6, 7, 13A/B, 14, 15), and within the OPM footprint (ROB-11-17, 18, 20 and ROB-12-19). In addition to the overburden wells, two bedrock 300 m deep inclined bedrock wells (RBR-12-01 and RBR-12-02) were installed in the Rose Pit area to assess bedrock hydraulic properties.

The GE-series wells in the other component areas include: BH-GE-1, 2, 3 at the West Plant; BH-GE-4, 5, 6 along the Site access road; BH-GE-7, 8, 9, 10, 11 and 12 at the East Plant Area; BH-GE-13, 14 and 15 at the TMF; and BH-GE-16, 17, 18, 19 and 20 in the vicinity of the rail loading areas. Monitor well pairs are designated shallow (B) and Deep (A), with screens typically set in overburden and the till-bedrock interface.

Monitor Well Construction

Table B.1, Appendix B summarizes the monitoring well completion details. The monitoring wells were comprised of 51 mm diameter, schedule 40, and flush-threaded PVC pipe with No. 10 or 20 slot (0.25 to 0.5 mm) screens. The screened portion was stabilized with clean silica sand pack. The annulus above the sand pack was sealed to grade (shallow wells) or at least 1 m (very deep wells) with bentonite grout. Each well was completed with a 100 mm diameter locking steel protector with an approximate 1 m stick-up above grade. The top of the PVC pipe was sealed with a J-plug.

The monitor well screens range in length from 1.5 to 54.87 m, averaging 9.6 m. The sand packs range in length from 1.8 to 57.0 m, mean 12.8 m, and typically span the bedrock-overburden interface where encountered. The “effective” Screen length for assessment of water level pressure and hydraulic properties is the saturated sand pack length. Most monitor wells were screened the full length of the borehole, with bentonite seals in the upper few meters. Monitor well sand packs completed entirely in bedrock include BH-GE-01, BH-GE-16, ROB-11-1A and ROB-11-5A. Of the remaining wells, 16 are completed entirely in silty sand overburden glacial Till, and 25 span the till-bedrock interface.

Monitor Well Development

Prior to sampling or hydraulic testing, each completed monitoring well was develop by vigorous pumping or bailing to remove drilling debris and to render the sand pack and screen hydraulically efficient.

4.1.3.5 Surveying

Each monitoring well location, both Site Wide and in the Rose Pit, was surveyed for location and elevation. This information was compiled and is presented on Table B.1 in Appendix B in NAD 27 datum. Surveying was conducted by All North Consultants Limited and Alderon using a variety of methods including hand held GPS and differential GPS survey methods.

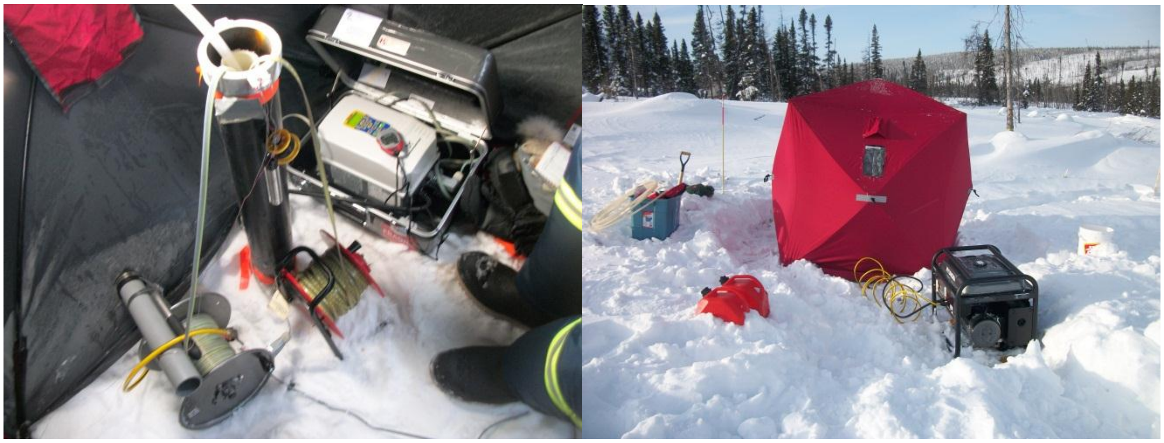
4.1.3.6 Hydraulic Testing

Drawdown-recovery Testing

Hydraulic testing consisted of step-pumping tests and recovery tests at accessible wells across the site. The resulting hydraulic conductivity (K) data was used to assess the seepage potential into Rose Pit and potential groundwater flow velocity throughout the site. The general procedure for each well tested was as follows;

- Arrive at site with required equipment via helicopter. Equipment included; gas powered generator, Grundfos variable flow pump (instrument / control box and submersible pump), water level meter, polyethylene tubing, ice fishing tent, Rubbermaid totes with various tools and small equipment (data loggers, wire, clamps, etc.). A photo of the testing set up, inside and outside of the tent can be seen in Photo 4.1 below.
- Set a tent up over the test well to shelter instruments and personnel (cold weather).
- Measure and record static groundwater level before any testing occurs.
- Measure and record total well depth.
- Depending on the well depth and the depth of water in the well, the pump was placed a minimum of 1 m off of the bottom of the well to allow as much drawdown as possible; wells with water depths less than 3 m were not tested.
- Polyethylene tubing connected to the pump was discharged outside of the tent and down gradient of the well to avoid any well recharge possibilities.
- Begin pumping at a low flow rate, and measure water levels in the following format, or until the water level stabilized;
    - Every 15 seconds for 2 minutes
    - Every 30 seconds for the next 3 minutes
    - Every minute for the next 15 minutes
    - Every 2 minutes for the next 10 minutes
    - Every 5 minutes for the next 20 minutes
    - Every 10 minutes for the remainder
- Once the water level stopped falling, the pumping rate was increased and the above measurement schedule would begin again. The number of increases in flow rate required to draw the water level down to the level of the pump intake varied between wells (typically one to four steps).
- During draw down the flow rate was measured using a 5 US gallon bucket and stop watch at each flow setting.
- Once the water level reached the level of the pump, the pump was switched off and groundwater levels were measured following the above schedule until they returned to the original static level (i.e., recovery test).
- In cases where very low well yield was present, only one pumping step was made, followed by recovery measurements (i.e., bail down test).

Photo 4.1 – Typical instrumentation setup inside and outside the tent at each site.



Packer Injection Testing

As part of the geotechnical investigations, a series of inclined boreholes were installed in the vicinity of the Rose Pit. Packer injection testing consisting of up to 25 overlapping 1.3 to 13.8 m packer zones per borehole were complete do two wells (RBR-12-01 and RBR-12-02) at the time of this assessment; work is on-going. The resulting hydraulic conductivity (K) data was compared with core log fracture frequency data to generate permeability profiles for each borehole (see examples in Appendix A).

4.1.3.7 Water Level Monitoring

Water level monitoring carried out in conjunction with stage 2 of the work plan encompasses both static water level measurements and the deployment of HOBO$^{@}$ water level data loggers. Manual water level measurements were taken during each well visit using a water level meter. Wells were accessed via helicopter and site visits were coordinated so that multiple tasks could be completed per visit (i.e. hydraulic testing or water quality sampling). Groundwater level data is used to confirm depth to groundwater, horizontal and vertical hydraulic gradients, groundwater recharge and discharge areas and directions of groundwater flow throughout the site.

A total of twenty-five (25) data loggers were installed in selected wells strategically distributed across the site, including ROB, BH, and K-series wells of varying depth, to ensure representative information was gathered for the entire site. These data loggers were connected to the top of the well with either high gauge fishing line or 1/16” aircraft cable. The loggers were set at a depth that is anticipated to keep them submersed year round and allow for continuous data collection, at six hour intervals. The data loggers were of two types, depending on the anticipated submerged depth of installation: those that could be submersed to a depth of 30.4 m (100 ft) and those that could be submersed to a depth of 9.14 m (30 ft). In addition, a precision data logger was installed in a “dry” well above the water table to monitor barometric pressure during the monitoring program; these data were used to correct the water levels for barometric influences.

4.1.3.8 Baseline Groundwater Quality Sampling

Groundwater sampling was carried out during winter conditions in late 2011 to characterize the chemistry of water in overburden and bedrock throughout the site. An understanding of groundwater chemistry is required in order to assess the potential effects of mine-related seepages, and the potential for the on-site development of water supply wells. Samples were recovered from twenty-one (21) wells across the site. Samples were taken from a variety of wells including, ROB, BH and Alderon drilled exploratory ‘K’ wells in an effort to collect a representative sampling of the site.

Samples were collected using polyethylene tubing connected to a variable flow rate sampling pump, powered by a portable gasoline powered generator, where water levels permitted. When shallow water levels were encountered, samples were collected manually by bailing with polyethylene tubing connected to a foot valve. Each monitoring well was purged a minimum of three casing volumes prior to sample collection. The samples were clearly labeled, placed in insulated shipping containers, and returned to the laboratory with appropriate chain-of-custody documentation.

4.1.3.9 Analytical Program

The groundwater samples were submitted to Maxxam Analytics, Bedford, NS (Maxxam) for analysis of general chemistry and dissolved metals. The samples submitted for dissolved metals analysis were field-filtered and preserved using 15 drops of nitric acid solution (1%). A summary of the sampling results is presented in Table B.2 (General Chemistry) and Table B.3 (Metals) in Appendix B.

Consistent sampling methods were used throughout this assessment. Sampling QA/QC involved the use of lab-supplied bottles and preservatives, use of monitor-well dedicated polyethylene sampling tubing, low flow pumping methods, chain-of-custody documentation, and random laboratory duplicate analysis. The seven random duplicate samples indicate a high degree of consistency (Tables B.2 and B.3, Appendix B).

4.1.3.10 Data Management

The size and duration of this project generates a significant amount of data which needs to be managed effectively to allow for its proper access, interpretation and use as the Project proceeds. To facilitate this, information is compiled in databases on a central server to allow company wide access and updates. Everything from detailed field notes, photographs, analytical data results and water level records are stored electronically for future reference.

4.2 Surface Water

Surface water in the study area includes an assessment of hydrology, water quality and sediment quality.

4.2.1 Approach and Methodology

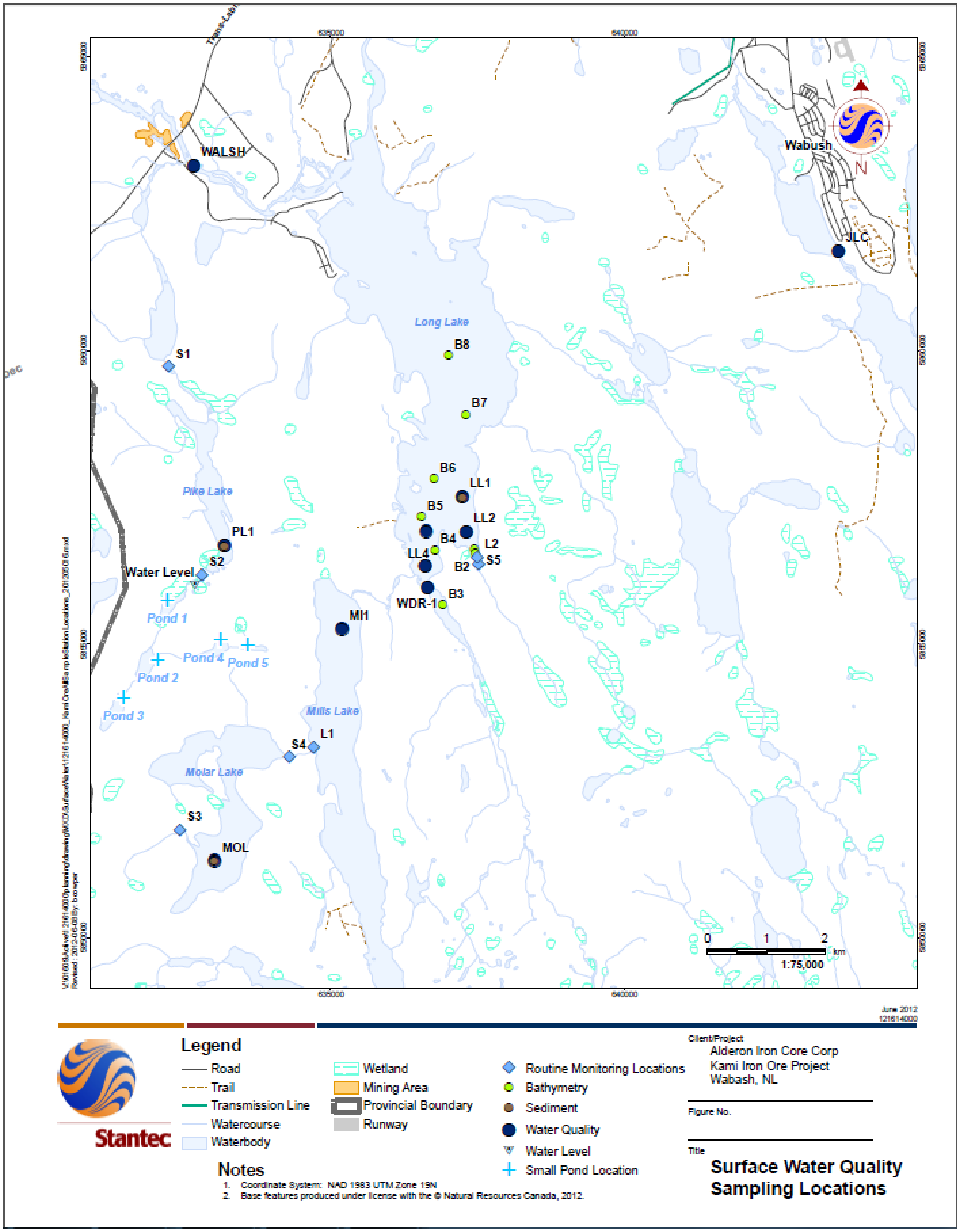
4.2.1.1 Hydrological Study Approach

The hydrological assessment is intended to characterize the baseline conditions in watersheds potentially affected by the proposed development of the Project. Figure 3.2 shows the LSA, RSA and local features. The hydrological study was designed to gain a better understanding of potential surface water impacts arising from the Project, sources of water for mine operations and to gain a better understanding of the assimilative capacity of the various watersheds under study. This hydrological assessment included the completion of:

- A Regional Hydrological Information Review;
- A Climate and Precipitation Assessment;
- A Water Balance Assessment;
- Hydrological Monitoring; and
- Empirical Hydrological Modeling.

The methodology used for each of the aforementioned components is discussed in detail throughout Section 4.2.1 of this report. The hydrological monitoring program included the installation of seven (7) continuous monitoring stations throughout the LSA to monitor representative water levels and to estimate flow rates at selected representative locations. Six (6) manual measurement staff gauges were installed in ponds associated with the proposed Rose Pit. Additionally, bathymetric information for local lakes was collected. Monitoring and instrumentation locations for the hydrological assessment are shown in Figure 4.1.

Figure 4.1 Surface Water Monitoring Locations


WALSH
Wabush
JLC
N
Long Lake
B8
B7
B6
LL1
B5
LL2
B4
L2
LL4
S5
B2
B3
WDR-1
MI1
S1
Pike Lake
PL1
S2
Water Level
Pond 1
Pond 4
Pond 5
Pond 2
Pond 3
Mills Lake
S4
L1
Molar Lake
S3
MOL
0
1
2
km
1:75,000
June 2012
121614000
Legend
Road
Trail
Transmission Line
Watercourse
Waterbody
Wetland
Mining Area
Provincial Boundary
Runway
Routine Monitoring Locations
Bathymetry
Sediment
Water Quality
Water Level
Small Pond Location
Notes
1. Coordinate System: NAD 1983 UTM Zone 19N
2. Base features produced under license with the © Natural Resources Canada, 2012.
Client/Project
Alderon Iron Core Corp
Kami Iron Ore Project
Wabash, NL
Figure No.
Title
Surface Water Quality Sampling Locations
Stantec

4.2.1.2 Hydrological Information

Climate and Precipitation Assessment

For the determination of climate normals for the Project, climate normal data for the latest 30-year period were obtained from Environment Canada Station 8504175 (Wabush Lake Airport) which is located approximately 12 km to the northeast from the project site. The data were analyzed and summarized for the minimum, maximum and mean values for parameters such as temperature, rainfall, snowfall, precipitation as well as snow on the ground. Dry year and wet year climatic conditions under the latest 30 year period were then further selected based on the analysis of the latest 30-year climate normal data obtained from Environment Canada.

Precipitation data for the 24-hour storm events were derived from the available intensity-duration-frequency (IDF) curves at *Wabush Lake A* station (climate ID: 8504175). Precipitation for the 500 year return period was determined by extrapolating the 24-hour storm event. Since there are limited sources of probable maximum precipitation (PMP) determination in Labrador, the common practice of using the return period of the 10,000-year storm event is applied in determining the PMP precipitation (Ponce, 1989).

The annual lake evaporation between year 1967 and 1992 were derived from the available data at *Churchill Falls A* station (climate ID: 8501132) and *Nitchequon* station (climate ID: 7095480). The data was then ranked from largest to smallest in order to determine the mean annual lake evaporation year, and the wetter year data set and the dryer year data set. Log Normal distribution was applied to develop the trends of the wetter curve and dryer curve and predicts the lake evaporation for 500 and 1000 years return periods. The mean evaporation was derived from Rollings' findings (1997) and the evaporation values from 5-yr to 1000-yr return periods were calculated from the log-normal distribution curves.

The potential effects of climate change on the Project were assessed with respect to temperature and precipitation change effects on water resources. The climate change assessment was conducted through a review of Labrador climate change literature and interpretation of potential effects over the Project life cycle.

Watershed Delineation, General Hydrological Data and Lake Bathymetry

To estimate low to high flows at selected flow nodes and discharge points important to the Project, watersheds and subwatersheds were first delineated using GIS tools, available LiDAR mapping, available digital topography and NL watershed delineation data. Existing mapping and aerial imagery were used to collect broad scale information on each watershed including watershed areas and lake areas. Lake area information collected in this manner was used in conjunction with collected lake depth data to generate bathymetry imagery used in the Report. No lake bathymetric information was publically available. Bathymetry data collected for local lakes were used to estimate relevant lake volumes that, in turn, were used in the estimation of retention times and effluent assimilation characteristics. Bathymetry data were collected in May 2012 by documenting water depth at regular intervals along transects across waterbodies using a sonic transducer. Additional bathymetric data was collected during March and April of 2012 by augering through ice cover and sounding with a weighted tape. Depth data points and transects locations were documented using a hand held GPS and sketched on field maps.

Water Balance Methods

The water balance assessment was conducted using the Thornthwaite Water Balance Method formalized in the USGS Thornthwaite Model (2012) and calibrated with regional and Project monitoring information. The Thornthwaite Monthly Water Balance Model is hereafter referred to as the Thornthwaite Model. The Thornthwaite Model develops water balance estimates for a specified location among various components of the hydrologic system using a monthly accounting procedure based on the methodology originally presented by Thornthwaite and subsequent authors (Thornthwaite, 1948; Mather, 1969, 1978, 1979; McCabe and Wolock, 1999). In the Thornthwaite Model, the change of state of water is a function of the amount of energy available, which, in turn, is governed by the latitude, length of day and season which combine to control the amount of energy received at the earth's surface. Infiltration and vegetation factors then control the fraction of excess water that infiltrates into the ground versus the fraction that runs off to nearby lakes and streams. The Thornthwaite Model requires input of climate information, local land use, geographical and environmental characteristics to further identify site specific conditions.

The general equation that describes the long term water balance estimation is:

$$P = ET + R + I$$

Where: P = precipitation

ET = evapotranspiration

R = surface runoff

I = infiltration and storage

The Thornthwaite model relies on the amount of energy available to evaporate water from free water-surfaces such as streams, wetlands, ponds, lakes, oceans, and the intercepting surfaces on which it falls as precipitation. Water loss can also take place in vegetation at the openings of stomata, found normally on the lower surface of leaves. Energy also vaporizes water drops present in the atmosphere.

To adequately describe the amount of both energy and water within a given system, the Thornthwaite and Mather (1957) method requires the input of monthly temperature and precipitation, Site hemisphere, latitude, elevation, vegetation type, land use, soil storage characteristics, size of the Study Area, average slope, and relative location within the governing watershed. The Thornthwaite model was applied to climate normal, 30-year wet year and 30-year dry year regimes to estimate the existing condition environmental water balance over a temporal scale compatible with the Project life cycle.

Input Data

Water balance calculations require the input of climate normal information, local land use, geographical and environmental characteristics to further identify site specific conditions. Using aerial photography, GIS applications and regional soil data, parameters best representing the watersheds surrounding the PDA were chosen. Site specific water balance input parameters are provided in the results section of this report (Section 5.2.4.4), along with the water balance results.

Evapotranspiration

Evapotranspiration (ET) estimations were obtained using the Thornthwaite Model. This model calculates evapotranspiration amounts based on average monthly temperatures and precipitation for the specific climate years of interest (normal, wet and dry), soil storage and vegetation cover type. Since the method uses monthly temperature averages and estimates of the transpiration of vegetation, it was assumed that in months with average temperatures below 0°C the only physical actor in ET was limited to the relatively small amount of sublimation which may occur. Following the same assumption, ET was assumed to reach its peak value in July in agreement with the peak in temperature according to the climate data.

Runoff

Runoff estimations were obtained using the Thornthwaite Model and were calibrated against field monitoring and regional extrapolation results. Runoff is calculated based on the precipitation, melt rate, antecedent moisture conditions, soil type, slope and vegetative cover of the site in question.

Infiltration

Infiltration estimations are calculated through the equation:

$$I = P - R - ET$$

Where: I = Infiltration
P = Precipitation
R = Surface Runoff
ET = Evapotranspiration

Infiltration values are dependent upon antecedent moisture conditions, soil porosity, permeability, vegetative cover characteristics and slope. In this case, the often relatively shallow soil depth and prevalence of exposed bedrock will have significant impacts on infiltration rates and subsequently the partition of infiltrated water into baseflow and recharge. In effect, incident precipitation that is not infiltrated is lost to evapotranspiration and runoff.

Infiltration can be broken down further into two sub-components; recharge and baseflow. Recharge is the component of infiltration best described as all water that migrates vertically downward eventually recharging the groundwater aquifer. Baseflow is that portion of recharge that discharges from groundwater aquifers to local lakes and streams. Baseflow and recharge components are estimated using the infiltration factor described in MOE (1995). The sum of factors for topography, soil and vegetation, the infiltration factor, is used to compute the proportion of total infiltration that is contributed to groundwater recharge. Reciprocally, "1 - infiltration factor" will compute the baseflow discharged to watercourses. Although within the temporal confines of a climate year recharge and baseflow may not balance, in the long-term all water that recharges groundwater aquifers is discharged as baseflow to lakes and streams. Therefore in the Project Study Area case, as all groundwater is assumed to flow in relatively localized groundwater watersheds highly correlated to the surface watersheds, all baseflow returns to the local watershed into which its source infiltration occurred. As a result of this convention, the water balance can be further simplified into ET and streamflow which includes all overland flow, interflow and baseflow.

Hydrological Monitoring Methods

The field monitoring program included the installation of seven (7) continuous monitoring stations around the LSA to routinely monitor water levels and to estimate flow rates at selected representative stream and lake locations (these stations were also used as routine, seasonal sampling locations for the water quality monitoring program). Continuous hydrological monitoring stations were installed in the Fall of 2011. Surface water flow and level monitoring locations are shown in Figure 4.1. In addition to the seven stations noted above, several locations were monitored solely as water quality monitoring sites, while staff gauges and were installed at others. A summary of hydrological monitoring installations at all stations is included in Table 4.1.

Lake / Pond Level Monitoring

Staff gauges were installed at five (5) pond locations associated with the proposed Rose Pit within the LSA in winter 2012, known as Byrd Lake, Elfie Lake, End Lake, Mid Lake and Rose Lake which drains into Pike Lake South (also referred to as Narrow Lake). These staff gauges are intended to monitor the seasonal fluctuations in lake water levels. Staff gauge readings were recorded seasonally, along with photographs of each Pond gauging station. Ice thickness was also measured when feasible and safe to do so at each staff gauge location.

Continuous lake level monitoring was accomplished through the installation of Solinst Leveloggers in stilling wells at two locations: Mills Lake (Station *L1*) and in Long Lake (Station *L2*), as described in Table 4.1. These Leveloggers were programmed to measure water level above the logger sensor at 10-minute intervals. These Leveloggers were installed on an arbitrary datum and at a depth that was anticipated to cover the entire range of lake elevations during seasonal changes as well as during high precipitation events. Levelogger data were downloaded seasonally at all stations. Continuous lake / pond level data were used to assess water level fluctuation, hydraulic connection to potentially connected waterbodies, lake volume fluctuations, ice effects and water temperatures.

Table 4.1 Continuous Monitoring Station Details

Station ID	Location*	Function	Instrumentation
S1	5859719.7 N, 632232.1 E	Provide baseline water quality, sediment quality and flow data at the exit of the Pike Lake South watershed that contains Rose Pit and Rose North waste rock disposal area and watershed monitoring during construction, operation and decommissioning of the mine.	A Solinst Levelogger was installed in Oct 6, 2011 below the channel bed on the east bank in a stilling well for water depth monitoring with a 10-minutre recording interval.
S2	5856173.5 N, 632802.9 E	Provide baseline water quality and flow data immediately at the exit of the Pike Lake South headwater watershed that contains Rose Pit and watershed monitoring during construction, operation and decommissioning of the mine.	A Levelogger and a Barologger were installed on Oct 7, 2011 in a stilling well for continuous water depth and atmospheric pressure monitoring with a 10-minute recording interval. The stilling well and loggers were installed on the east bank.
S3	5851833.0 N, 632431.0 E	Provide baseline water quality, sediment quality and flow data for a small headwater watershed draining into Molar Lake.	A Levelogger was installed in Oct 8, 2011 in a stilling well on the south bank for continuous water depth monitoring with a 10-minutre recording interval.
S4	5853070.8 N, 634296.2 E	Provide baseline water quality, sediment quality and flow measurements at the outlet of Molar Lake upstream of its discharge point into Mills Lake.	A Levelogger was installed in Oct 7, 2011 in a stilling well on the north bank for continuous water depth monitoring with a 10-minutre recording interval.
S5	5856368.7 N, 637517.1 E	Located downstream of the proposed TMF, the processing mill and other mine infrastructure to collect baseline water quality, sediment quality and flow monitoring.	A Levelogger and a Barologger were installed on Oct 8, 2011 in a stilling well for continuous water depth and atmospheric pressure monitoring with a 10-minute recording interval. The stilling well and loggers were installed on the north bank.
L1	5853238.3 N, 634702.7 E	Monitor water quality and water levels in Mills Lake which is a receiving water body for a portion of runoff from the proposed Rose South Dump.	A Levelogger was installed in Oct 7, 2011 in a stilling well in the lake for continuous water depth monitoring with a 10-minute recording interval.
L2	5856469.0 N, 637498.6 E	Monitor water levels in Long Lake which is the largest water body within the LSA and will also receive runoff from a large portion of the PDA. Due to its size and large upstream watershed catchment area, Long Lake is also proposed to be the primary raw water supply source and treated effluent discharge receiving water body for the Project.	A Levelogger was installed in Oct 8, 2011 in a stilling well in the lake for continuous water depth monitoring with a 10-minute recording interval.

Stream Level / Flow Monitoring

Leveloggers were installed in stilling wells in watercourses at Stations *S1, S2, S3, S4* and *S5* at locations detailed in Table 4.1. A typical Levelogger watercourse installation is depicted in Figure 4.2 and Photo 2. Leveloggers were programmed to collect water level data at 10-minute intervals. Leveloggers were downloaded seasonally. When present, ice thickness was also measured at the continuous level monitoring locations when feasible and safe to do so. Solinst Barologgers were also deployed to collect barometric pressure and ambient temperatures used to barometrically compensate Levelogger water level data. Levelogger data was also offset to compensate for differences between its installed depth and the channel thalweg to subsequently enable conversion of level data to flow using channel cross-section rating curves.

Figure 4.2 Typical Stilling Well Installation

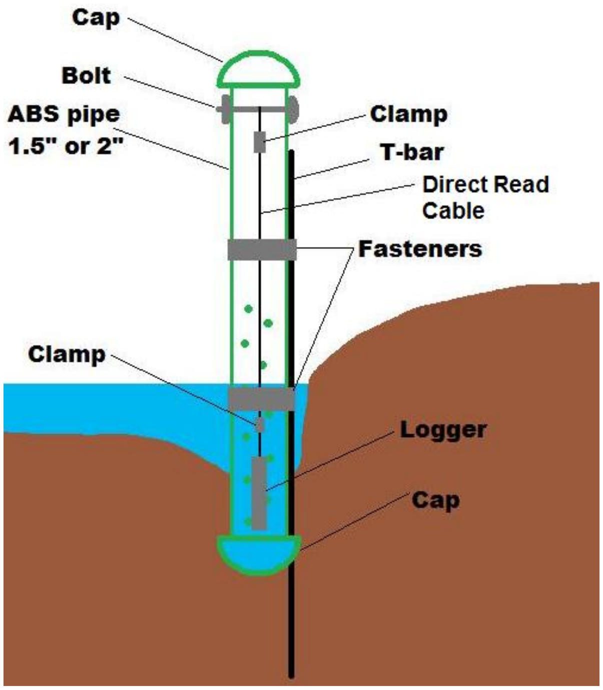

Cap
Bolt
ABS pipe
1.5" or 2"
Clamp
T-bar
Direct Read
Cable
Fasteners
Clamp
Logger
Cap

Photo 4.2 Typical Monitoring Station Installation at Station *S1*

Instantaneous Flow Data

Manual water level, velocity and discharge (flow) measurements were collected seasonally at the five continuous flow monitoring stations (Stations *S1, S2, S3, S4* and *S5*) when water / ice conditions permitted. Stream discharge was measured using the standard mid-section method of direct discharge (Environment Canada, 1999).

Velocity measurements were made using portable Marsh-McBirney FlowMate or SonTek Flowtracker ultrasonic velocity and flow meters with a velocity measurement range between 0.01 to 6 m/s and an accuracy of +/-2%. For all cases the stream transect was divided in a number of manageable subsections and the velocity was measured at the depth that corresponds to 60% of the total depth. All data were recorded in the field, checked for consistency and then transferred to Excel spreadsheets to estimate the total flow rate, which, for each site, is the sum of all flows measured at each subsection. The date and time of each flow measurement was recorded to correlate the flow rate with the corresponding Levelogger water depth measurement (adjusted for the total atmospheric pressure). Discharge data were used to develop a rating curve for each continuous flow monitoring station that, together with continuous level data were used to generate flow hydrographs at each station.

Rating Curve Development

To interpolate flow (discharge) between manual flow measurements, it is necessary to relate water column heights (stream stage) to flow by developing a stage-discharge relationship, also known as a rating curve, for each flow monitoring station. As mentioned previously, the monitoring stations selected for stream flow monitoring contained Leveloggers, which were installed in stilling wells and measured total pressure every ten minutes. The total pressure is equal to the sum of the water pressure (as caused by water depth above the logger) plus the atmospheric pressure. To determine the pressure cause by water depth only, the atmospheric pressure (which was obtained from barometric pressure data loggers (Barologgers) installed in the LSA), was subtracted from the total pressure. The level or stage data were then transformed into flow rates using the corresponding rating curve for each site.

The hydrological monitoring results of all five (5) stream gauging stations were used to prepare rating curves. Manning’s equation was applied in developing the rating curves. Parameters in Manning’s equation were determined using the hydrological monitoring results and the channel cross section profiles. Stream flows at different stages was then calculated using Manning’s equation in order to develop the discharge and stage relationship in the rating curve. Levelogger water level data was applied to the rating curves to generate continuous streamflow estimates. The rating curves are expected to remain valid for as long as the properties of the channel at the measurement point remain the same.

Empirical Hydrological Modeling Methods

Regional Extrapolation

The estimation of flow rates within the Project LSA and RSA was conducted using a flow proration method based on calibrated drainage area. The latest available daily flow data from five nearby Environment Canada river gauging HYDAT stations were used to derive mean monthly maximum, minimum and average daily flow rate relationships with respect to drainage areas Using years when all HYDAT stations were in operation enabled the development of calibrated regional extrapolation relationships. This approach accounted for the fact that larger watersheds are more hydraulically efficient and have higher total streamflow coefficients than smaller watersheds. As such, the relationships enable the accurate prorating or regional extrapolation of flow gauging records from larger watershed HYDAT stations with long record to the smaller watersheds characteristic of most of the PDA and LSA.

Flow duration curves (FDCs) indicate which percentage of time during the entire record a flow was equaled or exceeded. These curves are often used to aid in the determination of water allocations and to provide a measure of the magnitude of larger return period flows at specific flow nodes. The area-calibrated flow proration method was also applied to generate the FDCs of all the subwatersheds within the Project PDA and LSA. Station 03OA001 (Ashuanipi River at Menihek Rapids) was selected as the basis of FDC development since it has the longest flow monitoring records. The available mean daily flow data in station 03OA001 was used to prepare FDCs up to the 50-year return period, whereas the 100-year FDC was predicted from the previous FDCs. Previous analyses indicated that there is a statistically significant relationship between the natural logarithm of mean annual daily flows and the natural logarithm of drainage areas. Thus, proration factors were determined using cumulative drainage areas between station 03OA001 and other HYDAT watersheds. The FDCs of station 03OA001 were then prorated down to smaller watersheds level using the area-calibrated proration factors

Low and Maintenance Flows

A low flow analysis was conducted to provide an understanding of the water withdrawal capacity and instream flow needs or environmental (maintenance) flow requirements for watercourses throughout the Project PDA and LSA. The low flow analysis is essential to determine the quantity of water that can be taken from nearby water sources while minimizing any potential impacts to the environment. In terms of water withdrawal criteria there are different definitions that can be used to determine the safe yield from a stream or lake. For this study, low flows of four durations (1-day, 7-day, 15-day, and 30-day) with return periods 2-year, 5-year, 10-year, 20-year, and 50-year suggested by the Government of Newfoundland and Labrador (1991) will be used for the analysis.

Station 03OA001 was again used as the basis of low flow analysis due to its longest flow monitoring records. The data from station 03OA001 was applied using flow analysis software DFLOW version 3.1. DFLOW uses Log-Pearson Type III frequency distribution to adjust the entire record and calculate low flows with a given recurrence interval.

Maintenance Flows

Environmental flows, also referred to as maintenance flows or in-stream flow needs, describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems. Through implementation of environmental flows, a flow regime or pattern that provides for human uses and maintains the essential processes required to support healthy river ecosystems shall be achieved (eFlowNet, 2007). For this study, Tennant's method suggested by Fisheries and Oceans Canada (DFO) was used to estimate the environmental flows of all subwatersheds throughout the Project PDA and LSA (Stoneman, 2005; Maunder and Hindley, 2005).

Flood Flows

A flood is defined as the highest instantaneous river discharge in a year. In Newfoundland and Labrador, floods are caused by rainfall, snowmelt, or a combination of rainfall and snowmelt. The single station frequency analysis method with Log-Pearson Type III distribution between 2-year and 200-year return periods suggested by Newfoundland and Labrador Department of Environment and Conservation (Rollings, 1999) was used for the flood flow assessment. Flood data in station 03OA001 was selected as the basis of the flood flow assessment due to its long monitoring records.

4.2.1.3 Water Quality Study Approach

Water quality monitoring is a requirement for development of resource extraction projects. Updated and comprehensive information, including levels of contaminants, is needed to document baseline characteristics, assess potential for adverse environmental changes during all project phases and to formulate site-specific water quality objectives for the monitored systems. The following section discusses water quality study design as it relates to the routine seasonal, *in-situ* and spot water quality monitoring. Water quality monitoring was conducted to address many purposes, including but not limited to:

- Assist in assessment of aquatic habitat conditions;
- Benchmark existing water quality conditions against the CCME Canadian Water Quality Guidelines (CWQG-FAL) for the Protection of Freshwater Aquatic Life, and the Metal Mining Effluent Regulations (MMER);
- Characterize the seasonality of potential water extraction and receiving water quality;
- Identify potential points of existing water quality degradation due to existing natural or historic activities;
- Assess the acid buffering potential of receivers and sensitivity to acid rock drainage (ARD);
- Estimate existing condition chemical loading when combined with water flow information;
- From the water quality baseline data, establish summary water quality statistics;

- Understand natural chemical attenuation potential and assimilative capacity of receiving water bodies and potentially required mixing zones used in the development of water management and water treatment plans;
- Assist in establishment of effluent water quality objectives and limits for Project effluent;
- Assist in provision of water quality background to development of Certificate of Approval under the NL Water Resources Act;
- Provide baseline surface water quality information required as part of monitoring requirements for the Metal Mining Effluent Regulations SOR/2002/222;
- Provide an existing condition marker for the development of water quality goals and objectives for use during mine development and closure;
- Inform considerations regarding mine dewater and contact water reuse, process water and sedimentation pond design and sizing and the timing, duration, flow rate and seasonality of water discharges; and
- Calibrate and develop water quality models.

Seven (7) routine seasonal surface water quality monitoring locations were monitored commencing in 2011 and continued into 2012 and are identified in Figure 4.1. Each water quality monitoring station was verified for field suitability, and surveyed for GPS location and elevation. The purpose of this was to determine and assess:

- representivity of each station to the local watersheds potentially impacted by proposed mine operations;
- suitability to water quality monitoring during baseline study, operations and post-closure;
- accessibility; and
- linkage to NL-Canada Water Quality Monitoring Agreement (WQMA) water quality and Project proposed water quantity monitoring locations.

4.2.1.4 Water Quality Methods

In-situ water quality readings were collected using a YSI multi-parameter sonde. Routine seasonal water samples were collected by grab sampling and submitted to Maxxam analytical labs for analysis. Maxxam is a member of, and accredited by, the Canadian Association for Laboratory Accreditation (CALA). Water quality assessment methods were derived from the following technical guidance information:

- A Canada-wide framework for water quality monitoring. PN 1369. (CCME, 2006a);
- Water Quality Guidelines for the Protection of Aquatic Life – Freshwater, update 6.0 (CCME, 2006b);
- ISO 5667-1:2006, Water quality - Sampling - Part 1: Guidance on the design of sampling programs and sampling techniques;

- ISO 5667-3:2003, Water quality - Sampling - Part 3: Guidance on the preservation and handling of water samples;
- ISO 5667-6:2005, Water quality - Sampling - Part 6: Guidance on sampling of rivers and streams; and
- ISO 5667-14:1998, Water quality - Sampling - Part 14: Guidance on quality assurance of environmental water sampling and handling.

Quality Assurance / Quality Control

Sampling quality assurance and quality control was conducted in keeping with laboratory, regulatory and industry standards. QA/QC included the following measures:

- laboratory sample vial pre-labeling;
- trained and experienced sampling technician team of at least two persons;
- field spot measurements;
- routine random field duplicate collection;
- sample thermal preservation plans;
- primary chain of custody form completion and secondary review by alternate sampling technician;
- ensuring the integrity of the samples with proper shipping protocols for sample delivery to lab;
- analytical QA/QC in the Maxxam lab;
- analytical data review by qualified person subsequent to lab reporting; and
- statistical analyses to detect data outliers or avoid analytical skew from constituent anomalies.

Water Quality Sampling

Seven (7) water quality monitoring stations were established to provide routine seasonal water quality monitoring (Figure 4.2). These stations were expected to provide a sufficient amount of information for the purposes of this Project. Water quality samples from seven monitoring stations were taken during the field visits in October 2011, March 2012, April 2012 and May 2012. During the field visit in April 2012, an additional ten samples were collected at Long Lake, Waldorf River, Walsh River, Mills Lake, the Jean River crossing, Pike Lake and Molar Lake. All proposed sampling stations were described in greater detail in Table 4.1 presented earlier.

At the time of all water quality sample collection, *in-situ* water quality measurements were taken with a multi-parameter sonde such as YSI or Hydrolab sondes. These in-situ water quality measurements consist of temperature, pH/ORP, electrical conductivity, Dissolved Oxygen and Total Dissolved Solids. These were collected due to laboratory requirements and also for determination of derived parameters requiring field constituent concentrations and values.

Seasonal routine and spot water quality sample collection at each station and location included approved methods for grab sampling, sample vial labeling, sample storage in coolers to avoid thermal sample integrity breaches and completion of Chain of Custody sample submission documentation.

Analytical parameters for surface water monitoring samples are included in Table 4.2. The *Newfoundland and Labrador Environmental Control Water and Sewage Regulations, 2003* pursuant to the province's *Water Resources Act* sets maximum levels for several parameters including metals, organic compounds, hydrocarbons and other potential contaminants. However, an amendment was enacted in 2009 that states:

"Schedule C

"A person primarily in the Metal Mining Industry shall comply with sections 3 and 19.1 and 20 and Schedule 4 of the Metal Mining Effluent Regulations (Canada) SOR/2002-222, including any changes or amendments to those sections of and that schedule to those regulations over time."

The analytical suite included parameters listed in Schedule 4 of the Metal Mining Effluent Regulations SOR/2002/222.

Metals analysis included both total and dissolved concentrations. The Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life are used to assess baseline water quality. The CWQGs for metals are based on total metals concentrations. Water quality sampling analytical parameters are listed in Table 4.2.

Table 4.2 Water Quality Sampling Analytical Constituents

Anions (IC)	Cations	General Chemistry	Other Constituents	Metals
Chloride , Fluoride, Nitrate, Nitrite, Sulphate	Calcium, Magnesium, Potassium, Sodium	**Alkalinity, Conductivity, Dissolved Organic Carbon, Hardness, pH, Total Organic Carbon, Suspended Solids**	Acidity, Ammonium, Color, Strong Acid Dissociation Cyanide, Total Dissolved Solids, Total Phosphorus, Orthophosphate, Radium$_{226,}$ Reactive Silica	Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Baron, Cadmium, Chromium, Cobalt, Copper, Iron, Lead, Manganese, Mercury, Molybdenum, Nickel, Selenium, Silicon, Silver, Strontium, Sulphur, Tellurium, Thallium, Tin, Titanium, Uranium, Vanadium, Zinc

4.2.1.5 Sediment Quality Approach

Sediment quality assessment was conducted at a number of selected stream and lake stations and locations throughout the LSA. Sediment quality assessment included both sediment particle size distribution analysis and sediment chemistry analysis. Sediment samples and duplicates were collected at sediment sampling locations identified in Figure 4.1. Sediment samples were collected in November 2011, March 2012 and April 2012. Sediment sampling and assessment methods were derived from the following technical guidance and standards:

- Canadian Sediment Quality Guidelines for the Protection of Aquatic Life, Table 1 (CCME, 2002).
- ISO 5667-12:1995, Water quality - Sampling - Part 12: Guidance on sampling of bottom sediments.
- ISO 5667-15:1999, Water quality - Sampling - Part 15: Guidance on preservation and handling of sludge and sediment samples.
- ISO 4365:2005, Liquid flow in open channels - Sediment in streams and canals - Determination of concentration, particle size distribution and relative density.

4.2.2 Information Review

A wide range of publically-available government, scientific and industry literature on the hydrology, surface water quality and sediment quality of Labrador was consulted in the preparation of this report. Information sources are referenced throughout the report when used and references are documented in the References Section of the Report.

5.0 STUDY OUTPUTS

5.1 Hydrogeology

The following sections describe the physiological and hydrogeological conditions within the overall Project area.

5.1.1 Regional Hydrogeological Setting

5.1.1.1 Climate

A description of climate is provided in Section 5.2.3. In summary, the area of Labrador West experiences sub-arctic climatic conditions characterized by long cold winters and short mild summers. There exists a large variation in mean daily temperatures throughout the year, from -22.7^{o}C in January to 13.7^{o}C in July, with a mean annual daily temperature of -3^{o}C.

Annual precipitation averages 858 mm/year with a range of 623.6 to 1185.1 mm/yr., while annual evapotranspiration averages between 200-300 mm/year. Freeze up typically occurs between mid-October and early November, and major snow melt typically occurs between late-April and mid-June. The Kami Property is located in an area of ‘isolated patches of permafrost’ according to Natural Resources Canada, 1993, but experience suggests that no permafrost will be encountered.

5.1.1.2 Topography and Drainage

The Kami Property is comprised of hills and valleys landscape that trends northeast - southwest to north-south across the Site. Elevations range from 540 to 700 masl with local slope angles of 2 % to 15 %. The ground cover is made up of primarily coniferous vegetation with some isolated deciduous and alder growth covering areas of recent forest fires. The site is located in the Lake Plateau in the James region of the Shield Physiographic region. The dominant direction of overland drainage is north and east.

5.1.1.3 Overburden Geology

Intrusive geotechnical investigations are currently ongoing to determine subsurface conditions in the vicinity of the proposed open pit and mine site infrastructure developments. Based on the information to date (May 2012) obtained from the field investigations, site visits, and from previous experience in Labrador West, the overburden materials in this general area consist of veneers of organic soils overlying sequences of glacial till, and occasional glacio-fluvial and fluvial deposits overlying weathered to intact metamorphic bedrock.

Lithology

Figure A.4, Appendix A illustrates the surficial geology in the Project area. The natural overburden material for the Kami Property can be generally classified as ‘undifferentiated till’.

Based on the variety of depositional environments thought to have occurred in the area (glacial melting, river flow, glacial damming, moraines) it is anticipated there will be broad range of surficial materials and characteristics, which may include sands and gravels with varying proportions of silt, cobles and boulders; to bogs; to silt deposits and occasional clay deposits.

Surficial glacial expressions in the form of eskers, and rogen moraines have been reported in the area. Two (2) rogen moraine features, typically thicker deposits variably composed of diamicton, gravel, sand and minor amounts of silt and clay, are indicated to the south of the property boundaries (Figure A.4). Several eskers are also known to exist on, or near the project site. These sinuous, often dissected, elevated glaciofluvial landforms will be composed of poorly sorted sands and gravels. Numerous boggy areas containing various thicknesses of peat, often with interconnected drainage gullies, streams and brooks are observed throughout the site, with a high concentration in the north-eastern portion of the property. Topsoil is expected to be thin and discontinuous. Glacial erratics comprised of large boulders may be encountered in the study area.

The exploration drilling to date (ROB and GE-series boreholes) indicate a lithological profile characterized by a thin (typically <0.2 m) layer of rootmat and topsoil overlying lose to very compact, brown silty sand glacial till with cobbles and boulders, overlying compact to dense gray silty sand with gravel glacial till that increases in density and gravel content with depth. Zones of sand glacial till and silt are locally present, and up to 2 m of peat may occur in some topographically low areas.

Overburden Thickness

Based on the approximately 62 exploration and geotechnical boreholes completed to date, overburden thickness has ranged from 0.8 m to 52.4 m within apparent bedrock depressions, and averages 10.4 m (geometric mean) across the site. It is interpreted that thicker blankets of overburden deposits are generally encountered in topographic lows and valleys thought to represent geologic structures such as rock fold depressions and faults, or possibly buried glacial valleys in bedrock. Bedrock, either exposed or concealed by vegetation or thin overburden veneer, is typically found along the crests of ridges. Based on drilling results to date, the bedrock surface elevation in the Project area exhibits considerable topographic relief (60 to 90 m). Very deep overburden (> 30 m) occurs in the vicinity of the Rose Pit (ROB-11-01, 07, 17 and RBR-12-01), and the East Plant site (BH-GE-11). Very thin or negligible overburden (< 2 m) is noted at BH-GE-01 (West Plant), BH-GE-16 (rail area) and ROB-11-11 (Rose Pit). The remaining boreholes, including 20 2012 boreholes not yet available for assessment) indicate overburden thickness between 2.3 m and 26.5 m, mean 10.2 m.

Hydrogeological Properties

Table H5.1 summarizes available hydraulic conductivity data for the overburden materials. The overburden was found to have hydraulic conductivities (K) ranging from 2.4×10^{-7} to 2.61×10^{-5} metres per second (m/s) based on 8 rising head pump-recharge tests conducted at wells across the site. Wells were screened in two distinct types of overburden materials: sandy till and sandy silty till, with the single sandy till sample having a hydraulic conductivity of

2.61 x 10^{-5} m/s, and sandy silt till facies having a mean hydraulic conductivity of 8.8 x 10^{-7} m/s for the upper till. This range of K indicates a poorly permeable to slightly permeable overburden aquifer.

Three wells (ROB-11-02, 17 and 20) screened across the till-bedrock interface indicated K values ranging from 9.5 x 10^{-8} to 1.2 x 10^{-6} m/s, with a mean K of 4.3 x 10^{-7} m/s. These values can be considered to be representative of the deep till and upper fractured bedrock, where most of the flow is expected to originate from the overlying higher permeability till materials. There appears to be a general increase in till density and corresponding decrease in K with depth in the overburden, as would be expected in glaciated terrain.

Table H5.1 Hydraulic Testing Results – KAMI Monitoring Wells

Well ID	Location	Screened Unit	Screen Zone (m)	K (m/sec)
BH-GE-06	Access Road - Waldorf River Crossing	Sandy Till	3.1-15.8	2.6E-05
BH-GE-03	Main Plant East	Silty Sandy Till	6.4-15.5	6.78E-07
BH-GE-09	Process Plant Area	Silty Sandy Till	3.4-9.4	7.26E-07
BH-GE-10	Process Plant Area	Silty Sandy Till	2.4-9.2	2.55E-07
BH-GE-18	Kami Rail Infrastructure	Silty Sandy Till	2.4-12.2	2.41E-07
ROB-11-05B (run1)	Rose Pit Perimeter	Silty Sandy Till	3.1-13.7	1.81E-06
ROB-11-05B (run2)	Rose Pit Perimeter	Silty Sandy Till	3.1-13.7	5.06E-07
ROB-11-13B	Rose Pit Perimeter	Silty Sandy Till	1.4-10.7	1.92E-06
ROB-11-02	Rose Pit Perimeter	till/rock	3.1-25.9	9.48E-08
ROB-11-17	Rose Pit Interior	till/rock	4.6-47.8	3.17E-08
ROB-11-20	Rose Pit Interior	till/rock	1.5-15.0	1.16E-06
RBR-12-02	Rose Pit Interior	bedrock	33.1-290.0	1.16E-06
RBR-12-01	Rose Pit Interior	bedrock	16.4-300.0	2.58E-06
Mean Silty Sandy Till (m/sec)				**8.8E-07**
Mean Sandy Till (m/sec)				**2.6E-05**
Mean till/rock (m/sec)				**4.29E-07**
Mean Bedrock (m/sec)				**1.87E-06**

5.1.1.4 Bedrock Geology

The geotechnical investigations are currently ongoing to determine subsurface conditions in the vicinity of the proposed open pit and the other mine site infrastructure developments. Based on the extensive information obtained from the exploration program carried out by Alderon and supplemented by information from Stantec’s own drilling programs the bedrock geology is considered to have been adequately characterized. The following geological description is derived largely from Watts, Griffis and McQuat Limited, 2011.

Lithology

Figure A5, Appendix A (Watts, Griffis and McQuat Limited, 2011) illustrates the bedrock geology of the Project Area. The Kami Property is underlain by extremely old (1.8 to 2.5 billion years), Middle Proterozoic (Helikian) Archean granite gneiss and folded, metamorphosed sequences of the Ferriman Group which includes (from oldest to youngest): Denault (Duley) Formation dolomitic and calcitic marble, Wishart (Carol) Formation quartzite (meta-sandstone), schist and quartz pebble conglomerate, Sokoman (Wabush) Formation and Menihek Formation. The Sokoman Formation includes iron oxide, iron carbonate, and iron silicate facies and hosts the iron oxide deposits. The overlying Menihek Formation resulted from clastic politic sediments derived from emerging highlands into a deep-sea basin and marks the end of the chemical sedimentation of the Sokoman Formation. Middle Proterozoic aged biotite-garnet-amphibole dykes and sills intrude all formations, but are particularly common in the Menihek Formation schist.

The ROB and GE-series boreholes that were drilled 3 to 4 m into the bedrock surface in 2011 indicated strong to slightly weathered, schist and white quartz and marble bedrock with occasional marble banding of the Menihek and Wishart formations in the eastern areas (GE wells), and predominantly strong to severely weathered gray, metamorphic bedrock of the Menihek, Wishart and Sokomon formations in the Rose Pit area. Two deep 60 degree inclined boreholes in the Rose Pit area indicated alternating layers of Menihek and Sokomon bedrock with iron formation.

Structure

Mineralization on the property has been noted in three areas known as the Mills Lake, Rose Lake and the Mart Lake areas. Alderon has interpreted the Property to include two iron oxide hosting basins juxtaposed by thrust faulting. The principal basin, herein named the “Wabush Basin”, contains the majority of the known iron oxide deposits on the Property. This basin trends in a NNE direction from the Rose Lake OPM area, 9 km to the Wabush Mine and beyond the town of Wabush. The second basin called the “Mills Lake Basin”, lies south of the Elfie Lake Thrust Fault and extends southward, parallel with the west shore of Mills Lake. Each basin has characteristic lithological assemblages and iron formation variants. The Rose Lake deposit is the current focus of the proposed Project operation.

The Wabush Basin on the Property contains (from south to north) the South Rose / Elfie Lake Deposit, the Rose Central Deposit and the Rose North Deposit. These deposits are interpreted to represent different parts of a series of gently plunging NNE-SSW trending, upright to slightly overturned anticlines and synclines, but structural stacking may also play a role. The Wabush Basin is bounded to the south by a major SSE-trending thrust fault along Elfie Lake and on its north and west margins by steeply dipping contacts between the Sokoman Formation-Wishart Formation assemblage and the Archean granite gneiss basement. This contact is apparently drag-folded along a NNE trend toward the Wabush Mine. The eastern edge of the assemblage appears to be defined by a late fault (probably a thrust from the east). Deep, intense weathering and alteration has been reported along fault systems in the Rose North Zone and South-West Rose Zone.

The Mills Lake Basin outcrop is controlled by an ENE-trending asymmetrical open syncline overturned from the SSE with a steeper north limb and shallow-dipping (18°E) east-facing limb. The fold plunges moderately to the ENE. The Mills Lake Basin is fault-bounded. The northern limit of the basin is the Elfie Lake Thrust Fault pushed from the SSE where it rides over the Wabush Basin package. The east limit is an (interpreted) thrust fault from the east that pushes Denault marble over the Sokoman Formation. The SSE fault appears to be the older of the two. The details of the basin dimensions are unknown. It may be relatively small, extending only to Fermont, or it may include the Mont-Wright Deposit and several smaller iron deposits west of Fermont.

The portion of the Kami Property east of the western shore of Mills Lake is dominated by gently dipping Denault Formation marble with quartz bands paralleling crude foliation. This block is interpreted as being thrust from the east onto the two basin complexes noted above. The marble outcrops across the 8 km width of the Kami licenses 017926M and 0179948M with consistent eastward bedding dips. The thickness exposed suggests that several thrust faults may have repeated the Denault Formation stratigraphy. This area is the proposed location for the Rose South Waste Dump, TMF, and Main Plant Site with associated infrastructure, and rail loop.

Hydrogeological Properties

Information respecting the hydraulic properties of the bedrock underlying the Project site is derived from hydraulic response testing and packer testing performed on monitor wells and deep geotechnical boreholes respectively completed in bedrock. Table 5.1 summarizes available hydraulic conductivity results for bedrock on this site.

No hydraulic response tests were representative of bedrock, since most wells were sand-packed across the till-bedrock interface. Two recent deep boreholes (RBR-12-01 and RBR-12-02) indicated K values in the order of 1.2×10^{-6} m/s and 2.6×10^{-6} m/s, respectively.

Ancient metasedimentary and crystalline bedrock is typically considered to be a poor aquifer, with generally low bulk hydraulic conductivity in the order of 1E-5 m/s or lower, and poor well development potential (typically less than 100 liters per minute). The limited data to date are consistent with this hydrogeology. While unsuitable for large industrial water supply applications, the bedrock aquifer may be suitable for small scale water supply well development (see Section 6.1.5).

5.1.1.5 Groundwater Flow Patterns

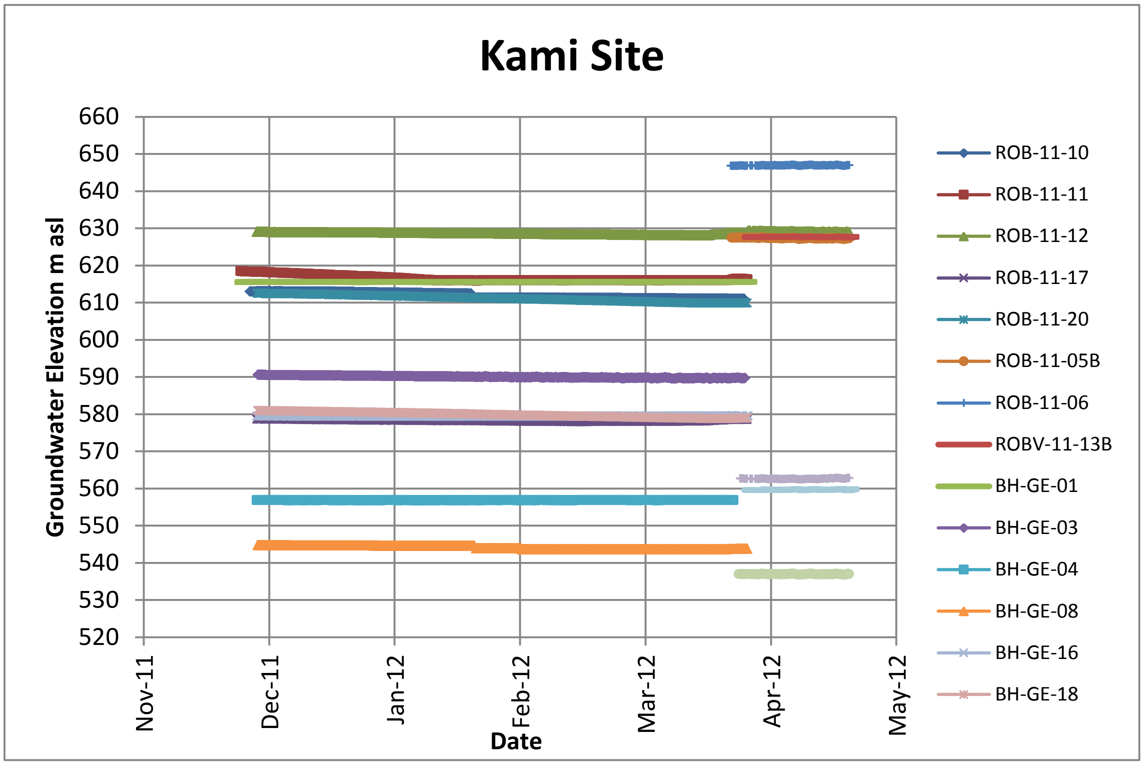
Groundwater Depth

Groundwater depths vary across the site and generally reflect the topographic relief of the area, with higher groundwater elevations occurring in wells located at higher topographic elevations. The groundwater level variation is as expected between wells in both close proximity and across larger distances. Groundwater levels varied from artesian flow 2 m or more above ground to 5.6 metres below ground (mbg). Table B4 in Appendix B summarizes available groundwater level information including; monitor well specifications, surveyed grade and top of casing elevations, water level depth in metres below top of casing (mbtoc) and metres below grade (mbg), and groundwater elevation in metres above sea level (masl). Table B5 summarizes the depth to static water level for four field monitoring events. Figure H5.1 illustrates the relative water levels across the Project site based on 14 monitoring wells with installed data-loggers.

Static groundwater elevations varied from 537 m at BH-GE-06 near the Waldorf River crossing to 646 masl at ROB-11-06 on the watershed divide west of the Rose Pit, a range of 109 m. Frozen wells were encountered at ten (10) wells (indicated in Table B5, Appendix B) during the March 2012 field program, four (4) wells in the November 2011 field visit and none in the January 2012 field program, as wells expected to be frozen were avoided. Dynamic water levels, collected from water level data loggers deployed across the site, support the manual water level measurements and confirm that groundwater levels closely follow topography. The water level loggers also show the variance in water levels over time, with most wells showing the same slight decreasing trend through the winter months due to the winter freeze and resulting lack of recharge. The logger output hydrographs are presented in Appendix E.

In general, water levels are highest (flowing artesian above top of casing) in the Rose Pit area around the lake and in the vicinity of the Waldorf River Crossing and lakes near the East Plant, Tailings polishing pond, and Riordan Lake rail crossing, and deepest along watershed divides such as BH-GE-04, BH-GE-16, ROB-11-06 10 and 13 in the upland areas around the Rose Pit.

Figure H5.1 Relative Static Water Levels Across Project Site



Groundwater Flow Directions

Across the site it was found that groundwater flow directions closely follow topography, flowing from local recharge areas at topographic highs towards local topographic lows. Figures A.6 and A.7 illustrate the likely groundwater flow pathways, recharge areas and discharge areas in the Eastern Plant area and Rose Pit area respectively. On a regional scale, groundwater is recharged in the uplands (Churchill River Basin watershed divide) located to the south and west of the Project, and discharges into the major lakes and streams in the vicinity of the Project. Based on how closely groundwater depths correspond with topography it is anticipated that local groundwater flow directions will also follow topography. Conceptually, the local groundwater flow directions can be expected to be from local upland areas towards local lowlands that host lakes, streams and wetlands. The groundwater contour map presented in Figure A6 suggests that the general flow of groundwater on the site is locally towards topographic lows and Long Lake from southwest to northeast across the site.

More specific information on flow directions at the main plant site, Rose Pit area, TMF, waste rock areas and the access road, rail line and power transmission line areas will be presented in later sections.

Horizontal Hydraulic Gradient

Horizontal gradients (dh/dl) were calculated by dividing the difference in elevation between two monitoring wells by the distance separating them. Groundwater gradients ranged from gradual, in the 0.001 m/m range near lakes and wetlands to much steeper in the 0.07 m/m range along the steeper slopes of highlands. Groundwater gradients closely followed, although always slightly less pronounced, the topographic gradients. Typical horizontal hydraulic gradients of 0.005 to 0.026 are suggested for the mine area, averaging about 0.01 m/m (about 1 %) in most construction locations.

Descriptions of local groundwater gradients specific to the various development locations across the site will be described in detail in later sections.

Vertical Hydraulic Gradient

The vertical hydraulic gradient between overburden and shallow bedrock was calculated using four (4) nested well pairs ROB-11-01A/B, ROB-11-05A/B, ROB-11-08A/B and ROB-11-13A/B. All of these well combinations are located just outside of the boundary of the Rose Pit, with ROB-08A/B located on the southwest boundary, ROB-13A/B located on the southeast boundary and ROB-05A/B located on the northwest boundary.

The vertical hydraulic gradient was strongly upwards from bedrock to overburden in the ROB-11-08A/B (2.61) and ROB-11-13A/B (0.062) well pairs, and downward in the ROB-11-05A/B well pair (0.023). Upward vertical hydraulic gradients are also inferred in the vicinity of all of the GE-series GE wells except BH-GE-1, 4, 5, 6, and 8, and ROB-series wells ROB-11-09 (flowing at 11 L/min), and ROB-2, 3, 6, 11, 12, 16 and 18 where water levels were measured slightly above ground level.

Groundwater Velocity Estimates

An estimate of potential groundwater velocity can be made for the various types of overburden, shallow weathered bedrock and deep bedrock can be made using the Darcy approach:

$$\tilde{V} = K(dh/dl)/\mu,$$

where:

$\tilde{V}$ = average linear groundwater velocity in m/d,

K = hydraulic conductivity in m/d ($m^3/m^2/d$),

dh/dl = horizontal hydraulic gradient (m/m) and

μ = effective porosity (e.g., total porosity – specific retention)

Table H5.2 summarizes estimated groundwater velocities for various geologic materials found on the Kami Property.

Table H5.2 Estimated Range of Groundwater Velocity – Kami Property

Material	K (m/s)	Eff. Porosity	Gradient (m/m)	V (m/yr)
	Min-max (mean)	Min-max (mean)	Min-max (mean)	Min-max (mean)
Silty Sand Glacial Till	2.4E-07 – 1.9E-06 (9.1E-07)	0.20 – 0.30 (0.25)	0.005 – 0.014 (0.0095)	1.26 - 4.24 (1.1)
Sandy Glacial Till	2.5E-05	0.20 – 0.30 (0.25)	0.005 – 0.014 (0.0095)	13.7 - 57.4 (31.2)
Deep Till/Weathered Bedrock	3.2E-08 – 1.2E-06 (4..3E-07)	.20 – 0.30 (0.25)	0.006 – 0.027 (0.016)	0.02 - 2.6 (0.51)
Bedrock	1.16E-6 to 2.58E-6 (1.92E-06)	0.001 – 0.01 (0.0055)	0.006 – 0.027 (0.016)	21.9 - 2197 (172)

Assuming a hydraulic conductivity range of 5.06E-07 to 2.13E-03, geometric mean 2.34E-06 m/s derived from hydraulic response tests on various monitoring wells completed into overburden (Table H5.1), an effective porosity of 0.20 to 0.30 for the silty sand glacial till materials, and local hydraulic gradients of 0.005 to 0.014, geometric mean 0.0095, an initial estimate of average linear groundwater flow velocity would be in the order of 1.2 to 4.2 m/year, mean 1.1m/yr for silty sand till. These velocities could be higher for the more permeable sand layers reported in the stratigraphy (e.g., mean 31.2 m/yr, Table 5.2), and considerably lower in the case of poorly permeable, dense till or clayey silt materials (e.g., mean 0.51 m/yr suggested for the till / bedrock interface).

Average velocity in the bedrock is more difficult to characterize, and is proportional to the degree of secondary fracturing and preferential flow pathways (joints, faults) within the rock mass. Using a range of hydraulic conductivity of 1.2E-06 to 2.6E-06, mean 1.9E-6 m/s m/s derived from hydraulic response tests packer injection testing in the Rose Pit area (Table H5.1), similar gradients of 0.006 to 0.027 m/m, and an effective bulk bedrock porosity of 0.001 to 0.01, average linear groundwater velocities of 22 to 2200 m/year mean 172 m/year are suggested on a regional scale. It should be noted that local velocities through permeable joints, faults or fracture pathways could be considerably higher, and velocities through deep dense bedrock would be considerably lower.

5.1.1.6 Groundwater Chemistry

The groundwater chemistry across the site was characterized with samples collected from twenty-one (21) wells ranging in depth from 5.8 to 585 mbg (mean depth 62.52 m). Samples were collected from the Rose Pit, Main Plant Site and Access Road and Railway areas; the TMF could not be sampled due to consistent frozen conditions. Samples were taken from eight (8) wells screened in the overburden, four wells completed in bedrock (including 3 samples from open borehole exploration wells drilled by Alderon) and nine (9) wells screened across the overburden / bedrock boundary.

Tables B2 and B3, Appendix B summarize the available chemistry and metals chemistry respectively. The pre-construction groundwater chemistry of the site is generally characterized as a clear, moderately hard (mean hardness 71 mg/L), electrochemically neutral (mean pH 8.0, mean alkalinity 76.5 mg/L, mean Langelier calcite saturation index -0.6), calcium bicarbonate water of low total dissolved solids (mean TDS 98 mg/L). All analyzed parameters typically meet Guidelines for Canadian Drinking Water Quality (GCDWQ), Health Canada, 2012, with the occasional exceptions of iron (mean 492 µg/L), manganese (mean 310 µg/L) and turbidity (mean 660 NTU (attributed to method of sampling – bailing). With the exception of two occurrences of total phosphorus (0.3 and 1.2 mg/L at ROB-11-13A and GE-11-09), the observed concentrations also meet the Ontario Ministry of the Environment (MOE) Soil, Groundwater, and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act: Table 9 - Generic Site Condition Standards for Use within 30 m of a Water Body in a Non-Potable Groundwater Condition (April 2011).

Overburden

The groundwater chemistry from the silty sand and sand glacial till overlying the Kami Property was characterized from eight (8) samples collected from wells 9.8 m to 15.9 m (mean 12.11 m) deep. In general, this water is described as a clear, moderately hard (mean hardness 83 mg/L), electrochemically neutral (mean pH 7.9, mean alkalinity 80.1 mg/L, mean Langelier calcite saturation index -0.6), calcium bicarbonate water of low total dissolved solids (mean TDS 105 mg/L). Anomalous chemistry (higher than background alkalinity, hardness and magnesium levels) is noted at BH-GE-09 and BH-GE-10, located in the Main Plant Site east. Well ROB-11-13B also indicates anomalous ionic composition, with lower than background alkalinity and pH and a slightly acidic mixture of sodium sulfate and calcium bicarbonate water types.

Groundwater chemistry was also collected from an additional nine (9) wells which were screened across the overburden / bedrock interface. These wells ranged in depth from 7.5 to 47.9 mbg (mean 20.6 mbg), and were all located in the Rose Pit Area. The chemistry of these wells is very similar to the samples screened in overburden, an indication that the groundwater infiltrating through the more permeable overburden portion of the screen is predominant. The only notable difference between the strictly overburden wells and the interface wells was slightly colored water in two wells, ROB-11-12 and ROB-11-05A, and higher mean concentrations of iron and manganese in the interface wells.

Bedrock

The groundwater chemistry from the upper bedrock zones on the Kami Property was characterized from one 29 m deep sample (ROB-11-8A) and three 216 to 585 m deep exploration wells (K-11-108, 113 and 163) assumed to be screened in bedrock. The open inclined borehole completions represent groundwater from the entire borehole depth, and the chemistry suggests that the inflow is dominated by the shallow zones which would be more fractured. In general, this water is described as clear, moderately soft (mean hardness 68 mg/L), slightly acidic (mean pH 8.4, mean alkalinity 79 mg/L, mean Langelier calcite saturation index -0.1), calcium bicarbonate water of low total dissolved solids (mean TDS 93 mg/L). The bedrock analysis showed several clear differences from the glacial till analysis, namely lower hardness, alkalinity and total dissolved solids and higher concentrations of reactive silica, iron, molybdenum and zinc.

5.1.1.7 Groundwater Recharge Potential

Groundwater recharge is locally variable based on topography, overburden thickness and permeability, bedrock permeability and seasonal thaw periods. Groundwater recharge and evapotranspiration would be expected to occur during the summer months of June through September; groundwater outflow to streams could occur during the remaining periods of the year (evident from declining water level hydrographs over winter 2011-12). In consideration of the low bedrock K compared to surficial K, the majority of base flow to local streams and lakes likely originates form the overburden. On a regional scale, groundwater recharge based on base flow analysis and modeling elsewhere is expected to be in the range of 10 to 15 % or mean annual P (e.g., 12-17% in Nova Scotia, Kennedy et al, 2010), 15% in Atlantic Region, Brown, 1975). In consideration of the long frozen period, and concurrence of evaporation during recharge periods, the lower estimate seems appropriate (about 12% P). Based on water balance modeling (Section 5.2.4.4), groundwater recharge in the Project area was estimated to be 7 % (dry year) to 12.1 % (wet year, average 6.3 % of total precipitation. Of this, about half would be expected to discharge to the surface water system as base flow and half as evapotranspiration.

5.1.1.8 Conceptual Water Balance for Project Site

A detailed water balance was compiled for the Project Site as part of the Hydrology studies (see Table 5.10, Section 5.2.4.4). A water balance essentially documents the water sources (precipitation, inflow from upstream sources, etc.) with groundwater outflow (evaporation, pumping, and downstream losses) in stream flow. For a given area, this can be simulated as:

$$P = R\ (R_{sw} + R_{gw}) + E_t + \Delta S,$$

where:

P – annual precipitation;

R – total runoff (R_{sw} +R_{gw});

E_t – Evapotranspiration;

ΔS – change in storage (assumed to be 0 mm in the long term);

R_{sw} – surface water runoff component of Runoff R;

R_{gw} – Groundwater component of R (base flow);

I – Total Infiltration.

Table H5.3 Water Balance Summary

	Mean		Wet		Dry	
	(mm)	**(%)**	**(mm)**	**(%)**	**(mm)**	**(%)**
Precipitation (P)	858.1		1172	100.0%	623	
Evapotranspiration (E_t)	318.5	37.1%	376.9	32.2%	376.9	60.5%
Total Runoff R	539.6	62.9%	794.8	67.8%	245.7	39.4%
Direct Runoff (R_{sw})	485.2	56.5%	652.6	55.7%	202	32.4%
Infiltration (I)	54.4	6.3%	142.2	12.1%	43.7	7.0%
Effective GW Recharge (I_{gw})	27.2	3.2%	71.1	6.1%	21.9	3.5%
Baseflow (R_{gw})	27.2	3.2%	71.1	6.1%	21.9	3.5%

Source: Table 5.10, Section 5.2.4.4 Hydrology

5.1.2 Main Plant Site and Access Road

The Main Plant site was considered as two (2) distinct areas, Main Plant east and Main Plant west, as they are anticipated to have different characteristics and require different design considerations. The Main Plant site west encompasses BH-GE-01 to BH-GE-03 and BH-GE-03, while the Main Plant site east encompasses BH-GE-07 to BH-GE-12 (Figure A.3, Appendix A). The east and west sites are separated by an intervening low area between two lakes (Long Lake and Mills Lake) and an area of increased elevation, meaning groundwater interactions between the east and west sites are only anticipated at the regional scale (e.g., deep bedrock). Three wells (BH-GE-04, 05 and 06) are located along the access road and Waldorf River crossing between the two Plant sites (Figure A.3, Appendix A).

5.1.2.1 Overburden Description and Thickness

The Main Plant site (West) is a low lying area and has relatively subdued topography that generally slopes northward towards Long Lake and the Waldorf River. Overburden thickness will vary depending on location, but generally it is anticipated that the overburden will be relatively thick in this area, and feature alluvial deposits of finer sands and potentially significant silt contents. A large glacial fluvial esker feature is observed to the south of this area, paralleling Waldorf River.

Based on three boreholes, the overburden thickness at the West Plant Site ranged from 0.8 m at BH-GE-01 to greater than 15.5 m at BH-GE-03, and tends to thicken towards the lake shore. The lithological profile consisted of a thin (0.05 m to 0.3 m) layer of rootmat and topsoil overlying a compact to very dense silty sand glacial till. The material encountered was described as a loose to dense, brown, silty sand, with trace gravel and boulders throughout.

The Main Plant Site east was found to have an overburden thickness range from 5.1 m at BH-GE-08 to 48.4 m at BH-GE-11B. A large variation in overburden thickness (> 36 m) is observed between BH-GE-10 and BH-GE-11 within a very short distance, suggesting presence of a bedrock channel. The lithological profile typically consisted of a thin (0.1 m to 0.3 m) layer of topsoil / rootmat overlying loose to compact brown, silty sand with trace gravel and boulders changing to a very dense, grey silty sand with trace gravel and boulders at depth. BH-GE-12 also contained very dense, yellow, well graded sand with trace gravel and cobbles at a depth below 10 m. Wells BH-GE-11 and BH-GE-12 were found to have 1.3 to 1.7 m of peat overlaying very loose to dense glacial till. Low laying areas found in stream beds or bogs are anticipated to have this slightly thicker peat layer while areas on slopes or with sparse vegetative cover are anticipated to have a thin topsoil covering.

The Waldorf River crossing area (BH-GE-04, 05 and 06) was found to have 8.7 to 13.5 m of compact to very dense, brown, silty sand till with trace gravel and boulders changing to a very dense, grey to brown, silty sand (coarseness varying with depth) with trace gravel and boulders, overlying strong quartzite bedrock.

5.1.2.2 Bedrock Description

Bedrock was only encountered in four of the wells drilled in the Main Plant east area, (BH-GE-07, 08, 10 and 11), one well (BH-GE-01) in the Plant Site West area, and two wells (BH-GE-04 and 05) in the intervening access road area. With the exception of schist identified at BH-GE-01 in the West Plant Area, the bedrock encountered no the can be described as medium strong, intact to moderately jointed, white marble and white quartzite bedrock.

The bedrock surface appears to vary with topography, being shallowest near apparent ridges (0.9 m at BH-GE-01 in the West Plant area, 8.6 m at BH-GE-04 on the access road, 5.1 at BH-GE-07 and 7.9 mbg at BH-GE-08) in the east area, and deepest within apparent depressions below the streams (e.g., 13.5 m at BH-GE-05) on the access road and 48.4 m at BH-GE-11 in the east area near a stream). Based on available drilling data the bedrock is anticipated to be closer to the surface in areas of higher elevation.

5.1.2.3 Groundwater Levels

Tables B4 (Datalogger Details) and B5 (Static water levels) in Appendix B summarize the available water level data. Groundwater levels were collected during each well visit using a water level tape and select wells have had water level data loggers installed in them to monitor water levels over time. To date, static groundwater levels have been measured at ten (10) wells across the Main Plant sites, two (2) on the west site (BH-GE-01 and BE-GH-03), two (2) along the intervening access road (BH-Ge-04 and BH-GE-06) and six (6) on the east site (BH-GE-07 through BH-GE-12). Water level data loggers have been installed in seven (7) wells (BH-GE-01, 03, 04, 07, 08, 09 and 10). Figure A.3 shows the locations of these wells and provides a summary of the work completed to date.

Static water table depth in the Main Plant site closely follow topography and range from 7.36 metres below grade (mbg) in areas of high elevation to 1.02 meters above grade (mag) in areas of lower elevations. The groundwater elevations closely reflect the topography in these areas.

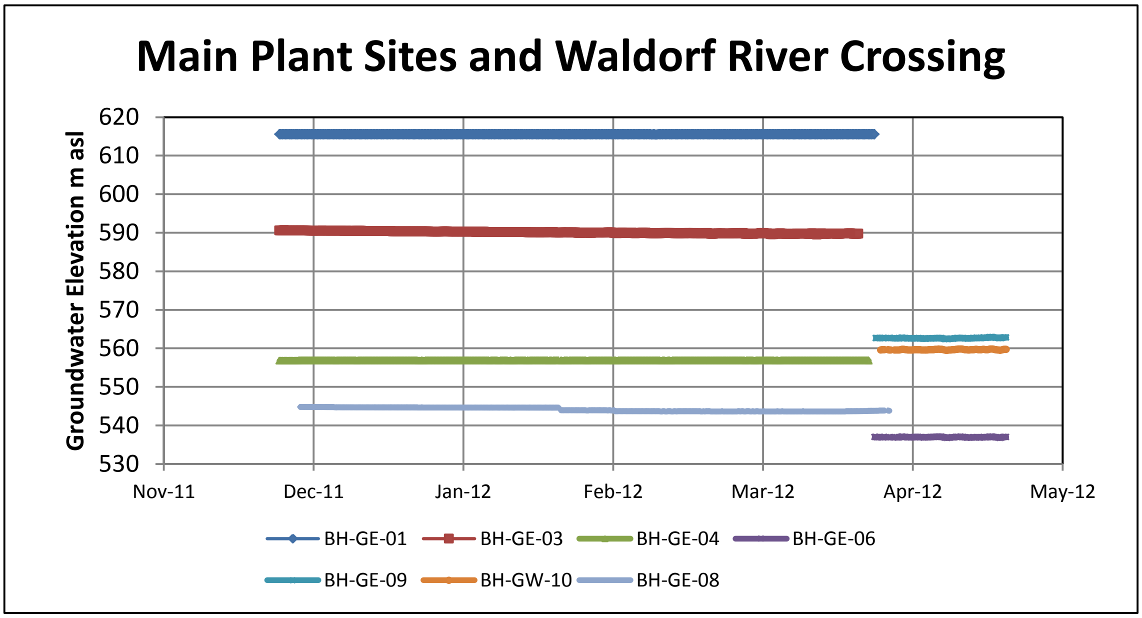
The static groundwater levels were used to create a groundwater contour map, Figure A.6, Appendix A, which shows how groundwater level elevation change closely follows topographical change. In areas of locally low elevation, groundwater levels were found to be near the surface or flowing above grade, as seen in BH-GE-07, BH-GE-11 and BH-GE-12 which all lay near a stream bed in the Main Plant site east. In contrast, wells located at high elevations or on significant slopes had much deeper groundwater levels, including, BH-GE-01 (mean 4.3 mbg), BH-GE-04 (mean 6.84 mbg and BH-GE-08 (mean 3.92 mbg).

Information downloaded from the data loggers during the March and April 2012 field programs is provided in hydrograph form in Appendix E. These hydrographs show a general decreasing trend in water levels over the course of the winter, when frozen ground conditions and predominance of snow limits the degree of groundwater recharge. Some evidence of recharge was noted in late March, correlating with a period of warming and rain precipitation.

A comparison of relative water levels between December 2011 and April 2012 is shown on Figure H5.2; detailed monthly hydrograph are presented in Appendix E. At the Main Plant site west the relative elevations ranged from 589.6 masl at BH-GE-03, to a high 615.5 of masl at BH-GE-01, a difference of 25.9 m within a short distance (675 m). At the Main Plant site east the relative elevations ranged from 543.6 masl at BH-GE-08, to a high of 562.7 masl at BH-GE-09, a difference of 19.1 m within 210 m.

The detailed hydrographs (Appendix E) show a wide range of responses, likely attributed to aquifer type, depth, and location within the local groundwater flow field. Across both the east and west Main Plant sites, the overburden wells exhibit a short term fluctuation of 0.25 to 0.3 m over the winter of 2011-12, possibly related to barometric and short term recharge effects along with a generally decreasing trend of up to 1 m over the winter of 2012. The deeper glacial till and bedrock wells tend to exhibit much smaller degree of fluctuation, in the order of 0.1 m or less. It is noted that some of the monitoring wells were frozen during the monitoring period; it is anticipated that a better opinion on water levels will be available after the spring thaw and next round of field work.

Figure H5.2 Relative Water Levels Main Plant Sites and Waldorf River Crossing



5.1.2.4 Groundwater Flow Directions

The groundwater flow in the local area of the Main Plant site west is southeast and east towards Mills Lake and Long Lake. This is confirmed by the 3 percent hydraulic gradient between BH-GE-01 and BH-GE-03 in a southeastern direction towards the lake.

Figure A6, Appendix A illustrates the expected groundwater flow pathways in the Plant and TMF areas. The dominant direction of groundwater flow in the Main Plant site east area is northwest towards Long Lake. This area was examined in conjunction with the TMF as it is believed that they share similar groundwater flow directions and patterns. The hydraulic gradients in the area tend to follow topography and flow predominantly west until a local depression (streambed) is encountered and the dominant flow direction becomes north with the surface water gradient.

Horizontal hydraulic gradients for the Main Plant site west were found to be in the southeast direction with a gradient of 0.03 (3 %) between BH-GE-01 and BH-GE-03, closely following the topographic gradient. Horizontal hydraulic gradients for the Main Plant site east locally range between 0.006 and 0.083 in a northwest direction, and closely follow the topographic gradient.

No vertical hydraulic gradients were determined for the Main Plant sites as there are no nested well pairs in the area. However, the very shallow water table or flowing artesian conditions noted in the vicinity of BH-GE-07, 09, 10, 11 and 12 in the East Plant area suggest upward vertical gradients in these areas (i.e., groundwater discharge area).

5.1.2.5 Hydraulic Properties

A hydraulic conductivity (K) of 6.8×10^{-7} for the overburden in the vicinity of the Main Plant site west was determined from a pump recharge test conducted at BH-GE-03 in January 2012. This value correlates well with the mean hydraulic conductivity value found across the Kami Property of 9.1 x 10^{-7} for silty sand till. K values of 7.3 x 10^{-7} (BH-GE-09) and 2.6 x 10^{-7} (BH-GE-10) were determined for the Main Plant site east from pumping tests carried out in March 2012. Both of these values are also consistent with the site wide averages for silty sandy till. A moderate K of 2.6 x 10^{-5} was indicated at Well BH-GE-06 screened in sandy till near the Waldorf River crossing; this higher than average value (almost two orders of magnitude higher than silty sand) may reflect the presence of permeable strata such as sand or gravel associated with a bedrock channel below the river / lake. No bedrock hydraulic testing data is available in the Plant areas.

5.1.2.6 Groundwater Chemistry

As described above, the Main Plant site was separated into two (2) distinct areas for assessment. The Main Plant site east and Main Plant site west are separated by two (2) lakes and an area of increased elevation so groundwater interactions are only anticipated at the regional scale. To date, only one (1) sample (BH-GE-03 screened in overburden) was collected at the Main Plant site west due to frozen conditions throughout the sampling period. This groundwater is characterized as clear, slightly soft (hardness 63 mg/L), naturally acidic (alkalinity 54 mg/L, pH 8.05), calcium bicarbonate water type with low total dissolved solids (84 mg/L), consistent with the background chemistry of the area. All parameters except manganese (254 µg/L) meet the GCDWQ.

Two (2) samples from overburden at the Main Plant site east (BH-GE-09 and BH-GE-10) indicated clear, hard (130-160 mg/L), alkaline (alkalinity 130-140 mg/L, pH 8.2), calcium bicarbonate water with low total dissolved solids (129 to 156 mg/L TDS). Both wells contained similar characteristics which were anomalous in comparison to background with elevated levels of hardness, alkalinity, TDS, pH, and magnesium. This higher calcium-bicarbonate and hardness correlates with the presence of white marble bedrock indicated at 48.4 m depth at BH-GE-11. All parameters except manganese (587 µg/L at GE-11-10) meet the GCDWQ.

BH-GE-04 and BH-GE-06 occur in close proximity to each other, in between the east and west Main Plant sites (Figure A.3, Appendix A), and while screened in different material (BH-GE-04 in the bedrock / till interface and BH-GE-06 in sandy overburden) both display similar characteristics of clear, moderately soft (39 to 49 mg/L hardness), slightly acidic (alkalinity 42 to 44 mg/L, pH 7.6 to 8.2), calcium bicarbonate water with low total dissolved solids (52 to 77 mg/L). All analyzed parameters meet the GCDWQ.

5.1.3 Rose Pit Area

Figure A2, Appendix A illustrates the borehole and well locations in the vicinity of the Rose Pit. Figure A8, Appendix A is a geological cross-section through the Rose Pit that illustrates the interpreted overburden thickness, water levels, and bedrock surface topography. This cross-section also illustrates the proposed maximum mine excavation level and a preliminary operational water table configuration (described in Sections 5.1.3.6 and 5.1.3.7).

5.1.3.1 Overburden Description and Thickness

Based on 22 boreholes that reached the bedrock-till interface (Table B1. Appendix B), the overburden in the vicinity of the Rose pit exhibits a highly variable range in thickness and a complex bedrock surface topography. In general, glacial till thicknesses range from 1.8 m in the vicinity of ROB-11-11 to 52.4 m below grade at ROB-11-07, averaging 19.1 m based on the ROB-series boreholes. There appears to be a bedrock depression trending SW to NE across the Rose Pit, with bedrock highs (thinner overburden) underlying the SE side and the western pit wall (Figure A.8, Appendix A).

The overburden in the Rose Pit area is generally described as a thin layer of organic topsoil or peat, overlying loose to compact brown silty sand glacial till with cobbles and boulders, becoming denser with depth. Strata of stiff silt or silt with sand are not din some boreholes (ROB-11-01, 05, 17 and 18). The interface with the bedrock sometimes exhibits sand and gravel, possibly highly weathered bedrock in some boreholes.

5.1.3.2 Bedrock Description

The Kami Iron Ore deposit is a stratabound iron formation deposit. The iron formation is assumed to be ductile, medium strong (or better) rock in which the overall rock mass failure may only be a potential concern for slopes where the in-situ stress exceeds the rock mass strength, or where the rock mass has deteriorated in quality due to secondary leaching and/or weathering processes.

For the purpose of conceptual slope design, the rock formations within the Property have been classified into two general types: Type 1) massive rock formations (e.g. gneiss, quartzite, dolostone) and Type 2) bedded or foliated formations (e.g. schist and iron formation).

For benches excavated in Type 1 rocks, and for Type 2 rocks in the hanging wall orientation, the key failure mechanisms that control bench geometry and stability include toppling on bedding, stepped-path plane failure, and raveling. Bench widths are selected to control rock fall hazard and to provide rock fall catchment for raveling debris.

Based on the nineteen (19) ROB-series boreholes and two RBR-series borehole that reached bedrock (typically 3 to 4 m of core), the shallow bedrock zone can range from a highly competent (Rock Quality Designation – RQD) white quartzite, to highly weathered and fractured material with minimal core recovery (RQD = 0). Strong to very strong rock conditions (with likely poor permeability) were noted at ROB-11-06, 10, 11, 12, 15, 17 and 20 and RBR-12-01 and 02; poor rock conditions consistent with highly weathered or severely fractured conditions (and possible moderate permeability) were noted at ROB-11-07, 08, 08, 18 and 19. Moderately strong to slightly fractured conditions are noted at ROB-11-01, 02, 03, 04, 05, 13, 14 and 16.

5.1.3.3 Groundwater Levels

Groundwater levels in the Rose Pit area closely follow topography and range from 11.64 mbg in areas of high elevation (ROB-11-06 of the hill west of the pit) to artesian flow in areas of low elevations. To date, static Groundwater levels have been measured at 16 ‘ROB’ wells and 8 Alderon exploratory ‘K’ wells. Water level data loggers have been installed in 13 ‘ROB’ wells and in 7 ‘K’ wells. Figure A.2 shows the locations of these wells.

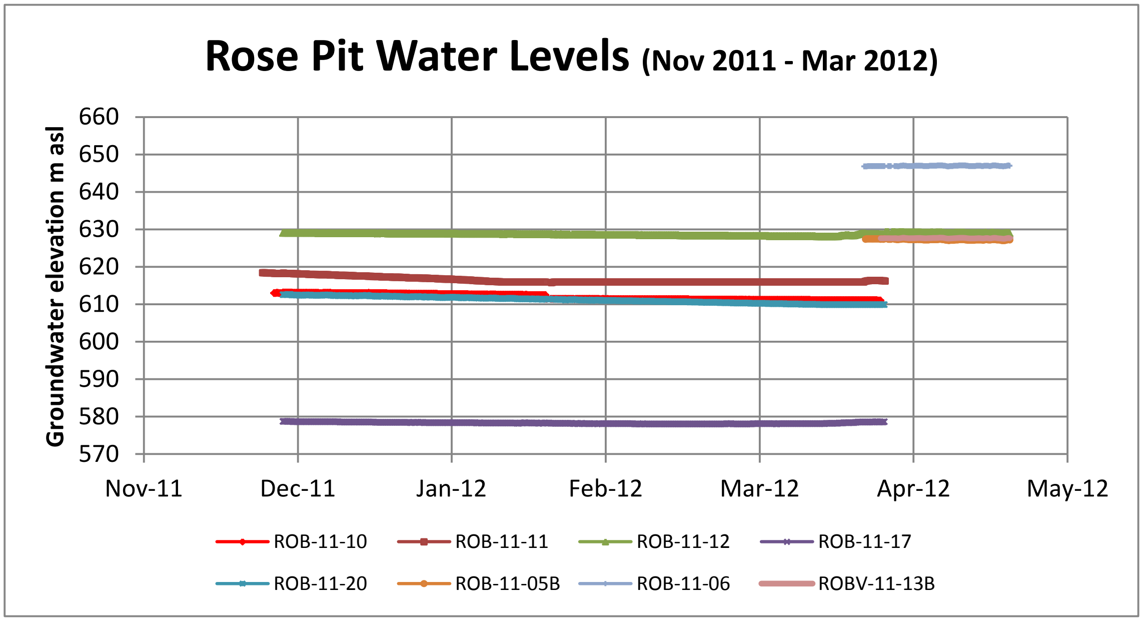
The cross-section shown on Figure A.8 shows how groundwater level elevation change closely follows topographical change. In areas of locally low elevation, groundwater levels were found to be near or above the surface, as seen in wells ROB-11-01, 02, 03, 08A, 08B, 0.9, 12 and 14. In contrast, those wells located in high elevations or on significant slopes had much deeper groundwater levels, including, ROB-11-06, ROB-11-10, ROB-11-13 and ROB-11-20. A summary of all static groundwater level measurements collected to date is provided in Table B.5, Appendix B.

Water level hydrographs from the data loggers covering the December 2011 to April 2012 period are provided in Appendix E. These hydrographs show a general decreasing trend in water levels over the course of the winter, when frozen ground conditions and predominance of snow limits the degree of groundwater recharge. Some evidence of recharge was noted in late March, correlating with a period of warming and rain precipitation.

A comparison of relative water levels (December 2011 to April 2012) is shown on Figure H5.3; additional monthly hydrographs are contained in Appendix E. The relative elevations range from 647 masl at ROB-11-06,on the western up gradient side of the Pit, to a low of 578.1 masl at ROB-11-17 located in the north-central lowland area of the Pit, a difference of 69 m within a relatively small area (850 m). These high relative elevations account for the numerous flowing artesian wells in the lower areas of the site.

The detailed monthly hydrographs show a wide range of responses, likely attributed to aquifer type, depth, and location within the local groundwater flow field. In general, the overburden wells exhibit a decreasing water level trend on the scale of 1 to 3 m over the winter months, as well as short term fluctuation of 0.25 to 0.3 m, possibly related to barometric and short term recharge effects. With the exception of ROB-11-5B (overburden) all of these wells are completed in the till-bedrock interface. It is noted that some of the monitoring wells were frozen during the monitoring period; it is anticipated that a better opinion on water levels will be available after the spring thaw.

Figure H5.3 Relative Water Levels Rose Pit Area



5.1.3.4 Groundwater Flow Directions and Gradient

Figures A.7 and A8, Appendix A illustrate the expected local groundwater flow directions, recharge areas and discharge areas near the Rose Pit. The groundwater flow directions and gradients in the local area of the Rose Pit vary greatly across the site due to topography and the presence of water bodies at differing elevations. In general groundwater flow is expected to closely follow topography and flow towards a topographic low running southwest to northeast though the center of the pit area (Rose Lake). Hydraulic gradients were found to range from 0.0001 to 0.078 and closely follow topography. Strong horizontal hydraulic gradients towards the central low area are indicated between ROB-11-20 and ROB-11-17 (0.06 m/m), a westerly gradient of 0.06 m/m is indicated between ROB-11-05 and ROB-11-02, and a northerly gradient of 0.04 to 0.05 m/m is suggested between ROB-11-06 and ROB-11-02 and ROB11-12 and ROB-11-20, respectively.

The local groundwater discharge zone with flowing artesian of near surface water levels is indicated around the chain of lakes through the center of the Rose Pit (Figure A.7). Local groundwater recharge areas are indicated at topographical highs to the west, south and east of the Rose Pit, with two local recharge areas within the Pit foot-print. The cross-section (Figure A.8) also shows water table gradient towards the lake and wetland areas.

Vertical hydraulic gradients were estimated for the Rose Pit area at well pairs ROB-11-05A/B, ROB-11-08A/B and ROB-11-13A/B, where the B-series wells are completed in glacial till, and the A-series wells are completed in the deeper till-bedrock interface. The vertical hydraulic gradient was upwards from deep till / bedrock to shallow till at ROB-11-08A/B (0.066 or 6.6%) and ROB-11-13A/B (0.144 or 14.4%), and downward from shallow till to deep till / bedrock at ROB-11-05A/B (0.047, 4.7 %). This is in line with what would be expected in the area as

ROB-11-05A/B is located near the top of a large (595 m elevation) slope while ROB-11-8A/B is situated in a local depression (elevation 579 m). The upward gradient at ROB-11-3A/B in an upland area is attributed to shallow bedrock which may be locally confined by the overburden.

5.1.3.5 Hydraulic Properties

The hydraulic conductivity (K) for the Rose Pit area was determined from pump recharge tests conducted at wells ROB-11-02, ROB-11-05B, ROB-11-13B, ROB-11-17 and ROB-11-20 in January and March of 2012. These wells are screened in silty sandy till and the till / shallow bedrock interface, and were found to have the following hydraulic conductivities:

Table H5.4 Hydraulic Conductivity – Rose Pit Wells

Well ID	Location	Well Screen Material	Hydraulic Conductivity (m/s)
ROB-11-02	Rose Pit Perimeter	Till/bedrock	9.5×10^{-8}
ROB-11-05B (run 1)	Rose Pit Perimeter	Silty sandy till	1.8×10^{-6}
ROB-11-05B (run 2)	Rose Pit Perimeter	Silty sandy till	5.1×10^{-7}
ROB-11-13B	Rose Pit Perimeter	Silty sandy till	1.9×10^{-6}
ROB-11-17	Rose Pit Interior	Till/bedrock	3.2×10^{-8}
ROB-11-20	Rose Pit Interior	Till/bedrock	1.2×10^{-6}
RBR-12-02	Rose Pit Interior	Bedrock	1.2×10^{-6}
RBR-12-01	Rose Pit Interior	Bedrock	2.6×10^{-6}

The three values for silty sandy till average 1.3×10^{-6} m/s; the three values for the till-bedrock interface average 1.5×10^{-7} m/s. These values are in line with the mean hydraulic conductivity value found across the site for silty sandy till (9.1×10^{-7}) and the till / shallow bedrock interface (4.3×10^{-7}). Well ROB-11-20 is screened in both the silty sandy till and the shallow bedrock while its hydraulic conductivity aligns with the mean value for silty sandy till; this is as expected as the till would contribute the majority of the wells recharge. Two (2) 300 m 60 degree inclined boreholes subjected to packer injection testing indicate a bedrock K averaging 1.9×10^{-6} m/s.

5.1.3.6 Estimated Pit Inflow Potential

A preliminary estimate of potential open pit mine pit inflows from groundwater was made using the range of hydraulic conductivities provided for overburden and bedrock in the Rose Pit Area. This assessment, and an assessment of the possible spatial extent of groundwater drawdown from the pit dewatering, is addressed in the Water Resource VEC sections of the EIS.

5.1.3.7 Groundwater Chemistry

The groundwater quality in the Rose Pit area was characterized from ten (10) wells located along the perimeter of the proposed pit and four (4) wells located within the pit area. Based on the elevations of the saturated sand packs, seven wells were screened across the till / bedrock interface (ROB-11-5A, 10, 11, 12, 13A, 17 and 20), three (3) wells were completed within the glacial till (ROB-11-5B, 8B and 13B), and four (4) wells represent groundwater from the fractured bedrock units (ROB-11-8A and Alderon boreholes WS-K-11-108, 113 and 163).

The major ion concentrations of all 14 sampled wells were similar, and generally described as a clear to slightly colored, moderately soft (mean hardness 62.3 mg/L), neutral to slightly acidic (mean alkalinity 72.4 mg/L, mean pH 7.9, mean calcite saturation index -0.7 at 4 degrees Celsius), calcium-bicarbonate water type of low TDS (mean 95.5 mg/L). Chloride is notably low (mean 1.3 mg/L; maximum 5.4 mg/L) in these groundwater samples.

The overburden chemistry represented by shallow wells ROB-11-05B, ROB-11-08B, ROB-11-13B is described as a clear, moderately soft (mean hardness 60.3 mg/L), slightly acidic (mean alkalinity 59 mg/L, mean pH 7.7), calcium bicarbonate water type with low total dissolved solids (mean 101 mg/L). All parameters except manganese (mean 297 µg/L) met GCDWQ (Health Canada, 2010). In comparison to the deeper till / bedrock and bedrock chemistry, the overburden chemistry appears to be slightly higher in sodium, chloride and TDS concentration, and lower in alkalinity, organic carbon, and trace metals concentration.

The groundwater from seven (7) wells screened across the till / bedrock interface (ROB-11-5A, ROB-11-10, ROB-11-11, ROB-11-12, ROB-11-13A, ROB-11-17, and ROB-11-20) is characterized as a clear, moderately soft (mean hardness 60.1 mg/L), slightly acidic (mean alkalinity 73.6 mg/L, mean pH 7.7) calcium bicarbonate water with low total dissolved solids (mean 64.6 mg/L). All parameters except iron (mean 635 µg/L) and manganese (mean 396 µg/L) meet GCDWQ. The interface chemistry typically has higher total organic carbon concentration (mean 27.5 mg/L, maximum 120 mg/L) than the other units.

Several outliers do exist within these wells including ROB-11-12, ROB-11-17 and ROB-11-20 which were found to be softer than average (< 50 mg/L), and ROB-11-13B which had a higher than average proportion of sodium and sulfate ; possibly attributed to grout.

The bedrock chemistry in bedrock within the Rose Pit area (ROB-11-05A, K-11-108, K-11-113, and K-11-163) is generally described as a clear, moderately soft (mean hardness 62.3 mg/L), slightly acidic (mean alkalinity 78.6 mg/L, mean pH 8.4) calcium bicarbonate with low total dissolved solids (mean TDS 93 mg/L). The GCDWQ are typically exceeded for iron (mean 1187 µg/L) and manganese (mean 107.2 µg/L). In comparison to the overburden wells, the bedrock typically has higher concentrations of alkalinity, pH, copper, iron and zinc.

5.1.4 Tailings Management Facility (TMF)

5.1.4.1 Overburden Description and Thickness

Information at the proposed TMF is currently limited to three boreholes drilled in the general vicinity (Figure A.3, Appendix A). The TMF was found to have an overburden thickness range from 9.7 m at BH-GE-15 to 11.1 m at BH-GE-14. Due to the large area of the TMF, both the thickness of the peat or rootmat layer and the thickness of glacial till are expected to vary based on elevation and topography. The glacial till encountered was consistent with other areas of the Project, and is described as a loose to very dense grey, silty sand with trace gravel and boulders changing to a very dense, grey to brown, silty sand with trace gravel and boulders at depth. A thin layer of rootmat (0.1 m) was found to overlay very loose to very dense glacial till in well BH-GE-15. Wells BH-GE-13 and BH-GE-14 were found to have 1.5 to 2.1 m of peat and organic soil overlaying loose to very dense glacial till.

5.1.4.2 Bedrock Description

Bedrock was not encountered in any of the three wells drilled in the TMF, but it assumed that it is of a similar composition and depth below grade as wells in the adjacent Main Plant site east (white quartzite and marble bedrock encountered 5.1 to 48.4 m depth below ground).

5.1.4.3 Groundwater Levels

Groundwater levels in the TMF were only measured during winter conditions in which all three wells in the area were found to be frozen at apparent levels within 0.1 m of grade (Table B5, Appendix B). All three of these wells are situated in local topographical lows near to streams or lakes and it is likely the frozen water levels measured are fairly representative of local levels. It is anticipated that a better opinion on water levels will be available after the spring thaw. No water level data loggers are installed in this area.

5.1.4.4 Groundwater Flow Directions

The groundwater flow in the local area of the TMF is assumed to closely follow topography and predominately flow in a westerly and northwest direction towards Waldorf River and Long Lake respectively (Figure A8, Appendix A). A low northerly hydraulic gradient of 0.014 m/m is indicated between BH-GE-14 and BH-GE-13, and a similar westerly gradient of 0.017 m/m is indicated between BH-GE-15 and BH-GE-13. Horizontal hydraulic gradients between wells in the TMF and wells at the Main Plant site further suggest this northwestern direction of groundwater flow.

No vertical hydraulic gradients were determined for the TMF as there are no nested well pairs in the area. However, the apparent very shallow depth to water level suggest upward vertical gradient would dominant in this area.

5.1.4.5 Hydraulic Properties

No hydraulic conductivity testing of overburden and bedrock was done at the TMF due to frozen conditions at all wells in the area. The site mean hydraulic conductivity values of 9.1×10^{-7} m/s for silty sandy till, 1.1×10^{-4} for sandy till, 4.3×10^{-7} for till / shallow bedrock and 1.9×10^{-6} m/s for deep bedrock can be assumed to represent conditions in this area as well.

5.1.4.6 Groundwater Chemistry

No groundwater chemistry information is available for the TMF due to winter frozen conditions. Samples will be collected during the next scheduled sampling event. The water chemistry of the overburden and bedrock is expected to be consistent with the general chemistry results of the area.

5.1.5 Waste Rock Areas

No site-specific information is available for the Rose North and Rose South waste rock disposal areas.

5.1.5.1 Overburden

Based on the overburden mapping (Figure A.4, Appendix A, the overburden is expected to be consistent with other areas of the site, consisting of variable thicknesses of loose to compact silty sand glacial till that becomes denser with depth. No hydraulic testing data is available in this area.

5.1.5.2 Bedrock Description

No bedrock information or hydraulic properties data are available for these areas. Based on the geology mapping (Figure A.5, Appendix A), the Rose South area is underlain by dolomite and calcitic marble of the Denault-Duley Formation, and the Rose North area is underlain by schist of the Katsao formation.

5.1.5.3 Groundwater Levels

There has not been any investigation into groundwater levels in the Waste Rock Areas as no investigative boreholes or wells have been drilled to date. Based on ground elevation (600 to 670 m), and the closest monitor wells (ROB-11-3, 4, 5, 6, 7), the groundwater levels would be expected to range from -1.45 m above grade to 1.91 m bgl, averaging 0.3 m in the vicinity of Rose North Waste Rock area.

5.1.5.4 Groundwater Flow Directions

Groundwater flow directions or horizontal gradients were not determined specific to the Waste Rock Areas as no monitoring wells are present in the area. Based on the strong correlation (nearly 1:1) between topographic and groundwater gradients across the rest of the site it is assumed that groundwater flow directions in the Waste Rock Areas will also closely follow topography. Based on the topography and drainage, these locations are situated on the watershed divide on the Labrador side of the Quebec-Labrador border. The dominant directions of groundwater flow are expected to be eastward towards Pike Lake (Rose North) and both eastward towards Mills Lake and westward towards Waldorf River (Rose South). Inferred horizontal hydraulic gradients are about 12.5% east towards Pike Lake in the vicinity of Rose North. No detailed mapping is available for the Rose South Area; however based on regional topography the dominant groundwater flow directions would be radial from the Waste Rock area towards Mills Lake, Waldorf River and Long Lake (Figure A.3, Appendix A).

5.1.5.5 Hydrogeology

No site-specific hydraulic conductivity testing was done in the vicinity of the two Waste Rock Areas. The site mean hydraulic conductivity values of 9.1 x 10^{-7} m/s for silty sandy till, 1.1 x 10^{-4}

for sandy till, 4.3 x 10^{-7} for till / shallow bedrock and 1.9 x 10^{-6} m/s for deep bedrock can be assumed to represent conditions in this area pending future site-specific investigation.

5.1.5.6 Groundwater Chemistry

No groundwater samples have been collected from the Waste Rock Areas as there are no monitoring wells in the proposed areas. The chemistry conditions discussed for the general site would be relevant pending site-specific investigation.

5.1.6 Access Road, Rail Line and Power Transmission Line

The infrastructure for the Access Roads, Rail Line and Transmission Lines extends across the site, from the eastern entrance of the Kami Property to the Rose Pit area. The wells used to characterize the area are quite dispersed and will be examined in two separate clusters. The area around the Waldorf River crossing represented by wells BH-GE-04 to BH-GE-06 was discussed in conjunction with the Main Plant areas. This section will deal with the Rail Line loop and eastern portions of the road and transmission infrastructure represented by wells BH-GE-16 to BH-GE-20.

5.1.6.1 Overburden Description and Thickness

The Rail Loop and Power Transmission Line areas were found to have an overburden thickness range from 0.9 m at BH-GE-16 to 7.2 m at BH-GE-17. Lithology consisted of a thin layer of rootmat / topsoil (0.1 to 0.6 m) over very loose to compact brown sandy silt or silty sand glacial till in all wells with the exception of BH-GE-20 which had 1.1 m of peat overlying glacial till.

5.1.6.2 Hydraulic Properties

The hydraulic conductivity (K) of overburden at the Rail Line and Power Transmission Lines was determined from pump recharge tests conducted at BH-GE-18 in March 2012. A K of 2.4 x 10^{-7} was indicated at BH-GE-18 screened in silty sandy till. This value is in line with the mean hydraulic conductivity value found across the site for silty sandy till (8.8 x 10^{-7}), (Table H5.1).

5.1.6.3 Bedrock Description

Bedrock was encountered In the eastern sections, in wells BH-GE-16, BH-GE-17 and BH-GE-19 at depths of 0.9, 7.0, and 6.1 mbg respectively is characterized as fractured to intact, medium strong, grey quartzite with some marble banding. No site-specific hydraulic testing data is yet available for these areas.

5.1.6.4 Groundwater Levels

Groundwater levels in the Rail Line and Power Transmission Line areas closely follow topography and range from 4.4 mbg to +1.02 mag (flowing). To date, static groundwater levels have been measured at 4 wells in the area (BH-GE-16, BH-GE-18, BH-GE-19 and BH-GE-20). Water level data loggers have been installed in two (2) wells (BH-GE-16 and BH-GE-18).

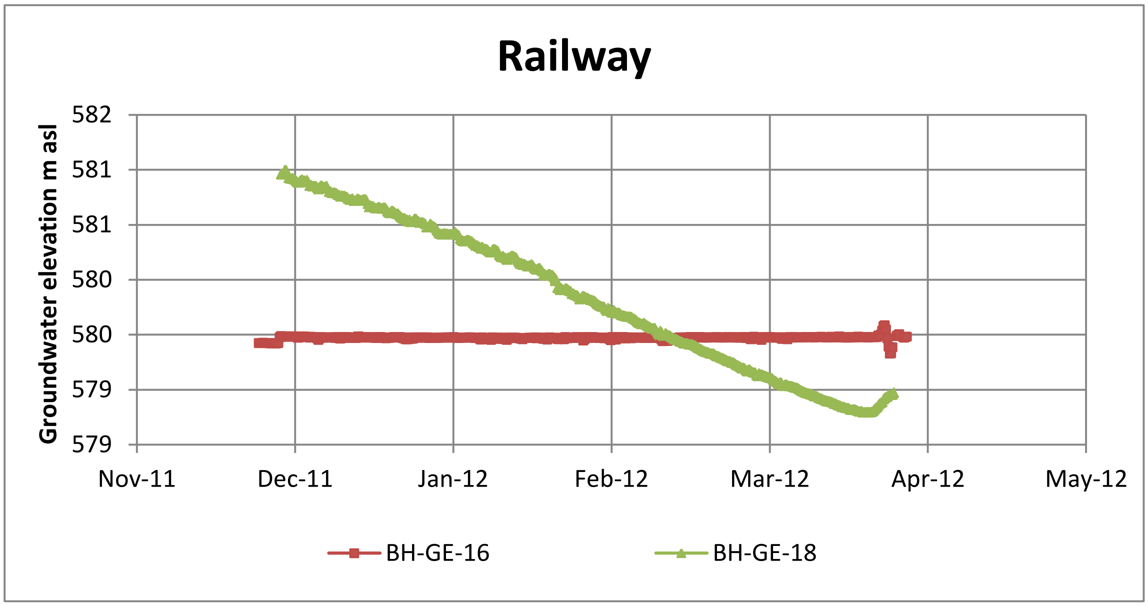
Figure A.3 (Appendix A) shows the locations of these wells and provides a summary of the work completed to date.

The static groundwater levels were used to create a groundwater contour map, Figure A.6, shows likely groundwater flow patterns in this area. In general, areas of locally low elevation had groundwater levels near the surface, as seen in wells BH-GE-19 and BH-GE-20. In contrast wells located in locally high elevations or on significant slopes had much deeper groundwater levels, including BH-GE-16 (mean 4.4 m below grade). A Summary of static groundwater level measurements is provided in Table B.5, Appendix B.

Information downloaded from the data loggers in March and April 2012 is provided in Appendix E. These hydrographs show a general decreasing trend in water levels over the course of the winter when frozen ground conditions and predominance of snow limits the degree of groundwater recharge. Some evidence of recharge was noted in late March, correlating with a period of warming and rain precipitation.

Figure H5.4 presents water level hydrographs for BH-GE-16 and BH-GE-18 between November 2011 and March 2012. In general, BH-GE-16 exhibits a slight decreasing water level trend with the exception of BH-GE-18 which declined over 2 meters between November 2011 and March 2012. It is noted that some of the monitoring wells were frozen during the monitoring period; a better opinion on water levels will be available after the spring thaw.

Figure H5.4 Relative Water Levels Rail and Power Transmission Areas



5.1.6.5 Groundwater Flow Directions and Gradients

The groundwater flow direction for the Rail Line and Power Transmission Line areas closely follows topography. Due to the dispersed nature of this infrastructure the flow direction varies between clusters of monitoring wells (one cluster west of Long Lake and one cluster east) with gradients flowing towards local topographical lows.

The groundwater flow directions in the eastern portion of the Rail Lines and Power Transmission Lines were in two distinct directions. A groundwater divide passes north-south through the site and results in gradients to slope west towards Long Lake and east towards Elephant Head Lake depending on location related to the inferred divide. At the east end of the site where this infrastructure is planned to enter the site, an easterly groundwater flow direction towards Elephant Head Lake is indicated between BH-GE-18 and BH-GE-19 at a gradient of 0.013 m/m, and between BH-GE-19 and BH-GE-20 at a gradient of 0.023 m/m. West of the inferred groundwater divide, a westerly flow direction is observed between BH-GE-16 and BH-GE-07 towards Long Lake at a horizontal gradient of 0.025 m/m.

No vertical hydraulic gradients were determined for the Rail Lines and Power Transmission Lines as there are no nested well pairs in the area to test. Based on above grade water levels at BH-GE-19 and BH-GE-20, upward vertical hydraulic gradients would be expected in these low-lying areas.

5.1.6.6 Groundwater Chemistry

The Rail Lines and Power Transmission Lines were characterized by one (1) sample (BH-GE-18). Further sample collection was restricted by persistent frozen conditions across the site. Due to the dispersed nature of the road, rail and transmission infrastructure it is difficult to generalize the results from one sample location together. Samples The third well sampled, BH-GE-18 is located near the eastern entrance to the site where the rail, road and transmission lines are proposed to enter the site. The well is screened in the till / bedrock interface and is characterized as clear, moderately hard (hardness 86 mg/L), slightly acidic (alkalinity 92 mg/L, pH 8.0), calcium bicarbonate water type with low total dissolved solids (86 mg/L). All parameters except manganese (0.79 mg/L) meet the GCDWQ.

5.1.7 Groundwater-Surface Water Interaction

Groundwater is an integral component of the hydrologic cycle, and forms part of the runoff component in the Water Balance of a given areas. At the Project site, the shallow depth to groundwater and the large variations in topographic elevation (up to 113 m of relief) within short horizontal distances results in considerable interaction between groundwater and surface water. In general, the groundwater recharging on elevated areas moves along the topographic gradient towards low lying areas such as wetlands, streams and lakes where it discharges into the surface water environment. Under the pre-mining or baseline conditions, there are strong upward vertical hydraulic gradients from overburden and bedrock into local streams. Under the proposed mining scenario, some of this upward flow would be expected to reverse, as local groundwater flow patterns become dominated by the OPM.

Further discussion of the potential interactions between groundwater and surface water on the Project site is provided in the Hydrology sections.

5.1.8 Groundwater Resources

5.1.8.1 Local (Nearest) Groundwater Users

Within the immediate vicinity of the Project there are no permanent dwellings that rely on groundwater as a drinking water source. There are numerous cabins or hunting camps in the area that may have drinking water wells, specifically on the eastern edge of the site; however, it would be necessary to conduct a visual inspection of these locations to confirm presence or absence of a supply. From experience, seasonal camps generally rely on surface water, springs or bottled water for potable use. The surrounding towns of Labrador City and Wabush, in Labrador and Fermont in Quebec rely on lakes for their municipal drinking water supplies and it is not anticipated that they would be impacted by any groundwater issues.

The closest water supply wells would be located in the unserviced areas adjacent to these three communities, and are at least 3 km away from the Project operations. No effects on water supply wells at these distances are anticipated.

5.1.8.2 On-Site Water Well Development Potential

Water supply wells are proposed to be developed in the Main Plant area to use for both potable and non-potable purposes. Based on this assessment, it is our opinion that site wells will be drilled wells, and cased through the overburden into the underlying bedrock aquifer. Pending confirmation by proposed groundwater exploration and testing, these wells are likely to exhibit low to moderate yields in the order of 45 to 55 m^3/day (11 to 12 igpm) assuming a well depth of 120 m. With on-site storage, these yields could meet specific potable demands.

Groundwater exploration of a specific location would involve the drilling of a test well and an observation well, followed by hydraulic testing (step drawdown test and constant rate pumping test), and water chemistry analysis. The test data would be analyzed by a hydrogeologist to determine the sustainable yield of the well, well interference parameters, and recommended pump setting and pumping rates.

5.2 Surface Water

5.2.1 Regulatory Guidance and Criteria

Section 4.18 of the EIS guidelines prescribed that the EIS should provide existing environment baseline detail of the following surface water items:

- include delineation of drainage basins, at appropriate scales;
- describe and present monitored hydrological data, such as water levels and flow rates in local streams and selected local lakes;

- describe and assess hydrological regimes, including monthly, seasonal and year-to-year variability, normal flows , low flows, environmental (maintenance) flows and flood flows for selected return period flood events;
- include flows or design peak flows for selected periods for the Project area, bridge and culvert design at stream crossings for access roads and railway lines, and an assessment of potential ice problems;
- describe the interactions between surface water and groundwater flow systems under pre-development conditions and potential impacts on these interactions during the various phases of the Project;
- describe any local and regional potable surface water resource (e.g., from Wahnahnish Lake, Perchard Lake); and provide seasonal water quality field and lab analytical results and interpretation at several representative local stream and lake monitoring stations established at the Project site.

5.2.2 Regional Hydrology

Naturally flowing rivers in Labrador enter their baseflow recession phase in fall when the ambient temperatures drop below 0ºC and a permanent snow cover is established (Rollings, 1997). Baseflow recession lasts as long a May. The spring freshet typically occurs in May – June and accounts for most of the annual flow. During the subsequent summer and early fall attenuated storage contribute to the falling limb of the annual hydrograph and rainfall – runoff events produce hydrograph responses with inverse proportionality to watershed area. A secondary annual hydrograph peak typically occurs in October. Figure 5.1 presents the seasonal flows for western Labrador (Rollings 1997). Figure 5.2 presents mean annual runoff for Labrador. Figure 5.3 presents monthly runoff from selected HYDAT stations.

The mean peak flow per unit area for select watersheds in Labrador with no outlet control was 0.1681 m^3/s/km with standard deviation of 0.0342 m^3/s/km and range from 0.1403 m^3/s/km to 0.2238 m^3/s/km. In general, low flow periods extend from late fall, through winter to the onset of the spring freshet. Distinct upward streamflow trends are being observed in Labrador (Dawe, 2006) and are depicted in Figure 5.4.

Figure 5.1 Seasonal Flows in Western Labrador (Rollings, 1997).

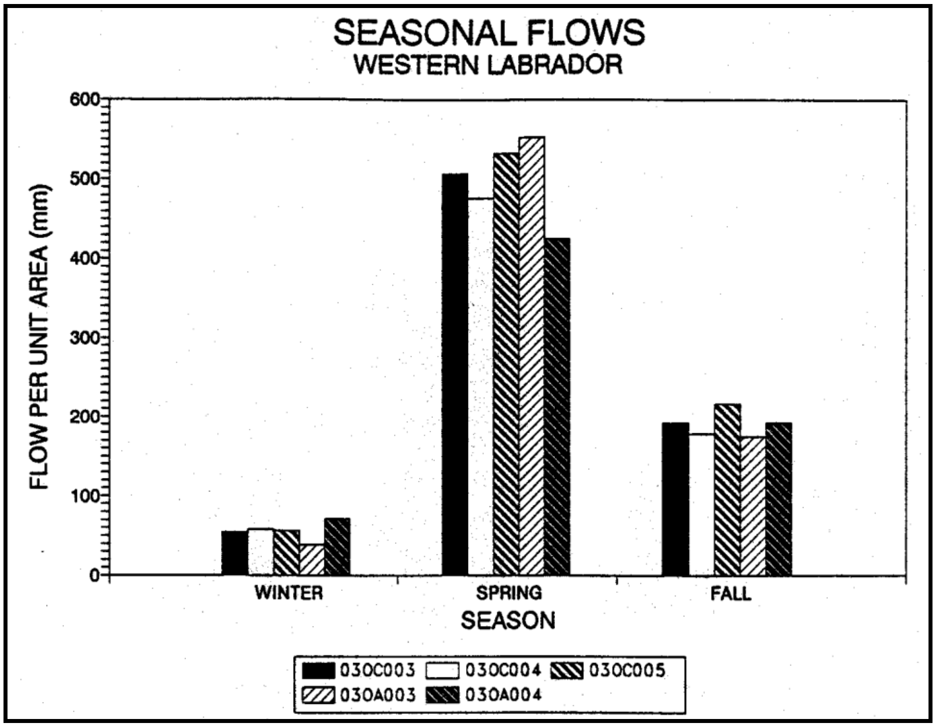


Figure 5.2 Mean Annual Runoff for Labrador (Rollings, 1997).

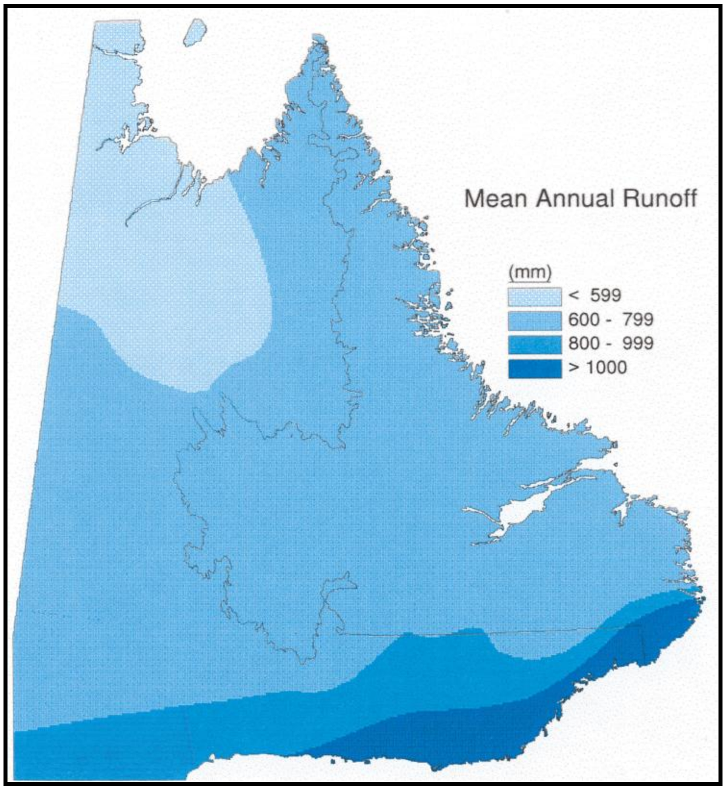

Mean Annual Runoff
(mm)
< 599
600 - 799
800 - 999
> 1000

Figure 5.3 Monthly Runoff from Select HYDAT Stations in Labrador (Rollings, 2007).

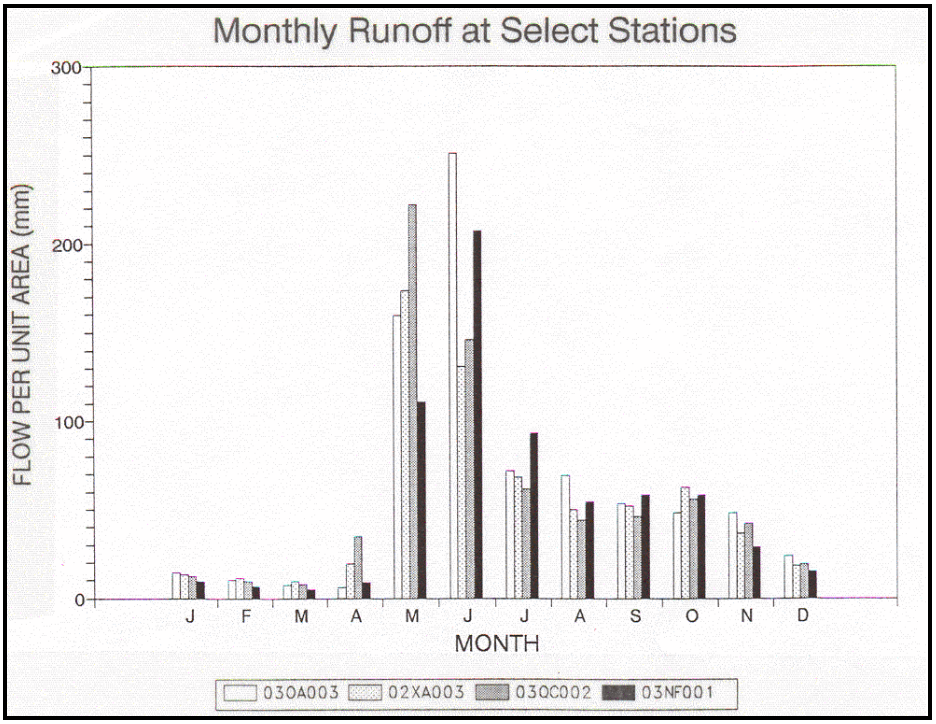
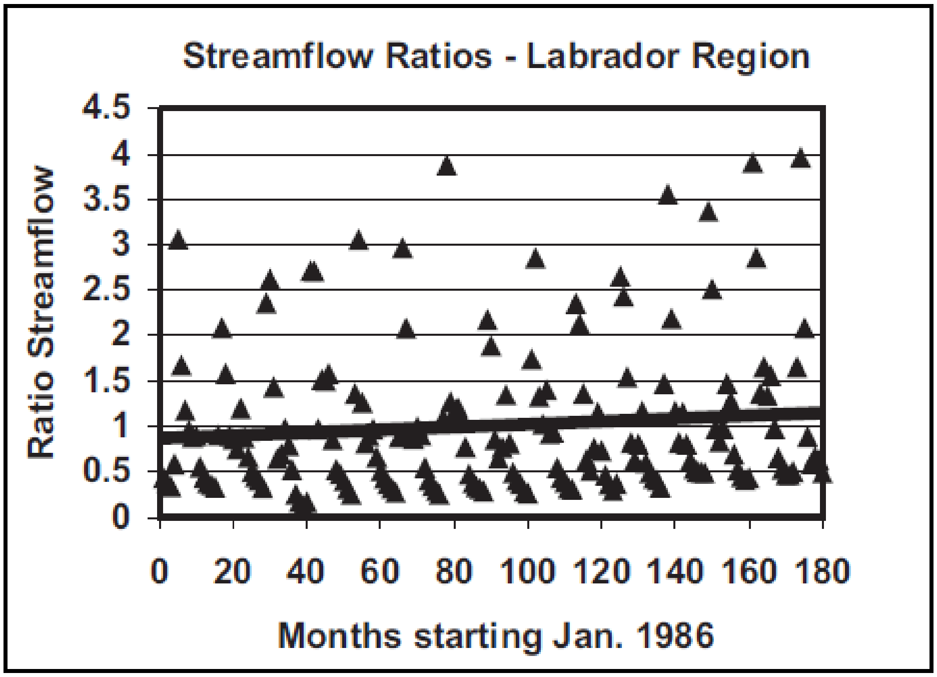


Figure 5.4 Streamflow trends in Labrador (Dawe, 2006).



5.2.3 Physiographic Setting

5.2.3.1 Climate

Climate Normals

The climatic conditions in the LSA are sub-arctic, characterized by long cold winters and short mild summers. Climate normals for the latest 30-year period (1982 – 2011) (Table 5.2) were obtained from Environment Canada Station 8504175 (Wabush Lake Airport) locating approximately 12 km to the northeast from the site. Monthly mean temperature extremes in the area can range from -22°C in the winter to 14°C in the summer, with a mean annual temperature of -3°C. The climate normal precipitation is approximately 858 mm/year, which is typical of western Labrador. The annual snowfall is estimated to be 444 cm/year occurring mainly between October and May.

The Project site is located within the zone of ‘isolated patches of permafrost’, near the southern extremity of the ‘sporadic discontinuous permafrost’ zone (NRC, 1993). Snow cover is an important hydrological parameter in this area. Water stored as snow cover is released when temperatures climb above zero and is responsible for high freshet runoff flows experienced in the spring. The mean monthly snow cover peaks during February and March; from March to April a 34% reduction can be anticipated on average. The snow cover is usually melted by the end of May and returns in November with mean a monthly value of 19 cm.

Table 5.2 Climate Normals for the latest 30-year period (1982 to 2011) at Wabush Lake Airport Station (Station # 8504175).

Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-21.8	-20.4	-13.5	-4	4	10.5	13.9	12.7	7.6	0.6	-7.7	-16.9	**-2.9**
Rainfall (mm)	2.5	1.3	2.6	12.4	41.8	81.5	115.9	107.5	90.4	45.1	14	2.8	**517.9**
Snowfall (cm)	66.4	51.7	68.4	49.3	13.8	1.8	0	0.3	4.3	37.6	77.4	72.9	**443.9**
Precipitation (mm)	50	39	54.2	51.9	54.1	83.3	116.1	107.7	94.4	77.3	75.5	54.5	**858.1**
Snow on Ground (cm)	70.2	81.7	86.6	56.8	5.8	0	0	0	0	2.4	19	47.2	**30.8**

Dry Year

A review of annual climate conditions observed at the Wabush Airport weather station indicated that 1993 was the driest year in the latest 30-year records. Table 5.3 presents the recorded monthly climate values for 1993. 1993 had 623.6 mm of total precipitation which was 27.3% less precipitation than the climate normal condition. Statistically, 1993 is in the range of the 1:100 year dry year which is discussed further in Section 5.2.4.4.

Table 5.3 Climate values for 1993 (a dry year) at Wabush Lake Airport Station (8504175).

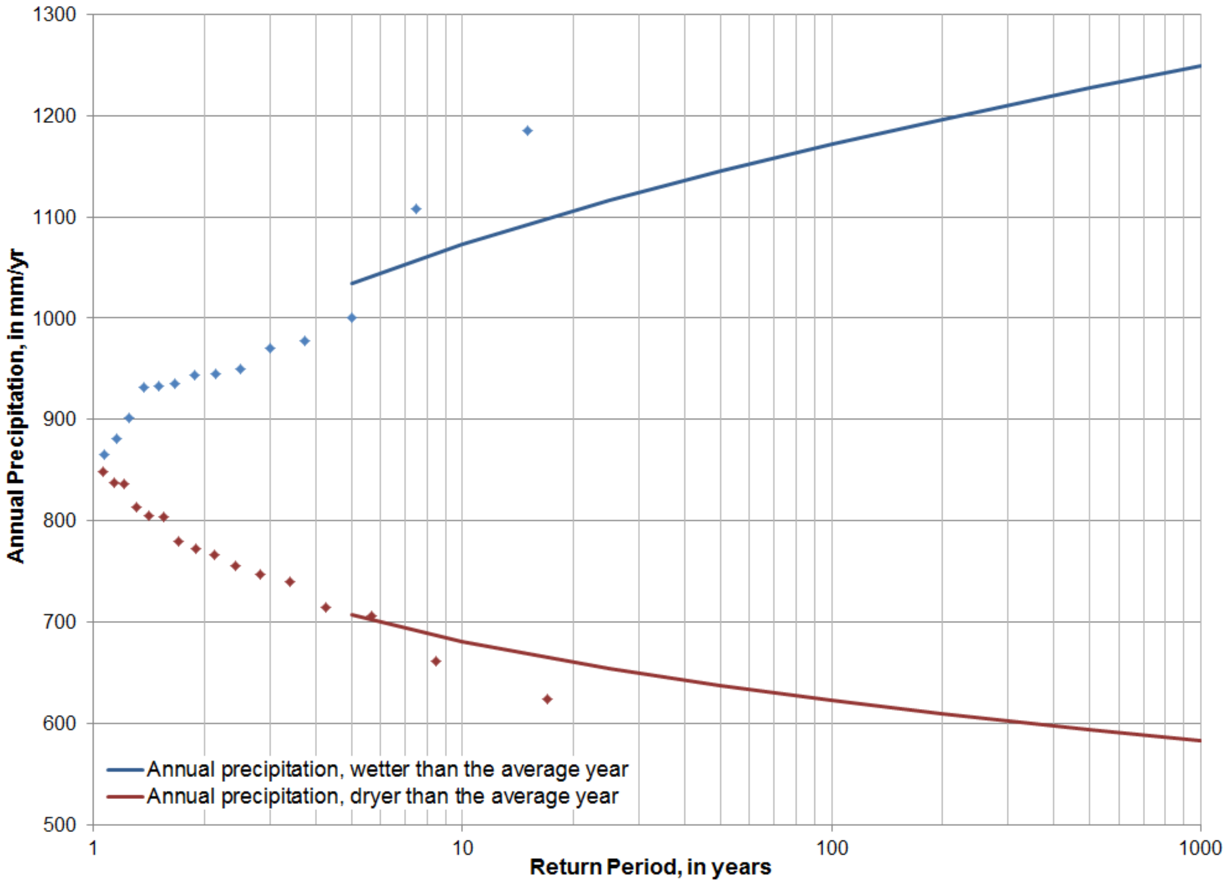
Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-19.4	-21.4	-14.1	-3.3	3.9	10.8	14.1	12.5	5.4	-2.9	-11.2	-17.3	**-3.6**
Rainfall (mm)	0	0	0	20.2	48.3	37.6	88.4	151.6	59.5	9.3	10.8	0	**425.7**
Snowfall (cm)	19.6	18.7	16	15.9	11.4	0	0	0	8.4	30	47	70.8	**237.8**
Precipitation (mm)	17.7	17.6	15.6	35.2	57.9	37.6	88.4	151.6	67.5	33	48.9	52.6	**623.6**
Snow on Ground (cm)	48.4	61	47.8	8.8	1.2	0	0	0	0	2.8	19.5	28.5	**18.2**

Table 5.4 presents precipitation analysis results for a range of return periods that are wetter or dryer than the average climate normal condition. The annual data was then ranked from greatest to smallest in order to determine the average precipitation year, the wetter year data set and the dryer year data set. Log Normal distribution was applied to develop the trends of the wetter curve and dryer curve (Figure 5.5) and predict the annual precipitation for 500-year and 1000-year return periods.

Table 5.4 Annual Precipitation Analysis for a Range of Return Periods

Annual Return Periods, in years	Precipitation Analysis	
	Wetter Years, in mm/yr	Dryer Years, in mm/year
Mean	858.1	
5	1034	708
10	1073	681
25	1116	654
50	1145	637
100	1172	623
200	1197	609
500	1228	594
1000	1249	583

Figure 5.5 Annual Precipitation Wetter / Dryer than the Average Year.



Wet Year

A review of annual climate conditions observed at the Wabush Airport weather station indicated that 1983 was the wettest year in the latest 30-year records. Table 5.5 presents the recorded monthly climate values for 1983. 1983 had 1185.1 mm of total precipitation which was 38.1% more precipitation than the climate normal condition. Statistically, 1983 is in the range of the 1:100 year wet year which is discussed further in Section 5.2.4.4.

The dry-wet year assessment indicates that considerable precipitation variability occurs year over year within the LSA and demonstrates the importance of assessing climatic-driven VECs such as water resources over a range of climate conditions in order to fully understand Project effects.

Table 5.5 Climate values for 1983 (a wet year) at Wabush Lake Airport Station (8504175).

Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-21.6	-21.1	-12.9	-1.4	3.1	12.1	12.8	11.8	8	0.2	-8.7	-20.6	**-3.2**
Rainfall (mm)	0.5	1.2	0.2	57.4	30.5	91.2	155.7	92.6	124.1	51.4	1	0	**605.8**
Snowfall (cm)	108.1	67.3	141.9	47.3	11.7	4.3	0	0	0	33.6	161.2	117.7	**693.1**
Precipitation (mm)	91.4	59.9	115.5	101.5	42	95.5	155.7	92.6	124.1	85.2	124.9	96.8	**1185.1**
Snow on Ground (cm)	69.9	100.7	114	100.7	10.4	0.1	0	0	0	0.9	29.4	112.6	**44.9**

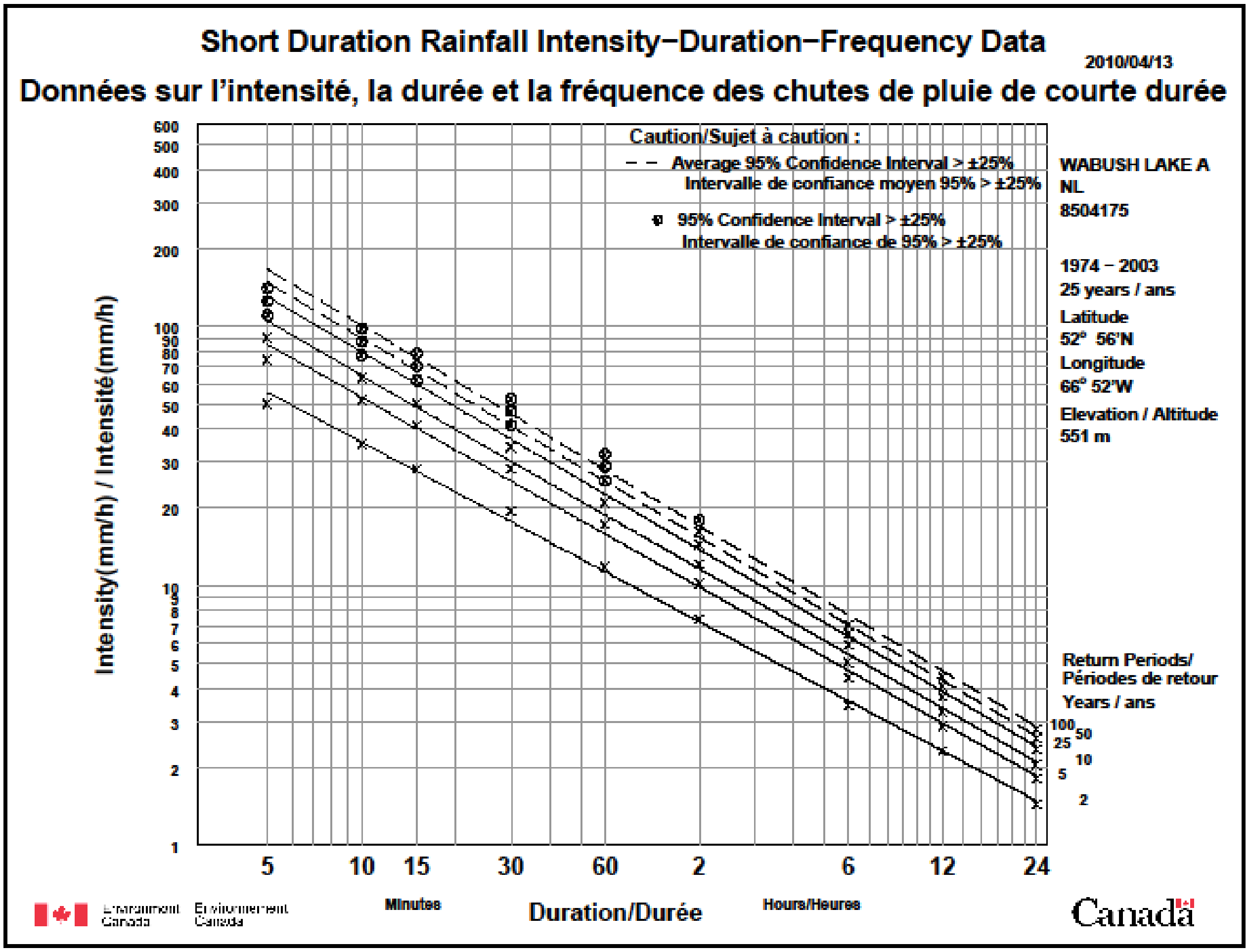
Major Storm Assessment

The return periods for major storm events of duration ranging from 5 minutes to 24 hours and return periods from the 2-year to 100-year events were developed by Environment Canada using the Gumbel – Method of Moments and are presented in Table 5.6. Figure 5.6 presents the Intensity-Duration-Frequency (IDF) rainfall curves for the Wabush Lake Airport weather station (Stn # 8504175).

Table 5.6 Major Storm Return Period Rainfall Amounts at the Wabush Lake Airport

Duration	Return Period (Years)					
	2	5	10	25	50	100
5 min	4.2	6.2	7.5	9.2	10.4	11.7
10 min	5.9	8.7	10.5	12.8	14.6	16.3
15 min	7.0	10.4	12.6	15.4	17.5	19.6
30 min	9.7	14.1	17.0	20.7	23.5	26.2
1 hr	11.8	17.2	20.8	25.3	28.7	32.0
2 hr	14.8	20.4	24.1	28.7	32.2	35.6
6 hr	20.7	26.5	30.4	35.3	38.9	42.5
12 hr	27.6	34.5	39.0	44.7	49.0	53.2
24 hr	34.3	43.1	48.9	56.2	61.6	67.0

Figure 5.6 Precipitation IDF Curves for Wabush Lake Airport



Climate Change

The climate of Labrador is influenced by both atmospheric and oceanographic forces. Some of the main characteristics that shape the climate in Labrador are Labrador's latitude, geographic location, prevailing winds, elevation and relief (Bell et al., 2008). Both the location of Labrador (between 50 to 60 degrees north of the equator) and the seasonally ice covered Labrador Sea contribute to its cold weather. The direction of the prevailing winds is from the northwest to the southwest. In addition, the topography of the region with its mountains, plateaus and lakes contribute to the complexity of the climate in the region (Bell et al., 2008). Other influences include the Labrador Current and the North Atlantic Oscillation (NAO). The NAO is defined by changes of pressure and wind patterns in the North Atlantic region. A positive NAO mode is characterized by colder and drier winters in northeastern Canada and a negative mode is characterized by warmer and wetter winters. The NAO has been in a negative mode for the past 15 years with a few exceptions (Bell et al., 2008).

However, the inland part of Labrador exhibits more continental influences. It is characterized by temperatures ranging between above 30ºC in the summer to -30ºC in the winter. The average daily maximum temperatures are similar to the rest of Atlantic Canada (~21ºC). Labrador is the coldest region in Atlantic Canada during the winter with an average daily minimum of -22ºC. The coastal region of Labrador is milder than the inland region due to the oceanic influence. During the summer, southwesterly winds carry with them warm, moist and unstable air and severe thunderstorm sometimes develop in the western part of Labrador (Whiffen, 2002).

Small changes in temperature have occurred in Labrador since 1961. A small cooling was found along the coast and a minor warming trend was observed inland (Whiffen, 2002). Since the early-mid nineties, there has been a warming trend in all seasons (Bell *et al*., 2008). Overall, the projected increase in annual surface air temperature along the eastern continental edge for the next century according to the Intergovernmental Panel on Climate Change (IPCC) is between 2ºC and 3ºC and up to more than 5ºC in the northern part of the continent. The largest change is projected to occur in the northernmost part of Canada during the winter with up to 10º increase in temperature. The winter temperature in the northern part of the continent is projected to be higher by 7º in the winter and 2º in the summer. In general, the entire continent is projected to warm with the highest variations in the northern regions during the winter (Christensen *et al*., 2007).

Environment Canada predicts for Newfoundland and Labrador an increase in mean temperature of 2ºC during spring, summer and fall and 4ºC increase in mean temperature during winter over the next 70 years. In the interior areas of Labrador, warmer and drier summers are predicted by Environment Canada as well as warmer winters (Vasseur *et al*., 2008).

Precipitation showed an increase on average in the last 50 years throughout coastal Labrador. However, in western Labrador, precipitation remained steady (Whiffen, 2002). Bell *et al.,* (2008) indicates that regional stream flow in Labrador has decreased since the 70's as a result of an increase in evaporation and transpiration.

According to the IPCC, the predicted increased overall temperature will result in an increase in atmospheric moisture flux and therefore increase in precipitation. The IPCC predicts based on its models an increase of 20% or more in annual mean precipitation in northern North America and 30% in the winter during this century (Christensen et al., 2007). The projections of Environment Canada agree with those of the IPCC of an overall increase in precipitation. Over the next 70 years, Environment Canada predicts an increase of almost 10% in precipitation during spring and winter and less than 5% increase in fall and summer in Newfoundland and Labrador (Vasseur *et al*., 2008).

5.2.3.2 Soils and Geology

Local soils and geology are described in the Sections 4.1 and 5.1.

5.2.3.3 Topography

The Kami Property is situated amidst gently rolling hills and valleys, which vary in trend from northeast-southwest to north-south. Topography across the site is relatively rugged and is governed by the underlying geological structure with elevations ranging from 580 m to over 700 m, with local slope angles of 2% to 15%.

5.2.3.4 Vegetation

Ground cover consists of sedges in open wetland bogs and coniferous and deciduous trees, with alder growth over those areas exposed by past forest fires.

5.2.4 Local Hydrology

5.2.4.1 Watershed Delineation

The Kami Property contains a complex system of watercourses and lakes which eventually discharges into Wabush Lake locating in the upper sections of the Churchill River watershed. The Churchill River Watershed is coded as watershed #225 in the Water Resources Atlas of Newfoundland (1992) which ultimately discharges to the Atlantic Ocean.

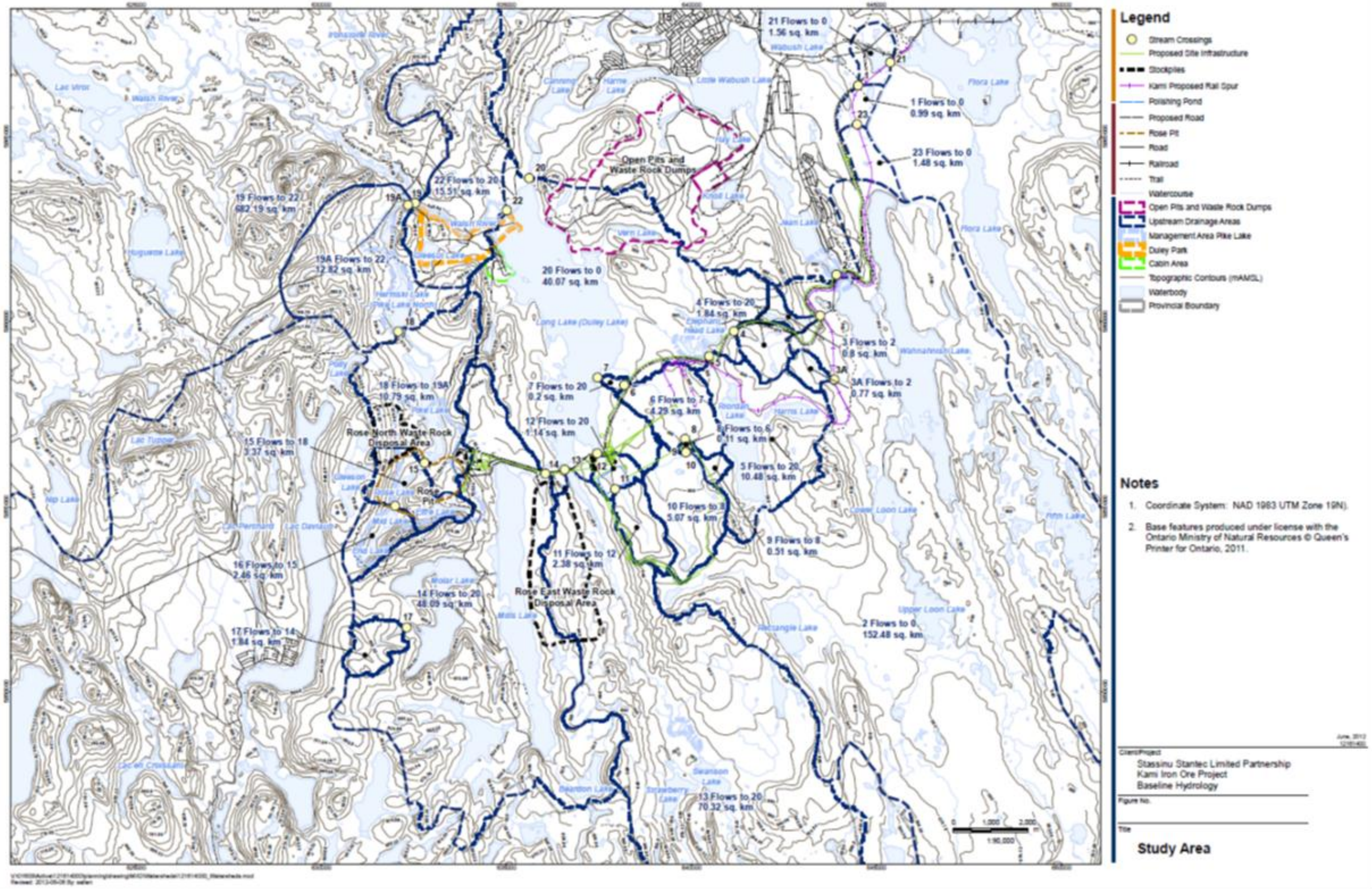
The Project site was divided into twenty-five (25) watersheds and sub-watersheds delineated based on basin and stream order as well as the upstream catchment area at key Project water crossing locations. Watershed surface area, perimeter and elevations were determined using GIS tools (Table 5.7) and their watershed delineations presented in Figure 5.7.

Table 5.7 Watershed and Subwatershed Details.

Subwatershed Code	Local Catchment Area, in km^2	Local Catchment Perimeter, in km	Cumulative Catchment Area, in km^2	Stream Order	Elevation at Headwaters, in metres	Elevation at Exit, in metres
1	0.99	4.40	0.99	1	538	516
2	152.48	97.63	154.05	4	609	538
3	0.8	6.20	0.8	1	594	560
3A	0.77	5.01	0.77	1	598	572
4	1.84	7.04	1.84	2	617	587
5	10.48	21.02	10.48	2	603	570
6	4.29	12.88	9.98	2	579	553
7	0.2	2.88	10.18	1	553	539
8	0.11	2.16	5.69	2	582	579
9	0.51	4.41	0.51	1	582	582
10	5.07	13.75	5.07	2	613	582
11	2.38	9.72	2.38	1	590	557
12	1.14	6.32	3.52	1	557	540
13	70.32	65.48	70.32	3	579	538

Subwatershed Code	Local Catchment Area, in km^2	Local Catchment Perimeter, in km	Cumulative Catchment Area, in km^2	Stream Order	Elevation at Headwaters, in metres	Elevation at Exit, in metres
14	48.09	56.15	49.93	3	597	560
15	3.37	11.93	5.83	1	579	571
16	2.46	7.94	2.46	1	631	579
17	1.84	8.08	1.84	1	669	597
18	10.79	20.50	16.62	2	571	567
19	682.19	175.54	682.19	5	635	548
19A	12.82	17.71	29.44	2	567	554
20	40.07	47.95	913.44	5	538	537
21	1.56	4.91	1.56	1	515	514
22	15.51	28.22	727.14	2	548	537
23	1.48	6.04	1.48	1	516	514

Figure 5.7 PDA and LSA Watershed and Subwatershed Map


21 Flows to 0 1.56 sq. km
1 Flows to 0 0.99 sq. km
23 Flows to 0 1.48 sq. km
22 Flows to 20 15.51 sq. km
19 Flows to 22 682.19 sq. km
19A Flows to 22 12.82 sq. km
20 Flows to 0 40.07 sq. km
Open Pits and Waste Rock Dumps
4 Flows to 20 1.84 sq. km
3 Flows to 2 0.8 sq. km
3A Flows to 2 0.77 sq. km
18 Flows to 19A 10.79 sq. km
7 Flows to 20 0.2 sq. km
6 Flows to 7 4.29 sq. km
12 Flows to 20 1.14 sq. km
8 Flows to 6 0.11 sq. km
Rose North Waste Rock Disposal Area
15 Flows to 18 3.37 sq. km
Rose Pit
5 Flows to 20 10.48 sq. km
10 Flows to 8 5.07 sq. km
9 Flows to 8 0.51 sq. km
16 Flows to 15 2.46 sq. km
11 Flows to 12 2.38 sq. km
Rose East Waste Rock Disposal Area
14 Flows to 20 48.09 sq. km
17 Flows to 14 1.84 sq. km
2 Flows to 0 152.48 sq. km
13 Flows to 20 70.32 sq. km
Legend
Stream Crossings
Proposed Site Infrastructure
Stockpiles
Kami Proposed Rail Spur
Polishing Pond
Proposed Road
Rose Pit
Road
Railroad
Trail
Watercourse
Open Pits and Waste Rock Dumps
Upstream Drainage Areas
Management Area Pike Lake
Duley Park
Cabin Area
Topographic Contours (mAMSL)
Waterbody
Provincial Boundary
Notes
1. Coordinate System: NAD 1983 UTM Zone 19N).
2. Base features produced under license with the Ontario Ministry of Natural Resources © Queen's Printer for Ontario, 2011.
June, 2012
Client/Project
Stassinu Stantec Limited Partnership
Kami Iron Ore Project
Baseline Hydrology
Figure No.
Title
Study Area

5.2.4.2 Watershed Characterization

Drainage across the site is generally directed north and east through a series of wetlands, lakes and connecting streams that form part of the headwaters of the Churchill River watershed. The west side of the Project site drains through the Pike Lake South and North watershed north to the Walsh River, which flows into Long Lake. The center and east side of the Project site drains to Mills Lake, the Waldorf River and Long Lake. Long Lake is the largest lake in the LSA and has a large upstream drainage area. Major project components such as the access road, power corridor and rail link extend to the east through the Jean Lake and Flora Lake watersheds and represent the only project components not located within the greater Long Lake watershed.

5.2.4.3 Hydrological Monitoring Results

The hydrological monitoring results of all five (5) stream gauging stations (Table 4.1) were used to prepare rating curves present below and in Appendix I. A rating curve is a graph of discharge versus stage for a given point on a stream. Its function is to facilitate conversions between stream flows and stages during stream and river monitoring and modeling. Manning's equation was applied in developing the rating curves. Parameters in Manning's equation were determined using the hydrological monitoring results and the channel cross section profiles. Stream flows at different stages was then calculated using Manning's equation in order to develop the discharge and stage relationship in the rating curve. Levelogger water level data was applied to the rating curve to generate continuous streamflow estimates.

Stream Flows

The rating curve developed for station *S4* is presented in Figure 5.8. Other stream flow monitoring stations rating curves are presented in Appendix G. Monitored water levels and derived flows from application of the rating curve at station *S4* are presented in Figure 5.9, with other station monitored water levels and derived flows presented in Appendix G. Baseflow continued even in the smallest monitored streams throughout the winter period. Generally, from the October 2011 – May 2012 monitored period stream flows in local streams declined from approximately November to mid-April. These findings indicate the importance of groundwater discharge to support baseflow through winter when no overland flow occurs. From about mid-April, baseflows began to increase in local streams and peak toward the end of May. This is considered characteristic of the relatively small and headwater nature of most streams in the LSA. The observed seasonal stream flow hydrograph correlates well to the annual stream flow hydrograph presented below based on regional extrapolation. Ice thickness in local streams ranged from open water to approximately 25 cm at the time of the March 2012 field visit.

Figure 5.8 Station S4 Rating Curve

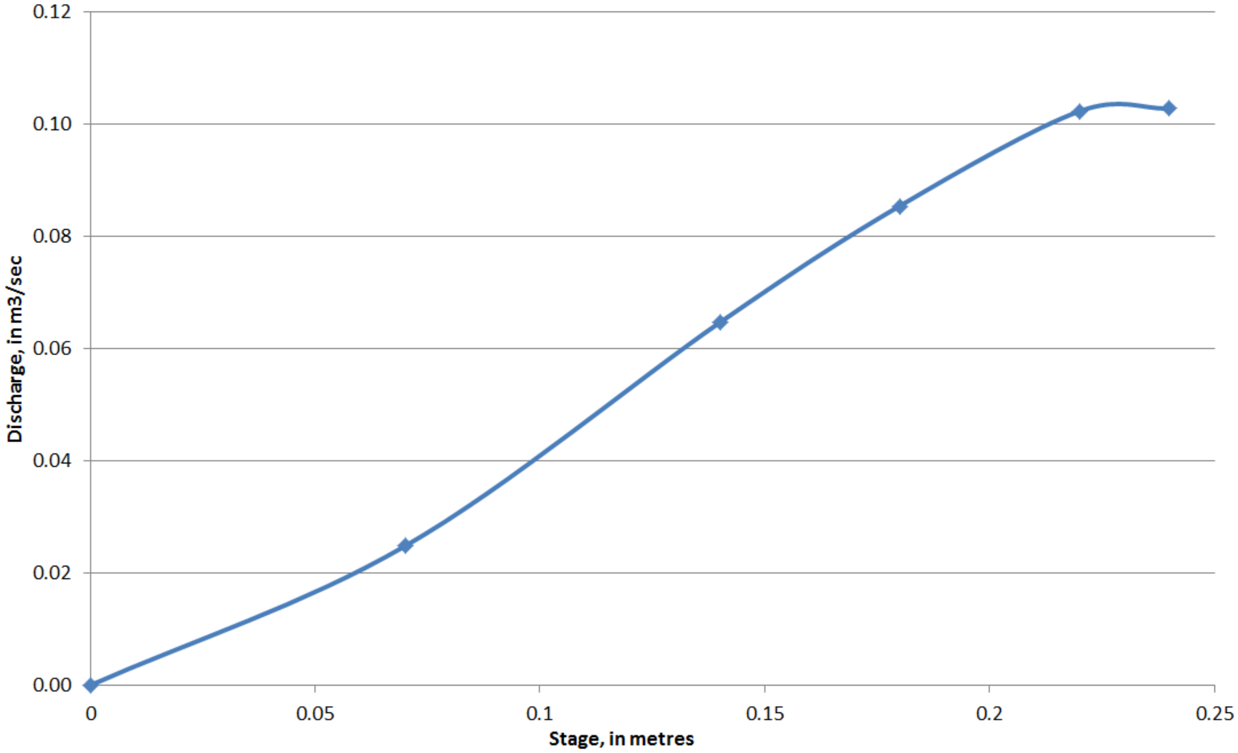
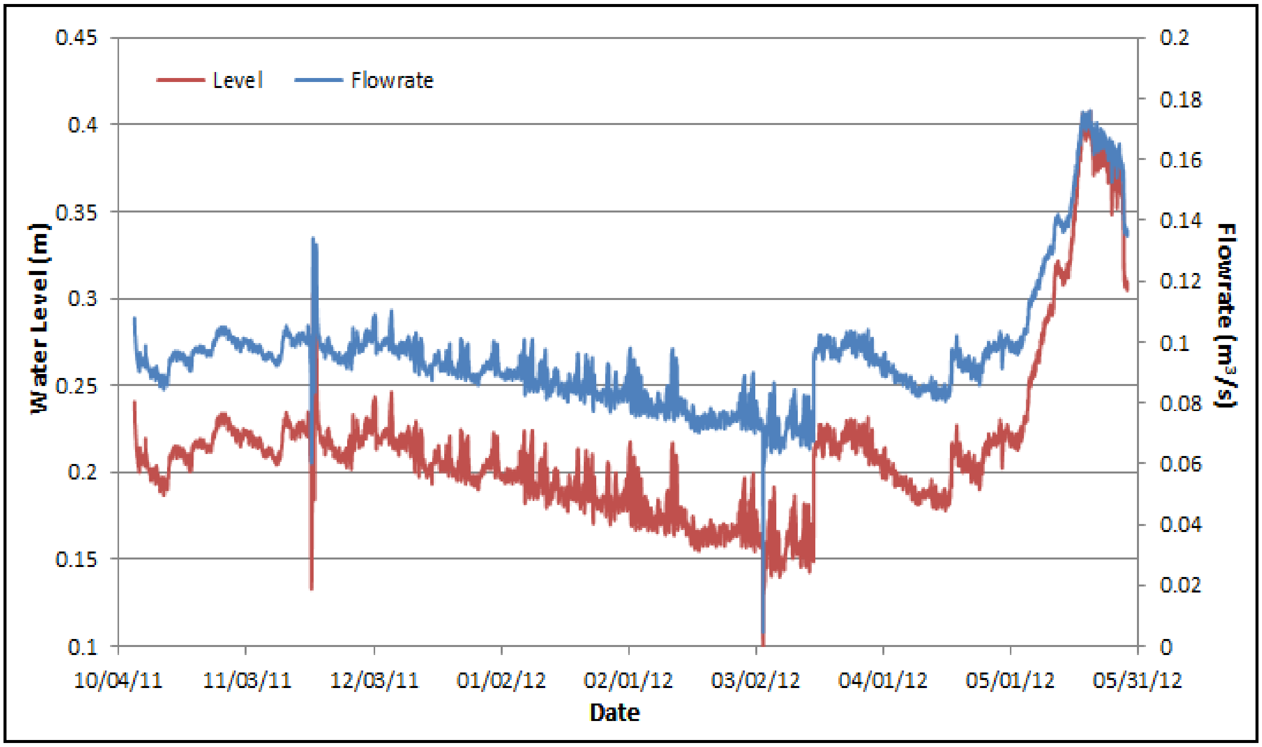


Figure 5.9 Water Level and Streamflow at Station *S4*



Lake Levels, Bathymetry and Ice Depths

In addition to streamflow monitoring, continuous lake level monitoring stations were established on Long Lake (*L2*) and Mills Lake (*L1*) (Table 4.1). The continuous water level of Mills Lake is presented in Figure 5.10. Lake level information is presented in Appendix G. Similarly to the observations for stream flows lake levels decreased over the winter period and began increasing in mid-April as the spring freshet commenced. And similarly, local lake levels peaked toward the end of May.

Figure 5.10 Continuous Water Level Record for Mills Lake

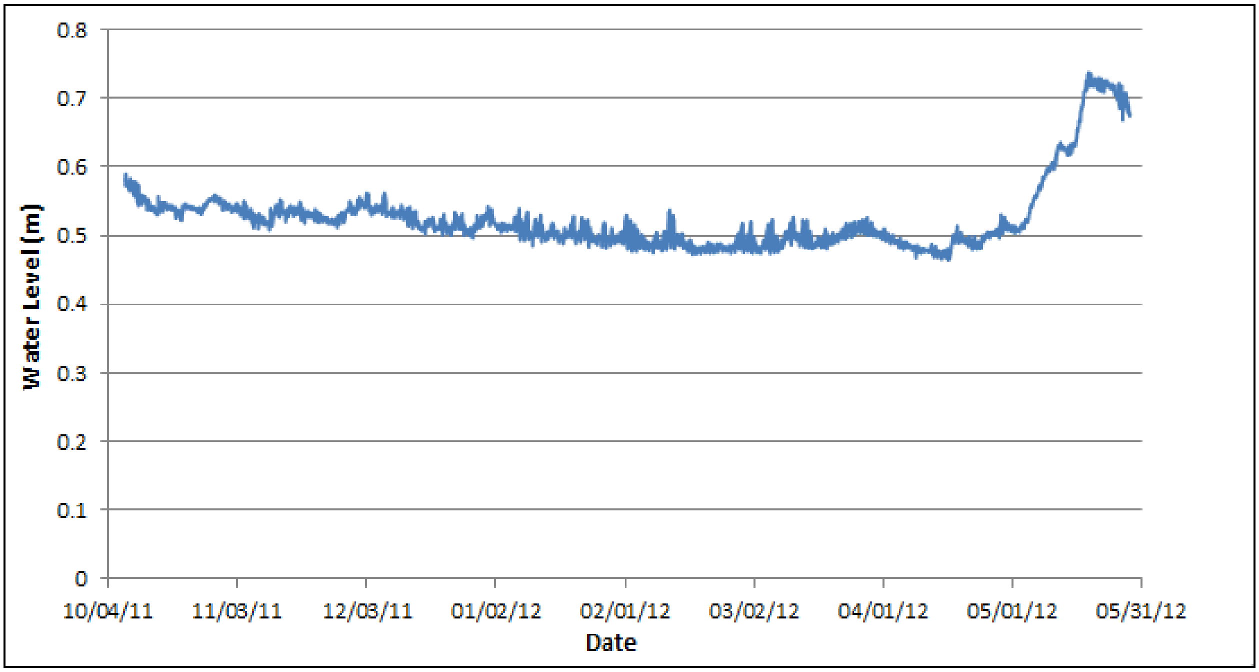
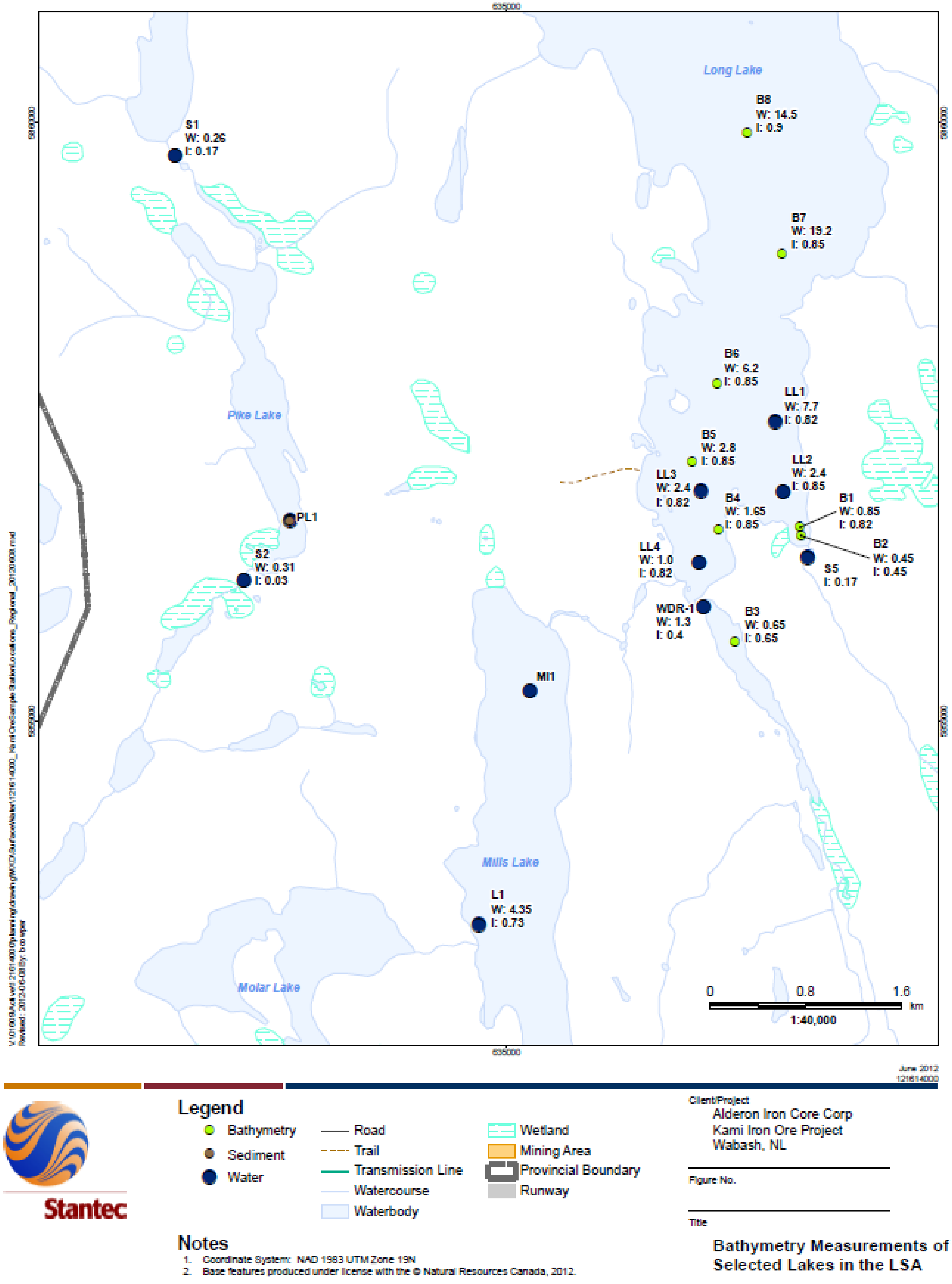


Figure 5.11 presents the bathymetric survey results for Long Lake as well as selected depth measurements for other local lakes in the LSA. Of note, the southern end of Long Lake is relatively shallow ranging in depth from <1 m to about 3.5 m. Long Lake does deepen toward the north.

Ice thickness was measured during the March and April 2012 field visits. Ice thickness is presented in Figure 5.11 and ranged from 0.45 to 0.85 m in local lakes

Figure 5.11 Bathymetry Measurements of Selected Lakes in the LSA.


635000
5860000
5855000
Long Lake
B8
W: 14.5
I: 0.9
S1
W: 0.26
I: 0.17
B7
W: 19.2
I: 0.85
B6
W: 6.2
I: 0.85
LL1
W: 7.7
I: 0.82
Pike Lake
B5
W: 2.8
I: 0.85
LL2
W: 2.4
I: 0.85
LL3
W: 2.4
I: 0.82
B4
W: 1.65
I: 0.85
B1
W: 0.85
I: 0.82
PL1
S2
W: 0.31
I: 0.03
LL4
W: 1.0
I: 0.82
B2
W: 0.45
I: 0.45
S5
I: 0.17
WDR-1
W: 1.3
I: 0.4
B3
W: 0.65
I: 0.65
MI1
Mills Lake
L1
W: 4.35
I: 0.73
Molar Lake
0
0.8
1.6
km
1:40,000
June 2012
121614000
Stantec
Legend
● Bathymetry
● Sediment
● Water
Road
Trail
Transmission Line
Watercourse
Waterbody
Wetland
Mining Area
Provincial Boundary
Runway
Notes
1. Coordinate System: NAD 1983 UTM Zone 19N
2. Base features produced under license with the © Natural Resources Canada, 2012.
Client/Project
Alderon Iron Core Corp
Kami Iron Ore Project
Wabash, NL
Figure No.
Title
Bathymetry Measurements of Selected Lakes in the LSA

5.2.4.4 Environmental Water Balance Assessment

The PDA/LSA environmental water balance was modeled on a monthly basis using the USGS Thornthwaite Monthly Water Balance Model, hereafter referred to as Thornthwaite Model (USGS, 2012). The Thornthwaite Model develops water balance estimates for a specified location among various components of the hydrologic system using a monthly accounting procedure based on the methodology originally presented by Thornthwaite (Thornthwaite, 1948; Mather, 1969, 1978, 1979; McCabe and Wolock, 1999). In the Thornthwaite Model, the change of state of water is a function of the amount of energy available. That, in turn, is governed by the latitude, length of day and season which combine to control the amount of energy received at the earth's surface. Infiltration and vegetation factors then control the fraction of excess water that infiltrates into the ground versus the fraction that runs off to nearby streams.

The Thornthwaite Model requires input of climate normal information, local land use, geographical and environmental characteristics to further identify site specific conditions. Using climate information, aerial photography, GIS applications and regional soil data, parameters best representing the landscape surrounding the LSA are presented in Table 5.8.

Table 5.8 Site Specific Water Balance Input Parameters

	Latitude	Longitude	Elevation (m.a.s.l.)
Climate Station #8504175 (Wabush)	52.93 N	66.87 W	551.1
Project Site	52.84 N	66.96 W	580 to 670
Parameter	**Value**		
Soil Storage (mm water / m soil)	125 to 142 for silty clay [a]		
Runoff Factor	50%		
Direct Runoff Factor	5%		
Maximum Melt Rate	50%		
Rain / Snow Temperature Threshold	0 degree Celsius		
Watershed Location	Headwater		

[a] Reference: (Ball, 2012)
m.a.s.l. stands for Meters Above Sea Level.

The water balance was first calculated using the Thornthwaite Model and calibrated with monitored streamflow data as well as streamflow data from the Environment Canada HYDAT database. Numerical results were then validated with previous studies (Hare, 1965; Findlay, 1969; Rollings, 1997; Stassinu Stantec, 2011*a*). Table 5.9 to 5.12 show the water balance results under the 30-year climate normal, wet year and dry year conditions. Previous studies of water balance estimates within the Labrador area (Hare, 1965; Findlay, 1969; Rollings, 1997) indicate that streamflow is highly variable across small and large watersheds, ranging streamflow coefficients from 55% to 85%. The scoping level hydrology assessment report by Stassinu Stantec (2011*a*) also estimated similarly higher total streamflow coefficients based on a review of flow gauging data from regional rivers. Since the Project site is situated within headwater areas of smaller watersheds, the streamflow estimations by the Thornthwaite Model with a total streamflow coefficient of 63% under 30-year climate normal conditions agreed with the findings in the previous studies and was chosen to estimate the mean annual total streamflow (surface runoff, interflow and groundwater discharge baseflow).

Table 5.9 Water Balance Results under the 30-year Climate Normal (Year 1982 to 2011) Conditions

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Precipitation (mm)	50.0	39.0	54.2	51.9	54.1	83.3	116.1	107.7	94.4	77.3	75.5	54.5	**858.1**
Evapotranspiration (mm)	2.3	3.2	3.7	8.5	20.0	74.7	89.7	67.5	35.1	8.0	3.1	2.8	**318.5**
Streamflow (mm)	7.5	3.7	1.9	1.0	81.3	95.3	87.8	78.3	77.9	61.1	29.2	14.6	**539.6**
Surface Runoff (mm)	6.7	3.4	1.7	0.9	73.1	85.7	79.0	70.4	70.1	54.9	26.3	13.1	**485.2**
Infiltration (mm)	41.0	32.5	48.8	42.5	-39.0	-77.1	-52.5	-30.2	-10.7	14.4	46.2	38.6	**54.4**
Recharge (mm)	20.5	16.3	24.4	21.2	-19.5	-38.6	-26.3	-15.1	-5.4	7.2	23.1	19.3	**27.2**
Baseflow (mm)	20.5	16.3	24.4	21.2	-19.5	-38.6	-26.3	-15.1	-5.4	7.2	23.1	19.3	**27.2**

Table 5.10 Water Balance Results under 1:100 Year Wet Year Conditions

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Precipitation (mm)	68.3	53.3	74.0	70.9	73.9	114	159	147	129	106	103	74.4	**1172**
Evapotranspiration (mm)	3.0	4.1	9.8	22.2	45.6	74.5	89.8	67.4	35.0	16.3	6.4	2.8	**376.9**
Streamflow (mm)	15.5	7.8	3.9	1.9	92.3	112	119	118	121	119	56.3	28.1	**794.8**
Surface Runoff mm)	12.7	6.4	3.2	1.6	75.8	91.8	98.1	96.9	99.1	97.7	46.2	23.1	**652.6**
Infiltration (mm)	52.6	42.8	61.0	47.1	-47.5	-52.6	-29.3	-17.2	-5.2	-8.5	50.5	48.5	**142.2**
Recharge (mm)	26.3	21.4	30.5	23.5	-23.8	-26.3	-14.7	-8.6	-2.6	-4.2	25.2	24.3	**71.1**
Baseflow (mm)	26.3	21.4	30.5	23.5	-23.8	-26.3	-14.7	-8.6	-2.6	-4.2	25.2	24.3	**71.1**

Table 5.11 Water Balance Results under 1:100 Year Dry Year Conditions

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Precipitation (mm)	36.3	28.3	39.3	37.7	39.3	60.4	84.3	78.2	68.5	56.1	54.8	39.5	**623**
Evapotranspiration (mm)	3.0	4.1	9.8	22.2	45.6	74.5	89.8	67.4	35.0	16.3	6.4	2.8	**376.9**
Streamflow (mm)	15.4	7.8	3.9	1.9	32.1	29.7	23.0	23.2	37.1	42.3	19.5	9.7	**245.7**
Surface Runoff (mm)	12.7	6.4	3.2	1.6	26.4	24.4	18.9	19.1	30.5	34.8	16.0	8.0	**202.0**
Infiltration (mm)	20.6	17.8	26.3	13.9	-32.7	-38.5	-24.4	-8.3	3.0	5.0	32.4	28.7	**43.7**
Recharge (mm)	10.3	8.9	13.2	6.9	-16.4	-19.2	-12.2	-4.2	1.5	2.5	16.2	14.4	**21.9**
Baseflow (mm)	10.3	8.9	13.2	6.9	-16.4	-19.2	-12.2	-4.2	1.5	2.5	16.2	14.4	**21.9**

The annual evapotranspiration (ET) under the 30-year climate normal conditions was 318.5 mm. This value was also calculated using the Thornthwaite Model which was based on average monthly temperatures, precipitation, soil storage and vegetation cover type. The monthly mean ET peaks between June to August. The trend is in agreement with the peak in temperature according to the climatic data in Table 5.2.

The infiltration factor for the Kami Property was calculated to be 0.5. This value represents a topographical factor of 0.1 for an average slope of 0.0987 m/m, a soil factor of 0.2 for silty clay and a vegetation factor of 0.2 representing open pasture grassland and woodland cover types. This implies that 50% of net infiltrated precipitation will be discharged to surface water via baseflow. Furthermore, the total infiltration and storage calculated in Project site was 54 mm/yr or approximately 6.3% of incident precipitation under the 30-year climate normal condition.

It is important to note that that all water recharging aquifers eventually cycles back to the surface as groundwater discharge providing baseflow to local streams and lakes. Therefore all water that infiltrates and does not get routed back to the surface as ET supports surface water baseflow and thereby total streamflow. As a result, the water balance can be further simplified into precipitation inputs and ET and total streamflow outputs.

Hydrologic Normals and Variability

As per NL hydrological guidance, regional extrapolation was used to prorate flows from large river gauging stations to local watersheds in the LSA. The estimation of flow rates within the Project LSA was conducted using a flow proration method based on drainage area. The latest available daily flow data from five nearby Environment Canada river gauging HYDAT stations (Table 5.12) were used to derive mean monthly maximum, minimum and average daily flow rate relationships with respect to drainage areas (Figure 5.12 to 5.14). Flow hydrographs of all watersheds and subwatersheds (Table 5.7) within the Project LSA were determined from these thirty-six (36) relationships and are presented in AppendixH. Using years when all stations were in operation enabled the development of calibrated regional extrapolation relationships. This approach accounted for the fact that larger watersheds are more hydraulically efficient and have higher total streamflow coefficients than smaller watersheds. As such, the relationships enable the accurate prorating or regional extrapolation of flow gauging records from larger watershed HYDAT stations with long record to the smaller watersheds characteristic of most of the LSA.

Table 5.12 Details of Environment Canada HYDAT Stations Near the Project LSA

Station ID	Name	Available Years of Data	Distance from Project	Watershed Area (km^2)*
03OA010	Flora Creek Below Flora Lake	2002, 2003, 2007, 2008	18 km – NE	316.4
03OA012	Luce Brook Below Tinto Pond	2002, 2003, 2007, 2008	18 km – N	43.4 *
03OA001	Ashuanipi River at Menihek Rapids	1955 to 2009	178 km - N	19000 *
03OC006	Atikonak River at Gabbro Lake	1975 to 2009	143 km - NE	21400 *
03OA005	Wabush Lake at Lake Outlet	2007, 2008	35 km - S	1613

* From Environment Canada’s HYDAT database. Other watershed areas were determined using GIS tools.

Figure 5.12 Mean Monthly Maximum Daily Flows versus Drainage Areas Relationships

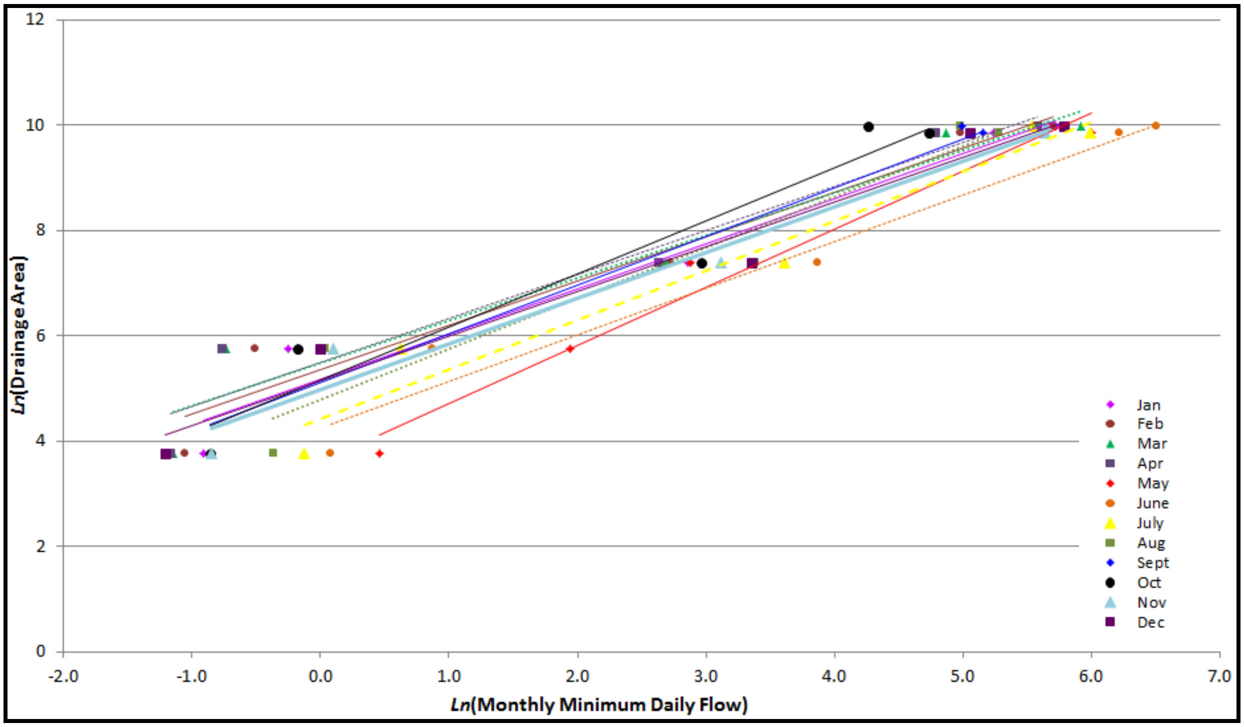


Figure 5.13 Mean Monthly Minimum Daily Flows versus Drainage Areas Relationships

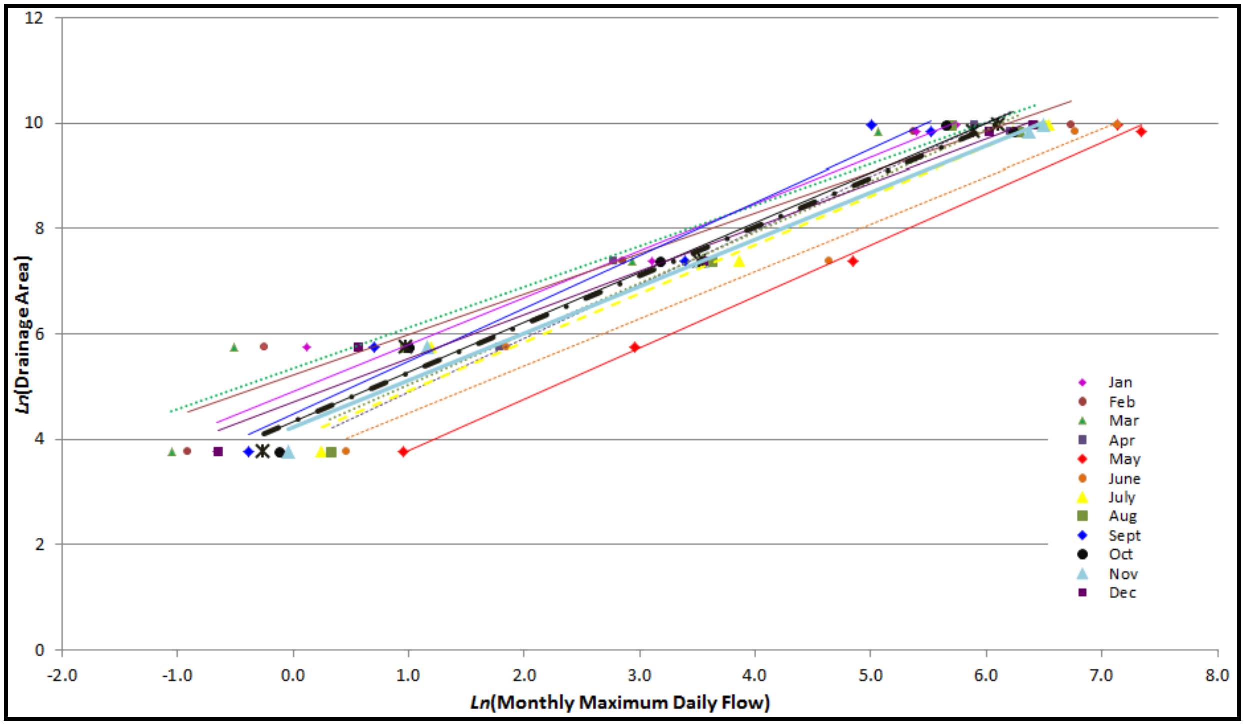
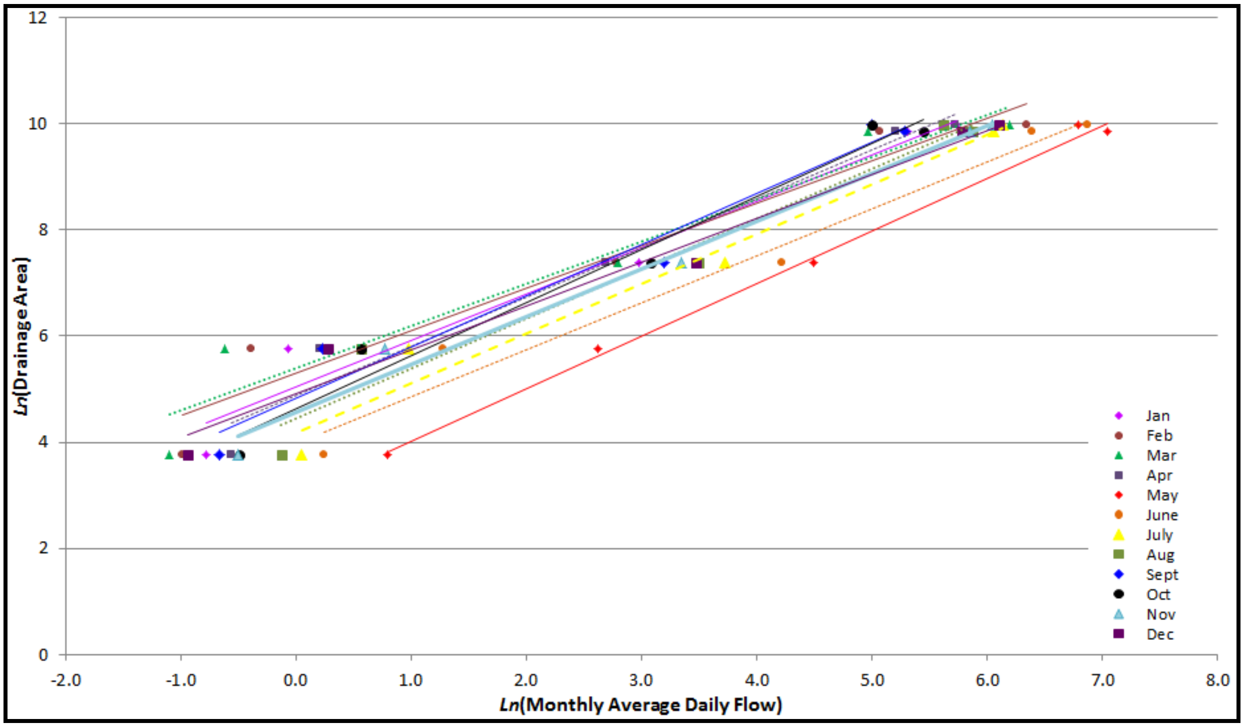


Figure 5.14 Mean Monthly Average Daily Flows versus Drainage Areas Relationships



Using watershed #20, the outlet of Long Lake, with a cumulative drainage area of 914 km^2 as an example, Table 5.13 and Figure 5.15 present the calculated monthly maximum, minimum, and mean daily flows which were determined from the relationships in Figure 5.12 to 5.14. By comparing the monthly runoff distribution between the prorated flows (Table 5.13) and water balance results (Table 5.9 to 5.12), both annual hydrograph estimates show a general agreement between the prorated flows and the estimated runoff from the water balance estimations. Moreover, the flow hydrographs from the outlet of Long Lake illustrate seasonal trends during a typical year with the spring freshet normally occurring between May and June and higher flow rates during the summer months when compared to the winter months. The flow hydrographs also show the attenuating influence of the lakes that are capable of storing water during late spring and releasing it gradually during the warmer months.

Table 5.13 Monthly Maximum, Minimum, and Mean Daily Flows at the Outlet of Long Lake Using the Area-Calibrated Flow Proration Method

Flow Characteristics	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Monthly Maximum Daily Flow, in m^3/sec	12.5	12.3	10.2	25.1	85.5	51.9	30.2	24.0	14.1	19.8	26.9	19.0
Monthly Minimum Daily Flow, in m^3/sec	10.1	8.5	8.0	7.2	35.3	26.8	18.5	11.7	9.1	7.3	12.3	10.7
Monthly Mean Daily Flow, in m^3/sec	11.1	10.2	9.0	11.5	63.8	35.8	24.1	17.7	11.0	12.5	17.9	14.9

Figure 5.15 Hydrograph Presentation of Monthly Maximum, Minimum, and Mean Flows at the Outlet of Long Lake Using the Area-Calibrated Flow Proration Method

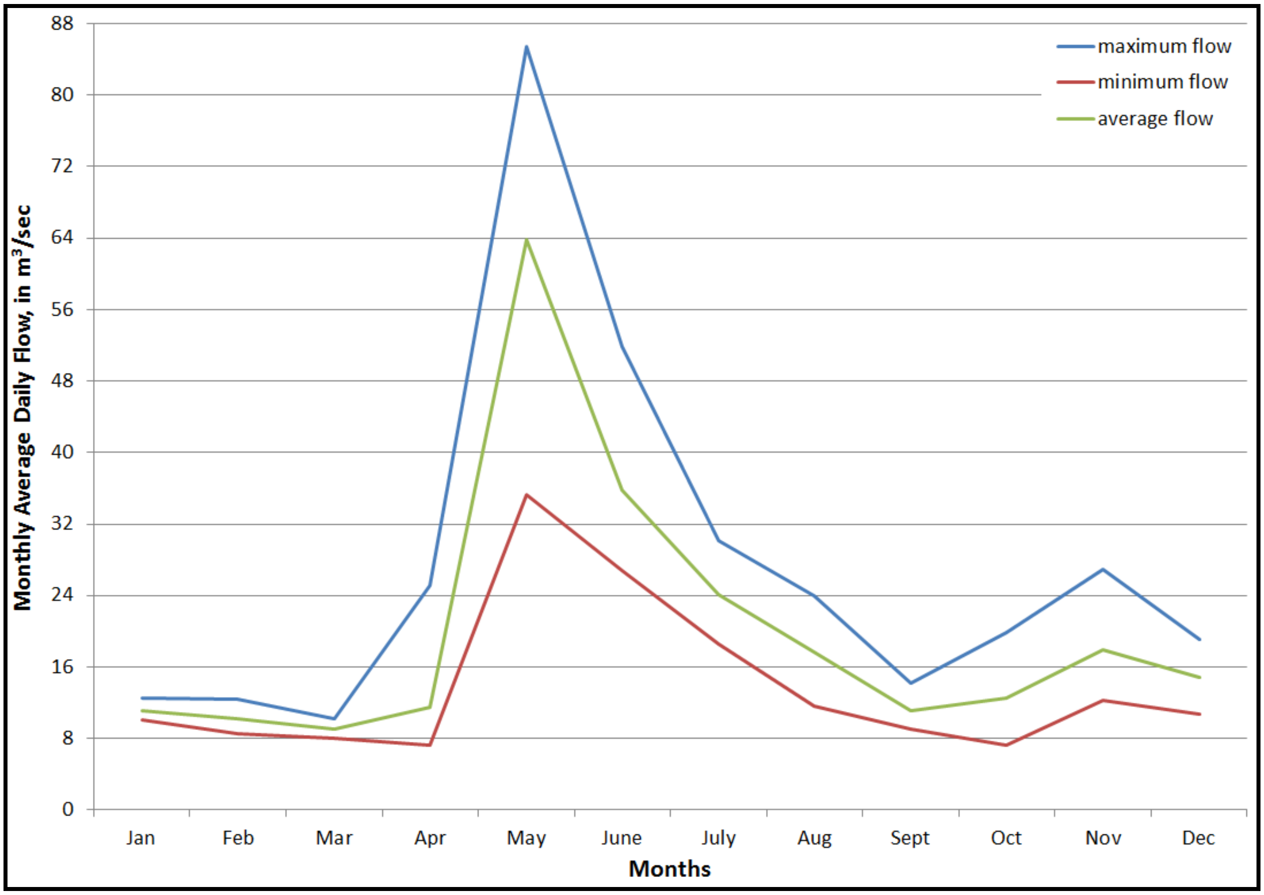
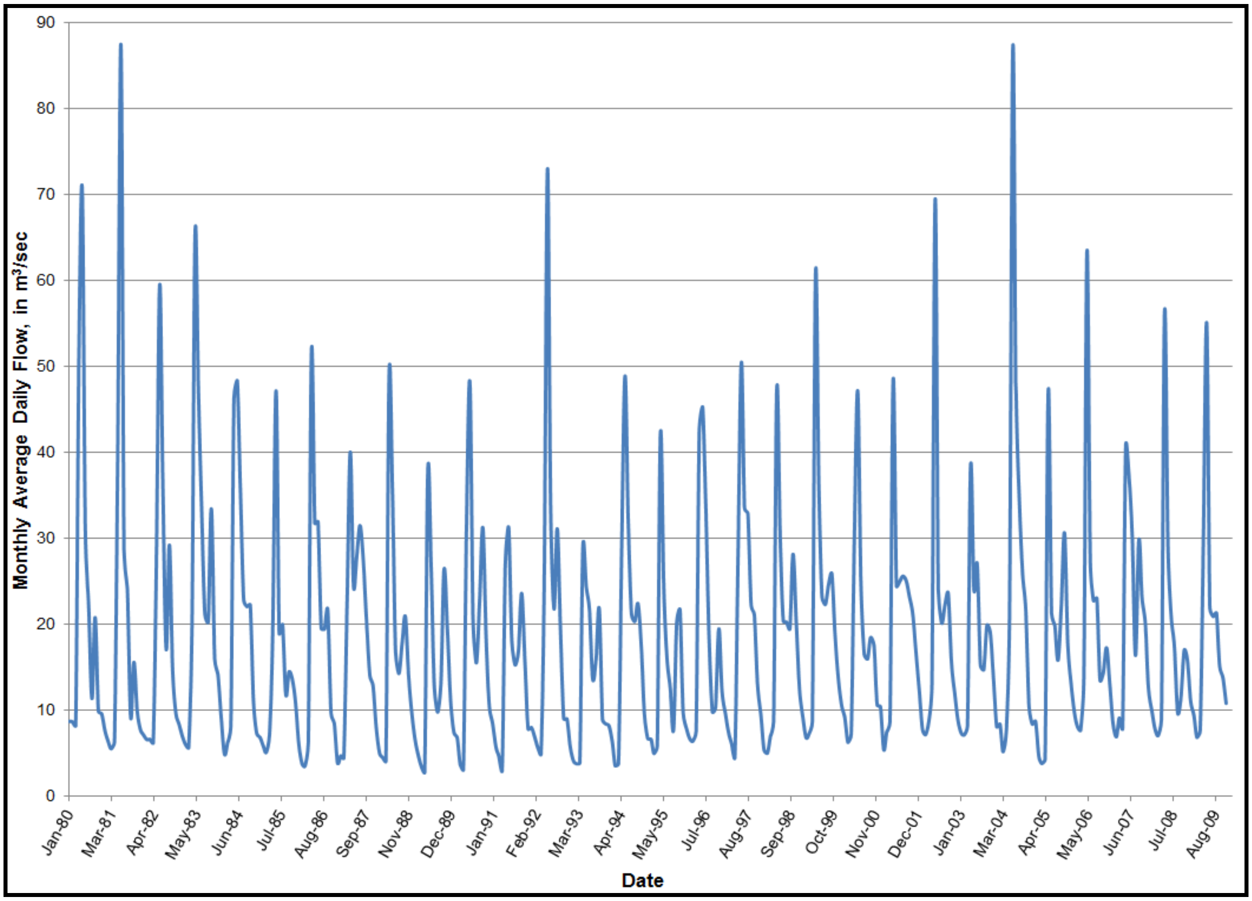


Figure 5.16 presents the area-calibrated prorated flows from the outlet of Long Lake from 1980 to 2009 flow normal periods. This figure illustrates the dominance of seasonal round of high spring freshet and summer flows followed by later fall to winter low flow periods. The figure also depicts the year–to–year variability of flows which are driven primarily by annual precipitation variability.

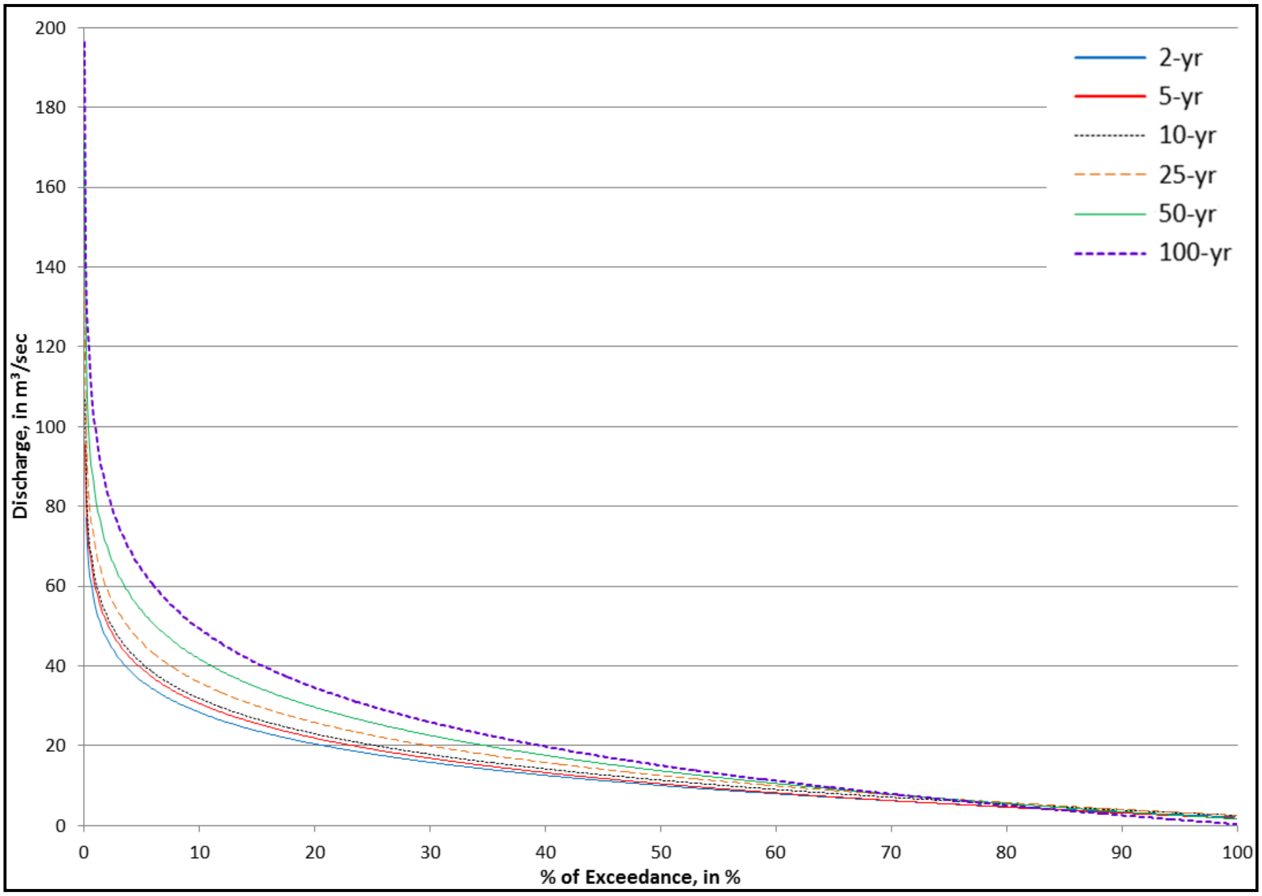
Figure 5.16 Hydrograph of 1980 – 2009 Area-calibrated Prorated Flows at the Outlet from Long Lake



Flow Duration Analysis

Flow duration curves (FDCs) indicate which percentage of time during the entire record a flow was equaled or exceeded. These curves are often used to aid in the determination of water allocations and to provide a measure of the magnitude of larger return period flows at specific flow nodes. The area-calibrated flow proration method was also applied to generate the FDCs of all the watersheds and subwatersheds (Table 5.7) within the Project PDA and LSA. Station 03OA001 (Ashuanipi River at Menihek Rapids) was selected as the basis of FDC development since it has the longest flow monitoring records (Table 5.12). The available mean daily flow data in station 03OA001 was used to prepare FDCs up to 50-year return period, whereas the 100-year FDC was predicted from the previous FDCs. Previous analyses indicated that there is a statistically significant relationship between the natural logarithm of mean annual daily flows and the natural logarithm of drainage areas. Thus, proration factors were determined using cumulated drainage areas between station 03OA001 and subwatersheds. The FDCs of station 03OA001 were then prorated down to subwatersheds level using the proration factors. Figure 5.17 illustrates the FDCs for the outlet from Long Lake. Appendix I presents the FDCs of all watersheds and subwatersheds delineated within the Project PDA and LSA.

Figure 5.17 Flow Duration Curves for Varying Return Periods at the Outlet from Long Lake



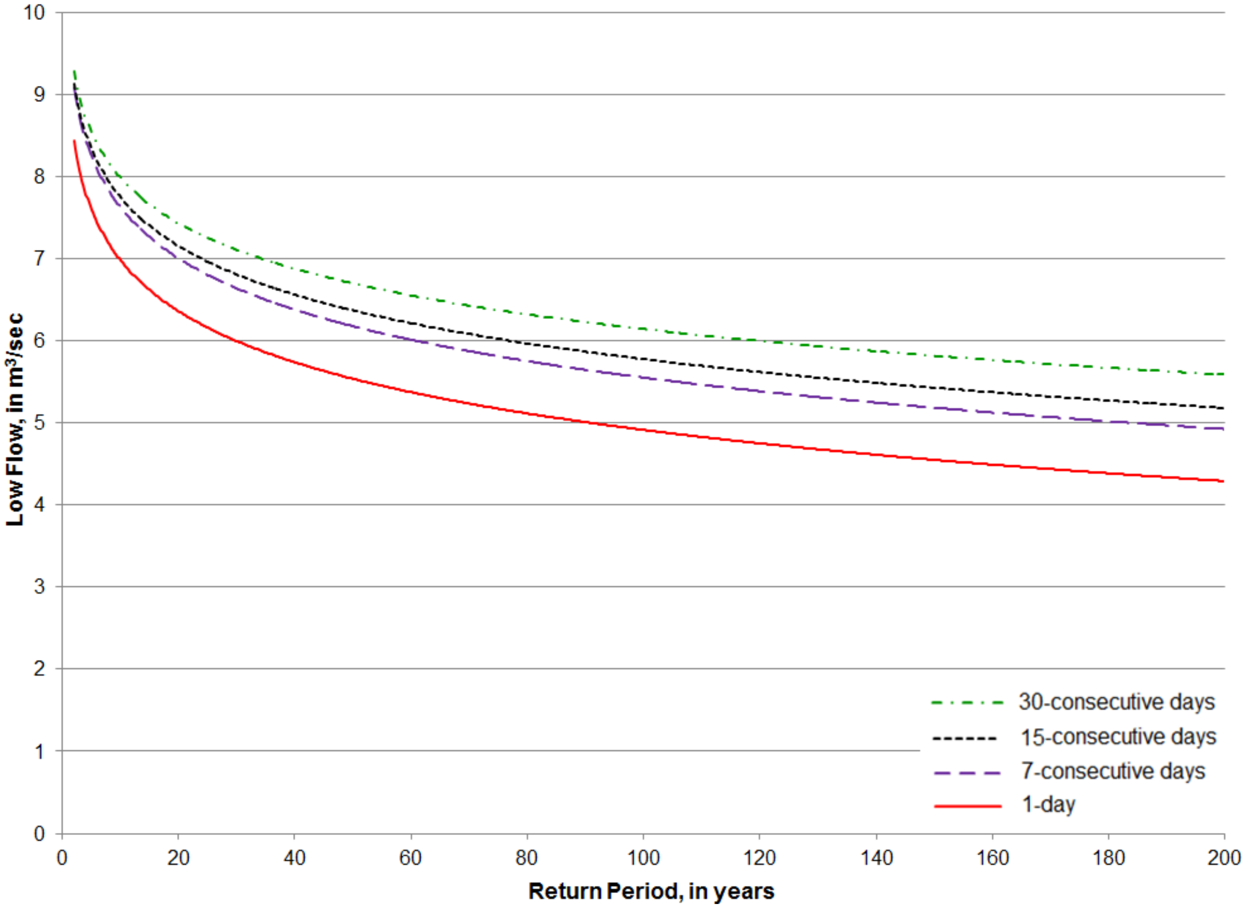
Low and Environmental Flows

A low flow analysis was conducted to provide a preliminary idea of the water withdrawal capacity and instream flow needs or environmental (maintenance) flow requirements for watercourses throughout the Project PDA and LSA. For this study, low flows of four durations (1-day, 7-day, 15-day, and 30-day) with return periods 2-year, 5-year, 10-year, 20-year, and 50-year suggested by the Government of Newfoundland and Labrador (1991) was used for the analysis.

Station 03OA001 on the Ashuanipi River at Menihek Rapids was again used as the basis of low flow analysis due to its longest flow monitoring records (Table 5.12). The data from station 03OA001 was applied using flow analysis software DFLOW version 3.1. DFLOW uses Log-Pearson Type III frequency distribution to adjust the entire record and calculate low flows with a given recurrence interval. Figure 5.18 illustrates the low flow curves at subwatershed #20, the outlet from Long Lake, Using the 7-consecutive days curve as an example, the 7Q2 flow (the annual minimum average daily flow that is sustained during 7 consecutive day with a recurrence interval of every 2 years at the outlet from Long Lake is 8.78 m^3/sec and the

7Q10 flow is 7.74 m^3/sec. Appendix L presents the low flow analysis of all delineated watersheds and subwatersheds within the Project PDA and LSA.

Figure 5.18 Low Flow Results for the Outlet from Long Lake



Environmental flows, also referred to as maintenance flows or instream flow needs, describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems. Through implementation of environmental flows, a flow regime or pattern that provides for human uses and maintains the essential processes required to support healthy river ecosystems shall be achieved (eFlowNet, 2007). For this study, Tennant's method suggested by Fisheries and Oceans Canada (DFO) was used to estimate the environmental flows of all subwatersheds throughout the Project PDA and LSA (Stoneman, 2005; Maunder and Hindley, 2005). Based on the climatic characteristics of the LSA (Table 5.2), the winter period is defined as between November 1st to April 30th and the summer period is between May 1st to Oct 31st. The flow requirement for the summer period is 40% of the mean annual flow (MAF) and for the winter period is 20% of the MAF.

The latest 30-year flow data from HYDAT station 03OA001 was first used to determine the mean monthly flow (MMF) and MAF. The area-calibrated relationships between HYDAT station 03OA001 and the subwatersheds delineated for Project PDA and LSA were then used in developing the environmental flows as shown in Table 5.14. Environmental flows at the outlet to Long Lake are estimated at 3.74 m^3/sec for the winter period and 7.47 m^3/sec for the summer period, and at Station *S2* are 0.0225 m^3/sec for the winter period and 0.0450 m^3/sec for the summer period.

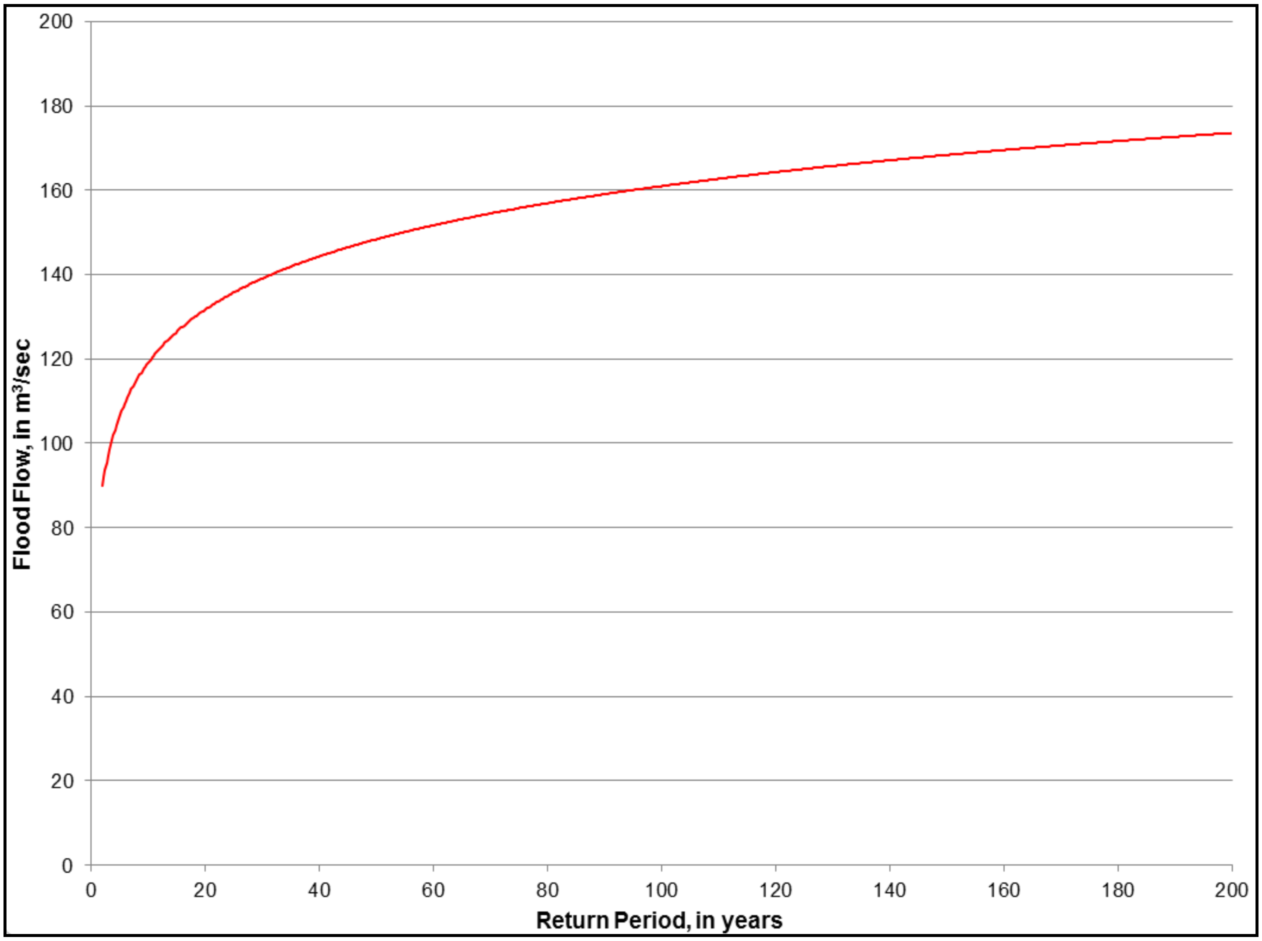
Table 5.14 Environmental Flows for Subwatersheds within Project PDA and LSA

Subwatershed ID	Environmental Flow, in m^3/sec	
	Nov to Apr	May to Oct
1	0.00375	0.00749
2	0.617	1.23
3	0.00302	0.00604
3A	0.00291	0.00581
4	0.00701	0.0140
5	0.0407	0.0815
6	0.0388	0.0775
7	0.0396	0.0791
8	0.0220	0.0439
9	0.00192	0.00383
10	0.0195	0.0391
11	0.00910	0.0182
12	0.0135	0.0270
13	0.279	0.559
14	0.198	0.395
15	0.0225	0.0450
16	0.00941	0.0188
17	0.00701	0.0140
18	0.0649	0.130
19	2.78	5.56
19A	0.116	0.232
20	3.74	7.47
21	0.00593	0.0119
22	2.97	5.93
23	0.00563	0.0113

Flood Flows

A flood is defined as the highest instantaneous river discharge in a year. In Newfoundland and Labrador, floods are caused by rainfall, snowmelt, or a combination of rainfall and snowmelt. The single station frequency analysis method with Log-Pearson Type III distribution between 2-year and 200-year return periods suggested by Newfoundland and Labrador Department of Environment and Conservation (Rollings, 1999) was used for the flood flow assessment. Flood data in station 03OA001 was selected as the basis of the flood flow assessment due to its long monitoring records (Table 5.12). Figure 5.19 illustrates the flood flow assessment for the outlet from Long Lake over a range of return periods return periods. Similar flood flow curves for the watersheds and subwatersheds delineated for the Project PDA and LSA are presented in Appendix K.

Figure 5.19 Flood Flow Assessment in for the Outlet from Long Lake



Design Peak Flows for Project Component Areas

Newfoundland and Labrador uses a “two zone” approach to flood design (NL DEL, 1992). The “designated floodway” is defined as the 1:20 year flood zone and the area subject to the most frequent flooding. The “designated floodway fringe” is defined as the 1:100 year flood zone and constitutes the remainder of the flood risk area. While no building or structure should be erected in the “designated floodway”, it may be acceptable to use land in the designated floodway for agricultural or recreational purposes. Development within the floodway fringe may be acceptable provided that the structure is floodproofed.

Stormwater control and sedimentation facilities associated with the Project will use the 1:100 year flood as the primary quantity control design criteria. However, this criterion may be augmented by water quality control criteria to ensure that mine contact-water will be in compliance with MMER effluent limits. These criteria will be further defined and applied in the effects assessment portions of the EIS Water Resources VEC chapter.

Outlet structures and discharge channels associated with stormwater control and sedimentation facilities would ensure post- to pre-peak flow attenuation to avoid erosion, scour and flooding in receiving watercourses and waterbodies. Therefore, the flooding criterion for stormwater control and sedimentation features discharge channels is expected to be bankfull containment of the attenuated 1:100 year discharge peak from the respective facility. This criterion will avoid potential flooding of downstream mine infrastructure.

Water Crossing Hydrological Design Flows

The rail infrastructure is being designed in accordance with the American Railway Engineering and Maintenance of Way Association (AREMA) guidelines for flood control at rail line water crossings. Project culvert and bridge crossings will be designed according to AREMA (2009) requirements that state that culverts should have hydraulic capacity to pass the 25-year flood without static head at the entrance. In addition AREMA (2009) specifies headwater depth ratio and freeboard criteria for the 100-year flood to avoid excessive culvert submergence and flooding of the rail bed.

As the access road and rail infrastructure share a corresponding linear alignment for considerable portions of their length, the water crossing design for the access road should be compatible with the AREMA criteria. The AREMA water crossing hydraulic design criteria generally exceed provincial road standards for water crossings, therefore the AREMA water crossing hydraulic design criteria are assumed to be the design criteria for all Project water crossings.

5.2.5 Surface Water – Groundwater Interactions

Groundwater is an integral component of the hydrologic cycle that can interact with and indirectly affect fresh water resources and fresh water ecosystems at points of discharge. There is a dynamic interaction between groundwater resources and surface water resources. Groundwater generally sustains the baseflow of springs, streams and wetlands during dry periods of the year. More rarely, surface water bodies and perched wetlands can seasonally contribute to groundwater storage under specific hydrogeological conditions.

Surface water includes all water running or in storage above the ground surface. Surface water originates as precipitation and can be delivered to the earth’s surface as direct rain or snowfall. During warmer months precipitation in the form or rainfall will deposit directly to exposed ground and water surfaces and be intercepted by secondary surfaces such as trees and other forms of vegetation. In colder months, most precipitation falls as snow and remains in storage in the snowpack until it is ablated during the spring freshet or mid-winter melt periods. The ground surface will either store water in depression storage, evaporate or infiltrate water until the precipitation intensity overcomes the depression storage capacity and rates of evaporation and infiltration, yielding excess runoff or overland flow. Evaporation cycles water back to the atmosphere. Infiltration includes vectors such as vegetation transpiration where plants uptake water at the root and use it to thermally-regulate or transpire and metabolize, interflow and recharge. Interflow is that portion of infiltrated water that flows through the upper unsaturated zone to nearby surface water bodies such as wetlands, lakes and streams. Recharge is the infiltrated water that reaches the saturated zone and becomes groundwater and charges the surficial (water table) and other aquifers. Recharge will change the storage in aquifers. Both interflow and groundwater discharge contribute baseflow to surface water bodies. Although recharge cycles through the sub-surface much slower than surface water and will change aquifer levels on a seasonal and year-to-year basis, in the long-term all water entering the groundwater system will exit either as groundwater discharge or transpiration via plant root water uptake. As such surface water and groundwater are highly interconnected and interdependent systems.

Surface water – groundwater interactions are evident in the hydrological flow assessment in the form of baseflow contribution to streamflow. In order to appreciate the magnitude of baseflow contributions to streamflow in local streams, the minimum monthly flow presented in Figure 5.15 and Appendix H for all other LSA watershed flow nodes can be viewed as primarily derived from baseflow. With this in mind, the contribution of baseflow and by extension the interaction of surface water and groundwater is a major feature of LSA hydrology.

5.2.6 Surface Water Supply

5.2.6.1 Surface Water Supply Capacity Assessment

Surface water takings in NL are assessed based on the sustainability of yield, impacts to downstream users, ecological effects and the hierarchy of water taking use prescribed in legislation. The sustainable yield of surface water sources is determined through estimation of several low flow statistics including the 30Q50 (NL DEL, 1992; NL DEC, 2005). NL DEC (2005) indicates that a surface water quantity assessment should include a review of the available yield of the water supply and should demonstrate that:

1. Where possible, a minimum drought return period of one in fifty years has been used for calculating the safe yield (Q50);
2. A minimum drought duration of 30 days has been used (30Q50);
3. The yield is adequate to provide ample water for other legal users of the source including any required fish flows;
4. The yield is adequate to meet the maximum current and future water demand including any required fish flows without significantly affecting the watercourse habitat downstream of the intake; and
5. Only live storage has been used in the yield calculations.

Where site-specific stream flow data is available, yield can be estimated by generated mass flow curves. The stream flow data should also be used to estimate the minimum perennial yield on record and to estimate a drought return period for that year.

Fish flows, also referred to as maintenance flow, environmental flows and instream flow needs are determined as per the method described in Section 5.2.4.4.

The greater of these flows are considered the minimum environmental flow threshold, beyond which water extractions cannot impinge. Section 5.2.4.4 provided estimates of low and environmental (maintenance flows). For instance, at the outlet from Long Lake the 30Q50 low flows were estimated at 6.70 m^3/s. Maintenance flows at the outlet from Long Lake were estimated at 3.74 m^3/s during the winter period and 7.47 m^3/s during the summer period. Maintenance flows are assumed to set the lower water taking limit during summer and 30Q50 during winter. Summer and winter period takings could not result in flow impingement on respective maintenance/30Q50 flow thresholds at the outlet of Long Lake meaning that when lake outflow decreases below these thresholds, water extractions should cease. For illustration purposes Figure 5.20 indicates the total portion of the Long Lake outlet annual hydrograph above the 30Q50 and maintenance flow threshold potentially available for water extraction purposes. The exact water extraction rates, duration and frequency will be subject to climate conditions and further discussions with NL DEC and DFO. However, this level of water supply potential assessment indicates that significant available surface water sustainable yield is available from Long Lake.

Project water demands are expected to include:

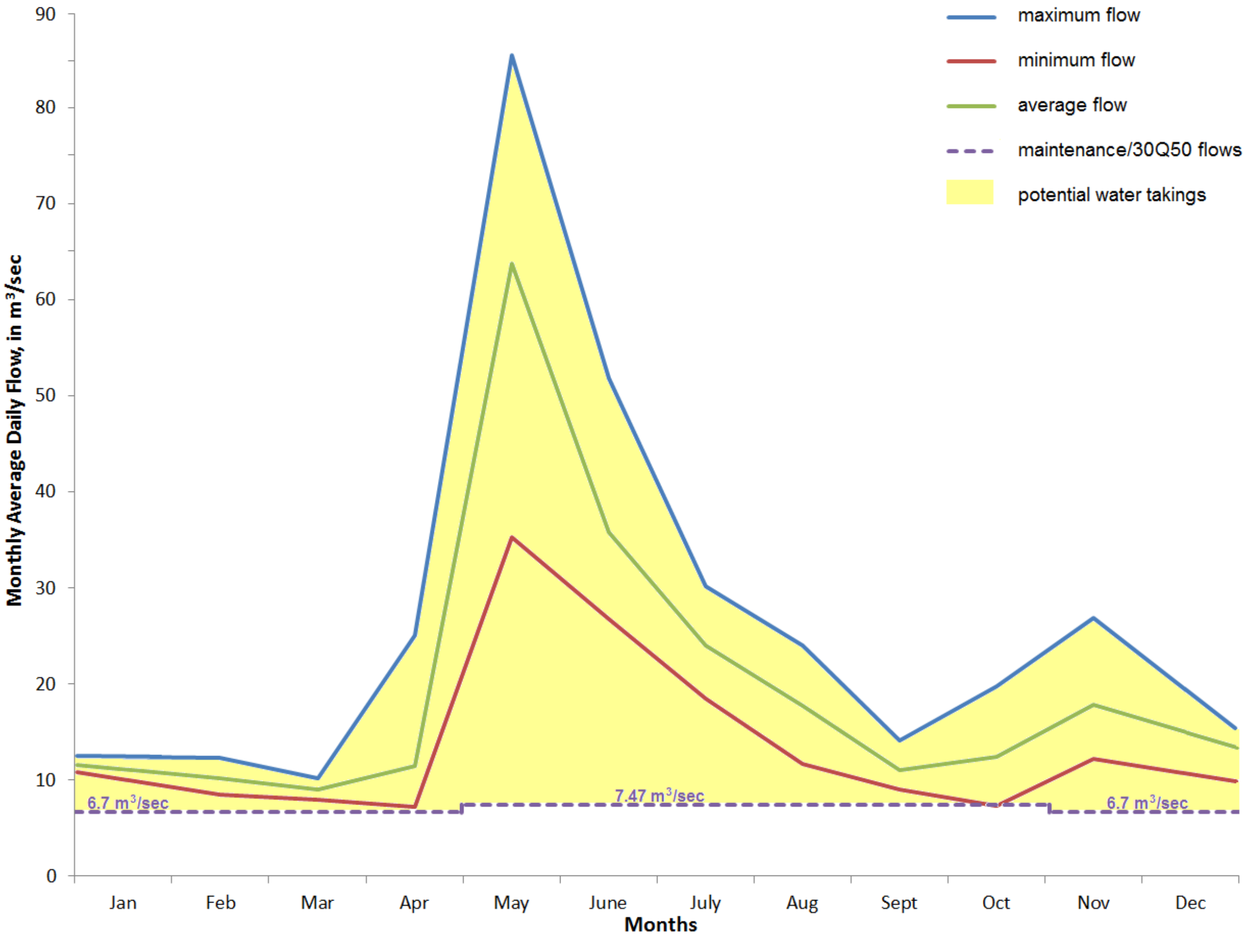
- Process water uses;
- Sanitary water uses; and
- Dust suppression water uses.

Sanitary water uses are non-consumptive meaning that all the water taken for sanitary uses is cycled back to the environment after treatment. Sanitary water uses are generally continuous throughout the year. Most water used for dust suppression is non-consumptive, with the consumptive portion being lost to evaporation. Dust suppression water use peaks during the warmer snow-free season with little need for dust suppression during the snow-cover season. Process water demand is the largest water demand of the Project and is proportionally related to annual ore production. Most water used in the process is mixed with tailings to produce a pumpable slurry freely drains from the TMF back to the Tailings Pond and Polishing Pond. However, a portion of the tailings slurry water is expected to be retained in the pore space of the tailings matrix and for the purposes of the project water balance is considered to be a consumptive water loss. Additional process water losses include concentrate moisture.

As long as non-consumptive losses do not undergo a significant time lag between the surface water taking and the return to the surface water environment, they can be viewed as not impinging on sustainable yield thresholds. However, consumptive losses as those portions of water takings not expected to be cycled back to the local surface water environment. These consumptive losses therefore are the focus of the surface water supply assessment.

Based on use of the sustainable yield criteria, potential water takings from Long Lake are depicted in Figure 5.20. Raw water takings from local waterbodies such as Long Lake can be offset and minimized through the construction and operational of reservoirs which collect and store mine contact waters.

Figure 5.20 Long Lake Surface Water Supply Capacity



5.2.6.2 Local Surface Water Supplies

Surface water is used locally as the public water supply such as for the Towns of Labrador City, Wabush and Fermont as well as local cottagers. The sustainability of water supply and preservation of water quality are critical to maintain and are protected in NL and QC public water supply regulation. In NL the authority to designate protected water supply areas is enshrined in Section 39 of the *Water Resources Act*. Subsection 30 (4) describes activities prohibited in a protected water supply area, as follows:

(a) place, deposit, discharge or allow to remain in that area material of a kind that might impair the quality of the water;

(b) fish, bathe, boat, swim or wash in, or otherwise impair the quality of the water; or

(c) use or divert water that may unduly diminish the amount of water available in that area as a public water supply.

Any commission of the above prohibited activities constitutes a violation under Section 90 of the *Water Resources Act*. Subsection 39 (6) provides further direction regarding resource development activities in protected water supply areas as follows:

The minister shall regulate resource development and other activities to be undertaken in an area established under subsection (1) that, in the minister's opinion, may impair the quality of water, and those activities shall not be undertaken without first obtaining authorization from the minister.

The required management of protected water supply areas is mandated in NL DEC (2004) which describes that any development within 15 m of a water body within a protected water supply area may be subject to additional approvals such as water crossings and watercourse alterations. Provisions must address measures to control erosion and prevent sedimentation, minimize the risk of accidental spill and leaks as well as contingency plans oil spills or leaks. Bulk fuel storage is not permitted in protected water supply areas. In addition, development plans must provide information on how Project derived waste material will be handled and disposed of, the environmental protection measures proposed to minimize adverse impacts on water quality and proposed measures for site closure, restoration and rehabilitation.

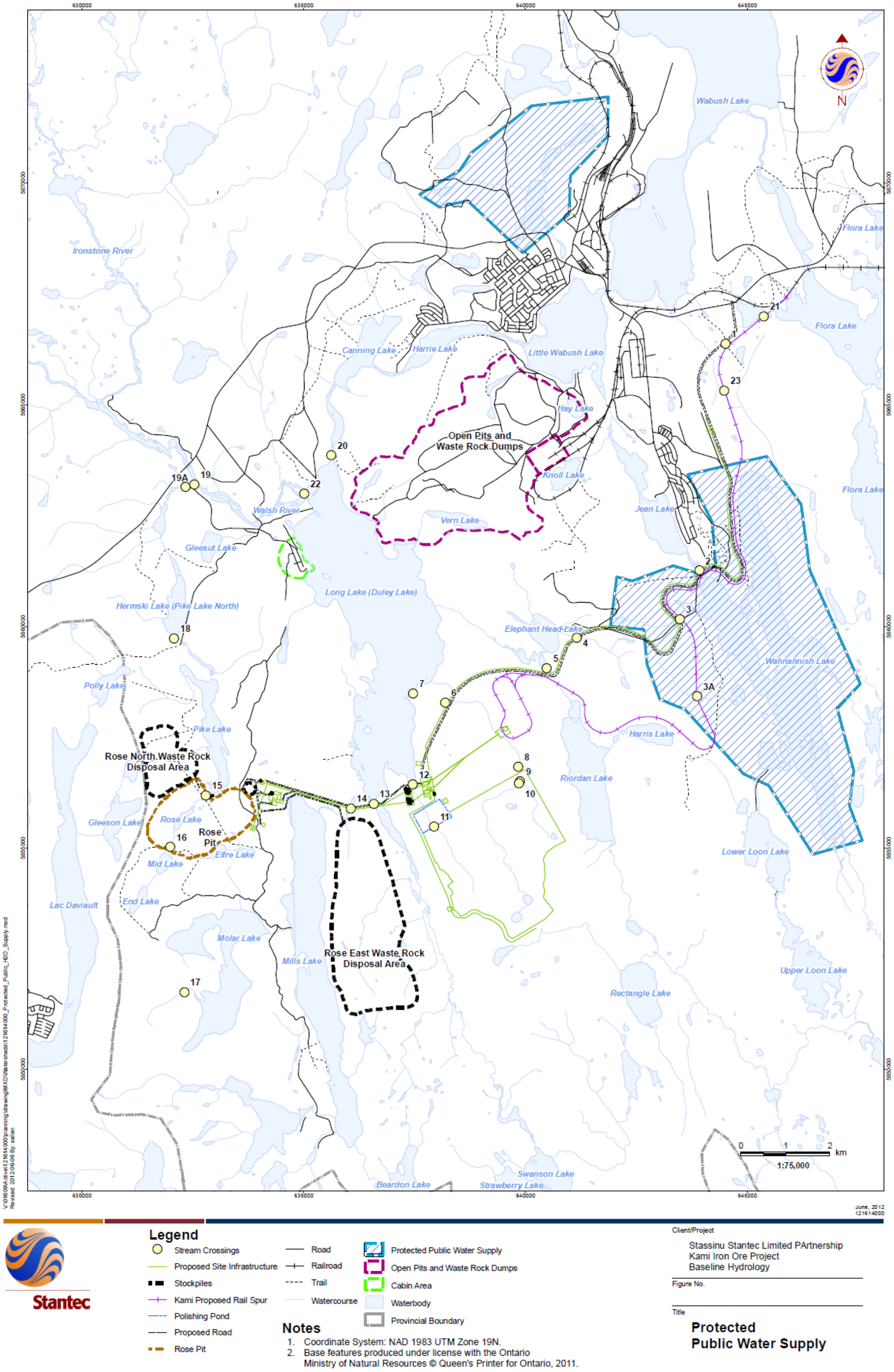
The Town of Labrador City manages a total area of 446 km^2, and has a surface water municipal water supply source from Beverly Lake located northeast of the Town, with a 500,000 igal reservoir, treatment plant and a grid distribution network servicing approximately 3,200 homes and businesses. Beverly Lake drains into Little Wabush Lake, via a tributary to the Lake. Beverly Lake is offline from the Long Lake to Wabush Lake flow system. The Town of Labrador City protected water supply area is depicted in Figure 5.21.

The Town of Wabush manages a total area of 428 km^2, and also is served by a municipal distribution system sourced from Wahnahnish Lake. The Project interacts with the Wabush protected water supply area via the proposed location of portions of the access road and rail link within the protected water supply drainage area, including the Jean River crossing at the outlet from Wahnahnish Lake and several crossings of small tributaries to the Lake. However, the Wabush protected water supply is offline from the Long Lake – Wabush Lake flow system. The Town of Wabush protected water supply area is depicted in Figure 5.21. The Wabush drinking water intake is located in Wahnahnish Lake approximately 175 m upstream of the Lake outlet. Intake water is chlorinated at a pump house and then pumped into a 475,000 igal reservoir which supplies the entire Town of Wabush's water distribution network. A multi-barrier approach starting with water supply watershed protection, uninterrupted chlorination, annual water tower cleaning and a series of quality checks including chlorine residual monitoring, monthly bacteriological analysis and quarterly physical and chemical analysis are taken to ensure the delivery of clean, safe drinking water. The Town of Wabush follows the Standards for Bacteriological Quality of Drinking Water as provided by the Provincial Department of Environment and the Guidelines for Canadian Drinking Water Quality prepared by Health Canada.

The Town of Fermont, Quebec is located west of Lac Daviault and has a municipal water distribution system that is fluoridated; the source lake is Lac Perchard north of the Town's urban area. Lac Perchard and Lac Daviault drain south toward the Gulf of St. Lawrence, whereas surface water in the PDA/LSA drains east to the Labrador Sea.

In addition to local water extractions associated with public water supplies, Cliff Natural Resources Wabush Mines and cottagers extract surface water from the LSA/PDA for industrial and domestic purposes. The public water supplies draw water from sources offline from the Long Lake – Wabush Lake flow system and therefore are not expected be adversely affected by water withdrawals from Long Lake or other waterbodies near the PDA. Wabush Mines derives it water source from Flora Lake, which has its own large, offline upstream watershed catchment area and would not be adversely affected by Project water extractions. The IOC-Rio Tinto Carol Mine derives its water supply from Wabush Lake which is beyond the PDA/LSA scope of direct water resources effects. However, the potential residual effects of net water takings from the Project on the water supply potential of Wabush Lake will be assessed in the Water Resources VEC chapter of the EIS under the cumulative effects assessment. Domestic surface water takings by PDA/LSA cottagers is expected to be very minimal in relation to sustainable yield and Project water demands and extraction points located in the near-shore zone of Long and Mills Lakes.

Figure 5.21 Kami Study Area Surface Water Supply Areas


630000
635000
640000
645000
5870000
5865000
5860000
5855000
5850000
N
Wabush Lake
Flora Lake
Ironstone River
Flora Lake
21
Canning Lake
Harrie Lake
Little Wabush Lake
23
Hay Lake
Open Pits and
Waste Rock Dumps
20
Knoll Lake
19A
19
22
Flora Lake
Walsh River
Vern Lake
Jean Lake
Gleesut Lake
2
Long Lake (Duley Lake)
Hermski Lake (Pike Lake North)
3
18
Elephant Head Lake
4
5
Wahnahnish Lake
Polly Lake
7
6
3A
Pike Lake
Harris Lake
Rose North Waste Rock
Disposal Area
8
9
12
Riordan Lake
15
13
10
14
Gleeson Lake
Rose Lake
11
16
Rose
Pit
Elfre Lake
Mid Lake
Lower Loon Lake
Lac Daviault
End Lake
Molar Lake
Rose East Waste Rock
Disposal Area
Mills Lake
Upper Loon Lake
17
Rectangle Lake
0
1
2
km
1:75,000
Swanson Lake
Beardon Lake
Strawberry Lake
V:\01609\Active\121614000\planning\drawing\MXD\Watersheds\121614000_Protected_Public_H2O_Supply.mxd
Revised: 2012-06-06 By: sallen
June, 2012
121614000
Stantec
Legend
Stream Crossings
Proposed Site Infrastructure
Stockpiles
Kami Proposed Rail Spur
Polishing Pond
Proposed Road
Rose Pit
Road
Railroad
Trail
Watercourse
Protected Public Water Supply
Open Pits and Waste Rock Dumps
Cabin Area
Waterbody
Provincial Boundary
Client/Project
Stassinu Stantec Limited PArtnership
Kami Iron Ore Project
Baseline Hydrology
Figure No.
Title
Protected
Public Water Supply

Notes
1. Coordinate System: NAD 1983 UTM Zone 19N.
2. Base features produced under license with the Ontario
Ministry of Natural Resources © Queen's Printer for Ontario, 2011.

5.2.7 Water Quality

5.2.7.1 Regulatory Criteria

The primary water quality criteria applicable to this study include the following:

- CCME Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life;
- Schedule 4 of the *Metal Mining Effluent Regulations* (MMER)(Canada) SOR/2002-222 promulgated under the *Fisheries Act*; and
- Schedule C of NEWFOUNDLAND AND LABRADOR REGULATION 65/03 *Environmental Control Water and Sewage Regulations, 2003* under the *Water Resources Act* (O.C. 2003-231).

Schedule C of NL Reg. 65/03 states:

A person primarily in the Metal Mining Industry shall comply with sections 3 and 19.1 and 20 and Schedule 4 of the *Metal Mining Effluent Regulations* (Canada) SOR/2002-222, including any changes or amendments to those sections of and that schedule to those regulations over time.

Therefore, as the Project is the proposed development of a metal mine the CWQG and MMER are the primary water quality criteria. The CWQG are those used to assess baseline water quality and assimilative capacity and MMER are those used to set effluent limits. CWQG and MMER criteria for parameters assessed in this study are presented in Table 5.15.

5.2.7.2 Regional Water Quality

The Canada – Newfoundland Water Quality Monitoring Agreement (WQMA) facilities the monitoring of water quality across the province. The NL Dept. of Environment and Conservation (NL DEC) has mapped water quality concentration contours across the province. Mapping of those contours is presented in Appendix L. Average WQMA site values for the Project area are presented in Table 5.15. Water quality contour maps display regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5.

Table 5.15 Summary Regulatory Criteria and Reference Water Quality in Western Labrador

Parameter	Units	Regulatory Criteria and Reference Water Quality			
		CWQG	MMER[1]		WQMA
			(Max Monthly Mean)	(Max Grab)	
Alkalinity	mg/L				4.0332 – 6.5461
Colour	TCU	Narrative			18.5 – 27.7 (RU)
Conductivity	uS/cm				8.9 – 515.9
DO	mg/L	6.5 – 9.5 (cold water –life stage)			1.68 – 3.60
pH	pH	6.5 - 9			6.51 – 6.61
Turbidity	NTU	Narrative			0.0 – 1.98 (JTU)
Temperature	Deg C	Narrative			3.7 – 5.1
TSS	mg/L	Narrative	15	30	
Calcium	mg/L				0.81 – 1.69
Chloride	mg/L				0.15 – 30.12
Flouride	mg/L	0.120 (inorganic F)			0.025
Magnesium	mg/L				0.23 – 1.43
Potassium	mg/L				0.0 – 0.80
Sodium	mg/L				0.0 – 10.55
Sulphate	mg/L				0.41 – 6.38
Cyanide	mg/L	0.005 (as free CN)	1	2	
DOC	mg/L			2000	4.4 – 4.5
Total Ammonia - N	mg/L	TºC and pH dependent			0.136 – 0.150
Un-ionized Ammonia	µg/L	19			
Nitrite	mg/L	0.06			
Nitrate	mg/L	13			
Phosphorus	µg/L	< 4 - >100 (trophic status)			7.12 – 11.36
Aluminum	µg/L	5 if pH <6.5, 100 if pH > 6.5			35 - 82
Arsenic	µg/L	5	500	1000	0.05 – 0.08
Boron	µg/L	1500 (Long Term)			
Cadmium	µg/L	Hardness adjusted			0.103 – 0.117
Copper	µg/L	Hardness adjusted, a minimum of 2 µg/l regardless of water hardness (*Demayo and Taylor, 1981*)	300	600	4.35 – 4.93
Iron	µg/L	300			61.8 – 185.9

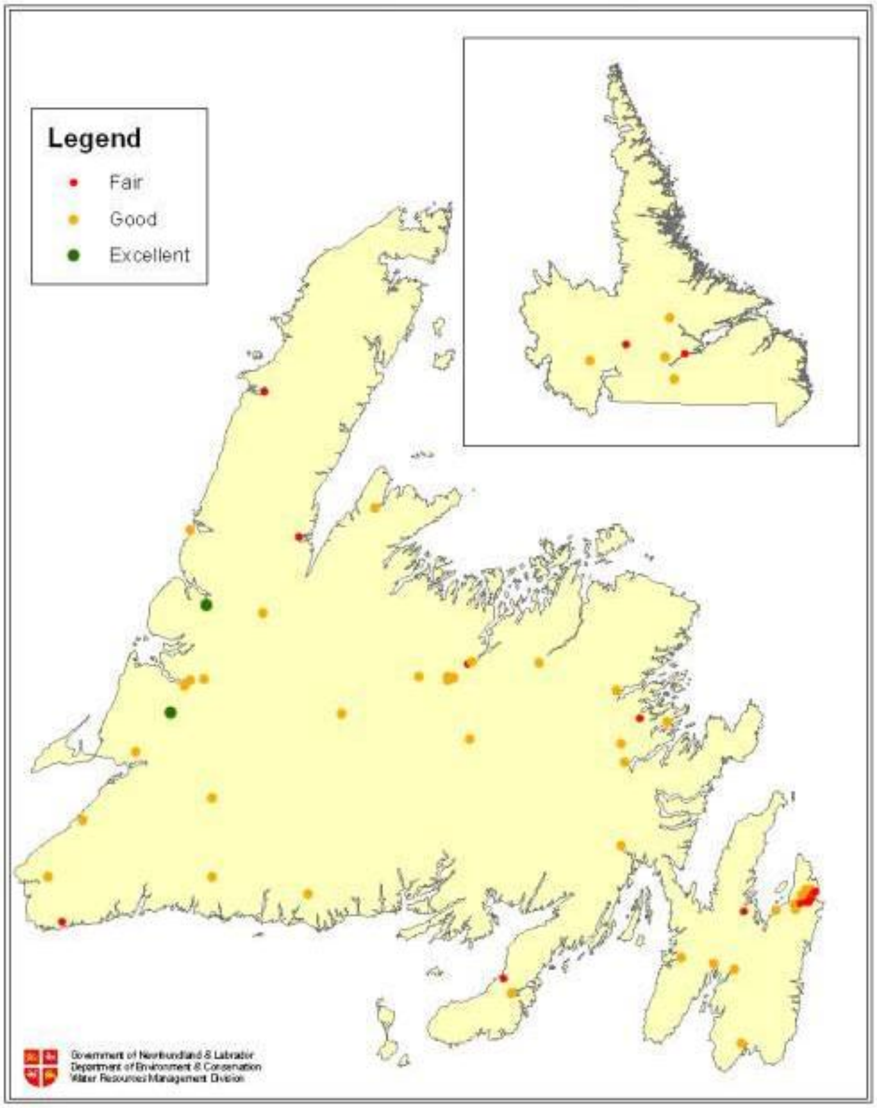
Parameter	Units	Regulatory Criteria and Reference Water Quality			
		CWQG	MMER[1] (Max Monthly Mean)	MMER[1] (Max Grab)	WQMA
Lead	µg/L	Hardness adjusted, a minimum of 1 µg/L regardless of water hardness (*CCREM, 1987: Table 3-10*)	200	400	0.34 – 0.42
Mercury	µg/L	0.026			0.087 – 0.103
Molybdenum	µg/L	73			0.05 – 0.062
Nickel	µg/L	Hardness adjusted, a minimum of 25 µg/L regardless of water hardness (*IJC, 1976*)	500	1000	2.3 – 3.6
Selenium	µg/L	1			0.05 – 0.057
Silver	µg/L	0.1			
Thallium	µg/L	0.8			
Uranium	µg/L	33 (short term), 15 (long term)			
Zinc	µg/L	30	500	1000	3.4 – 3.8
Radium$_{226}$	Bq/L		0.37	1.11	

Notes:

[1] The MMER provides three effluent water quality limits including the maximum authorized monthly mean concentration, maximum authorized concentration in a composite sample and maximum authorized concentration in a grab sample. The Maximum Authorized Monthly Mean Concentration will be the MMER effluent criteria carried forward in Project effects assessments.

Application of the Canadian Water Quality Index to WQMA sites in Labrador indicates Good to Excellent water quality as depicted in Figure 5.22.

Figure 5.22 Water Quality Index Ranking Map for Labrador (NL DEC, 2011).


Legend
● Fair
● Good
● Excellent
Government of Newfoundland & Labrador
Department of Environment & Conservation
Water Resources Management Division

5.2.7.3 PDA/LSA Water Quality

General Constituents

As discussed in previous sections, leveloggers were installed at five continuous stream monitoring stations including *S1* to *S5* as well as two lake monitoring stations *L1* and *L2*. Water temperature for each station was recorded at a 10 minute intervals commencing from October 2011. Figure 5.23 and 5.24 present the continuous temperature monitoring results from the on-site leveloggers at five stream monitoring stations and two lake monitoring stations from October 2011 to the end of May 2012.

Water temperature information recorded at the time of water quality sampling is presented in Appendix N.

Figure 5.23 Water Temperature for Stream Monitoring Stations *S1* to *S5*.

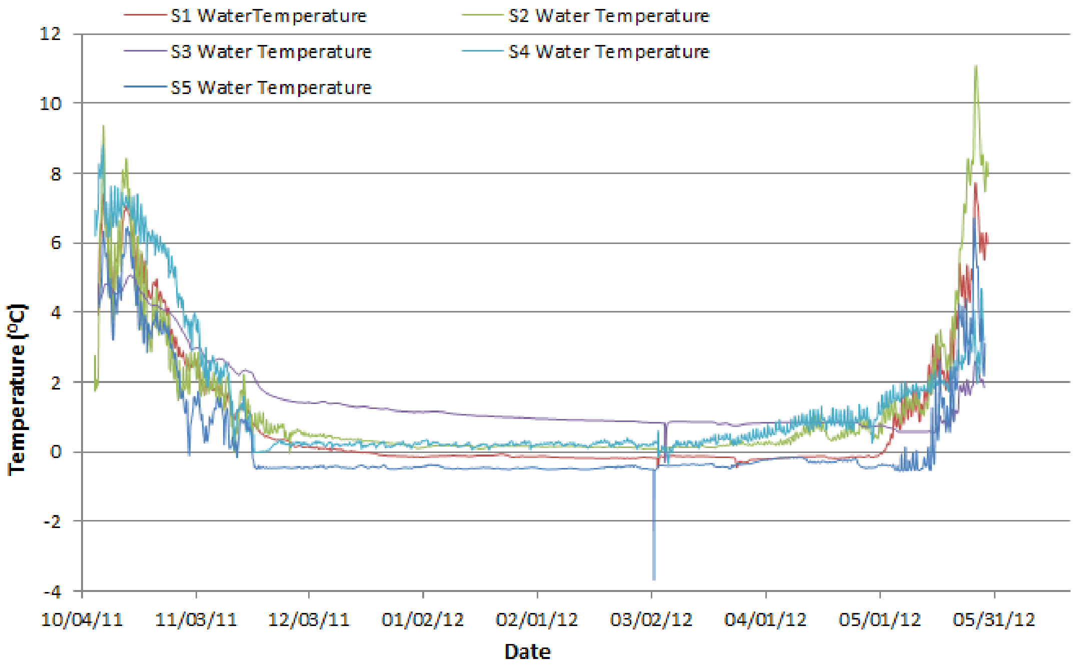


Figure 5.24 Water Temperature for Long Lake and Mills Lake at Monitoring Stations *L1* and *L2*.

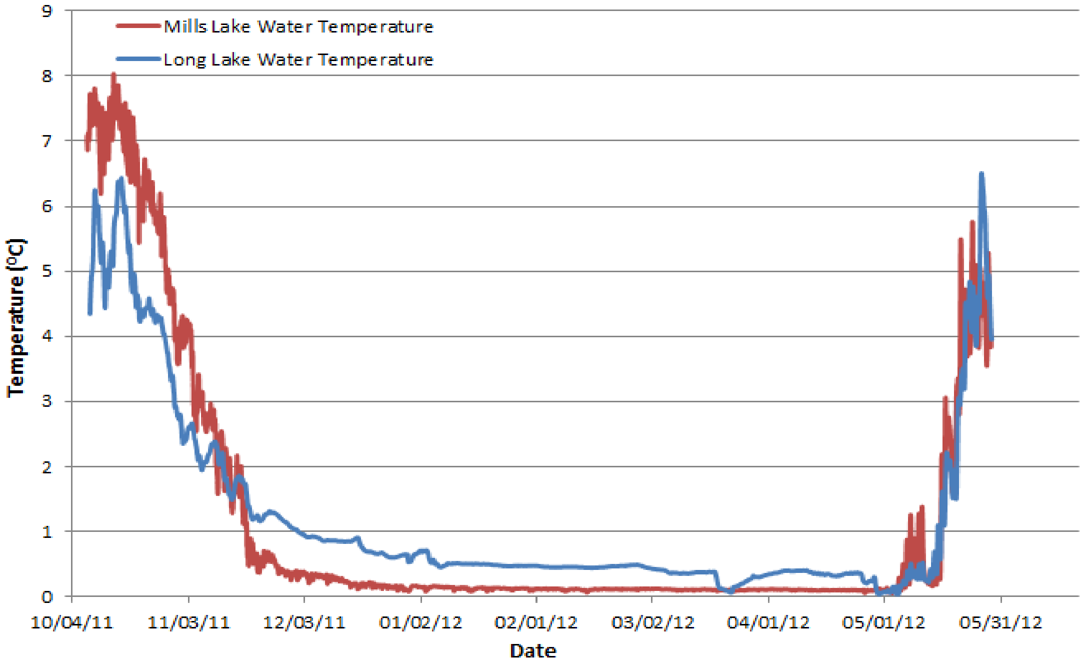


Table 5.16 presents summary statistics for all lab analytical general constituents. All lab analytical water quality results are presented in Appendix M.

The lab results indicate that pH for the seven (7) routine monitoring stations ranged from 7.5 to 8.06, demonstrating slightly alkaline conditions and no strong difference between stream and lake pH values. All routine monitoring pH results were within CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQG) which is from 6.5-9.0. The April monitoring results demonstrated similar pH range to the routine seasonal monitoring results. One exception was a pH sample value of 5.67 in the composite sample on Molar Lake. However, the in-situ pH spot measurement in Molar Lake indicated a pH value of 7.77. The pH range observed throughout the LSA is more alkaline than the WQMA pH range for western Labrador which tends to be slightly acidic.

Total Alkalinity (as $CaCO_3$) for routine monitoring stations ranged from 27 mg/L (as $CaCO_3$) to 110 mg/L with mean concentration of 50 mg/L. Higher concentrations of 87 mg/L and 110 mg/L were observed from the samples taken in October 2011 and March 2012 for routine monitoring station *S5* which is located in a tributary that discharges to the southeast end of Long Lake. Another higher alkalinity value of 89 mg/L from the October sample was observed at routine monitoring station *L2* which is located at the southeast end of Long Lake. The April monitoring results show a similar alkalinity range to the routine monitoring stations results. Higher concentrations of 76 mg/L and 72 mg/L were observed from samples taken at the southern end of the Long Lake (LL4) and Waldorf River (WDR-1). However, alkalinity values in this range are considered to be low. Low alkalinity values suggest limited acid buffering potential in local lakes and streams.

Hardness (as $CaCO_3$) ranged from 29 mg/L (as $CaCO_3$) to 110 mg/L with mean of 52 mg/L for the routine monitoring stations. Relatively higher values of 89 mg/L, 110 mg/L as well as 90 mg/L were observed at the routine monitoring stations *S5* (October and March) and *L2*. For the April field samples, hardness values ranged from 29 mg/L to 71 mg/L with mean of 46.8 mg/L. Similarly, higher values of 67 mg/L and 71 mg/L were observed at sampling locations LL4 and WDR-1. *LL4* is located at the southern end of the Long Lake. And WDR-1 is located at Waldorf River in proximity to *LL4*. The value range for routine monitoring stations and April monitoring locations indicated hardness ranging from soft (<60 mg/L (as $CaCO_3$)) to moderately hard (61 – 120 mg/L). Parameters such as copper, cadmium, lead and nickel are hardness-adjusted in the CWQG. The range of hardness values result in lower CWQG thresholds for lower hardness concentrations to higher thresholds for higher concentrations.

Langelier Saturation Index (LSI) values for most routine monitoring stations and all of the April monitoring locations are negative and indicative of pH under-saturation with calcium carbonate ($CaCO_3$). The negative LSI values indicate that the local surface waters will tend to dissolve solid $CaCO_3$ and will not be scale-forming. However, there is one exception for the result from routine monitoring station *S5* for which the LSI was higher than the rest with a positive value of + 0.15 in the March 2012 sample. The positive value shows that the water is over-saturated and tends to precipitate a scale layer of $CaCO_3$. However the October sample from the same locations shows a negative value of- 0.08. The potential for scale formation is an important consideration in the selection and design of water infrastructure.

Electrical conductivity for routine monitoring stations ranged from 56 µS/cm to 210 µS/cm with mean of 106.4 µS/cm. The highest value of 210 µS/cm was observed from Station *S5* in the March sample. For April monitoring results the electrical conductivity values ranged from 66 µS/cm to 140 µS/cm No strong lake to stream concentration trend or relationship was observed. Conductivity within the 150 µS/cm and 500 µS/cm range in freshwaters are indicative of the potential to support good mixed fisheries.

Ionic balance for routine monitoring stations and April monitoring samples were moderately positive and expected in light of the soft to moderate water hardness observations above. Concentrations of major cations such as calcium, sodium, potassium, magnesium, manganese, ammonium, iron and aluminum were low as were concentrations of major anions such as chloride, fluoride, sulphate, and nitrate resulting in relatively weak ionic strength.

Total Dissolved Solids (TDS) concentrations were generally low for routine monitoring stations, ranging from 27 mg/L – 110 mg/L with mean of 56.6 mg/L. The maximum value of 110 mg/L was observed from the March sample at routine monitoring station *S5*. Another higher value of 100 mg/L was observed from the October sample at routine monitoring station *L2*. For April monitoring results the TDS values ranged from 29 mg/L to 90 mg/L. The value of 90 mg/L was observed at April monitoring location LL4. However, these TDS values are much less than the TDS tolerance maxima of 1000 mg/L estimated by Boyd (1999) in mixed fish fauna aquatic ecosystems. Total suspended solids concentrations for routine monitoring stations were low ranging from <1 mg/L (below the detection limit) to a maximum of 5.2 mg/L. The April monitoring results present a range between <1 mg/L - 2.0 mg/L which is similar to the routine seasonal monitoring results. Turbidity levels observed are typical of very low values. Colour ranged from 7.9 – 44 TCU with mean of 15.24 TCU. The mean colour value is only marginally above the Canadian Drinking Water Quality Aesthetic Guideline of 15 TCU for colour.

Cyanide is comprised of triple bound carbon and nitrogen atoms. Most cyanide species are highly toxic. The free cyanide CWQG threshold is 5 µg/L. All cyanide samples from routine monitoring stations and April monitoring locations were below the detection limit of 2 µg/L.

Table 5.16 Summary of General Constituents for Routine Monitoring and April Field Samples

Parameter	Units	CWQG Guideline	Min	Mean	Max	75th
General Constituents						
Anion Sum	me/L		0.55	1.09	2.32	1.41
Bicarb. Alkalinity (calc. as CaCO3)	mg/L		27	51	110	64
Calculated TDS	mg/L		34.0	58.1	116.0	75.8
Carb. Alkalinity (calc. as CaCO3)	mg/L		0.5	0.5	1.2	0.5
Cation Sum	me/L		0.630	1.064	2.220	1.280
Hardness (CaCO3)	mg/L		29	50	110	59
Ion Balance (% Difference)	%		0.54	3.26	8.33	4.66

Parameter	Units	CWQG Guideline	Min	Mean	Max	75th
General Constituents						
Langelier I0.5ex (@ 20C)	N/A		-3.28	-0.97	0.15	-0.54
Langelier Index (@ 4C)	N/A		-3.53	-1.22	-0.10	-0.79
Saturation pH (@ 20C)	N/A		7.91	8.61	9.03	8.87
Saturation pH (@ 4C)	N/A		8.16	8.86	9.28	9.12
pH	pH	6.5-9	5.64	7.58	8.06	7.81
Acidity	mg/L		2.5	3.5	12.0	4.4
Total Alkalinity (Total as CaCO3)	mg/L		27	50	110	60
Dissolved Chloride (Cl)	mg/L		0.5	0.7	2.2	0.5
Color	TCU	Narrative[1]	8	14	44	14
Strong Acid Dissoc. Cyanide (CN)	mg/L	0.005 (as free CN)	0.0010	0.0010	0.0010	0.0010
Total Dissolved Solids	mg/L		27	55	110	68
Dissolved Fluoride (F-)	mg/L	0.120 (inorganic F)	0.05	0.05	0.11	0.05
Reactive Silica (SiO2)	mg/L		3.2	5.1	9.4	6.4
Total Suspended Solids	mg/L	Narrative[2]	0.5	1.3	5.2	1.7
Dissolved Sulphate (SO4)	mg/L		1.0	3.0	5.8	3.9
Turbidity	NTU	Narrative[3]	0.05	0.41	1.30	0.58
Conductivity	uS/cm		56	101	210	130

Note:

[1] *True Color:* The mean absorbance of filtered water samples at 456 nm shall not be significantly higher than the seasonally adjusted expected value for the system under consideration.

[2] *Total Suspended Solids for Clear Flow:* Maximum increase of 25 mg/L from background levels for any short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 h and 30 d).

[3] *Turbidity for Clear Flow:* Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from background levels for a longer term exposure (e.g., 30-d period).

Nutrients

Table 5.17 presents summary statistics for all lab analytical nutrient results and all lab analytical nutrient results are presented in Appendix M.

Total ammonia-N for routine monitoring stations and April monitoring locations ranged from below the 0.05 mg/L detection limit to 0.16 mg/L and were all consistently below the CWQG of 4.84 mg/L (Ammonia concentration at pH 7.5, temperature 5°C). Un-ionized ammonia was calculated from Total ammonia-N, pH and temperature using the formula developed by Emerson *et al*. (1975). All un-ionized ammonia concentrations were well below CWQG of 19µg/L. Nitrate concentrations ranged from below 0.05mg/L to 0.27mg/L for routine monitoring stations and April monitoring locations. The results were well below the CWQG for nitrate of 13 mg/L. Similarly, all nitrite concentrations were below the detection limit of 0.01 and the CWQG of 0.06 mg/L.

Orthophosphate levels for routine monitoring stations and April monitoring locations were below the detection limit of 10 ug/L. Total Phosphorus (TP) values for routine monitoring stations fell in the range of 0.003 mg/L to 0.018 mg/L. For April monitoring locations, TP values ranged from 0.005 mg/L to 0.014 mg/L which is similar to the results for routine monitoring stations. The CWQGs indicate that TP concentrations from 0.003 – 0.018 mg/L range from ultra-oligotrophic to meso-trophic, respectively.

Sulphate concentrations for routine monitoring stations and April monitoring stations ranged from below 2 mg/L to 5.8 mg/L which is much lower than the maximum concentration of sulphate of 250 mg/L and the 65 mg/L 30-day average concentration proposed for the protection of aquatic life in the Draft BC ambient water quality guideline for sulphate (Meays and Nordin, 2011). No CWQG exists for sulphate.

Table 5.17 Summary of Nutrients for Routine Monitoring and April Field Samples.

Parameter	Units	CWQG Guideline	Min	Mean	Max	75th
Nutrients						
Nitrate + Nitrite	mg/L		0.03	0.06	0.27	0.08
Nitrate (N)	mg/L	13.000	0.025	0.062	0.270	0.086
Nitrite (N)	mg/L	0.1	0.005	0.005	0.005	0.005
Nitrogen (Ammonia Nitrogen)	mg/L	See Table[1]	0.025	0.038	0.160	0.025
Dissolved Organic Carbon (C)	mg/L		1.500	4.873	20.000	5.225
Total Organic Carbon (C)	mg/L		1	4	20	4
Orthophosphate (P)	mg/L		0.01	0.01	0.01	0.01
Total Phosphorus	mg/L	See notes[2]	0.00	0.01	0.02	0.01

Notes:

[1] Ammonia concentration under different pH and temperatures, please see table at http://st-ts.ccme.ca/?lang=en&factsheet=5#aql_fresh_concentration

[2] Ultra-oligotrophic <4, oligotrophic 4-10, mesotrophic 10-20, meso-eutrophic 20-35, eutrophic 35-100, hyper-eutrophic >100

Metals

Table 5.18 presents summary statistics for all lab analytical metals results and all lab analytical metals results are presented in Appendix M.

Cadmium, copper, lead and nickel all have hardness-adjusted CWQG thresholds, however in the cases of copper, lead and nickel an arbitrary lower limit is implemented as indicated in Table 5.18. Comparison of observed analytical results for these metals was conducted by calculating the individual sample hardness-adjusted CWQG limit or lower arbitrary limit. The total cadmium values for routine monitoring stations ranged from below 0.017 ug/L RDL to 0.048 ug/L with mean of 0.011 ug/L and most analytical results indicated cadmium concentrations better than the CWQG. However, several total cadmium exceedences of the hardness-adjusted CWQG limits were observed including *S1* (downstream of Pike Lake South) in October, 2011 and at the Waldorf River WDR and Long Lake *LL2* and *LL3* sample locations in April, 2012 samples.

Copper concentration for routine and April monitoring locations are generally below the Reportable Detection Limit (RDL). The CWQG threshold for copper concentration is based on hardness-adjustment. However, the minimum CWQG threshold for copper is 2 µg/L regardless of water hardness (Damayo and Taylor, 1981) Therefore, the CWQG thresholds ranged from 2 µg/L – 2.6 µg/L. Based on the ½ DL convention (Clark, 1998) a slight copper exceedences was observed at *L1* on October sample with a value of 2.4 µg/L which exceeded the CWQG minimum threshold of 2 µg/L.

The minimum CWQG threshold for lead is 1 µg/L regardless of water hardness (CCREM, 1987). Similarly, the minimum threshold for nickel is 25 µg/L (IJC, 1976). The concentrations for lead and nickel at all locations were below values of the CWQG thresholds. Total iron concentrations were all below the CWQG with the single exception of station *S2* in March sampling. Arsenic, Uranium and Radium_{226} concentrations were well below their respective CWQG and/or MMER criteria.

Table 5.18 Summary of Water Quality Metals for Routine Monitoring and April Field Samples

Parameter	Units	CWQG Guideline	Min	Mean	Max	75th%
Metals						
Dissolved Mercury (Hg)	µg/L	0.026	0.01	0.01	0.07	0.01
Dissolved Aluminum (Al)	µg/L		3	13	80	14
Total Aluminum (Al)	µg/L	5 if pH <6.5, 100 if pH > 6.5	2.5	22.7	73.6	19.9
Total Antimony (Sb)	µg/L		0.5	0.5	0.5	0.5
Total Arsenic (As)	µg/L	5.000	0.500	0.500	0.500	0.500
Total Barium (Ba)	µg/L		9	15	31	18
Total Beryllium (Be)	µg/L		0.50	0.50	0.50	0.50
Total Bismuth (Bi)	µg/L		1.00	1.00	1.00	1.00
Total Boron (B)	µg/L	1500	25	25	25	25
Total Cadmium (Cd)	µg/L	see note[1]	0.0085	0.01626	0.056	0.0085
Total Calcium (Ca)	µg/L		6860	12307.6	25300	14500
Total Chromium (Cr)	µg/L		0.5	0.5	0.5	0.5
Total Cobalt (Co)	µg/L		0.2	0.2	0.2	0.2
Total Copper (Cu)	µg/L	see note[2]	1	1.056	2.4	1
Total Iron (Fe)	µg/L	300	25	111.76	493	140
Total Lead (Pb)	µg/L	see note[3]	0.25	0.2876	0.84	0.25
Total Magnesium (Mg)	µg/L		2580	5620.8	13000	7080
Total Manganese (Mn)	µg/L		1	32.84	185	45
Total Molybdenum (Mo)	µg/L	73	1	1	1	1
Total Nickel (Ni)	µg/L	see note[4]	1	1	1	1

Parameter	Units	CWQG Guideline	Min	Mean	Max	75th%
Metals						
Total Potassium (K)	µg/L		849	1302.08	2690	1410
Total Selenium (Se)	µg/L	1	0.5	0.5	0.5	0.5
Total Silicon (Si)	µg/L		1560	2529.6	4940	3410
Total Silver (Ag)	µg/L	0.1	0.05	0.05	0.05	0.05
Total Sodium (Na)	µg/L		538	999.52	3040	946
Total Strontium (Sr)	µg/L		12.4	17.892	29.9	22.5
Total Sulphur (S)	µg/L		2500	2500	2500	2500
Total Tellurium (Te)	µg/L		1	1	1	1
Total Thallium (Tl)	µg/L	0.8	0.05	0.05	0.05	0.05
Total Tin (Sn)	µg/L		1	1	1	1
Total Titanium (Ti)	µg/L		1	1.232	4.1	1
Total Uranium (U)	µg/L		0.05	0.2072	0.96	0.22
Total Vanadium (V)	µg/L		1	1	1	1
Total Zinc (Zn)	µg/L	30	2.5	5.952	30.7	5.2
Radium$_{226}$	Bq/L		0.0025	0.00629	0.02	0.007

Notes:

1. http://st-ts.ccme.ca/?lang=en&factsheet=20#aql_fresh_concentration
2. Minimum 2 µg/L and see equation at http://st-ts.ccme.ca/?lang=en&factsheet=71#aql_fresh_concentration
3. Minimum 1 µg/L and see equation at http://st-ts.ccme.ca/?lang=en&factsheet=124#aql_fresh_concentration
4. Minimum 25 µg/L and see equation at **Error! Hyperlink reference not valid.**

5.2.8 Sediment Quality

5.2.8.1 Regulatory Criteria

Sediment quality is used to indicate long-term water quality conditions, potential historic contaminant releases, aquatic / benthic community potential and health and the sensitivity of aquatic sediment to environmental changes. The sediment quality assessment is completed to compare baseline sediment quality with the CCME Canadian Sediment Quality Guidelines (CSQG) for the protection of Aquatic Life and other relevant regulatory standards. The sediment quality assessment examine the following parameters and parameter groups:

- Particle Size Distribution (PSD): determines the grain size of sediment and is used to assess its potential for benthic community types and composition, the hydraulic velocity environment and the depositional or aggradational conditions in the sediment transport environment;
- Moisture Content: determines the amount of water in sediment pore spaces and is used to assess sediment porosity;
- Soil Salinity Package and Chloride: Include pH, Sodium Absorption Ratio (SAR) and chloride used to assess sediment acid buffering potential, and indicate historic / current anthropogenic sediment disturbance;

- Metals including Mercury: sets the baseline metals concentration in sediment and the metals concentrations to which the local aquatic and benthic communities have adapted;
- Total Organic Carbon (TOC); Total Kjeldhal Nitrogen (TKN), Total Phosphorus (TP): TOC is used to assess the level of primary productivity in the watershed from sediment chemistry; TKN and TP are used to assess the nutrient health of sediment and its trophic state (eutrophic to oligotrophic); and
- PAHs, BTEX and F1 – F4 Hydrocarbon fractionation: assesses evidence of historic spills / releases in the watershed.

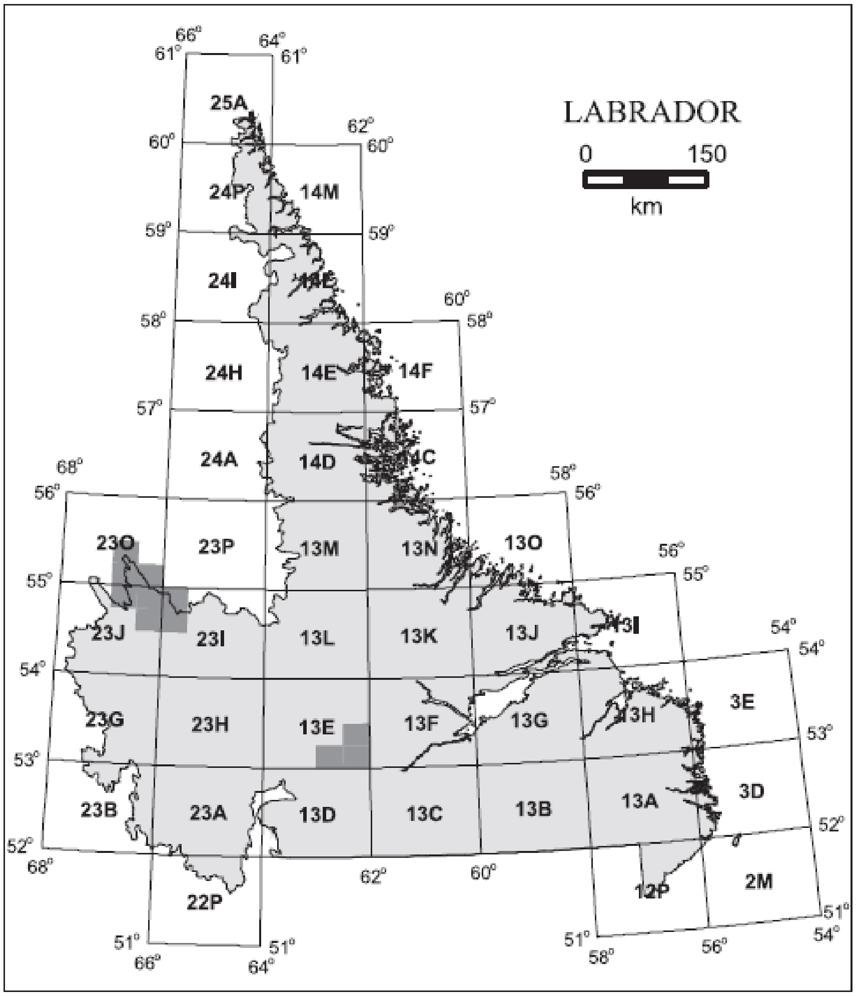
5.2.8.2 Regional Sediment Quality

In 2006, a detailed lake sediment and water survey was conducted in central and western Labrador. Samples were collected from NTS map areas 13E/1, 2 and 8 in the Winokapau Lake as well as in the Schefferville area which covers the NTS map areas 23I/12 (north half), 23I/13, 23J/9, 15 and 16 and 23O/1, 2 and 7. The Schefferville area is located at the about 200 km north of the Project site, and the Winokapau Lake area is located at about 250 km east of the Project. Figure 5.25 presents the locations of survey area in Map zone 23J, I and Q as well as 13E (McConnell and Ricketts, 2011).

As reported in previous studies, the Winokapau Lake area had anomalously high levels of uranium in sediment and water in an earlier reconnaissance survey (Friske et al., 1993). For the Schefferville area, the sediment has been reported to have high levels of gold, copper, nickel, zinc and antimony in previous surveys (Hornbrook et al., 1989). Copper and zinc mineralization occurrences are also known within the survey areas.

The laboratory analytical results showed that samples from the Schefferville area generally have higher values for arsenic, cadmium, chromium, copper and zinc which exceeded the (Interim Sediment Quality Guideline (ISQG) but below the Probable Effect Levels (PEL) values. The results for Winokapau Lake survey area samples were lower than the samples from Schefferville area and generally less than the ISQG values with one exception for chromium which exceeded the ISQG value of 37.3 mg/kg but below the PEL value of 90 mg/kg.

Figure 5.25 Locations for Sediment and Water Survey in Central and Western Labrador in 2006 (McConnell and Ricketts, 2011)


LABRADOR
0
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14E
14F
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56°
24A
14D
14C
58°
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23O
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62°
60°
22P
12P
2M
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51°
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64°
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58°
56°
51°
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5.2.8.3 PDA/LSA Sediment Quality

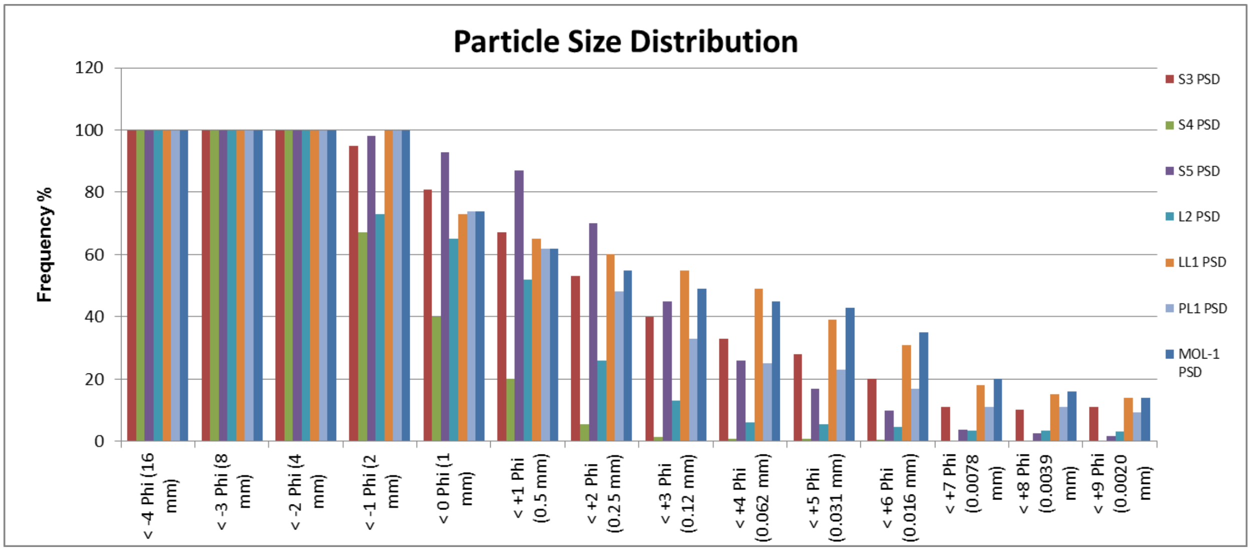
All laboratory testing and analytical results for sediment are presented in Appendix M.

Particle Size Distribution (PSD)

Sediment sampling locations are mapped in Figure 4.1. The PSD for all sediment samples is plotted in Figure 5.27. Sediment from routine monitoring station *S3* is described as silty sand with trace gravel and clay having grain sizes of 5.2% gravel, 61% sand, 23% silt as well as 10% clay. The observed sand dominance was also observed at the rest of the six (6) other sampling locations including the southern end of Long Lake (*L2*), Long Lake (*LL1*), Molar Lake (*MOL1*), and Pike Lake (*PL1*) as well as the stream connecting Molar Lake and Mills Lake (*S4*) and the small tributary to Long Lake (*S5*). Note however that cobble and boulder class materials were also observed in all of the stream sampling locations. Stream monitoring station *S1* (outlet channel of Pike Lake South) and *S2* (inlet channel to Pike Lake South and channel draining

Pike Lake South headwaters) were all visually observed to have a mix of gravel-cobble-boulder class materials in their channel beds. Finally, routine monitoring station *L1* on Mills Lake had a sand, gravel and cobble bed.

Figure 5.26 Particle Size Distributions for Routine Monitoring and April Field Visit Samples



Metals

Most metals concentrations from all sediment samples were below their respective CSQG Interim Sediment Quality Guideline (ISQG) and the Probable Effect Level (PEL). However, exceedances for the chromium ISQG value of 37.3 mg/kg were observed in samples from *S3* in March, as well as *LL1* and *MOL1* in April. The chromium value for *S3* in March sampling is 48 mg/L. As for *LL1* and *MOL1* April samples, the chromium values are 65 mg/kg and 71 mg/kg, respectively. These values have exceeded the ISQG value of 37.3 mg/kg but still fall below the PEL value of 90 mg/kg. The sample from Molar Lake (*MOL1*) has slightly higher values for cadmium (0.65 mg/kg) and copper (37 mg/kg) which exceeded the ISQG values of 0.6 mg/kg (cadmium) and 35.7 mg/kg (copper) but well below the PEL values of 3.5 mg/kg (cadmium) and 197 mg/kg (copper). A summary of the metal concentrations for routine monitoring station and April field visit samples are presented in Table 5.18.

Table 5.19 Summary of Metal Concentrations for Routine Monitoring and April Field Visit Samples

Parameter	Units	CSQG Guidelines		Min	Mean	Max	75th
		ISQG	PEL				
Available Aluminum (Al)	mg/kg			1500	7880	23000	12250
Available Antimony (Sb)	mg/kg			1	1	1	1
Available Arsenic (As)	mg/kg	5.9	17	1	1.41	2.6	1.9
Available Barium (Ba)	mg/kg			17	213	860	278

Parameter	Units	CSQG Guidelines		Min	Mean	Max	75th
		ISQG	PEL				
Available Beryllium (Be)	mg/kg			1	1	1	1
Available Bismuth (Bi)	mg/kg			1	1	1	1
Available Boron (B)	mg/kg			2.5	2.5	2.5	2.5
Available Cadmium (Cd)	mg/kg	0.6	3.5	0.15	0.32	0.65	0.46
Available Chromium (Cr)	mg/kg	37.3	90	9	31	71	44
Available Cobalt (Co)	mg/kg			1.7	7.0	17	10.7
Available Copper (Cu)	mg/kg	35.7	197	1.0	11.6	37.0	15.5
Available Iron (Fe)	mg/kg			5500	33290	71000	50000
Available Lead (Pb)	mg/kg	35	91.3	1.1	4.1	16	4.6
Available Lithium (Li)	mg/kg			1.0	6.5	16	10.18
Available Manganese (Mn)	mg/kg			110	5397	16000	12275
Available Mercury (Hg)	mg/kg	0.17	0.486	0.05	0.08	0.17	0.10
Available Molybdenum (Mo)	mg/kg			1	7	14	14
Available Nickel (Ni)	mg/kg			4.0	20.1	49.0	31.3
Available Rubidium (Rb)	mg/kg			1.0	6.0	19.0	5.0
Available Selenium (Se)	mg/kg			1	1	1	1
Available Silver (Ag)	mg/kg			0.25	0.25	0.25	0.25
Available Strontium (Sr)	mg/kg			5	15.82	39	21.75
Available Thallium (Tl)	mg/kg			0.05	0.329	0.81	0.47
Available Tin (Sn)	mg/kg			1	1	1	1
Available Uranium (U)	mg/kg			0.23	7.46	28.00	10.68
Available Vanadium (V)	mg/kg			7	19.5	42	28.3
Available Zinc (Zn)	mg/kg	123	315	8.0	53.5	130.0	85.8

Hydrocarbons

All BTEX constituent concentrations were below the detection level. PHC C1-C4 were at background level and reached baseline at C50. All PAH parameter concentrations were below the detection limit and CSQG threshold concentrations. Sediment quality results for all the sampling locations are presented in Table 5.19

Table 5.20 Summary of Hydrocarbon Concentrations for Routine Monitoring Station and April Field Visit Samples.

Parameter	Units	CSQG Guidelines		Min	Mean	Max	75th
		ISQG	PEL				
Polyaromatic Hydrocarbons							
1-Methylnaphthalene	mg/kg			0.0025	0.0025	0.0025	0.0025
2-Methylnaphthalene	mg/kg	0.0202	0.2010	0.0025	0.0025	0.0025	0.0025
Acenaphthene	mg/kg	0.0067	0.0889	0.0025	0.0025	0.0025	0.0025
Acenaphthylene	mg/kg	0.0059	0.1280	0.0025	0.0025	0.0025	0.0025

Parameter	Units	CSQG Guidelines		Min	Mean	Max	75th
		ISQG	PEL				
Anthracene	mg/kg	0.0469	0.2450	0.0025	0.0025	0.0025	0.0025
Benzo(a)anthracene	mg/kg	0.0317	0.3850	0.0025	0.0025	0.0025	0.0025
Benzo(a)pyrene	mg/kg	0.0319	0.7820	0.0025	0.0025	0.0025	0.0025
Benzo(b)fluoranthene	mg/kg			0.0025	0.0025	0.0025	0.0025
Benzo(g,h,i)perylene	mg/kg			0.0025	0.0025	0.0025	0.0025
Benzo(j)fluoranthene	mg/kg			0.0025	0.0025	0.0025	0.0025
Benzo(k)fluoranthene	mg/kg			0.0025	0.0025	0.0025	0.0025
Chrysene	mg/kg	0.0571	0.8620	0.0025	0.0025	0.0025	0.0025
Dibenz(a,h)anthracene	mg/kg	0.0062	0.1350	0.0025	0.0025	0.0025	0.0025
Fluoranthene	mg/kg	0.1110	2.3550	0.0025	0.0025	0.0025	0.0025
Fluorene	mg/kg	0.0212	0.1440	0.0025	0.0025	0.0025	0.0025
Indeno(1,2,3-cd)pyrene	mg/kg			0.0025	0.0025	0.0025	0.0025
Naphthalene	mg/kg	0.0346	0.3910	0.0025	0.0025	0.0025	0.0025
Perylene	mg/kg			0.0025	0.7691	2.3000	1.4500
Phenanthrene	mg/kg	0.0419	0.5150	0.0025	0.0025	0.0025	0.0025
Pyrene	mg/kg	0.0530	0.8750	0.0025	0.0052	0.0200	0.0025
Surrogate Recovery (%)							
D10-Anthracene	%			79	84	92	86
D14-Terphenyl	%			91	102	130	104.5
D8-Acenaphthylene	%			76	79	82	80
BTEX & F1 Hydrocarbons							
Benzene	µg/g			0.010	0.049	0.100	0.100
Toluene	µg/g			0.010	0.049	0.100	0.100
Ethylbenzene	µg/g			0.010	0.049	0.100	0.100
o-Xylene	µg/g			0.010	0.049	0.100	0.100
p+m-Xylene	µg/g			0.020	0.097	0.200	0.200
Total Xylenes	µg/g			0.020	0.097	0.200	0.200
F1 (C6-C10)	µg/g			5	24	50	50
F1 (C6-C10) - BTEX	µg/g			5	24	50	50
F2-F4 Hydrocarbons							
F4G-sg (Grav. Heavy Hydrocarbons)				440	743	1200	895
F2 (C10-C16 Hydrocarbons)	µg/g			5	28	50	50
F3 (C16-C34 Hydrocarbons)	µg/g			5	143	720	140
F4 (C34-C50 Hydrocarbons)	µg/g			5	48	240	50
Reached Baseline at C50	µg/g						
Surrogate Recovery (%)							
1,4-Difluorobenzene	%			97	100	103	102
4-Bromofluorobenzene	%			85	101	109	108
D10-Ethylbenzene	%			87	98	110	99

Parameter	**Units**	**CSQG Guidelines**		**Min**	**Mean**	**Max**	**75th**
		ISQG	**PEL**				
D4-1,2-Dichloroethane	%			92	95	98	96
o-Terphenyl	%			84	104	127	115

Note:

1. Parameters under detection limits are adjusted to the half value of detection limits for statistic purpose.

Based on the analytical assessment, sediment quality at routine monitoring stations (including *S3, S4, S5* and *L2*) and April sampling locations (including Long Lake, Pike Lake) are considered to be good and unimpaired. Only a few exceedances of ISQG for chromium, cadmium and copper values were observed from the Molar Lake April sample. Also samples from *S3* and *LL1* exceeded the chromium ISQG. However, the exceedances from Molar Lake, *S3* and *LL1* sample were well below the PEL values.

5.2.9 Local Receiving Water Assimilative Capacity

5.2.9.1 Existing Water Uses, Impacts and Constraints

Existing water taking uses important to assimilative capacity assessments include extractive uses as described in section 5.2.6.2, effluent discharge uses, recreational uses, and water quality and ecological sensitivities.

Except for Cliffs Scully Mine discharges to Flora Lake, no other surface water discharges are known to occur in the PDA/LSA. Local cottage domestic sewage effluent is expected to be routed through septic leaching beds, pits or to holding tanks for periodic effluent pump-out. No direct surface water effluent discharges are known to occur within the PDA/LSA.

Key local surface water effluent discharge constraints are considered to include:

- Avoidance of the near-shore zone in the effluent mixing zone and the adoption of a near-shore zone buffer zone to avoid domestic water takings. The protected water supply area guidance on buffer areas from water supply intakes (150 m buffer) can be applied in this instance. As the domestic surface water intakes are near-shore, the use of the 150 m shoreline buffer is applied as a physical constraint;
- In addition to the shoreline buffer, areas with large shallow zones, such at the southeast embayment of Long Lake near station *L2* should be avoided due to ice cover depth and limited vertical mixing potential;
- Avoidance of shallow zones also addresses ecological concerns for areas utilized by fish for red development and juvenile rearing;
- Effluent discharge points and configuration should be in locations deep enough and at discharge orientations to avoid or minimize the potential for:
    - outfall / diffuser jetting effects causing bottom scour;

    - outfall / diffuser discharge related reductions in local ice cover;
    - outfall / diffuser interference with the navigability of the receiving water body;
    - surface breakout of the mixing zone;
- To avoid residual effects in PDA/LSA effluent receivers, and to the extent feasible, receivers with the largest assimilative capacity should preferentially be selected as receiving waterbodies;
- Effluent mixing zones should be minimized to the point where the mixing zone does not extend beyond the boundary of the receiver and definitely not beyond the boundary of the LSA; and
- Project water quality effects on local receivers should not be contained within the LSA boundary, thereby minimizing the potential for water quality residual and downstream cumulative effects.

The larger lakes in the Project site likely have the greatest potential as water supply sources for the project. Therefore, the potential sites for water extraction include the Long and Mills Lakes due to their size and proximity to major project component facilities, however, Project effluents are expected to be derived from the Open pit and Rose North Dump in the Pike Lake South watershed and the Waldorf River where a portion of drainage from the Rose South Dump is expected to drain. The approximate surface area of both the Long and Mills Lakes are 1150 Ha and 510 Ha respectively. The surface water field program was able to collect some bathymetric information for Long Lake, Mills Lake, Pike Lake South and Molar Lake which has been presented above.

5.2.9.2 Existing Net Assimilative Capacity

NL DEC (2005) provides guidance on the development of receiving water quality objectives through the conduct of a receiving water study (RWS). The typical level of effluent treatment required for a new wastewater treatment plant (WWTP) in NL is secondary treatment with disinfection. The assimilative capacity is the water quality attenuation capacity between the baseline water quality of the receiver and the Canadian Environmental Quality Guidelines (CEQGs), of which the applicable guidelines in this case is the CWQG for the protection of freshwater aquatic life. Dilution ratios should be based on receiver flows at the 7Q20 low flow threshold and the peak hourly effluent discharge rate.

NL DEC (2005) indicates the following mixing zone criteria:

No conditions within the mixing zone should be permitted which:

1. Are rapidly lethal to important aquatic life (resulting in conditions which result in sudden fish kills and mortality of organisms passing through the mixing zones);
2. Cause irreversible responses which could result in detrimental postexposure effects;
3. Result in bioconcentration of toxic materials which are harmful to the organism or its consumer; or

4. Attract organisms to the mixing zones, resulting in a prolonged and lethal exposure period.

The mixing zone should be designed to satisfy the following conditions:

1. Shall allow an adequate zone of passage for the movement or drift of all stages of aquatic life (specific portions of a cross-section of flow or volume may be arbitrarily allocated for this purpose);
2. Shall not interfere with the migratory routes, natural movements, survival, reproduction (spawning and nursery areas), growth, or increase the vulnerability to predation, of any representative aquatic species, or endangered species;
3. Eliminate rapid changes in the water quality, which could kill organisms by shock effects;
4. Total loading from all mixing zones within a water body must not exceed the acceptable loadings from all point source discharges required to maintain satisfactory water quality;
5. Mixing zones should not result in contamination of natural sediments so as to cause or contribute to exceedances of the water quality objectives outside the mixing zone

The mixing zone shall be:

1. Free from substances in concentrations or combinations which may be harmful to human, animal or aquatic life;
2. Free from substances that will settle to form putrescent or otherwise objectionable sludge deposits, or that will adversely affect aquatic life or waterfowl;
3. Free from debris, oil, grease, scum or other materials in amounts sufficient to be noticeable in the receiving water;
4. Located so as not to interfere with fish spawning and nursery areas;
5. Free from colour, turbidity or odour-producing materials that would:
    a. Adversely affect aquatic life or waterfowl;
    b. Significantly alter the natural colour of the receiving water;
    c. Directly or through interaction among themselves or with chemicals used in water treatment, result in undesirable taste or odour in treated water; and
    d. Free from nutrients in concentrations that create nuisance growths of aquatic weeds or algae or that results in an unacceptable degree of eutrophication of the receiving water.

Based on the work undertaken in this study, the Long Lake watershed is considered to have the greatest assimilative capacity for mine effluent discharge, however assimilative capacity is generally assessed on an individual parameter basis. As such the assimilative capacity of one parameter may be different from another. The full extent or boundary of the effluent mixing zone is therefore viewed as the dilution / assimilation zone required by the most conservative parameter to return to either baseline or CWQG conditions, whichever is greater.

More detailed assessments of local receiving water body assimilative capacity will be provided in the EIS Water Resources VEC chapter, however Table 5.27 provides the instantaneous assimilative load capacity for Long Lake, Mills Lake and Pike Lake South as measured by estimated 7Q20 outlet flow, for several selected MMER metal parameters based on the 75th% water quality presented in Table 5.16.

Table 5.21 Instantaneous Assimilative Capacity Load of Selected LSA Lakes (kg/s)

Parameter	Units	CWQG Guideline	75th%	Long Lake	Mills Lake	Pike Lake South	Waldorf River
7Q20 flow	m^3/sec	-----	-----	7.01	0.367	0.120	0.518
Instantaneous Load				kg/sec			
Arsenic	µg/L	5	0.5	3.15×10^{-5}	1.65×10^{-6}	5.42×10^{-7}	2.33×10^{-6}
Copper	µg/L	2	1	7.01×10^{-6}	3.67×10^{-7}	1.20×10^{-7}	5.18×10^{-7}
Iron	µg/L	300	140	1.12×10^{-3}	5.86×10^{-5}	1.93×10^{-5}	8.29×10^{-5}
Lead	µg/L	1	0.25	5.25×10^{-6}	2.75×10^{-7}	9.04×10^{-8}	3.89×10^{-7}
Nickel	µg/L	25	1.0	1.68×10^{-4}	8.80×10^{-6}	2.89×10^{-6}	1.24×10^{-5}
Zinc	µg/L	30	5.2	1.74×10^{-4}	9.09×10^{-6}	2.99×10^{-6}	1.29×10^{-5}

6.0 CLOSURE

This report has been prepared for the sole benefit of Alderon Resource Corp. The report may not be used by any other person or entity without the express written consent of Stassinu Stantec Limited Partnership and Alderon Resource Corp.

Any uses that a third party makes of this report, or any reliance on decisions made based on it, are the responsibility of such third parties. Stassinu Stantec Limited Partnership accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made, or actions taken, based on this report.

The information and conclusions contained in this report are based upon work undertaken by trained professional and technical staff in accordance with generally accepted engineering and scientific practices current at the time the work was performed. Conclusions and recommendations presented in this report should not be construed as legal advice.

The conclusions presented in this report represent the best technical judgement of Stassinu Stantec Limited Partnership based on the data obtained from the work. If any conditions become apparent that differ significantly from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein.

Respectfully submitted,

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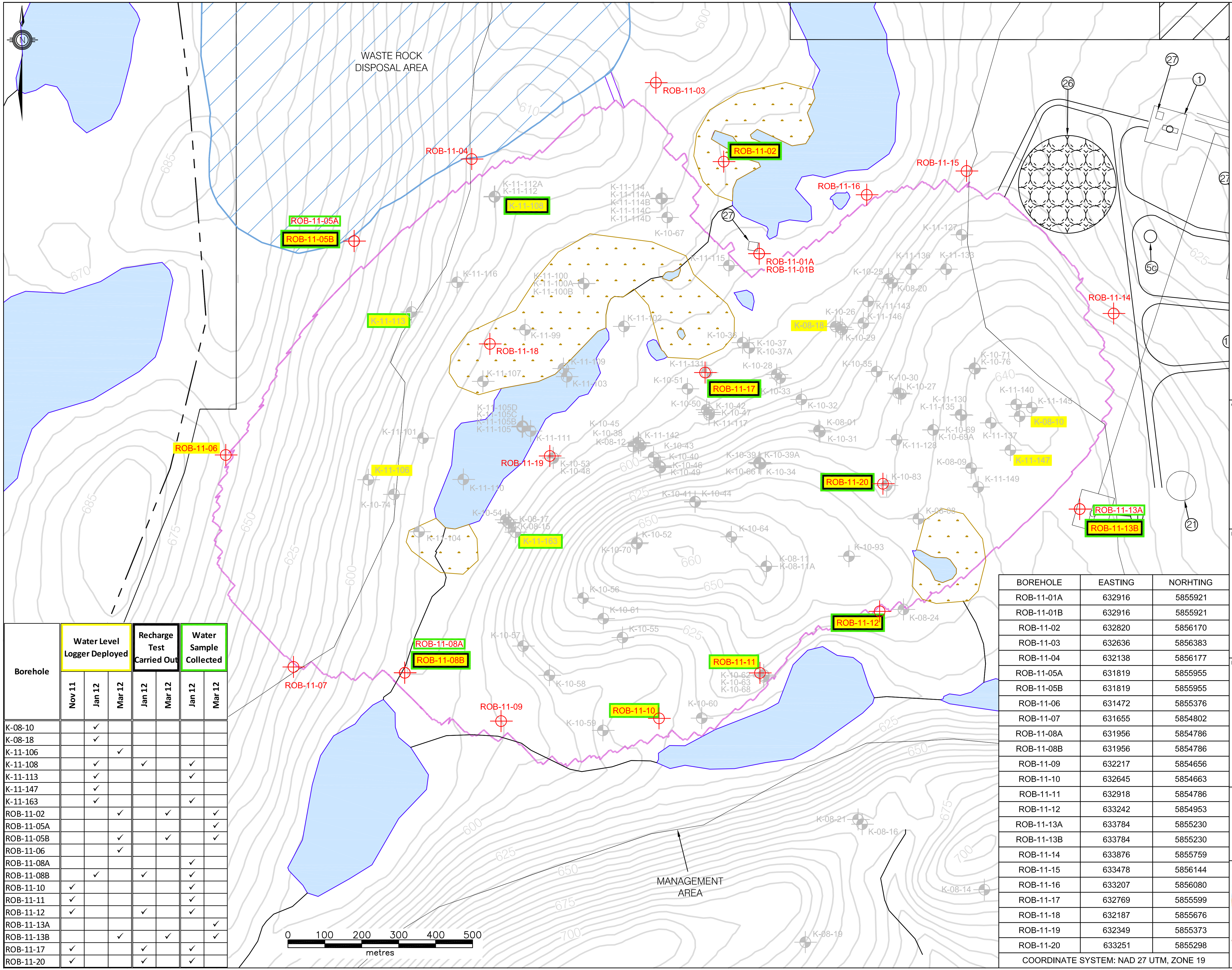
Appendix A

Figures and Drawings


WASTE ROCK DISPOSAL AREA
MANAGEMENT AREA
ROB-11-01A
ROB-11-01B
ROB-11-02
ROB-11-03
ROB-11-04
ROB-11-05A
ROB-11-05B
ROB-11-06
ROB-11-07
ROB-11-08A
ROB-11-08B
ROB-11-09
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ROB-11-11
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K-08-18
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K-11-114C
K-11-114D
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K-08-21
K-08-16
K-08-14
K-08-19
600
610
625
640
650
660
670
675
685
700
(1)
(5c)
(21)
(26)
(27)
0 100 200 300 400 500
metres

LEGEND

⊕	OVB BOREHOLE (2012 / 2011)
⊕	EXPLORATION BOREHOLE
—	PIT SHELL
—	CLAIM BLOCK
═	PROPOSED ROADS
⬭	LAKES
⬭	WETLANDS

PROPOSED SITE FEATURES

①	Primary Crusher Building
(5c)	Fuel Tank Farm And Fueling Station (Mine Vehicles)
⑮	Mine Truck Wash Bay
㉑	Explosives Magazine
㉖	ROM Stockpile
㉗	Run-Off Water Retention Basin

NOTE:
1) THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC CONSULTING LTD. REPORT AND MUST NOT BE USED FOR OTHER PURPOSES.
2) DRAWING IS BASED ON CLIENT PROVIDED CAD DRAWING "3054001-004000-45-D00-0001-RAJ".
3)COORDINATE SYSTEM: ZONE 19 UTM, NAD 27
4) ROSE PIT SHELL FOOTPRINT REVISED JANUARY 31, 2012 BY BBA.

Borehole	Water Level Logger Deployed			Recharge Test Carried Out		Water Sample Collected	
	Nov 11	Jan 12	Mar 12	Jan 12	Mar 12	Jan 12	Mar 12
K-08-10		✓					
K-08-18		✓					
K-11-106			✓				
K-11-108		✓		✓		✓	
K-11-113		✓				✓	
K-11-147		✓					
K-11-163		✓				✓	
ROB-11-02			✓		✓		✓
ROB-11-05A							✓
ROB-11-05B			✓		✓		✓
ROB-11-06			✓				
ROB-11-08A						✓	
ROB-11-08B		✓		✓		✓	
ROB-11-10	✓					✓	
ROB-11-11	✓					✓	
ROB-11-12	✓			✓		✓	
ROB-11-13A							✓
ROB-11-13B			✓		✓		✓
ROB-11-17	✓			✓		✓	
ROB-11-20	✓			✓		✓	

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BOREHOLE	EASTING	NORHTING
ROB-11-01A	632916	5855921
ROB-11-01B	632916	5855921
ROB-11-02	632820	5856170
ROB-11-03	632636	5856383
ROB-11-04	632138	5856177
ROB-11-05A	631819	5855955
ROB-11-05B	631819	5855955
ROB-11-06	631472	5855376
ROB-11-07	631655	5854802
ROB-11-08A	631956	5854786
ROB-11-08B	631956	5854786
ROB-11-09	632217	5854656
ROB-11-10	632645	5854663
ROB-11-11	632918	5854786
ROB-11-12	633242	5854953
ROB-11-13A	633784	5855230
ROB-11-13B	633784	5855230
ROB-11-14	633876	5855759
ROB-11-15	633478	5856144
ROB-11-16	633207	5856080
ROB-11-17	632769	5855599
ROB-11-18	632187	5855676
ROB-11-19	632349	5855373
ROB-11-20	633251	5855298
COORDINATE SYSTEM: NAD 27 UTM, ZONE 19		

CLIENT:

ALDERON
IRON ORE CORP

PROJECT TITLE:

KAMI IRON ORE PROJECT
HYDROGEOLOGY

DRAWING TITLE:

HYDROGEOLOGY INVESTIGATION STATUS
AND BOREHOLE LOCATION PLAN

Stantec Consulting Ltd.

Stantec

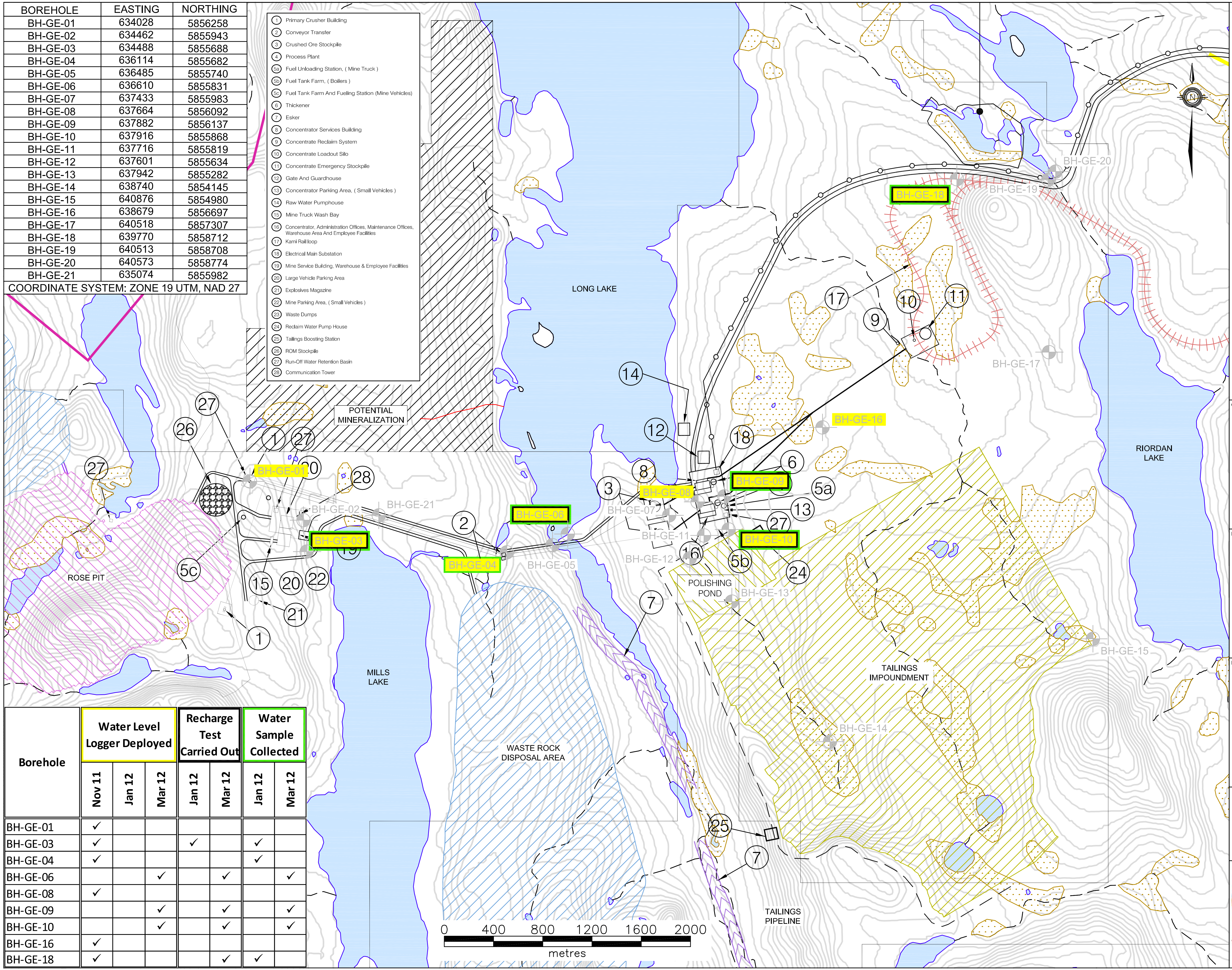
SCALE:	1:10,000	DATE:	JUNE 12, 2012
DRAWN BY:	R.L.	CHECKED BY:	
EDITED BY:	-	REV. No.	0
DRAWING No:	121614000-306-GE-06		
CAD FILE:	121614000-306-GE-AS-06.DWG		

12JUNE12 2:30PM

BOREHOLE	EASTING	NORTHING
BH-GE-01	634028	5856258
BH-GE-02	634462	5855943
BH-GE-03	634488	5855688
BH-GE-04	636114	5855682
BH-GE-05	636485	5855740
BH-GE-06	636610	5855831
BH-GE-07	637433	5855983
BH-GE-08	637664	5856092
BH-GE-09	637882	5856137
BH-GE-10	637916	5855868
BH-GE-11	637716	5855819
BH-GE-12	637601	5855634
BH-GE-13	637942	5855282
BH-GE-14	638740	5854145
BH-GE-15	640876	5854980
BH-GE-16	638679	5856697
BH-GE-17	640518	5857307
BH-GE-18	639770	5858712
BH-GE-19	640513	5858708
BH-GE-20	640573	5858774
BH-GE-21	635074	5855982

COORDINATE SYSTEM: ZONE 19 UTM, NAD 27

①	Primary Crusher Building
②	Conveyor Transfer
③	Crushed Ore Stockpile
④	Process Plant
(5a)	Fuel Unloading Station, (Mine Truck)
(5b)	Fuel Tank Farm, (Boilers)
(5c)	Fuel Tank Farm And Fueling Station (Mine Vehicles)
⑥	Thickener
⑦	Esker
⑧	Concentrator Services Building
⑨	Concentrate Reclaim System
⑩	Concentrate Loadout Silo
⑪	Concentrate Emergency Stockpile
⑫	Gate And Guardhouse
⑬	Concentrator Parking Area, (Small Vehicles)
⑭	Raw Water Pumphouse
⑮	Mine Truck Wash Bay
⑯	Concentrator, Administration Offices, Maintenance Offices, Warehouse Area And Employee Facilities
⑰	Kami Rail loop
⑱	Electrical Main Substation
⑲	Mine Service Building, Warehouse & Employee Facilities
⑳	Large Vehicle Parking Area
㉑	Explosives Magazine
㉒	Mine Parking Area, (Small Vehicles)
㉓	Waste Dumps
㉔	Reclaim Water Pump House
㉕	Tailings Boosting Station
㉖	ROM Stockpile
㉗	Run-Off Water Retention Basin
㉘	Communication Tower


POTENTIAL MINERALIZATION
LONG LAKE
RIORDAN LAKE
ROSE PIT
MILLS LAKE
WASTE ROCK DISPOSAL AREA
POLISHING POND
TAILINGS IMPOUNDMENT
TAILINGS PIPELINE
BH-GE-01
BH-GE-02
BH-GE-03
BH-GE-04
BH-GE-05
BH-GE-06
BH-GE-07
BH-GE-08
BH-GE-09
BH-GE-10
BH-GE-11
BH-GE-12
BH-GE-13
BH-GE-14
BH-GE-15
BH-GE-16
BH-GE-17
BH-GE-18
BH-GE-19
BH-GE-20
BH-GE-21
N
0 400 800 1200 1600 2000
metres

Borehole	Water Level Logger Deployed			Recharge Test Carried Out		Water Sample Collected	
	Nov 11	Jan 12	Mar 12	Jan 12	Mar 12	Jan 12	Mar 12
BH-GE-01	✓						
BH-GE-03	✓			✓		✓	
BH-GE-04	✓					✓	
BH-GE-06			✓		✓		✓
BH-GE-08	✓						
BH-GE-09			✓		✓		✓
BH-GE-10			✓		✓		✓
BH-GE-16	✓						
BH-GE-18	✓				✓	✓	

LEGEND

—	EXISTING RAIL SPUR
┼┼┼┼	KAMI PROPOSED RAIL SPUR
—	EXISTING ROADS
—	EXISTING ROADS TO UPGRADE
—	PROPOSED ROADS
-//-//-	POWER LINE (315 kV)
—	WATERCOURSES
⌖	BOREHOLE
●	LAKES
▨	WETLANDS
🟨	WATER LEVEL LOGGER DEPLOYED
☐	RECHARGE TEST CARRIED OUT
🟩	WATER SAMPLE COLLECTED

NOTE:
1) THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC CONSULTING LTD. REPORT AND MUST NOT BE USED FOR OTHER PURPOSES.
2) BASED ON BBA PROVIDED DRAWING "3054001-004000-45-D00-XXXX_ROAD ALT. N°1_018-08-11_wastedumps_ WITHOUT MILLS.DWG AND STANTEC DRAWING No. 121614000-300-01.DWG.
3)COORDINATE SYSTEM: NAD27, ZONE 19U

CLIENT:

ALDERON IRON ORE CORP

PROJECT TITLE:

KAMI IRON ORE PROJECT
HYDROGEOLOGY

DRAWING TITLE:

HYDROGEOLOGY INVESTIGATION STATUS AND BOREHOLE LOCATION PLAN

Stantec Consulting Ltd.

Stantec

SCALE: 1:30,000	DATE: JUNE 12, 2012
DRAWN BY: R.L.	CHECKED BY:
EDITED BY: -	REV. No. 0
DRAWING No: 121614000-306-GE-07	
CAD FILE: 121614000-306-GE-AS-07.DWG	

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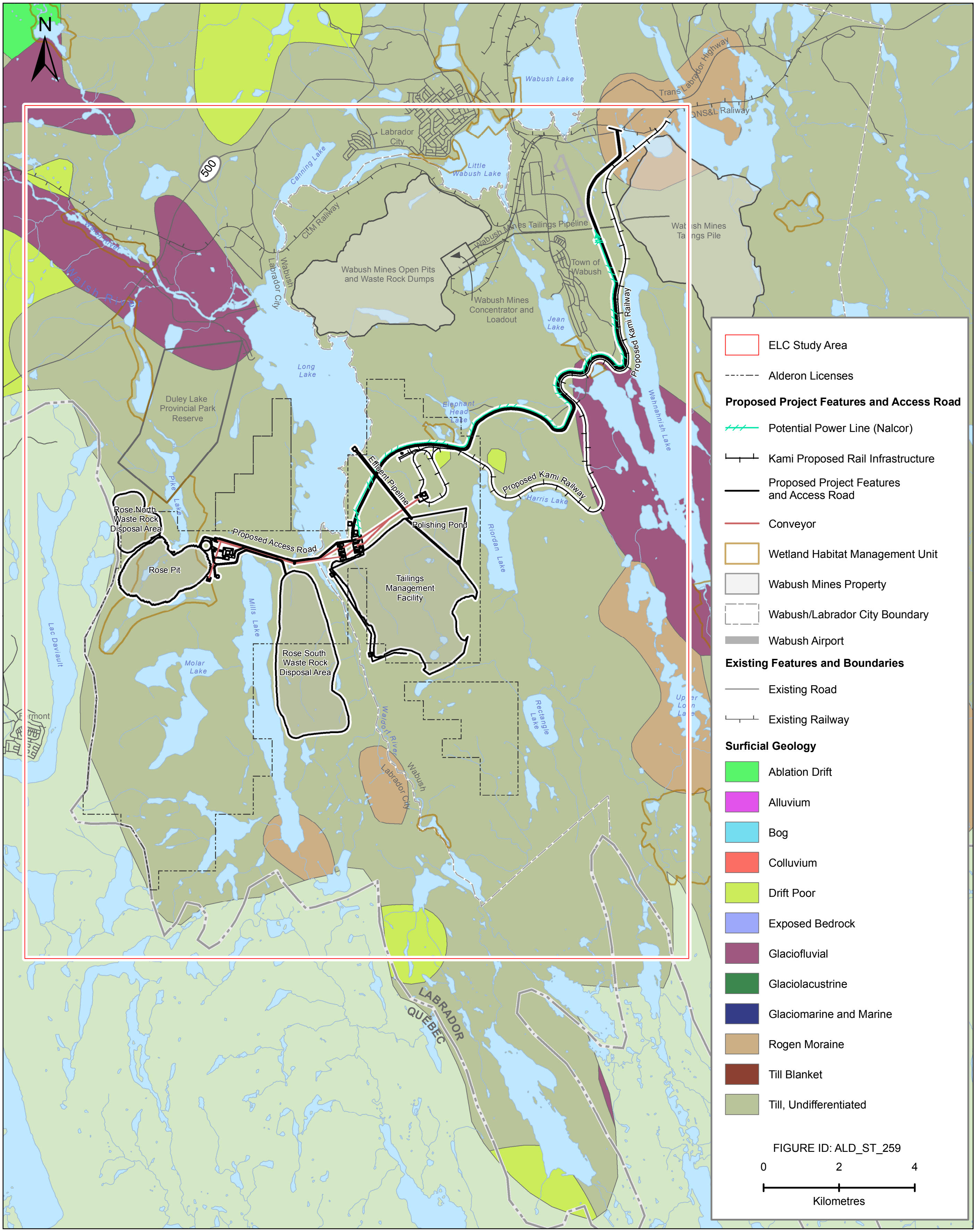
13JUNE12 3:30PM


N
500
Labrador City
Canning Lake
Wabush Lake
Little Wabush Lake
Trans Labrador Highway
QNS&L Railway
CLM Railway
Walsh River
Wabush Mines Tailings Pipeline
Wabush Mines Tailings Pile
Wabush Mines Open Pits and Waste Rock Dumps
Town of Wabush
Wabush Mines Concentrator and Loadout
Jean Lake
Wabush Labrador City
Long Lake
Proposed Kami Railway
Wahnahnish Lake
Elephant Head Lake
Duley Lake Provincial Park Reserve
Pike Lake
Effluent Pipeline
Polishing Pond
Harris Lake
Riordan Lake
Rose North Waste Rock Disposal Area
Proposed Access Road
Rose Pit
Tailings Management Facility
Mills Lake
Lac Daviault
Molar Lake
Rose South Waste Rock Disposal Area
Fermont
Waldorf River
Wabush Labrador City
Rectangle Lake
Upper Lorn Lake
LABRADOR
QUEBEC
ELC Study Area
Alderon Licenses
Proposed Project Features and Access Road
Potential Power Line (Nalcor)
Kami Proposed Rail Infrastructure
Proposed Project Features and Access Road
Conveyor
Wetland Habitat Management Unit
Wabush Mines Property
Wabush/Labrador City Boundary
Wabush Airport
Existing Features and Boundaries
Existing Road
Existing Railway
Surficial Geology
Ablation Drift
Alluvium
Bog
Colluvium
Drift Poor
Exposed Bedrock
Glaciofluvial
Glaciolacustrine
Glaciomarine and Marine
Rogen Moraine
Till Blanket
Till, Undifferentiated
FIGURE ID: ALD_ST_259
0
2
4
Kilometres

CLIENT:

ALDERON IRON ORE CORP

DRAWING TITLE:

SURFICIAL GEOLOGY IN LABRADOR

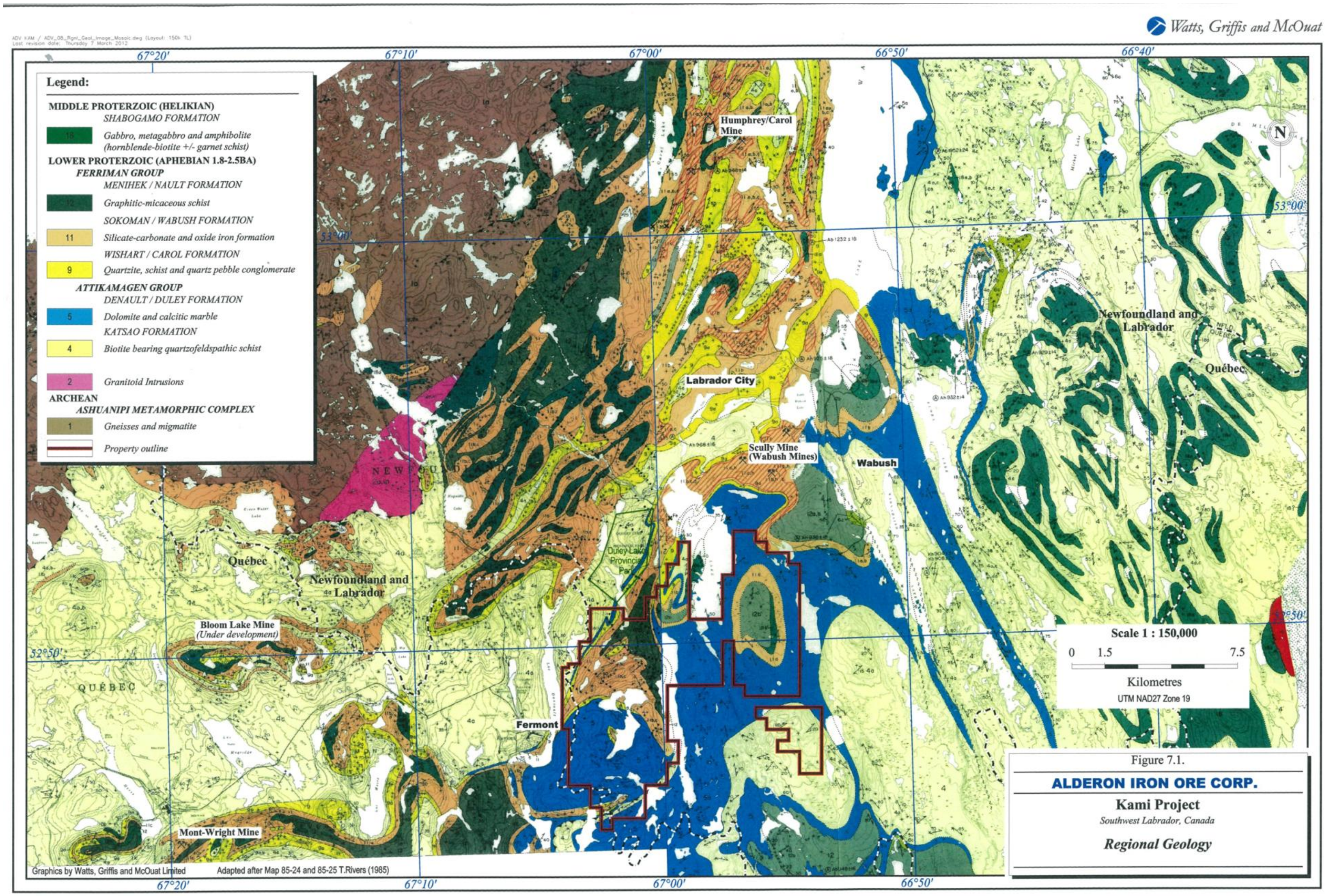

Watts, Griffis and McOuat
67°20'
67°10'
67°00'
66°50'
66°40'
53°00'
52°50'
Legend:
MIDDLE PROTERZOIC (HELIKIAN)
SHABOGAMO FORMATION
13 Gabbro, metagabbro and amphibolite (hornblende-biotite +/- garnet schist)
LOWER PROTERZOIC (APHEBIAN 1.8-2.5BA)
FERRIMAN GROUP
MENIHEK / NAULT FORMATION
12 Graphitic-micaceous schist
SOKOMAN / WABUSH FORMATION
11 Silicate-carbonate and oxide iron formation
WISHART / CAROL FORMATION
9 Quartzite, schist and quartz pebble conglomerate
ATTIKAMAGEN GROUP
DENAULT / DULEY FORMATION
5 Dolomite and calcitic marble
KATSAO FORMATION
4 Biotite bearing quartzofeldspathic schist
2 Granitoid Intrusions
ARCHEAN
ASHUANIPI METAMORPHIC COMPLEX
1 Gneisses and migmatite
Property outline
Humphrey/Carol Mine
Labrador City
Scully Mine (Wabush Mines)
Wabush
Newfoundland and Labrador
Québec
Duley Lake Provincial Park
Fermont
Bloom Lake Mine (Under development)
Mont-Wright Mine
QUÉBEC
NEWFOUNDLAND
N
Scale 1 : 150,000
0 1.5 7.5
Kilometres
UTM NAD27 Zone 19
Figure 7.1.
ALDERON IRON ORE CORP.
Kami Project
Southwest Labrador, Canada
Regional Geology
Graphics by Watts, Griffis and McOuat Limited
Adapted after Map 85-24 and 85-25 T.Rivers (1985)

Figure 7.1: Regional Geology

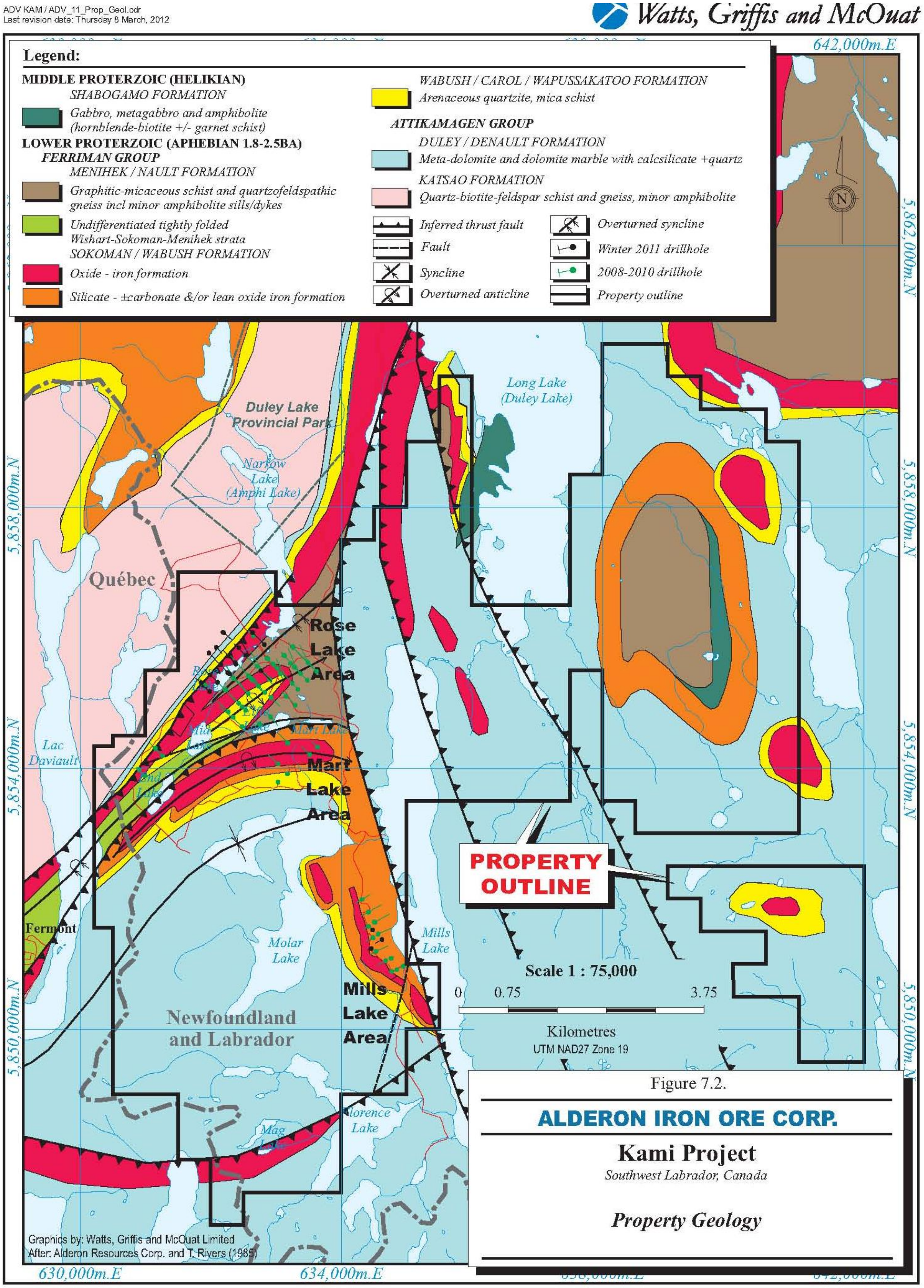
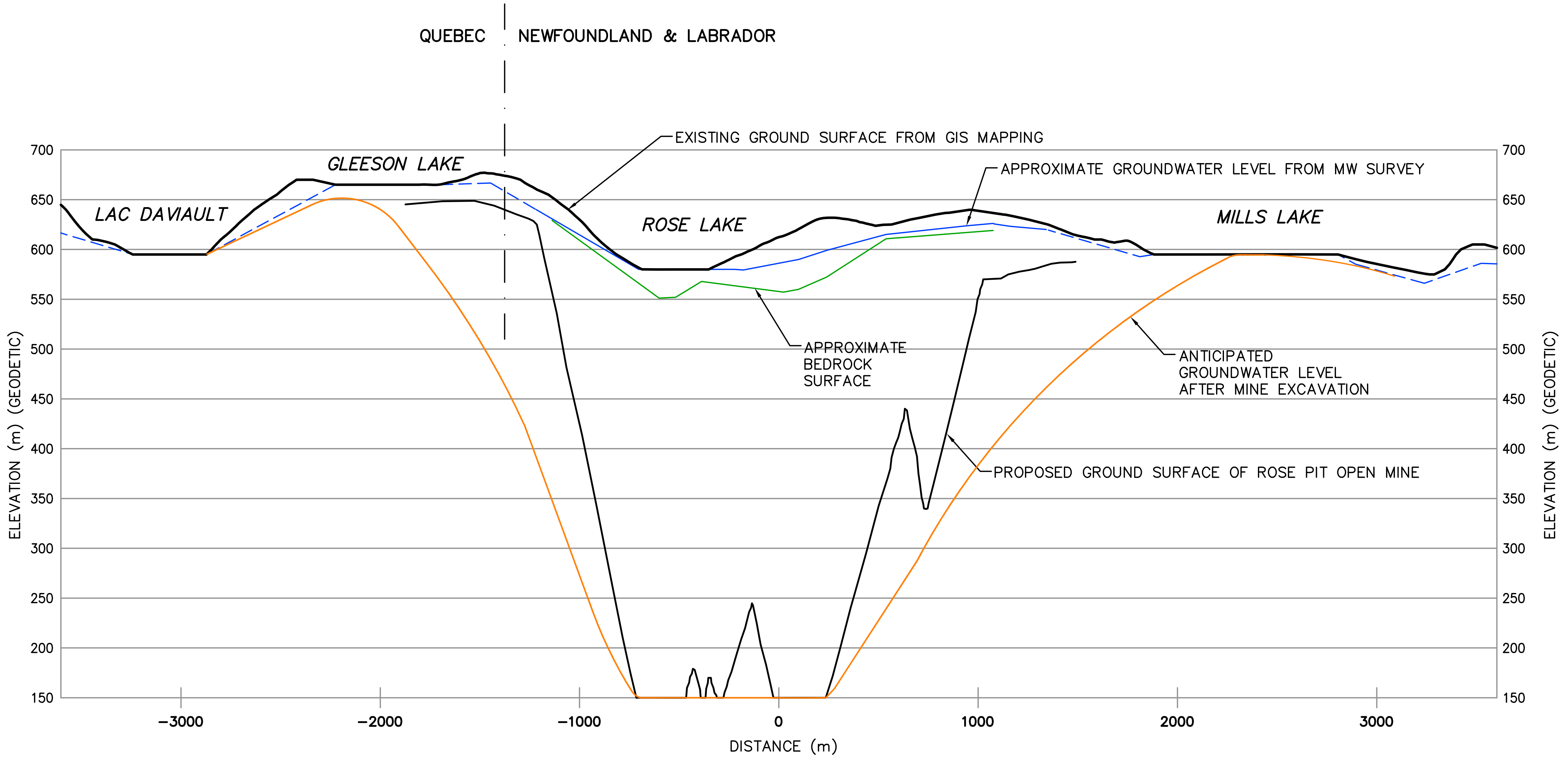

ADV KAM / ADV_11_Prop_Geol.cdr
Last revision date: Thursday 8 March, 2012
Watts, Griffis and McOuat
Legend:
MIDDLE PROTERZOIC (HELIKIAN)
SHABOGAMO FORMATION
Gabbro, metagabbro and amphibolite (hornblende-biotite +/- garnet schist)
LOWER PROTERZOIC (APHEBIAN 1.8-2.5BA)
FERRIMAN GROUP
MENIHEK / NAULT FORMATION
Graphitic-micaceous schist and quartzofeldspathic gneiss incl minor amphibolite sills/dykes
Undifferentiated tightly folded Wishart-Sokoman-Menihek strata
SOKOMAN / WABUSH FORMATION
Oxide - iron formation
Silicate - ±carbonate &/or lean oxide iron formation
WABUSH / CAROL / WAPUSSAKATOO FORMATION
Arenaceous quartzite, mica schist
ATTIKAMAGEN GROUP
DULEY / DENAULT FORMATION
Meta-dolomite and dolomite marble with calcsilicate +quartz
KATSAO FORMATION
Quartz-biotite-feldspar schist and gneiss, minor amphibolite
Inferred thrust fault
Fault
Syncline
Overturned anticline
Overturned syncline
Winter 2011 drillhole
2008-2010 drillhole
Property outline
642,000m.E
N
5,862,000m.N
5,858,000m.N
5,854,000m.N
5,850,000m.N
Long Lake (Duley Lake)
Duley Lake Provincial Park
Narrow Lake (Amphi Lake)
Québec
Rose Lake Area
Mart Lake
Mart Lake Area
Lac Daviault
Fermont
Molar Lake
Mills Lake
Mills Lake Area
Newfoundland and Labrador
Florence Lake
Mag Lake
PROPERTY OUTLINE
Scale 1 : 75,000
0 0.75 3.75
Kilometres
UTM NAD27 Zone 19
Figure 7.2.
ALDERON IRON ORE CORP.
Kami Project
Southwest Labrador, Canada
Property Geology
Graphics by: Watts, Griffis and McOuat Limited
After: Alderon Resources Corp. and T. Rivers (1985)
630,000m.E
634,000m.E

Figure 7.2: Property Geology



NOTE: THIS DRAWING ILLUSTRATES SUPPORTING INFORMATION SPECIFIC TO A STANTEC CONSULTING LTD. REPORT AND MUST NOT BE USED FOR OTHER PURPOSES.

CLIENT:	ALDERON RESOURCE CORP.
PROJECT TITLE:	PROJECT DEVELOPMENT DESIGN KAMI MINE SITE
DRAWING TITLE:	CROSS-SECTION SHOWING APPROXIMATE REGIONAL GROUNDWATER LEVEL

SCALE: 1:2500 H 1:500V	DATE: JUN. 1, 2012
DRAWN BY: BSP	CHECKED BY:
EDITED BY: -	REV. No. 0
DRAWING No: 121614000-306-GE-06	
CAD FILE: 121614000-306-GE-06.dwg	

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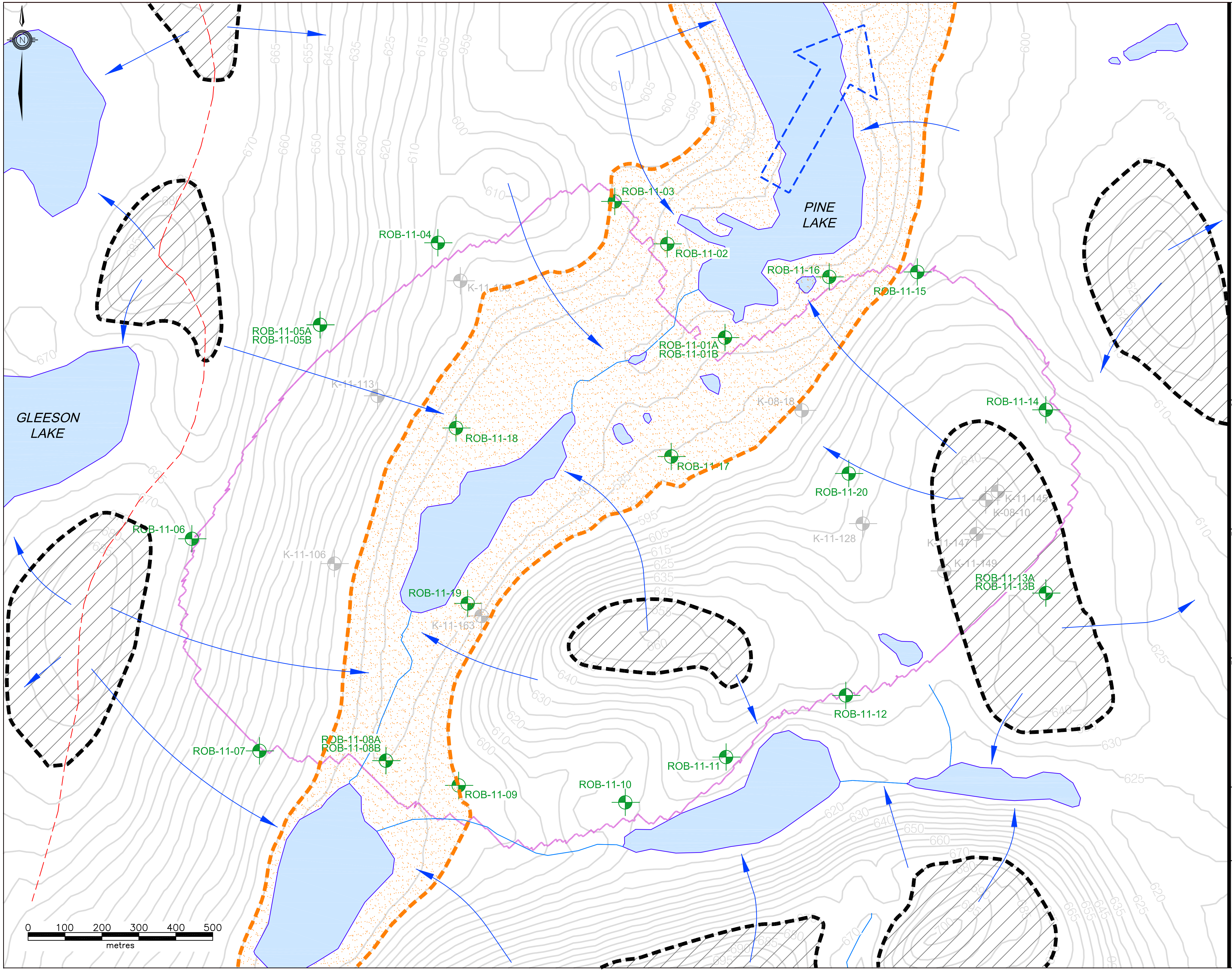
PINE LAKE
GLEESON LAKE
ROB-11-03
ROB-11-04
ROB-11-02
ROB-11-16
ROB-11-15
K-11-110
ROB-11-05A
ROB-11-05B
K-11-113
ROB-11-01A
ROB-11-01B
K-08-18
ROB-11-14
ROB-11-18
ROB-11-17
ROB-11-20
K-11-145
K-08-10
ROB-11-06
K-11-106
K-11-128
K-11-147
K-11-149
ROB-11-13A
ROB-11-13B
ROB-11-19
K-11-163
ROB-11-12
ROB-11-07
ROB-11-08A
ROB-11-08B
ROB-11-11
ROB-11-10
ROB-11-09
0 100 200 300 400 500
metres
N

LEGEND

OVB BOREHOLE (2012 / 2011)

EXPLORATION BOREHOLE

PIT SHELL

LAKES

LOCAL WATERSHED DIVIDE

INFERRED LOCAL GROUNDWATER FLOW DIRECTION

REGIONAL FLOW DIRECTION

LOCAL DISCHARGE AREA

LOCAL RECHARGE AREA

NOTE:
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2) DRAWING IS BASED ON CLIENT PROVIDED CAD DRAWING "3054001-004000-45-D00-0001-RAJ".
3)COORDINATE SYSTEM: ZONE 19 UTM, NAD 27
4) ROSE PIT SHELL FOOTPRINT REVISED JANUARY 31, 2012 BY BBA.

CLIENT:

ALDERON
IRON ORE CORP

PROJECT TITLE:

KAMI IRON ORE PROJECT
HYDROGEOLOGY

DRAWING TITLE:

GROUNDWATER FLOW
DIRECTIONS IN VICINITY OF
ROSE PIT

Stantec Consulting Ltd.

Stantec

SCALE: 1:10,000	DATE: JUNE 12, 2012
DRAWN BY: R.L. / BSP	CHECKED BY:
EDITED BY: -	REV. No. 0
DRAWING No: FIGURE A.7	
CAD FILE: 121614000-306-GE-AS-FigA7.DWG	

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04JUNE12 3:10PM

Appendix B

Summary Tables

Table B.1 Summary of Groundwater Monitoring Well Construction Details

Alderon Iron Ore Corp, Kami Iron Ore Project, Wabush, NL

Stantec Project No. 121614000.484

Borehole ID	Northing (m)	Easting (m)	Borehole Location^2	Screened Unit ^{1}	Date Completed	Depth (BH) (m)	Depth (MW) (m)^3	Elev Grade (m)	Elev TOC (m)	PVC Stick-up (m)	Water Level (mbtoc)	Water Level (mbg)	Screen		Sand Pack		Bedrock Depth (mbg)	K^4 (m/s)
													from (m)	to (m)	from (m)	to (m)		
BH-GE-01	5856263.6	634018.1	West Plant	Bedrock	5-Sep-11	4.62	4.62	618.74	619.60	0.86	3.91	3.05	3.05	4.62	2.83	4.62	0.8	-
BH-GE-02	5855948.7	634452.5	West Plant	overburden	6-Sep-11	15.38	15.38	592.46	593.58	1.12	0.18	-0.94	12.15	15.20	3.00	15.35	-	-
BH-GE-03	5855693.5	634478.4	West Plant	Overburden	8-Sep-11	15.47	15.47	591.41	592.32	0.91	0.26	-0.65	12.20	15.50	6.35	15.50	-	6.78E-07
BH-GE-04	5855687.5	636104.2	Access Rd	till/rock	9-Sep-11	11.78	11.78	563.90	564.81	0.91	5.56	4.65	8.73	11.78	2.74	11.78	8.68	-
BH-GE-05	5855745.5	636475.6	Access Rd	till/rock	11-Sep-11	16.58	15.58	542.21	543.10	0.89	4.06	3.17	13.53	16.58	2.44	16.58	13.5	-
BH-GE-06	5855836.4	636599.7	Access Rd	overburden	12-Sep-11	15.84	15.25	540.26	541.17	0.91	2.9	1.99	12.20	15.84	3.05	15.84	-	2.60E-05
BH-GE-07	5855987.9	637423.3	East Plant	till/rock	13-Sep-11	10.89	10.89	542.76	543.65	0.89	0.81	-0.08	7.85	10.89	3.05	10.89	7.85	-
BH-GE-08	5856097.4	637653.9	East Plant	till/rock	14-Sep-11	8.23	8.23	548.04	548.95	0.91	3.54	2.63	5.18	8.23	3.20	8.23	5.13	-
BH-GE-09	5856142.0	637871.8	East Plant	overburden	16-Sep-11	9.37	9.25	564.44	565.43	0.99	0.55	-0.44	6.10	9.37	3.35	9.37	-	7.26E-07
BH-GE-10A	5855873.3	637906.2	East Plant	overburden	17-Sep-11	9.19	9.15	559.71	560.88	1.17	0.05	-1.12	6.10	9.19	2.44	9.19	-	2.55E-07
BH-GE-10B	5855873.3	637906.2	East Plant	bedrock	14-Nov-11	16.53	16.55	-	-	-	-	-	-	-	-	-	12.26	-
BH-GE-11	5855824.8	637706.1	East Plant	overburden	15-Nov-11	9.14	9.14	550.24	551.28	1.04	-1.02	-2.06	6.10	9.14	2.74	9.14	-	-
BH-GE-11B	5855824.8	637706.1	East Plant	till/rock	1-Dec-11	53.00	53.00	-		-	-	-	-	-	-	-	48.4	-
BH-GE-12	5855639.7	637590.9	East Plant	overburden	18-Sep-11	12.42	12.20	553.51	554.53	1.02	-0.92	-1.94	4.57	12.42	2.74	12.42	-	-
BH-GE-13	5855287.6	637932.5	TMF	overburden	19-Sep-11	10.79	10.70	557.22	558.29	1.07	0.76	-0.31	4.57	10.81	2.74	10.81	-	-
BH-GE-14	5854150.1	638729.8	TMF	overburden	20-Sep-11	11.12	10.70	577.06	578.15	1.09	0.1	-0.99	4.57	11.12	2.44	11.12	-	-
BH-GE-15	5854985.4	640865.7	TMF	overburden	21-Sep-11	9.75	9.15	607.58	608.70	1.12	0.92	-0.2	4.57	9.75	2.95	9.75	-	-
BH-GE-16	5856702.0	638669.0	RR	bedrock	21-Sep-11	4.57	4.57	583.41	584.63	1.22	0.87	-0.35	2.44	4.57	1.67	4.57	0.9	-
BH-GE-17	5857312.9	640508.6	RR	till/rock	24-Sep-11	9.32	9.20	590.45	591.67	1.22	-0.35	-1.57	4.65	9.32	3.05	9.32	7.02	-
BH-GE-18	5858717.6	639760.4	RR	overburden	25-Sep-11	13.36	12.20	582.96	584.03	1.07	0.65	-0.42	3.05	12.20	2.44	12.20	-	2.41E-07
BH-GE-19	5858712.5	640502.7	RR	till/rock	28-Sep-11	10.67	10.67	573.26	574.20	0.94	0.15	-0.79	6.10	10.67	2.74	10.67	6.1	-
BH-GE-20	5858778.6	640562.7	RR	overburden	27-Sep-11	12.42	12.20	570.81	571.83	1.02	-1.00	-2.02	4.57	12.20	3.05	12.20	-	-
ROB-11-01A	5855909.0	632922.6	Rose Pit perimeter	bedrock	6-Oct-11	50.90	50.80	571.16	572.05	0.89	-0.60	-1.49	47.30	50.80	47.20	50.80	47.00	-
ROB-11-01B	5855909.2	632922.0	Rose Pit perimeter	overburden	9-Oct-11	46.60	46.60	571.16	572.12	0.96	-0.60	-1.56	3.96	46.53	3.05	46.53	-	-
ROB-11-02	632768.9	5856168.6	Rose Pit perimeter	till/rock	23-Feb-12	25.90	25.90	569.00	569.91	0.91	0.58	-0.33	4.57	25.90	3.05	25.90	21.43	9.49E-08
ROB-11-03	632768.9	5856168.6	Rose Pit perimeter	till/rock	9-Feb-12	23.60	23.60	569.00	570.12	1.12	-0.82	-1.94	3.82	23.60	2.74	23.60	20.11	-
ROB-11-04	632626.8	5856280.0	Rose Pit perimeter	till/rock	6-Apr-12	24.40	21.30	576.07	-	?	?	?	3.15	21.30	2.45	21.30	20.5	-
ROB-11-05A	632137.6	5856176.8	Rose Pit perimeter	bedrock	10-Mar-12	19.58	19.58	595.10	596.01	0.91	1.91	0.995	16.70	19.58	16.50	19.58	19.5	-
ROB-11-05B	632137.6	5856176.8	Rose Pit perimeter	overburden	15-Mar-12	13.72	13.72	595.10	595.10		1.63	1.63	4.70	13.72	3.10	13.72	-	1.16E-06
ROB-11-06	631477.2	5855363.8	Rose Pit perimeter	till/rock	28-Feb-12	13.72	13.72	653.32	654.46	1.14	12.14	11.00	4.57	13.72	2.44	13.72	9.96	-

Table B.1 Summary of Groundwater Monitoring Well Construction Details
Alderon Iron Ore Corp, Kami Iron Ore Project, Wabush, NL
Stantec Project No. 121614000.484

Borehole ID	Northing (m)	Easting (m)	Borehole Location[2]	Screened Unit [1]	Date Completed	Depth (BH) (m)	Depth (MW) (m)[3]	Elev Grade (m)	Elev TOC (m)	PVC Stick-up (m)	Water Level (mbtoc)	Water Level (mbg)	Screen		Sand Pack		Bedrock Depth (mbg)	K[4] (m/s)
													from (m)	to (m)	from (m)	to (m)		
ROB-11-07	631669.7	5854799.2	Rose Pit perimeter	till/rock	3-Apr-12	60.05	60.05	600.33	-	1.01	-	-	4.11	58.98	3.05	60.05	52.42	-
ROB-11-08A	5854776.0	631997.0	Rose Pit perimeter	till/rock	28-Oct-11	29.00	28.60	579.20	580.65	1.45	0.00	-1.45	6.71	28.55	6.80	29.00	22.86	-
ROB-11-08B	5854777.0	631998.0	Rose Pit perimeter	Overburden	11-Nov-11	9.10	9.10	579.20	580.11	0.91	-0.91	-1.82	6.10	9.04	2.15	9.04	-	-
ROB-11-09	5854709.0	632194.0	Rose Pit perimeter	till/rock	5-Nov-11	30.50	30.50	589.70	590.59	0.89	-0.90	-1.79	24.38	30.50	3.10	30.50	25.90	-
ROB-11-10	5854664.0	632653.0	Rose Pit perimeter	till/rock	18-Oct-11	7.60	7.60	617.29	618.36	1.07	4.29	3.22	1.52	7.52	0.91	7.60	3.58	-
ROB-11-11	5854769.9	632918.0	Rose Pit perimeter	till/rock	19-Oct-11	5.80	5.80	618.39	619.53	1.14	0.85	-0.29	2.77	5.80	2.20	5.80	1.75	-
ROB-11-12	5854944.1	633248.9	Rose Pit perimeter	till/rock	21-Oct-11	7.50	7.50	631.15	632.19	1.04	0.15	-0.89	1.37	7.37	0.90	7.37	3.92	-
ROB-11-13A	633783.7	5855229.5	Rose Pit perimeter	till/rock	18-Mar-12	15.24	15.24	633.20	633.20				12.30	15.24	11.60	15.24	11.28	-
ROB-11-13B	633786.7	5855229.5	Rose Pit perimeter	Overburden	24-Mar-12	10.67	10.67	633.20	633.20				1.60	10.67	1.40	10.67	-	1.92E-06
ROB-11-14	633875.6	5855758.7	Rose Pit perimeter	till/rock	25-Mar-12	9.14	9.15	605.80	605.80				3.15	9.14	2.40	9.14	4.82	-
ROB-11-15	5856144.5	633477.5	Rose Pit perimeter	till/rock	8-Apr-12	8.98	8.98	598.60	599.54	0.94	-	-	3.05	8.98	2.82	8.98	4.30	-
ROB-11-16	5856090.6	633217.9	Rose Pit perimeter	till/rock	25-Oct-11	16.50	16.50	571.24	572.31	1.07	-0.55	-1.62	4.32	16.41	3.05	16.41	12.20	-
ROB-11-17	5855590.8	632777.5	Rose Pit interior	till/rock	13-Oct-11	47.90	47.90	580.75	581.71	0.96	1.10	0.14	5.18	47.75	4.57	47.75	43.30	3.17E-08
ROB-11-18	5855668.2	632197.9	Rose Pit interior	till/rock	16-Oct-11	30.50	30.50	575.17	576.29	1.12	0.00	-1.12	3.05	30.38	2.44	30.38	26.50	-
ROB-11-19	632349.0	5855373.0	Rose Pit interior	till/rock	9-Apr-12	14.95	14.95	574.40	574.40				2.90	14.95	2.10	14.95	9.30	-
ROB-11-20	5855553.0	633250.0	Rose Pit interior	till/rock	23-Oct-11	15.10	15.10	612.00	613.06	1.06	2.49	1.43	3.05	15.01	1.51	15.01	10.20	1.16E-06
RBR-12-01				bedrock							-0.80						33.05	1.51E-06
RBR-12-02				bedrock							2.90						16.40	

Note 1: Overburden - silty sand glacial till; till/bedrock -sandpacked across till-bedrock interface; bedrock - sandpack sealed inbedrock
Note 2: TMF - Tailings Management faciilty; RR - Rail Loadout and Tracks; WWD - Waste Rock Disposal Area
Note 3: m - metres; mbg - metres below ground; mbtoc - metres below top of PVC casing
Note 4: K - Hydraulic Conductivity in meters per second (m/s)

Table B.2 - General Chemistry in Groundwater
Alderon Iron Ore Corp., Kami Iron Ore Project, Wabush, NL
Stantec Project No. 121614000.484

		Location		**ROB-11-02**	**ROB-11-05A**	**ROB-11-05B**	**ROB-11-08A**	**ROB-11-08B**	**ROB-11-08B**	**ROB-11-10**
		Sample Depth (m)		**3.1-25.9**	**16.5-19.6**	**3.1-13.7**	**6.8-29.0**	**2.2-9.0**	**Lab-Dup**	**0.9-7.6**
		Unit		**Till/Bedrock**	**Bedrock**	**Overburden**	**Till/Bedrock**	**Overburden**		**Till/Bedrock**
Parameters	**Units**	**RDL**	**GCDWQ[1]**							
Sodium (Na)	mg/L	0.1	200	4.1	4.3	10.2	1.7	1.3	-	3.3
Potassium (K)	mg/L	0.1	-	3.6	3.7	3.9	1.7	4.3	-	3.1
Calcium (Ca)	mg/L	0.1	-	21.4	19.6	19.2	19.1	18.5	-	34.9
Magnesium (Mg)	mg/L	0.1	-	8.9	6.8	4.7	8.3	7.5	-	7.2
Total Alkalinity (Total as CaCO3)	mg/L	5.0	-	98.0	87.0	78.0	92.0	67.0	-	110.0
Dissolved Chloride (Cl)	mg/L	1.0	250	1.4	1.3	4.7	ND	ND	-	1.4
Dissolved Sulphate (SO4)	mg/L	2.0	500	7.4	6.4	15.0	6.7	12.0	-	24.0
Reactive Silica (SiO2)	mg/L	0.50	-	8.1	7.1	15.0	8.9	5.1	-	13.0
Orthophosphate (P)	mg/L	0.010	-	ND	ND	ND	0.07	ND	-	ND
Total Phosphorus (P)	mg/L	0.1	-	ND	ND	ND	ND	ND		ND
Nitrate + Nitrite	mg/L	0.050	10	ND	0.08	0.12	0.05	ND	-	ND
Nitrate (N)	mg/L	0.050	45	ND	0.08	0.10	0.05	ND	-	ND
Nitrite (N)	mg/L	0.010	1	ND	ND	0.02	ND	ND	-	ND
Nitrogen (Ammonia Nitrogen)	mg/L	0.050	-	ND	0.40	0.85	ND	ND	-	ND
Colour	TCU	5.0	15	ND	15	ND	ND	ND	-	ND
Turbidity	NTU	3.0	2	1.5	81	30	ND	90	93	72
pH	pH	0.01	6.5 to 8.5	7.96	7.89	7.69	8.13	8.06	-	7.88
Conductivity	µS/cm	1.0	-	200	180	200	170	150	-	250
Total Organic Carbon (C)	mg/L	5.0	-	ND	120 (1)	13.0	ND	0.7	-	100.0
Hardness (CaCO3)	mg/L	1.0	-	90	77	67	82	77	-	120
Calculated TDS	mg/L	1.0	500	114	103	121	102	89	-	154
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	1.0	-	97.0	86.0	78.0	90.6	66.4	-	110.0
Carb. Alkalinity (calc. as CaCO3)	mg/L	1.0	-	ND	ND	ND	1.2	ND	-	ND
Cation Sum	me/L	-	-	2.07	1.88	1.95	1.75	1.71	-	2.57
Anion Sum	me/L	-	-	2.15	1.91	2.02	1.98	1.58	-	2.75
Ion Balance (% Difference)	%	-	-	1.90	0.79	1.76	6.17	3.95	-	3.38
Langelier Index (@ 4C)	N/A	-	-	-0.32	-0.48	-0.74	-0.23	-0.44	-	-0.16
Langelier Index (@ 20C)	N/A	-	-	-0.07	-0.23	-0.49	0.03	-0.19	-	0.10
Saturation pH (@ 4C)	N/A	-	-	8.28	8.37	8.43	8.36	8.50	-	8.04
Saturation pH (@ 20C)	N/A	-	-	8.03	8.12	8.18	8.11	8.25	-	7.78

Notes:
1 =Guidelines for Canadian Drinking Water Quality, Health Canada 2012 IOn-Line Update Table.
2 - mg/L - milligrams per liter; uS/cm - microseimens per centimeter; me/L - milliequivalents/Liter; NTU - nephelometer turbidity units; TCU - True Color Units
"-" = not analysed, not applicable or no applicable guideline
Bold/Shaded = value exceeds applicable criteria
ND = Not Detected above the RDL
RDL = Reportable Detection Limit
Lab-Dup = Laboratory QA/QC duplicate sample

Table B.2 - General Chemistry in Groundwater
Alderon Iron Ore Corp., Kami Iron Ore Project, Wabush, NL
Stantec Project No. 121614000.484

		Location		**ROB-11-11**	**ROB-11-11**	**ROB-11-12**	**ROB-11-13A**	**ROB-11-13B**	**ROB-11-13B**	**ROB-11-17**
		Sample Depth (m)		**2.2-5.8**	**Lab-Dup**	**0.9-7.4**	**11.6-15.2**	**1.4-10.7**	**Lab-Dup**	**4.6-47.8**
		Unit		**Till/Bedrock**		**Till/Bedrock**	**Till/Bedrock**	**Overburden**		**Till/Bedrock**
Parameters	**Units**	**RDL**	**GCDWQ[1]**							
Sodium (Na)	mg/L	0.1	200	0.7	0.7	0.9	4.2	12.5	-	2.1
Potassium (K)	mg/L	0.1	-	0.4	0.4	0.4	1.7	2.9	-	2.4
Calcium (Ca)	mg/L	0.1	-	19.7	20.2	6.2	13.4	9.1	-	12.3
Magnesium (Mg)	mg/L	0.1	-	3.8	3.8	1.7	3.3	3.4	-	3.7
Total Alkalinity (Total as CaCO3)	mg/L	5.0	-	82.0	-	66.0	52.0	32.0	-	73.0
Dissolved Chloride (Cl)	mg/L	1.0	250	ND	-	1.2	1.1	5.4	-	1.0
Dissolved Sulphate (SO4)	mg/L	2.0	500	6.8	-	4.4	14.0	30.0	-	13.0
Reactive Silica (SiO2)	mg/L	0.50	-	7.3	-	14.0	9.7	9.7	-	9.9
Orthophosphate (P)	mg/L	0.010	-	ND	-	ND	ND	ND	-	ND
Total Phosphorus (P)	mg/L	0.1	-	ND	ND	ND	0.33	ND		ND
Nitrate + Nitrite	mg/L	0.050	10	ND	-	0.25	0.08	0.07	-	ND
Nitrate (N)	mg/L	0.050	45	ND	-	0.25	0.08	0.07	-	ND
Nitrite (N)	mg/L	0.010	1	ND	-	ND	ND	ND	-	ND
Nitrogen (Ammonia Nitrogen)	mg/L	0.050	-	ND	-	ND	1.70	0.62	-	0.13
Colour	TCU	5.0	15	ND	-	**37**	8.9	ND	-	ND
Turbidity	NTU	3.0	2	660	-	120	83	30	35	64
pH	pH	0.01	6.5 to 8.5	8.08	-	7.40	7.43	7.26	-	8.02
Conductivity	µS/cm	1.0	-	160	-	130	130	150	-	160
Total Organic Carbon (C)	mg/L	5.0	-	6.5 (1)	-	9.9	1.6	6.8	-	3.0
Hardness (CaCO3)	mg/L	1.0	-	65	-	22	47	37	-	46
Calculated TDS	mg/L	1.0	500	88	-	73	82	93	-	88
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	1.0	-	81.1	-	65.7	52.0	32.0	-	71.8
Carb. Alkalinity (calc. as CaCO3)	mg/L	1.0	-	ND	-	ND	ND	ND	-	ND
Cation Sum	me/L	-	-	1.33	-	0.58	1.31	1.40	-	1.08
Anion Sum	me/L	-	-	1.78	-	1.46	1.36	1.41	-	1.74
Ion Balance (% Difference)	%	-	-	14.50	-	43.10	1.87	0.36	-	23.40
Langelier Index (@ 4C)	N/A	-	-	-0.30	-	-1.57	-1.31	-1.87	-	-0.62
Langelier Index (@ 20C)	N/A	-	-	-0.05	-	-1.32	-1.06	-1.62	-	-0.37
Saturation pH (@ 4C)	N/A	-	-	8.38	-	8.97	8.74	9.13	-	8.64
Saturation pH (@ 20C)	N/A	-	-	8.13	-	8.72	8.49	8.88	-	8.39

Notes:
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ND = Not Detected above the RDL
RDL = Reportable Detection Limit
Lab-Dup = Laboratory QA/QC duplicate sample

Table B.2 - General Chemistry in Groundwater
Alderon Iron Ore Corp., Kami Iron Ore Project, Wabush, NL
Stantec Project No. 121614000.484

		Location		**ROB-11-17**	**ROB-11-20**	**K-11-108**	**K-11-113**	**K-11-163**	**K-11-163**	**BH-GE-03**
		Sample Depth (m)		**Lab-Dup**	**1.5-15.0**				**Lab-Dup**	**6.4-15.5**
		Unit			**Till/Bedrock**	**Bedrock**	**Bedrock**	**Bedrock**	**Bedrock**	**Overburden**
Parameters	**Units**	**RDL**	**GCDWQ**^{1}							
Sodium (Na)	mg/L	0.1	200	-	1.8	2.9	4.3	2.7	-	1.2
Potassium (K)	mg/L	0.1	-	-	2.6	4.2	4.7	1.7	-	2.0
Calcium (Ca)	mg/L	0.1	-	-	11.8	8.2	16.8	19.3	-	16.0
Magnesium (Mg)	mg/L	0.1	-	-	3.5	4.5	5.2	9.2	-	5.7
Total Alkalinity (Total as CaCO3)	mg/L	5.0	-	76.0	43.0	56.0	79.0	84.0	82.0	54.0
Dissolved Chloride (Cl)	mg/L	1.0	250	ND	ND	1.1	1.2	1.6	1.5	ND
Dissolved Sulphate (SO4)	mg/L	2.0	500	12.0	11.0	ND	5.7	17.0	18.0	20.0
Reactive Silica (SiO2)	mg/L	0.50	-	10.0	18.0	ND	0.7	23.0	22.0	7.3
Orthophosphate (P)	mg/L	0.010	-	ND	ND	ND	ND	ND	ND	0.01
Total Phosphorus (P)	mg/L	0.1	-	-	ND	ND	ND	ND	-	ND
Nitrate + Nitrite	mg/L	0.050	10	ND	ND	ND	ND	ND	ND	ND
Nitrate (N)	mg/L	0.050	45	-	ND	ND	ND	ND	-	ND
Nitrite (N)	mg/L	0.010	1	ND	ND	ND	ND	ND	ND	ND
Nitrogen (Ammonia Nitrogen)	mg/L	0.050	-	-	ND	ND	0.13	0.16	-	ND
Colour	TCU	5.0	15	ND	ND	ND	11	14	**19**	ND
Turbidity	NTU	3.0	2	-	260	230	150	250	-	150
pH	pH	0.01	6.5 to 8.5	-	7.47	**8.87**	**8.96**	7.66	-	8.05
Conductivity	µS/cm	1.0	-	-	110	100	150	190	-	140
Total Organic Carbon (C)	mg/L	5.0	-	-	1.8	9.8	9.4	9.6	-	0.6
Hardness (CaCO3)	mg/L	1.0	-	-	44	39	63	86	-	63
Calculated TDS	mg/L	1.0	500	-	74	54	88	128	-	84
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	1.0	-	-	42.8	51.9	72.0	83.9	-	53.1
Carb. Alkalinity (calc. as CaCO3)	mg/L	1.0	-	-	ND	3.6	6.2	ND	-	ND
Cation Sum	me/L	-	-	-	1.03	1.01	1.66	1.98	-	1.37
Anion Sum	me/L	-	-	-	1.08	1.15	1.73	2.09	-	1.48
Ion Balance (% Difference)	%	-	-	-	2.37	6.48	2.06	2.70	-	3.86
Langelier Index (@ 4C)	N/A	-	-	-	-1.41	-0.07	0.46	-0.74	-	-0.60
Langelier Index (@ 20C)	N/A	-	-	-	-1.15	0.19	0.71	-0.49	-	-0.35
Saturation pH (@ 4C)	N/A	-	-	-	8.88	8.94	8.50	8.40	-	8.65
Saturation pH (@ 20C)	N/A	-	-	-	8.62	8.68	8.25	8.15	-	8.40

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Lab-Dup = Laboratory QA/QC duplicate sample

Table B.2 - General Chemistry in Groundwater
Alderon Iron Ore Corp., Kami Iron Ore Project, Wabush, NL
Stantec Project No. 121614000.484

		Location		BH-GE-04	BH-GE-06	BH-GE-06	BH-GE-09	BH-GE-10	BH-GE-10	BH-GE-18
		Sample Depth (m)		2.7-11.8	3.1-15.8	Lab-Dup	3.4-9.4	2.4-9.2	Lab-Dup	2.4-12.2
		Unit		Till/Bedrock	Overburden		Overburden	Overburden		Overburden
Parameters	**Units**	**RDL**	**GCDWQ[1]**							
Sodium (Na)	mg/L	0.1	200	3.1	1.0	-	0.6	1.0	-	2.4
Potassium (K)	mg/L	0.1	-	1.2	2.1	-	1.3	2.7	-	3.0
Calcium (Ca)	mg/L	0.1	-	11.4	10.8	-	27.8	33.7	-	21.3
Magnesium (Mg)	mg/L	0.1	-	4.9	3.0	-	15.2	17.9	-	8.0
Total Alkalinity (Total as CaCO3)	mg/L	5.0	-	44.0	42.0	-	130.0	140.0	-	92.0
Dissolved Chloride (Cl)	mg/L	1.0	250	ND	ND	-	ND	ND	-	1.5
Dissolved Sulphate (SO4)	mg/L	2.0	500	21.0	3.5	-	2.1	6.1	-	10.0
Reactive Silica (SiO2)	mg/L	0.50	-	9.4	6.4	-	5.6	8.1	-	6.6
Orthophosphate (P)	mg/L	0.010	-	ND	ND	-	ND	ND	-	ND
Total Phosphorus (P)	mg/L	0.1	-	ND	ND		1.18	ND		ND
Nitrate + Nitrite	mg/L	0.050	10	0.05	ND	-	0.11	ND	-	ND
Nitrate (N)	mg/L	0.050	45	0.05	ND	-	0.11	ND	-	ND
Nitrite (N)	mg/L	0.010	1	ND	ND	-	ND	ND	-	ND
Nitrogen (Ammonia Nitrogen)	mg/L	0.050	-	ND	ND	-	ND	ND	ND	0.21
Colour	TCU	5.0	15	ND	ND	-	ND	ND	-	ND
Turbidity	NTU	3.0	2	2.8	0.47	0.55	320	140	-	15
pH	pH	0.01	6.5 to 8.5	7.64	8.15	-	8.20	8.19	-	8.01
Conductivity	µS/cm	1.0	-	130	89	-	260	290	-	190
Total Organic Carbon (C)	mg/L	5.0	-	ND	ND	-	0.7	1.1	-	2.4
Hardness (CaCO3)	mg/L	1.0	-	49	39	-	130	160	-	86
Calculated TDS	mg/L	1.0	500	77	52	-	129	156	-	109
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	1.0	-	43.3	41.0	-	120.0	140.0	-	91.5
Carb. Alkalinity (calc. as CaCO3)	mg/L	1.0	-	ND	ND	-	1.9	2.1	-	ND
Cation Sum	me/L	-	-	1.14	0.88	-	2.69	3.28	-	1.92
Anion Sum	me/L	-	-	1.30	0.91	-	2.59	2.98	-	2.10
Ion Balance (% Difference)	%	-	-	6.56	1.68	-	1.89	4.79	-	4.48
Langelier Index (@ 4C)	N/A	-	-	-1.25	-0.77	-	0.13	0.25	-	-0.30
Langelier Index (@ 20C)	N/A	-	-	-0.99	-0.51	-	0.38	0.50	-	-0.05
Saturation pH (@ 4C)	N/A	-	-	8.89	8.92	-	8.07	7.94	-	8.31
Saturation pH (@ 20C)	N/A	-	-	8.63	8.66	-	7.82	7.69	-	8.06

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Bold/Shaded = value exceeds applicable criteria
ND = Not Detected above the RDL
RDL = Reportable Detection Limit
Lab-Dup = Laboratory QA/QC duplicate sample

Table B.3 - Dissolved Metals in Groundwater
Alderon Iron Ore Corp., Kami Iron Ore Project, Wabush, NL
Stantec Project No. 121614000.484

		Location		**ROB-11-02**	**ROB-11-05A**	**ROB-11-05B**	**ROB-11-08A**	**ROB-11-08B**	**ROB-11-10**	**ROB-11-11**	**ROB-11-11**
		Screen Depth (m)		**3.1-25.9**	**16.5-19.6**	**3.1-13.7**	**6.8-29.0**	**2.2-9.0**	**0.9-7.6**	**2.2-5.8**	**Lab-Dup**
		Screen Unit		**Till/Bedrock**	**Bedrock**	**Overburden**	**Till/Bedrock**	**Overburden**	**Till/Bedrock**	**Till/Bedrock**	**Till/Bedrock**
Parameter	**Units**	**RDL**	**GCDWQ[1]**								
Aluminum (Al)	µg/L	5.0	-	ND	71.2	ND	ND	8.0	8.9	7.6	7.7
Antimony (Sb)	µg/L	1.0	6	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic (As)	µg/L	1.0	10	ND	ND	ND	ND	ND	1.4	ND	ND
Barium (Ba)	µg/L	1.0	1000	16.1	10.7	13.2	4.6	40.6	42.0	10.6	10.8
Beryllium (Be)	µg/L	1.0	-	ND	ND	ND	ND	ND	ND	ND	ND
Bismuth (Bi)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND	ND	ND
Boron (B)	µg/L	50	5000	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium (Cd)	µg/L	0.017	10	ND	ND	ND	ND	ND	0.218	0.079	0.075
Chromium (Cr)	µg/L	1.0	50	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt (Co)	µg/L	0.40	-	ND	1.07	ND	ND	ND	2.46	ND	ND
Copper (Cu)	µg/L	2.0	1000	ND	6.7	2.3	ND	2.8	11.3	2.3	2.4
Iron (Fe)	µg/L	50	300	198	**1,110**	ND	ND	63	**382**	55	56
Lead (Pb)	µg/L	0.50	10	ND	ND	ND	ND	ND	ND	ND	ND
Manganese (Mn)	µg/L	2.0	50	**679**	**267**	**174**	ND	**538**	**773**	46	47
Molybdenum (Mo)	µg/L	2.0	-	ND	20.1	2.6	ND	15.0	11.8	ND	ND
Nickel (Ni)	µg/L	2.0	-	ND	2.3	2.6	ND	ND	18.5	ND	ND
Selenium (Se)	µg/L	1.0	10	ND	ND	ND	ND	ND	ND	ND	ND
Silver (Ag)	µg/L	0.10	-	ND	ND	ND	ND	ND	ND	ND	ND
Strontium (Sr)	µg/L	2.0	-	38.5	32	38.7	25.2	23.8	83.4	31.4	32.3
Thallium (Tl)	µg/L	0.10	-	ND	ND	ND	ND	ND	ND	ND	ND
Tin (Sn)	µg/L	2.0	-	ND	2.7	ND	ND	ND	ND	ND	ND
Titanium (Ti)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND	ND	ND
Uranium (U)	µg/L	0.10	20	0.4	0.2	0.2	2.3	0.6	0.9	0.2	0.2
Vanadium (V)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND	ND	ND
Zinc (Zn)	µg/L	5.0	5000	5.1	41.7	6	10.2	ND	20.2	ND	ND

Notes:

1 =Guidelines for Canadian Drinking Water Quality, Health Canada 2012 - On-Line Update Table.

2 - ug/L - micrograms per liter;

"-" = not analysed, not applicable or no applicable guideline

Bold/Shaded = value exceeds applicable criteria

Detected above

RDL = Reportable Detection Limit

Table B.3 - Dissolved Metals in Groundwater
Alderon Iron Ore Corp., Kami Iron Ore Projec
Stantec Project No. 121614000.484

		Location		ROB-11-12	ROB-11-13A	ROB-11-13B	ROB-11-17	ROB-11-20	K-11-108	K-11-113	K-11-163
		Screen Depth (m)		0.9-7.4	11.6-15.2	1.4-10.7	4.6-47.8	1.5-15.0			
		Screen Unit		Till/Bedrock	Till/Bedrock	Overburden	Till/Bedrock	Till/Bedrock	Bedrock	Bedrock	Bedrock
Parameter	**Units**	**RDL**	**GCDWQ[1]**								
Aluminum (Al)	µg/L	5.0	-	31.0	26.3	28.6	6.2	ND	ND	11.6	ND
Antimony (Sb)	µg/L	1.0	6	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic (As)	µg/L	1.0	10	1.1	ND	ND	ND	ND	ND	ND	ND
Barium (Ba)	µg/L	1.0	1000	9.1	19.2	31.7	28.2	30.9	4.2	17.1	10.5
Beryllium (Be)	µg/L	1.0	-	ND	ND	ND	ND	ND	ND	ND	ND
Bismuth (Bi)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND	ND	ND
Boron (B)	µg/L	50	5000	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium (Cd)	µg/L	0.017	10	0.035	0.035	0.09	0.043	ND	ND	0.037	0.026
Chromium (Cr)	µg/L	1.0	50	ND	ND	ND	ND	ND	ND	1.4	ND
Cobalt (Co)	µg/L	0.40	-	2.96	1.01	1.54	ND	0.58	ND	ND	ND
Copper (Cu)	µg/L	2.0	1000	3.6	2.8	6.4	ND	ND	ND	57.7	ND
Iron (Fe)	µg/L	50	300	**2,390**	**651**	163	93	**342**	ND	**2,120**	**2,620**
Lead (Pb)	µg/L	0.50	10	ND	ND	ND	ND	ND	ND	2.22	ND
Manganese (Mn)	µg/L	2.0	50	**1,130**	**366**	**178**	**243**	**297**	43.4	**79.3**	**305**
Molybdenum (Mo)	µg/L	2.0	-	12.4	5.2	4.0	5.2	3.2	21.4	8.2	2.7
Nickel (Ni)	µg/L	2.0	-	ND	5.9	10.8	ND	3.5	ND	ND	2.1
Selenium (Se)	µg/L	1.0	10	ND	ND	ND	ND	ND	ND	ND	ND
Silver (Ag)	µg/L	0.10	-	ND	ND	ND	ND	ND	ND	ND	ND
Strontium (Sr)	µg/L	2.0	-	8	24.6	46.0	24.4	29	12.7	47.4	17.7
Thallium (Tl)	µg/L	0.10	-	ND	ND	ND	ND	ND	ND	ND	ND
Tin (Sn)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND	ND	ND
Titanium (Ti)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND	ND	ND
Uranium (U)	µg/L	0.10	20	ND	ND	ND	0.2	0.2	ND	0.1	ND
Vanadium (V)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND	ND	ND
Zinc (Zn)	µg/L	5.0	5000	10.5	27.3	16	ND	34.6	ND	99.1	127

Notes:

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Detected above

RDL = Reportable Detection Limit

Table B.3 - Dissolved Metals in Groundwater
Alderon Iron Ore Corp., Kami Iron Ore Projec
Stantec Project No. 121614000.484

		Location		BH-GE-03	BH-GE-04	BH-GE-06	BH-GE-09	BH-GE-10	BH-GE-18
		Screen Depth (m)		6.4-15.5	2.7-11.8	3.1-15.8	3.4-9.4	2.4-9.2	2.4-12.2
		Screen Unit		Overburden	Till/Bedrock	Overburden	Overburden	Overburden	Overburden
Parameter	**Units**	**RDL**	**GCDWQ[1]**						
Aluminum (Al)	µg/L	5.0	-	ND	ND	9.0	6.9	ND	6.5
Antimony (Sb)	µg/L	1.0	6	ND	ND	ND	ND	ND	ND
Arsenic (As)	µg/L	1.0	10	ND	ND	ND	ND	2.1	ND
Barium (Ba)	µg/L	1.0	1000	43.6	10.4	4.1	21.7	191.0	45.0
Beryllium (Be)	µg/L	1.0	-	ND	ND	ND	ND	ND	ND
Bismuth (Bi)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND
Boron (B)	µg/L	50	5000	ND	ND	ND	ND	ND	ND
Cadmium (Cd)	µg/L	0.017	10	ND	ND	ND	0.029	ND	0.031
Chromium (Cr)	µg/L	1.0	50	ND	ND	ND	ND	ND	ND
Cobalt (Co)	µg/L	0.40	-	ND	ND	ND	ND	ND	ND
Copper (Cu)	µg/L	2.0	1000	ND	ND	ND	ND	ND	2.3
Iron (Fe)	µg/L	50	300	ND	ND	ND	ND	241	169
Lead (Pb)	µg/L	0.50	10	ND	ND	ND	ND	ND	ND
Manganese (Mn)	µg/L	2.0	50	**254**	2	ND	25.5	**587**	**786**
Molybdenum (Mo)	µg/L	2.0	-	6.9	ND	ND	4.2	10.0	11.7
Nickel (Ni)	µg/L	2.0	-	ND	ND	ND	4.6	2.0	ND
Selenium (Se)	µg/L	1.0	10	ND	ND	ND	ND	ND	ND
Silver (Ag)	µg/L	0.10	-	ND	ND	ND	ND	ND	ND
Strontium (Sr)	µg/L	2.0	-	19.1	18.7	13.1	12.1	29.4	36.5
Thallium (Tl)	µg/L	0.10	-	ND	ND	ND	ND	ND	ND
Tin (Sn)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND
Titanium (Ti)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND
Uranium (U)	µg/L	0.10	20	0.1	0.3	0.3	0.4	1.1	1.0
Vanadium (V)	µg/L	2.0	-	ND	ND	ND	ND	ND	ND
Zinc (Zn)	µg/L	5.0	5000	11.2	ND	ND	ND	ND	137

Notes:

1 =Guidelines for Canadian Drinking Water Qual

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Bold/Shaded = value exceeds applicable crite

Detected above

RDL = Reportable Detection Limit

Table B4 Summary of Water Level Monitoring Data - Hydrogeology
Alderon Iron Ore Corp, kami Iron Ore Project, Wabush, NL
Stantec Project No. 121614000.306

Monitor Well	Date	Top of Casing (mag)	Water Level (mbtoc)	Water Level (mbgs)	Approx. Ground Elevation (m)	Approximate Water Elevation	Water Level (mbtoc @ 45°)	Calculated Water Level (mbgs)	Logger Serial Number	Approximate Deployment Depth mbtoc	Calculated deployment depth	Data Collection Interval (hr)	Notes
November 2011 Program													
BH-GE-01	11/29/2011	0.775	4.92	4.14	618.74	614.60	-	-	10040141	4 mbtoc (0.5 m above bottom of well)		6	-
BH-GE-03	11/29/2011	0.885	1.64	0.76	591.41	590.65	-	-	10032177	8 mbtoc		6	-
BH-GE-04	11/29/2011	0.840	6.92	6.08	563.90	557.82	-	-	10040138	8 mbtoc		6	-
BH-GE-08	11/29/2011	0.884	4.66	3.78	548.04	544.26	-	-	10032160	7.7 mbtoc (0.5 m above bottom of well)		6	-
BH-GE-13	11/29/2011	1.015	1.02	0.01	557.22	557.21	-	-	-	-		-	-
BH-GE-15	11/29/2011	1.042	1.04	-0.01	607.58	607.59	-	-	-	-		-	-
BH-GE-16	11/29/2011	1.208	5.65	4.44	583.41	578.97	-	-	10032037	5.2 mbtoc (0.5 m above bottom of well)		6	WL almost at bottom of well and therefore may not be groundwater; Logger may also act as barometric reference until WL rises
BH-GE-18	11/29/2011	1.055	2.38	1.32	582.96	581.64	-	-	10040142	8 mbtoc		6	-
K-11-106	11/29/2011	0.490	-	-	583.98		10.08	6.64	-	-		-	No where to anchor logger on Alderon exploratory boreholes
ROB-11-01A	11/24/2011	0.890	-	-	571.16		-	-	-	-		-	-
ROB-11-01B	11/24/2011	0.960	-	-	571.16		-	-	-	-		-	-
ROB-11-09	11/27/2011	0.890	Artesian	Artesian	586.60		-	-	-	-		-	-
ROB-11-10	11/27/2011	1.072	5.45	4.38	617.30	612.92	-	-	10040143	7.6 mbtoc (1 m from bottom of well)		6	-
ROB-11-11	11/24/2011	1.140	-	1.05	618.39	617.34	-	-	10032123	5 mbtoc		6	Only 1 monitor well, no A or B as indicated in plan; Logger time is Newfoundland time not AST like rest of loggers (0.5 h ahead)
ROB-11-12	11/29/2011	1.054	1.51	0.46	631.15	630.69	-	-	10040139	8 mbtoc		6	-
ROB-11-12	11/29/2011	1.054	1.51	0.46	631.15	630.69	-	-	10040140	0.3 mbtoc		6	Barometric Reference
ROB-11-17	11/29/2011	1.000	2.31	1.31	580.75	579.44	-	-	10032140	8 mbtoc		6	-
ROB-11-20	11/29/2011	1.054	3.97	2.92	612.00	609.09	-	-	10032146	8 mbtoc		6	-
January 2012 Program													
ROB-11-08A		1.45	Artesian	-1.45	579.63	581.08	-	-	-	-		-	-
ROB-11-08B	1/21/2012	0.940	1.52	0.58	579.63	579.05	-	-	10040149	10.5 mbtoc		6	-
K-11-108	1/21/2012	assuming 0.5 m	-	-	586.48	-	4.14	2.43	10040135	12	7.985	6	-
K-11-113	1/21/2012		-	-	596.73	-	19.87	13.55	10040148	-		6	-
K-11-148	1/22/2012		-	-	n/a	-	-	-	-	-		-	Unable to land safely
K-11-114	1/22/2012		-	-	573.72	-	-	-	-	-		-	Unable to locate
K-11-163	1/22/2012		-	-	584.42	-	9.48	6.20	10040146	11	7.278	6	obstruction on bottom
K-11-145	1/22/2012		-	-	n/a	-	12.70	8.48	-	-		-	Obstruction @ 12 mbtoc: Could not install logger
K-11-140	1/22/2012		-	-	n/a	-	-	-	-	-		-	Could not detect WL

Table B4 Summary of Water Level Monitoring Data - Hydrogeology
Alderon Iron Ore Corp, kami Iron Ore Project, Wabush, NL
Stantec Project No. 121614000.306

Monitor Well	Date	Top of Casing (mag)	Water Level (mbtoc)	Water Level (mbgs)	Approx. Ground Elevation (m)	Approximate Water Elevation	Water Level (mbtoc @ 45°)	Calculated Water Level (mbgs)	Logger Serial Number	Approximate Deployment Depth mbtoc	Calculated deployment depth	Data Collection Interval (hr)	Notes
K-08-10	1/22/2012	0.31	-	-	636.94	627.64	13.86	9.30	10040147	-		6	-
K-08-18	1/22/2012	0.61	-	-	592.08	583.46	12.90	8.62	10040144	15	10.107	6	would not drop further
K-11-147	1/22/2012	assume 0.5 m	-	-	n/a	-	5.95	3.70	10040145	10	6.571	6	-
March 2012 Program													
BH-GE-01	3/28/2012	0.86	5.15	4.29	618.74	614.45	-	-	10040141	1' above bottom		6	downloaded; replaced line w/ cable
BH-GE-03	3/28/2012	0.91	2.49	1.58	591.41	589.83	-	-	10032177	9 mbtoc		6	downloaded; replaced line w/ cable
BH-GE-04	3/24/2012	0.91	8.27	7.36	563.90	556.54	-	-	10040138	36' btoc		6	downloaded; replaced line w/ cable
BH-GE-05	3/242012	-	-	-	542.21		-	-	-	-		-	Unable to locate, covered by snow
BH-GE-06	3/25/2012	0.91	4.05	3.14	540.26	537.13	-	-	10032244	10 mbtoc		6	Install 30 m logger w/ cable
BH-GE-07	3/25/2012	0.89	1.15	0.26	542.76	542.50	-	-	-	-		-	-
BH-GE-08	3/28/2012	0.91	4.96	4.05	548.04	543.99	-	-	10032160	1' above bottom			downloaded; replaced line w/ cable
BH-GE-09	3/25/2012	0.99	2.68	1.69	564.44	562.75	-	-	10032243	28' btoc		6	Install 30 m logger w/ cable
BH-GE-10	3/26/2012	1.17	1.57	0.40	559.71	559.32	-	-	10051462	8 mbtoc		6	Install 30 m logger w/ cable
BH-GE-11	3/26/2012	1.04	0.06	-0.98	550.24	551.22	-	-	-	-		-	-
BH-GE-12	3/26/2012	1.02	toc	-1.02	553.51	554.53	-	-	-	-		-	-
BH-GE-13	3/23/2012	1.07	1.03	-0.04	557.22	557.26	-	-	-	-		-	-
BH-GE-14	3/23/2012	1.09	1.13	0.04	577.06	577.02	-	-	-	-		-	-
BH-GE-15	3/23/2012	1.12	1.05	-0.07	607.58	607.65	-	-	-	-		-	-
BH-GE-16	3/23/2012	1.22	5.59	4.37	583.41	579.04	-	-	10032037	near bottom		6	Replaced line w/ cable
BH-GE-16	3/29/2012	-	-	-	583.41		-	-	10032037	-		-	redownloaded
BH-GE-18	3/28/2012	1.07	4.33	3.26	582.96	579.71	-	-	10040142	9 mbtoc		6	downloaded; replaced line w/ cable
BH-GE-18	3/29/2012	1.07	4.33	3.26	582.96	579.70	-	-	-	-		-	return for pump test
BH-GE-19	3/27/2012	0.94	0.53	-0.41	573.26	573.67	-	-	-	-		-	-
BH-GE-20	3/25/2012	1.02	toc	-1.02	570.81	571.83	-	-	-	-		-	-
K-08-10	3/28/2012	0.31	-	-	636.94	626.79	15.07	10.15	10040147	20 mtoc		6	downloaded; replaced line w/ cable
K-08-10	3/28/2012	-	-	-	637.14	-	-	-	10040147	-		-	redownloaded
K-08-18	3/28/2012	0.61	-	-	592.08	582.84	13.77	9.24	10040144	18 mbtoc		6	downloaded; replaced line w/ cable
K-11-106	3/29/2012		-	-	583.98	-	11.03		10051463	18	12.228	6	Install 30 m logger w/ cable
K-11-108	3/27/2012		-	-	586.48	-	4.64		10040135	-		6	downloaded, need to replace line
K-11-108	3/28/2012		-	-	586.48	-	-	-	10040135	-		-	redownloaded
K-11-113	3/27/2012		-	-	596.73	-	10.85		?	-		-	unable to download - frozen to pipe
K-11-147	3/28/2012		-	-	631.80	-	5.76		?	-		-	unable to download - frozen to pipe
K-11-163	3/27/2012		-	-	584.42	-	9.88		?	-		-	unable to download - fish out of borehole
ROB-11-02	3/22/2012	0.91	0.58	-0.33	569.00	569.33	-	-	10104224	8.84		6	Install 30 m logger w/ cable
ROB-11-03	3/24/2012	1.06	0.23	-0.83	576.07	576.90	-	-	-	-		-	-
ROB-11-05A	3/23/2012	1.06	2.97	1.91	629.00	627.10	-	-	-	-		-	-
ROB-11-05B	3/23/2012	0.82	2.45	1.63	629.00	627.37	-	-	10104226	9 mbtoc		6	Install 30 m logger w/ cable
ROB-11-06	3/23/2012	1.16	12.80	11.64	653.32	641.68	-	-	10104225	13 mbtoc		6	Install 30 m logger w/ cable
ROB-11-08	3/27/2012	0.91	1.06	0.15	579.63	579.48	-	-	?	-		-	unable to download - frozen
ROB-11-10	3/27/2012	1.07	7.52	6.45	617.30	610.86	-	-	10040143	7 mbtoc		6	downloaded, replaced line w/ cable
ROB-11-11	3/27/2012	1.14	4.53	3.39	618.39	615.00	-	-	10032123	1' above bottom		6	downloaded, replaced line w/ cable
ROB-11-12	3/27/2012	1.04	1.80	0.76	631.15	630.39	-	-	10040139	7 mbtoc		6	downloaded, replaced line w/ cable

Table B4 Summary of Water Level Monitoring Data - Hydrogeology
Alderon Iron Ore Corp, kami Iron Ore Project, Wabush, NL
Stantec Project No. 121614000.306

Monitor Well	Date	Top of Casing (mag)	Water Level (mbtoc)	Water Level (mbgs)	Approx. Ground Elevation (m)	Approximate Water Elevation	Water Level (mbtoc @ 45°)	Calculated Water Level (mbgs)	Logger Serial Number	Approximate Deployment Depth mbtoc	Calculated deployment depth	Data Collection Interval (hr)	Notes
ROB-11-12	3/28/2012	1.04	1.80	0.76	631.15	630.39	-	-	10040140	near top of casing		6	downloaded
ROB-11-12	3/28/2012	1.04	1.80	0.76	631.15	630.39	-	-	10040140	-		-	redownloaded
ROB-11-13A	3/26/2012	1.00	5.02	4.02	633.20	629.18	-	-	-	-		-	-
ROB-11-13B	3/26/2012	1.07	5.75	4.68	633.20	628.52	-	-	10032245	8 mbtoc		6	Install 30 m logger w/ cable
ROB-11-14	3/27/2012	0.85	1.05	0.20	605.80	605.60	-	-	-	-		-	-
ROB-11-17	3/27/2012	0.96	2.37	1.41	580.75	579.34	-	-	10032140	8 mbtoc		6	downloaded, replaced line w/ cable
ROB-11-17	3/28/2012	0.96	2.37	1.41	580.75	579.34	-	-	10032140	-		-	redownloaded
ROB-11-20	3/28/2012	1.04	6.72	5.68	612.00	606.32	-	-	10032146	11 mbtoc		6	downloaded; replaced line w/ cable
April 2012 Program													
BH-GE-06	4/21/2012	0.91	4.11	3.2	540.26	537.06	-	-	1003224				downloaded
BH-GE-09	4/21/2012	0.99	2.65	1.66	564.44	562.78	-	-	10032243				downloaded
BH-GE-10	4/21/2012	1.17	1.62	0.45	559.71	559.26	-	-	10051462				downloaded
K-11-106	4/21/2012		-		583.98		11.06	7.32	10051463				downloaded
ROB-11-02	4/21/2012	0.91	1.15	0.24	569.00	568.76	-	-	-				-
ROB-11-05A	4/21/2012	1.06	~6.28	5.22	629.00	623.78	-	-	-				-
ROB-11-05B	4/21/2012	0.82	probe not functioning		629.00	629.00	-	-	10104226				downloaded
ROB-11-06	4/21/2012	1.16	~10.35	9.19	653.32	644.13	-	-	10104225				downloaded
ROB-11-12	4/21/2012	1.04	3.25	2.21	631.15	628.94	--	-	10040139				downloaded
ROB-11-12	4/21/2012	1.04	3.25	2.21	631.15	628.94	-	-	10040140				downloaded; replaced line w/ cable
ROB-11-13A	4/21/2012	1.00	6.15	5.15	633.20	628.05	-	-	-				-
ROB-11-13B	4/21/2012	1.07	6.06	4.99	633.20	628.21	-	-	10032245				downloaded
K-11-163	4/24/2012		-		584.42	584.42	-	-	-				tried unsuccessfully to fish out lost logger

Table B.5 Static Water Levels - Hydrogeology

Alderon Iron Ore Corp, Kami Iron Ore Project, Wabush, NL

Stantec Project No. 121614000.306

Monitor Well ID		Water Levels (mbgs)				
		Date				
Plant Area	**Location**	**Nov-11**	**Jan-12**	**Mar-12**	**Apr-12**	**Mean**
BH-GE-01	West Plant	4.14	4.49	4.29		4.31
BH-GE-02	West Plant	-	-	-	-	-
BH-GE-03	West Plant	0.76	1.18	1.58	-	1.17
BH-GE-04	Access Rd	6.08	7.07	7.36	-	6.84
BH-GE-05	Access Rd	-	-	-	-	-
BH-GE-06	Access Rd	-	-	3.14	4.11	3.62
BH-GE-07	East Plant	-	-	0.26	-	0.26
BH-GE-08	East Plant	3.78	3.93	4.05	-	3.92
BH-GE-09	East Plant	-	-	1.69	2.65	2.17
BH-GE-10	East Plant	-	-	0.40	1.62	1.01
BH-GE-11	East Plant	-	-	-0.98	-	-0.98
BH-GE-12	East Plant	-	-	-1.02	-	-1.02
BH-GE-13	Tailings	0.01	-	-0.04	-	-0.02
BH-GE-14	Tailings	-	-	0.04	-	0.04
BH-GE-15	Tailings	-0.01	-	-0.07	-	-0.04
BH-GE-16	Rail/Loadout	4.44	4.35	4.37	-	4.39
BH-GE-17	Rail/Loadout	-	-	-	-	-
BH-GE-18	Rail/Loadout	1.32	2.19	3.26	-	2.26
BH-GE-19	Rail/Loadout	-	-	-0.41	-	-0.41
BH-GE-20	Rail/Loadout	-	-	-1.02	-	-1.02
Rose Pit Area	**Location**					**Apr-12**
ROB-11-01A	Pit Perimeter	frozen	-	-	-	-
ROB-11-01B	Pit Perimeter	frozen	-	-	-	-
ROB-11-02	Pit Perimeter	-	-	-0.33	1.12	0.40
ROB-11-03	Pit Perimeter	-	-	-0.83	-	-0.83
ROB-11-04	Pit Perimeter	-	-		-	-
ROB-11-05A	Pit Perimeter	-	-	1.91	6.28	4.09
ROB-11-05B	Pit Perimeter	-	-	1.63	-	1.63
ROB-11-06	Pit Perimeter	-	-	11.64	10.35	11.00
ROB-11-07	Pit Perimeter	-	-	-	-	-
ROB-11-08A	Pit Perimeter	-	-1.45(A)	-	-	-1.45
ROB-11-08B	Pit Perimeter	-	0.58	0.15	-	0.37
ROB-11-09	Pit Perimeter	-0.90(A)	-	-	-	-0.90
ROB-11-10	Pit Perimeter	4.38	5.02	6.45	-	5.28
ROB-11-11	Pit Perimeter	1.05	5.21	3.39	-	3.22
ROB-11-12	Pit Perimeter	0.46	0.78	0.76	3.25	1.31
ROB-11-13A	Pit Perimeter	-	-	4.02	6.15	5.09
ROB-11-13B	Pit Perimeter	-	-	4.68	6.06	5.37
ROB-11-14	Pit Perimeter	-	-	0.2	-	0.20

Table B.5 Static Water Levels - Hydrogeology

Alderon Iron Ore Corp, Kami Iron Ore Project, Wabush, NL

Stantec Project No. 121614000.306

Monitor Well ID		Water Levels (mbgs)				
ROB-11-15	Pit Perimeter	-	-	-	-	-
ROB-11-16	Pit Perimeter	-	-	-	-	-
ROB-11-17	Pit Interior	1.31	1.7	1.41	-	1.47
ROB-11-18	Pit Interior	-	-	-	-	-
ROB-11-19	Pit Interior	-	-	-	-	-
ROB-11-20	Pit Interior	2.92	2.45	5.68	-	3.68
K-11-106	Pit Interior	6.64	-	-	7.32	6.98
K-11-108	Pit Interior	-	2.43	-	-	2.43
K-11-113	Pit Interior	-	13.55	-	-	13.55
K-11-163	Pit Interior	-	6.20	-	-	6.20
K-11-145	Pit Interior	-	8.48	-	-	8.48
K-08-10	Pit Interior	-	9.30	-	-	9.30
K-08-18	Pit Interior	-	8.62	9.24	-	8.93
K-11-147	Pit Interior	-	3.70	-	-	3.70

1. *Shaded - data logger deployed*

2. *"-" - negative values indicate above groundwater water level*

3. *-value(A) - flowing artesian out top of casing*

Appendix C

Borehole and Monitor Well Records

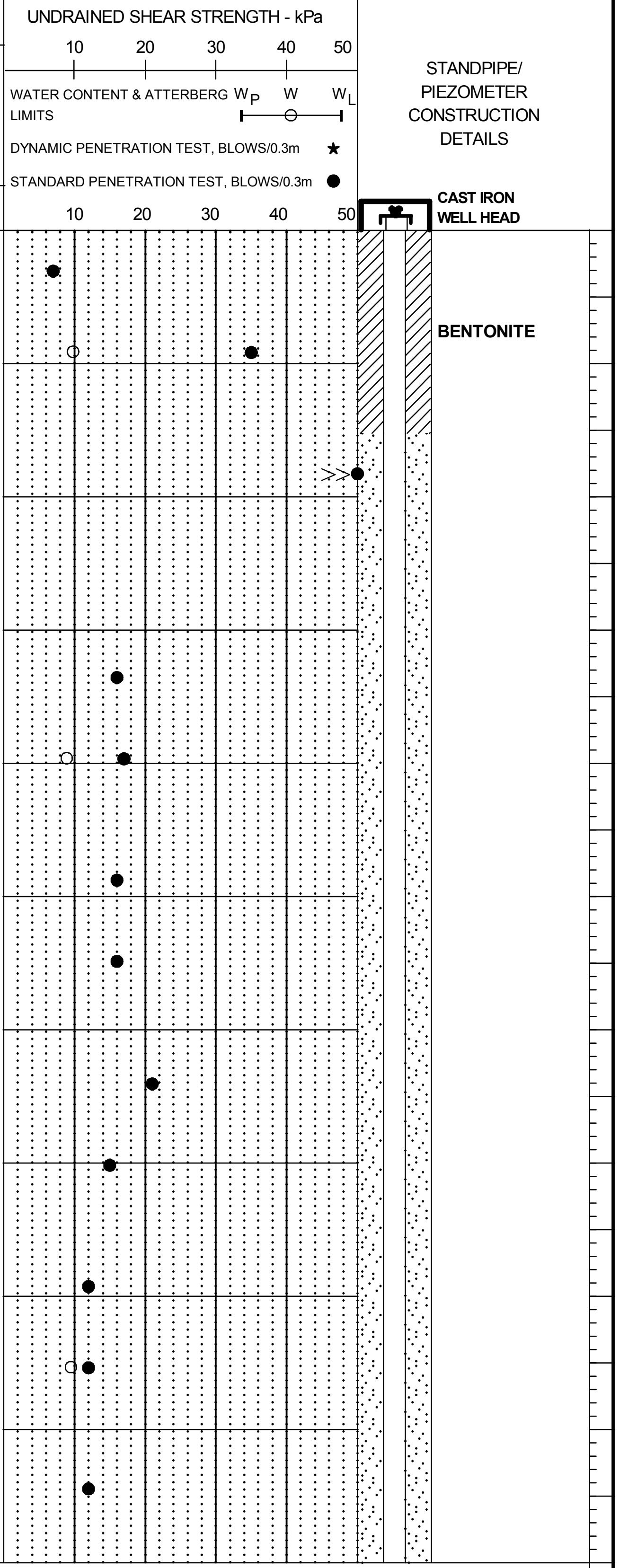
Stantec

BOREHOLE RECORD

BOREHOLE No.	ROB-11-01A
PAGE	1 of 6
CLIENT	Alderon Iron Ore Corp.
PROJECT	Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION	Kami Iron Ore Mine Site, Labrador West, NL
N	5855908.992 m
E	632922.609 m
DATES (mm-dd-yy): BORING	9-29-11 to 10-6-11
WATER LEVEL	0m 11-3-11
PROJECT No.	121614000-305
DRILLING METHOD	Wash/Dia
SIZE	HW/NW/NQ
DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION
0	570.22	
0.2	570.0	Very soft, black, ORGANIC SOIL (OL): PEAT
		Compact, grey, silty SAND (SM); trace to locally some gravel: TILL -occasional cobbles to 4.5 m depth.

SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	1	330	7	
SS	2	510	35	S
SS	3	175	57	
SS	4	0	50/75	
SS	5	25	16	
SS	6	255	17	S
SS	7	25	16	
SS	8	205	16	S H
SS	9	50	21	
SS	10	100	15	
SS	11	125	12	
SS	12	610	12	S
SS	13	100	12	



DRAFT

△ Unconfined Compression Test
□ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

Stantec

BOREHOLE RECORD

BOREHOLE No. **ROB-11-01A**
PAGE **2** of **6**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL**
N **5855908.992 m** E **632922.609 m**
SIZE **HW/NW/NQ**
DATES (mm-dd-yy): BORING **9-29-11** to **10-6-11**
WATER LEVEL **0m** **11-3-11**
DATUM **Geodetic**

DEPTH (m) | ELEVATION (m) | DESCRIPTION | STRATA PLOT | WATER LEVEL

Continued from Previous Page

Depth scale: 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

SAMPLES

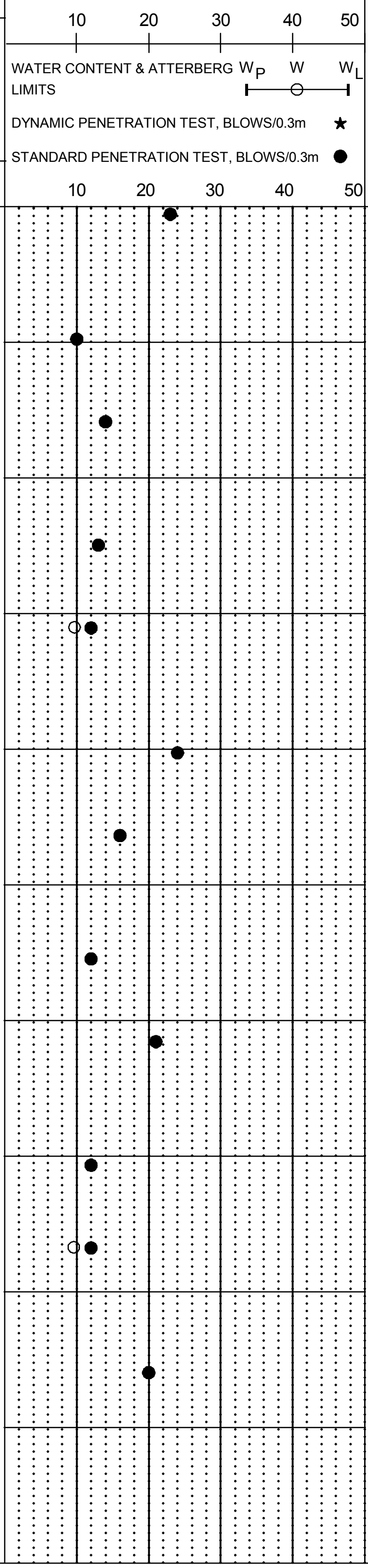
TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	14	175	23	
SS	15	150	10	
SS	16	240	14	
SS	17	205	13	
SS	18	480	12	S
SS	19	230	24	
SS	20	125	16	
SS	21	0	12	
SS	22	205	21	
SS	23	255	12	
SS	24	430	12	S
SS	25	125	20	

UNDRAINED SHEAR STRENGTH - kPa

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●



STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS

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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

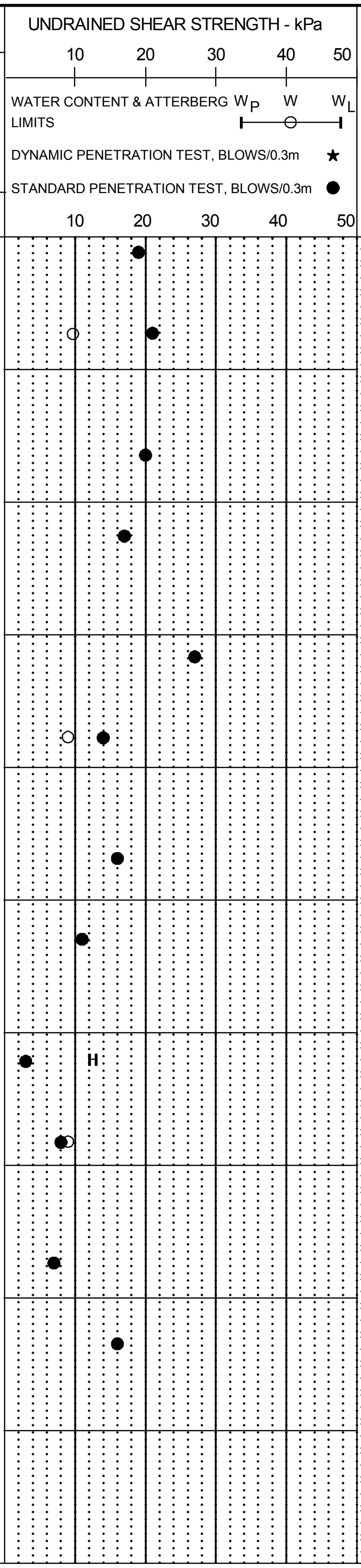
Stantec

BOREHOLE RECORD

BOREHOLE No. ROB-11-01A
PAGE 3 of 6
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N5855908.992 m E 632922.609 m
SIZE HW/NW/NQ
DATES (mm-dd-yy): BORING 9-29-11 to 10-6-11
WATER LEVEL 0m 11-3-11
DATUM Geodetic

Continued from Previous Page

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
20			SS	26	230	19	
			SS	27	560	21	S
21			SS	28	25	20	
22			SS	29	205	17	S H
23			SS	30	230	27	
			SS	31	305	14	S
24			SS	32	230	16	
25			SS	33	255	11	
26		-very loose to loose from 26.0 m to 29.0 m: Proportion of gravel and sand decreases from 26.0 to 29.0 m	SS	34	405	3	S H
			SS	35	610	8	S
27			SS	36	330	7	
28			SS	37	480	16	
29			SS	38	255	90/250	
30	540.3						



STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS

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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

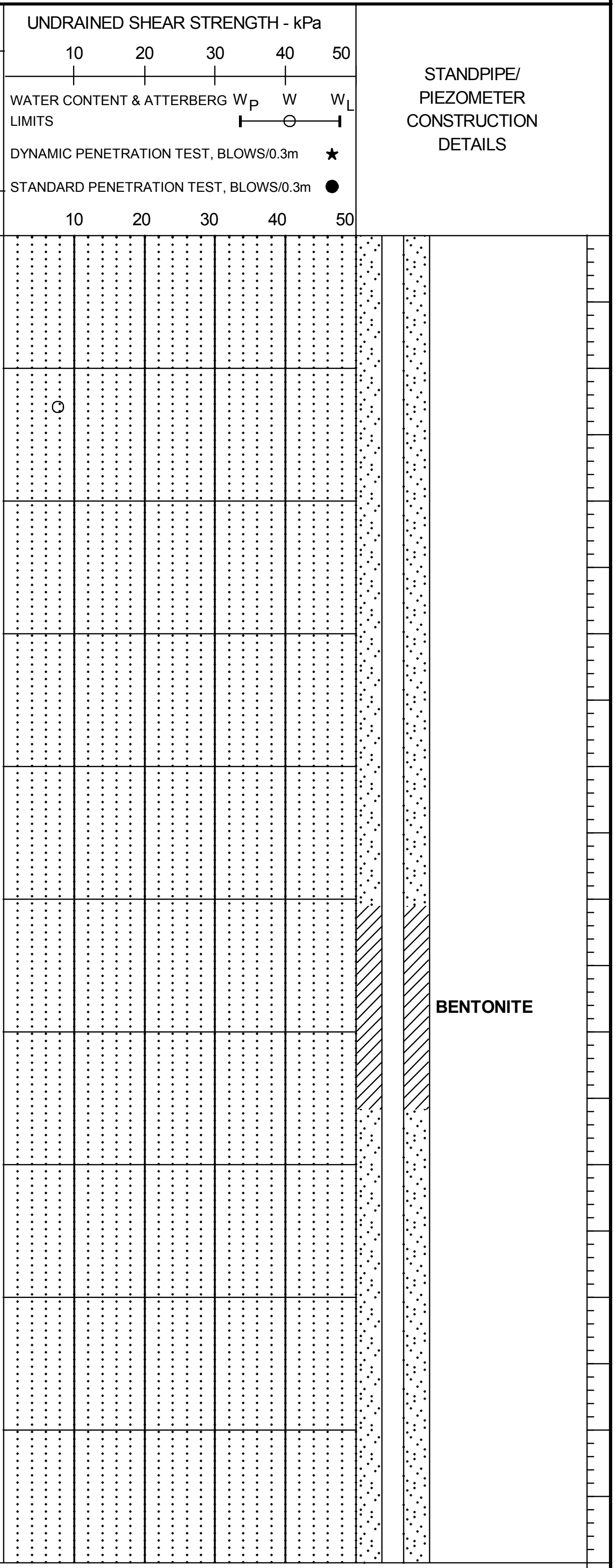
Stantec

BOREHOLE RECORD

BOREHOLE No. ROB-11-01A
PAGE 4 of 6
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N5855908.992 m E 632922.609 m
SIZE HW/NW/NQ
DATES (mm-dd-yy): BORING 9-29-11 to 10-6-11
WATER LEVEL 0m 11-3-11
DATUM Geodetic

Continued from Previous Page

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
30		Very dense, dark grey, silty SAND (SM); trace gravel; trace cobbles and boulders: TILL	SS	39	75	100/75	
			BS	40	-	-	
31			SS	41	96%	-	S
32			SS	42	100	50/100	
			BS	43	87%	-	
34			HQ	44	100%	-	
35			HQ	45	98%	-	
37			HQ	46	55%	-	
38			HQ	47	30%	-	
39			HQ	48	89%	-	



△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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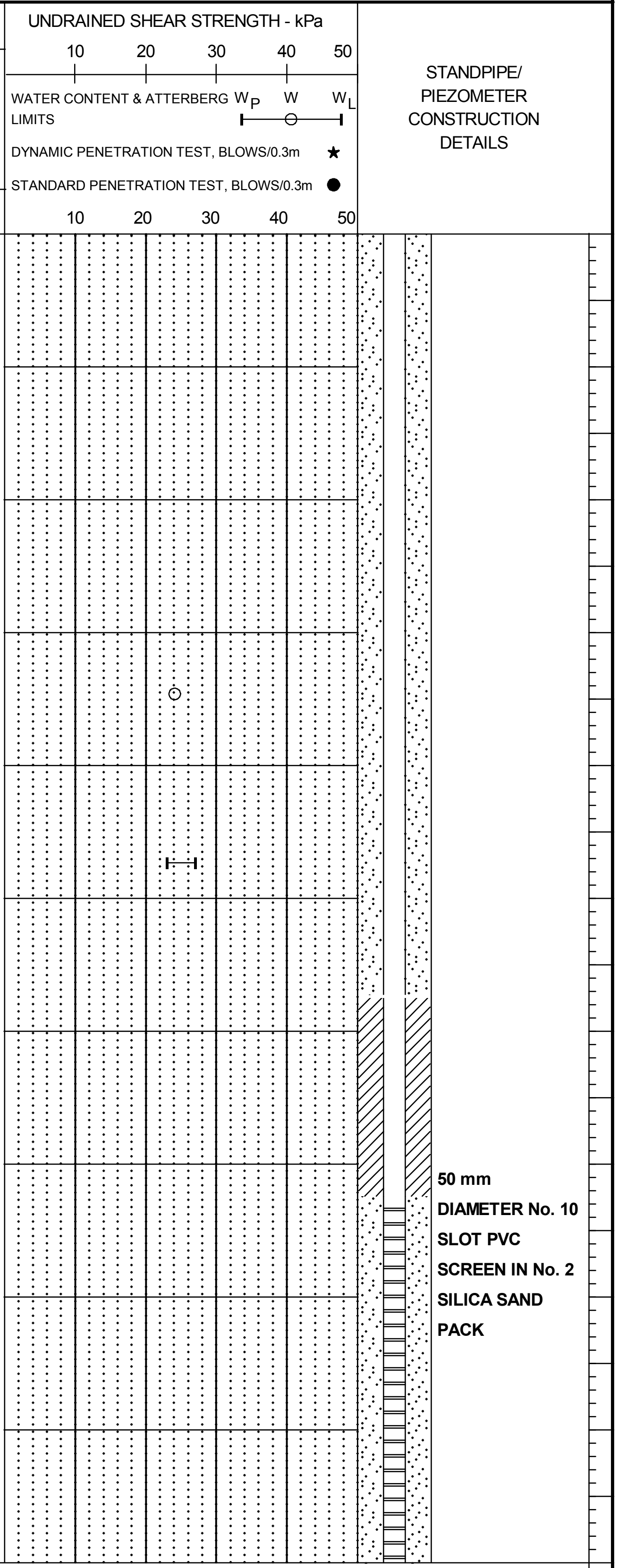
BOREHOLE RECORD

BOREHOLE No. **ROB-11-01A**
PAGE **5** of **6**

CLIENT **Alderon Iron Ore Corp.**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5855908.992 m** E **632922.609 m**
DATES (mm-dd-yy): BORING **9-29-11** to **10-6-11** WATER LEVEL **0m** **11-3-11**
PROJECT No. **121614000-305**
DRILLING METHOD **Wash/Dia**
SIZE **HW/NW/NQ**
DATUM **Geodetic**

Continued from Previous Page

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
41.2			SS	49	0	50/50	
43.0	527.2	Very dense, grey, SILT with sand (ML); trace gravel: TILL					
43.5			SS	50	355	128/360	S
44.7			BS	51	150	-	S H
46.3			BS	52	150	-	
47.0	523.2	Moderately jointed to intact, medium strong, dark grey, biotite muscovite quartz schist (Menihek Formation): BEDROCK					
47.4			NQ	53	100%	79%	
49.4			NQ	54	100%	96%	



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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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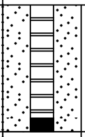
BOREHOLE RECORD

BOREHOLE No. **ROB-11-01A**
PAGE **6** of **6**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5855908.992 m** E **632922.609 m**
SIZE **HW/NW/NQ**
DATES (mm-dd-yy): BORING **9-29-11** to **10-6-11**
WATER LEVEL **0m** **11-3-11**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	SAMPLES: OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa (10 20 30 40 50); WATER CONTENT & ATTERBERG LIMITS W_P W W_L; DYNAMIC PENETRATION TEST, BLOWS/0.3m ★; STANDARD PENETRATION TEST, BLOWS/0.3m ● (10 20 30 40 50)	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									
50	519.3										END CAP
51		End of Borehole									
52											
53											
54											
55											
56											
57											
58											
59											
60											



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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

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BOREHOLE RECORD

BOREHOLE No. **ROB-11-01B**
PAGE **1** of **5**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5855909.162 m** E **632922.02 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **10-6-11 to 10-9-11**
WATER LEVEL **0m 11-3-11**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	SAMPLES: OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
0	570.22			▼							

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50

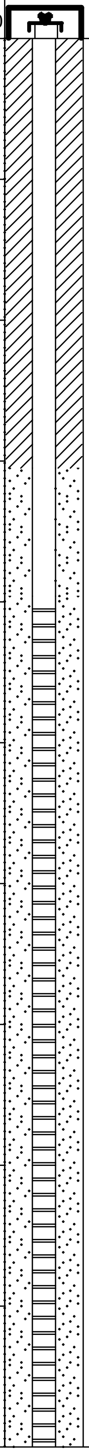
WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50

DEPTH (m): 0 1 2 3 4 5 6 7 8 9 10


CAST IRON WELL HEAD
BENTONITE
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

Stantec

BOREHOLE RECORD

BOREHOLE No. ROB-11-01B
PAGE 2 of 5
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N 5855909.162 m E 632922.02 m
SIZE HW/HQ
DATES (mm-dd-yy): BORING 10-6-11 to 10-9-11 WATER LEVEL 0m 11-3-11
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY(mm) OR TCR %	SAMPLES N-VALUE OR RQD %	SAMPLES OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									
10											
11											
12											
13											
14											50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
15											
16											
17											
18											
19											
20											

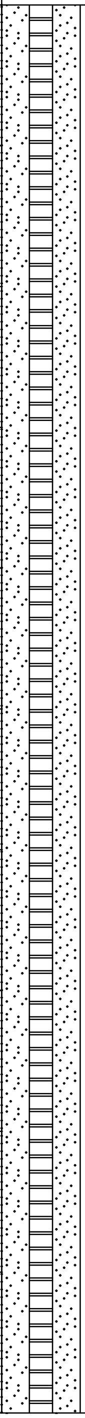
UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50



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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

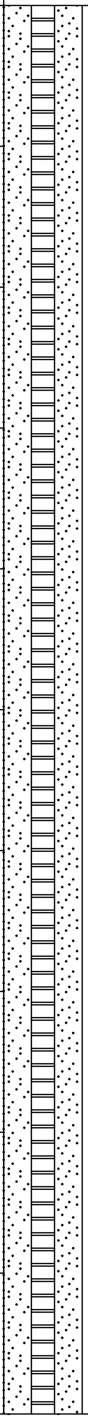
Stantec

BOREHOLE RECORD

BOREHOLE No. ROB-11-01B
PAGE 3 of 5

CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N 5855909.162 m E 632922.02 m
DATES (mm-dd-yy): BORING 10-6-11 to 10-9-11 WATER LEVEL 0m 11-3-11
PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY(mm) OR TCR %	SAMPLES N-VALUE OR RQD %	SAMPLES OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa 10 20 30 40 50	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page								WATER CONTENT & ATTERBERG LIMITS W_P W W_L DYNAMIC PENETRATION TEST, BLOWS/0.3m ★ STANDARD PENETRATION TEST, BLOWS/0.3m ● 10 20 30 40 50	
20											
21											
22											
23											
24											50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
25											
26											
27											
28											
29											
30											



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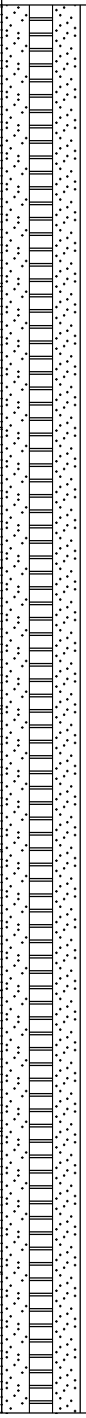
△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

Stantec

BOREHOLE RECORD

BOREHOLE No. **ROB-11-01B**
PAGE **4** of **5**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5855909.162 m** E **632922.02 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **10-6-11** to **10-9-11**
WATER LEVEL **0m** **11-3-11**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	SAMPLES: OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa (10, 20, 30, 40, 50) WATER CONTENT & ATTERBERG LIMITS W_P W W_L DYNAMIC PENETRATION TEST, BLOWS/0.3m ★ STANDARD PENETRATION TEST, BLOWS/0.3m ● 10 20 30 40 50	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									
30											
31											
32											
33											
34											50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
35											
36											
37											
38											
39											
40											



DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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BOREHOLE RECORD

BOREHOLE No. ROB-11-01B
PAGE 5 of 5

CLIENT	Alderon Iron Ore Corp.	PROJECT No.	121614000-305
PROJECT	Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study	DRILLING METHOD	Wash/Dia
LOCATION	Kami Iron Ore Mine Site, Labrador West, NL N5855909.162 m E 632922.02 m	SIZE	HW/HQ
DATES (mm-dd-yy): BORING	10-6-11 to 10-9-11 WATER LEVEL 0m 11-3-11	DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	SAMPLES: OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									
40											
41											
42											
43											
44											50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
45											
46	523.6										END CAP
		End of Borehole									
47											
48											
49											
50											

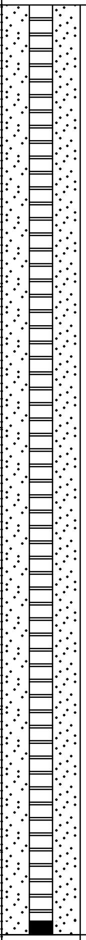
UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50



DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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BOREHOLE RECORD

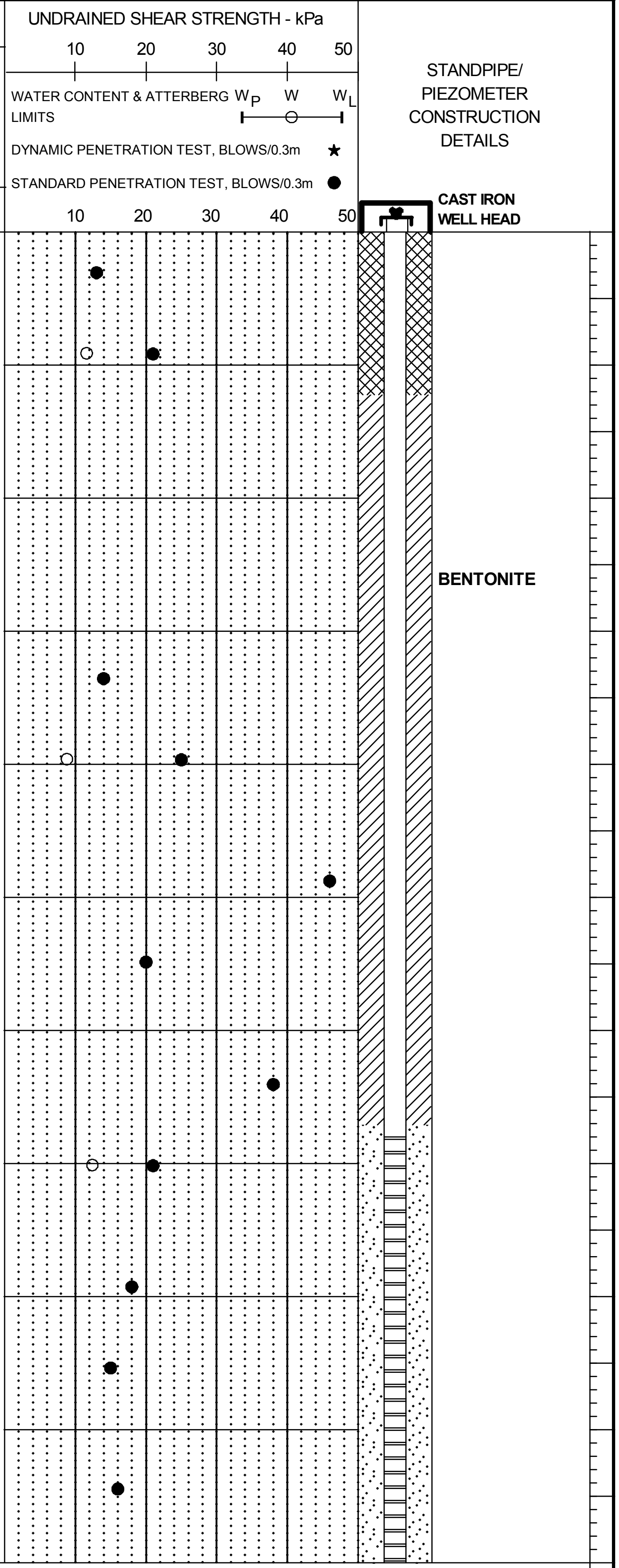
BOREHOLE No. **ROB-11-08A**
PAGE **1** of **4**

CLIENT	**Alderon Iron Ore Corp.**
PROJECT	**Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION	**Kami Iron Ore Mine Site, Labrador West, NL**
N	**5854776 m**
E	**631997 m**
DATES (mm-dd-yy): BORING	**10-26-11 to 10-28-11**
WATER LEVEL	**0m 11-3-11**
PROJECT No.	**121614000-305**
DRILLING METHOD	**Wash/Dia**
SIZE	**HW/HQ**
DATUM	**Geodetic**

ELEVATION (m)	DESCRIPTION
579.63	
579.3	Cobbles and boulders pile at surface with peat and topsoil veneer
	Compact to dense, grey to brown, silty SAND (SM); trace to locally some gravel: TILL -frequent cobbles and boulders to 1.5m depth; occasional cobbles below 1.5m depth
569.9	Compact to very dense, brown to grey,

SAMPLES

TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	1	560	13	
SS	2	405	21	S
SS	3	355	14	
SS	4	380	25	S
SS	5	280	46	
SS	6	230	20	
SS	7	50	38	
SS	8	535	21	S
SS	9	255	18	S H
SS	10	355	15	
SS	11	280	16	



DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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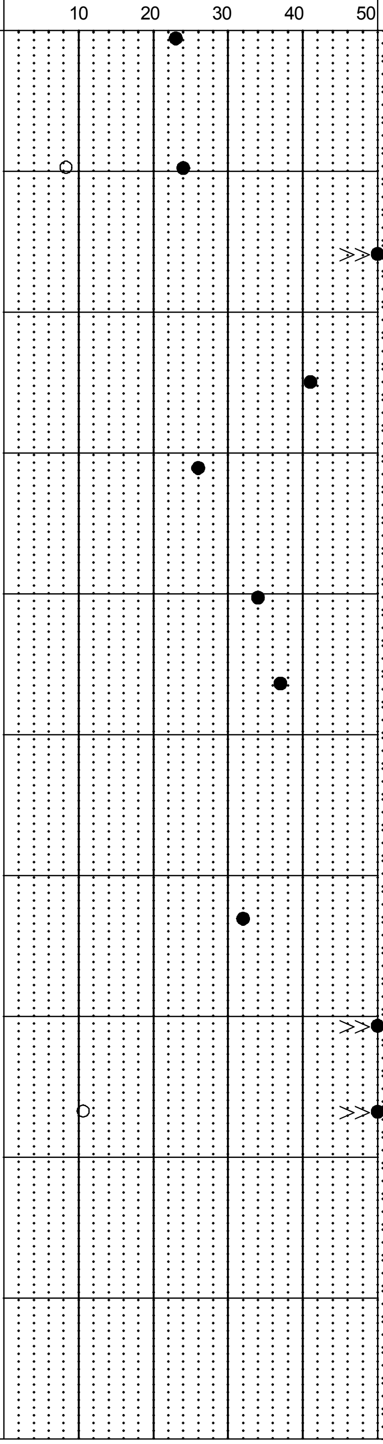
BOREHOLE RECORD

BOREHOLE No. **ROB-11-08A**
PAGE **2** of **4**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5854776 m** E **631997 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **10-26-11 to 10-28-11** WATER LEVEL **0m 11-3-11**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
		Continued from Previous Page					
10		silty SAND with gravel (SM); trace cobbles: TILL	SS	12	280	23	
11			SS	13	355	24	S
			SS	14	305	51	
12			SS	15	255	41	
13			SS	16	280	26	
14			SS	17	125	34	
			SS	18	255	37	
15							
16			SS	19	280	32	
17			SS	20	75	62	
			SS	21	330	54	S
18			SS	22	255	98/300	
	561.1	Very dense, dark grey, silty SAND with gravel (SM) to silty clayey SAND (SC-SM); occasional cobbles: TILL					
19			BS	23	-	-	
20							

UNDRAINED SHEAR STRENGTH - kPa
10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●



STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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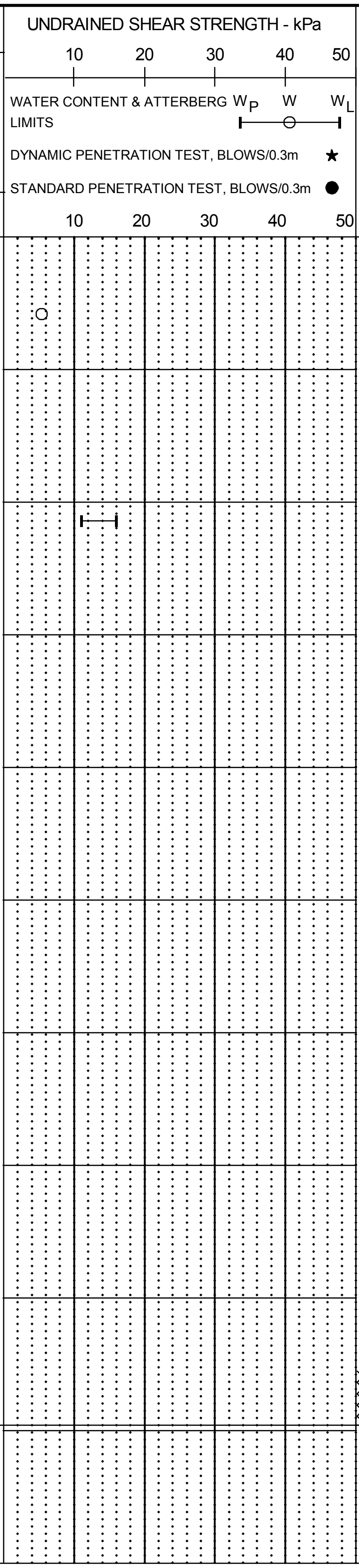
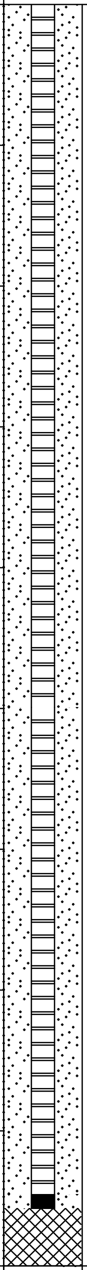
BOREHOLE RECORD

BOREHOLE No. **ROB-11-08A**
PAGE **3** of **4**
PROJECT No. **121614000-305**
DRILLING METHOD **Wash/Dia**
SIZE **HW/HQ**
DATUM **Geodetic**

CLIENT **Alderon Iron Ore Corp.**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5854776 m** E **631997 m**
DATES (mm-dd-yy): BORING **10-26-11 to 10-28-11** WATER LEVEL **0m 11-3-11**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
20		Continued from Previous Page						
			BS	24	92%	-	S	
21			~~SS~~	~~25~~	~~75~~	~~50/75~~		
22			BS	26	-	-	S H	
	556.8							
23		Very severely fractured to moderately jointed, medium strong to occasionally weak, grey, banded, metamorphic rock: BEDROCK	HQ	27	30%	-		
24			~~SS~~	~~28~~	~~0~~	~~50/0~~		
25			HQ	29	60%	0%		50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
26			HQ	30	100%	35%		
27–28			HQ	31	100%	81%		END CAP
29	550.7	End of Borehole - Artesian conditions encountered during drilling at approximately 17.7m						
30								





△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

DRAFT

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BOREHOLE RECORD

BOREHOLE No. **ROB-11-08A**
PAGE **4** of **4**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5854776 m** E **631997 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **10-26-11 to 10-28-11** WATER LEVEL **0m 11-3-11**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	SAMPLES: OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa (10, 20, 30, 40, 50); WATER CONTENT & ATTERBERG LIMITS W_P W W_L; DYNAMIC PENETRATION TEST, BLOWS/0.3m ★; STANDARD PENETRATION TEST, BLOWS/0.3m ● (10, 20, 30, 40, 50)	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									
30		to 19.9m depth and 22.9m to 29.0m depth.									
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											

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△ Unconfined Compression Test
□ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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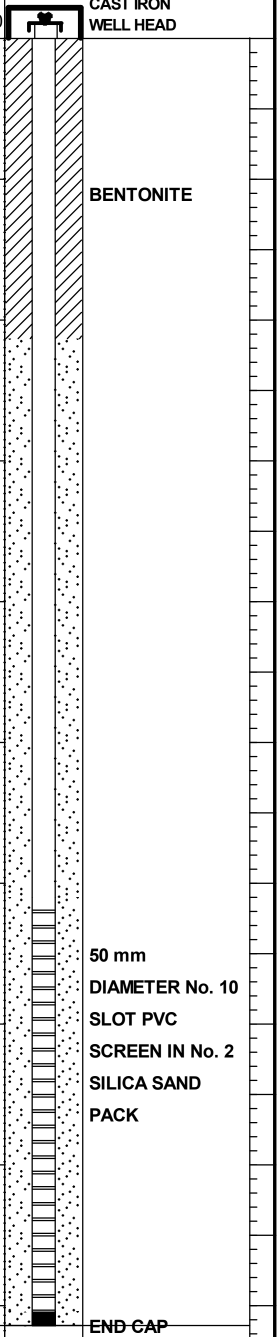
BOREHOLE RECORD

BOREHOLE No. **ROB-11-08B**
PAGE **1** of **1**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5854777 m** E **631998 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **11-10-11 to 11-11-11**
WATER LEVEL **N/A**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	SAMPLES: OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa (10, 20, 30, 40, 50) WATER CONTENT & ATTERBERG LIMITS W_P W W_L DYNAMIC PENETRATION TEST, BLOWS/0.3m ★ STANDARD PENETRATION TEST, BLOWS/0.3m ● (10, 20, 30, 40, 50)	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
0	579.63										
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											


CAST IRON WELL HEAD
BENTONITE
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
END CAP

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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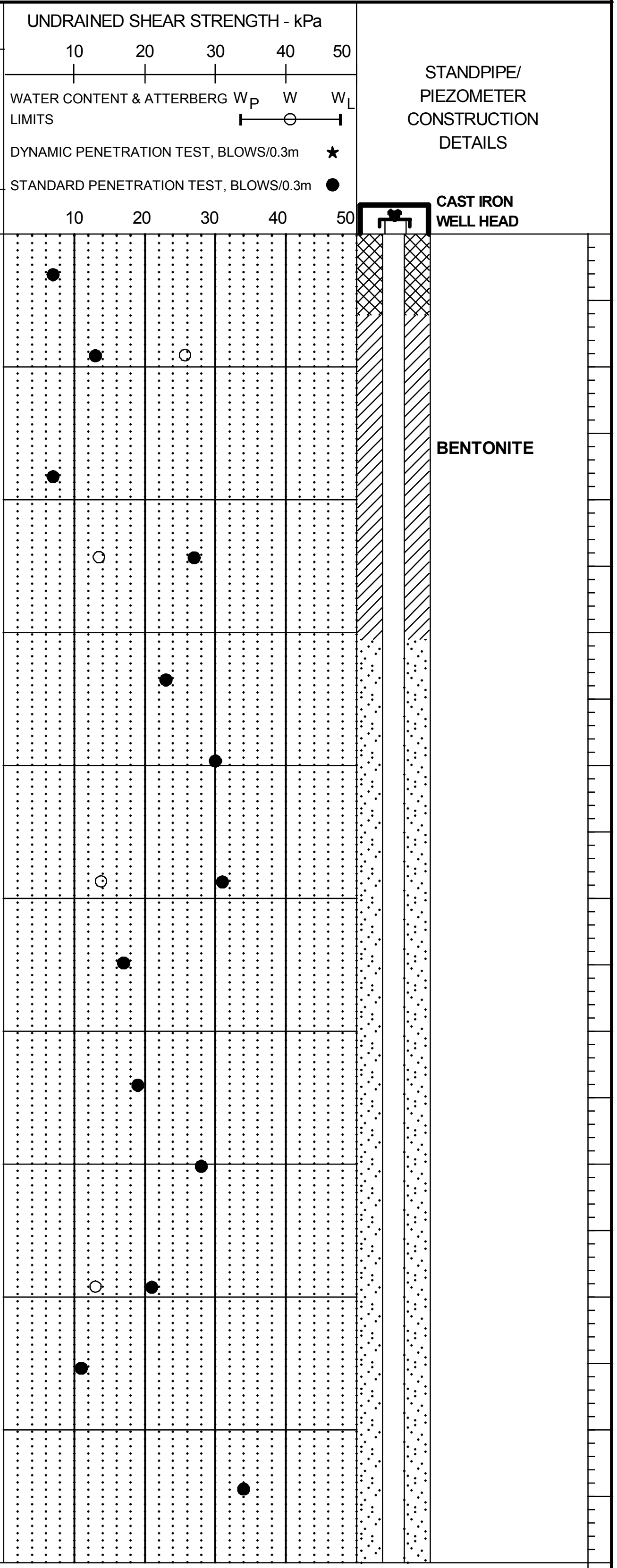
BOREHOLE RECORD

BOREHOLE No. **ROB-11-09**
PAGE **1** of **4**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5854709 m** E **632194 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **11-2-11** to **11-5-11** WATER LEVEL **0m**
DATUM **Geodetic**

ELEVATION (m)	DESCRIPTION
586.62	
586.5	Soft, black, Organic Soil (OL): PEAT
585.1	Loose to compact, brown, SILT (ML); trace sand: TILL
577.0	Loose to compact, brown, silty SAND (SM); trace gravel to poorly graded SAND with gravel (SP); occasional cobbles: TILL
	Compact to dense, grey, silty SAND with gravel (SM); trace cobbles and

SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	1	560	7	
SS	2	355	13	S
SS	3	205	7	S H
SS	4	455	27	S
SS	5	255	23	
SS	6	405	30	
SS	7	305	31	S
SS	8	405	17	
SS	9	330	19	
SS	10	480	28	
SS	11	455	21	S
SS	12	455	11	
SS	13	510	34	



DEPTH (m) 0 – 10

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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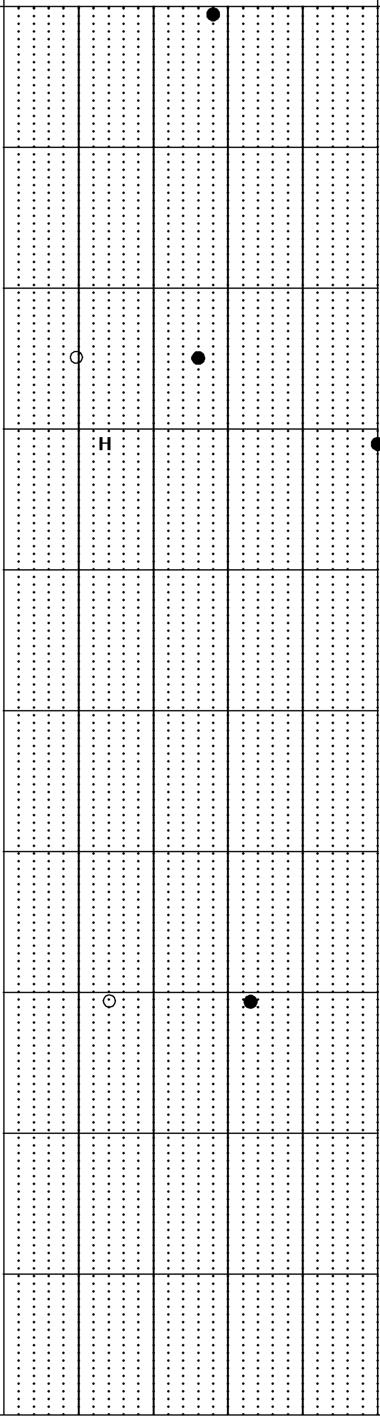
BOREHOLE RECORD

BOREHOLE No. **ROB-11-09**
PAGE **2** of **4**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5854709 m** E **632194 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **11-2-11 to 11-5-11** WATER LEVEL **0m**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
		Continued from Previous Page					
10		boulders: TILL	SS	14	230	28	
			SS	15	0	50/0	
			SS	16	355	26	S
			SS	17	355	50	S H
16	570.5	Dense to very dense, brown, silty SAND with gravel (SM); trace cobbles: TILL					
			SS	18	610	33	S
			SS	19	230	128/530	
20							

UNDRAINED SHEAR STRENGTH - kPa
10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50



STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

BOREHOLE RECORD

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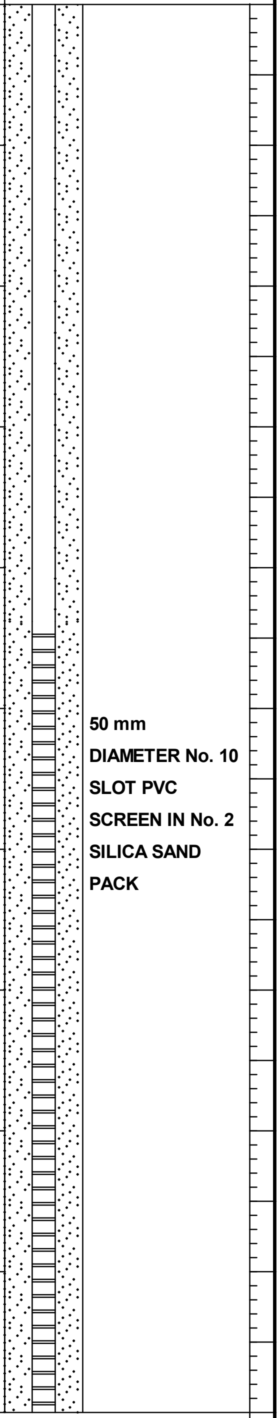
BOREHOLE No. ROB-11-09
PAGE 3 of 4

CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL
N 5854709 m E 632194 m
DATES (mm-dd-yy): BORING 11-2-11 to 11-5-11
WATER LEVEL 0m
PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATUM Geodetic

UNDRAINED SHEAR STRENGTH - kPa: 10, 20, 30, 40, 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
		Continued from Previous Page					
20			SS	20	150	112/300	
			SS	21	305	113/380	
	564.1	Very dense, grey, silty SAND with gravel (SM); trace cobbles and boulders: TILL					
			BS	22	150	-	S H
			BS	23	150	-	
	560.7	Fractured, extremely weak, orange brown, metamorphic rock: BEDROCK					
			HQ	24	100%	67%	
			HQ	25	100%	50%	
			HQ	26	83%	72%	
30							

STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS



50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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BOREHOLE RECORD

BOREHOLE No. **ROB-11-09**
PAGE **4** of **4**

CLIENT **Alderon Iron Ore Corp.**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL**
N **5854709 m** E **632194 m**
DATES (mm-dd-yy): BORING **11-2-11** to **11-5-11**
WATER LEVEL **0m**
PROJECT No. **121614000-305**
DRILLING METHOD **Wash/Dia**
SIZE **HW/HQ**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY(mm) OR TCR %	SAMPLES N-VALUE OR RQD %	SAMPLES OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa (10 20 30 40 50) WATER CONTENT & ATTERBERG LIMITS W_P W W_L DYNAMIC PENETRATION TEST, BLOWS/0.3m ★ STANDARD PENETRATION TEST, BLOWS/0.3m ● 10 20 30 40 50	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									
30	556.1										END CAP
		End of Borehole									
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											

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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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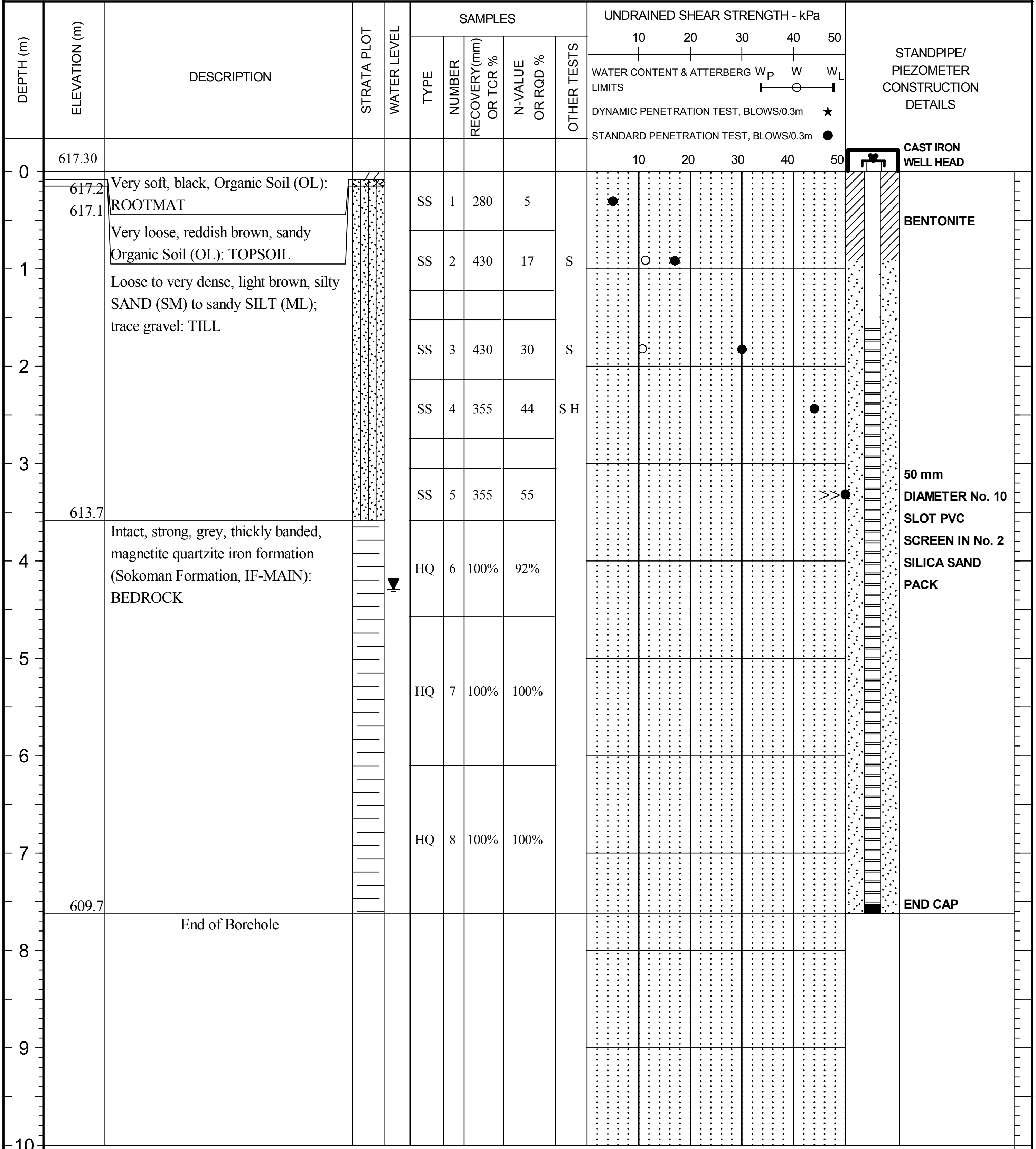
BOREHOLE RECORD

BOREHOLE No. **ROB-11-10**
PAGE **1** of **1**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5854664.046 m** E **632652.964 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **10-17-11 to 10-18-11**
WATER LEVEL **4.29m 11-3-11**
DATUM **Geodetic**

ELEVATION (m)	DESCRIPTION	WATER LEVEL	TYPE	NUMBER	RECOVERY (mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
617.30							
617.2	Very soft, black, Organic Soil (OL): ROOTMAT						
617.1	Very loose, reddish brown, sandy Organic Soil (OL): TOPSOIL		SS	1	280	5	
	Loose to very dense, light brown, silty SAND (SM) to sandy SILT (ML); trace gravel: TILL		SS	2	430	17	S
			SS	3	430	30	S
			SS	4	355	44	S H
			SS	5	355	55	
613.7	Intact, strong, grey, thickly banded, magnetite quartzite iron formation (Sokoman Formation, IF-MAIN): BEDROCK	▼	HQ	6	100%	92%	
			HQ	7	100%	100%	
			HQ	8	100%	100%	
609.7	End of Borehole						



△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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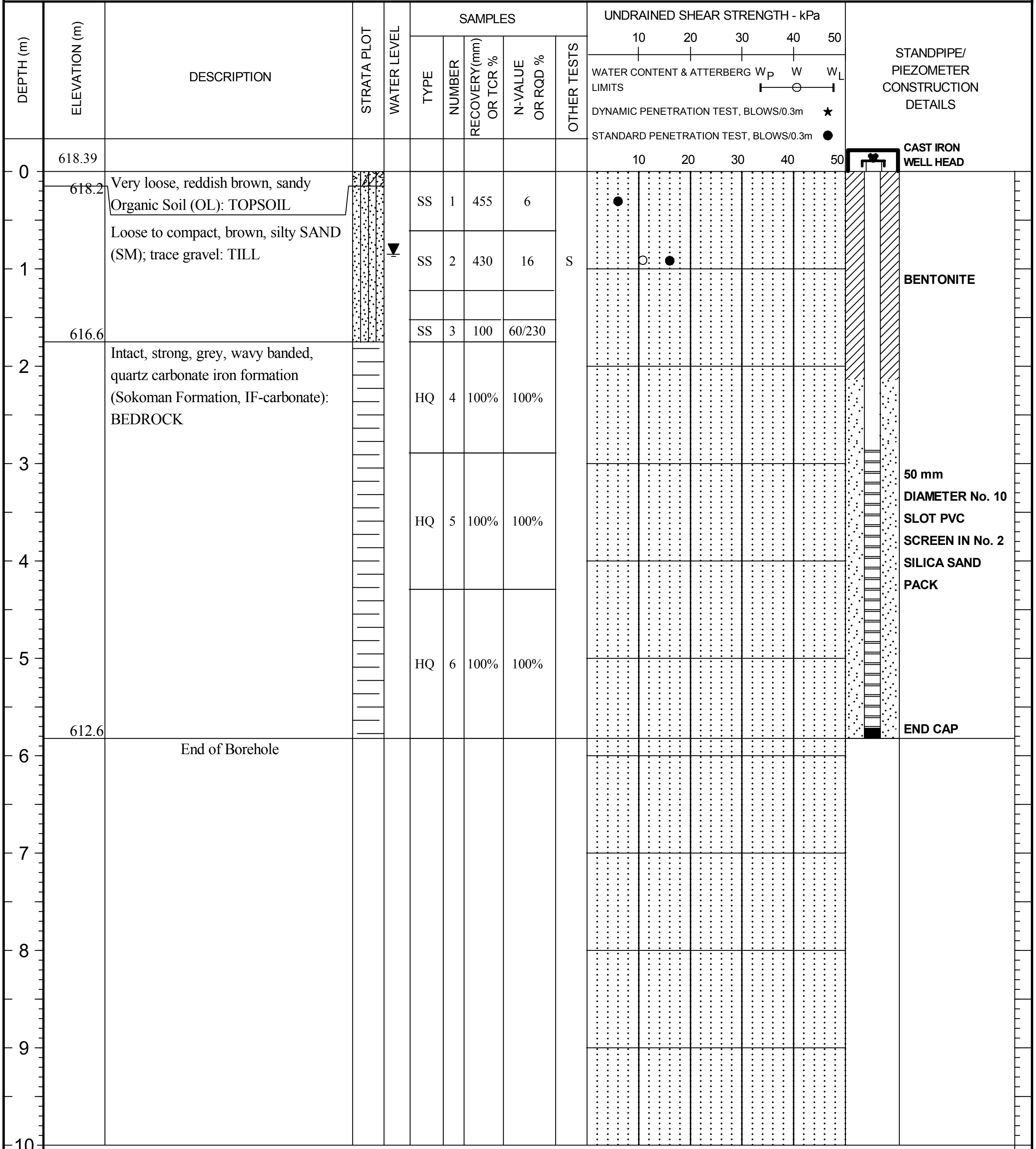
BOREHOLE RECORD

BOREHOLE No. ROB-11-11
PAGE 1 of 1
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL
N 5854769.872 m E 632917.994 m
SIZE HW/HQ
DATES (mm-dd-yy): BORING 10-19-11
WATER LEVEL 0.85m 11-3-11
DATUM Geodetic

ELEVATION (m)	DESCRIPTION	WATER LEVEL	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
618.39							
618.2	Very loose, reddish brown, sandy Organic Soil (OL): TOPSOIL		SS	1	455	6	
	Loose to compact, brown, silty SAND (SM); trace gravel: TILL	▼	SS	2	430	16	S
616.6			SS	3	100	60/230	
	Intact, strong, grey, wavy banded, quartz carbonate iron formation (Sokoman Formation, IF-carbonate): BEDROCK		HQ	4	100%	100%	
			HQ	5	100%	100%	
			HQ	6	100%	100%	
612.6	End of Borehole						


DEPTH (m)
0
1
2
3
4
5
6
7
8
9
10
STRATA PLOT
UNDRAINED SHEAR STRENGTH - kPa
10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS
W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50
STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
CAST IRON WELL HEAD
BENTONITE
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
END CAP

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

DRAFT

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BOREHOLE RECORD

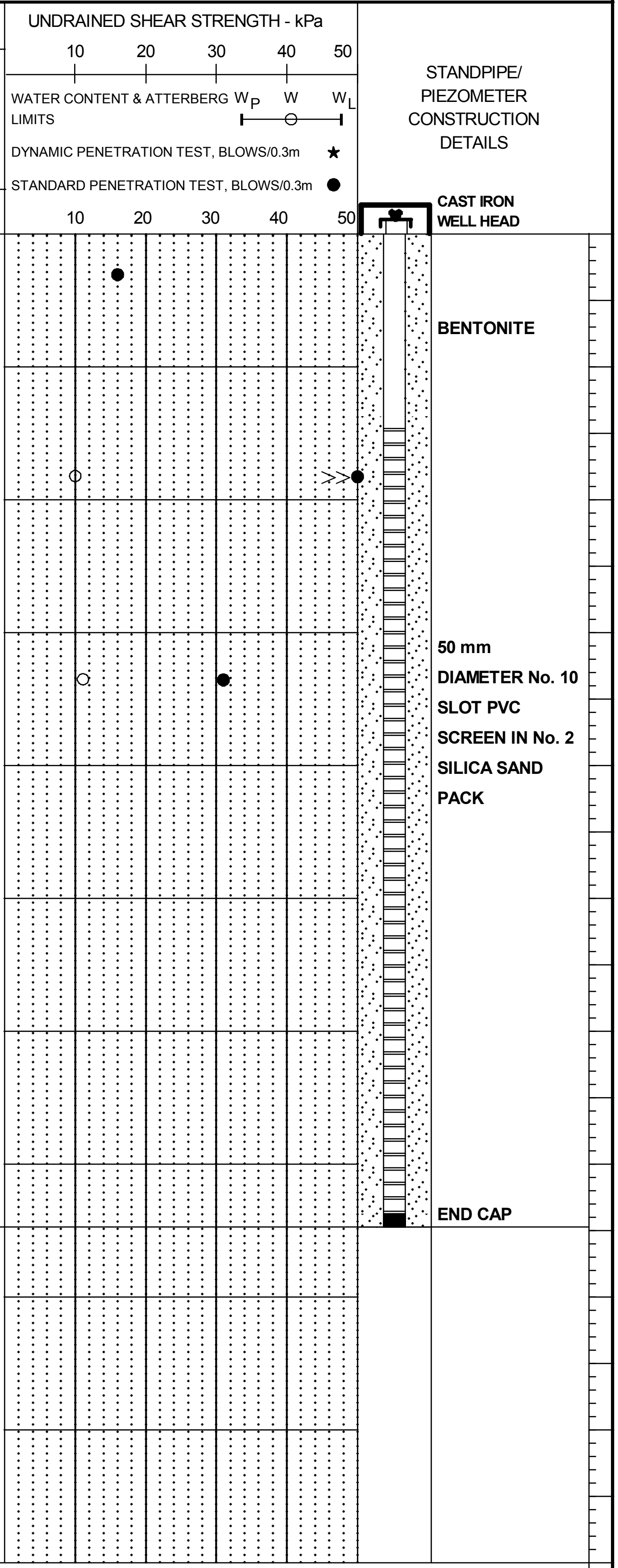
BOREHOLE No. **ROB-11-12**
PAGE **1** of **1**

CLIENT	**Alderon Iron Ore Corp.**
PROJECT	**Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION	**Kami Iron Ore Mine Site, Labrador West, NL**
N	**5854944.086 m**
E	**633248.884 m**
DATES (mm-dd-yy): BORING	**10-20-11 to 10-21-11**
WATER LEVEL	**0.15m 11-3-11**
PROJECT No.	**121614000-305**
DRILLING METHOD	**Wash/Dia**
SIZE	**HW/HQ**
DATUM	**Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION
0	631.15	
0.15	631.0	Soft, black, Organic Soil (OL): PEAT
0.15–3.95	627.2	Compact to very dense, brown, silty SAND with gravel (SM); trace cobbles and boulders: TILL
3.95–5.85	625.3	Intact, strong, grey, magnetite quartzite iron formation (Sokoman Formation, IF-main): BEDROCK
5.85–7.45	623.7	Intact, strong, grey, quartz silicate iron formation (Sokoman Formation, IF-silicate): BEDROCK
		End of Borehole

SAMPLES

TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	1	330	16	
SS	2	230	95/300	
SS	3	305	73	S
SS	4	380	31	S
SS	5	100	80/180	
HQ	6	100%	100%	
HQ	7	100%	100%	
HQ	8	100%	100%	
HQ	9	100%	95%	



△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

DRAFT

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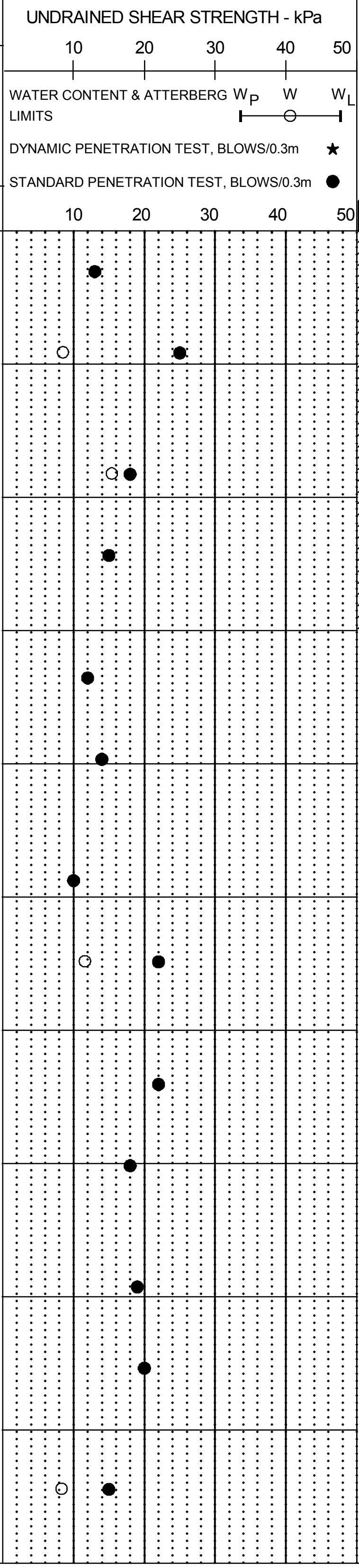
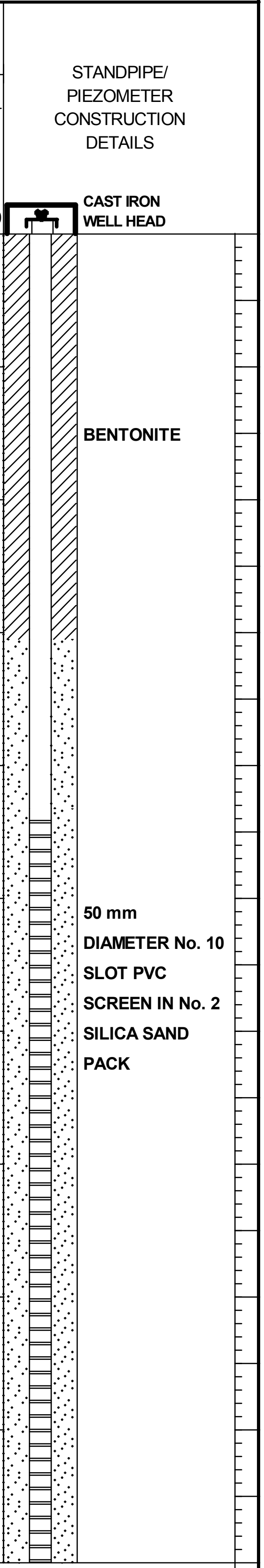
BOREHOLE RECORD

BOREHOLE No. **ROB-11-16**
PAGE **1** of **2**

CLIENT	**Alderon Iron Ore Corp.**
PROJECT	**Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION	**Kami Iron Ore Mine Site, Labrador West, NL** N **5856090.596 m** E **633217.885 m**
DATES (mm-dd-yy): BORING	**10-24-11 to 10-25-11** WATER LEVEL **0m 11-3-11**
PROJECT No.	**121614000-305**
DRILLING METHOD	**Wash/Dia**
SIZE	**HW/HQ**
DATUM	**Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
0	570.29						
	570.1	Soft, black, Organic Soil (OL): PEAT	SS	1	335	13	
	570.0	Compact, reddish brown, sandy Organic Soil (OL): TOPSOIL					
1		Compact, grey, silty SAND with gravel (SM) to silty SAND (SM); trace gravel: TILL	SS	2	280	25	S H
2			SS	3	175	18	S
			SS	4	175	15	
3			SS	5	175	12	
4			SS	6	150	14	
5			SS	7	175	10	
			SS	8	330	22	S
6			SS	9	100	22	
7			SS	10	355	18	
8			SS	11	205	19	
			SS	12	175	20	
9			SS	13	205	15	S
10							





STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
CAST IRON WELL HEAD
BENTONITE
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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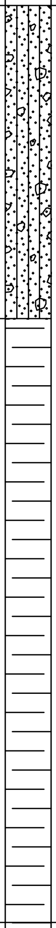
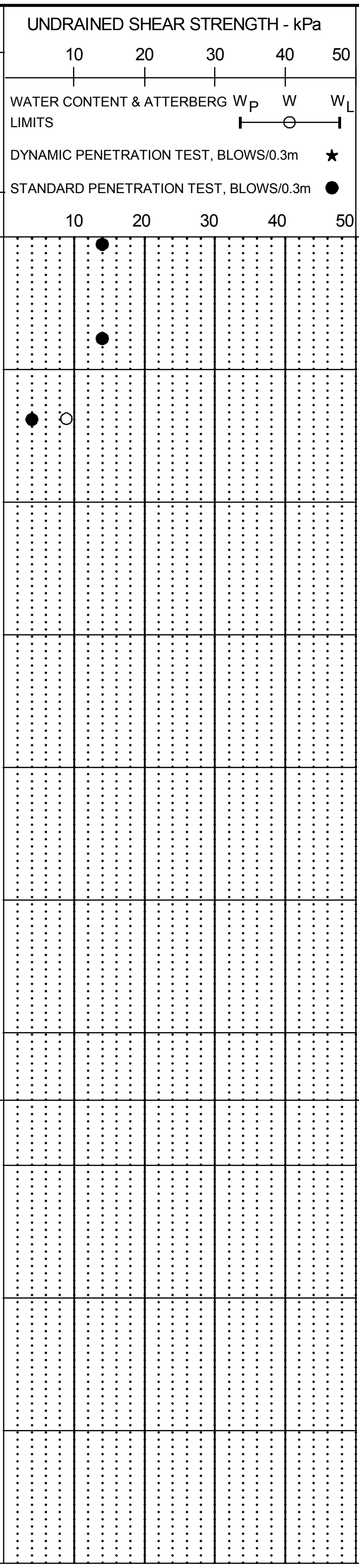
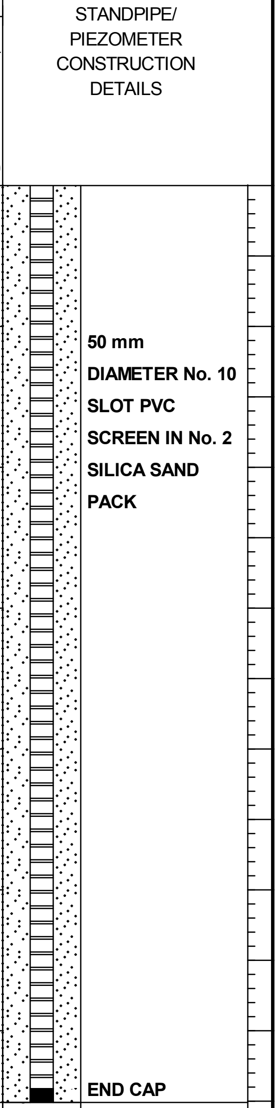
BOREHOLE RECORD

BOREHOLE No. ROB-11-16
PAGE 2 of 2
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N5856090.596 m E 633217.885 m
SIZE HW/HQ
DATES (mm-dd-yy): BORING 10-24-11 to 10-25-11
WATER LEVEL 0m 11-3-11
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
		Continued from Previous Page					
10			SS	14	230	14	S H
			SS	15	150	14	
11		-locally loose from 11.1m to 11.7m depth	SS	16	610	4	S
12	558.1		SS	17	230	90/230	
		Fractured to intact, medium strong to strong, black, banded, biotite muscovite quartz schist, graphitic muscovite quartz schist, and hornblende biotite garnet gneiss (Menihek Formation): BEDROCK	HQ	18	100%	98%	
14			HQ	19	98%	50%	
15			HQ	20	100%	100%	
16	553.8						
		End of Borehole					


STRATA PLOT
WATER LEVEL




STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
END CAP

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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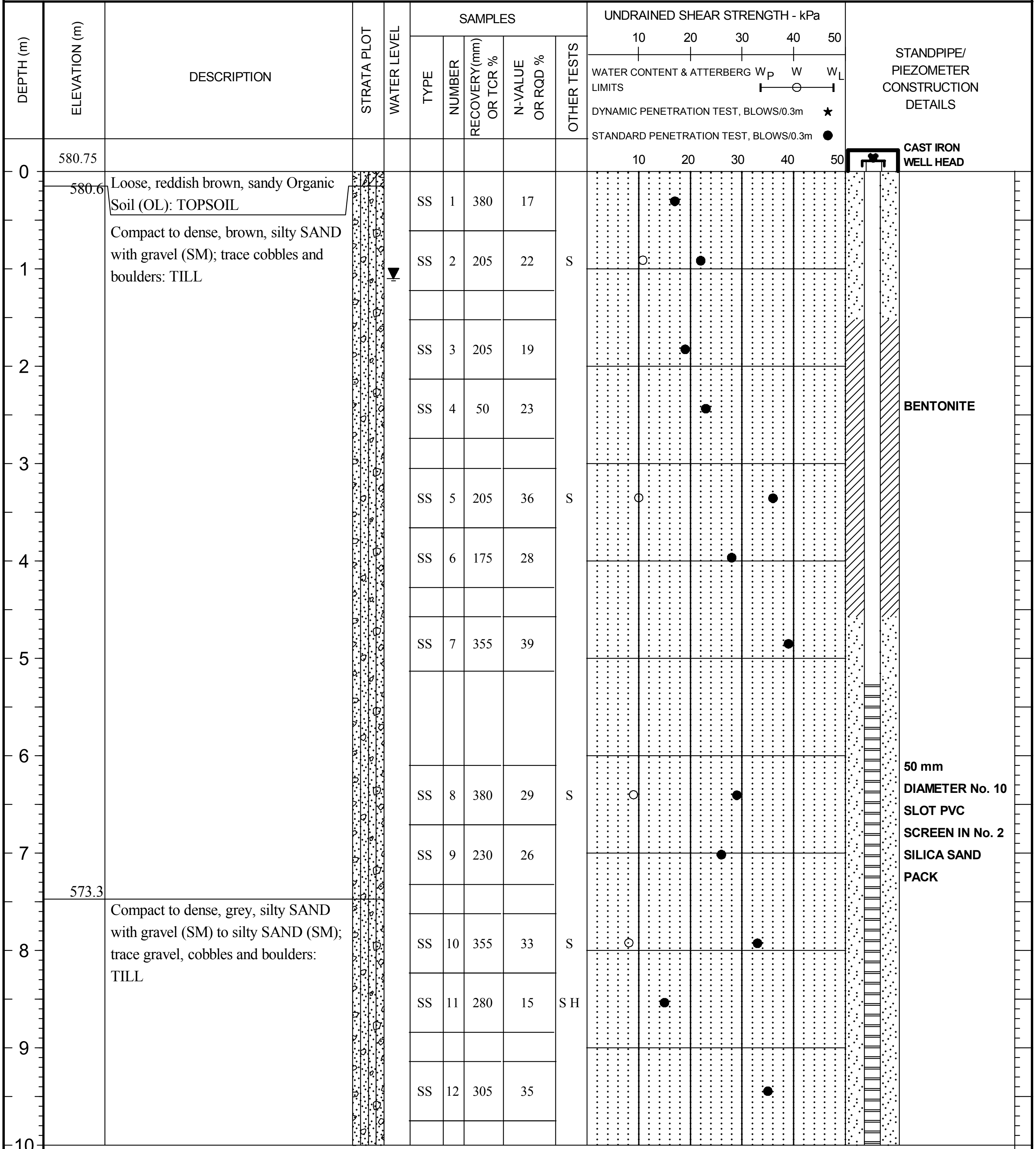
BOREHOLE RECORD

BOREHOLE No. **ROB-11-17**
PAGE **1** of **5**

CLIENT **Alderon Iron Ore Corp.**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5855590.76 m** E **632777.525 m**
DATES (mm-dd-yy): BORING **10-10-11 to 10-13-11** WATER LEVEL **1.1m 11-3-11**
PROJECT No. **121614000-305**
DRILLING METHOD **Wash/Dia**
SIZE **HW/HQ**
DATUM **Geodetic**



ELEVATION (m)	DESCRIPTION
580.75	
580.6	Loose, reddish brown, sandy Organic Soil (OL): TOPSOIL
	Compact to dense, brown, silty SAND with gravel (SM); trace cobbles and boulders: TILL
573.3	Compact to dense, grey, silty SAND with gravel (SM) to silty SAND (SM); trace gravel, cobbles and boulders: TILL

TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	1	380	17	
SS	2	205	22	S
SS	3	205	19	
SS	4	50	23	
SS	5	205	36	S
SS	6	175	28	
SS	7	355	39	
SS	8	380	29	S
SS	9	230	26	
SS	10	355	33	S
SS	11	280	15	S H
SS	12	305	35	

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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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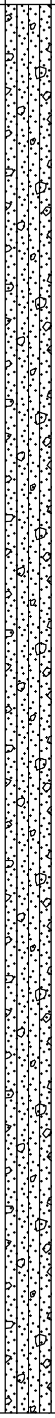
BOREHOLE RECORD

BOREHOLE No. **ROB-11-17**
PAGE **2** of **5**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5855590.76 m** E **632777.525 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **10-10-11 to 10-13-11**
WATER LEVEL **1.1m 11-3-11**
DATUM **Geodetic**

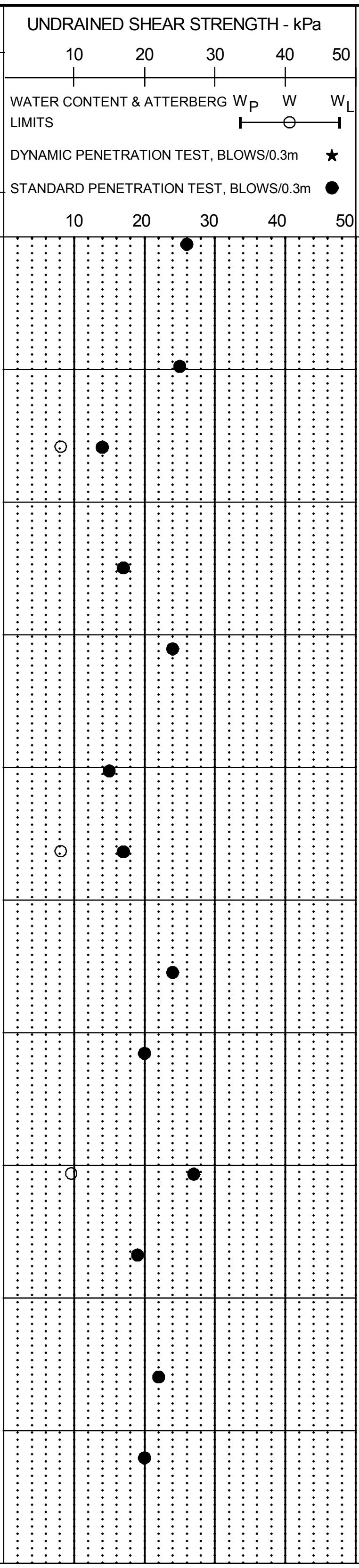
DESCRIPTION: Continued from Previous Page

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
10			SS	13	355	26	
			SS	14	280	25	
			SS	15	355	14	S
			SS	16	330	17	
			SS	17	480	24	
			SS	18	50	15	
			SS	19	380	17	S
			SS	20	280	24	
			SS	21	330	20	
			SS	22	355	27	S
			SS	23	230	19	
			SS	24	280	22	
			SS	25	405	20	S H
20							

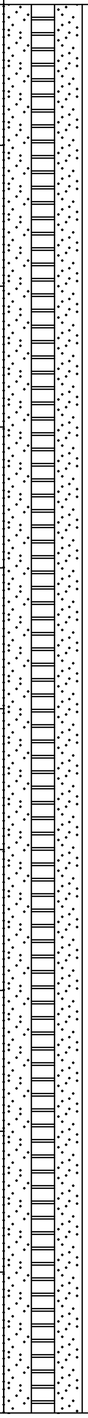
STRATA PLOT



WATER LEVEL



STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS



50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
□ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

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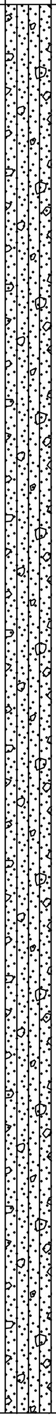
BOREHOLE RECORD

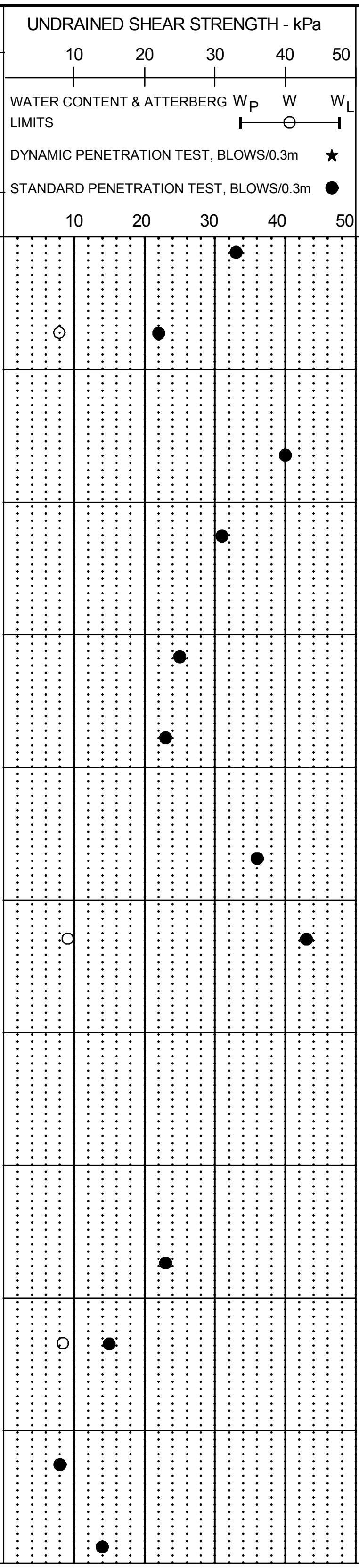
BOREHOLE No.	ROB-11-17
PAGE	3 of 5
CLIENT	Alderon Iron Ore Corp.
PROJECT	Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION	Kami Iron Ore Mine Site, Labrador West, NL
N	5855590.76 m
E	632777.525 m
DATES (mm-dd-yy): BORING	10-10-11 to 10-13-11
WATER LEVEL	1.1m 11-3-11
PROJECT No.	121614000-305
DRILLING METHOD	Wash/Dia
SIZE	HW/HQ
DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
		Continued from Previous Page					
20			SS	26	175	33	
			SS	27	380	22	S
21			SS	28	175	40	
22			SS	29	280	31	
23			SS	30	355	25	
			SS	31	330	23	
24			SS	32	150	36	
25			SS	33	480	43	S
26			SS	34	0	73/230	
27			SS	35	150	23	
28			SS	36	510	15	S
29		-locally loose from 29.0m to 29.6m depth	SS	37	175	8	
			SS	38	330	14	
30							

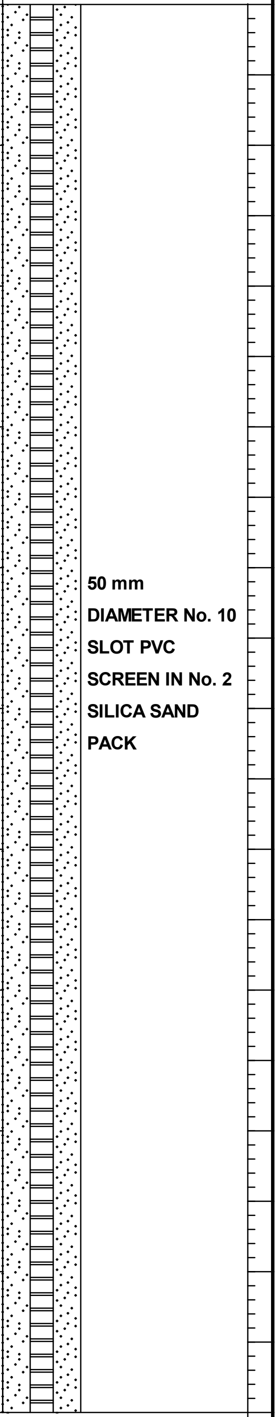
STRATA PLOT



WATER LEVEL



STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS



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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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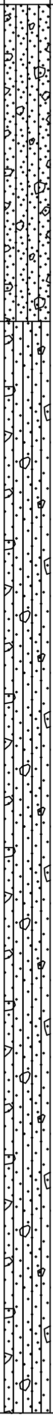
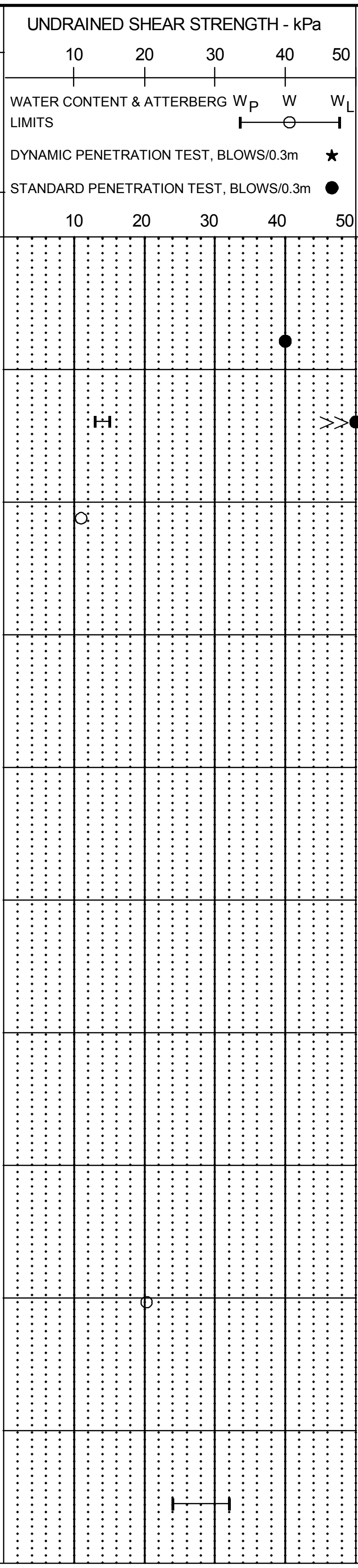
BOREHOLE RECORD

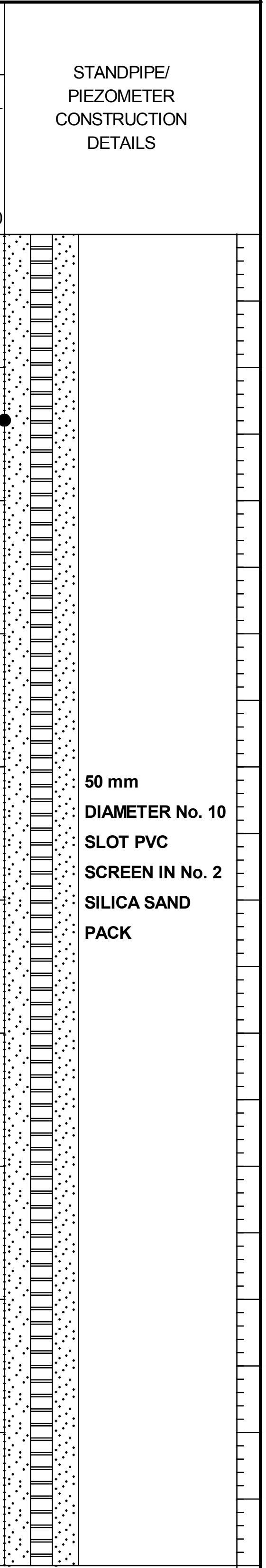
BOREHOLE No. ROB-11-17
PAGE 4 of 5
CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N 5855590.76 m E 632777.525 m
DATES (mm-dd-yy): BORING 10-10-11 to 10-13-11
WATER LEVEL 1.1m 11-3-11
PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY (mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
30		Continued from Previous Page					
30.8			SS	39	480	40	
31.4			SS	40	480	52	S H
32.1			SS	41	255	94/250	S
32.25	548.5	Very dense, grey, SILT with sand (ML); trace gravel to gravelly SILT (ML); trace sand, cobbles and boulders throughout: TILL					
33.5			BS	42	0%	-	
34.5			BS	43	100%	-	
36.6			~~SS~~	~~44~~	~~0~~	~~50/50~~	
38			BS	45	100%	-	S
39.5			BS	46	100%	-	S H
40							





UNDRAINED SHEAR STRENGTH - kPa
10
20
30
40
50
WATER CONTENT & ATTERBERG LIMITS
W_P
W
W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10
20
30
40
50
>>



STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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BOREHOLE RECORD

BOREHOLE No. ROB-11-17
PAGE 5 of 5
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N 5855590.76 m E 632777.525 m
SIZE HW/HQ
DATES (mm-dd-yy): BORING 10-10-11 to 10-13-11
WATER LEVEL 1.1m 11-3-11
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
40.0 – 40.5	540.2	Continued from Previous Page	
40.5 – 43.3	537.5	Very dense, dark grey, silty SAND (SM); trace gravel, cobbles and boulders: TILL	
43.3 – 47.9	532.9	Intact, strong, dark grey, foliated, biotite muscovite quartz schist (Menihek Formation): BEDROCK	50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK END CAP
47.9		End of Borehole	

SAMPLES

TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	47	175	90/180	
BS	48	100%	-	S
NQ	49	100%	100%	
NQ	50	100%	100%	

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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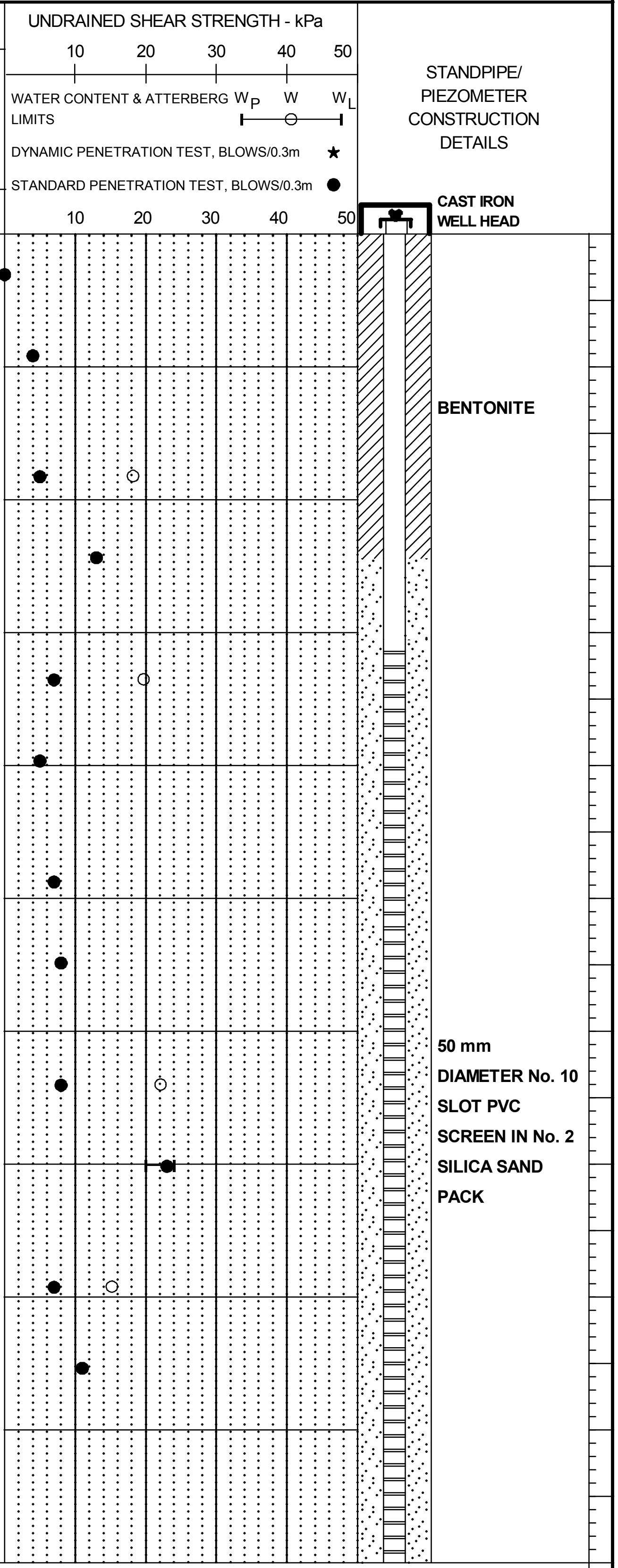
BOREHOLE RECORD

BOREHOLE No. **ROB-11-18**
PAGE **1** of **4**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5855668.193 m** E **632197.922 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **10-14-11 to 10-16-11**
WATER LEVEL **0m 11-3-11**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
0	574.23			▼					
		Very soft to soft, black, Organic Soil (OL): PEAT			SS	1	0	0	
1					SS	2	125	4	
2	572.6	Loose to compact, grey, silty SAND (SM): TILL			SS	3	380	5	S
					SS	4	380	13	S H
3	571.2	Firm to very stiff, grey, sandy SILT (ML) to SILT (ML); trace sand: TILL			SS	5	480	7	S
4					SS	6	355	5	S H
5					SS	7	405	7	
					SS	8	430	8	
6					SS	9	535	8	S
7		-locally clayey below 6.7m depth			SS	10	355	23	S H
8	566.6	Loose to very dense, grey, silty SAND with gravel (SM); occasional cobbles: TILL			SS	11	355	7	S
		- Grain size and relative density increase with depth.			SS	12	280	11	S H
9					SS	13	75	70/230	
10									



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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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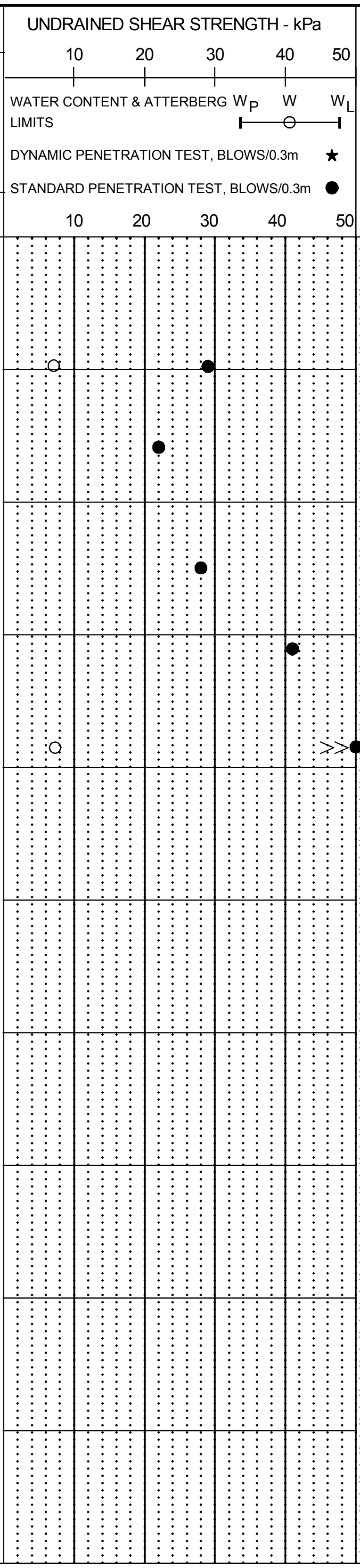
BOREHOLE RECORD

BOREHOLE No. **ROB-11-18**
PAGE **2** of **4**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5855668.193 m** E **632197.922 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **10-14-11 to 10-16-11**
WATER LEVEL **0m 11-3-11**
DATUM **Geodetic**

DEPTH (m) | ELEVATION (m) | DESCRIPTION | STRATA PLOT | WATER LEVEL | SAMPLES | OTHER TESTS | STANDPIPE/PIEZOMETER CONSTRUCTION DETAILS

Continued from Previous Page

TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	14	455	29	S
SS	15	280	22	
SS	16	380	28	
SS	17	455	41	
SS	18	480	85	S
~~SS~~	~~19~~	~~0~~	~~50/0~~	
~~SS~~	~~20~~	~~100~~	~~50/100~~	
BS	21	100%	-	
BS	22	100%	-	



Depth scale: 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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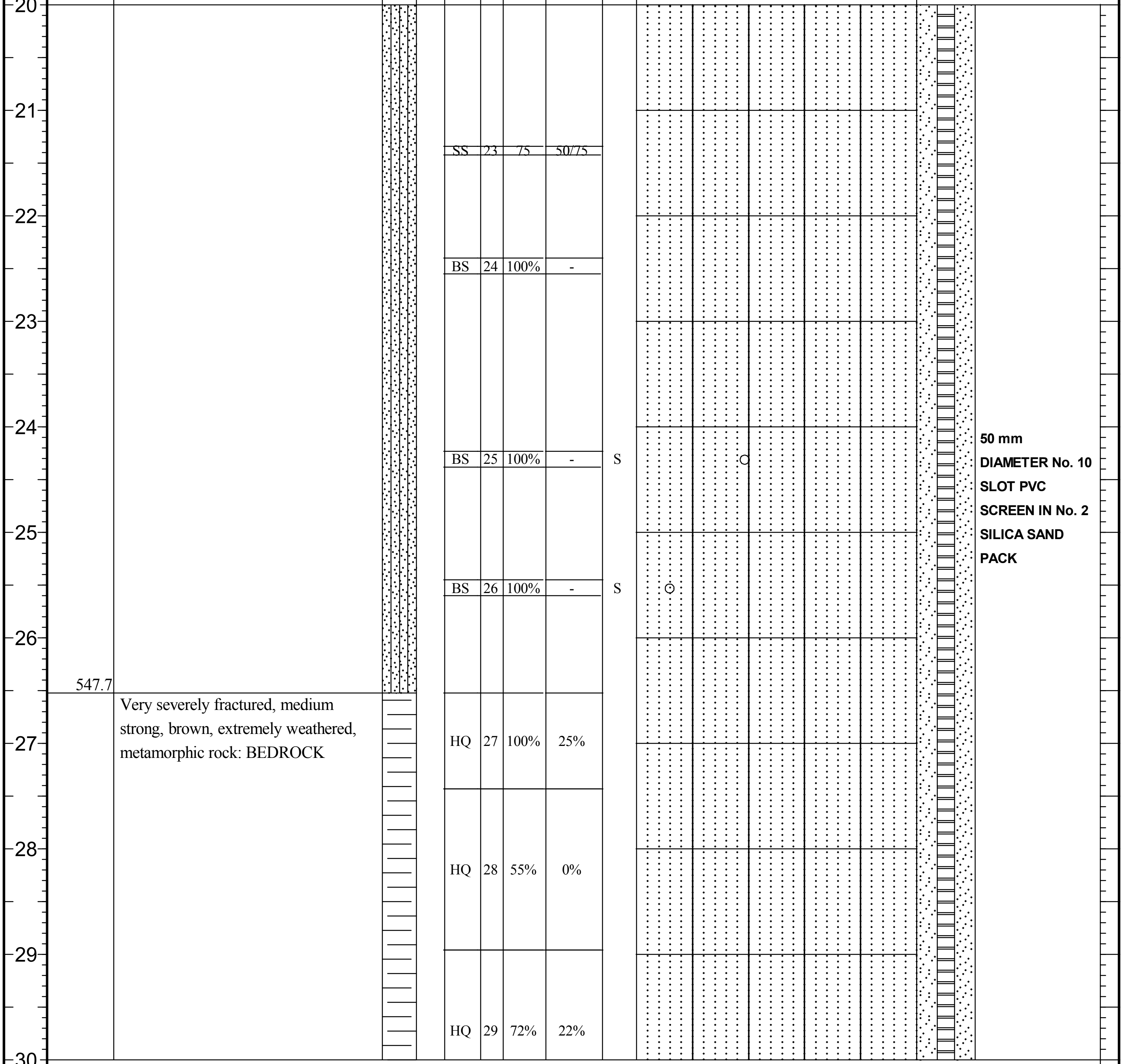
BOREHOLE RECORD

BOREHOLE No. **ROB-11-18**
PAGE **3** of **4**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5855668.193 m** E **632197.922 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **10-14-11 to 10-16-11**
WATER LEVEL **0m 11-3-11**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
		Continued from Previous Page							
21.4					SS	23	75	50/75	
22.5					BS	24	100%	-	
24.3					BS	25	100%	-	S
25.5					BS	26	100%	-	S
26.5	547.7	Very severely fractured, medium strong, brown, extremely weathered, metamorphic rock: BEDROCK							
27.0					HQ	27	100%	25%	
28.2					HQ	28	55%	0%	
29.7					HQ	29	72%	22%	

UNDRAINED SHEAR STRENGTH - kPa
10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50

STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS



50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

Stantec

BOREHOLE RECORD

BOREHOLE No. **ROB-11-18**
PAGE **4** of **4**

CLIENT	**Alderon Iron Ore Corp.**	PROJECT No.	**121614000-305**
PROJECT	**Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**	DRILLING METHOD	**Wash/Dia**
LOCATION	**Kami Iron Ore Mine Site, Labrador West, NL** N **5855668.193 m** E **632197.922 m**	SIZE	**HW/HQ**
DATES (mm-dd-yy): BORING	**10-14-11** to **10-16-11** WATER LEVEL **0m** **11-3-11**	DATUM	**Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	SAMPLES: OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa (10, 20, 30, 40, 50); WATER CONTENT & ATTERBERG LIMITS W_P W W_L; DYNAMIC PENETRATION TEST, BLOWS/0.3m ★; STANDARD PENETRATION TEST, BLOWS/0.3m ● (10, 20, 30, 40, 50)	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									
30	543.8										END CAP
		End of Borehole									
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											

DRAFT

△ Unconfined Compression Test	
☐ Field Vane Test	■ (Remolded)
◇ Fall Cone Test	◆ (Remolded)
▽ Hand Penetrometer Test	◪ Torvane

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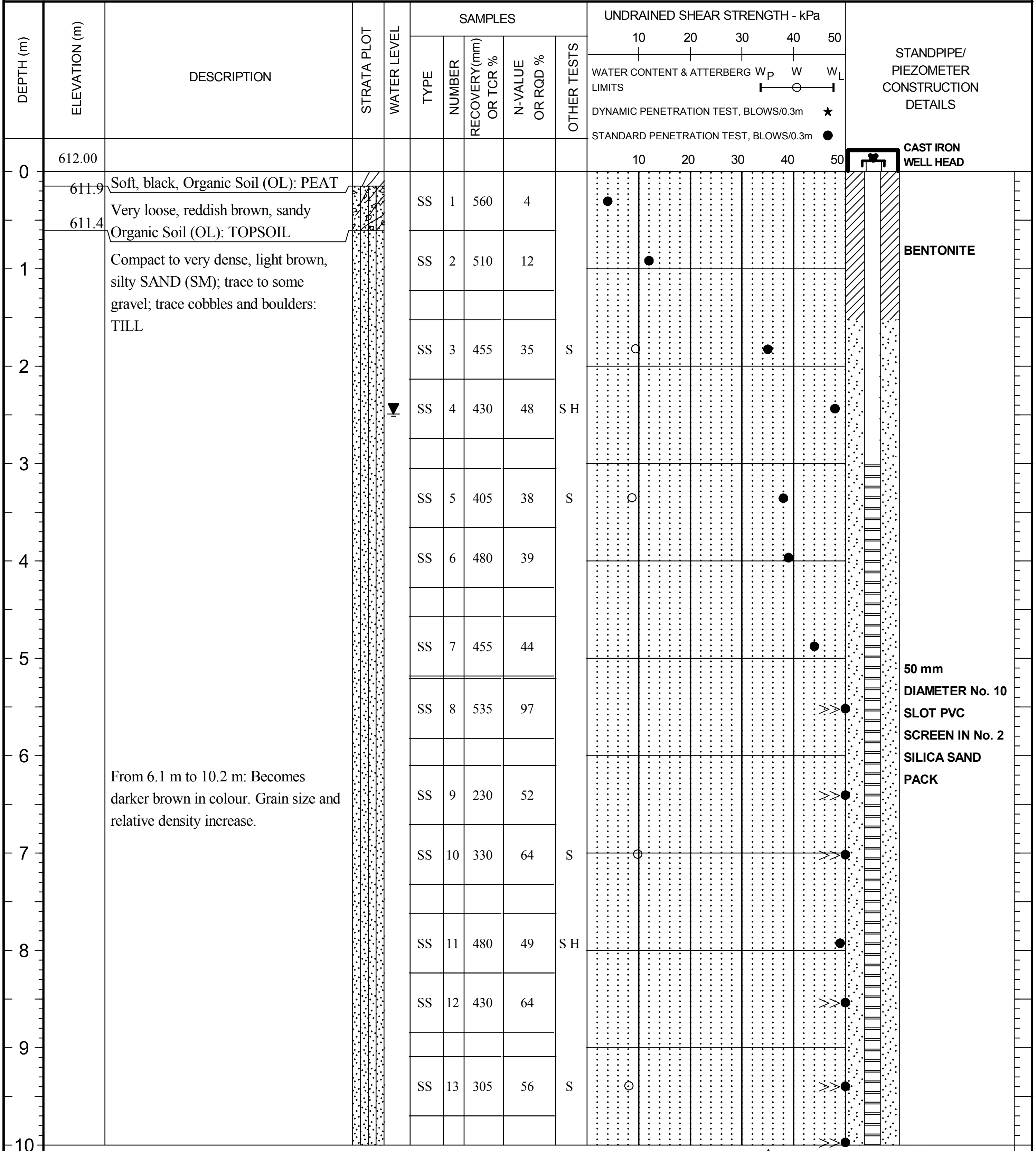
BOREHOLE RECORD

BOREHOLE No. ROB-11-20
PAGE 1 of 2
CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL
N 5855553 m E 633250 m
SIZE HW/HQ
DATES (mm-dd-yy): BORING 10-23-11
WATER LEVEL 2.49m 11-3-11
DATUM Geodetic



ELEVATION (m)	DESCRIPTION
612.00	
611.9	Soft, black, Organic Soil (OL): PEAT
611.4	Very loose, reddish brown, sandy Organic Soil (OL): TOPSOIL
	Compact to very dense, light brown, silty SAND (SM); trace to some gravel; trace cobbles and boulders: TILL
	From 6.1 m to 10.2 m: Becomes darker brown in colour. Grain size and relative density increase.

WATER LEVEL	TYPE	NUMBER	RECOVERY (mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
	SS	1	560	4	
	SS	2	510	12	
	SS	3	455	35	S
▼	SS	4	430	48	S H
	SS	5	405	38	S
	SS	6	480	39	
	SS	7	455	44	
	SS	8	535	97	
	SS	9	230	52	
	SS	10	330	64	S
	SS	11	480	49	S H
	SS	12	430	64	
	SS	13	305	56	S

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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BOREHOLE RECORD

BOREHOLE No. **ROB-11-20**
PAGE **2** of **2**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **5855553 m** E **633250 m**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **10-23-11** WATER LEVEL **2.49m 11-3-11** DATUM **Geodetic**

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY(mm) OR TCR %	SAMPLES N-VALUE OR RQD %	OTHER TESTS	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page						
10	601.8		SS	14	610	81		**50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK**
		Fractured to intact, strong to very strong, dark grey, banded, hornblende biotite garnet gneiss (Menihek Formation): BEDROCK	HQ	15	92%	92%		
11			HQ	16	100%	77%		
12–13			HQ	17	100%	90%		
14			HQ	18	100%	65%		
15	596.9							**END CAP**
		End of Borehole						
16								
17								
18								
19								
20								

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

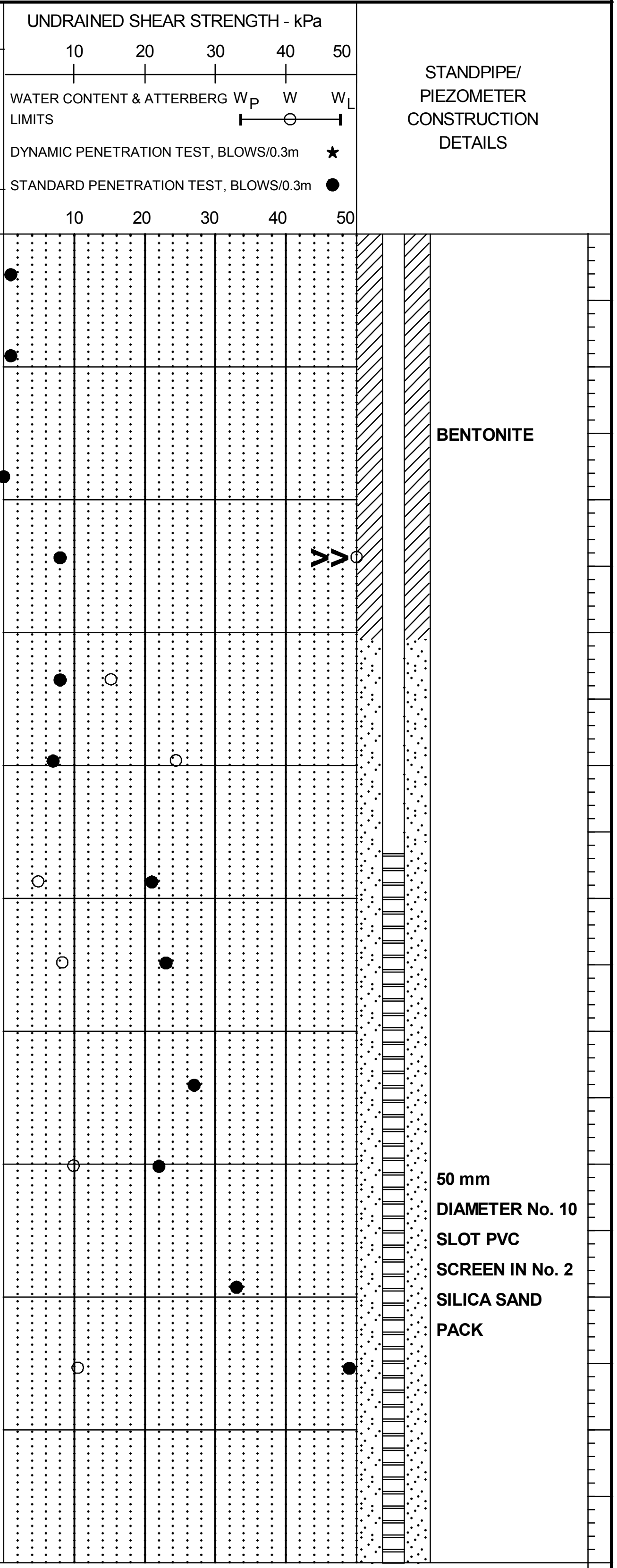
Stantec

BOREHOLE RECORD

BOREHOLE No. **ROB-12-02**
PAGE **1** of **3**

CLIENT **Alderon Iron Ore Corp.**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **N/A** E **N/A**
DATES (mm-dd-yy): BORING **2-14-12 to 2-23-12** WATER LEVEL **N/A**
PROJECT No. **121614000-305**
DRILLING METHOD
SIZE
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
0		Frozen to very loose, black, Organic Soil (OL): PEAT	SS	1	125	1	
			SS	2	0	1	
			SS	3	255	0	
		Loose to dense, grey, silty SAND (SM); trace gravel, cobbles and boulders: TILL	SS	4	330	8	
			SS	5	430	8	
			SS	6	330	7	
			SS	7	230	21	
			SS	8	255	23	S
			SS	9	280	27	
			SS	10	150	22	
			SS	11	0	33	
			SS	12	100	49	
10							



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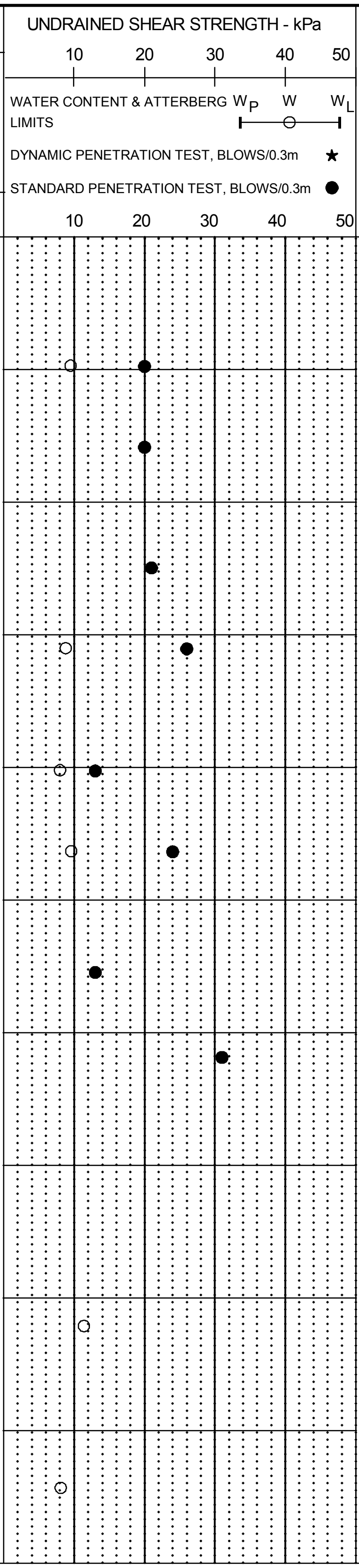
△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

BOREHOLE RECORD

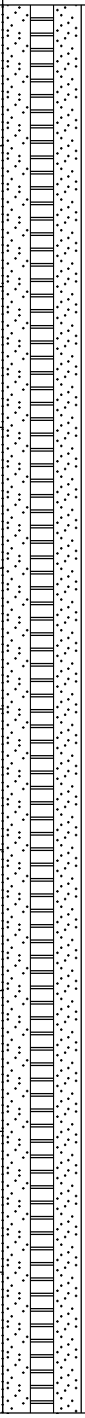
Stantec

BOREHOLE No. ROB-12-02
PAGE 2 of 3
CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL
N N/A E N/A
DATES (mm-dd-yy): BORING 2-14-12 to 2-23-12
WATER LEVEL N/A
PROJECT No. 121614000-305
DRILLING METHOD
SIZE
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
10		Continued from Previous Page					
11			SS	13	175	20	
			SS	14	355	20	
12			SS	15	150	21	
13			SS	16	330	26	
14			SS	17	175	13	
			SS	18	280	24	
15			SS	19	75	13	
16			SS	20	75	31	
			~~SS~~	~~21~~	~~-~~	~~50/0~~	
17							
18		Very dense, grey to brown, silty SAND (SM); trace gravel, cobbles and boulders: TILL	BS	22	100%	-	
19			BS	23	100%	-	S
20							



STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS



50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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BOREHOLE RECORD

BOREHOLE No. ROB-12-02
PAGE 3 of 3
CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N N/A E N/A
DATES (mm-dd-yy): BORING 2-14-12 to 2-23-12 WATER LEVEL N/A
PROJECT No. 121614000-305
DRILLING METHOD
SIZE
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
		Continued from Previous Page							
20.0–21.4					BS	24	100%	-	
21.4–26.0		Fractured to intact, medium strong, grey, metamorphic rock: BEDROCK			HQ	25	93%	85%	
					HQ	26	100%	93%	
					HQ	27	100%	70%	
26.0		End of Borehole							

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50

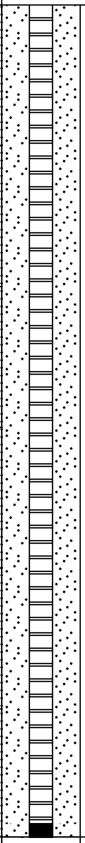
WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50

STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS



50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

END CAP

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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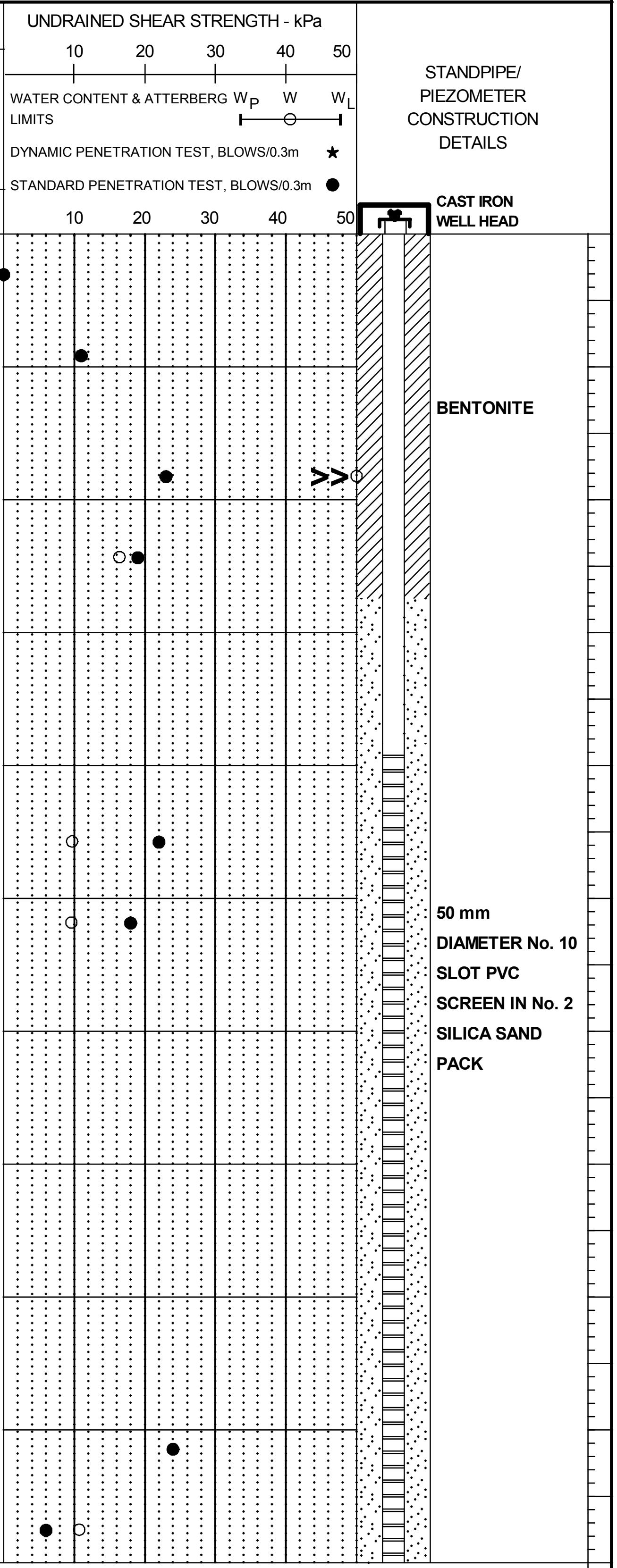
BOREHOLE RECORD

BOREHOLE No. ROB-12-03
PAGE 1 of 3
CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
PROJECT No. 121614000-305
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N N/A E N/A
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATES (mm-dd-yy): BORING 2-6-12 to 2-9-12 WATER LEVEL N/A
DATUM Geodetic

DEPTH (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY (mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
0	Frozen rootmat	SS	1	75	0	
	Loose, black, Organic Soil (OL): PEAT	SS	2	380	11	
1	Compact, brown, silty SAND (SM); trace gravel and boulders: TILL					
2		SS	3	75	23	
		SS	4	205	19	S
4	Compact to very dense, grey, silty SAND (SM); trace gravel, cobbles and boulders: TILL					
		SS	5	205	22	
5		SS	6	175	18	
6		SS	7	0	68/380	
9		SS	8	230	24	
	-locally loose from 9.5 m to 10.1 m depth	SS	9	305	6	S H
10						



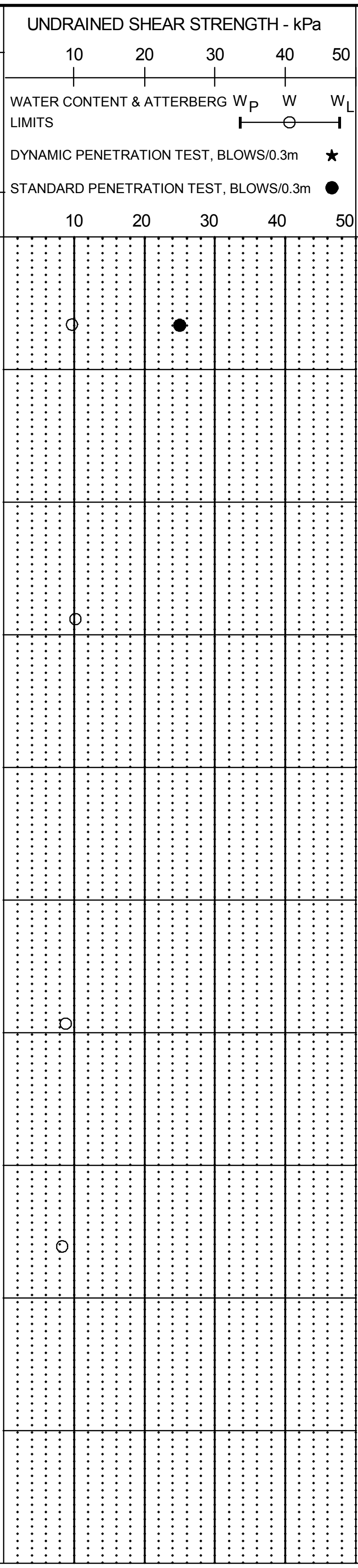
DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

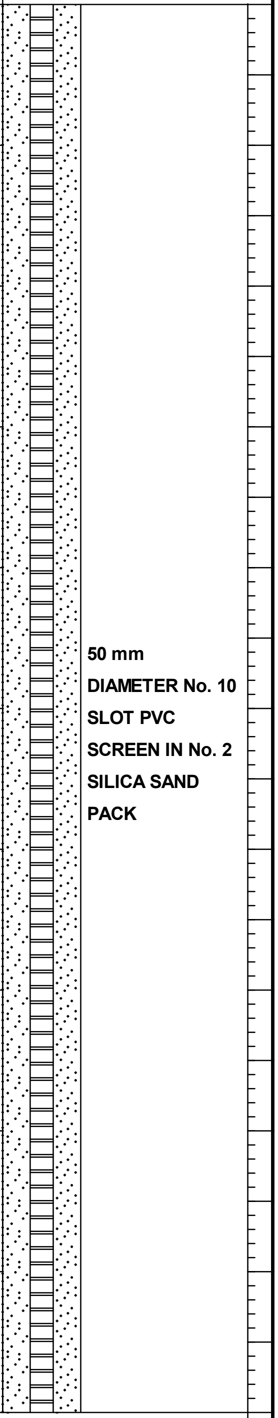
BOREHOLE RECORD

BOREHOLE No. **ROB-12-03**
PAGE **2** of **3**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **N/A** E **N/A**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **2-6-12** to **2-9-12**
WATER LEVEL **N/A**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
10		Continued from Previous Page							
					SS	10	75	25	
11					SS	11	305	110/300	
12					SS	12	255	88/300	
		Very dense, brown, silty SAND (SM); trace gravel and cobbles: TILL			BS	13	100%	-	
14					BS	14	100%	-	
16					BS	15	100%	-	
					BS	16	100%	-	
19					BS	17	100%	-	
20									



STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS



50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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BOREHOLE RECORD

BOREHOLE No. ROB-12-03
PAGE 3 of 3
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL
N N/A E N/A
SIZE HW/HQ
DATES (mm-dd-yy): BORING 2-6-12 to 2-9-12
WATER LEVEL N/A
DATUM Geodetic

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50

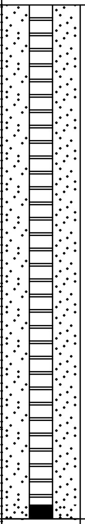
WATER CONTENT & ATTERBERG LIMITS: W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page								
20		Severely fractured, medium strong, tan to grey, quartzite (Wishart Formation): BEDROCK			HQ	18	100%	42%		50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
21					HQ	19	100%	39%		
22–23					HQ	20	100%	49%		END CAP
23.6		End of Borehole								



24 25 26 27 28 29 30

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

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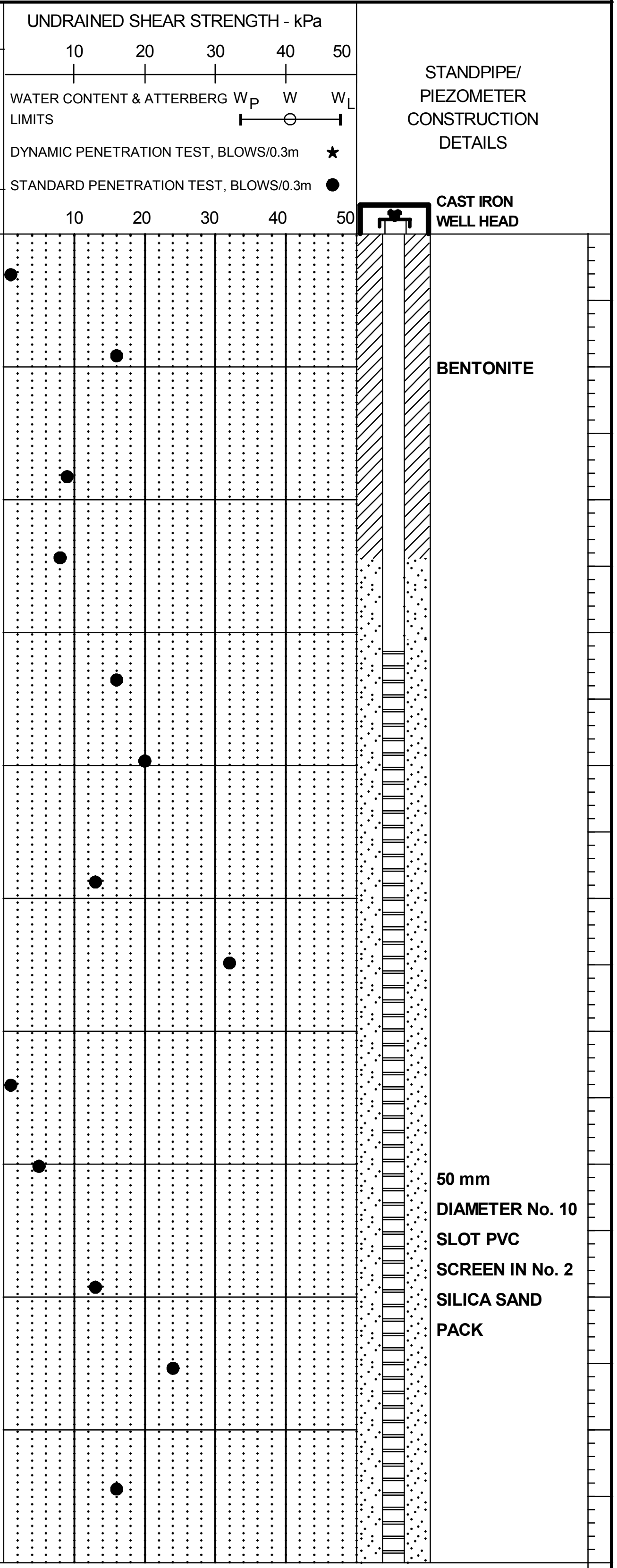
BOREHOLE RECORD

BOREHOLE No. ROB-12-04
PAGE 1 of 3

CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N N/A E N/A
DATES (mm-dd-yy): BORING 4-4-12 to 4-6-12 WATER LEVEL N/A
PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION
0 – 0.3		Frozen, black, Organic Soil (OL): PEAT
0.3 – 10		Very loose to very dense, grey, silty SAND (SM); trace gravel: TILL

SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	1	305	1	
SS	2	355	16	
SS	3	150	9	
SS	4	150	8	
SS	5	305	16	
SS	6	125	20	
SS	7	0	13	
SS	8	305	32	
SS	9	510	1	
SS	10	510	5	
SS	11	255	13	
SS	12	305	24	
SS	13	330	16	



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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

BOREHOLE RECORD

Stantec

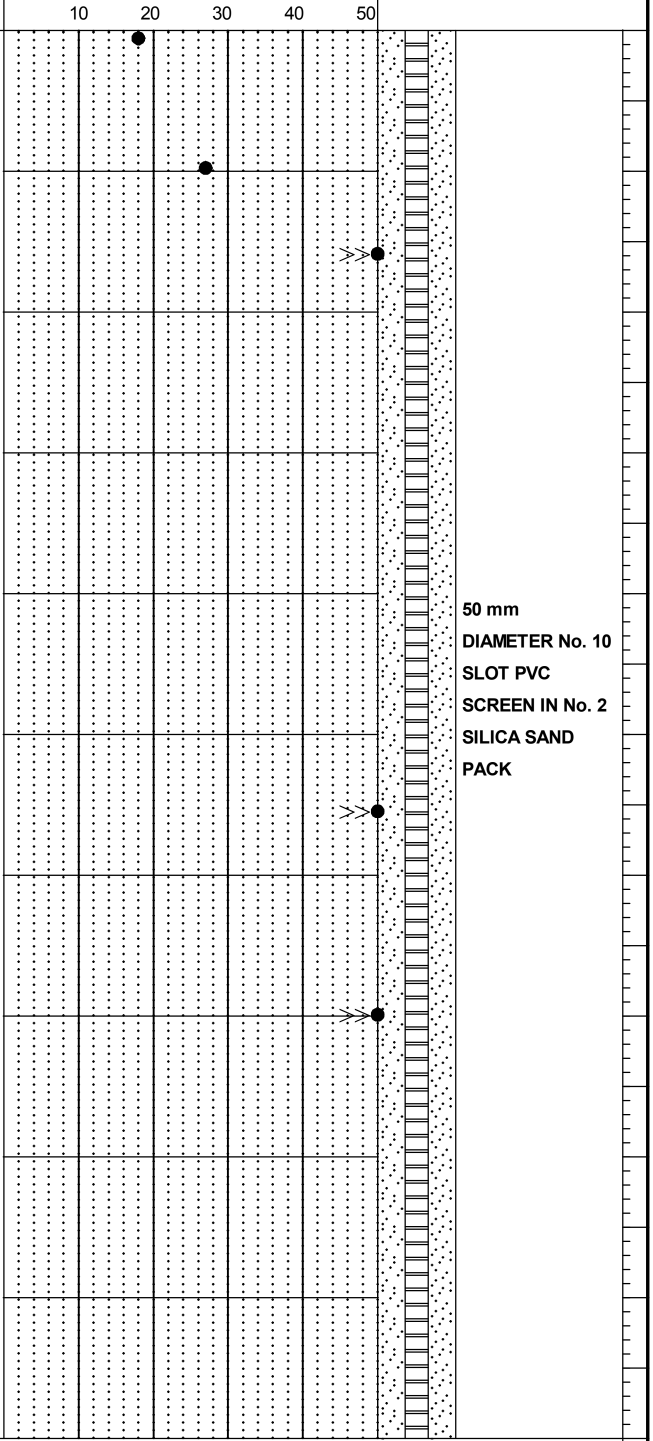
BOREHOLE No. ROB-12-04
PAGE 2 of 3
CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N N/A E N/A
DATES (mm-dd-yy): BORING 4-4-12 to 4-6-12 WATER LEVEL N/A
PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATUM Geodetic

Continued from Previous Page

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
10					SS	14	405	18	
11					SS	15	305	27	
					SS	16	380	83	
12		-trace cobbles below 11.89 m depth							
13					BS	17	100%	-	
14									
15					SS	18	355	54	
16									
17					SS	19	305	92	
18					SS	20	200	154/405	
19									
20					SS	21	175	79/255	

UNDRAINED SHEAR STRENGTH - kPa
10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●

STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS



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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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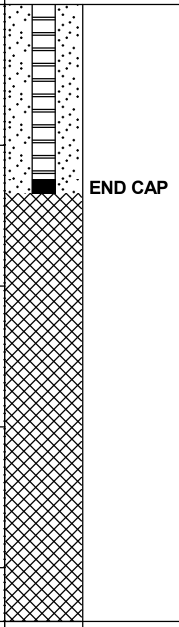
BOREHOLE RECORD

BOREHOLE No. **ROB-12-04**
PAGE **3** of **3**
CLIENT **Alderon Iron Ore Corp.**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL**
DATES (mm-dd-yy): BORING **4-4-12** to **4-6-12**
N **N/A** E **N/A**
WATER LEVEL **N/A**
PROJECT No. **121614000-305**
DRILLING METHOD **Wash/Dia**
SIZE **HW/HQ**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
		Continued from Previous Page							
20		Intact, medium strong, grey, quartz muscovite biotite schist (Wishart Formation): BEDROCK			HQ	22	100%	100%	
22					HQ	23	100%	100%	
23					HQ	24	100%	100%	
24		End of Borehole							

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS: W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50

STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS



DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

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BOREHOLE RECORD

BOREHOLE No. ROB-12-05A
PAGE 1 of 2
CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N N/A E N/A
DATES (mm-dd-yy): BORING 3-3-12 to 3-9-12 WATER LEVEL N/A
PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATUM Geodetic

DEPTH (m) | ELEVATION (m) | DESCRIPTION | STRATA PLOT | WATER LEVEL

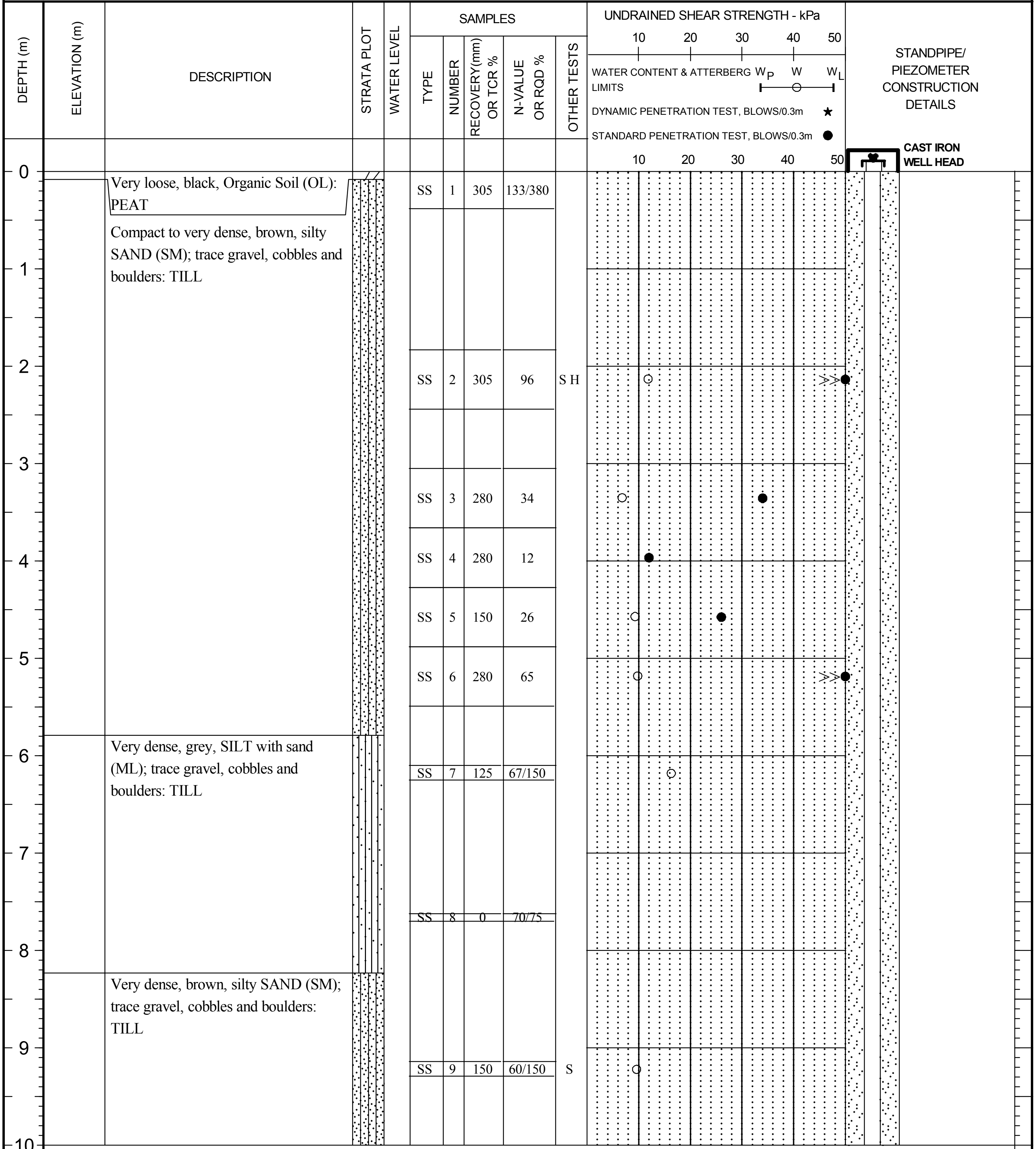
Very loose, black, Organic Soil (OL): PEAT

Compact to very dense, brown, silty SAND (SM); trace gravel, cobbles and boulders: TILL

Very dense, grey, SILT with sand (ML); trace gravel, cobbles and boulders: TILL

Very dense, brown, silty SAND (SM); trace gravel, cobbles and boulders: TILL

SAMPLES				
TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	1	305	133/380	
SS	2	305	96	S H
SS	3	280	34	
SS	4	280	12	
SS	5	150	26	
SS	6	280	65	
SS	7	125	67/150	
SS	8	0	70/75	
SS	9	150	60/150	S

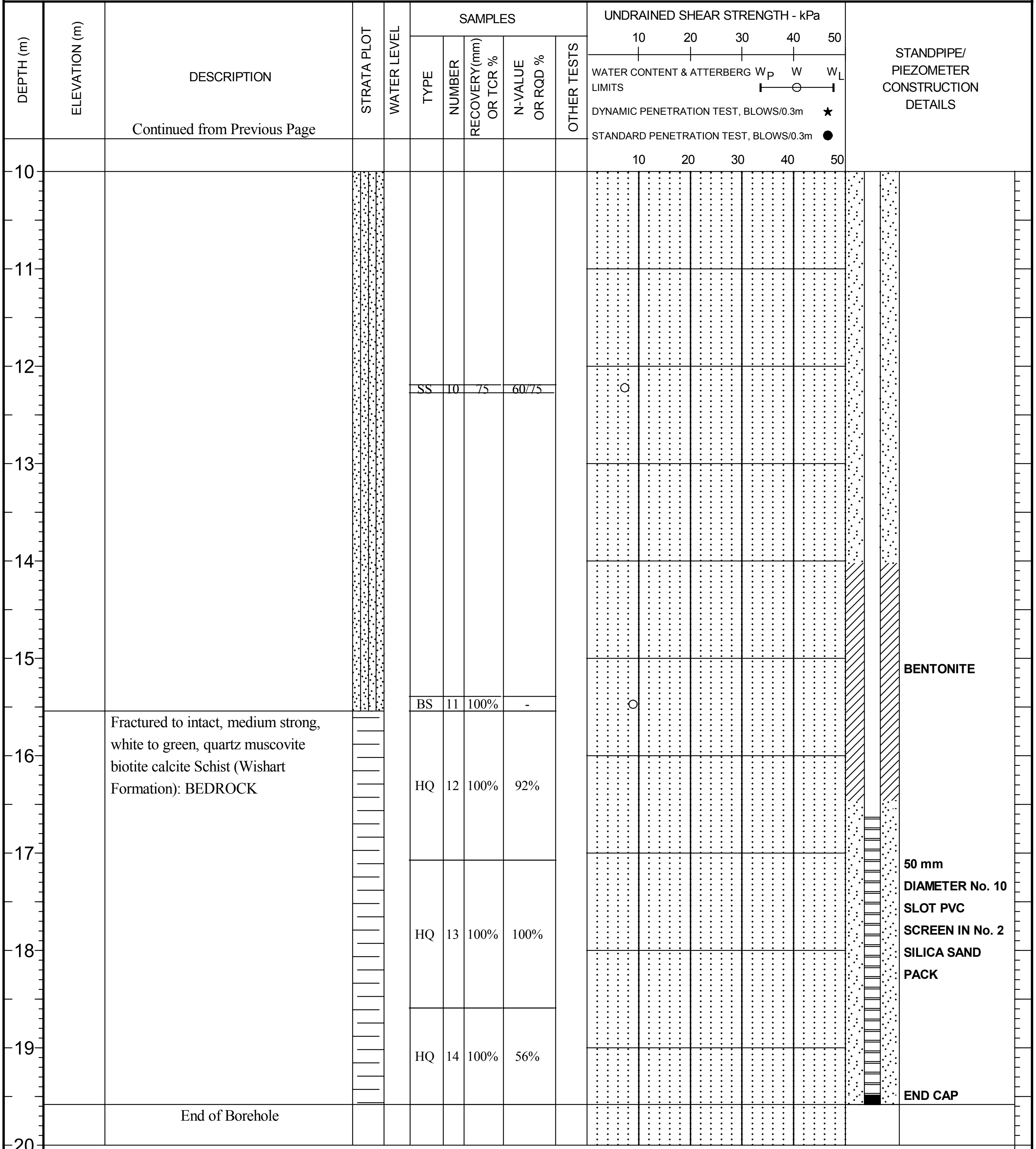


△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

DRAFT

BOREHOLE RECORD

BOREHOLE No. ROB-12-05A
PAGE 2 of 2
CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N N/A E N/A
SIZE HW/HQ
DATES (mm-dd-yy): BORING 3-3-12 to 3-9-12
WATER LEVEL N/A
DATUM Geodetic



DEPTH (m)
ELEVATION (m)
DESCRIPTION
STRATA PLOT
WATER LEVEL
SAMPLES
TYPE
NUMBER
RECOVERY(mm) OR TCR %
N-VALUE OR RQD %
OTHER TESTS
UNDRAINED SHEAR STRENGTH - kPa
10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50
STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
10
11
12
13
14
15
16
17
18
19
20
BENTONITE
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
END CAP

Continued from Previous Page

DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %
	SS	10	75	60/75
	BS	11	100%	-
Fractured to intact, medium strong, white to green, quartz muscovite biotite calcite Schist (Wishart Formation): BEDROCK	HQ	12	100%	92%
	HQ	13	100%	100%
	HQ	14	100%	56%

End of Borehole

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

Stantec

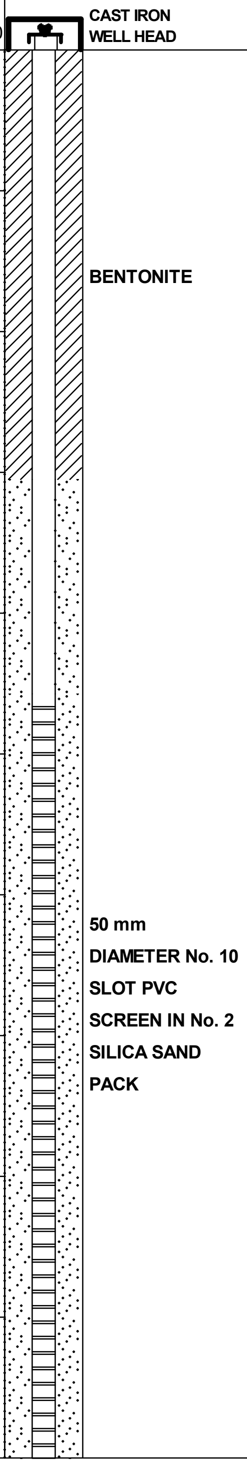
BOREHOLE RECORD

BOREHOLE No. ROB-12-05B
PAGE 1 of 2

CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N N/A E N/A
DATES (mm-dd-yy): BORING WATER LEVEL N/A

PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY(mm) OR TCR %	SAMPLES N-VALUE OR RQD %	SAMPLES OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa 10 20 30 40 50; WATER CONTENT & ATTERBERG LIMITS W_P W W_L; DYNAMIC PENETRATION TEST, BLOWS/0.3m ★; STANDARD PENETRATION TEST, BLOWS/0.3m ● 10 20 30 40 50	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											


CAST IRON WELL HEAD
BENTONITE
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

BOREHOLE RECORD

Stantec

BOREHOLE No.	ROB-12-05B
PAGE	2 of 2
CLIENT	Alderon Iron Ore Corp.
PROJECT No.	121614000-305
PROJECT	Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD	Wash/Dia
LOCATION	Kami Iron Ore Mine Site, Labrador West, NL
N	N/A
E	N/A
SIZE	HW/HQ
DATES (mm-dd-yy): BORING	
WATER LEVEL	N/A
DATUM	Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50

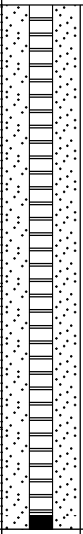
WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50

Depth (m): 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20



50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

END CAP

DRAFT

△ Unconfined Compression Test

☐ Field Vane Test ■ (Remolded)

◇ Fall Cone Test ◆ (Remolded)

▽ Hand Penetrometer Test ◪ Torvane

Stantec

BOREHOLE RECORD

BOREHOLE No.	ROB-12-06
PAGE	1 of 2
CLIENT	Alderon Iron Ore Corp.
PROJECT	Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
PROJECT No.	121614000-305
LOCATION	Kami Iron Ore Mine Site, Labrador West, NL
N	N/A
E	N/A
DRILLING METHOD	Wash/Dia
SIZE	HW/HQ
DATES (mm-dd-yy): BORING	2-26-12 to 2-28-12
WATER LEVEL	N/A
DATUM	Geodetic

DEPTH (m) | ELEVATION (m) | DESCRIPTION | STRATA PLOT | WATER LEVEL

DESCRIPTION

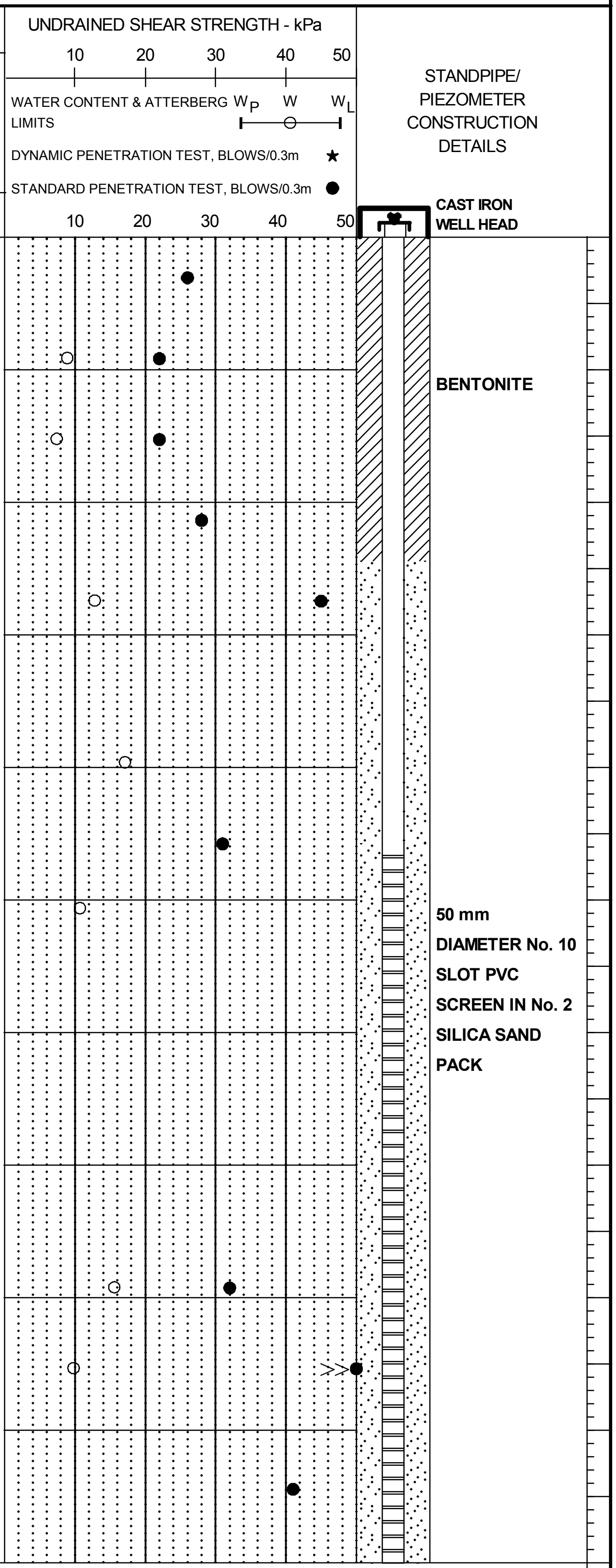
Very loose, reddish brown, sandy Organic Soil (OL): TOPSOIL

Compact, grey, silty SAND (SM)

Compact to very dense, light brown, silty SAND (SM); trace gravel, frequent cobbles and boulders: TILL

SAMPLES

TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	1	405	26	
SS	2	205	22	
SS	3	355	22	S
SS	4	355	28	
SS	5	205	45	
SS	6	0	105/230	
SS	7	305	31	
SS	8	150	115/355	
HQ	9	79%	-	
HQ	10	57%	-	
SS	11	280	32	
SS	12	305	71	
SS	13	280	41	
SS	14	0	50/150	



△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

DRAFT

BOREHOLE RECORD

BOREHOLE No. **ROB-12-06**
PAGE **2** of **2**
CLIENT **Alderon Iron Ore Corp.**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL**
DATES (mm-dd-yy): BORING **2-26-12 to 2-28-12**
N **N/A** E **N/A**
WATER LEVEL **N/A**
PROJECT No. **121614000-305**
DRILLING METHOD **Wash/Dia**
SIZE **HW/HQ**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									
10		Moderately jointed to intact, strong, grey, quartz muscovite biotite schist (Wishart Formation): BEDROCK			HQ	15	100%	89%			50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
11					HQ	16	100%	100%			
12					HQ	17	100%	100%			
13.7		End of Borehole									END CAP

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50

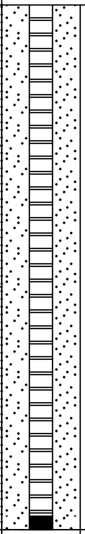
WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50

Depth scale: 10 11 12 13 14 15 16 17 18 19 20



DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

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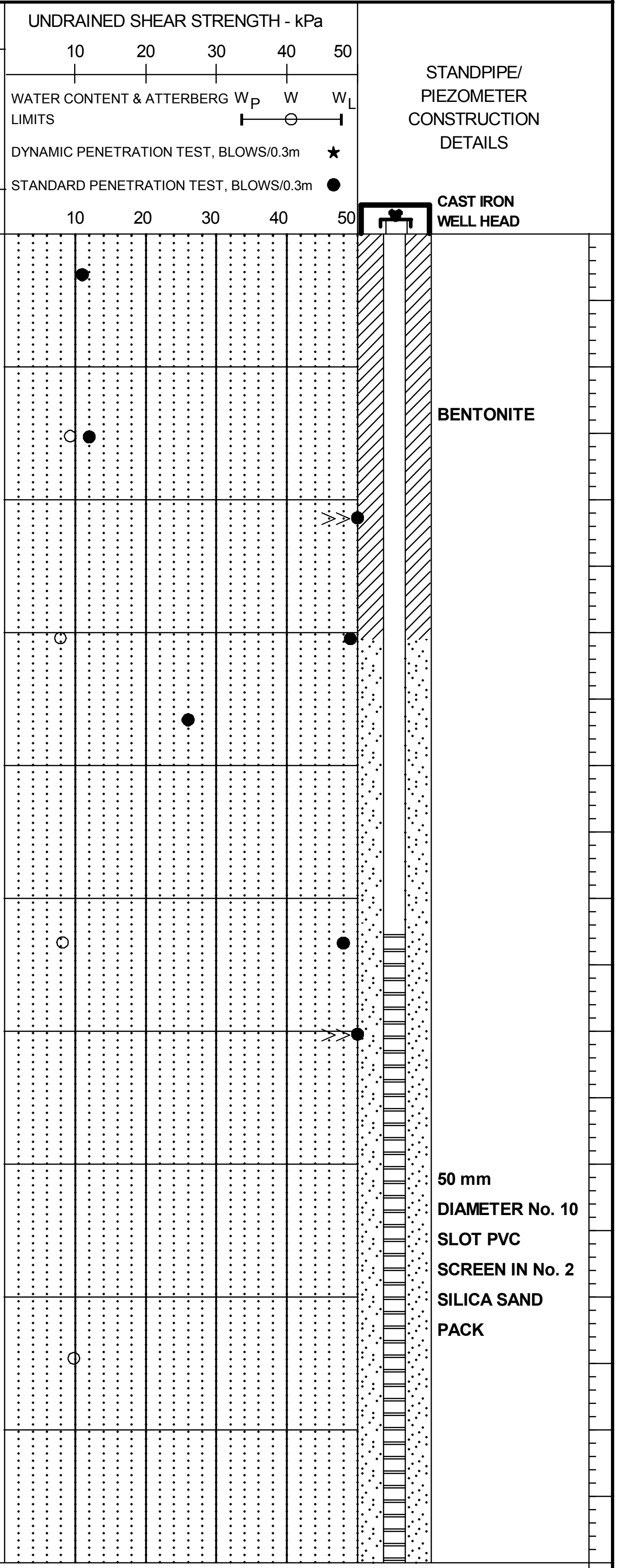
BOREHOLE RECORD

BOREHOLE No. ROB-12-07
PAGE 1 of 7
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL
N N/A E N/A
SIZE HW/HQ
DATES (mm-dd-yy): BORING 3-27-12 to 4-3-12
WATER LEVEL N/A
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION
0 – 0.3		Frozen, black Organic Soil (OL): PEAT
0.3 – 10		Compact to very dense, brown, silty SAND (SM); trace gravel, cobbles and boulders: TILL

SAMPLES

TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
SS	1	205	11	
SS	2	280	12	S H
SS	3	230	64	
SS	4	280	49	
SS	5	230	26	
SS	6	205	48	
SS	7	355	116	
BS	8	100%	-	
BS	9	100%	-	
BS	10	100%	-	



DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

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BOREHOLE RECORD

BOREHOLE No. ROB-12-07
PAGE 2 of 7

CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL
N N/A E N/A
DATES (mm-dd-yy): BORING 3-27-12 to 4-3-12
WATER LEVEL N/A
PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATUM Geodetic

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50

STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS

Continued from Previous Page

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
11.3			BS	11	100%	-	
12.2		Very dense, grey, silty SAND (SM); trace gravel and cobbles: TILL					
15.2			SS	12	380	93	S
18.1			BS	13	100%	-	
19.1			BS	14	100%	-	

50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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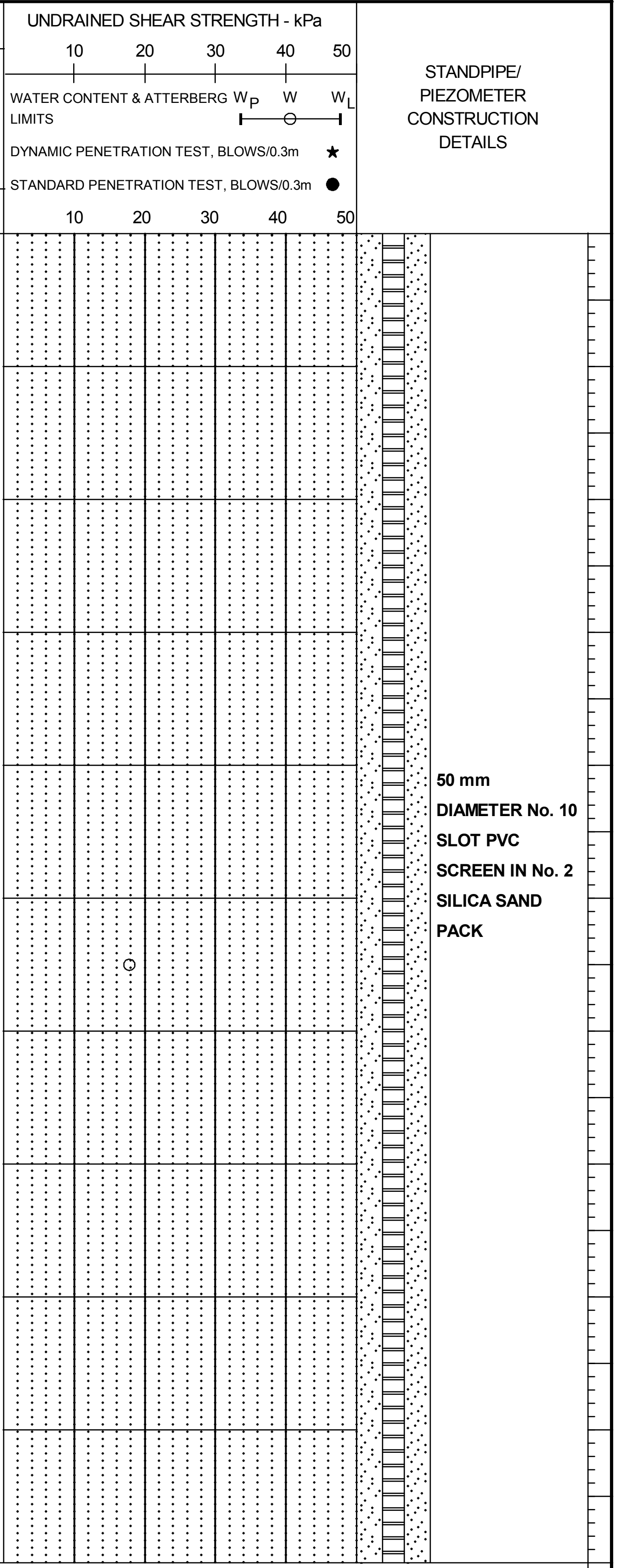
BOREHOLE RECORD

BOREHOLE No. ROB-12-07
PAGE 3 of 7

CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL
DATES (mm-dd-yy): BORING 3-27-12 to 4-3-12
N N/A E N/A
WATER LEVEL N/A
PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
20		Continued from Previous Page							
21					BS	15	100%	-	
22					BS	16	100%	-	
25					BS	17	100%	-	
27					BS	18	100%	-	
		Very dense, brown, silty SAND (SM); trace gravel and cobbles: TILL							
28					BS	19	100%	-	
30									



△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

DRAFT

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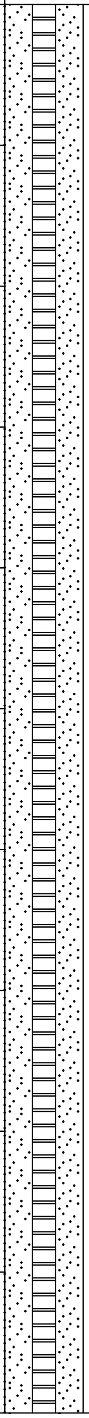
BOREHOLE RECORD

BOREHOLE No. **ROB-12-07**
PAGE **4** of **7**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **N/A** E **N/A**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **3-27-12** to **4-3-12**
WATER LEVEL **N/A**
DATUM **Geodetic**

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page								
30					BS	20	100%	-		
31										
32		Very dense, grey, silty SAND (SM); trace gravel and cobbles: TILL								
33					BS	21	100%	-		
34										50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
35										
36					BS	22	100%	-		
37										
38		Very dense, brown, silty SAND (SM); trace gravel and cobbles: TILL								
39					BS	23	100%	-		
40										



50 mm
DIAMETER No. 10
SLOT PVC
SCREEN IN No. 2
SILICA SAND
PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

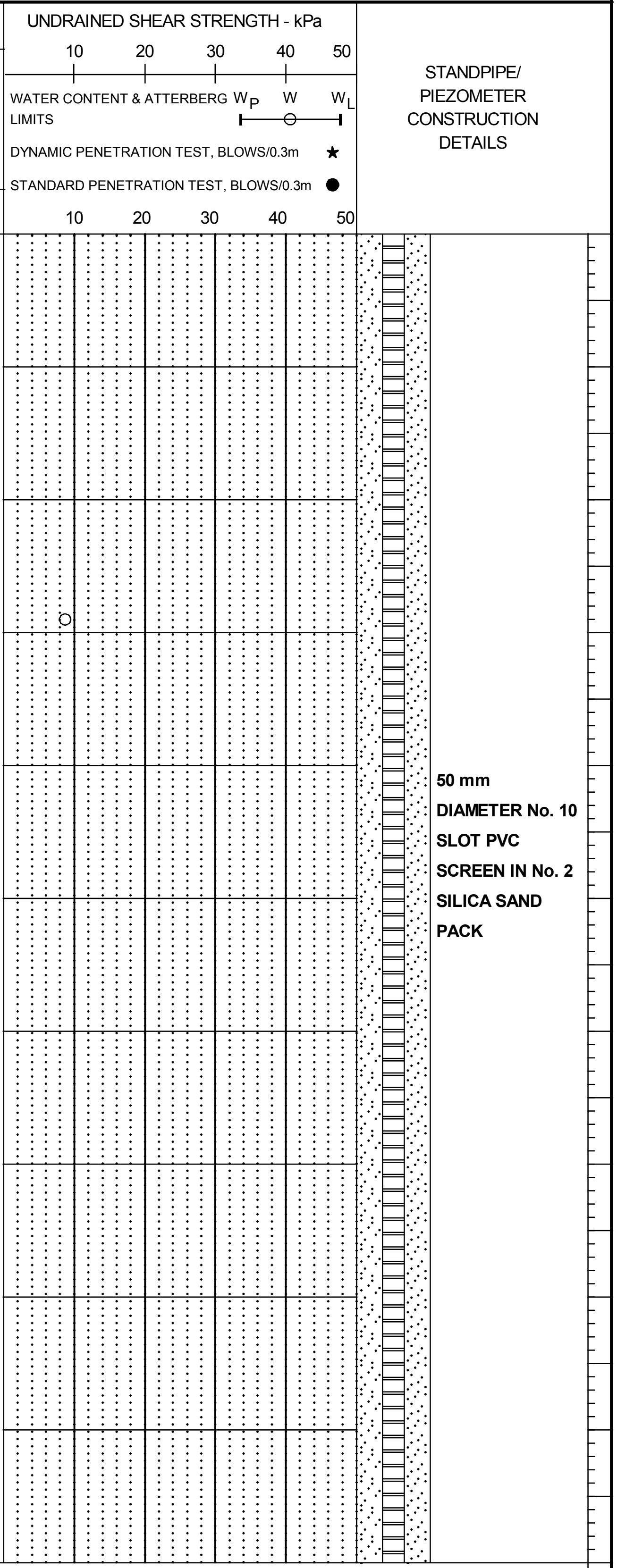
BOREHOLE RECORD

Stantec

BOREHOLE No. ROB-12-07
PAGE 5 of 7
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N N/A E N/A
SIZE HW/HQ
DATES (mm-dd-yy): BORING 3-27-12 to 4-3-12 WATER LEVEL N/A
DATUM Geodetic

Continued from Previous Page

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
40.4			BS	24	100%	-	
42.2			BS	25	100%	-	S
43.3		Very dense, grey, silty SAND (SM); trace gravel, cobbles and boulders: TILL					
44.6			BS	26	100%	-	
47.8			~~SS~~	~~27~~	~~0~~	~~50/0~~	



DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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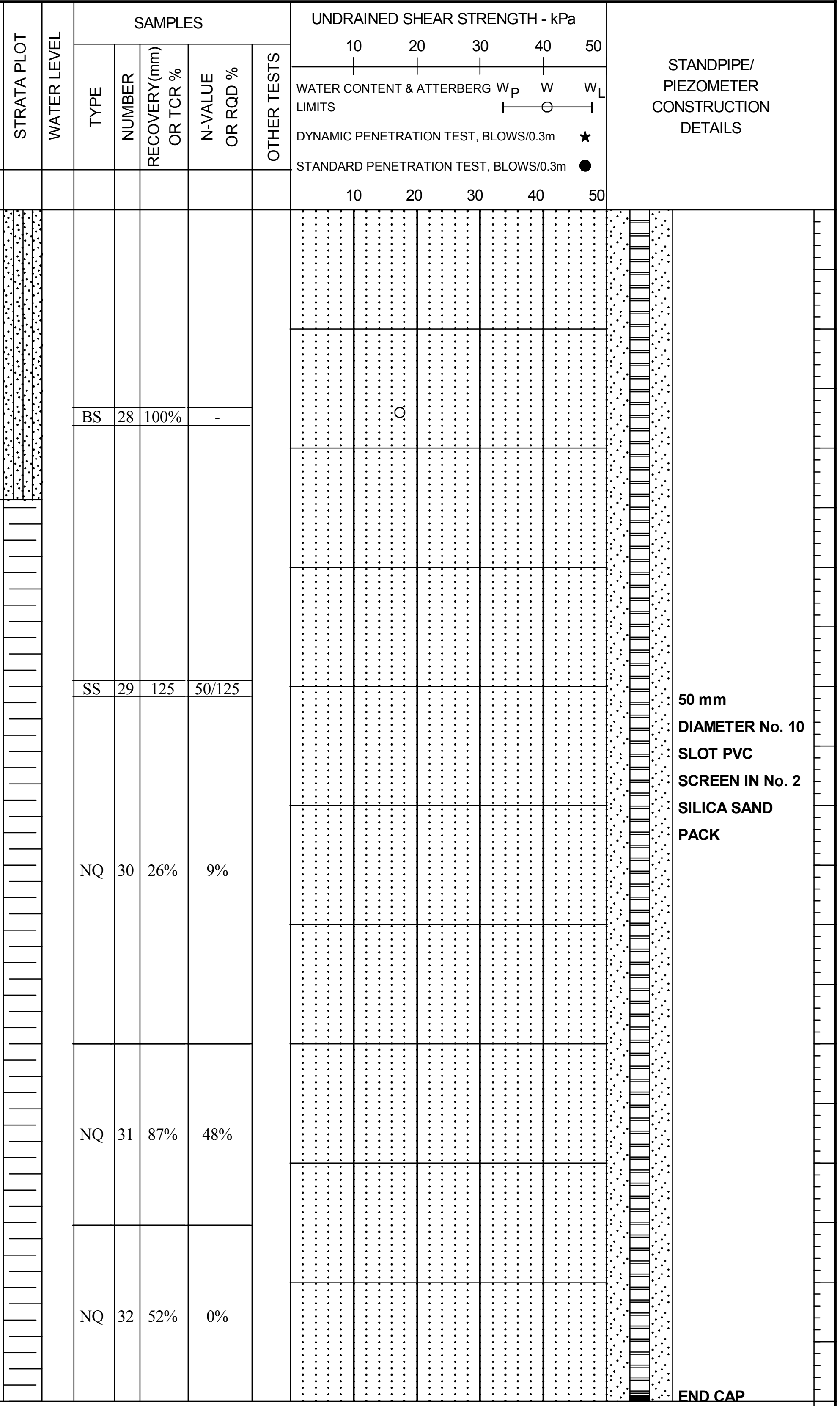
BOREHOLE RECORD

BOREHOLE No. **ROB-12-07**
PAGE **6** of **7**

CLIENT **Alderon Iron Ore Corp.**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **N/A** E **N/A**
DATES (mm-dd-yy): BORING **3-27-12** to **4-3-12** WATER LEVEL **N/A**
PROJECT No. **121614000-305**
DRILLING METHOD **Wash/Dia**
SIZE **HW/HQ**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	SAMPLES TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
50		Continued from Previous Page					
51.7			BS	28	100%	-	
52.45		Very severely fractured to severely fractured, extremely weak, dark grey, muscovite biotite schist (Menihek Formation): BEDROCK Note: Bedrock is so weak some of it is getting washed out with the drilling water.					
54			SS	29	125	50/125	
55.5			NQ	30	26%	9%	
57.7			NQ	31	87%	48%	
59.3			NQ	32	52%	0%	
60							


STRATA PLOT
WATER LEVEL
UNDRAINED SHEAR STRENGTH - kPa
10
20
30
40
50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10
20
30
40
50
STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
END CAP

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

DRAFT

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BOREHOLE RECORD

BOREHOLE No. ROB-12-07
PAGE 7 of 7

CLIENT Alderon Iron Ore Corp.
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N N/A E N/A
DATES (mm-dd-yy): BORING 3-27-12 to 4-3-12 WATER LEVEL N/A

PROJECT No. 121614000-305
DRILLING METHOD Wash/Dia
SIZE HW/HQ
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	SAMPLES: OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa (10, 20, 30, 40, 50); WATER CONTENT & ATTERBERG LIMITS W_P W W_L; DYNAMIC PENETRATION TEST, BLOWS/0.3m ★; STANDARD PENETRATION TEST, BLOWS/0.3m ● (10, 20, 30, 40, 50)	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									
60		End of Borehole									
61											
62											
63											
64											
65											
66											
67											
68											
69											
70											

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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

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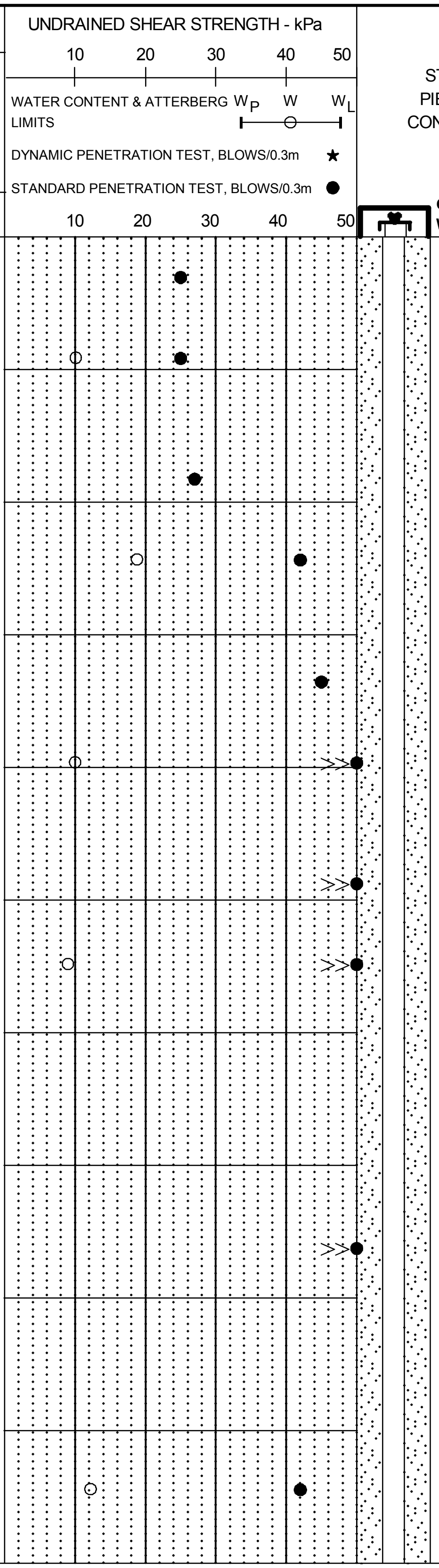
BOREHOLE RECORD

BOREHOLE No. **ROB-12-13A**
PAGE **1** of **2**

CLIENT	**Alderon Iron Ore Corp.**	PROJECT No.	**121614000-305**
PROJECT	**Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**	DRILLING METHOD	**Wash/Dia**
LOCATION	**Kami Iron Ore Mine Site, Labrador West, NL** N **N/A** E **N/A**	SIZE	**HW/HQ**
DATES (mm-dd-yy): BORING	**3-18-12** WATER LEVEL **N/A**	DATUM	**Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
0		Rootmat/topsoil							
		Compact, light brown to grey, silty SAND with gravel (SM); occasional cobbles and boulders: TILL			SS	1	560	25	
1					SS	2	255	25	
2					SS	3	150	27	
					SS	4	305	42	
		Dense to very dense, grey to light brown, silty SAND to silty SAND with gravel (SM); occasional cobbles and boulders: TILL							
3					SS	5	305	45	
4					SS	6	255	55	
5					SS	7	305	60	
					SS	8	305	62	S
6					SS	9	150	126/380	
7					SS	10	0	81	
8									
9		Dense, light brown, silty SAND with gravel (SM); occasional cobbles and boulders: TILL			SS	11	255	42	
10									



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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

Stantec

BOREHOLE RECORD

BOREHOLE No. **ROB-12-13A**
PAGE **2** of **2**

CLIENT **Alderon Iron Ore Corp.**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **N/A** E **N/A**
DATES (mm-dd-yy): BORING **3-18-12** WATER LEVEL **N/A**
PROJECT No. **121614000-305**
DRILLING METHOD **Wash/Dia**
SIZE **HW/HQ**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY(mm) OR TCR %	SAMPLES N-VALUE OR RQD %	OTHER TESTS
		Continued from Previous Page							
10					SS	12	75	50/75	
11.3		Moderately jointed to intact, medium strong, dark grey, muscovite biotite schist (Menihek Formation): BEDROCK			HQ	13	100%	88%	
					HQ	14	94%	88%	
					HQ	15	92%	92%	
					HQ	16	100%	100%	
15.2		End of Borehole							

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50

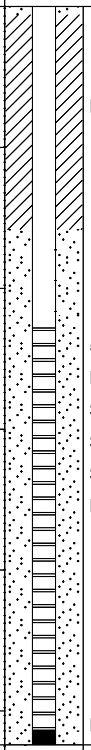
WATER CONTENT & ATTERBERG LIMITS W_P W W_L

DYNAMIC PENETRATION TEST, BLOWS/0.3m ★

STANDARD PENETRATION TEST, BLOWS/0.3m ●

10 20 30 40 50

STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS


BENTONITE
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK
END CAP

DRAFT

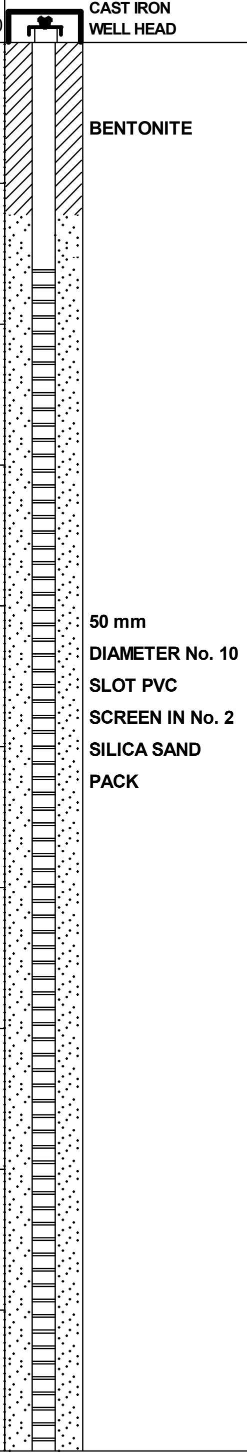
△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

BOREHOLE RECORD

BOREHOLE No. **ROB-12-13B**
PAGE **1** of **2**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **N/A** E **N/A**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING
WATER LEVEL **N/A**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	SAMPLES: OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
0											
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

UNDRAINED SHEAR STRENGTH - kPa: 10 20 30 40 50
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
DYNAMIC PENETRATION TEST, BLOWS/0.3m ★
STANDARD PENETRATION TEST, BLOWS/0.3m ●
10 20 30 40 50



CAST IRON WELL HEAD
BENTONITE
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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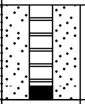
BOREHOLE RECORD

BOREHOLE No. **ROB-12-13B**
PAGE **2** of **2**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL**
N **N/A** E **N/A**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING
WATER LEVEL **N/A**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES: TYPE	SAMPLES: NUMBER	SAMPLES: RECOVERY(mm) OR TCR %	SAMPLES: N-VALUE OR RQD %	SAMPLES: OTHER TESTS	UNDRAINED SHEAR STRENGTH - kPa (10, 20, 30, 40, 50); WATER CONTENT & ATTERBERG LIMITS W_P W W_L; DYNAMIC PENETRATION TEST, BLOWS/0.3m ★; STANDARD PENETRATION TEST, BLOWS/0.3m ● (10, 20, 30, 40, 50)	STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
		Continued from Previous Page									
10											END CAP
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											



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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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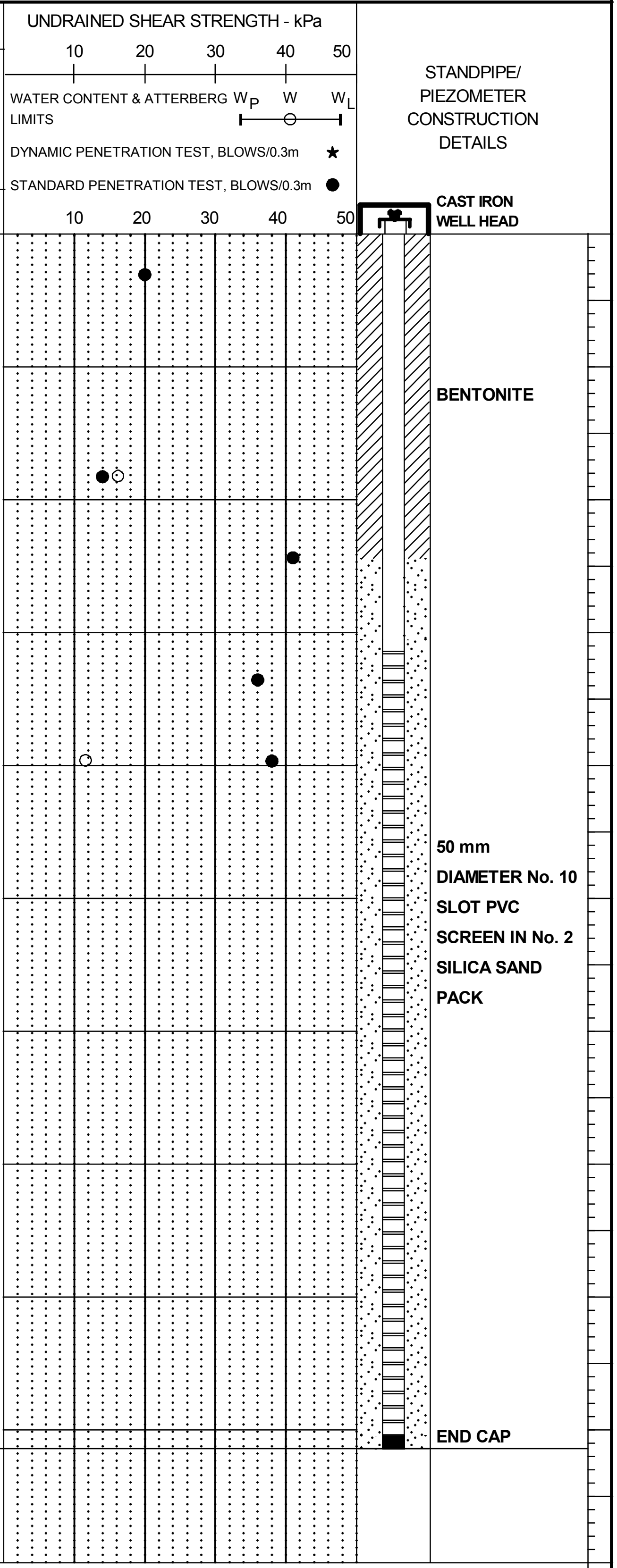
BOREHOLE RECORD

BOREHOLE No. **ROB-12-14**
PAGE **1** of **1**
CLIENT **Alderon Iron Ore Corp.**
PROJECT No. **121614000-305**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
DRILLING METHOD **Wash/Dia**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **N/A** E **N/A**
SIZE **HW/HQ**
DATES (mm-dd-yy): BORING **3-25-12**
WATER LEVEL **N/A**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
0		Rootmat/topsoil							
		Compact, dark brown, silty SAND with gravel (SM); occasional cobbles, occasional rootlets			SS	1	255	20	
		Comapct to dense, grey to brown, silty SAND (SM); trace gravel, occasional cobbles and boulders: TILL			SS	2	100	14	
					SS	3	255	41	
					SS	4	205	36	
					SS	5	355	38	S
					SS	6	150	92/250	
		Moderately jointed to intact, medium strong, dark grey, muscovite biotite schist (Menihek Formation), occasional quartz and pyrite, occasional sand seams: BEDROCK			HQ	7	100%	96%	
					HQ	8	93%	80%	
					HQ	9	100%	100%	
		End of Borehole							



Depth scale (m): 0 1 2 3 4 5 6 7 8 9 10

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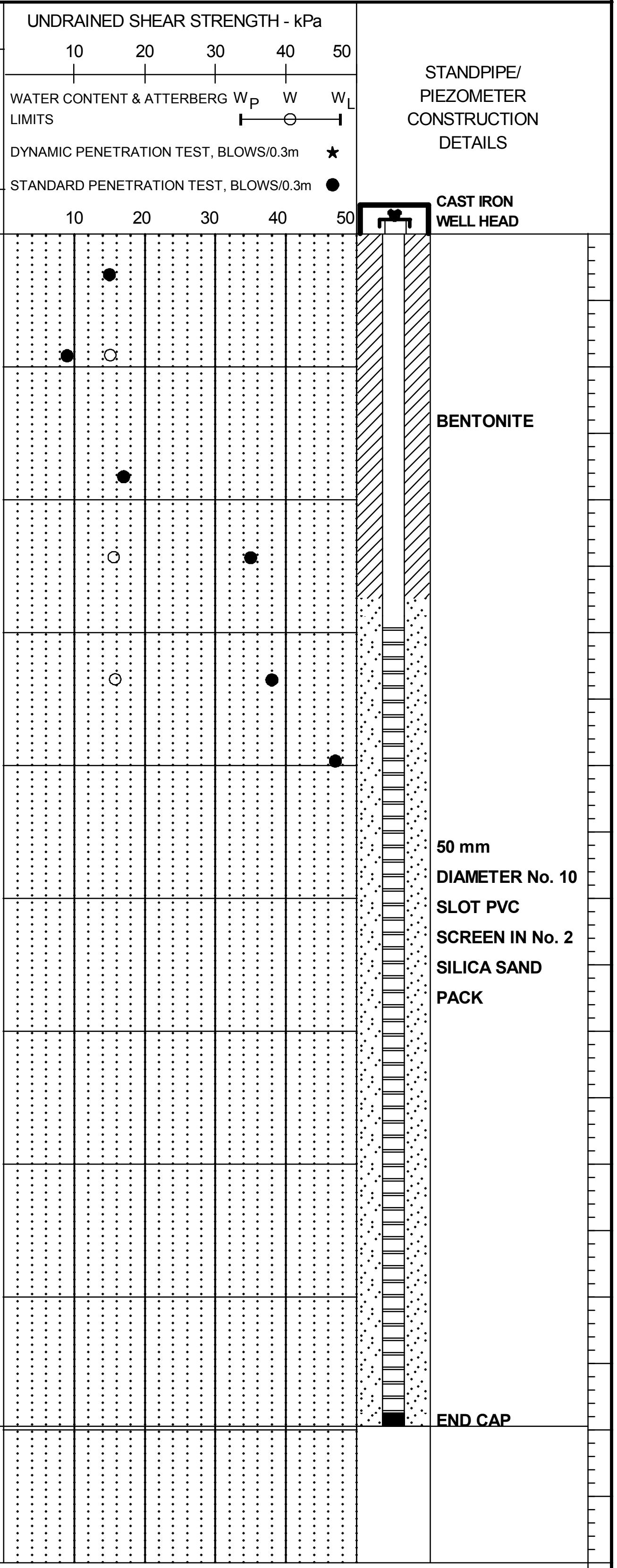
△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

Stantec

BOREHOLE RECORD

BOREHOLE No. ROB-12-15
PAGE 1 of 1
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL
N N/A E N/A
SIZE HW/HQ
DATES (mm-dd-yy): BORING 4-8-12
WATER LEVEL N/A
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
0		Frozen, black to dark brown, Organic Soil (OL): PEAT	SS	1	405	15	
		Loose to dense, brown, silty SAND (SM); trace gravel & cobbles: TILL	SS	2	305	9	
1							
2			SS	3	305	17	
			SS	4	305	35	S
3			SS	5	430	38	
4			SS	6	330	47	
		Moderately jointed to intact, medium strong, dark grey, muscovite biotite schist (Menihek Formation): BEDROCK	HQ	7	100%	100%	
5			HQ	8	100%	81%	
6			HQ	9	100%	92%	
7							
8			HQ	10	100%	92%	
9		End of Borehole					
10							



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△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◩ Torvane

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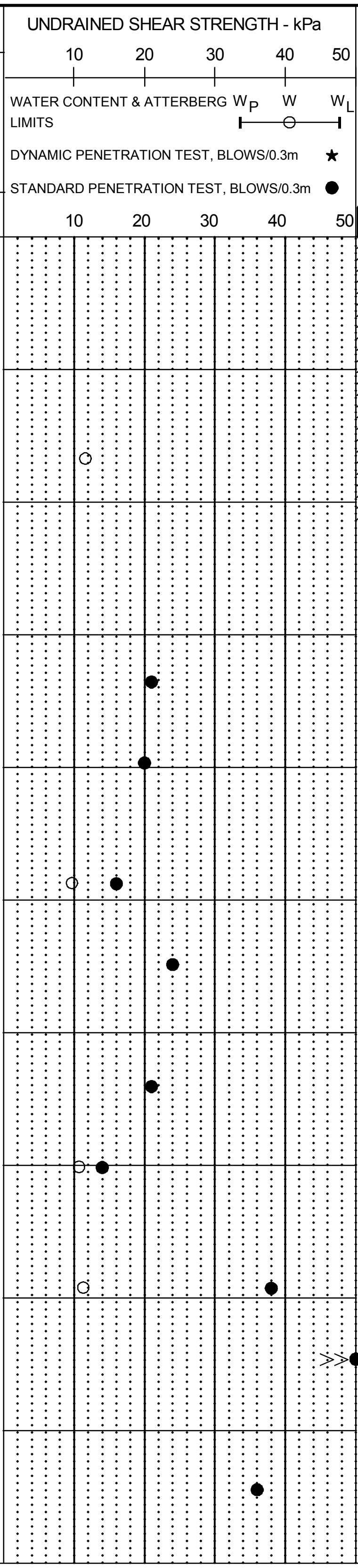
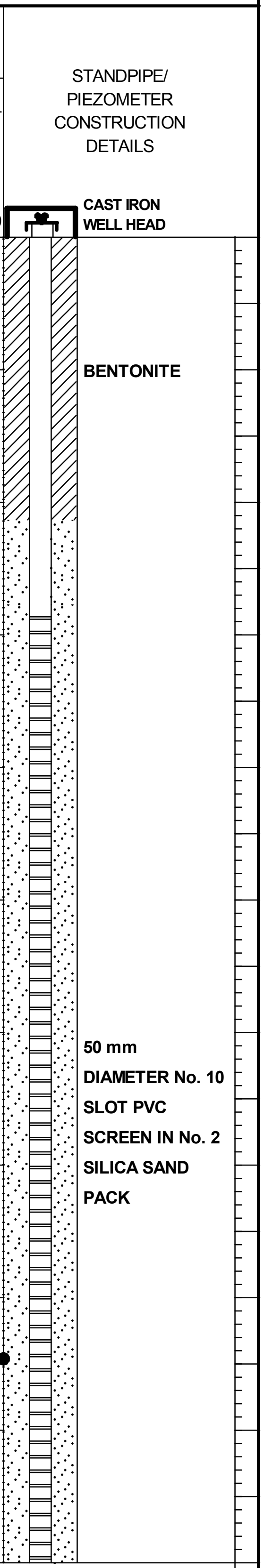
BOREHOLE RECORD

BOREHOLE No. **ROB-12-19**
PAGE **1** of **2**

CLIENT **Alderon Iron Ore Corp.**
PROJECT **Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study**
LOCATION **Kami Iron Ore Mine Site, Labrador West, NL** N **N/A** E **N/A**
DATES (mm-dd-yy): BORING **4-9-12** WATER LEVEL **N/A**
PROJECT No. **121614000-305**
DRILLING METHOD **Wash/Dia**
SIZE **HW/HQ**
DATUM **Geodetic**

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	TYPE	NUMBER	RECOVERY(mm) OR TCR %	N-VALUE OR RQD %	OTHER TESTS
0		Frozen, black, Organic Soil (OL): PEAT			SS	1	175	55/300	
		Compact to very dense, grey, silty SAND (SM); trace gravel & cobbles: TILL							
					SS	2	305	132/300	
					SS	3	50	21	
					SS	4	230	20	
					SS	5	380	16	
					SS	6	255	24	
					SS	7	125	21	
					SS	8	330	14	
					SS	9	610	38	S H
					SS	10	175	78	
		Very severely fractured to fractured, weak, dark green silicate iron formation (Sokoman Formation):			SS	11	455	36	




STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS
CAST IRON WELL HEAD
BENTONITE
50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

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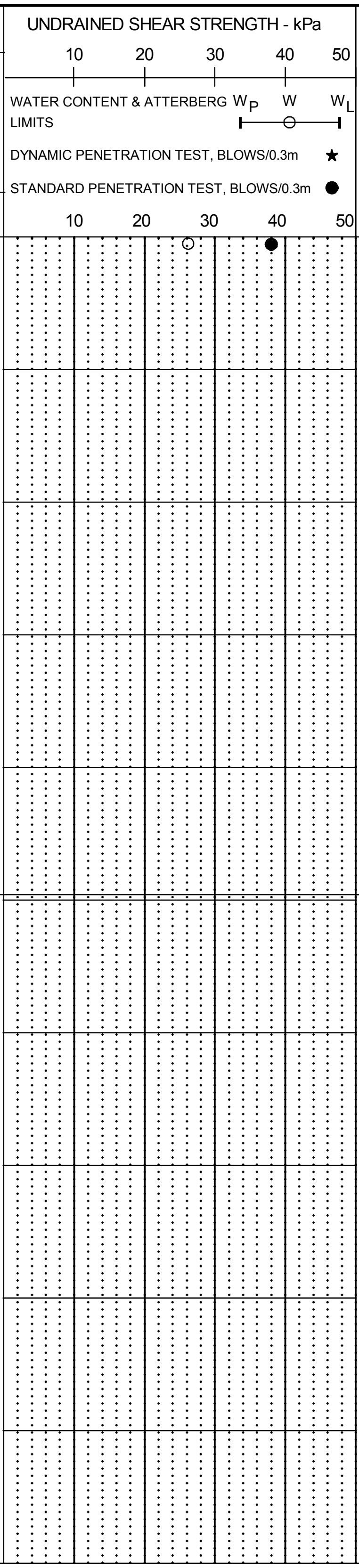
Stantec

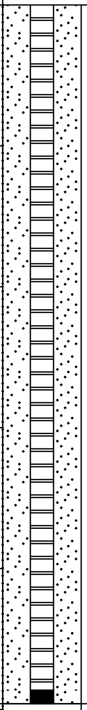
BOREHOLE RECORD

BOREHOLE No. ROB-12-19
PAGE 2 of 2
CLIENT Alderon Iron Ore Corp.
PROJECT No. 121614000-305
PROJECT Kami Iron Ore Project, Rose Pit Overburden Geotechnical Investigation - Feasibility Study
DRILLING METHOD Wash/Dia
LOCATION Kami Iron Ore Mine Site, Labrador West, NL N N/A E N/A
SIZE HW/HQ
DATES (mm-dd-yy): BORING 4-9-12
WATER LEVEL N/A
DATUM Geodetic

DEPTH (m)	ELEVATION (m)	DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY(mm) OR TCR %	SAMPLES N-VALUE OR RQD %	OTHER TESTS
		Continued from Previous Page							
10		BEDROCK			SS	12	205	38	
11					HQ	13	100%	27%	
12		Very severely fractured to fractured, weak, dark green to grey, magnetite-silicate iron formation (Sokoman Formation): BEDROCK			HQ	14	95%	18%	
14		Very severely fractured to fractured, weak, dark grey, muscovite biotite schist (Menihek Formation): BEDROCK			HQ	15	100%	55%	
15		End of Borehole							



STANDPIPE/ PIEZOMETER CONSTRUCTION DETAILS



50 mm DIAMETER No. 10 SLOT PVC SCREEN IN No. 2 SILICA SAND PACK

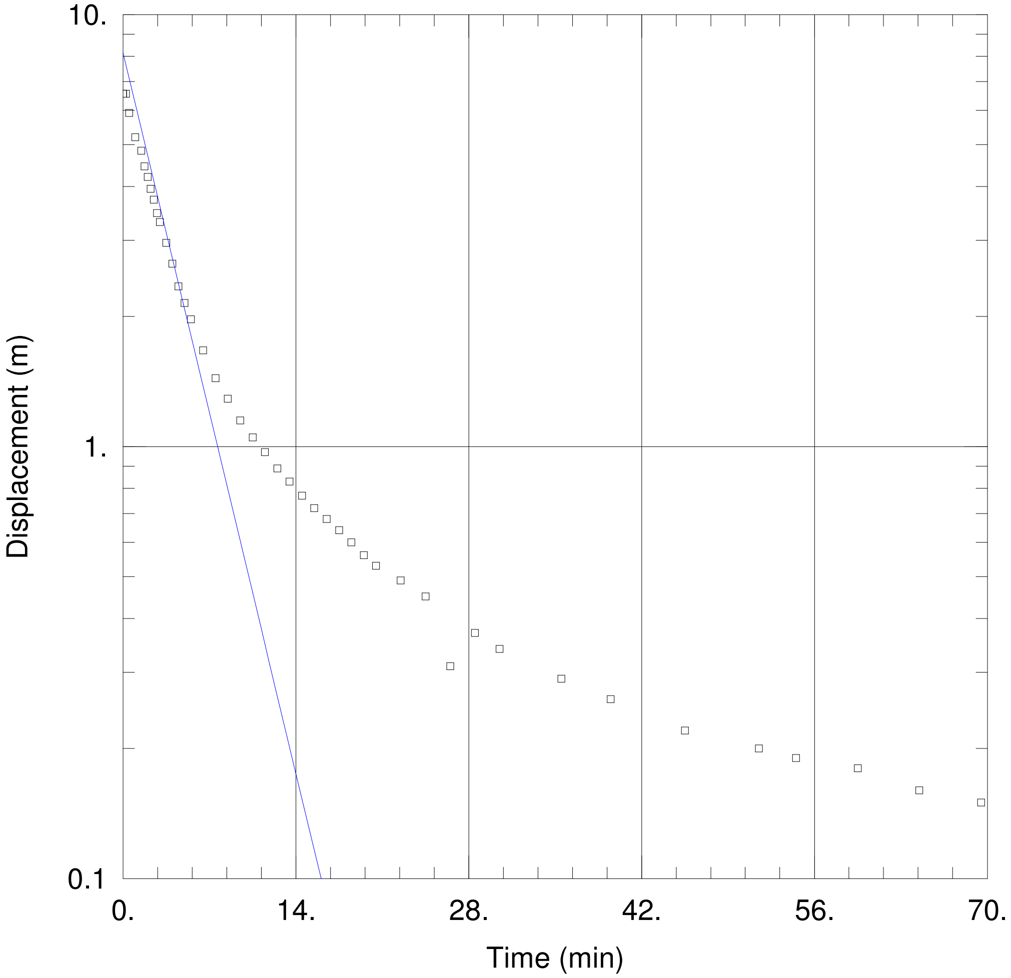
END CAP

DRAFT

△ Unconfined Compression Test
☐ Field Vane Test ■ (Remolded)
◇ Fall Cone Test ◆ (Remolded)
▽ Hand Penetrometer Test ◪ Torvane

Appendix D

Hydraulic Testing Data



BH-GE-03 RISING HEAD

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Kamistiatusset Property
Test Well: BH-GE-03
Test Date: Jan 31, 2012

AQUIFER DATA

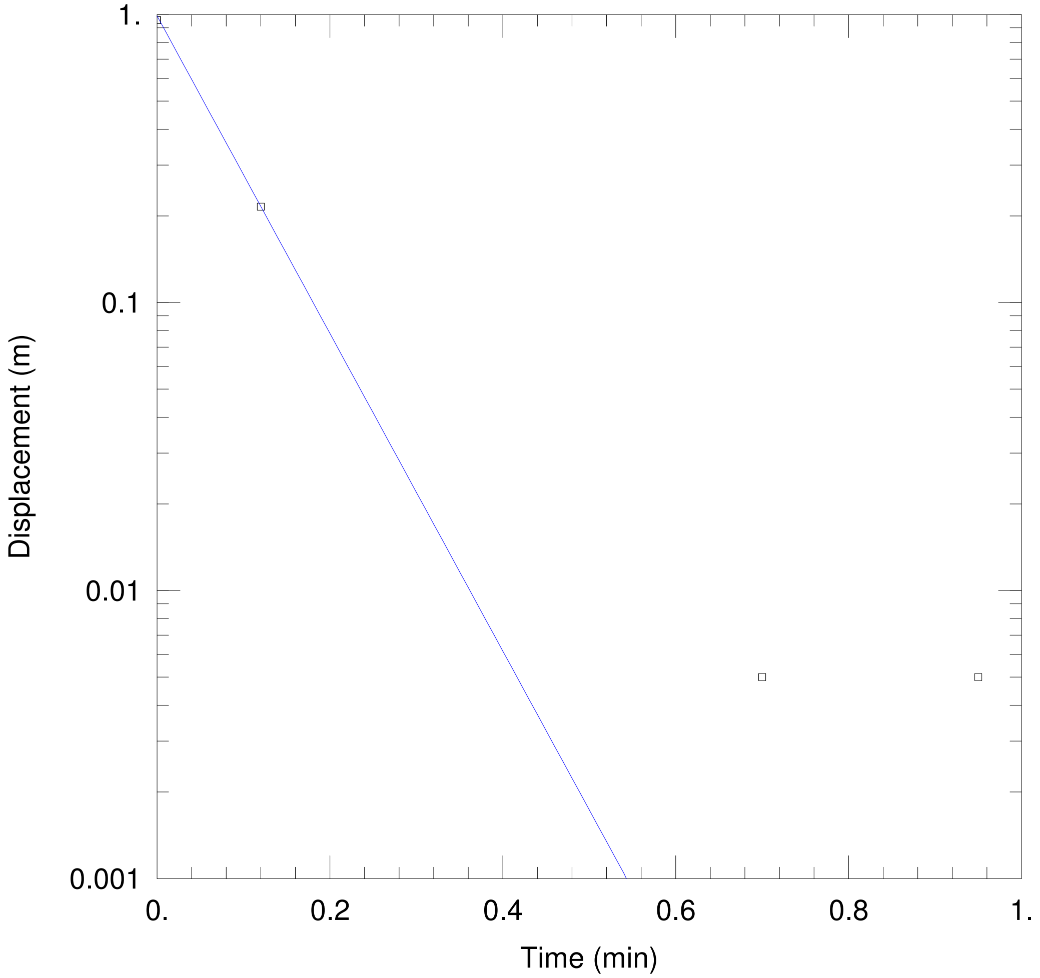
Saturated Thickness: 9.02 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH-GE-03)

Initial Displacement: 6.56 m
Total Well Penetration Depth: 13.12 m
Casing Radius: 0.025 m
Static Water Column Height: 13.23 m
Screen Length: 9.02 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 6.778E-7 m/sec
y0 = 8.148 m



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Kamistiatusset Property
Test Well: BH-GE-06
Test Date: March 25, 2012

AQUIFER DATA

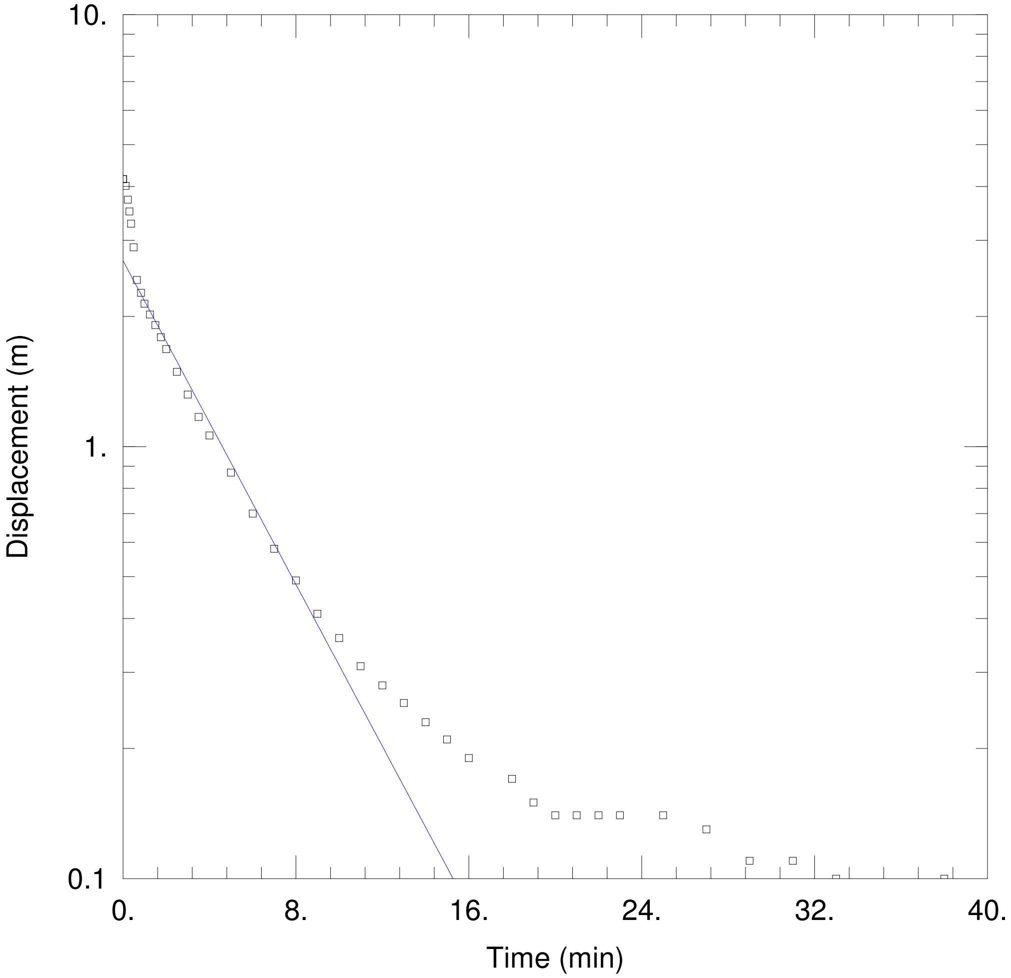
Saturated Thickness: 11.1 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH-GE-06)

Initial Displacement: 0.955 m
Total Well Penetration Depth: 12.09 m
Casing Radius: 0.025 m
Static Water Column Height: 11.81 m
Screen Length: 12.09 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.551E-5 m/sec
y0 = 0.9891 m



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Process Plant Area
Test Well: BH-GE-09
Test Date: March 25, 2012

AQUIFER DATA

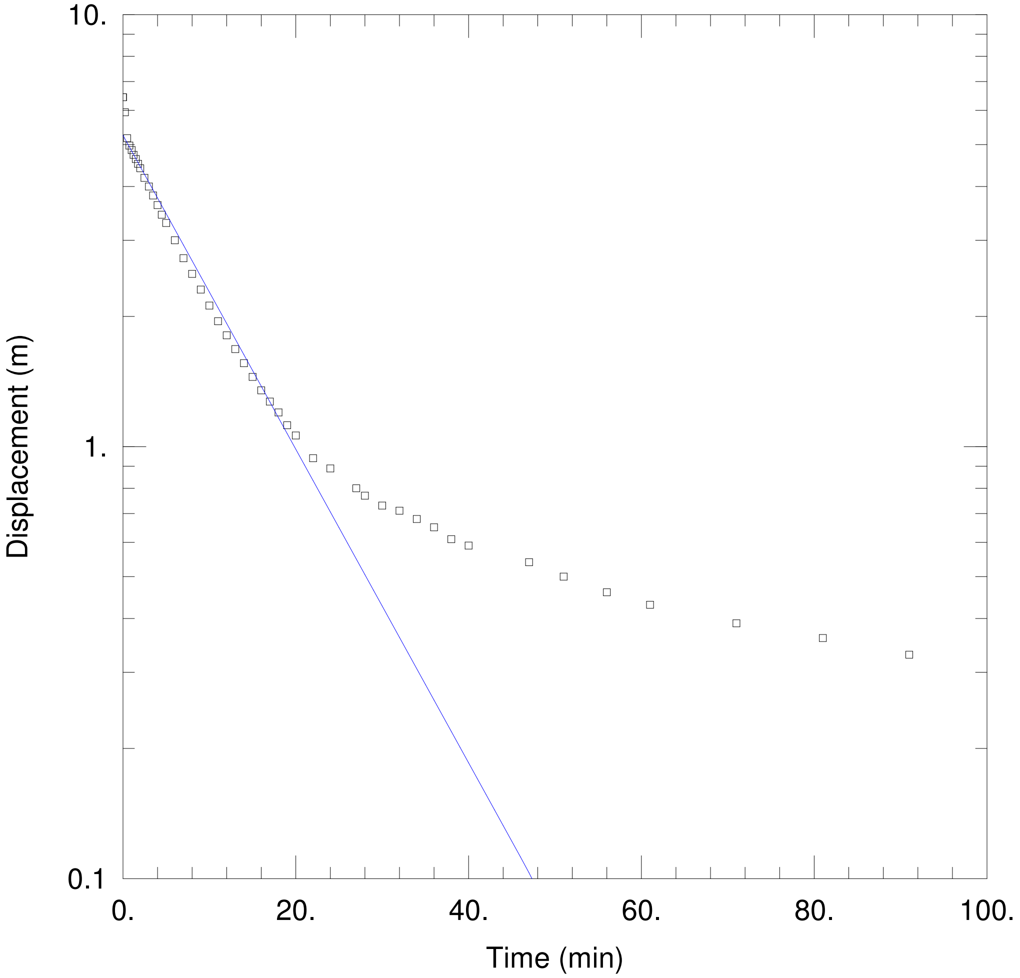
Saturated Thickness: 5.79 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH-GE-09)

Initial Displacement: 4.16 m
Total Well Penetration Depth: 6.53 m
Casing Radius: 0.025 m
Static Water Column Height: 6.76 m
Screen Length: 5.79 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 7.258E-7 m/sec
y0 = 2.692 m



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Process Plant Area
Test Well: BH-GE-10
Test Date: March 25, 2012

AQUIFER DATA

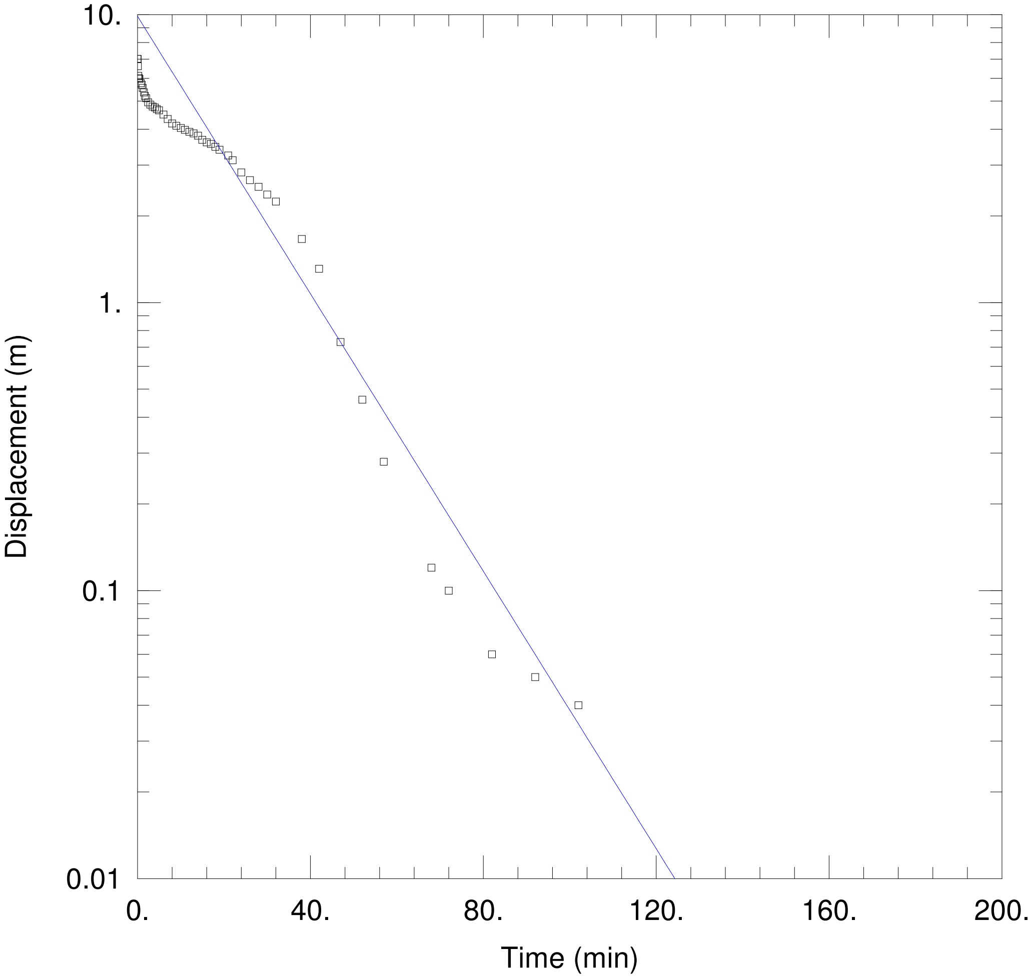
Saturated Thickness: 6.6 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH-GE-10)

Initial Displacement: 6.43 m
Total Well Penetration Depth: 7.675 m
Casing Radius: 0.025 m
Static Water Column Height: 7.825 m
Screen Length: 6.6 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 2.553E-7 m/sec
y0 = 5.254 m



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Kami Rail Spur
Test Well: BH-GE-18
Test Date: March 29, 2012

AQUIFER DATA

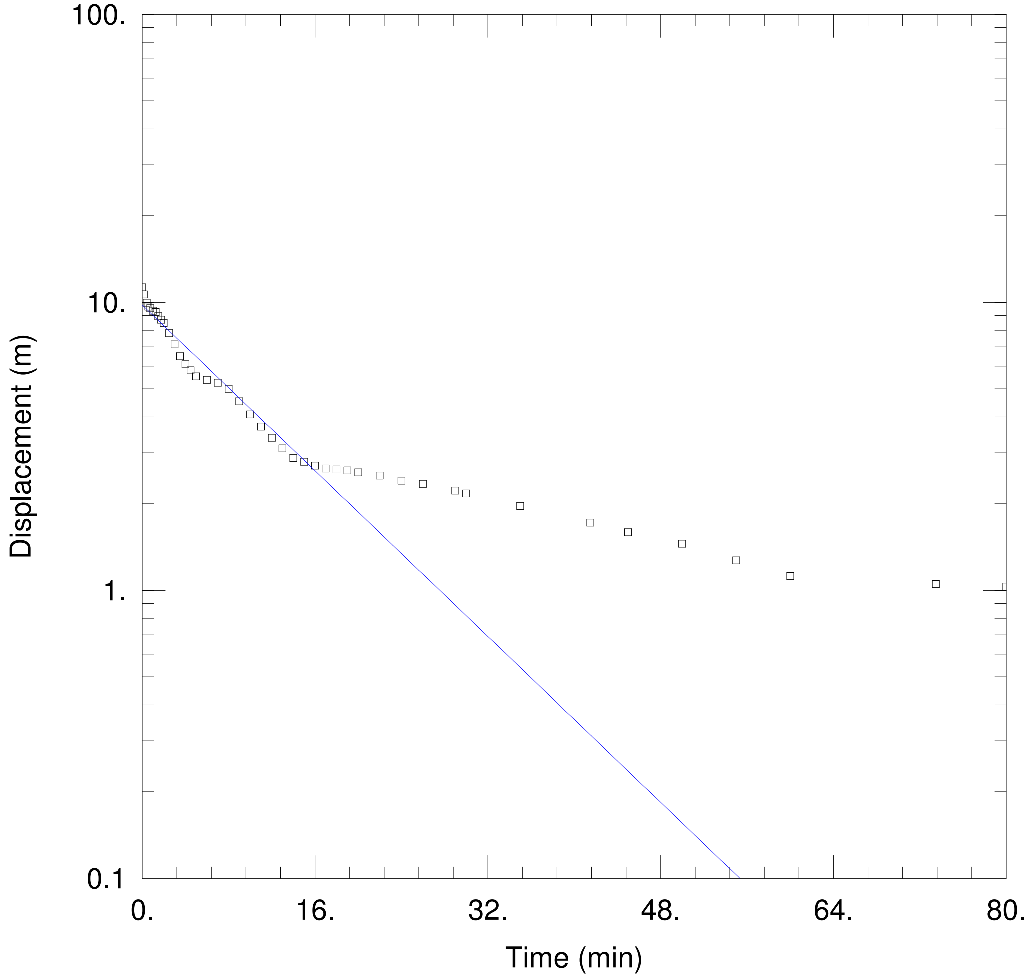
Saturated Thickness: 7.81 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH-GE-18)

Initial Displacement: 7.02 m
Total Well Penetration Depth: 9.65 m
Casing Radius: 0.025 m
Static Water Column Height: 9.08 m
Screen Length: 9.65 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 1.498E-7 m/sec
y0 = 9.848 m



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Rose Pit
Test Well: ROB-11-02
Test Date: March 22, 2012

AQUIFER DATA

Saturated Thickness: 22.86 m

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (ROB-11-02)

Initial Displacement: 11.27 m
Total Well Penetration Depth: 25.58 m
Casing Radius: 0.025 m

Static Water Column Height: 25.58 m
Screen Length: 22.86 m
Well Radius: 0.05 m

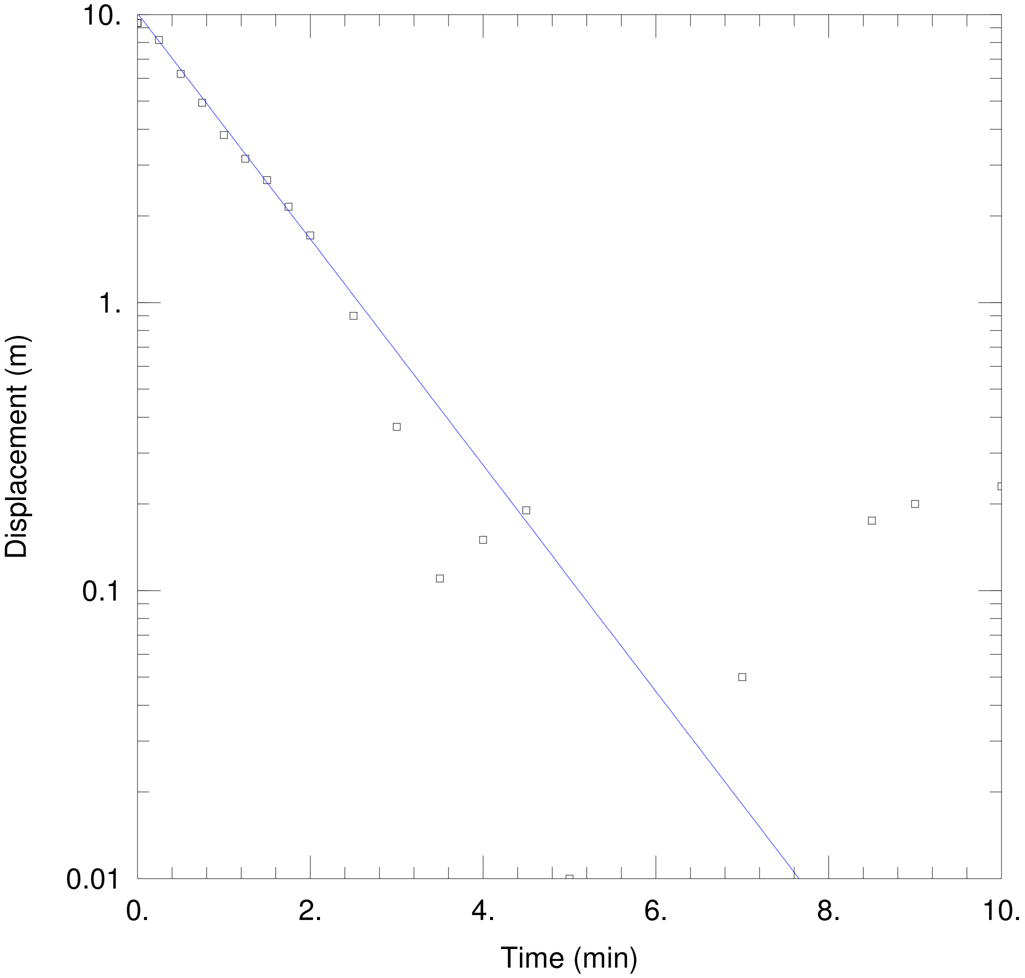
SOLUTION

Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

K = 9.487E-8 m/sec

y0 = 9.781 m



RUN 1

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Rose Pit
Test Well: ROB-11-05B
Test Date: March 23, 2012

AQUIFER DATA

Saturated Thickness: 10.98 m
Anisotropy Ratio (Kz/Kr): 1.

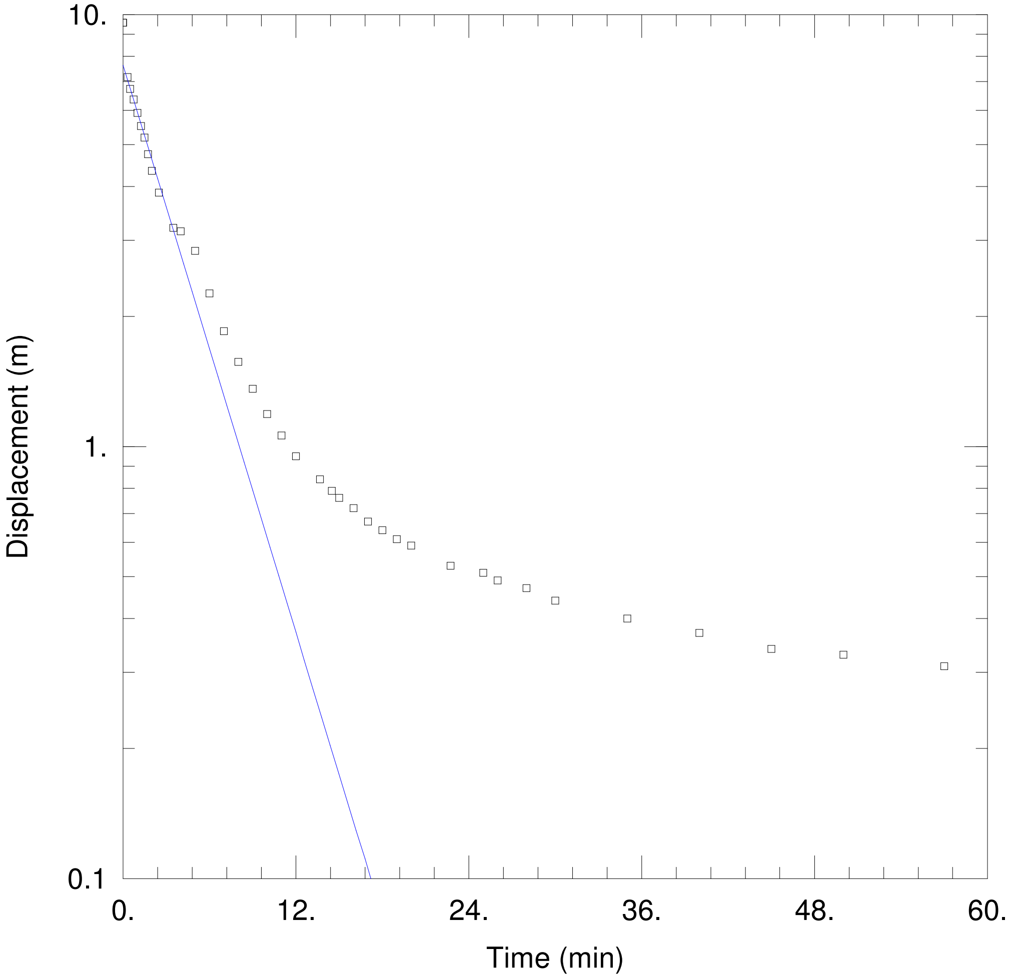
WELL DATA (ROB-11-05B)

Initial Displacement: 9.35 m
Total Well Penetration Depth: 11.27 m
Casing Radius: 0.025 m
Static Water Column Height: 11.27 m
Screen Length: 10.98 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.814E-6 m/sec
y0 = 10.12 m



RUN 2

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Rose Pit
Test Well: ROB-11-05B
Test Date: March 23, 2012

AQUIFER DATA

Saturated Thickness: 10.98 m
Anisotropy Ratio (Kz/Kr): 1.

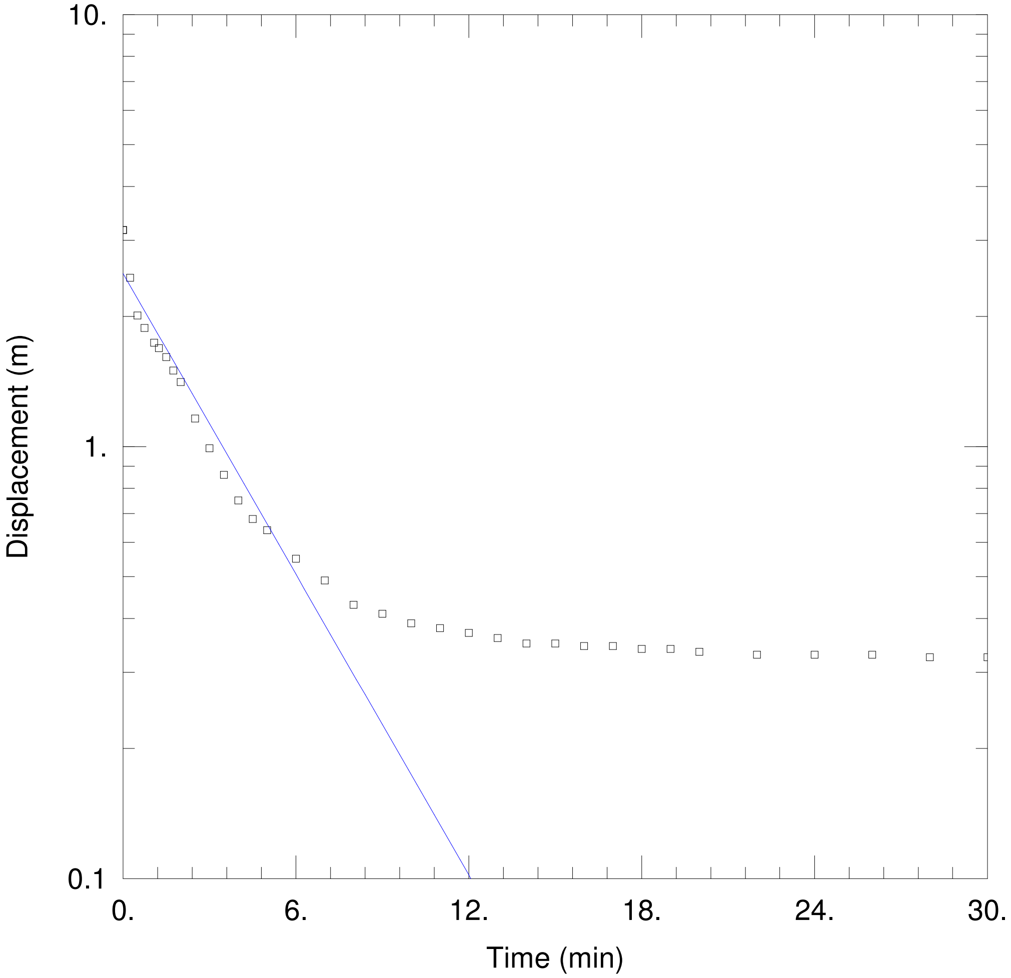
WELL DATA (ROB-11-05B)

Initial Displacement: 9.57 m
Total Well Penetration Depth: 11.27 m
Casing Radius: 0.025 m
Static Water Column Height: 11.27 m
Screen Length: 10.98 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 5.056E-7 m/sec
y0 = 7.636 m



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Rose Pit
Test Well: ROB-11-13B
Test Date: March 26, 2012

AQUIFER DATA

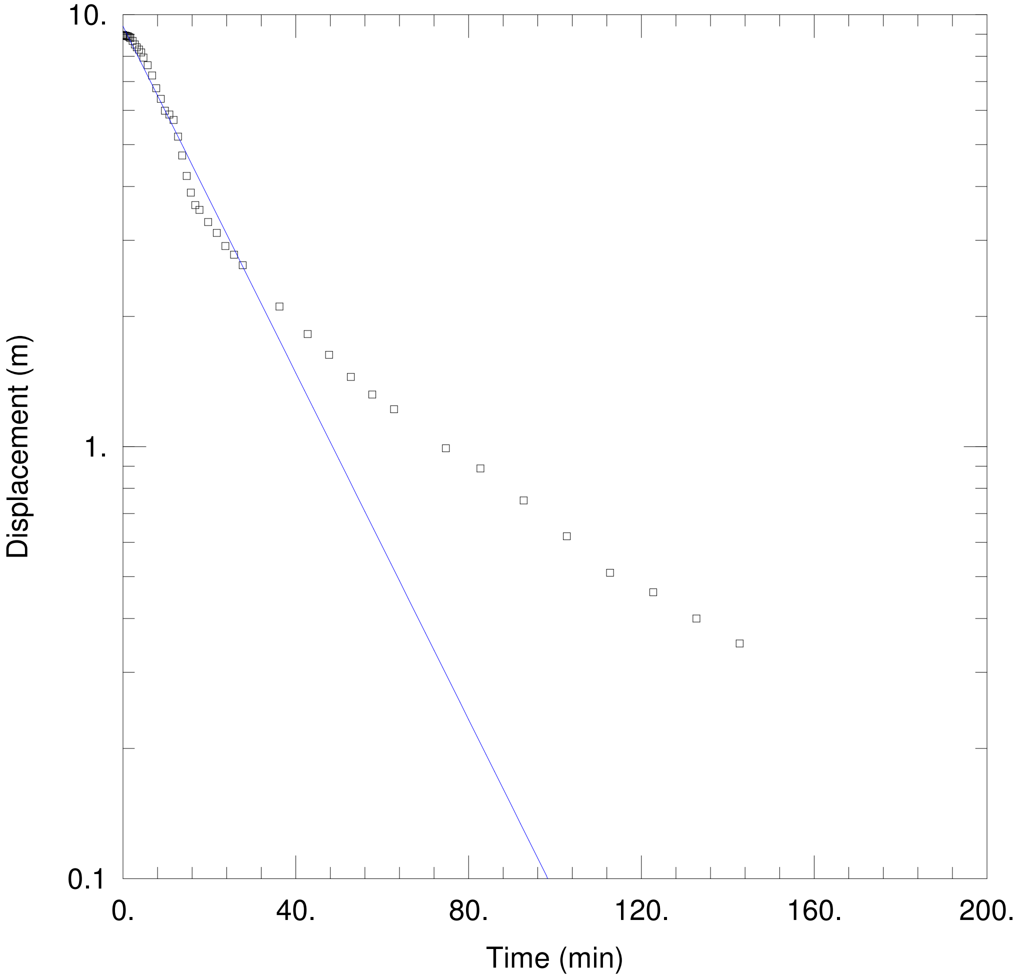
Saturated Thickness: 4.98 m	Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (ROB-11-13B)

Initial Displacement: 3.17 m	Static Water Column Height: 4.98 m
Total Well Penetration Depth: 9.15 m	Screen Length: 9.15 m
Casing Radius: 0.025 m	Well Radius: 0.05 m
	Gravel Pack Porosity: 0.25

SOLUTION

Aquifer Model: Unconfined	Solution Method: Bouwer-Rice
K = 1.921E-6 m/sec	y0 = 2.516 m



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Rose Pit
Test Well: ROB-11-17
Test Date: Jan 23, 2012

AQUIFER DATA

Saturated Thickness: 43.18 m
Anisotropy Ratio (Kz/Kr): 1.

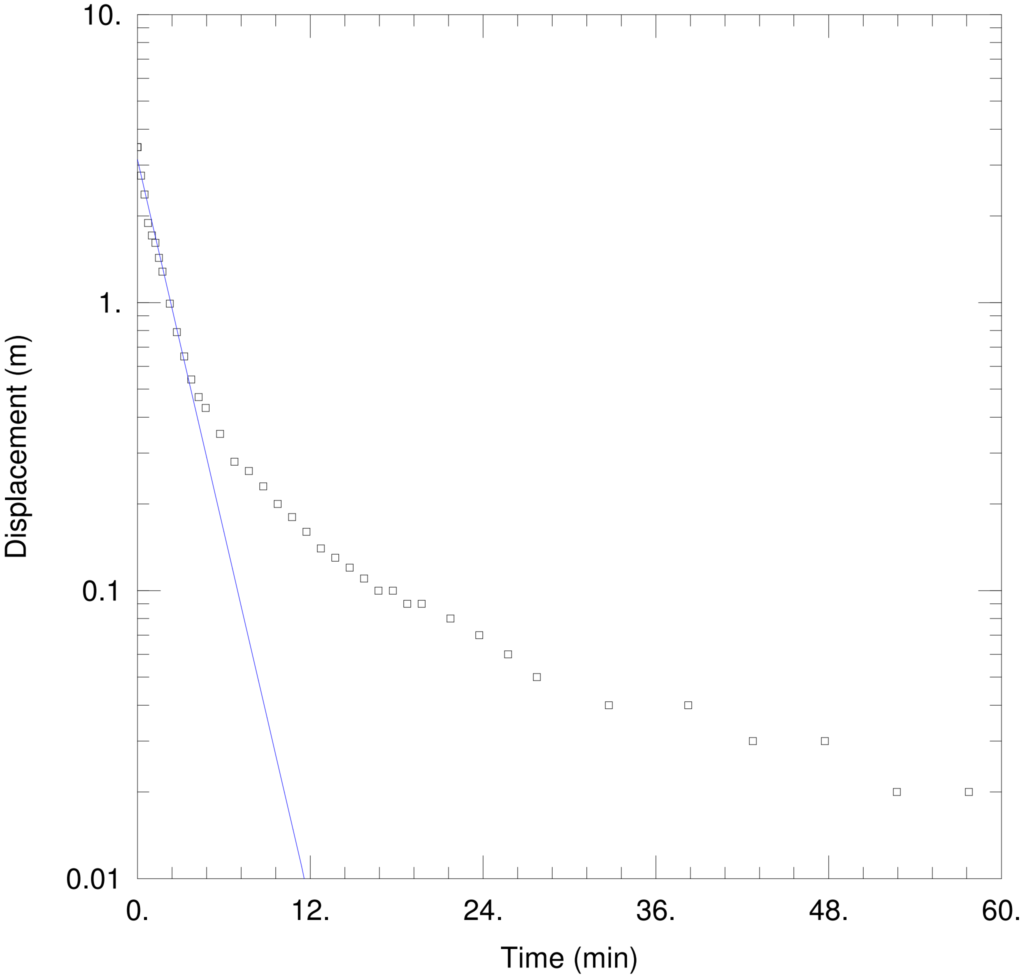
WELL DATA (New Well)

Initial Displacement: 8.97 m
Total Well Penetration Depth: 44.88 m
Casing Radius: 0.025 m
Static Water Column Height: 44.98 m
Screen Length: 43.18 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 3.169E-8 m/sec
y0 = 9.39 m



WELL TEST ANALYSIS

PROJECT INFORMATION

Company: Stantec Consulting Ltd
Client: Alderon Iron Ore Corp.
Project: 121614000
Location: Rose Pit
Test Well: ROB-11-20
Test Date: Jan 31, 2012

AQUIFER DATA

Saturated Thickness: 9.61 m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (New Well)

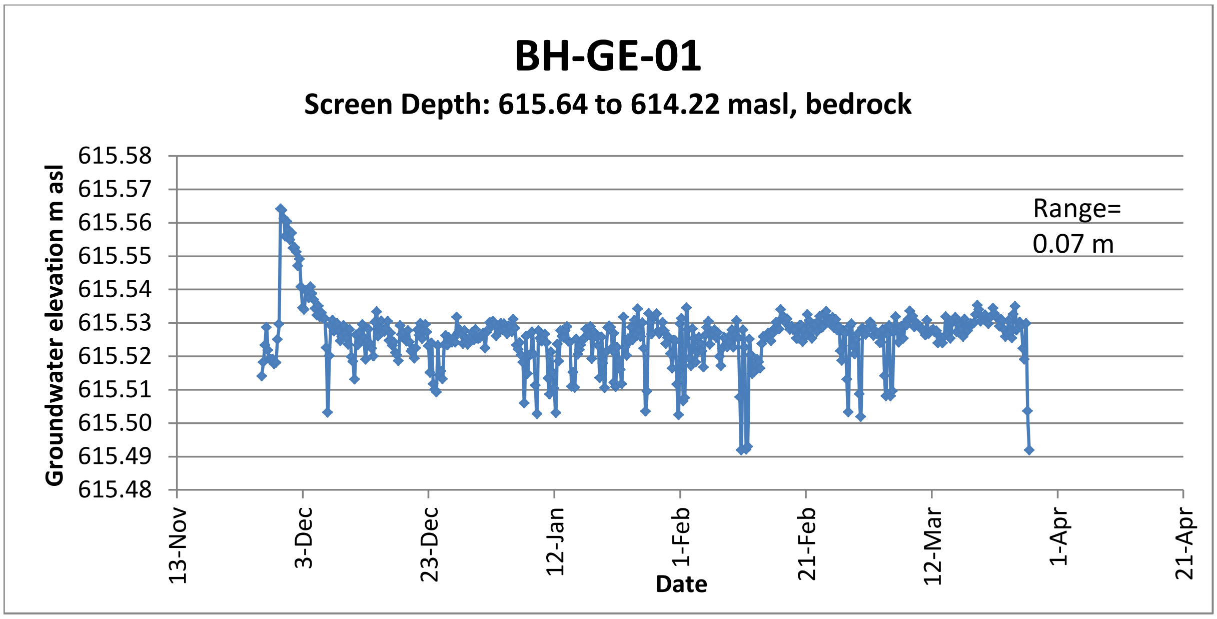
Initial Displacement: 3.46 m
Total Well Penetration Depth: 13.6 m
Casing Radius: 0.025 m
Static Water Column Height: 9.61 m
Screen Length: 13.6 m
Well Radius: 0.05 m

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 1.162E-6 m/sec
y0 = 3.132 m

Appendix E

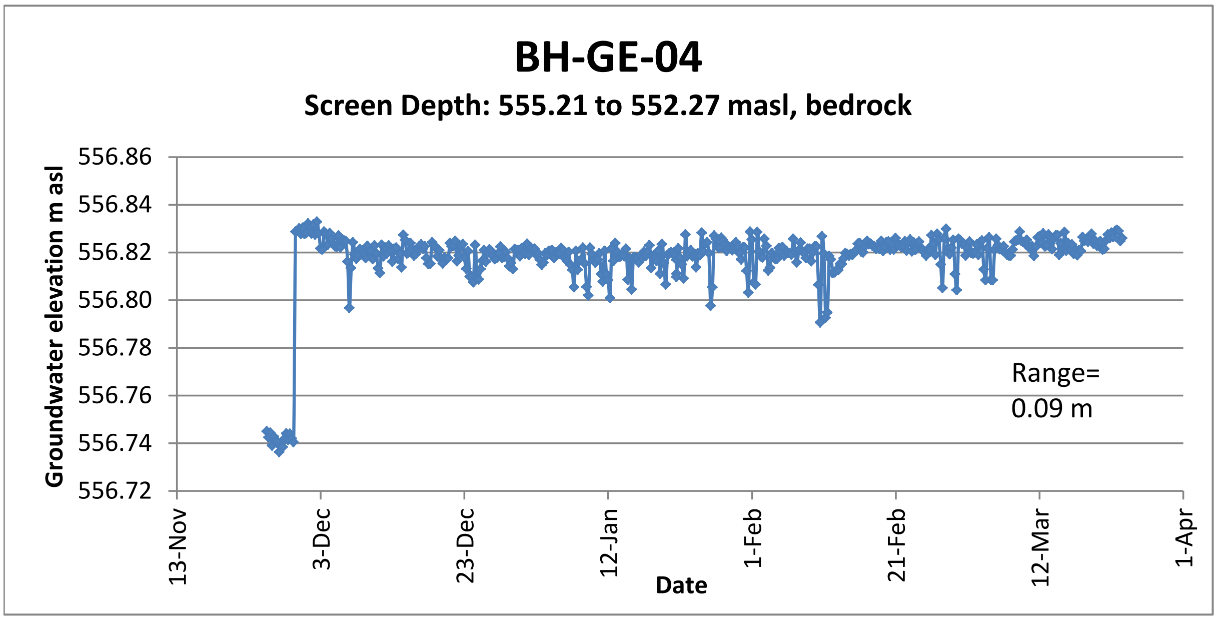
Water Level Data


BH-GE-01

Screen Depth: 615.64 to 614.22 masl, bedrock

Range= 0.07 m

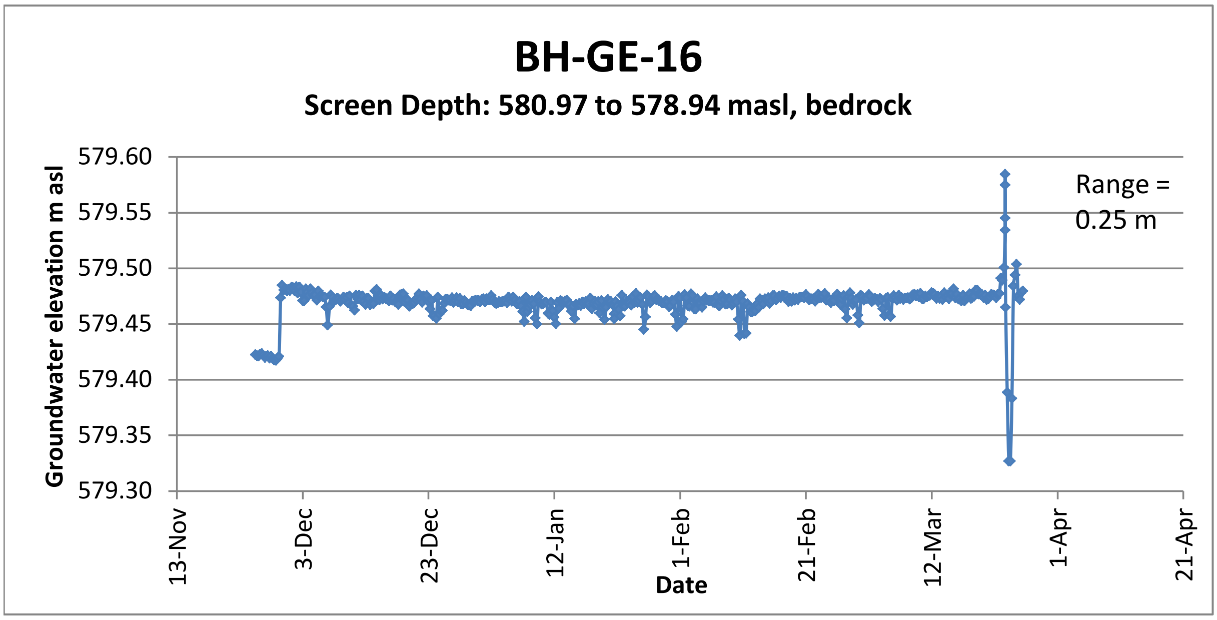
Logger is placed only 0.15 m below the top of the screen


BH-GE-04

Screen Depth: 555.21 to 552.27 masl, bedrock

Range= 0.09 m

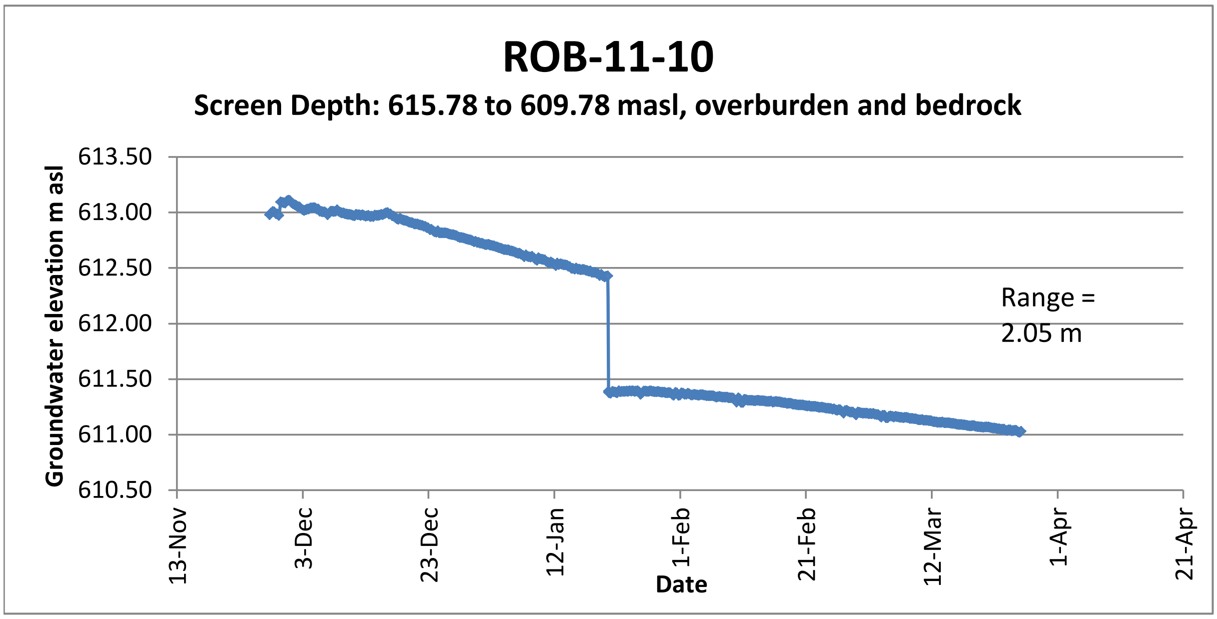
Logger is placed about 1.5 m above the top of the screen


BH-GE-16

Screen Depth: 580.97 to 578.94 masl, bedrock

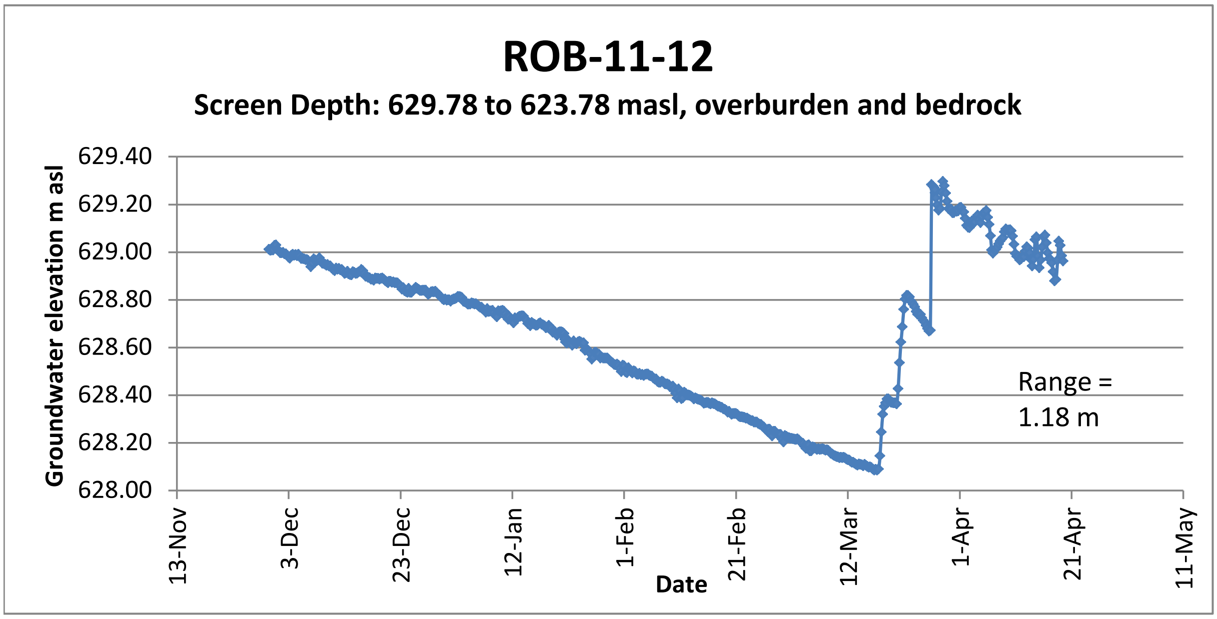
Range = 0.25 m

Logger is placed 1.5 m below the top of the screen



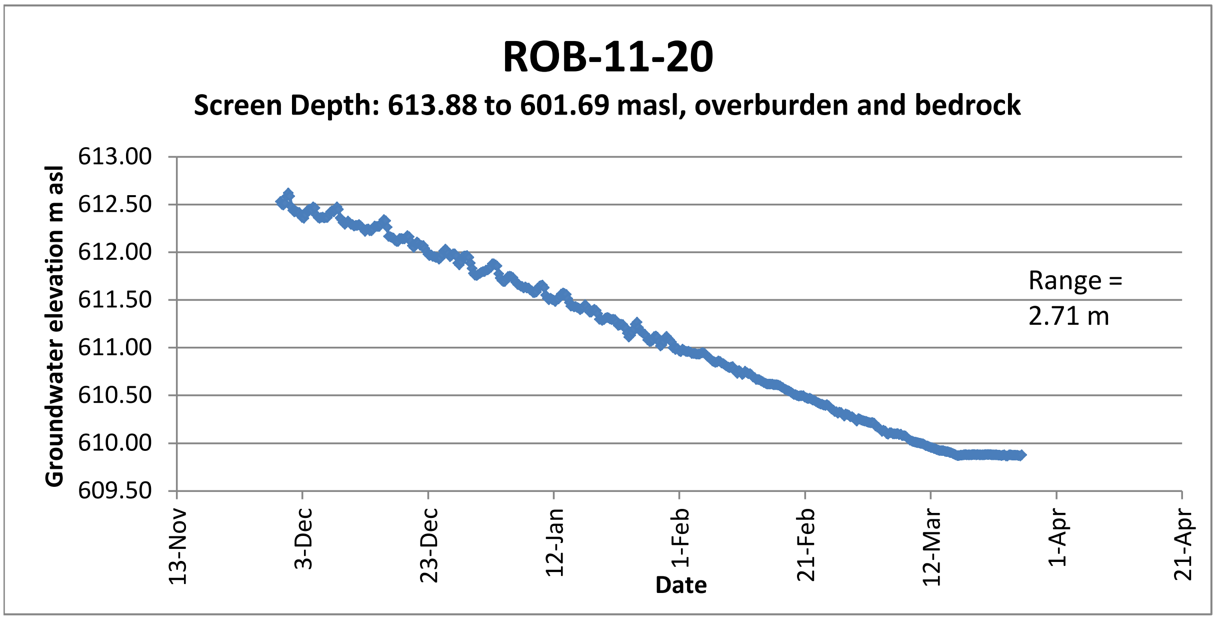
Logger is splaced
about 5 m below the
top of the screen

Sharp drop occurs
after downloading
logger data and
replacing line

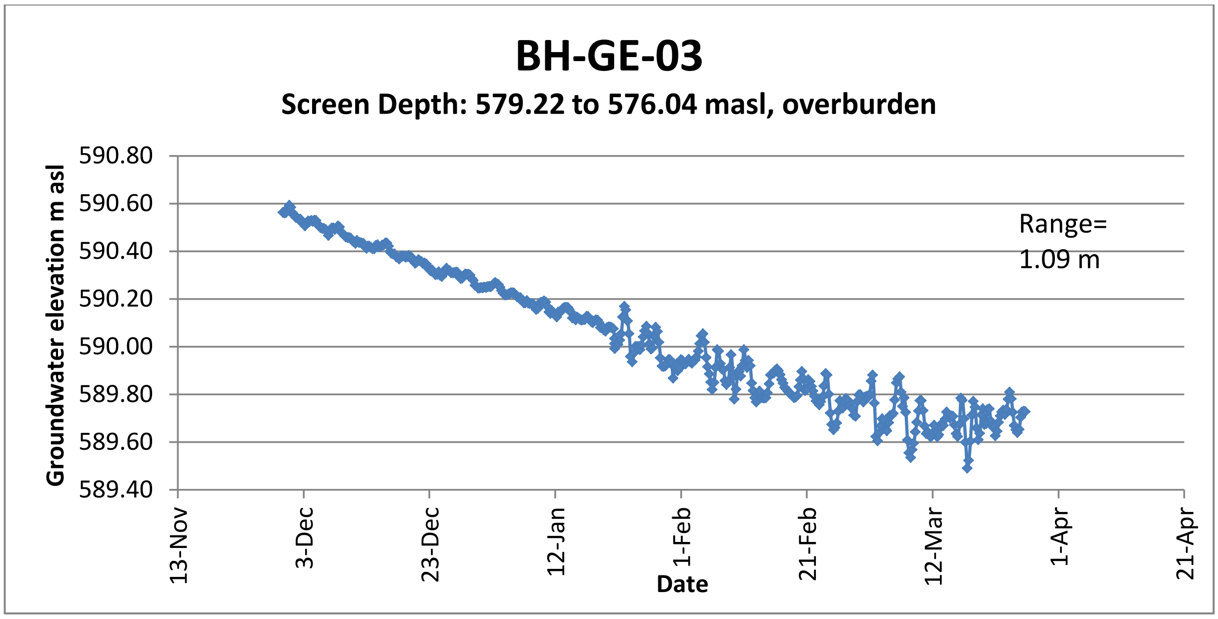


Logger is placed
about 5.5 m below
top of screen

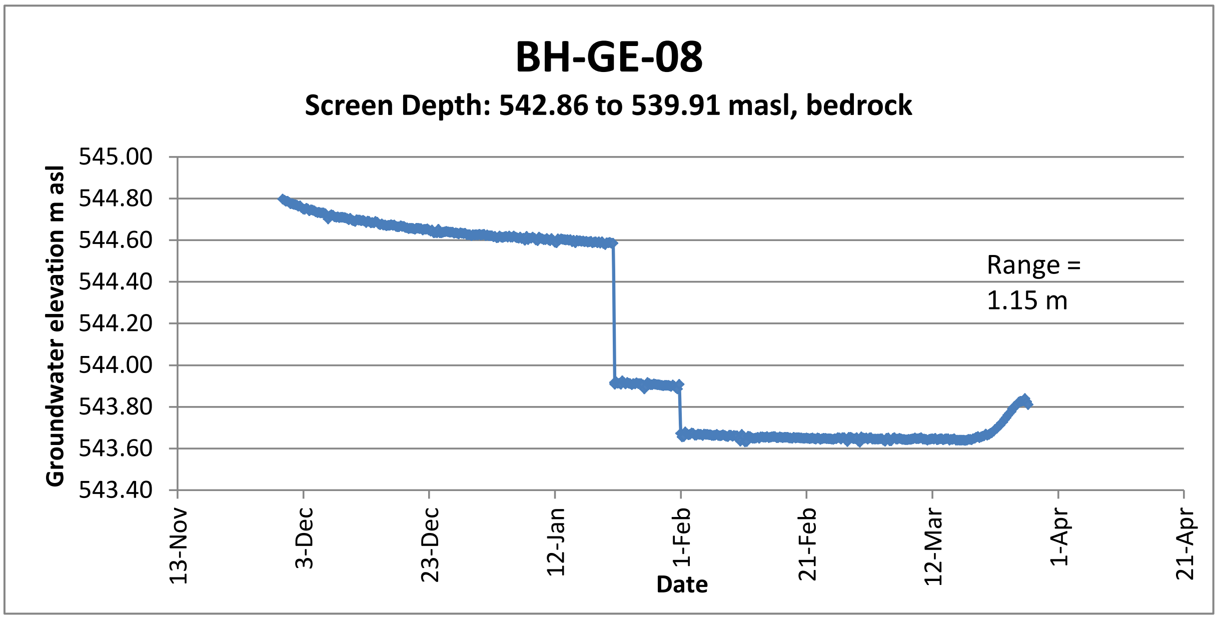
Recharge could be
due to a period of
unseasonally warm
temperatures
causing early snow
melt



Logger is placed
about 4 m below the
top of the screen

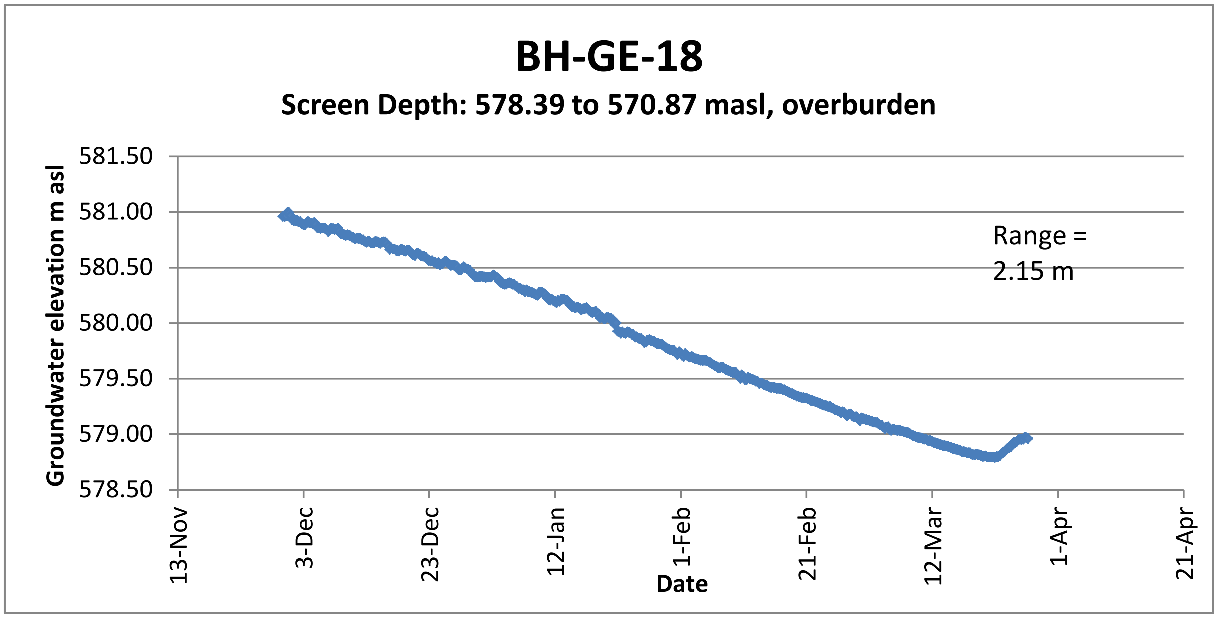


Logger is placed
about 5 m above
the top of the
screen.



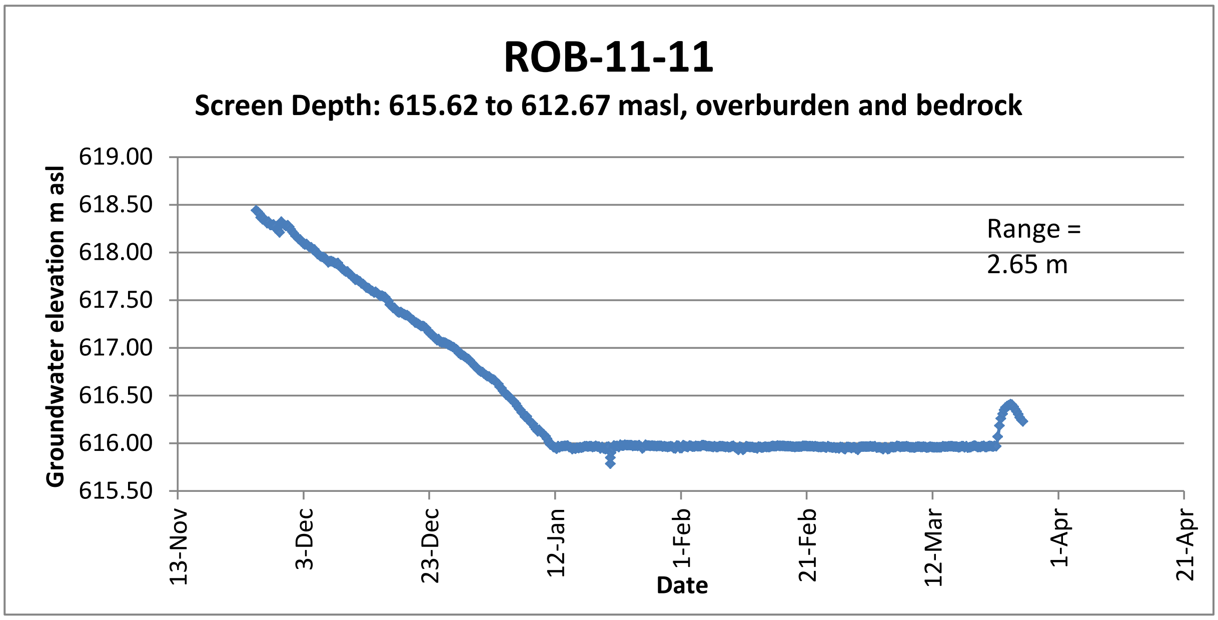
Recharge due to
warm
temperatures?

Logger is placed
about 1.6 m
below the top of
the screen
The first drop
corresponds to
taking the logger
out for
downloading.



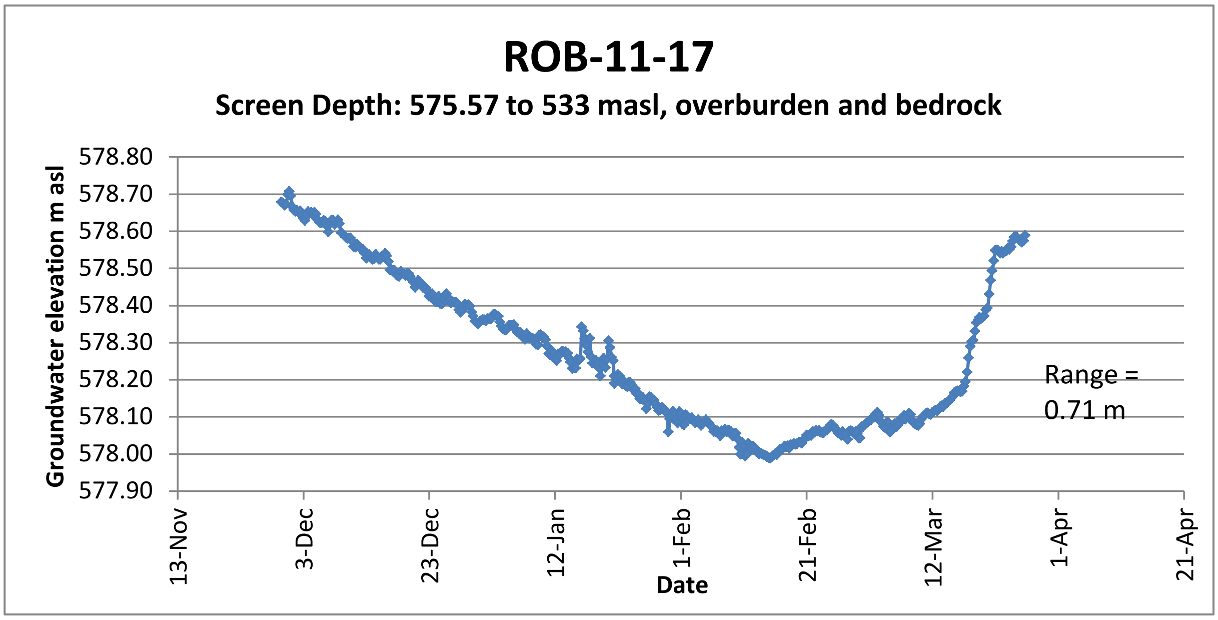
Logger is set at
about 2.5 m
below the top of
the screen

Recharge due to
warm
temperatures?



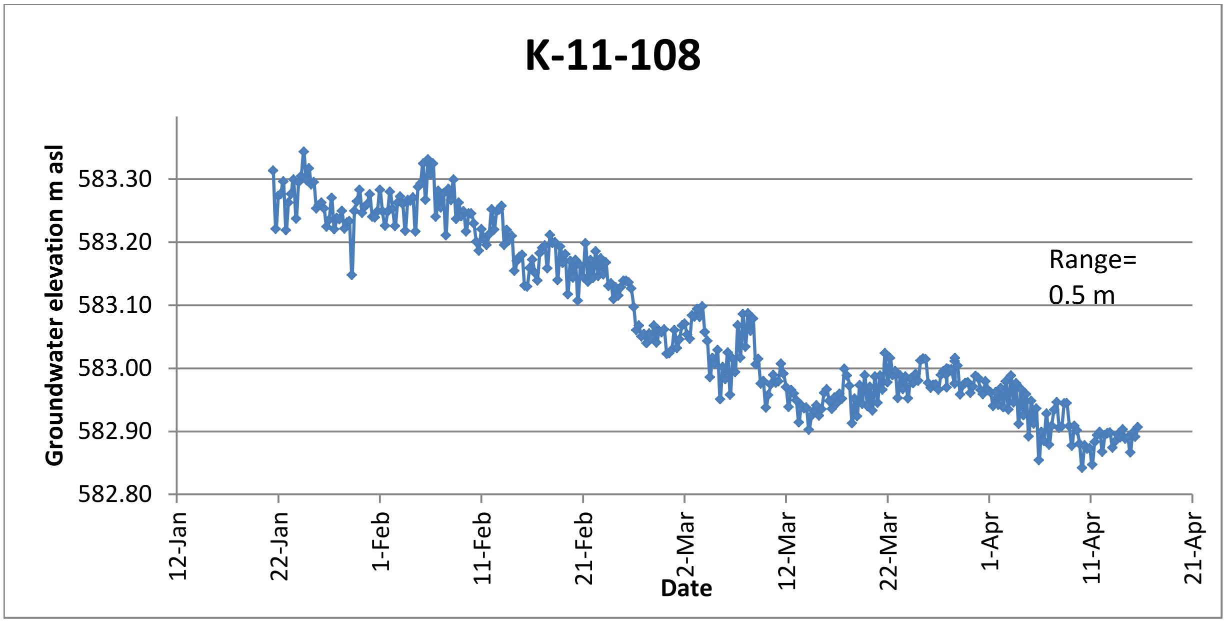
Logger is placed about 1 m below the top of the screen

Well very close to a lake, gw levels may have fallen until reaching equilibrium with

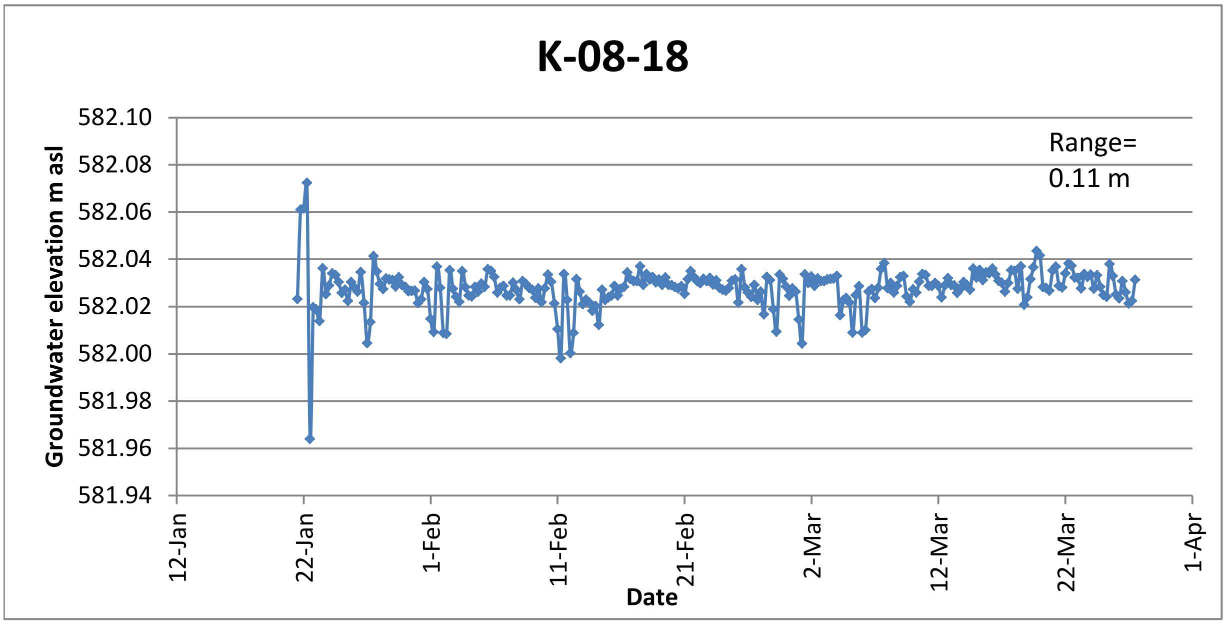


Logger is placed about 2 m belosw the top of the screen

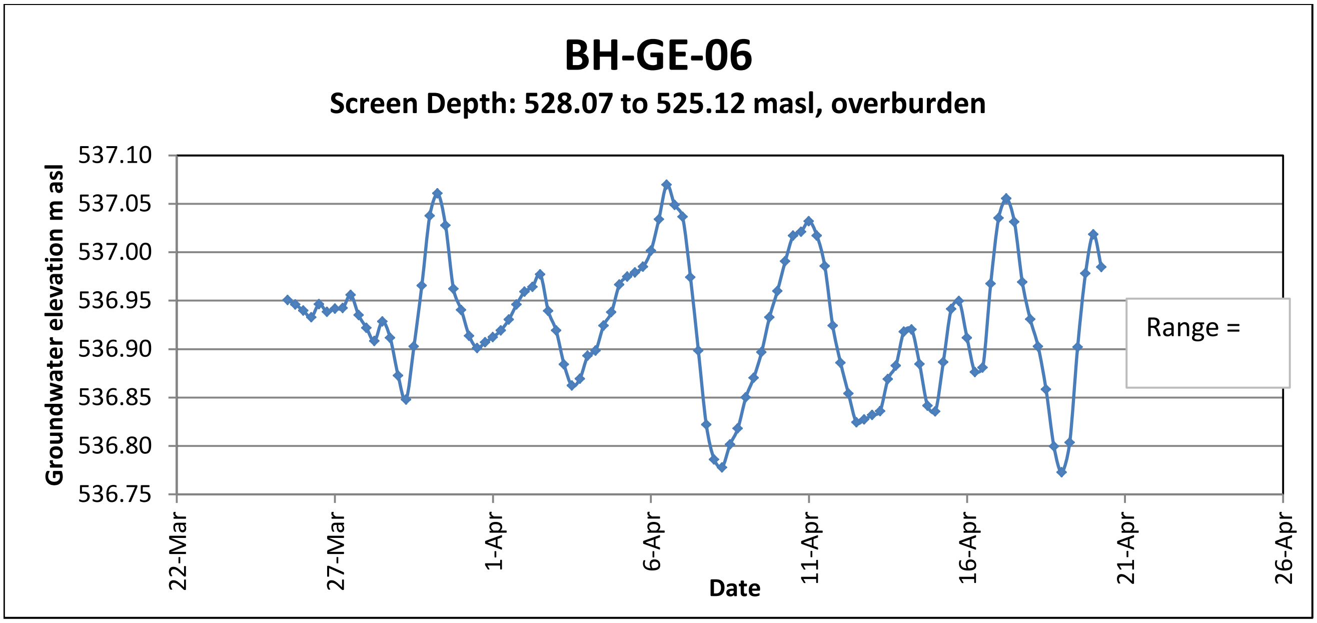
Recharge could be due to a period of unseasonably warm temperatures causing early snow melt



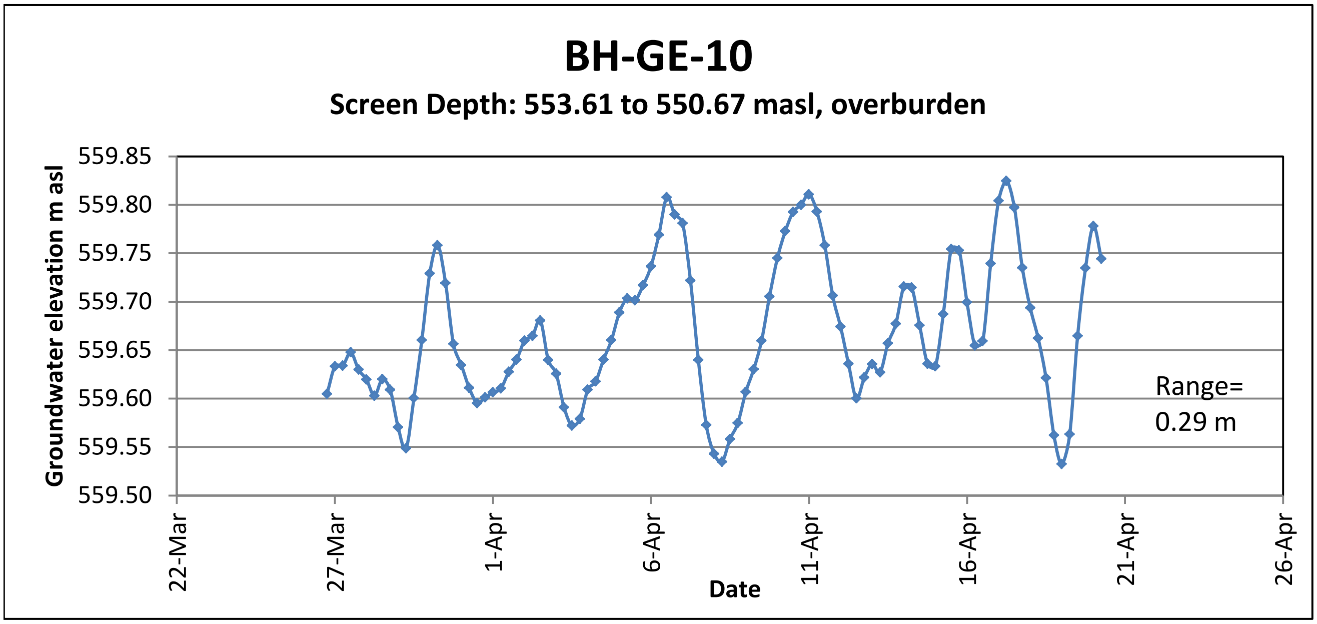
Don't have information on screen depth



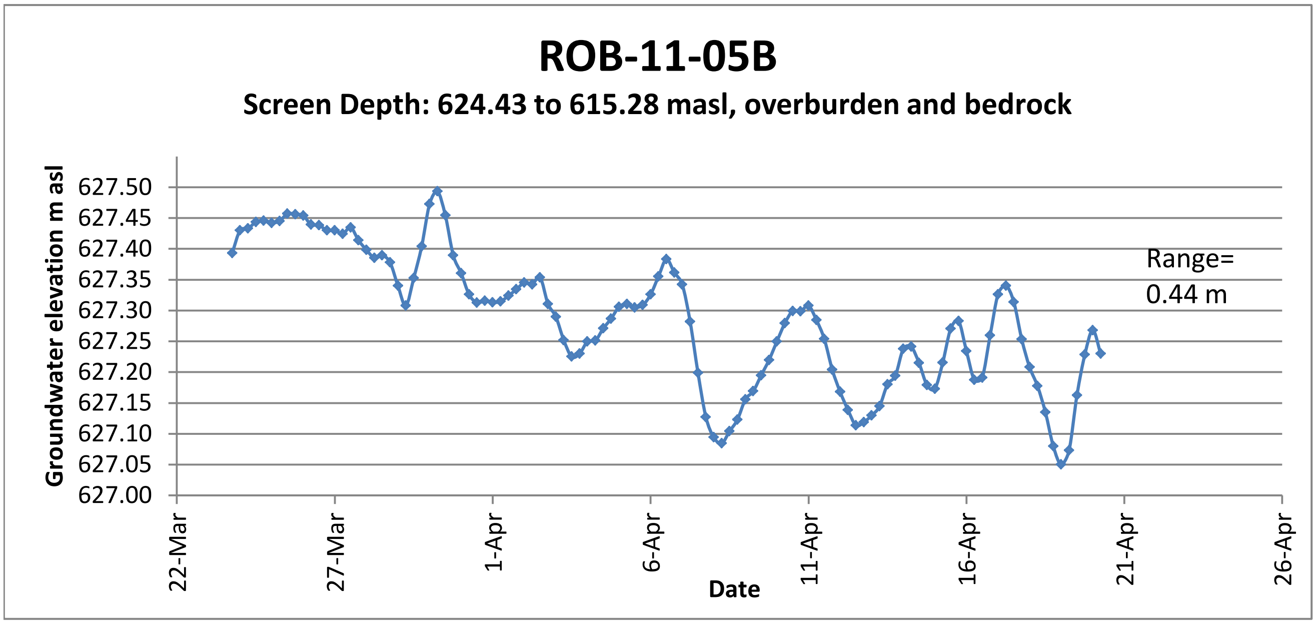
Don't have information on screen depth



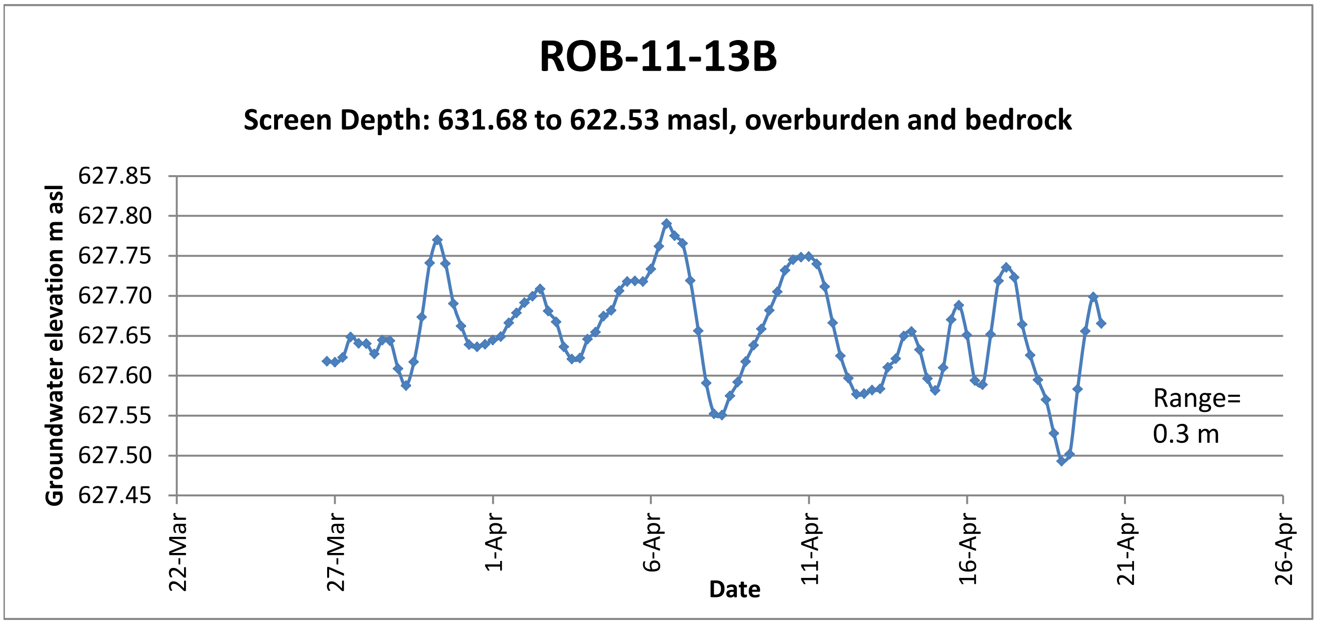
Logger is placed
about 3 m above
the top of the
screen



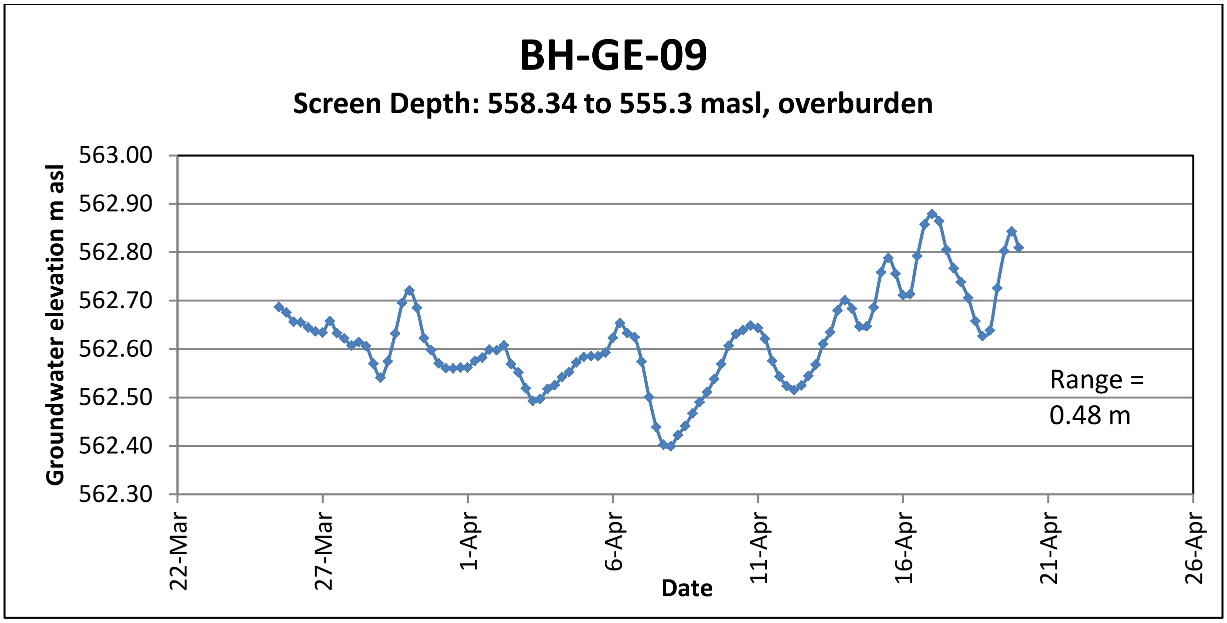
Logger is placed
about 0.5 m
below the top of
the screen



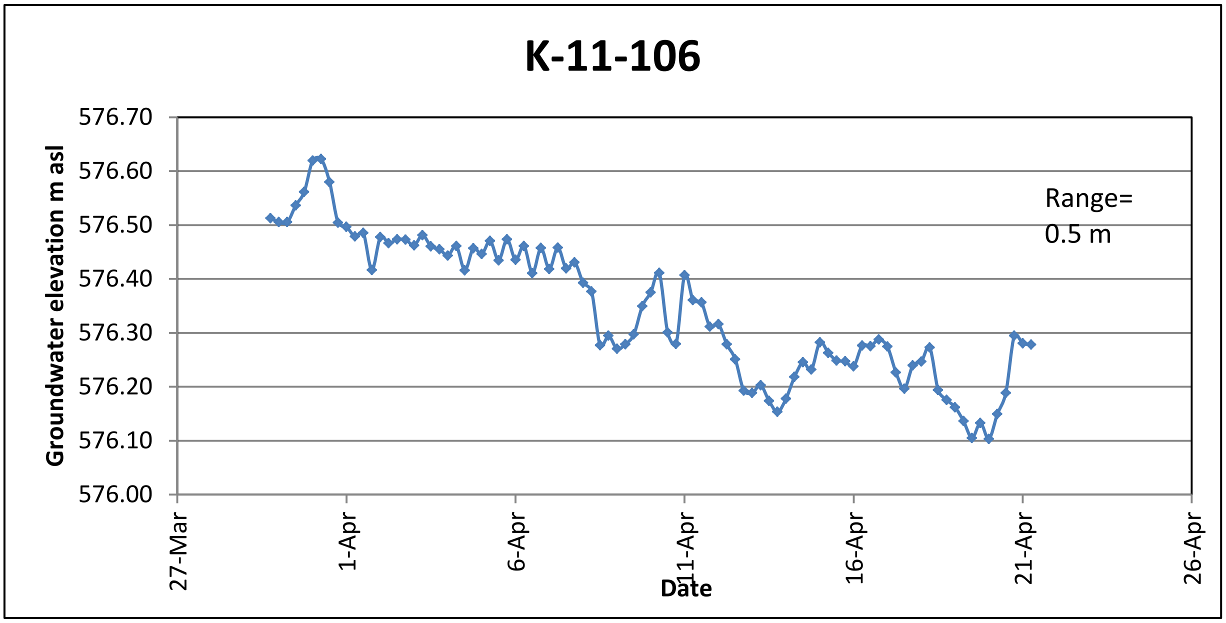
Logger is placed
about 4 m below
the top of the
screen



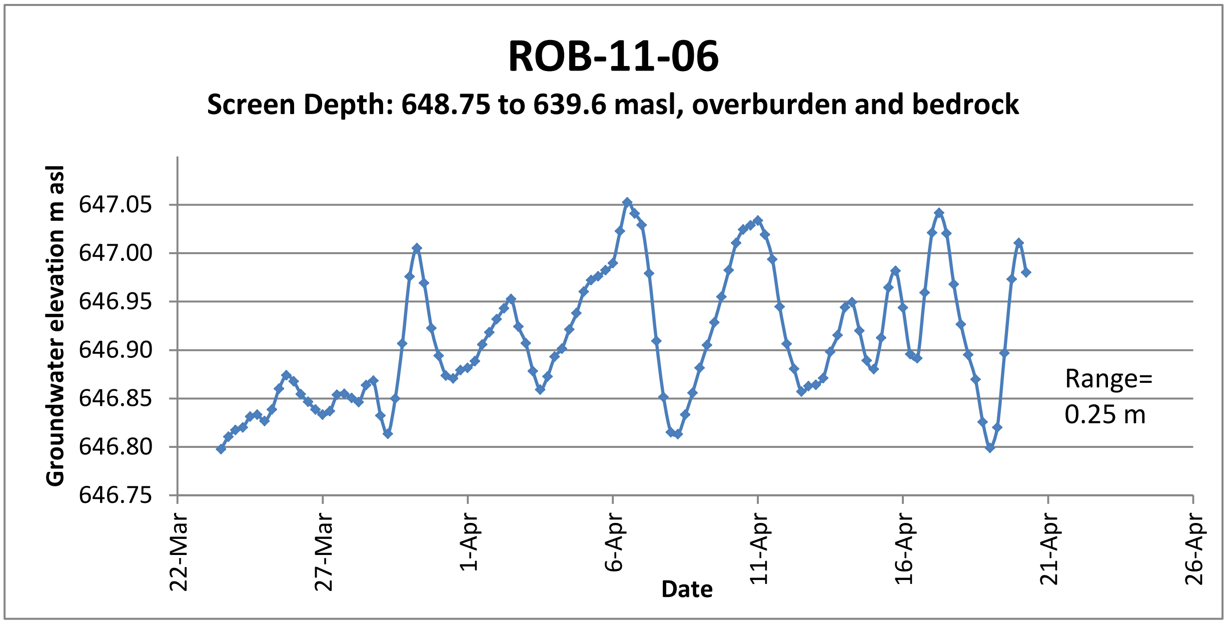
Logger is placed
about 5.5 m
below the top of
the screen



Logger is placed 1.5
m below the top of
the screen



No information on
screen depths



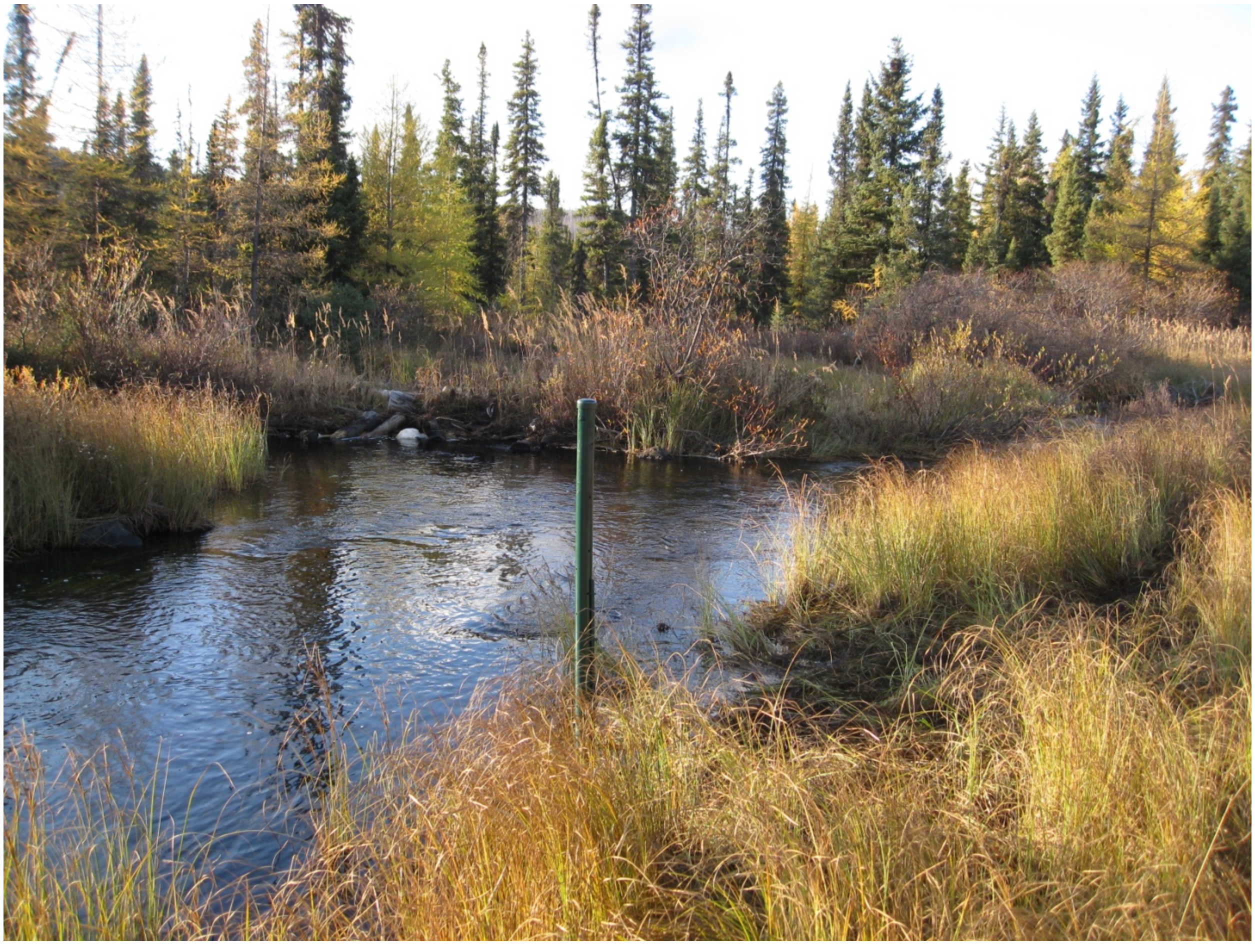
Logger is placed
about 7 m below
the top of the
screen

Appendix F

Summary of Hydrological Monitoring Stations

STATION *S1*

Date: Oct 06, 2011



*Looking downstream

Location

Station *S1* is located at the exit of Narrow Lake approximately 10 m upstream of the access trail on the right bank. The coordinates (UTM NAD83) of the station are northing 5859719.680 and easting 632232.086.

Rationale

Station *S1* will provide baseline flow data at the exit of the watershed that contains the Rose Pit and the Rose North waste rock disposal area. This station can also be used to monitor the watershed during construction, operation and decommissioning of the mine.

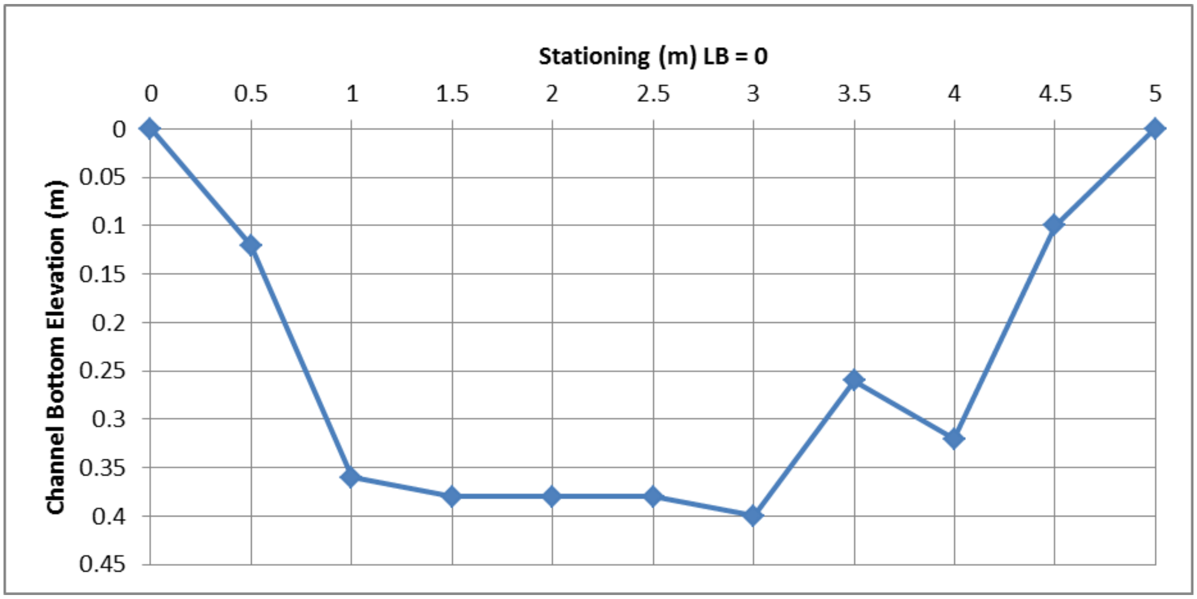
Access

Station *S1* is accessible by land (all terrain vehicle only) following access points A2 and A3 (coordinates included at the end of this summary). Faster access can be provided by helicopter.

Instrumentation

Station *S1* contains a Levelogger installed in a stilling well for continuous water depth monitoring with a 10 minute interval. Station *S1* is also a water quality sampling location. This station was installed in Oct. 6, 2011. The Levelogger was installed with RV antifreeze about 20 cm below the channel bed on the right bank.

Cross Section



Channel profile starting at left bank looking downstream, units in m.
Flat flood plain about 10 cm higher.

Flow Measurement

A flow measurement was conducted using a Sontek Flowtracker on Oct 6, 2011 at 4:30 pm.

$Q = 0.282\ m^3/s$

Channel Slope and Stream Bottom

Water surface -%

- 14 m upstream of station to 11m downstream of station
- Upstream Thalweg -15cm
- Downstream Thalweg -38 cm

Stream has bottom consisting mainly of gravel-cobbles-boulders.

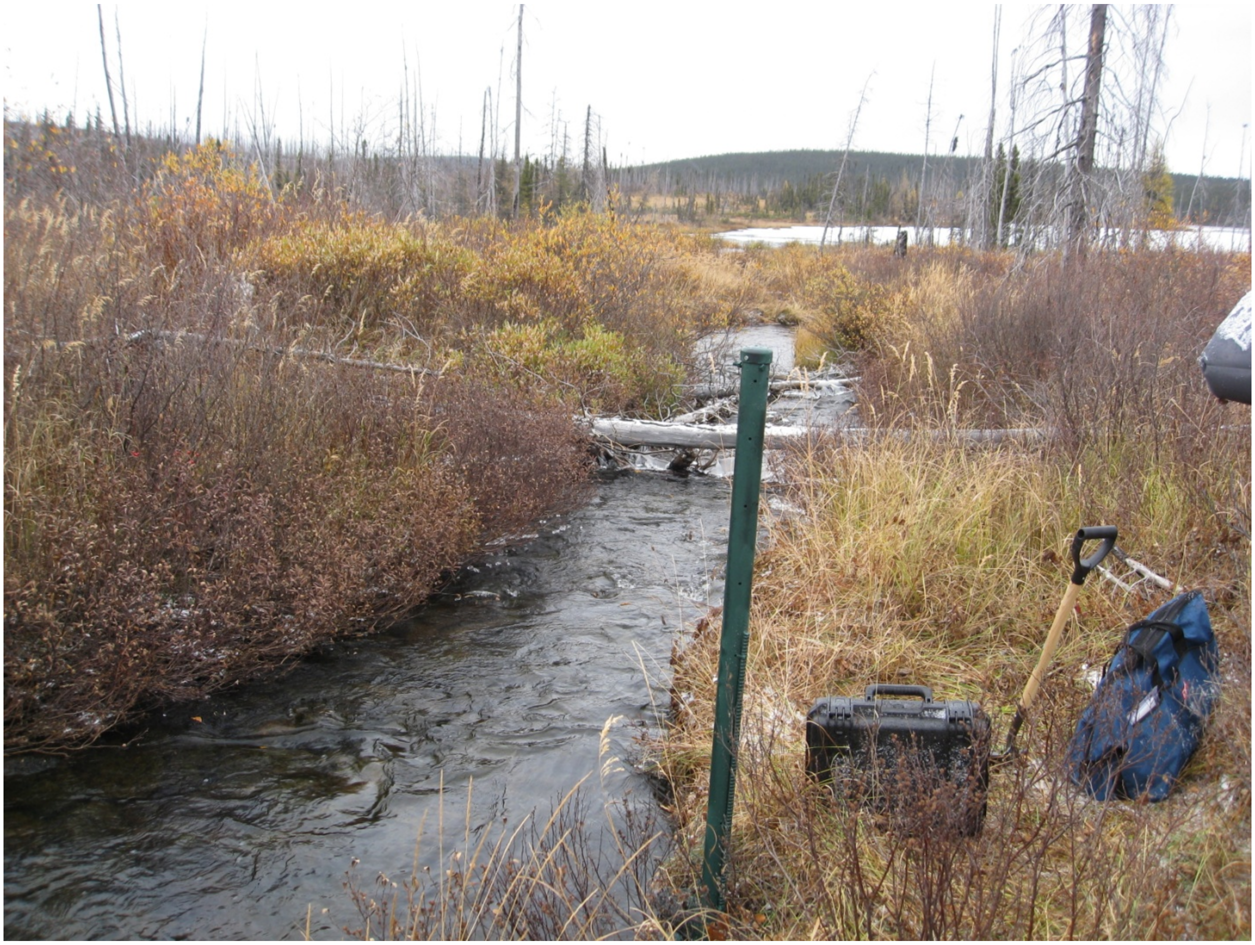
Spot Water Quality Measurements at Station *S1*

Oct 8, 2011 at 9:00 am

Temp. = 3.57 °C
Specific Conductance = 65 µS/cm
Electrical Conductivity = 38 µS/cm
TDS = 0.042 g/L
Salinity = 0.03
DO = 90.1 %
DO = 11.93 mg/L
pH = 9.00
pHmV = -85.0

STATION *S2*

Date: Oct 07, 2011



*Looking downstream

Location

Station *S2* is located at the exit of Rose Lake and just upstream of Narrow Lake (approximately 150 m upstream). The coordinates (UTM NAD 83) of the station are northing 5856173.459 and easting 632802.882.

Rationale

Station *S2* will provide baseline data and further flow monitoring capabilities immediately at the exit of the watershed that contains the Rose Pit and partially the Rose North waste rock disposal area.

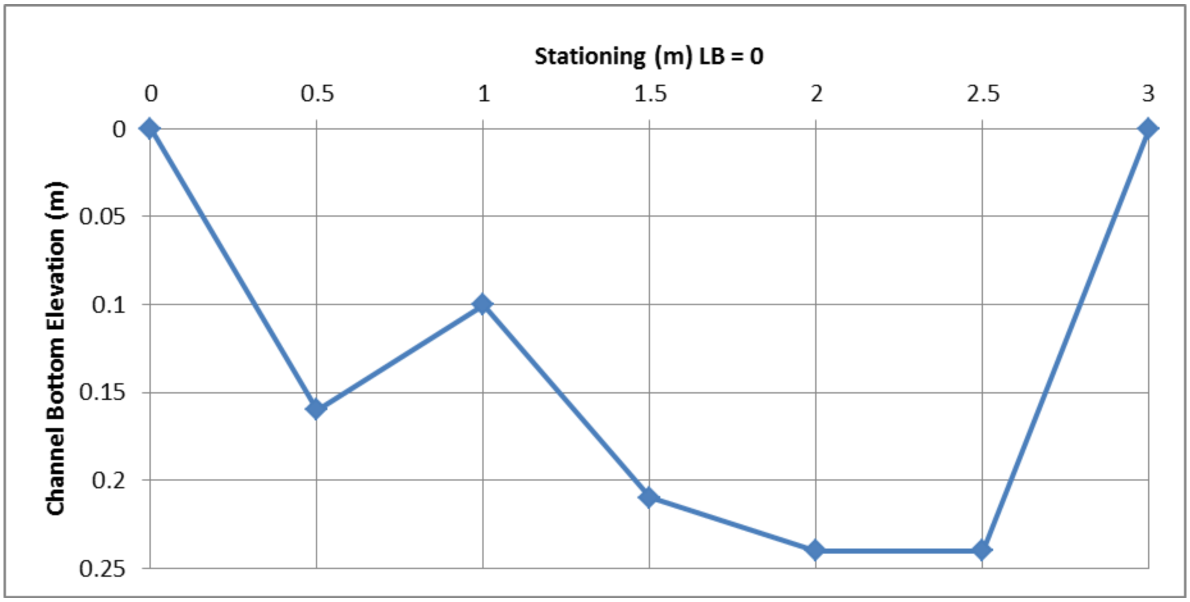
Access

Station *S2* can be accessed from the road to the proposed Rose Pit (following access point A4 and turning right on coordinates (UTM) N 5855966.109 and E 633587.110 and N 5855701.659 and E 633099.105.

Instrumentation

Station *S2* contains a Levelogger (serial #22001599) and a Barologger (serial #11064953). Both instruments are installed in a stilling well for continuous water depth and atmospheric pressure monitoring with a 10 minute interval. Station *S2* is also a water quality sampling location. This station was installed in Oct. 7, 2011. The Levelogger was installed with RV antifreeze on the right bank.

Cross Section



Channel profile starting at left bank looking downstream, units in m.
Flat flood plain about 40 cm higher.

Flow Measurement

A flow measurement was conducted using a Sontek Flowtracker on Oct 7, 2011 at 11:00 am.

Q = 0.0874 m^3/s

Channel Slope and Stream Bottom

Water surface -%

- 5 m upstream of station to 7m downstream of station
- Upstream Thalweg -13cm
- Downstream Thalweg -17 cm

Stream has bottom consisting mainly of cobbles-boulders.

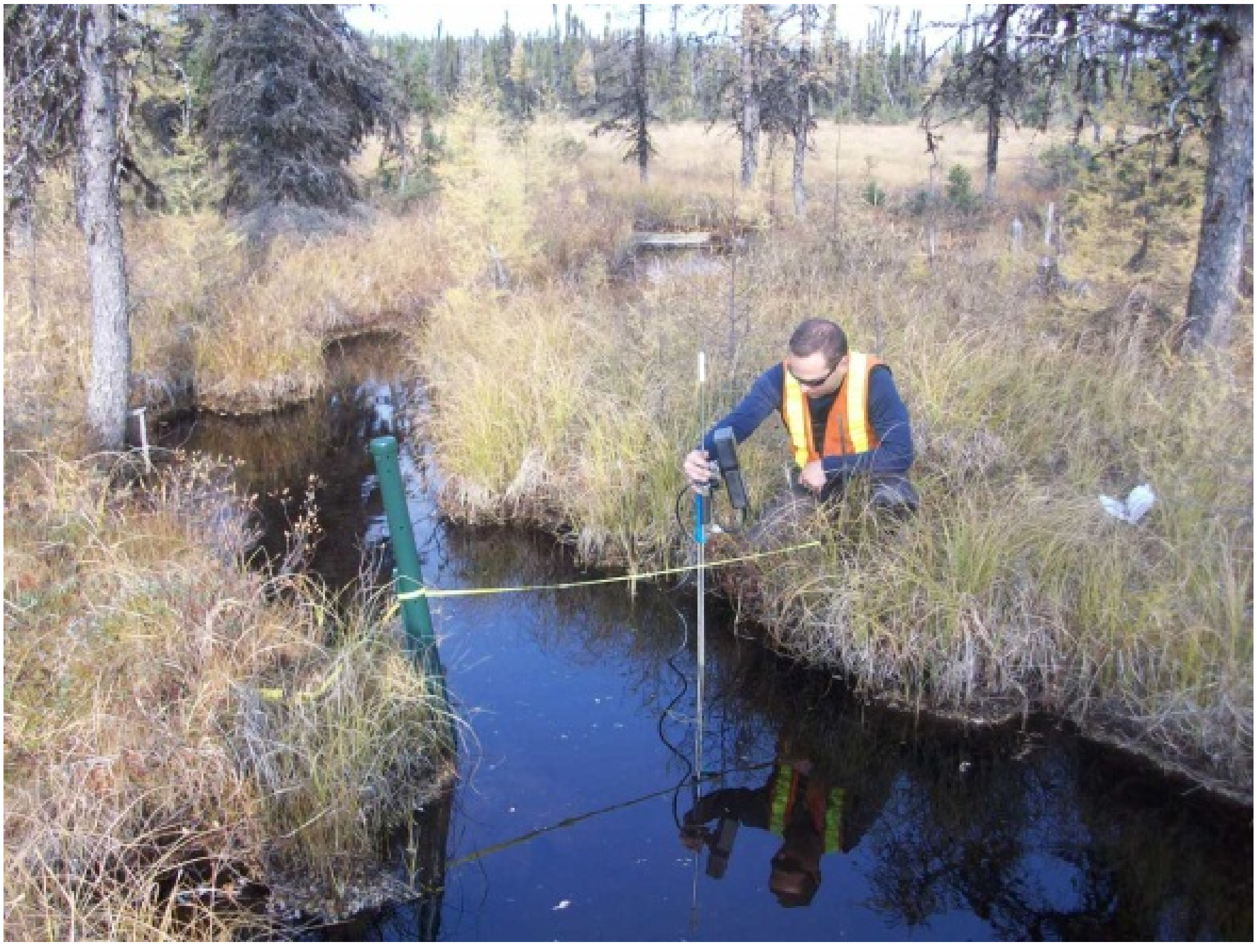
Spot Water Quality Measurements at Station *S2*

Oct 7, 2011 at 1:00 pm

Temp. = 1.85 ∘C
Specific Conductance = 111 µS/cm
Conductivity = 62 µS/cm
TDS = 0.072 g/l
Salinity = 0.05
DO = 103.4%
DO = 14.36 mg/l
pH = 8.90
pHmV = -81.7

STATION *S3*

Date: Oct 08, 2011



*Looking upstream

Location

Station *S3* is located on a small tributary and approximately 150 m upstream of Molar Lake. The coordinates (UTM NAD83) of the station are northing 5851832.982 and easting 632431.028.

Rationale

Station *S3* is located to provide baseline data and monitor the exit of the watershed that contains the Rose South waste rock disposal area.

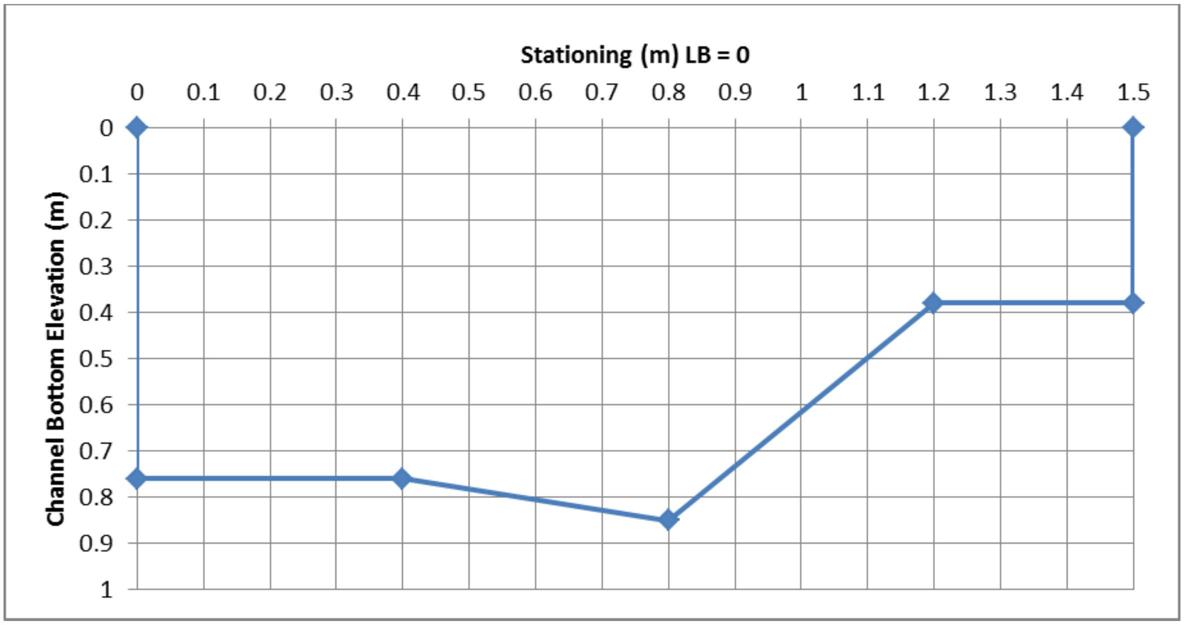
Access

Station *S3* can be accessed only by helicopter. Landing coordinates are northing 5851777.851 and easting 632518.039.

Instrumentation

Station *S3* contains a Levelogger (serial #22001511). The Levelogger is installed in a stilling well for continuous water depth monitoring with a 10 minute interval. Station *S2* is also a water quality sampling location. This station was installed in Oct. 8, 2011. The Levelogger was installed with RV antifreeze on the right bank.

Cross Section



Channel profile starting at left bank looking downstream, units in m.
Flat flood plain about 35 cm higher.

Flow Measurement

A flow measurement was conducted using a Sontek Flowtracker on Oct 8, 2011 at 10:00 am.

Q = 0.0223 m^3/s

Channel Slope and Stream Bottom

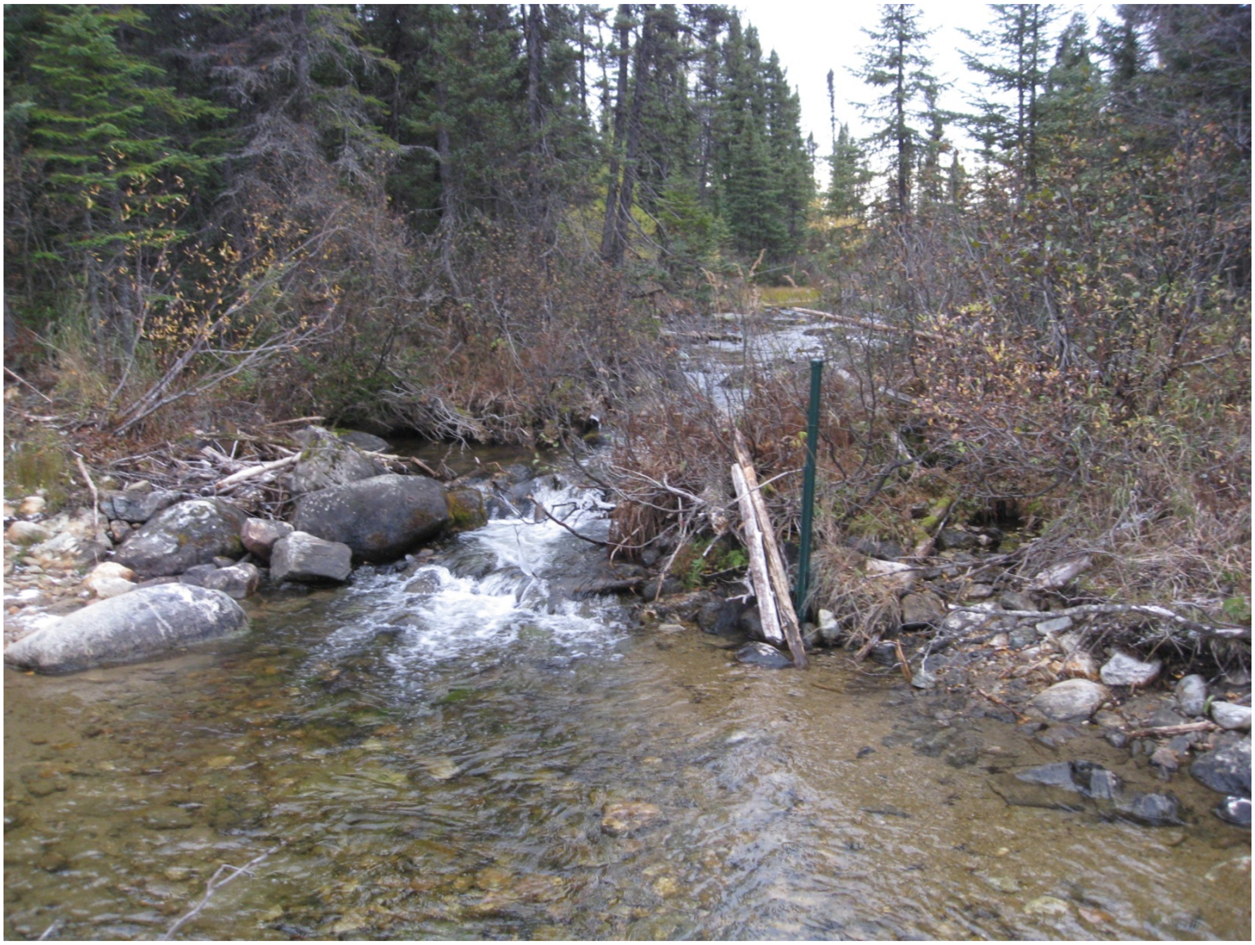
- Very low slope channel, slope was not measured
- Stream is well defined with soft turf/moss on banks
- Bottom at cross section is sandy-cobble (mostly sand)
- Other reaches have boggy/organic bottom

Spot Water Quality Measurements at Station *S3*

Oct. 8, 2011 at 10:00
Temp. = 3.64 ∘C
Specific Conductivity = 56 μS/cm
Electrical Conductivity = 33 μS/cm
TSS = 0.037g/L
Salinity = 0.03
DO = 87.6%
DO = 11.59 mg/L
pH = 9.10 ph
pHmV = -90.0

STATION *S4*

Date: Oct 7, 2011



*Looking upstream

Location

Station *S4* is located in the stream that connects Molar Lake to Mills Lake adjacent to the access road bridge (upstream side). The coordinates (UTM NAD83) of the station are northing 5853070.825 and easting 634296.231.

Rationale

Station *S4* was setup to provide baseline flow data and to monitor the outflow of Molar Lake which is just downstream of the Rose South waste rock disposal area and discharges into Mills Lake.

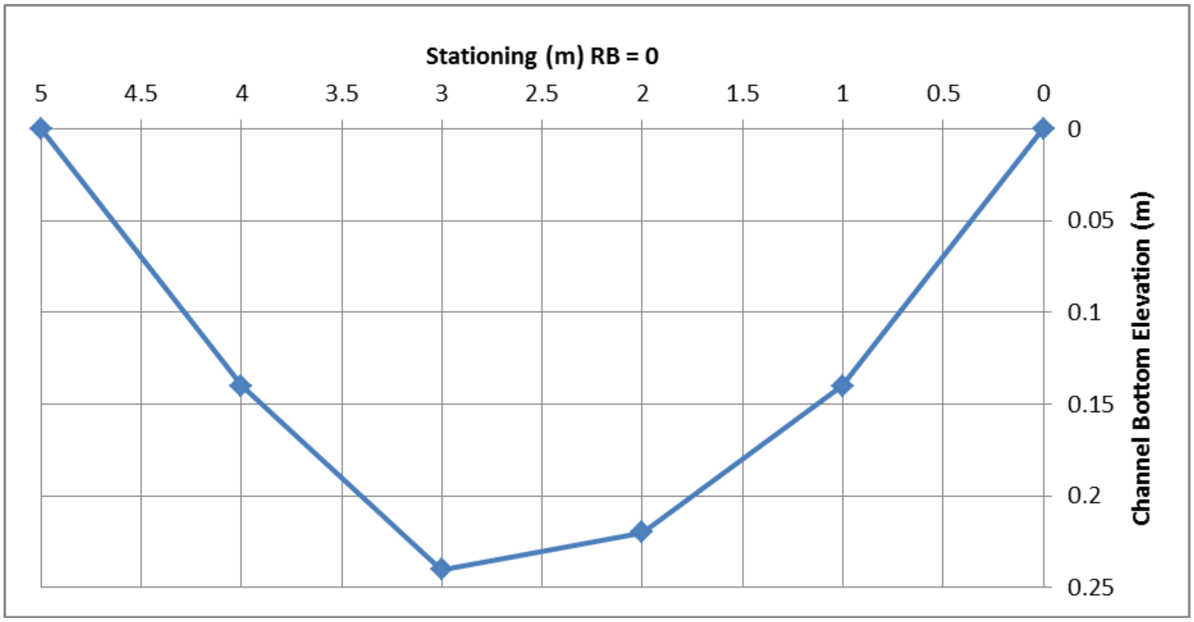
Access

Station *S4* can be accessed by all terrain vehicle, snowmobile or by helicopter depending on road and snow conditions. The station is located approximately 1 km after access point A6 (keep left at this access point).

Instrumentation

Station *S4* contains a Levelogger (serial #22001617). The Levelogger is installed in a stilling well for continuous water depth monitoring with a 10 minute interval. Station S2 is also a water quality sampling location. This station was installed in Oct. 7, 2011. The Levelogger was installed with RV antifreeze on the left bank.

Cross Section



Channel profile starting @ right bank looking downstream, units in m.
Flat flood plain about 90 cm higher.

Flow Measurement

A flow measurement was conducted using a Sontek Flowtracker on Oct 8, 2011 at 4:30 pm.

Q = 0.103 m^3/s

Channel Slope and Stream Bottom

Channel meandering obstructed the measurement of slope. Channel bottom is mainly gravel-cobbles-boulders

Spot Water Quality Measurements at Station *S4*

Oct. 7, 2011 at 4:30 pm

Temp. = 7.0 ◦C
Specific Conductance = 57 μS/cm
Electrical Conductivity = 38 μS/cm
TDS = 0.037 g/L
Salinity = 0.03
DO = 100.5%
DO = 12.18 mg/L
pH = 8.94
pHmV = -83.2

STATION *S5*

Date: Oct 8, 2011

*Looking downstream

Location

Station *S5* is located in a tributary that feeds to the southern end of Long Lake (upstream side of lake). The coordinates (UTM NAD83) of the station are northing 5856368.709 and easting 637517.073.

Rationale

Station *S5* is located downstream of the proposed tailings impoundment and other mine infrastructure to collect baseline flow data and monitoring data during different project phases.

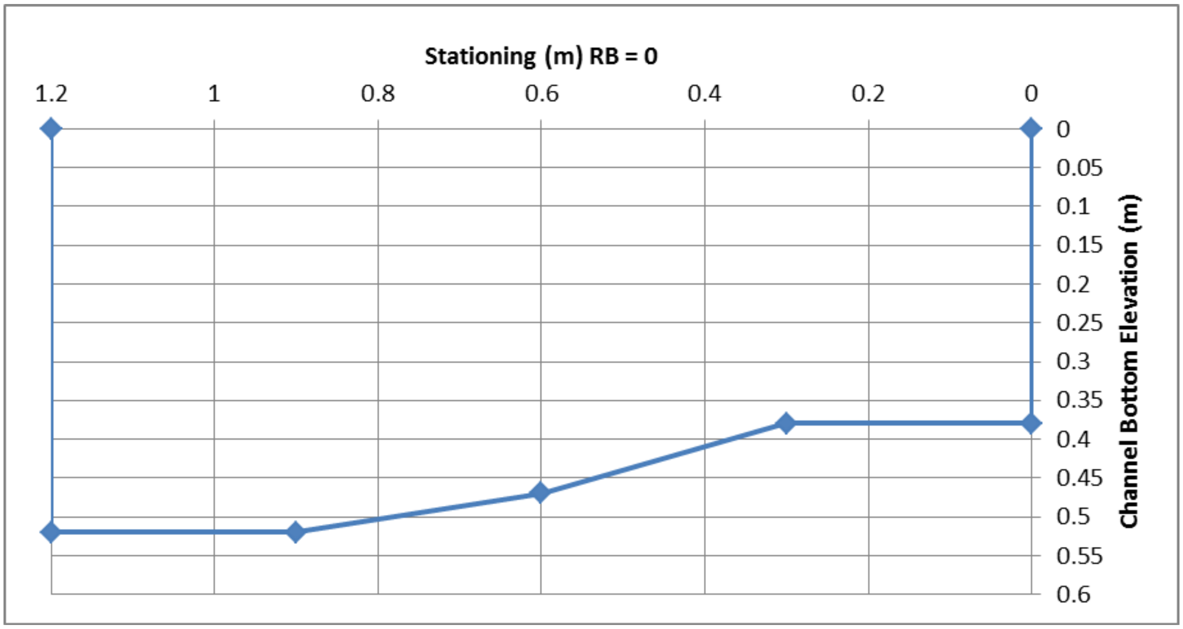
Access

Station *S5* can be accessed by helicopter or by boat from Long Lake. The landing coordinates are 5856445.012 and easting 637473.843.

Instrumentation

Station *S5* contains a Levelogger (serial #21063654) and a Barologger (serial #11064951). Both instruments are installed in a stilling well for continuous water depth and atmospheric pressure monitoring with a 10 minute interval. Station *S5* is also a water quality sampling location. This station was installed in Oct. 8, 2011. The Levelogger was installed with RV antifreeze on the left bank.

Cross Section



Channel profile starting @ left bank looking downstream, units in m.
Flat floodplain about 30 cm higher.

Flow Measurement

A flow measurement was conducted using a Sontek Flowtracker on Oct 8, 2011 at 1:50 pm.

Q = 0.0047 m^3/s

Channel Slope and Stream Bottom

Channel slope was not measured. Meandering channel with bottom comprised of sand and boulders with lots of woody debris.

Spot Water Quality Measurements at Station *S5*

Oct. 8, 2011 at 2:25 pm
Temp. = 4.72 ∘C
Specific Conductance = 156 µS/cm
Electric Conductivity = 95 µS/cm
TDS = 0.101 g/L
Salinity = 0.07
DO = 87.8%
DO = 11.29 mg/L
Ph = 9.07
pHmV = -88.8

STATION *L1*

Date: Oct 7, 2011

Location

Station *L1* is located near landing for snowmobiles next to two cottages on the Mills Lake shore. The coordinates (UTM NAD83) of the station are northing 5853238.290 and easting 634702.660.

Rationale

Station *L1* was setup to monitor the level at Mills Lake which is the receiving waterbody for some project components.

Access

Station *L1* can be accessed by all terrain vehicle approximately 1 km south of access point A6 taking a left turn before continuing to Station *S4*.

Instrumentation

Station *L1* contains a Levelogger installed in a stilling well for continuous water depth monitoring with a 10 minute interval. Station *L1* is also a water quality sampling location. This station was installed in Oct. 7, 2011. The Levelogger was installed with RV antifreeze on the lake.

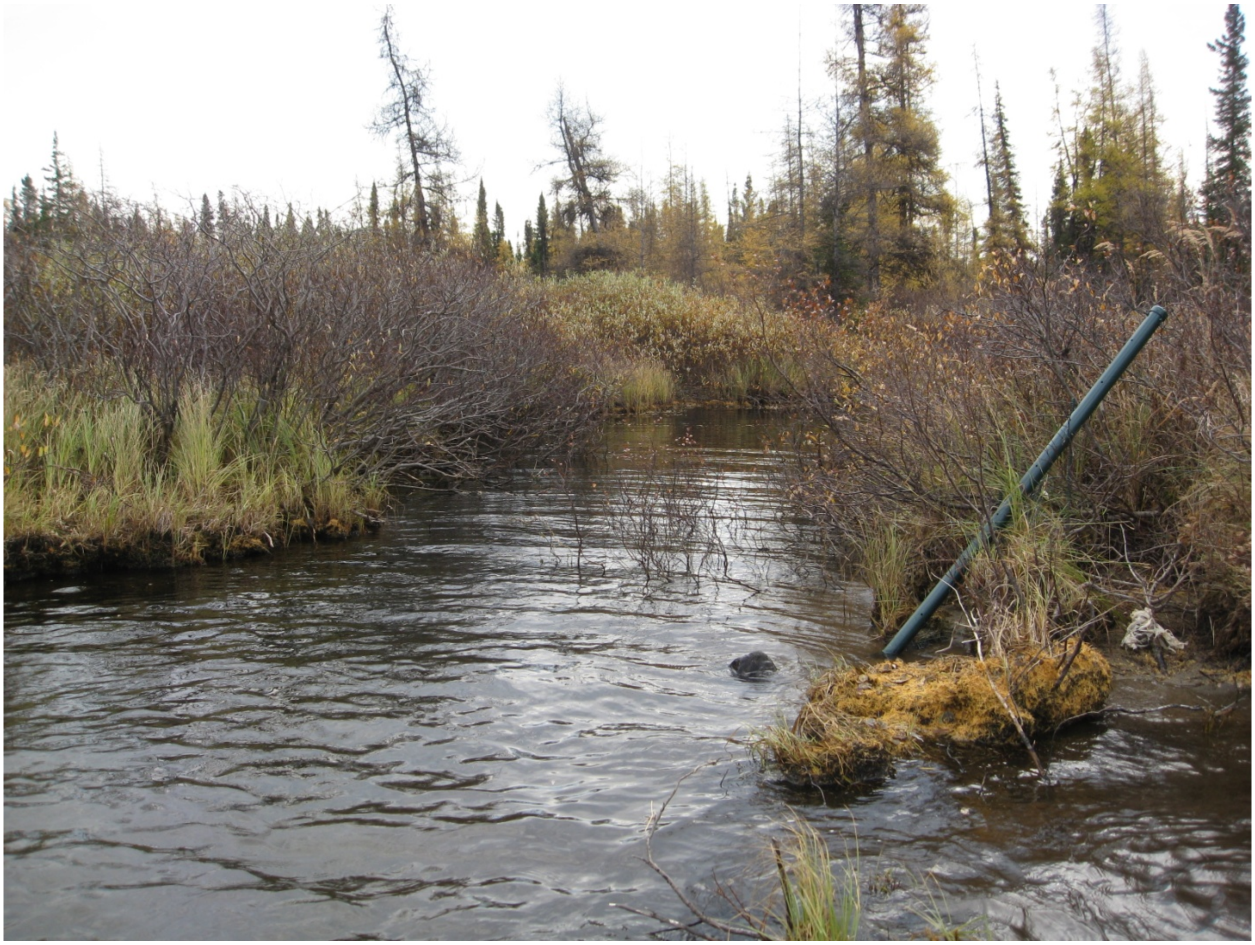
Spot Water Quality Measurements at Station *L1*

Oct. 7, 2011 at 5:45 pm
Temp. = 6.73 deg. ◦C
Specific Conductance = 66 µS/cm
Electrical Conductivity = 43 µS/cm
TDS = 0.043 g/L
Salinity = 0.03
DO = 101.1 %
DO = 12.35 mg/L
pH = 9.13
pHmV = -93.0

Estimated Water level at Levelogger at 6:25 pm = 60 cm

STATION *L2*

Date: Oct 8, 2011



Location

Station *L2* is located at the southern end of Long Lake at the mouth of a stream that feeds Long Lake (where station *S5* is installed). The coordinates (UTM NAD83) of the station are northing 5856468.955 and easting 637498.601.

Rationale

Station *L2* measures water levels at Long Lake which is the largest waterbody within the project area and also receives runoff from a large portion of the project. Because of its size, Long Lake can also be considered as the receiving body for the project effluent.

Access

Station *L2* can be accessed by helicopter or by boat on Long Lake. Landing coordinates (UTM) are northing 5856445.012 and easting 637473.843.

Instrumentation

Station *L2* contains a Levelogger installed in a stilling well for continuous water depth monitoring with a 10 minute interval. Station *L2* is also a water quality sampling location. This station was installed in Oct. 8, 2011. The Levelogger was installed with RV antifreeze on the lake.

Spot Water Quality Measurements at Station *L2*

Oct. 8, 2011 at 1:20 pm
Temperature = 5.0 ◦C
Specific Conductance = 157 µS/cm
Electric Conductivity = 97µS/cm
TDS = 0.102 g/L
Salinity = 0.07
DO = 93.2%
DO = 11.91 mg/L
pH = 9.06
pHmv = -88.4

Shallow embayment of long lake at south end with very shallow sandy bottom
Estimated Water level at Levelogger at 1:20 pm = 80 cm
Distance from water surface to 1st rebar= 0.6m

Access Point Coordinates (UTM NAD83)

ID	Easting	Northing
A1	627361.6758	5857387.03
A2	632169.6043	5863385.92
A3	633933.9818	5862172.91
A4	634132.4742	5859217.58
A5	634044.2554	5855005.13
A6	633889.8723	5853836.23

Appendix G

Hydrological Monitoring Results

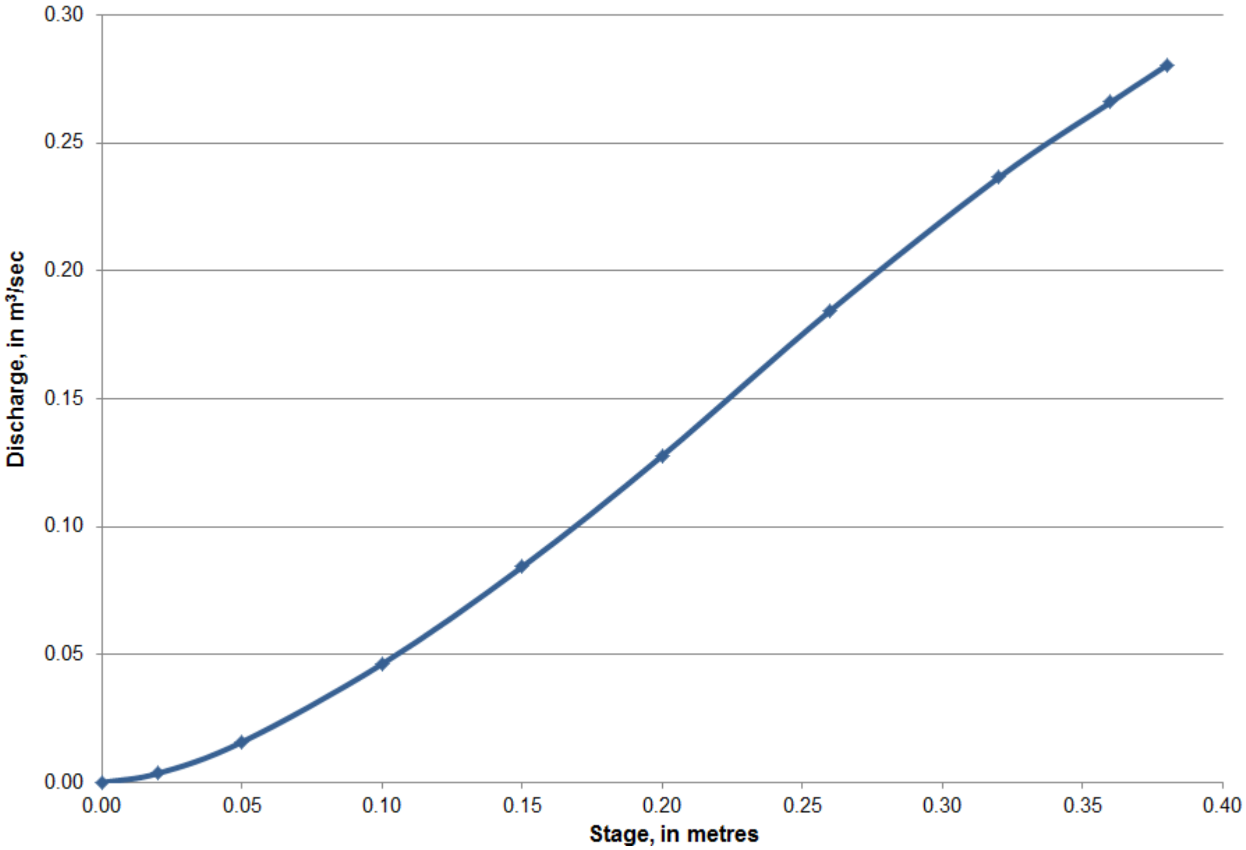


Figure G.1 Rating Curve of Stream Gauging Station *S1*.

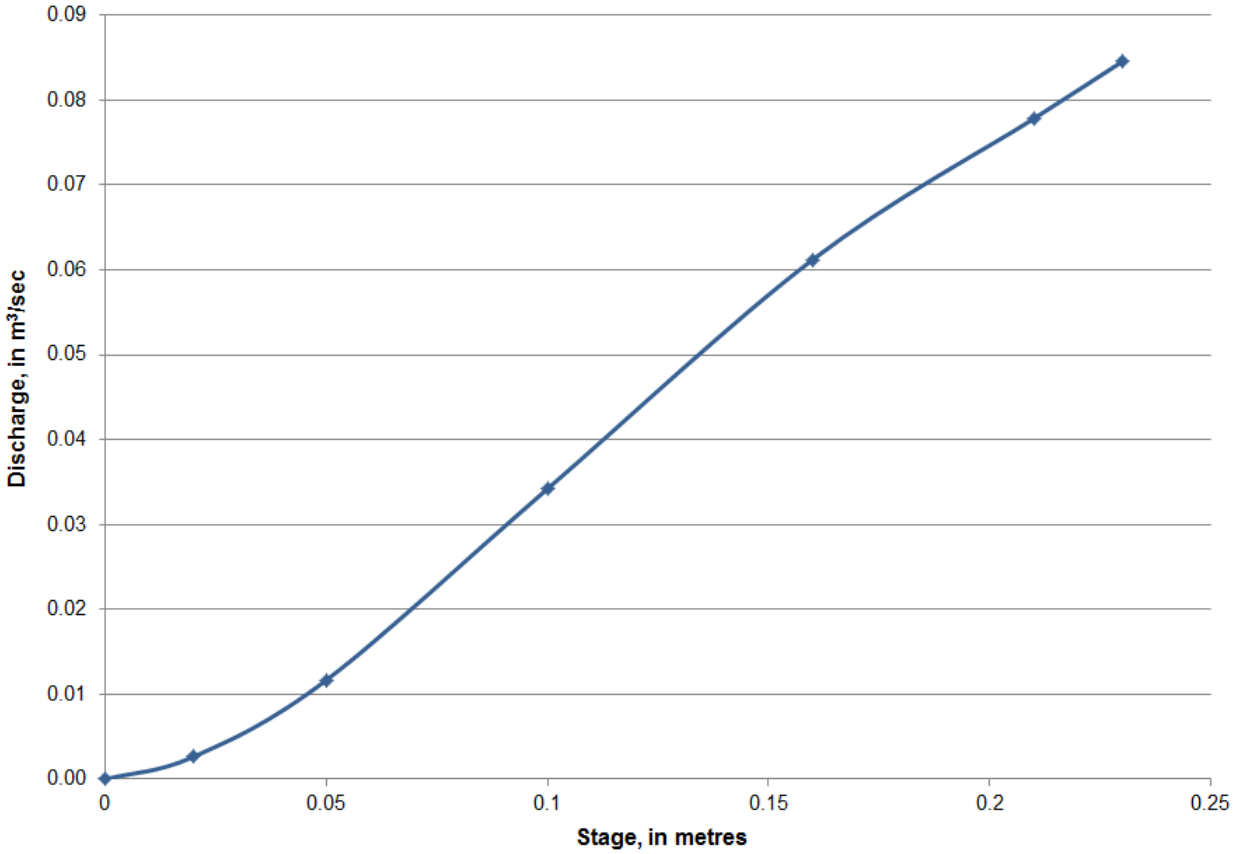


Figure G.2 Rating Curve of Stream Gauging Station *S2*.

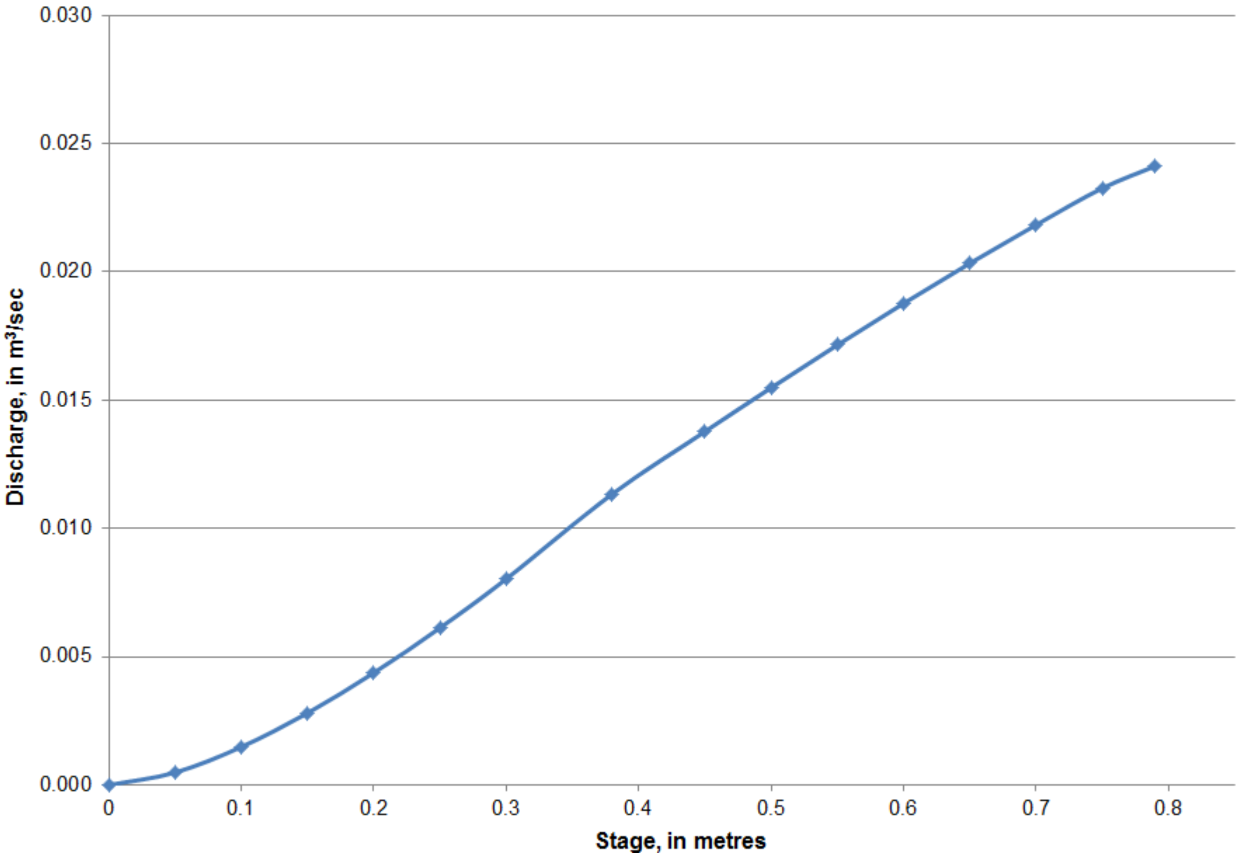


Figure G.3 Rating Curve of Stream Gauging Station *S3*.

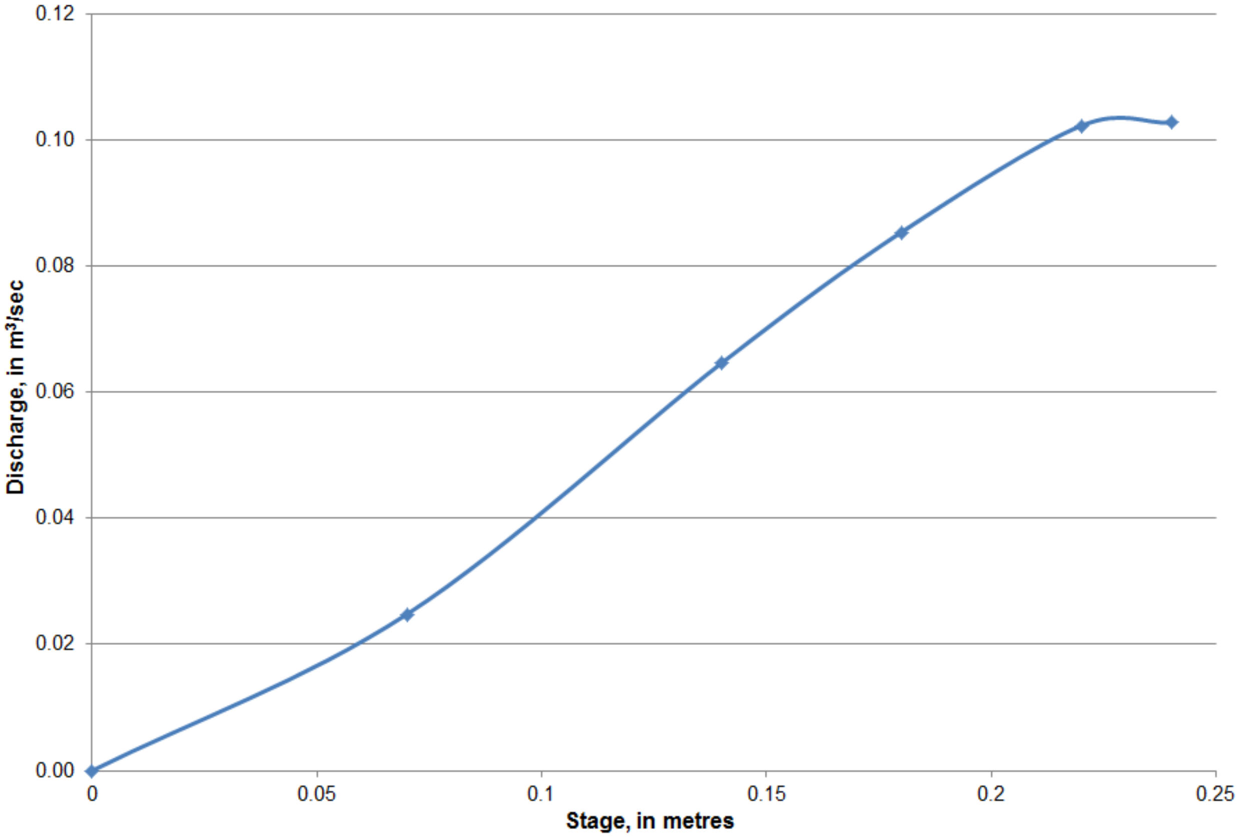


Figure G.4 Rating Curve of Stream Gauging Station *S4*.

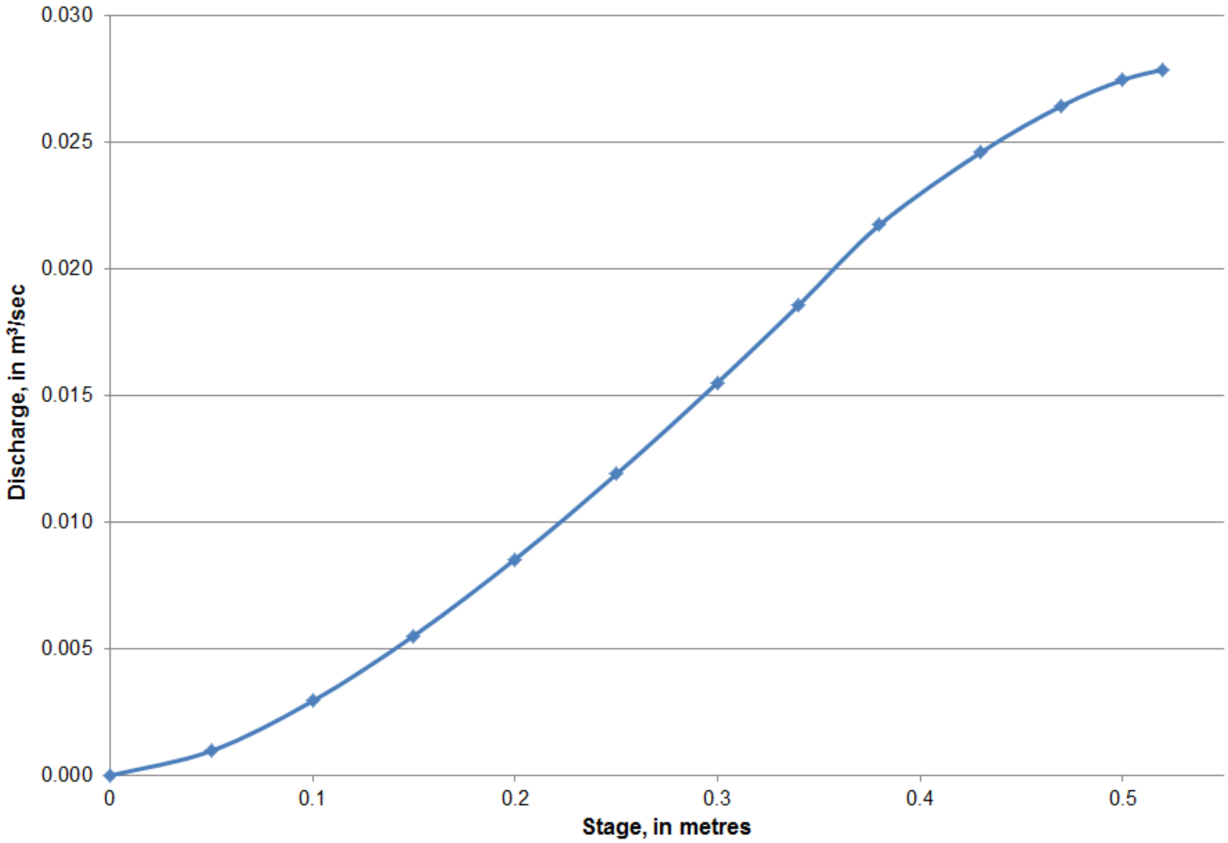


Figure G.5 Rating Curve of Stream Gauging Station *S5*.

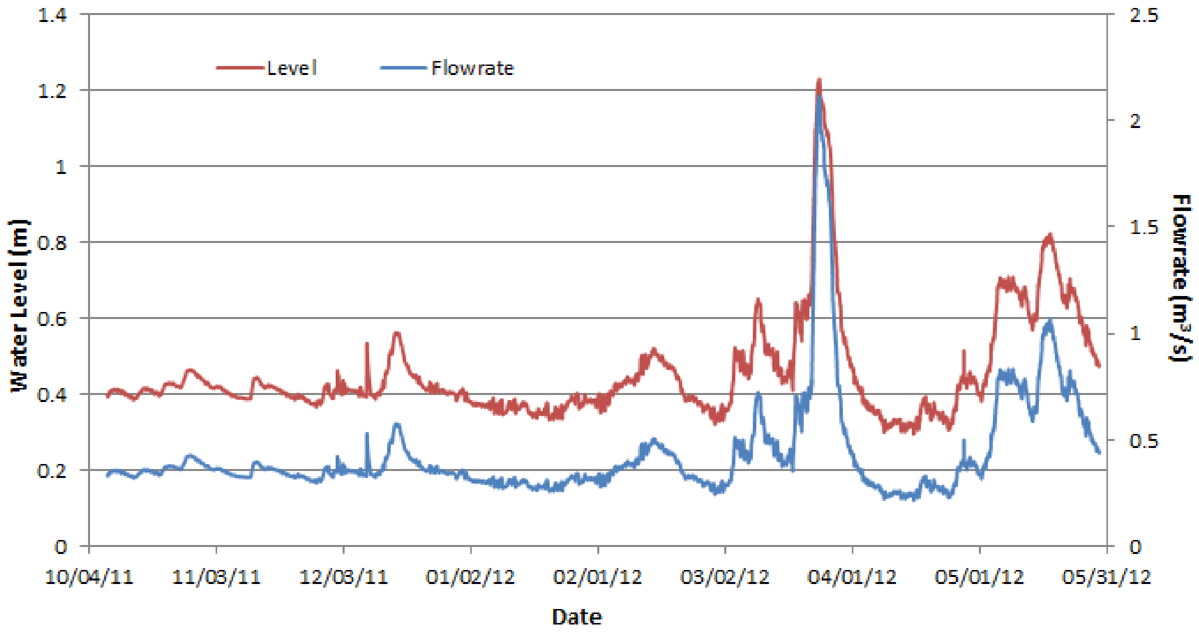


Figure G.6 Water Level and Streamflow at Station S1

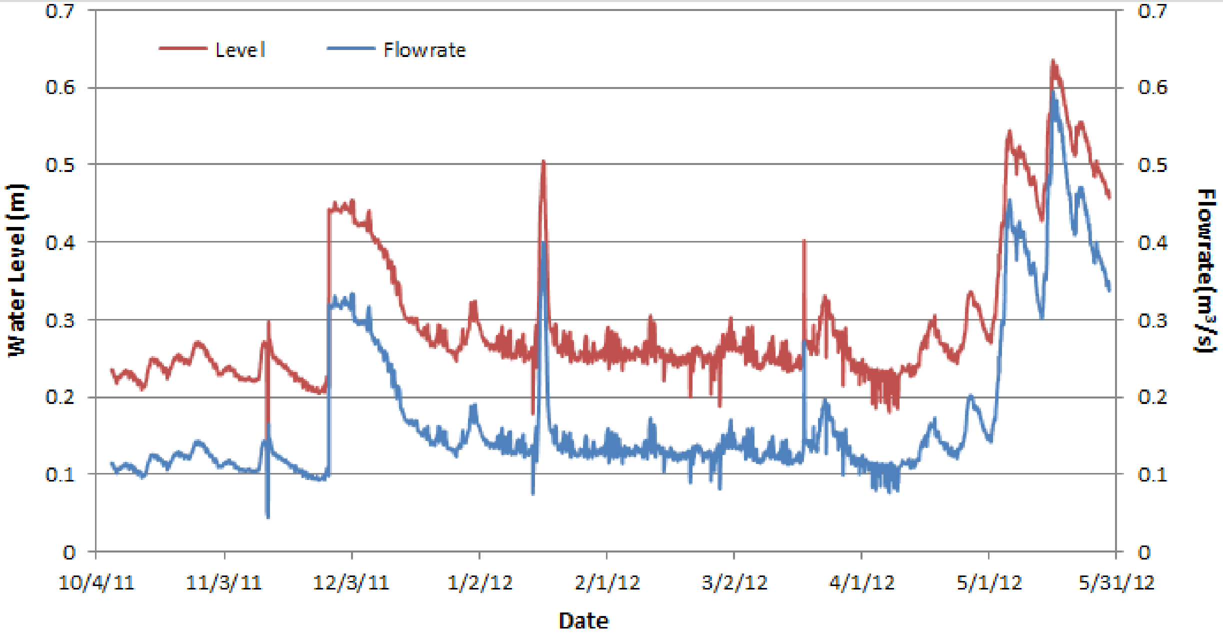


Figure G.7 Water Level and Streamflow at Station S2

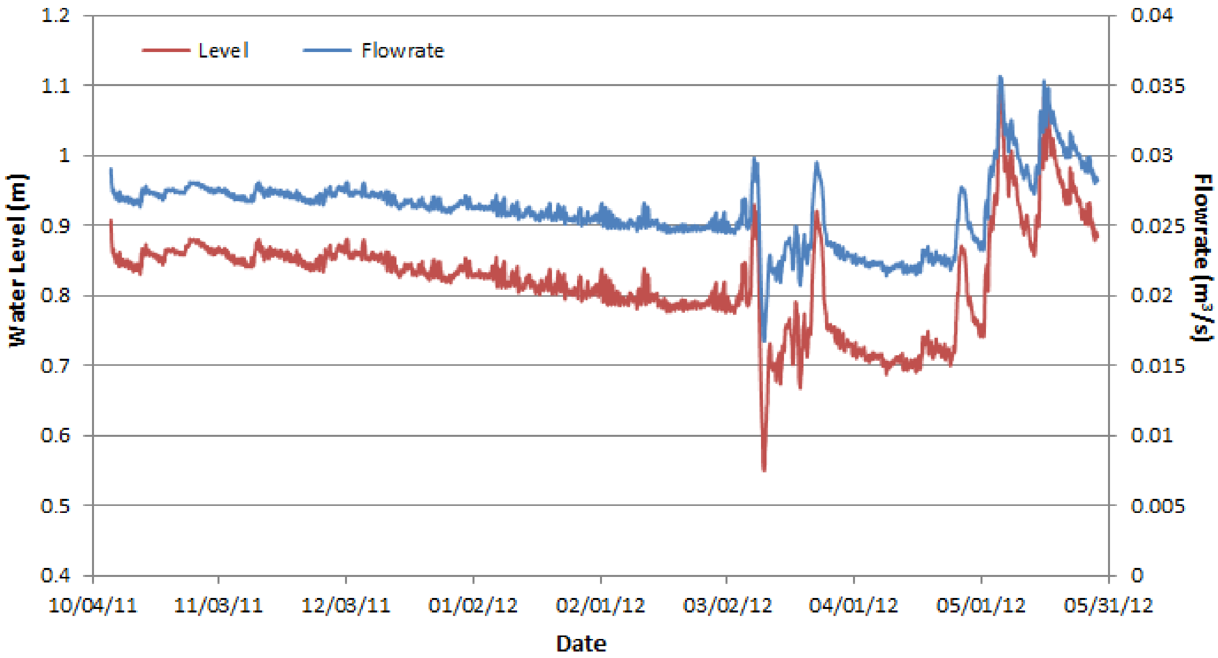


Figure G.8 Water Level and Streamflow at Station S3

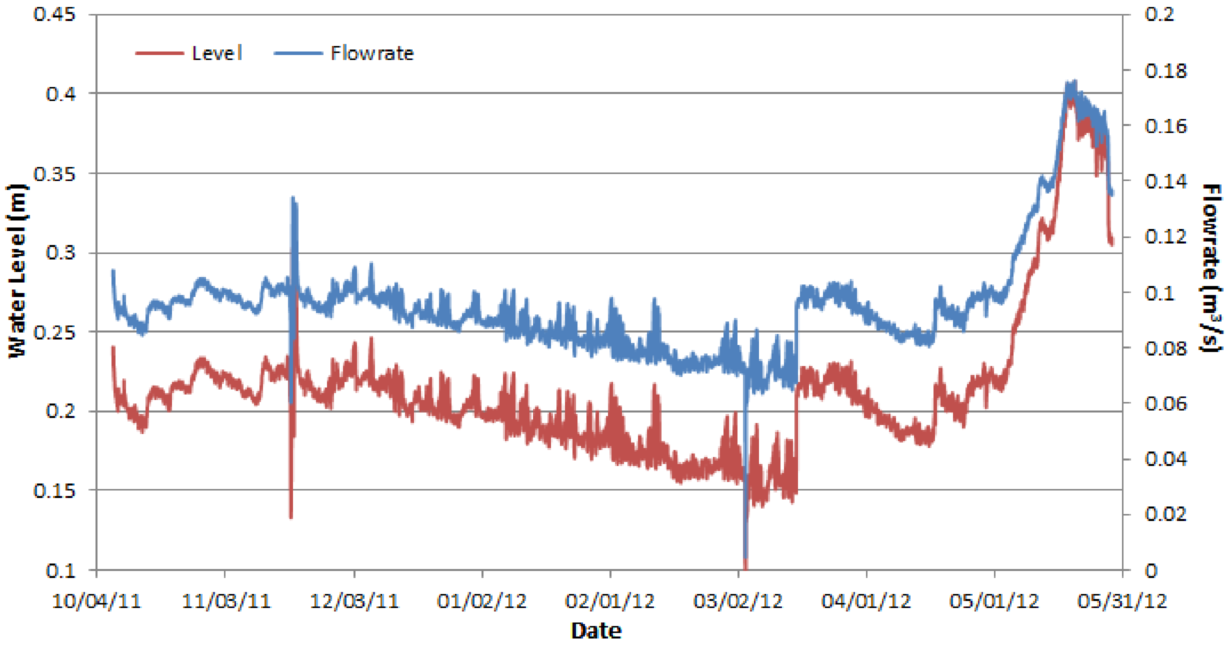


Figure G.9 Water Level and Streamflow at Station S4

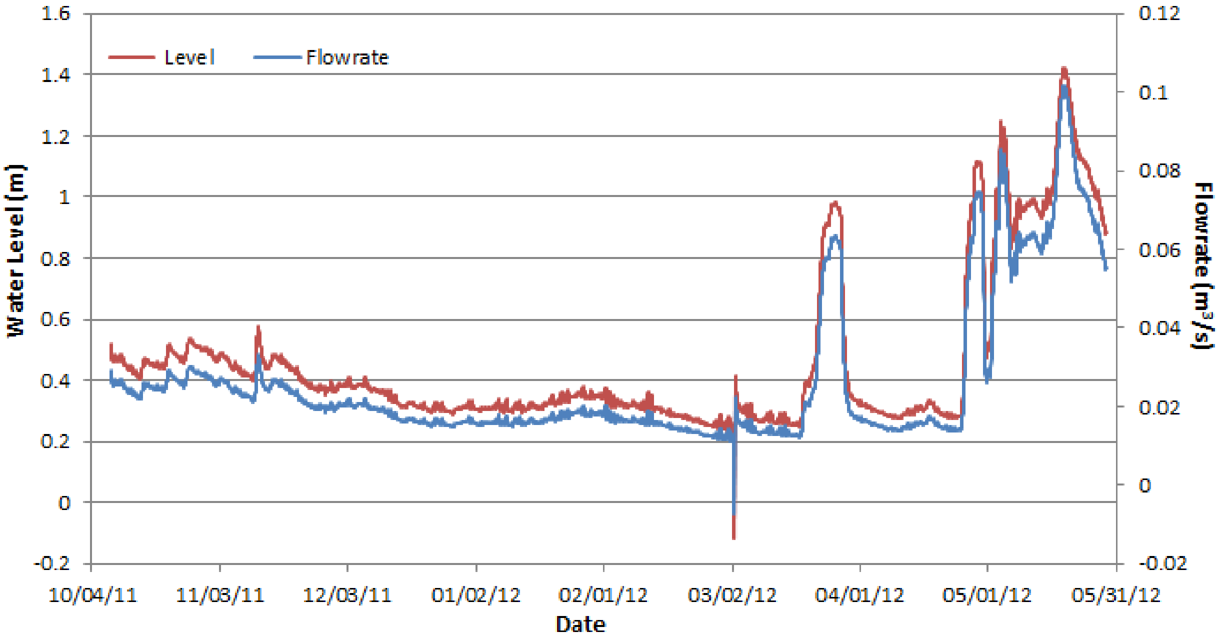


Figure G.10 Water Level and Streamflow at Station S5

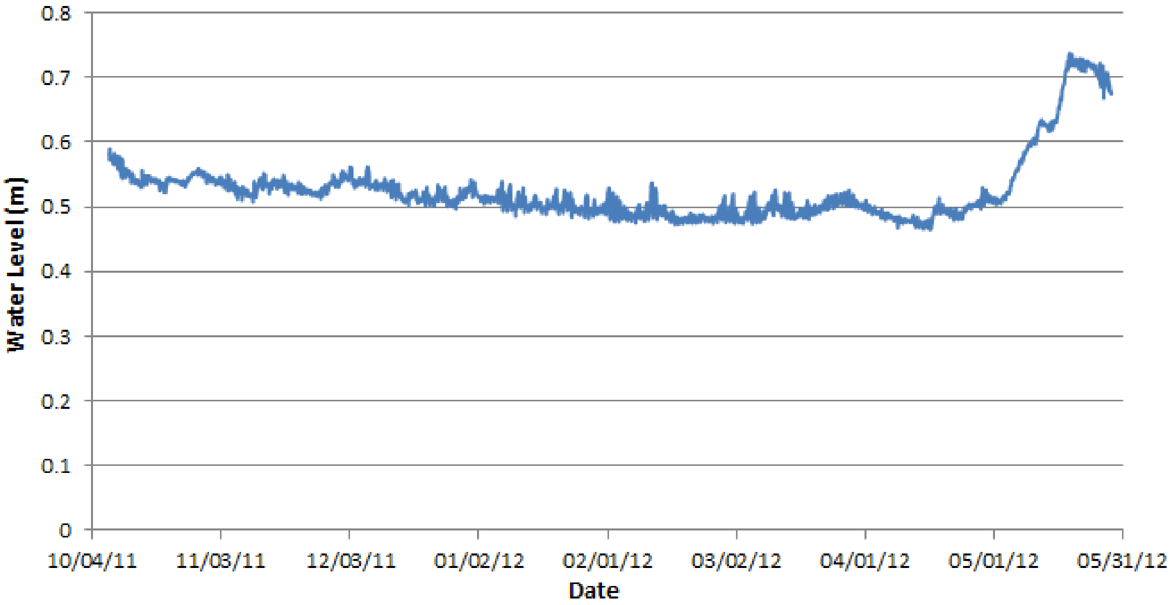


Figure G.11 Water Level at Station L1

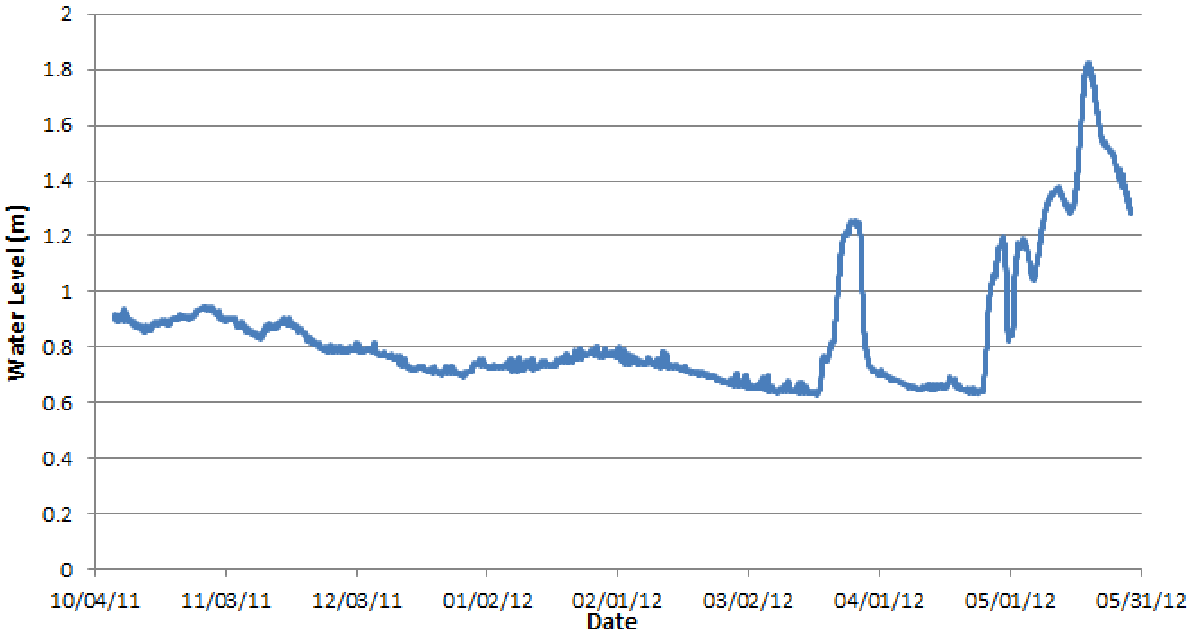


Figure G.12 Water Level at Station L2

Appendix H

Flow Hydrographs

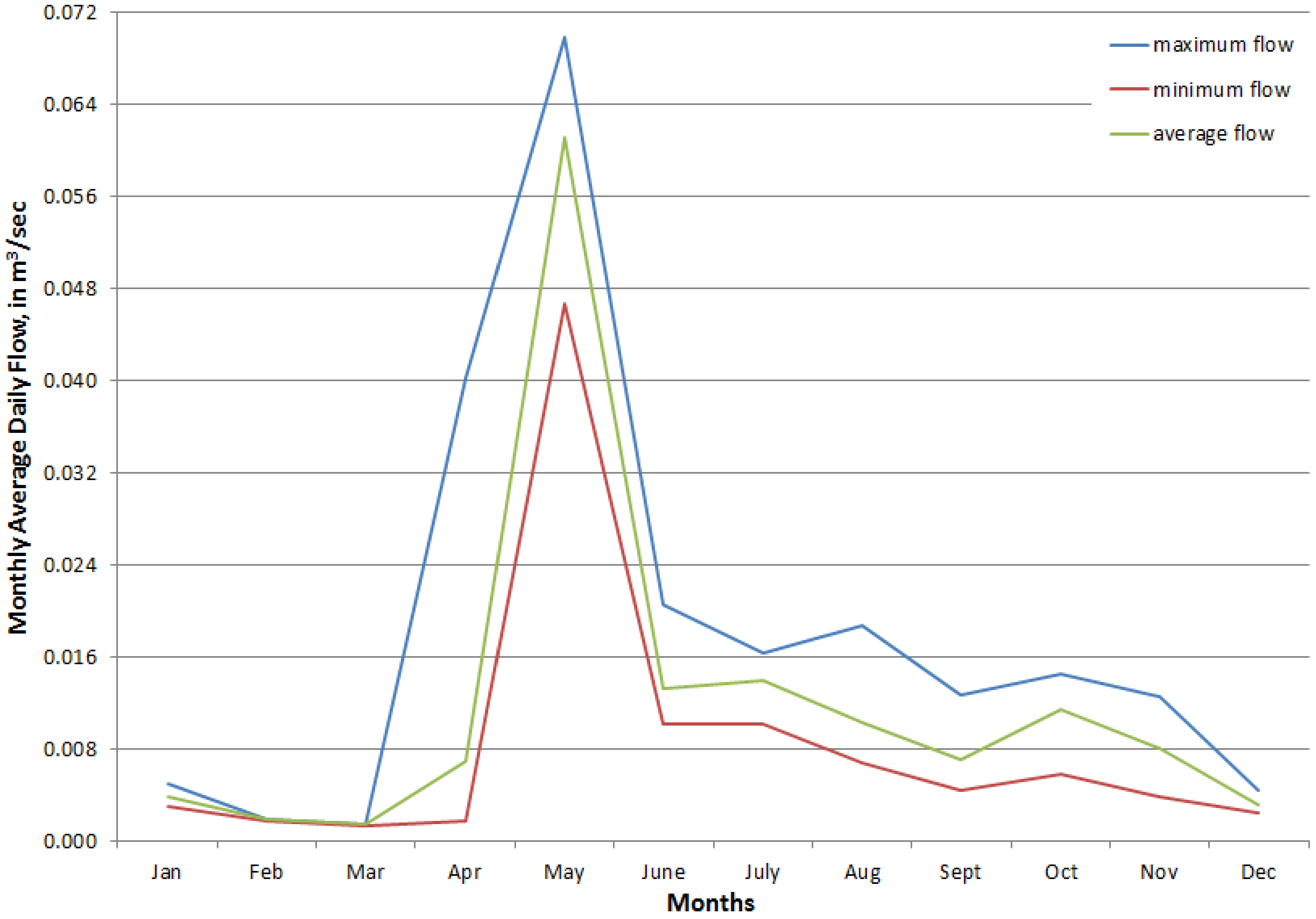


Figure H.1 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #1

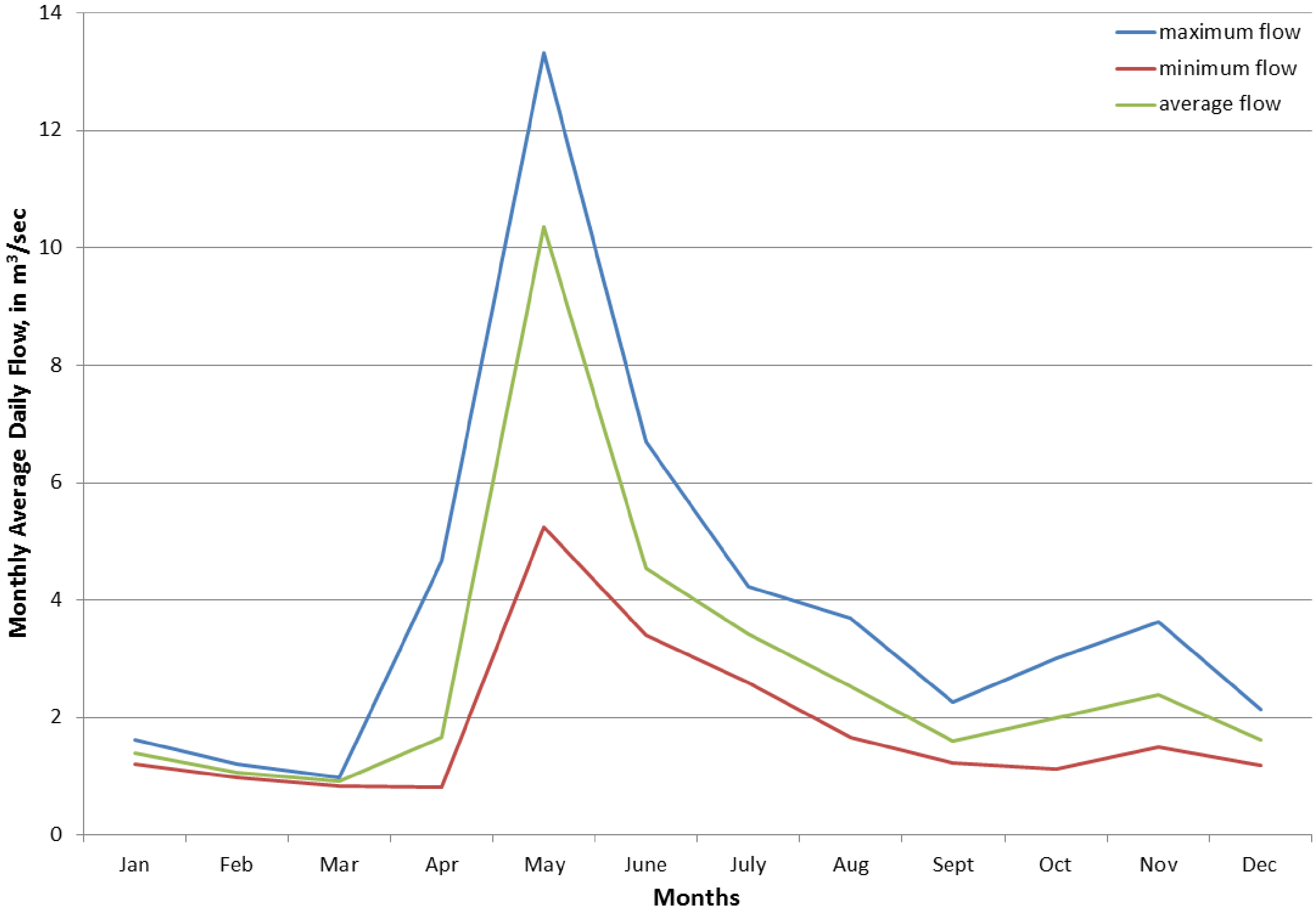


Figure H.2 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #2

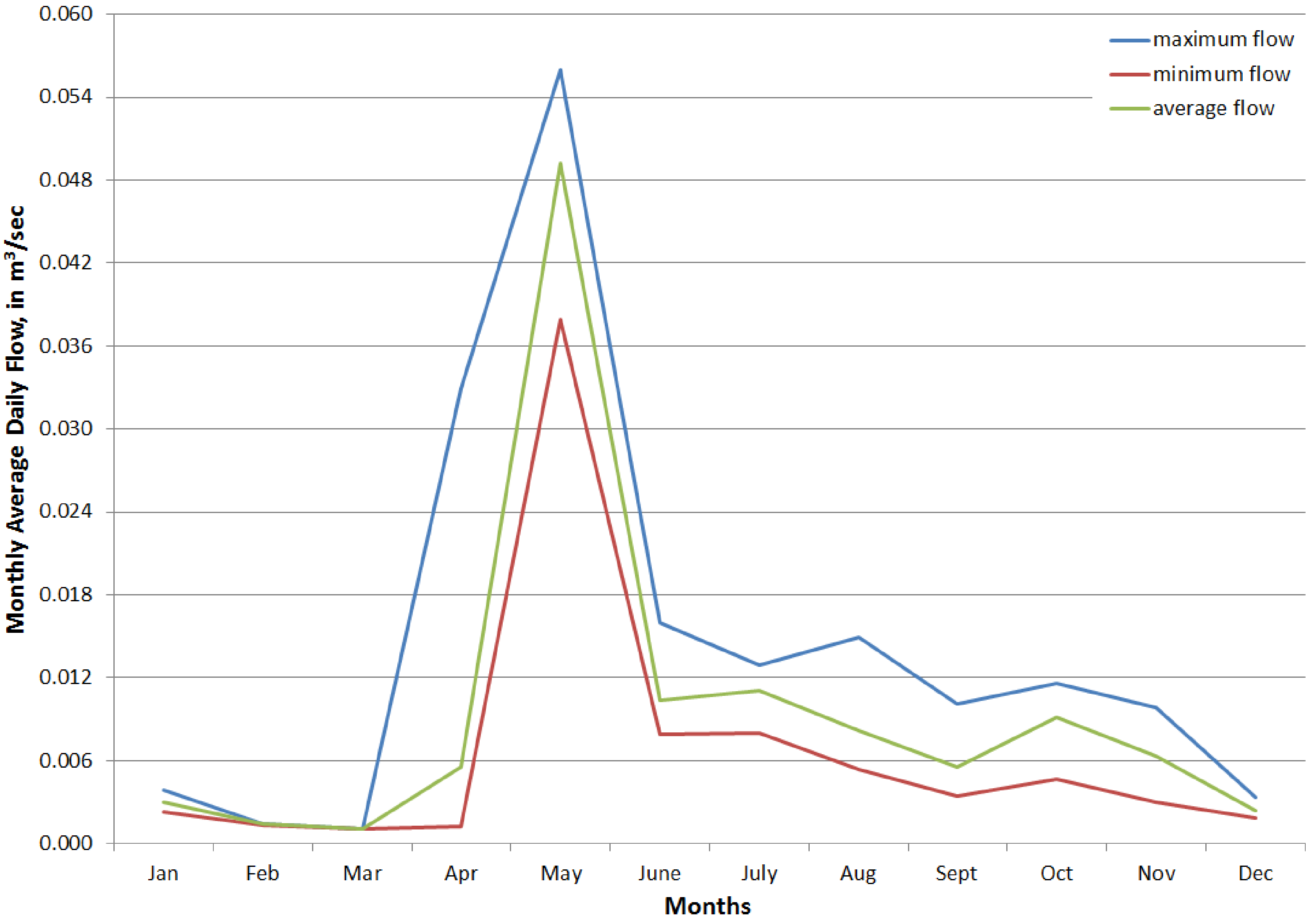


Figure H.3 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #3

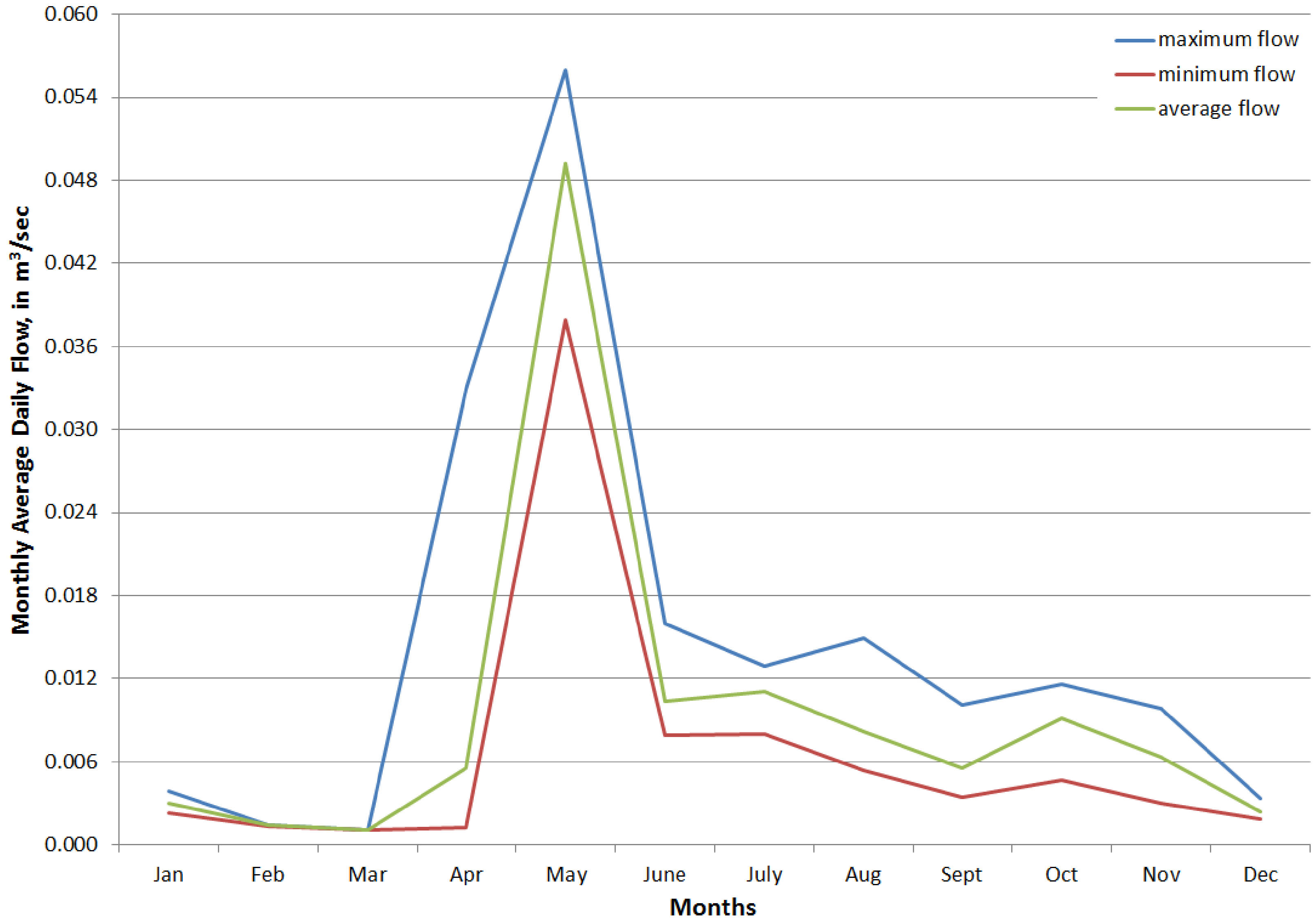


Figure H.4 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #3A

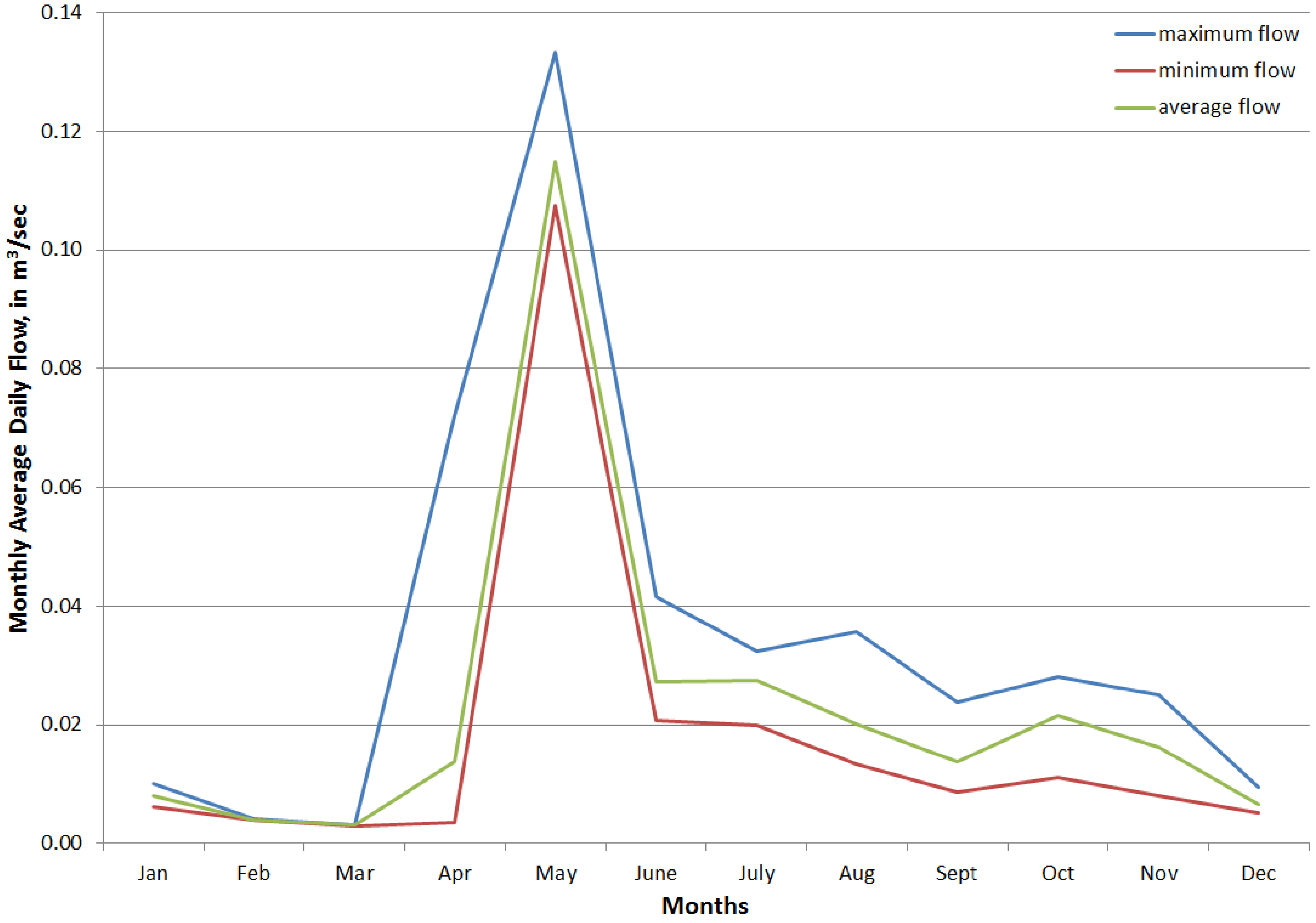


Figure H.5 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #4

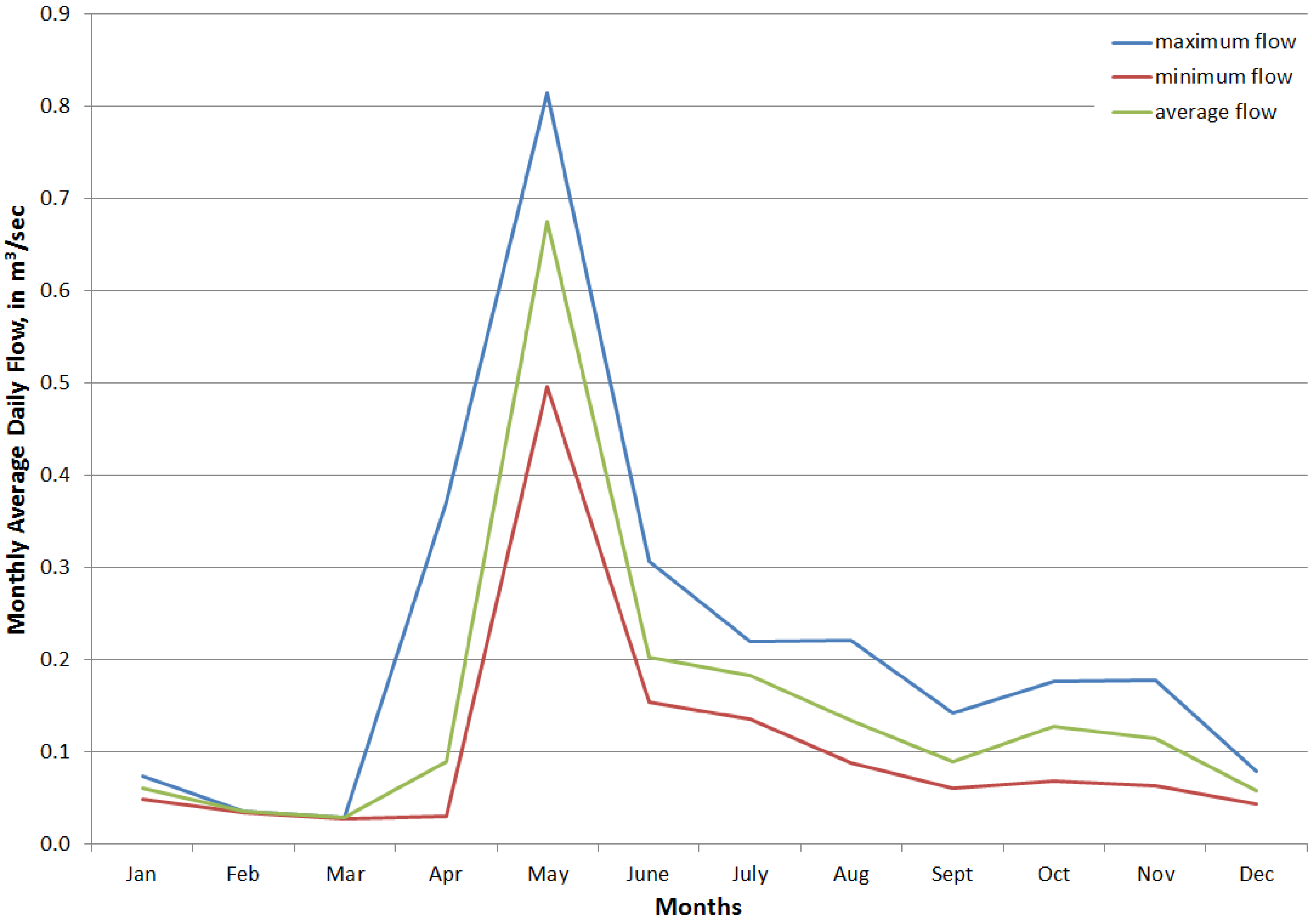


Figure H.6 **Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #5**

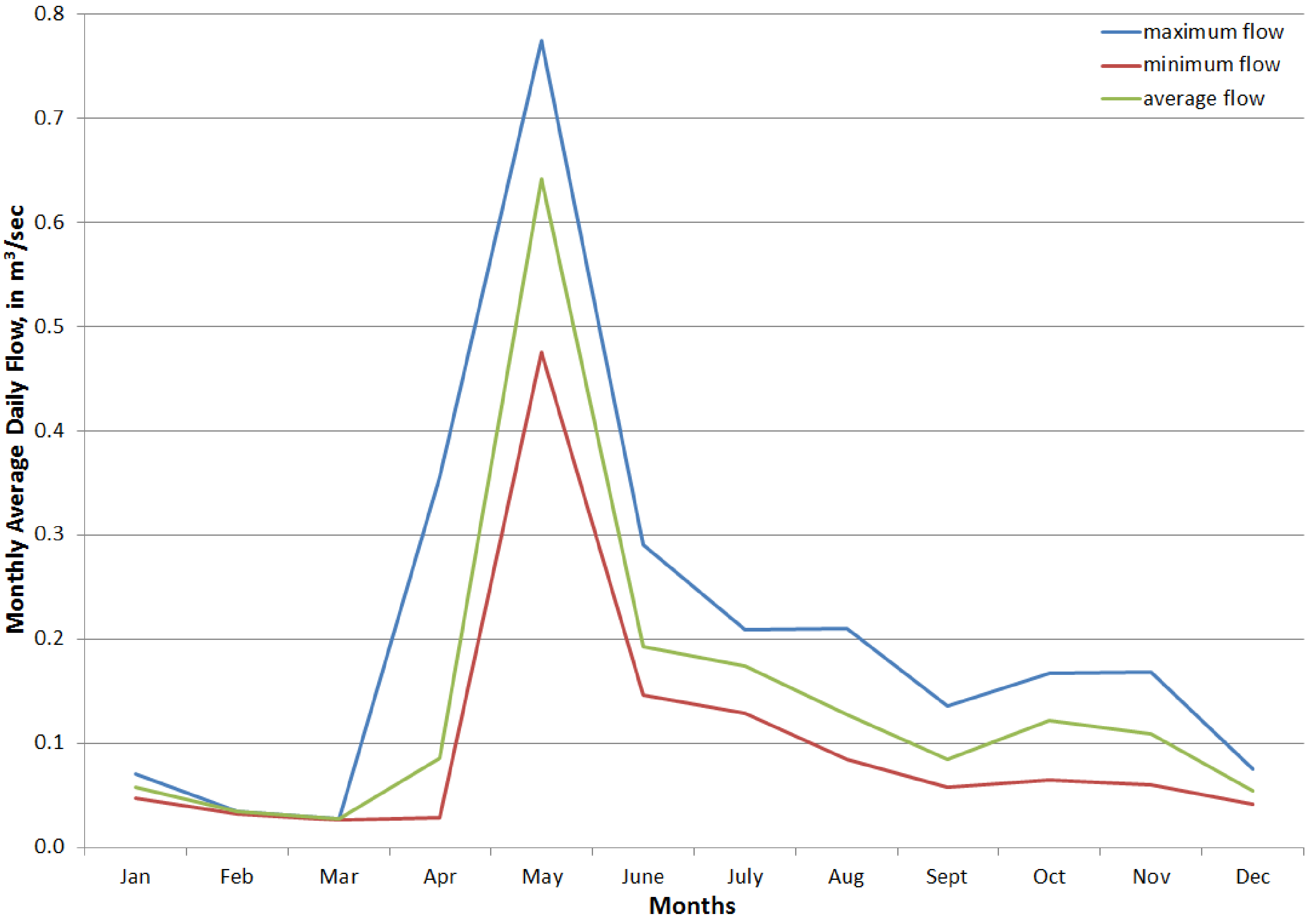


Figure H.7 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #6

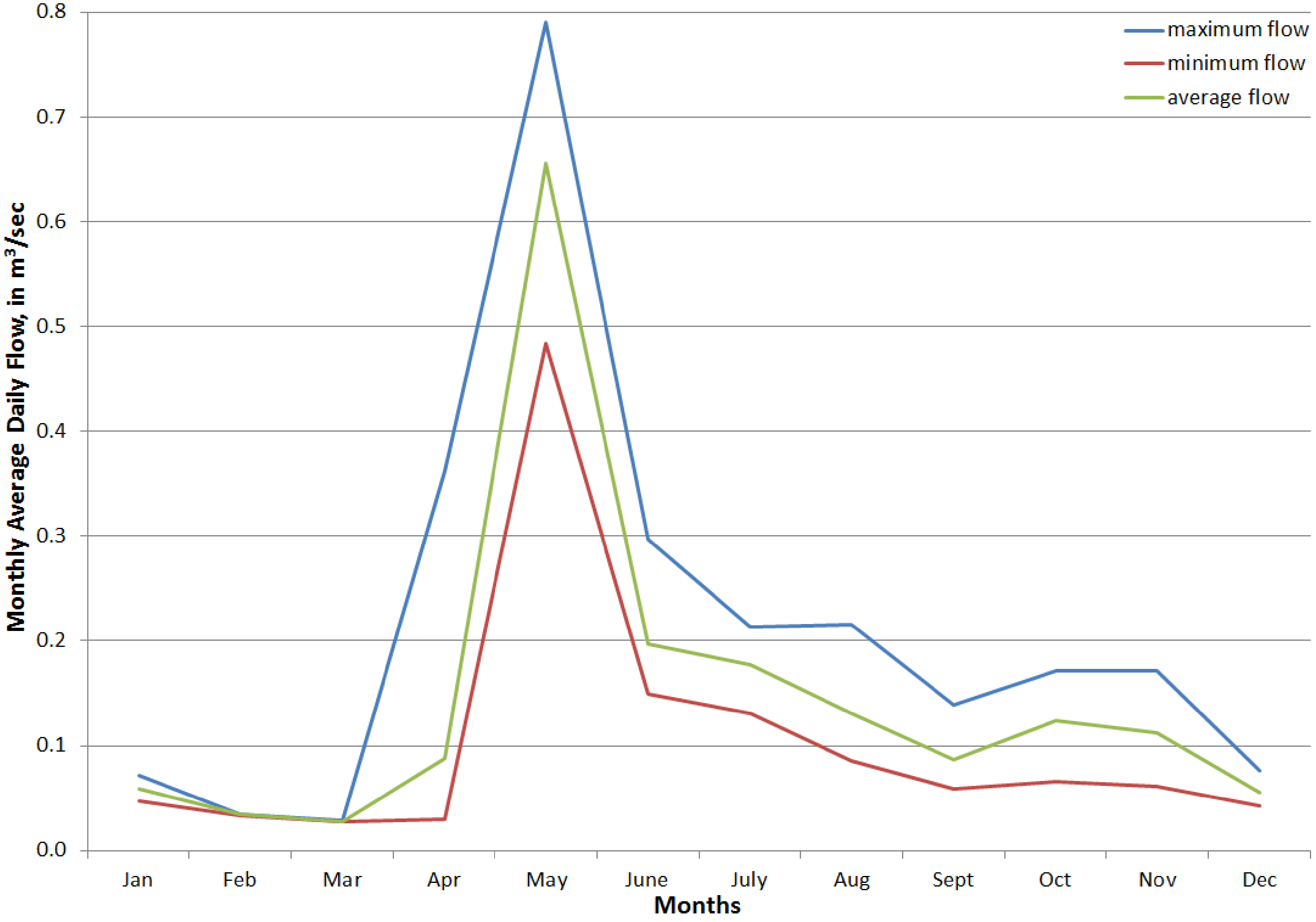


Figure H.8 **Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #7**

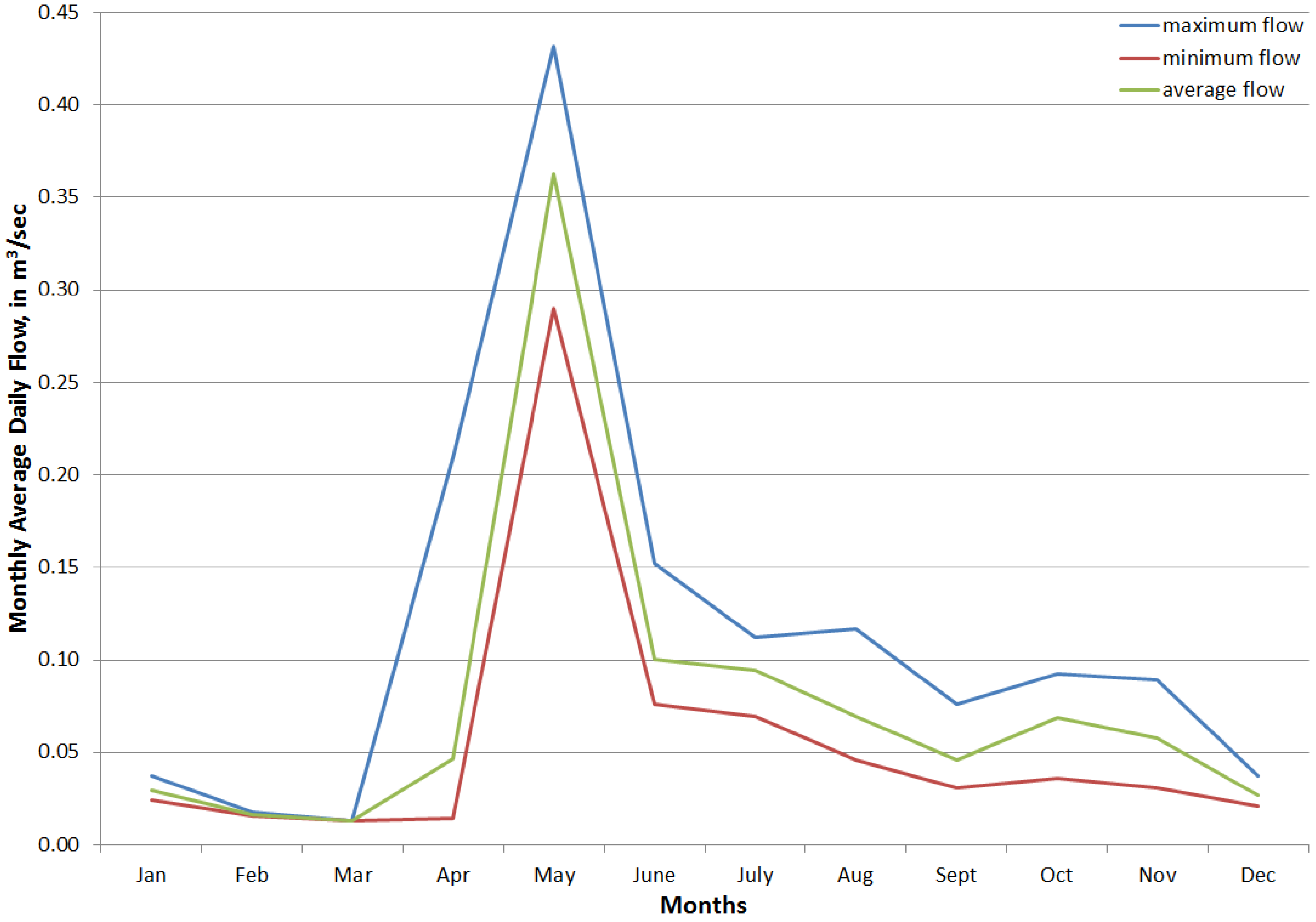


Figure H.9 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #8

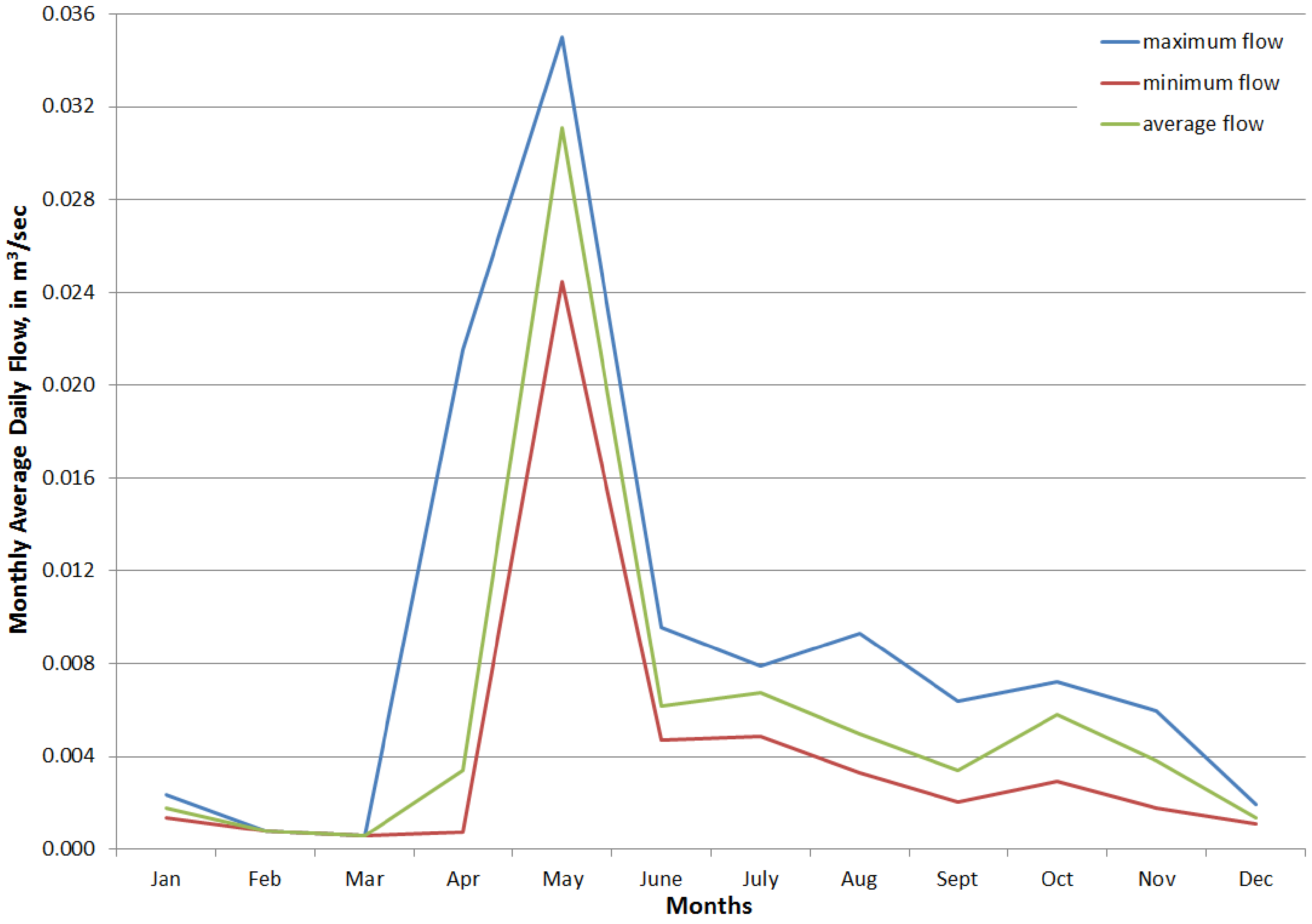


Figure H.10 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #9

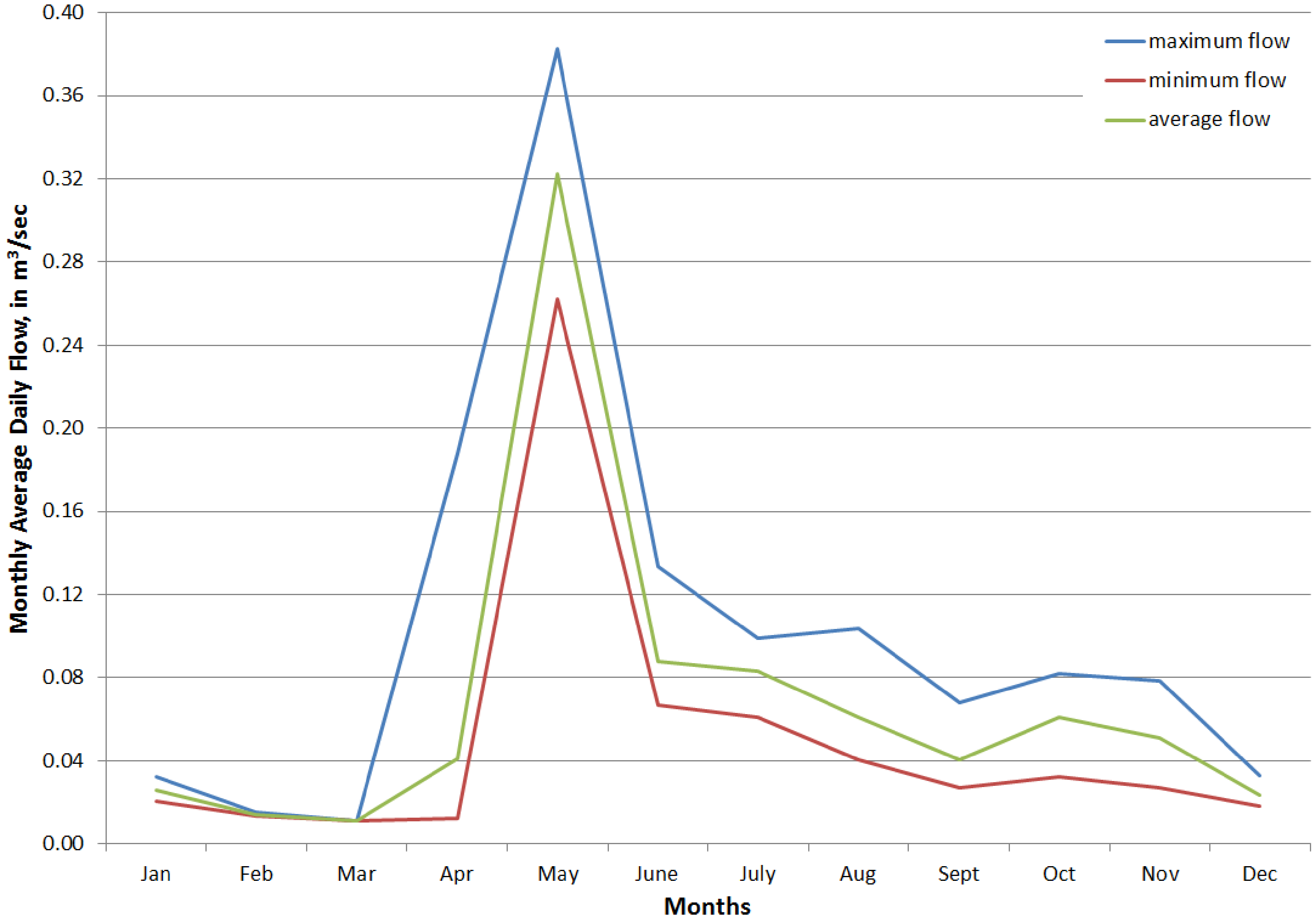


Figure H.11 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #10

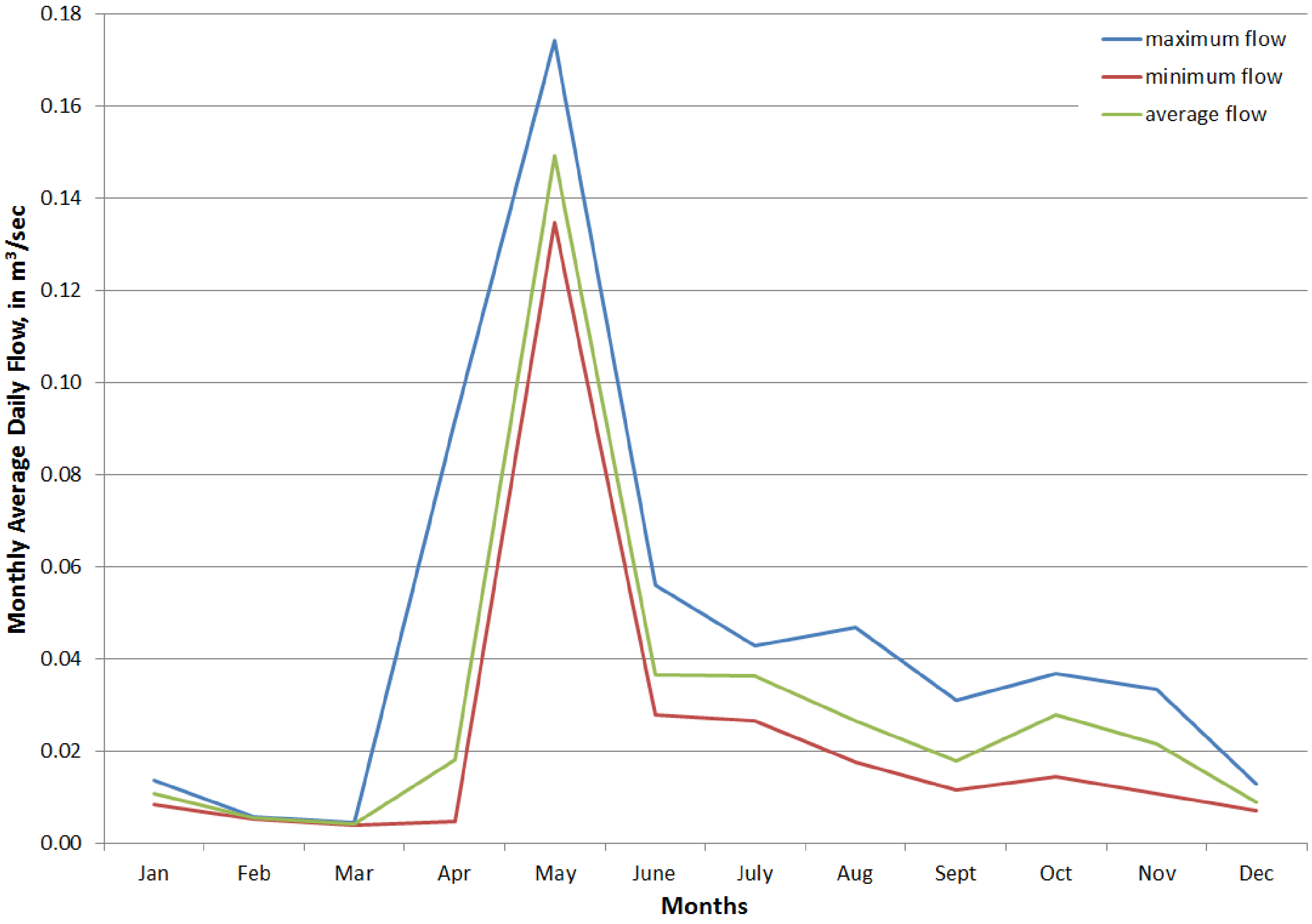


Figure H.12 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #11

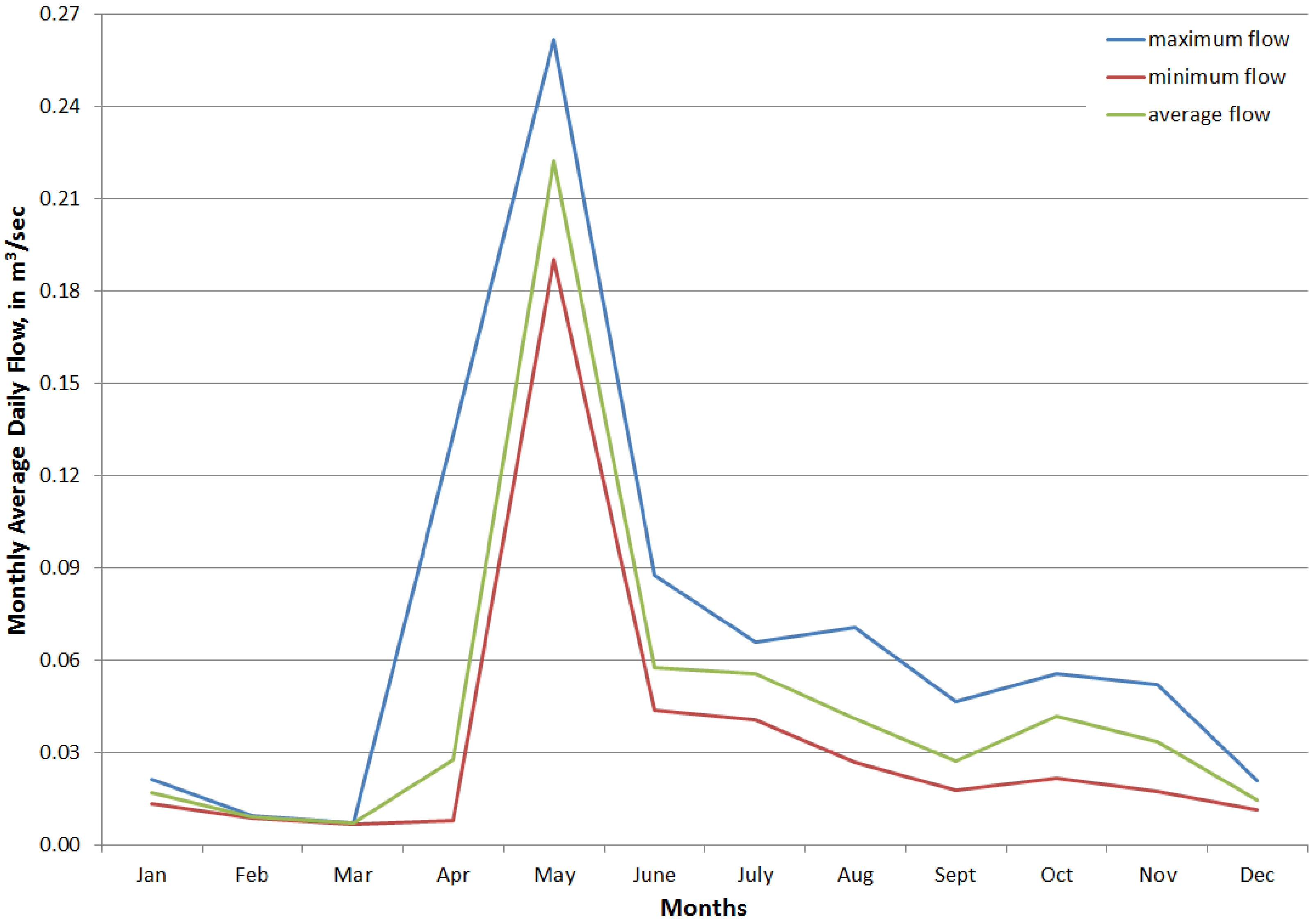


Figure H.13 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #12

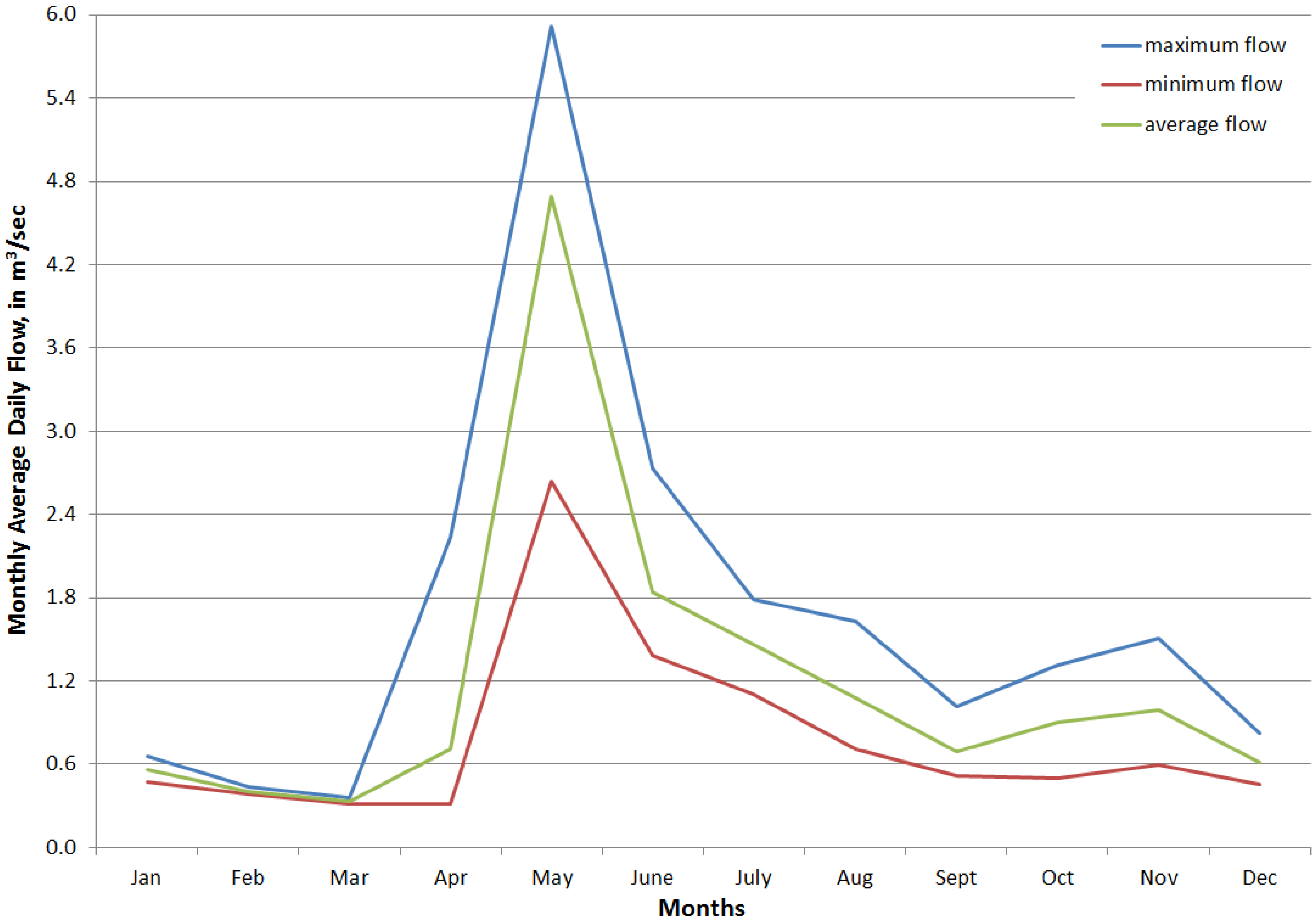


Figure H.14 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #13

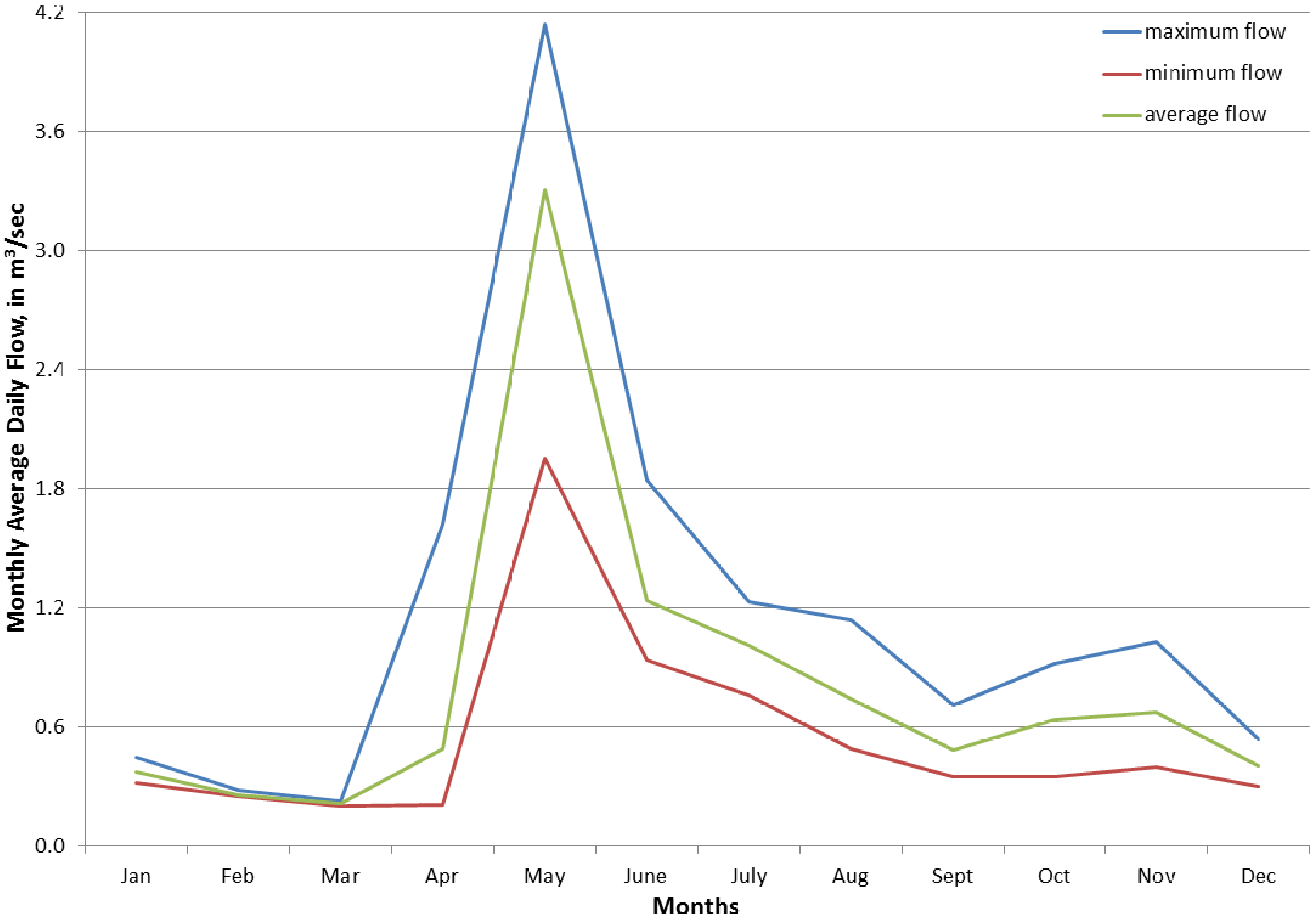


Figure H.15 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #14

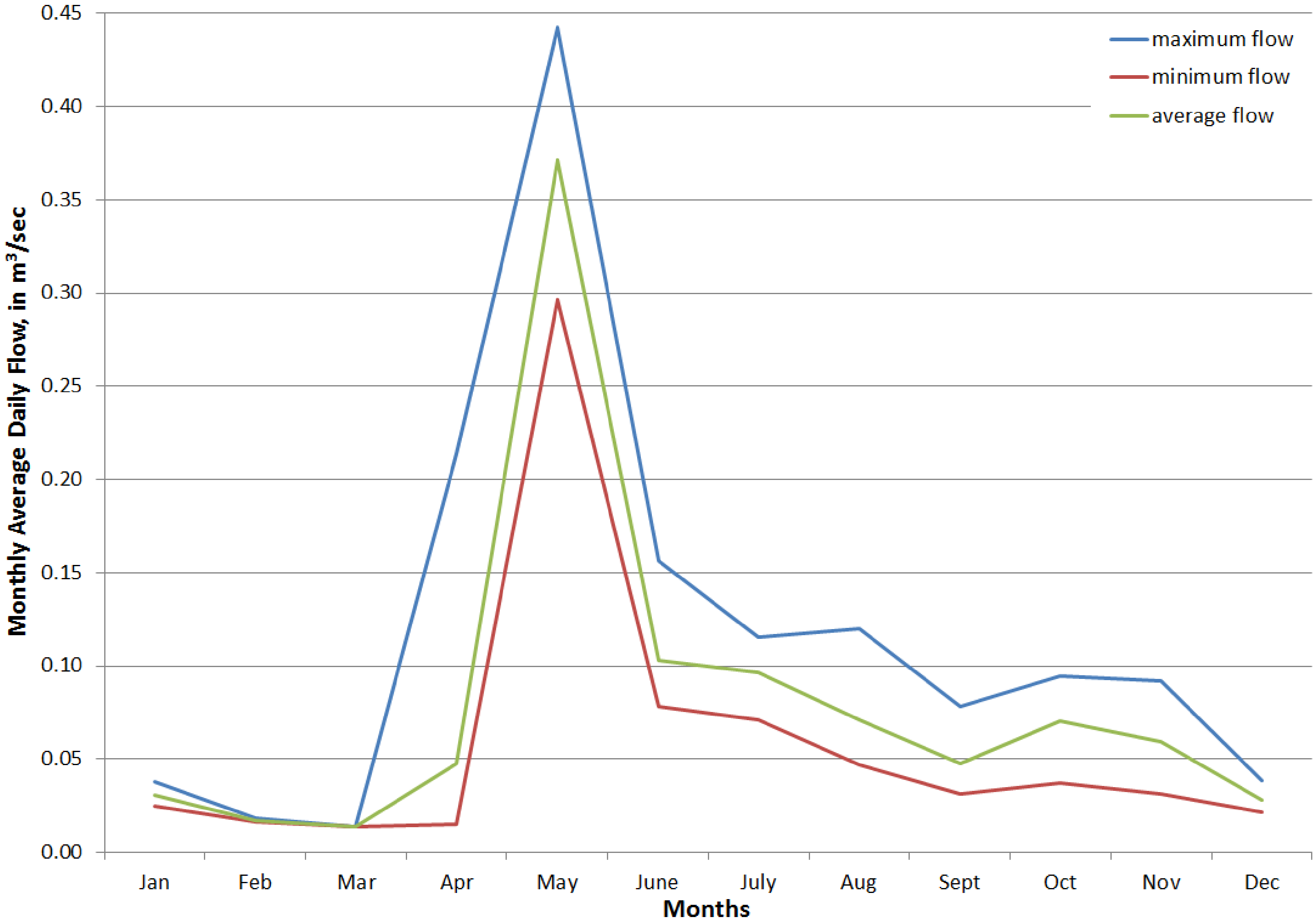


Figure H.16 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #15

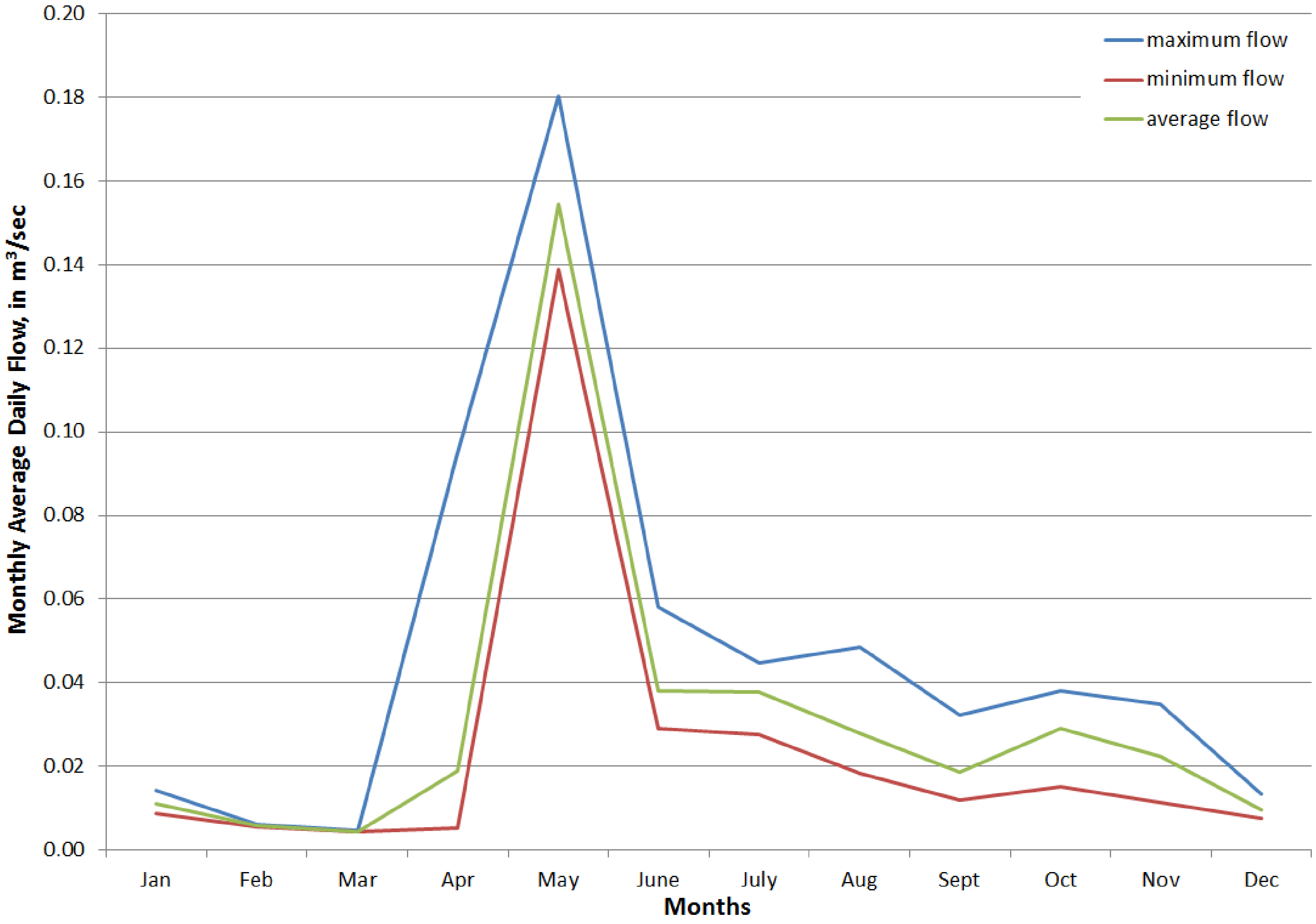


Figure H.17 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #16

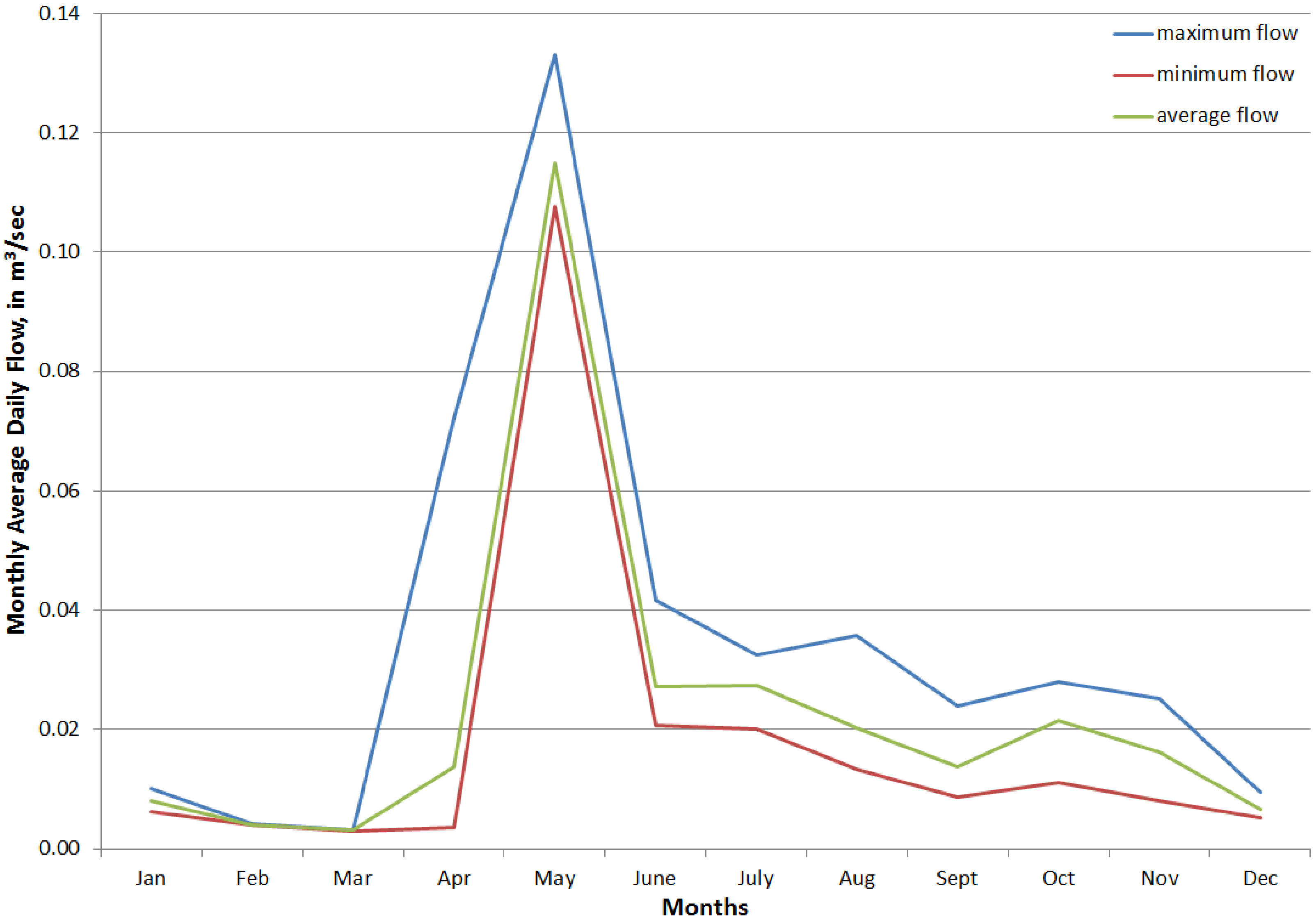


Figure H.18 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #17

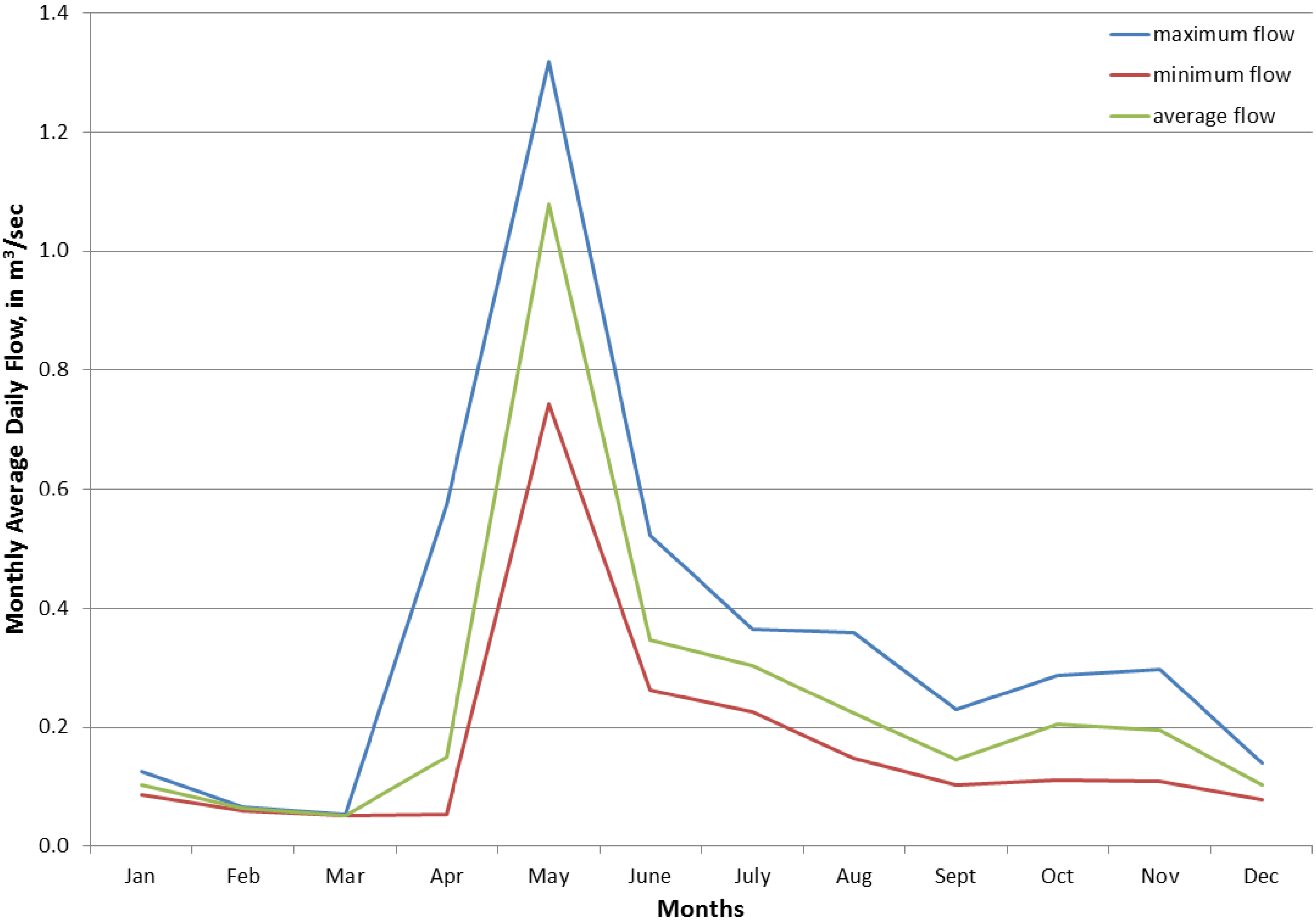


Figure H.19 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #18

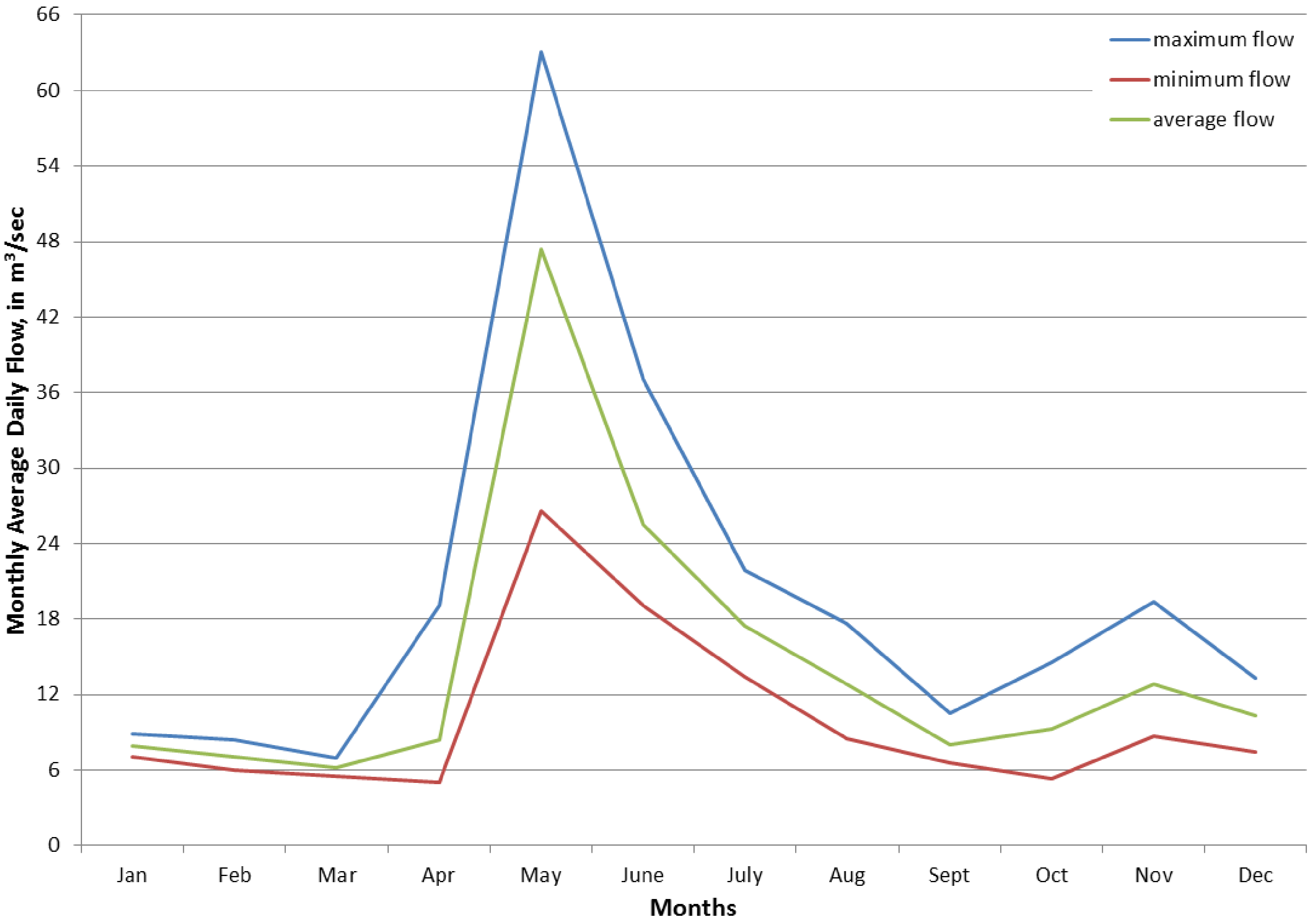


Figure H.20 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #19

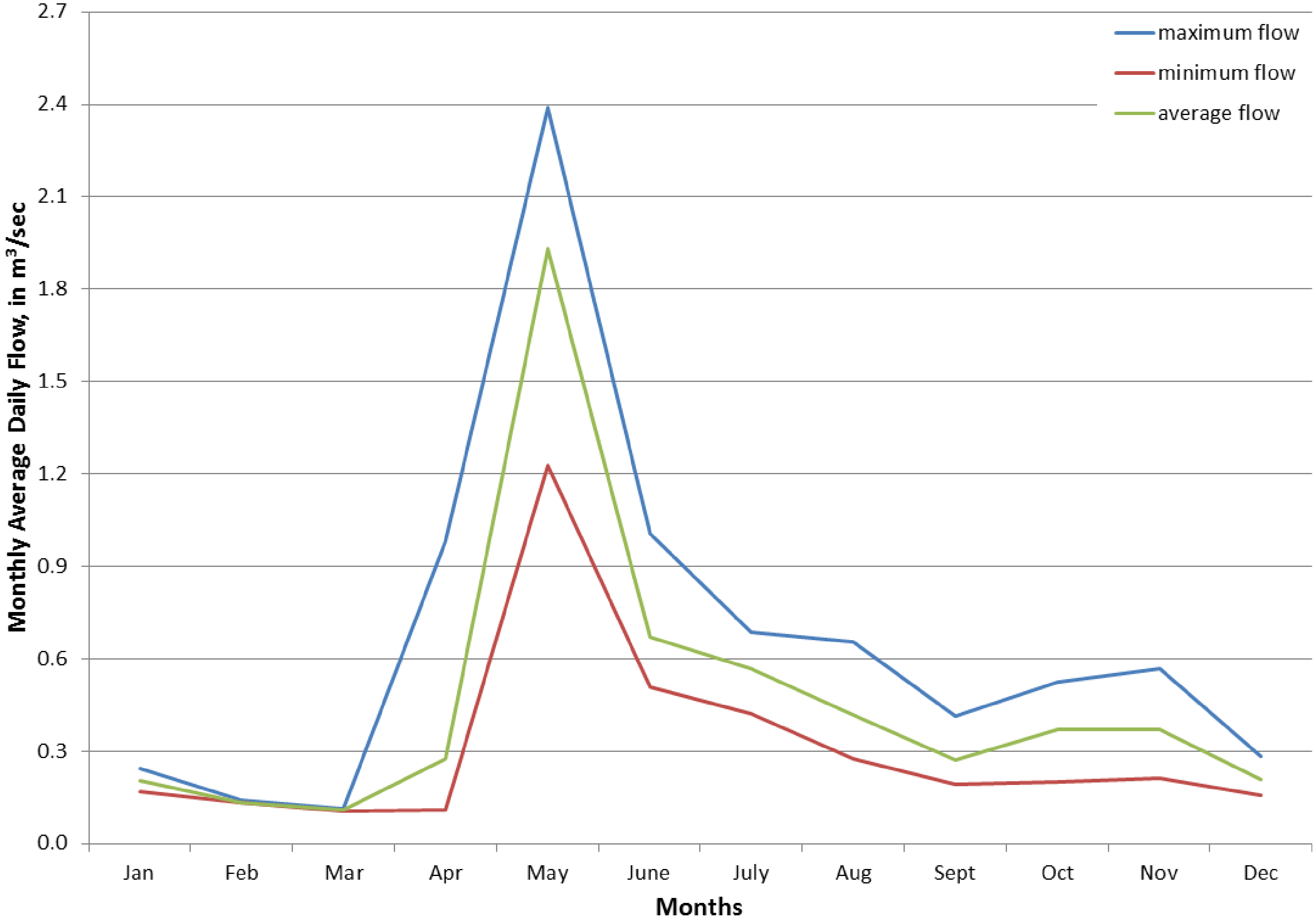


Figure H.21 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #19A

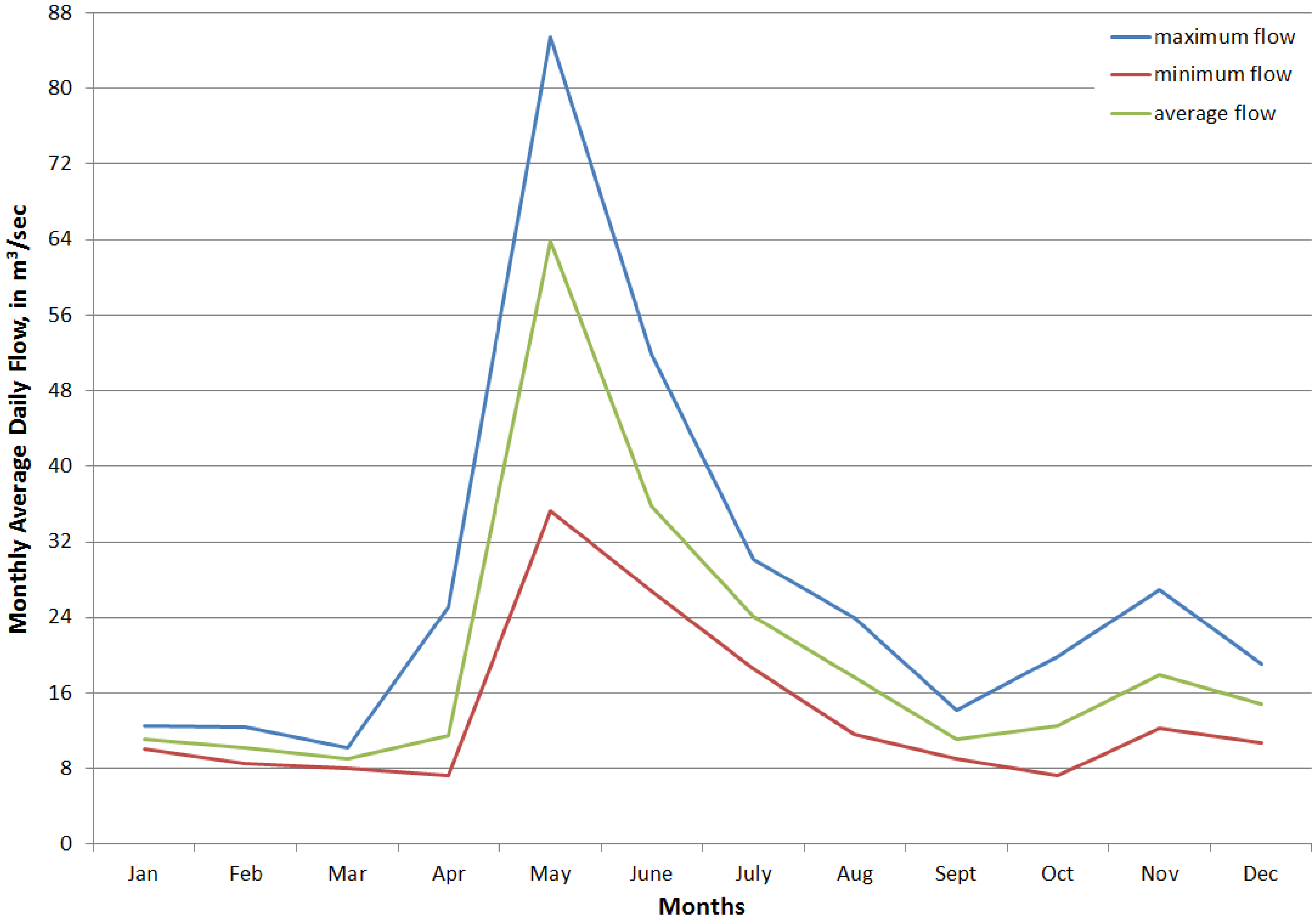


Figure H.22 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #20

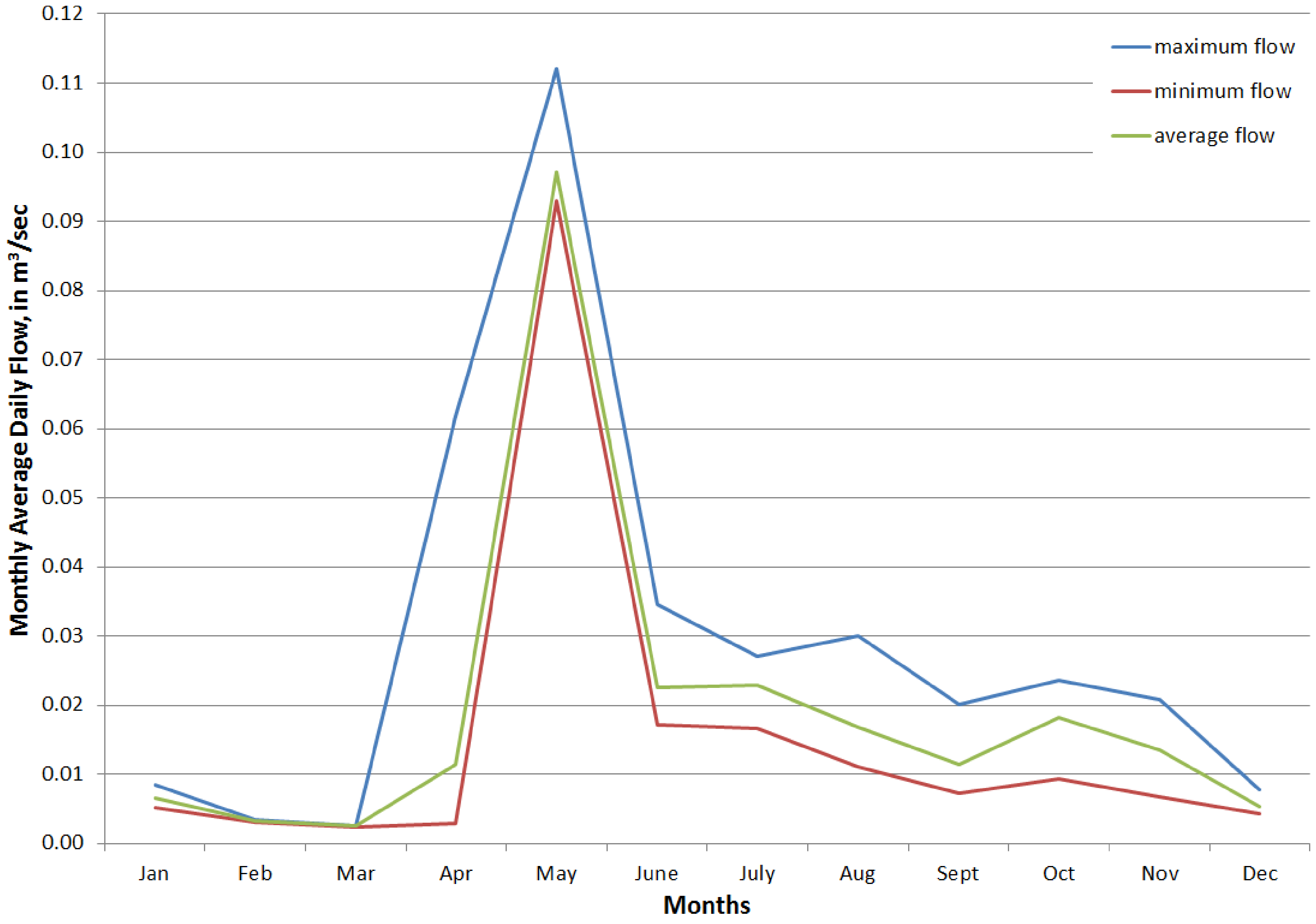


Figure H.23 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #21

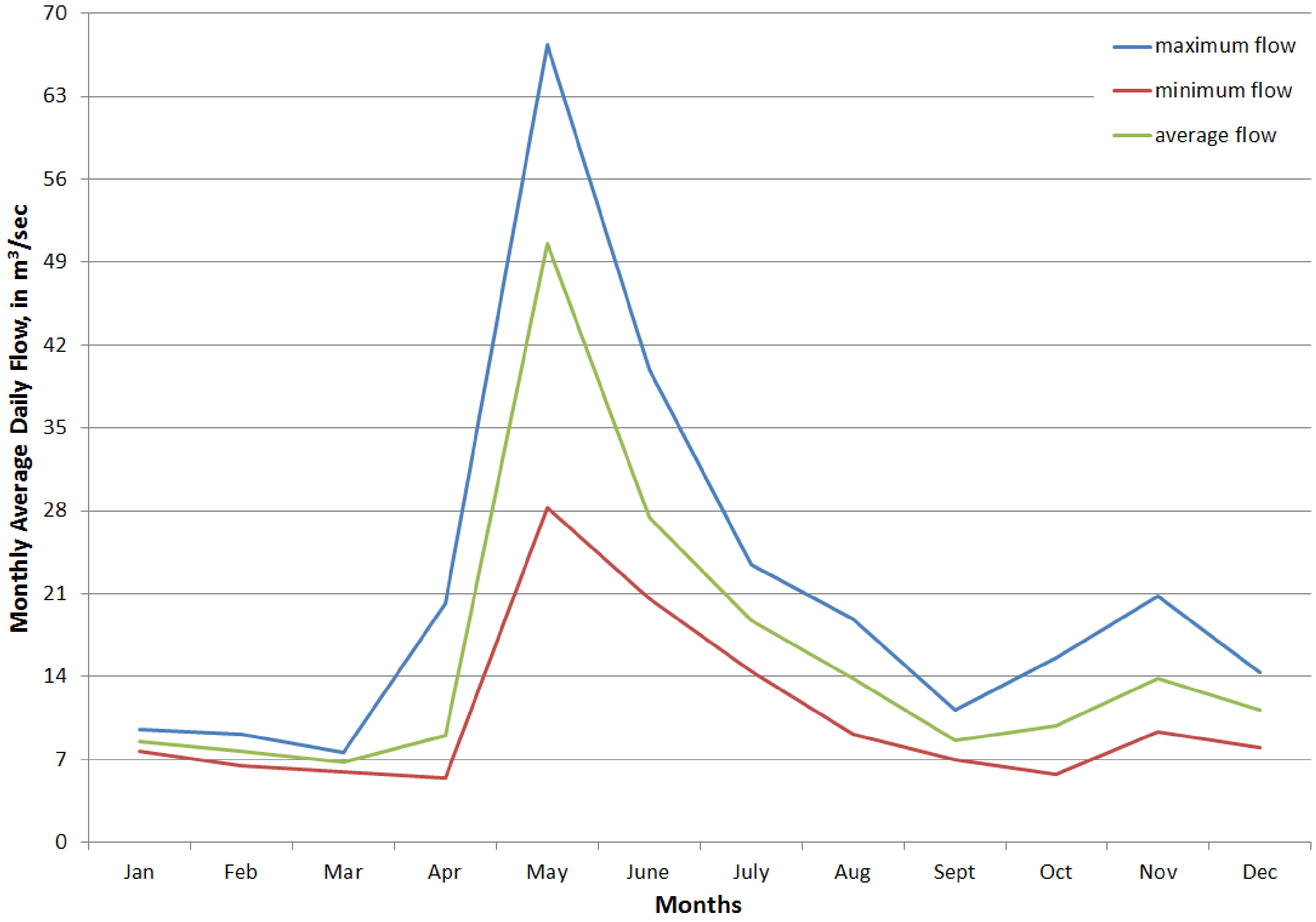


Figure H.24 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #22

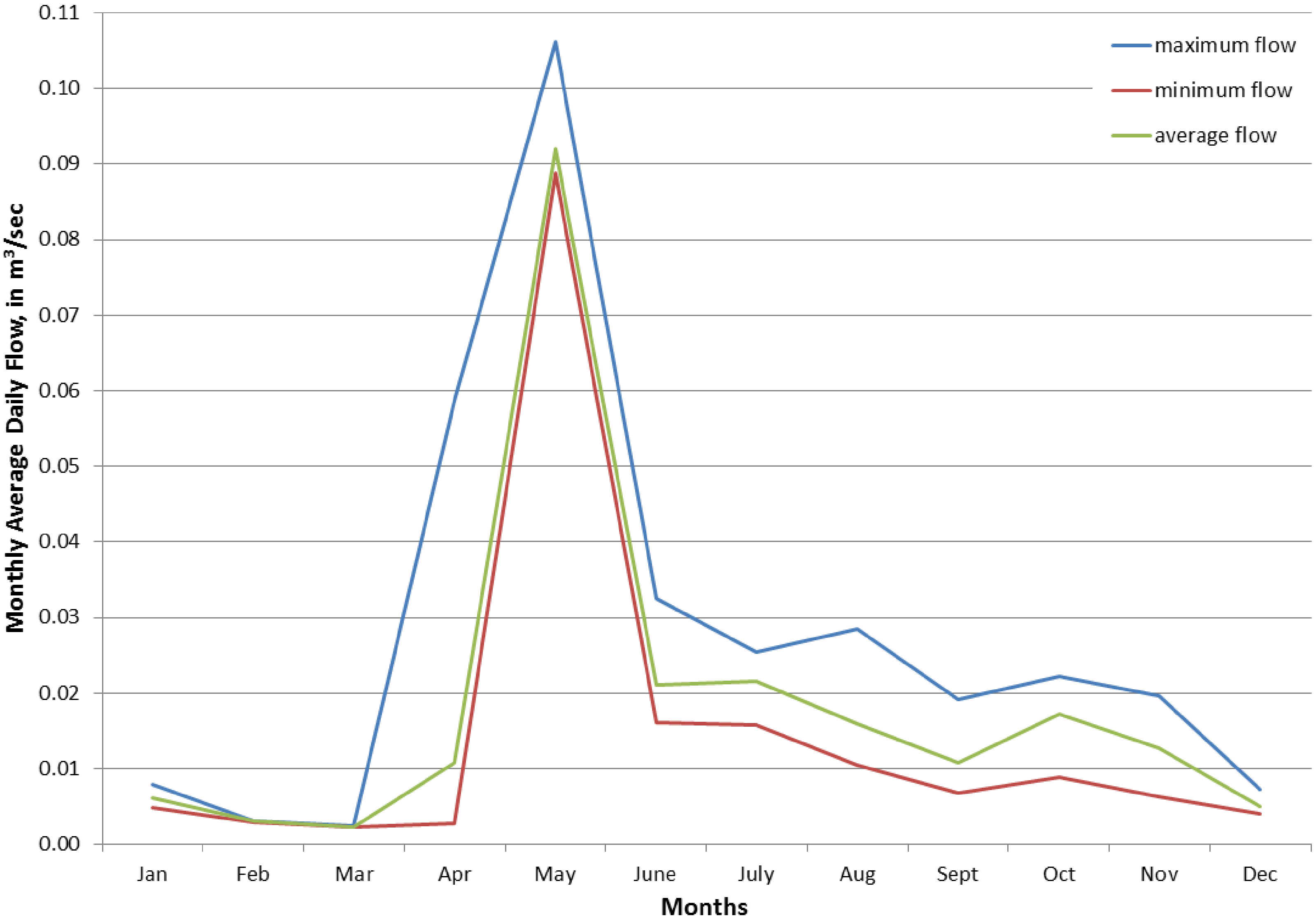


Figure H.25 Maximum, Minimum, and Average Flow Hydrographs of Subwatershed #23

Appendix I

Flow Duration Curves

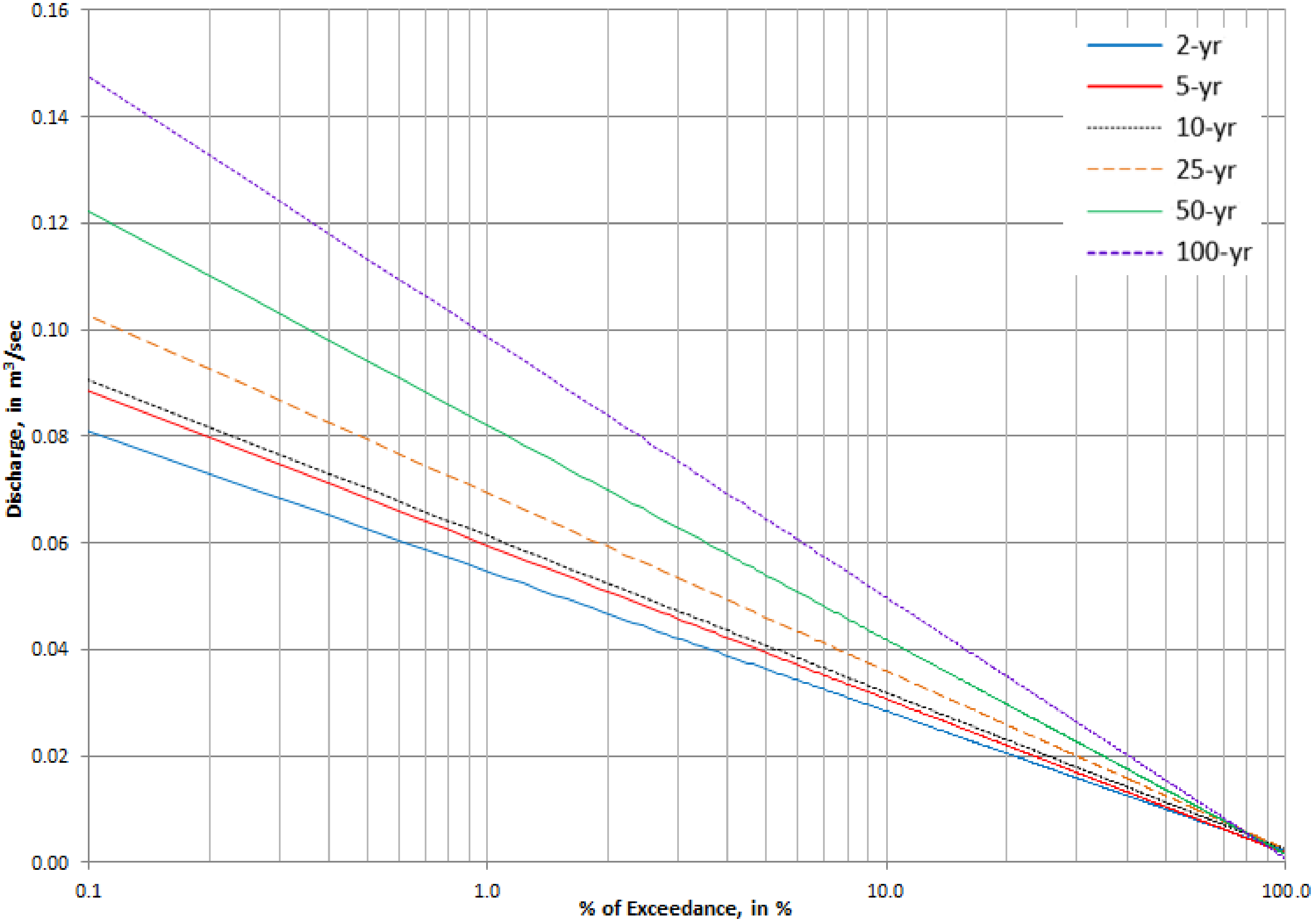


Figure I.1 Flow Duration Curves of Subwatershed #1

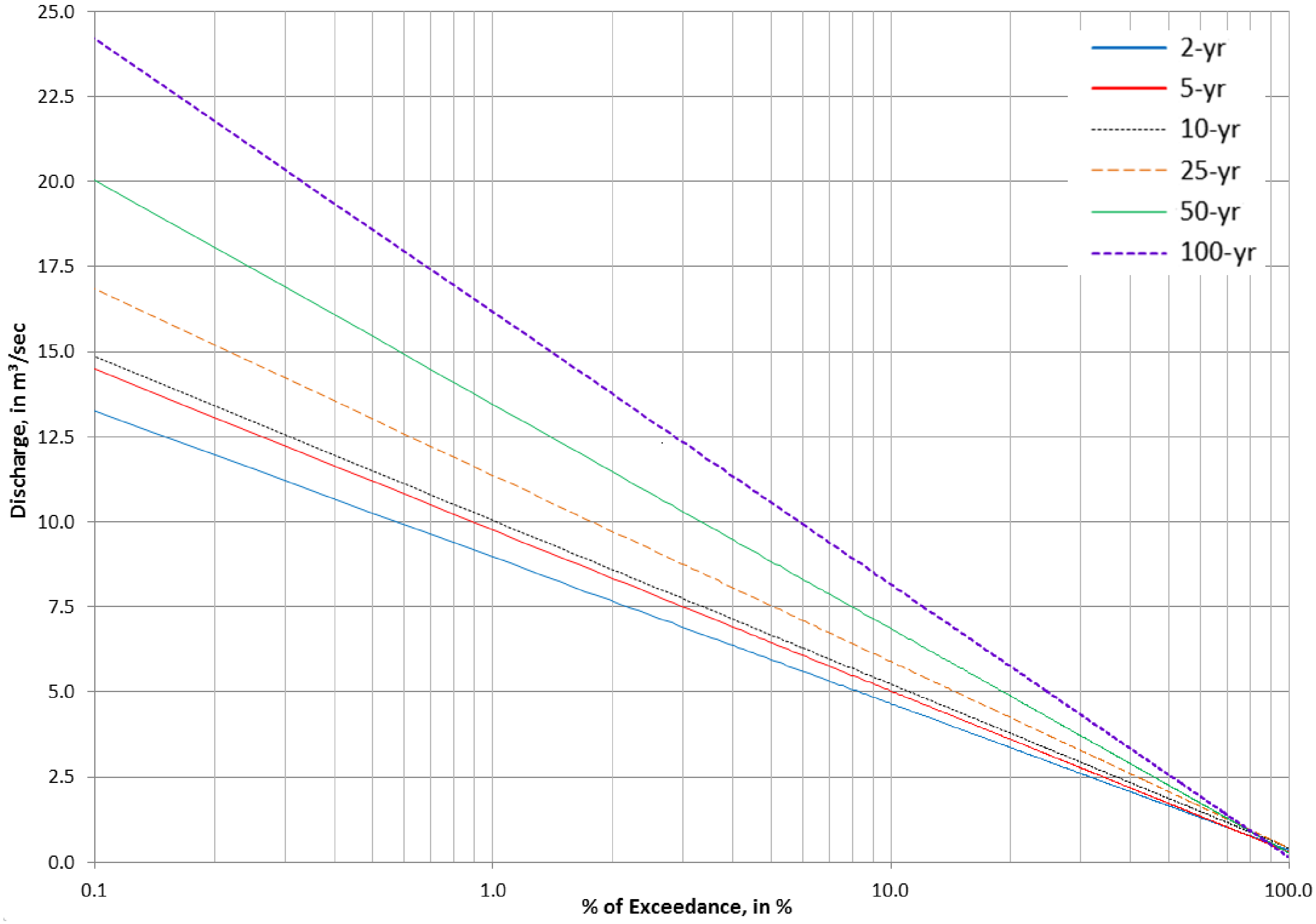


Figure I.2 **Flow Duration Curves of Subwatershed #2**

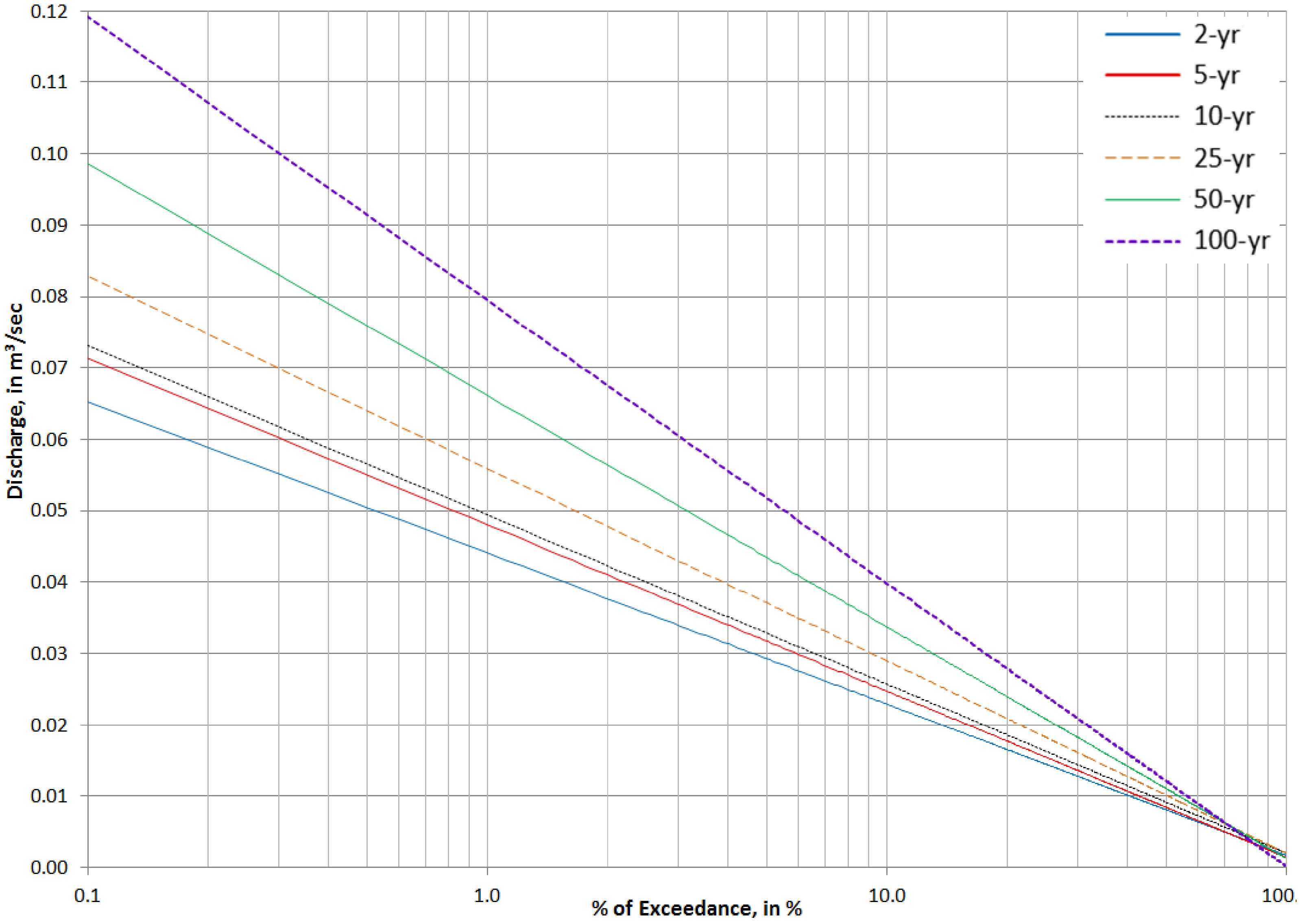


Figure I.3 Flow Duration Curves of Subwatershed #3

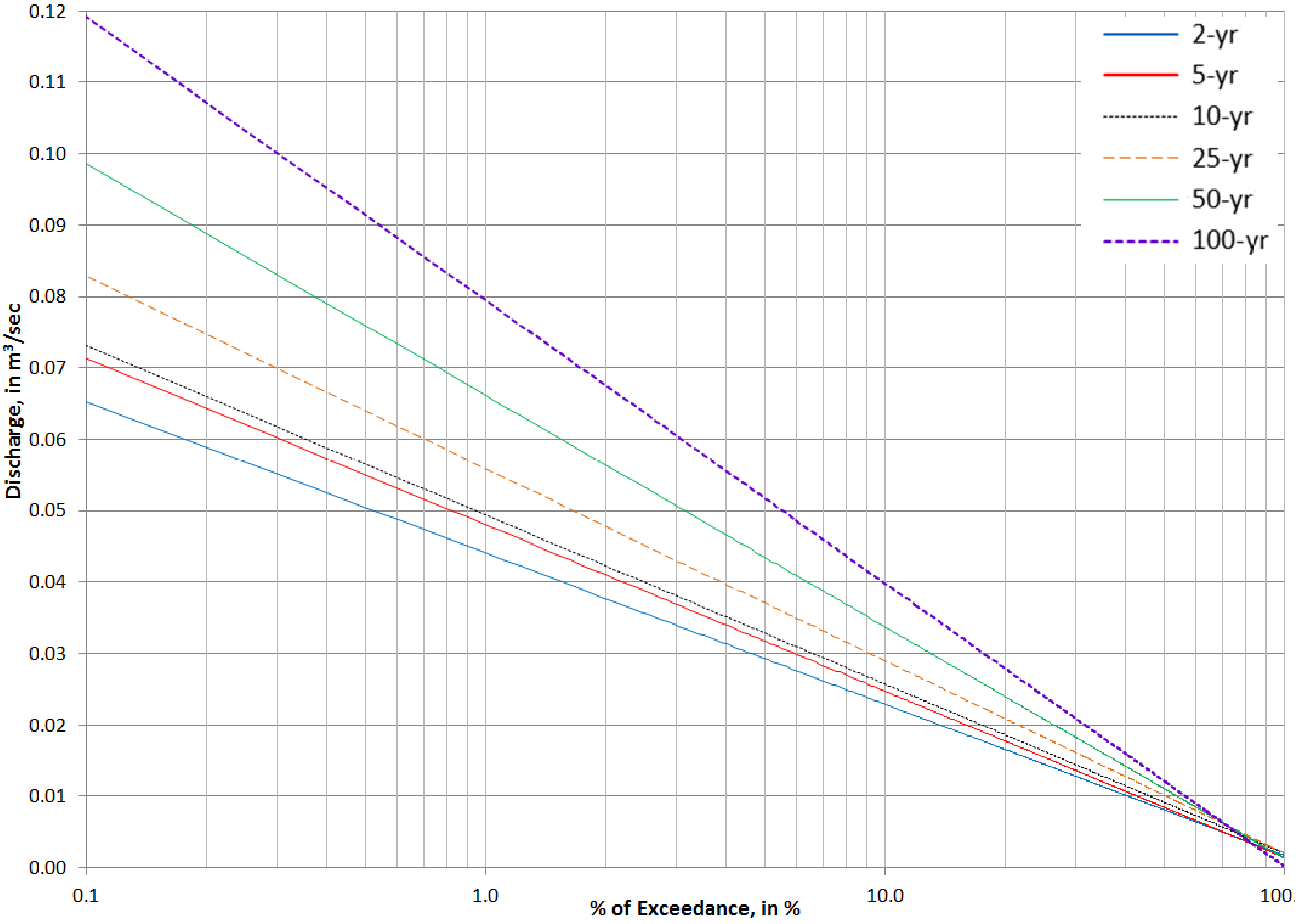


Figure I.4 **Flow Duration Curves of Subwatershed #3A**

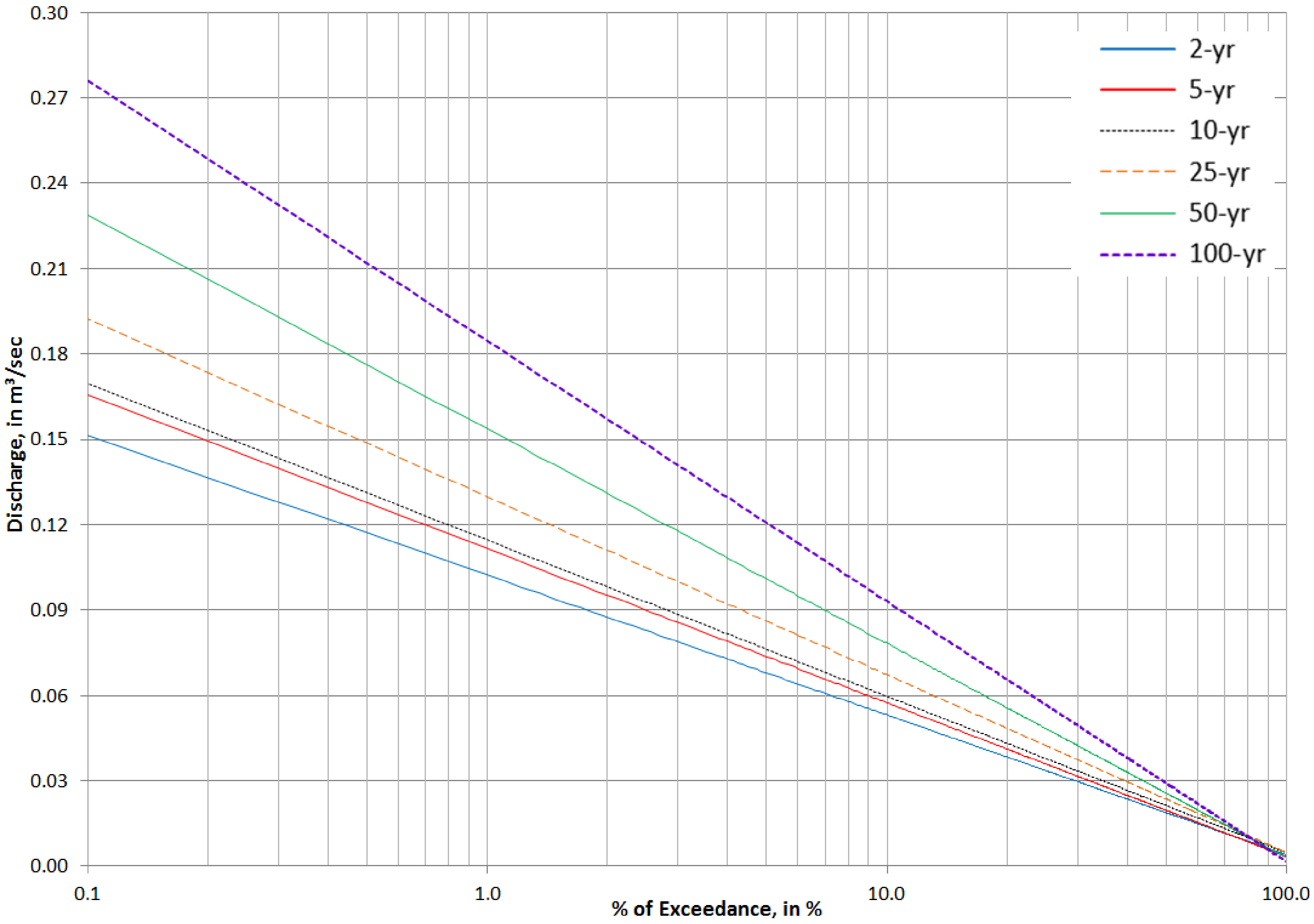


Figure I.5 **Flow Duration Curves of Subwatershed #4**

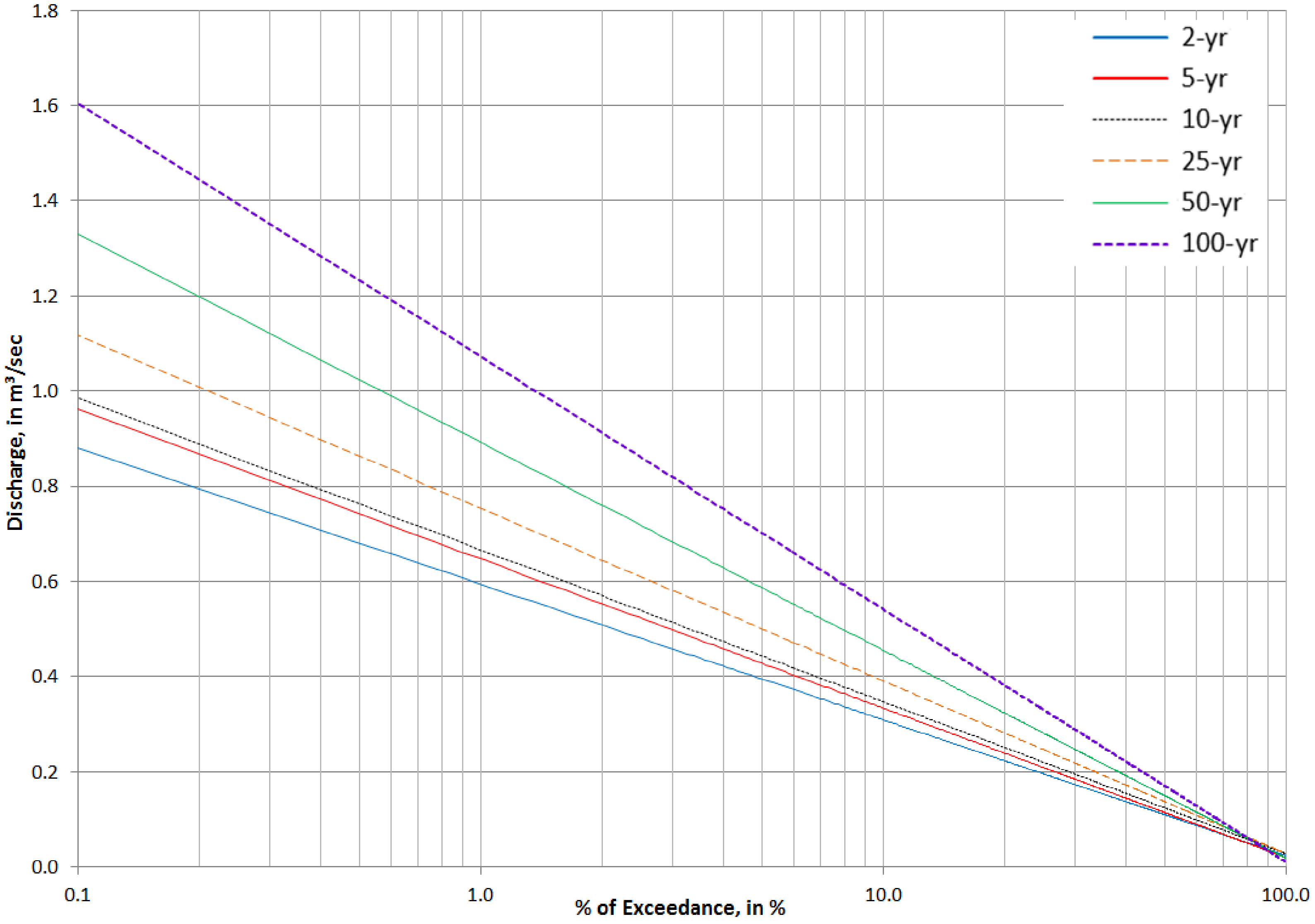


Figure I.6 Flow Duration Curves of Subwatershed #5

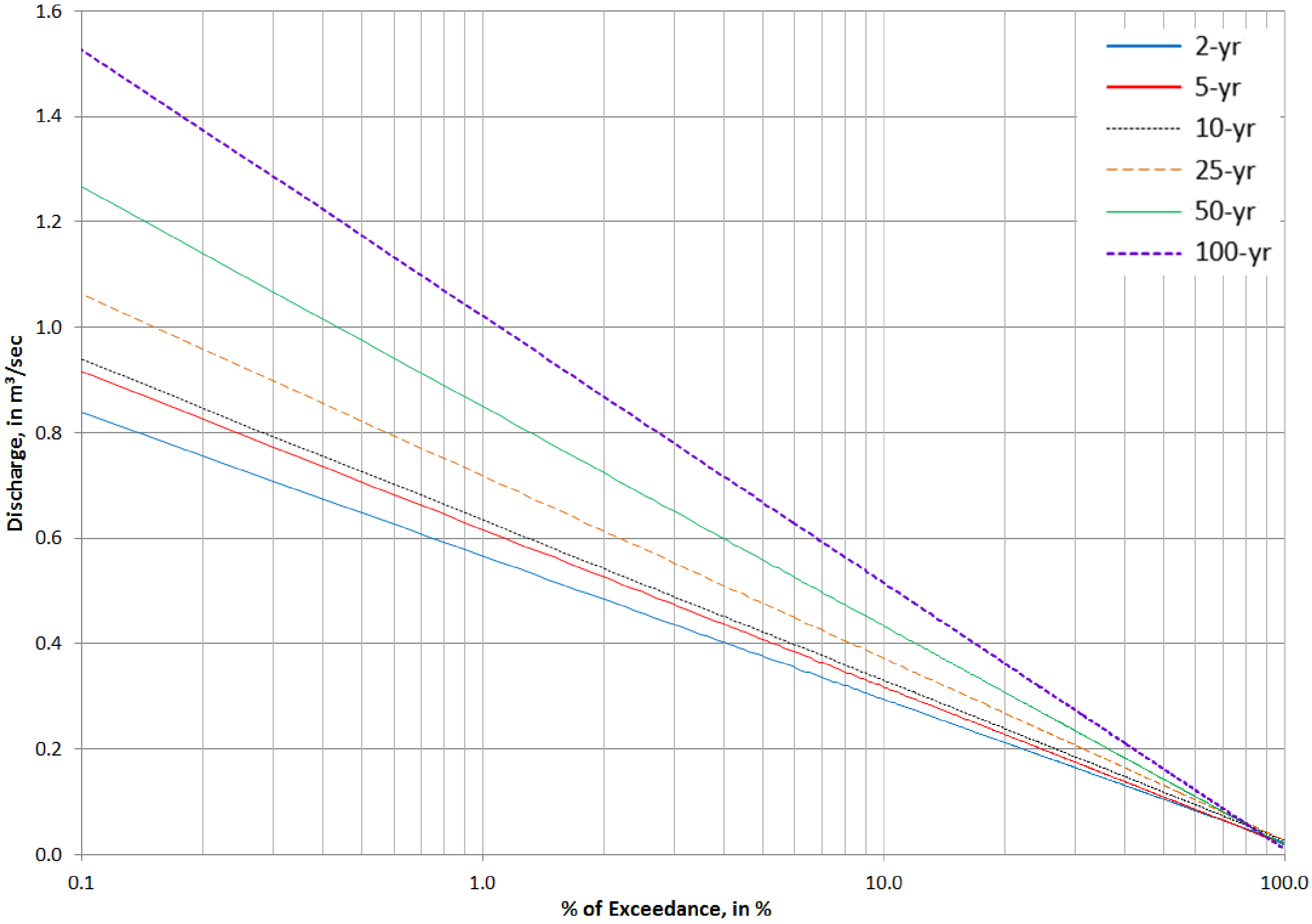


Figure I.7 **Flow Duration Curves of Subwatershed #6**

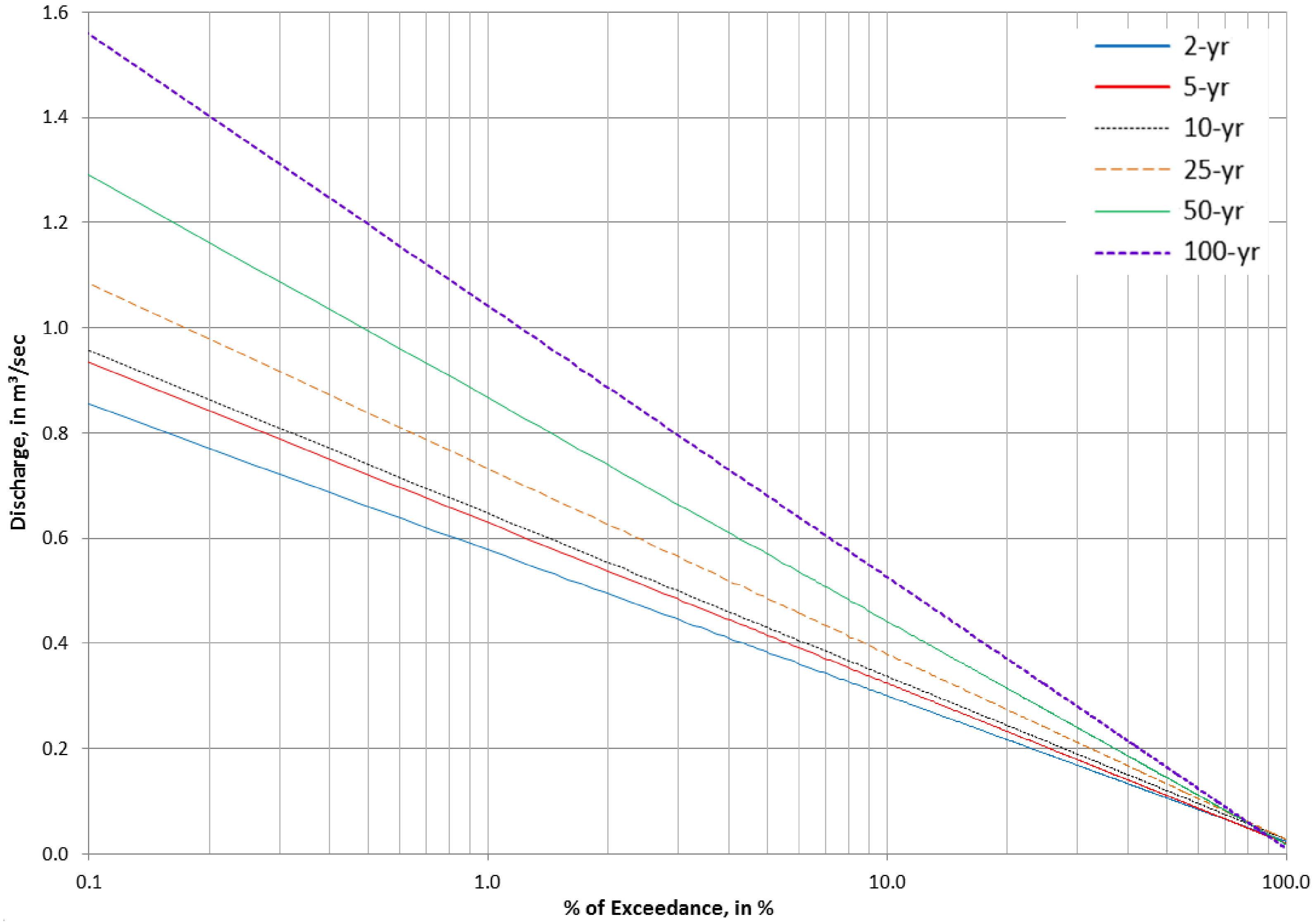


Figure I.8 Flow Duration Curves of Subwatershed #7

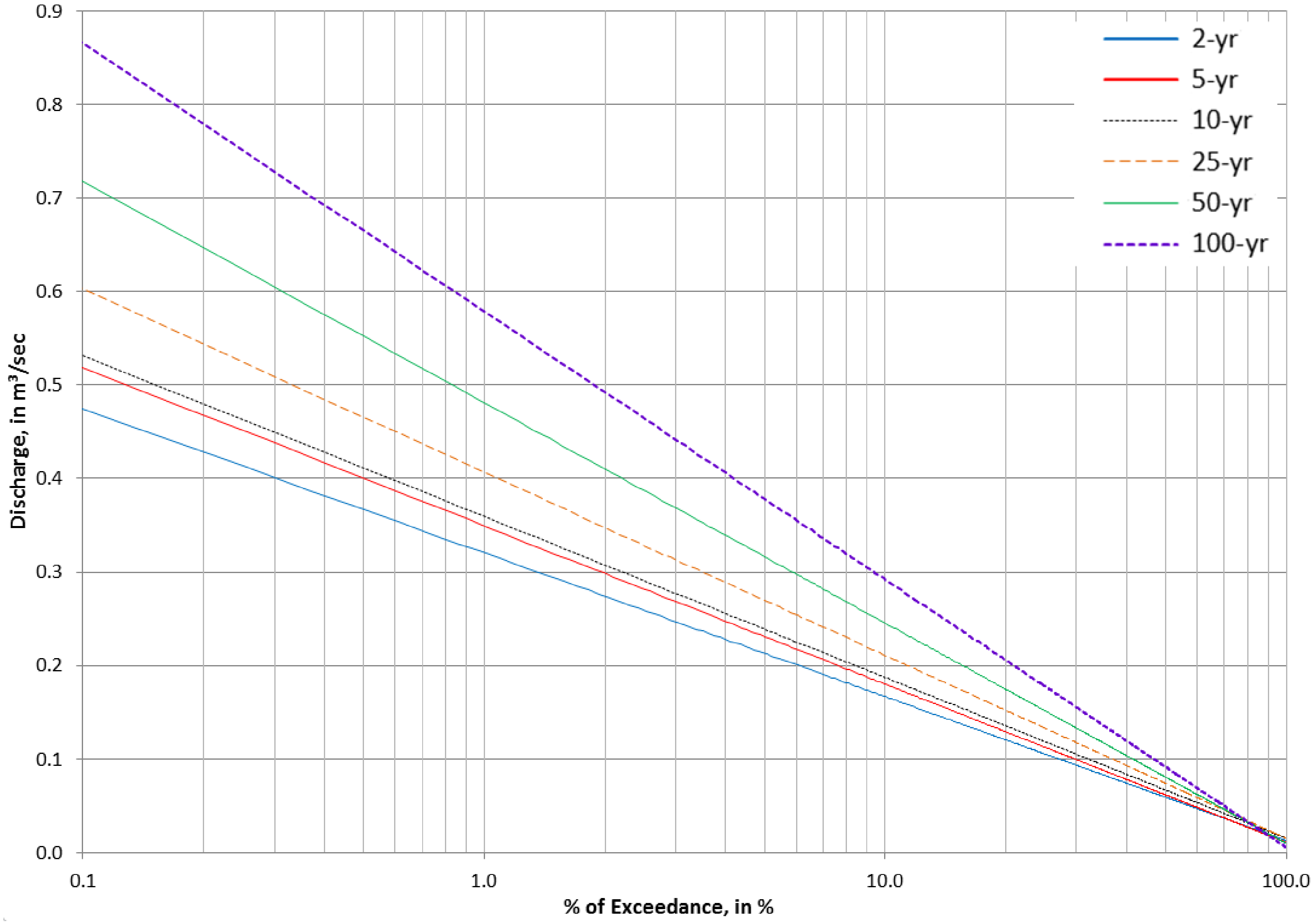


Figure I.9 Flow Duration Curves of Subwatershed #8

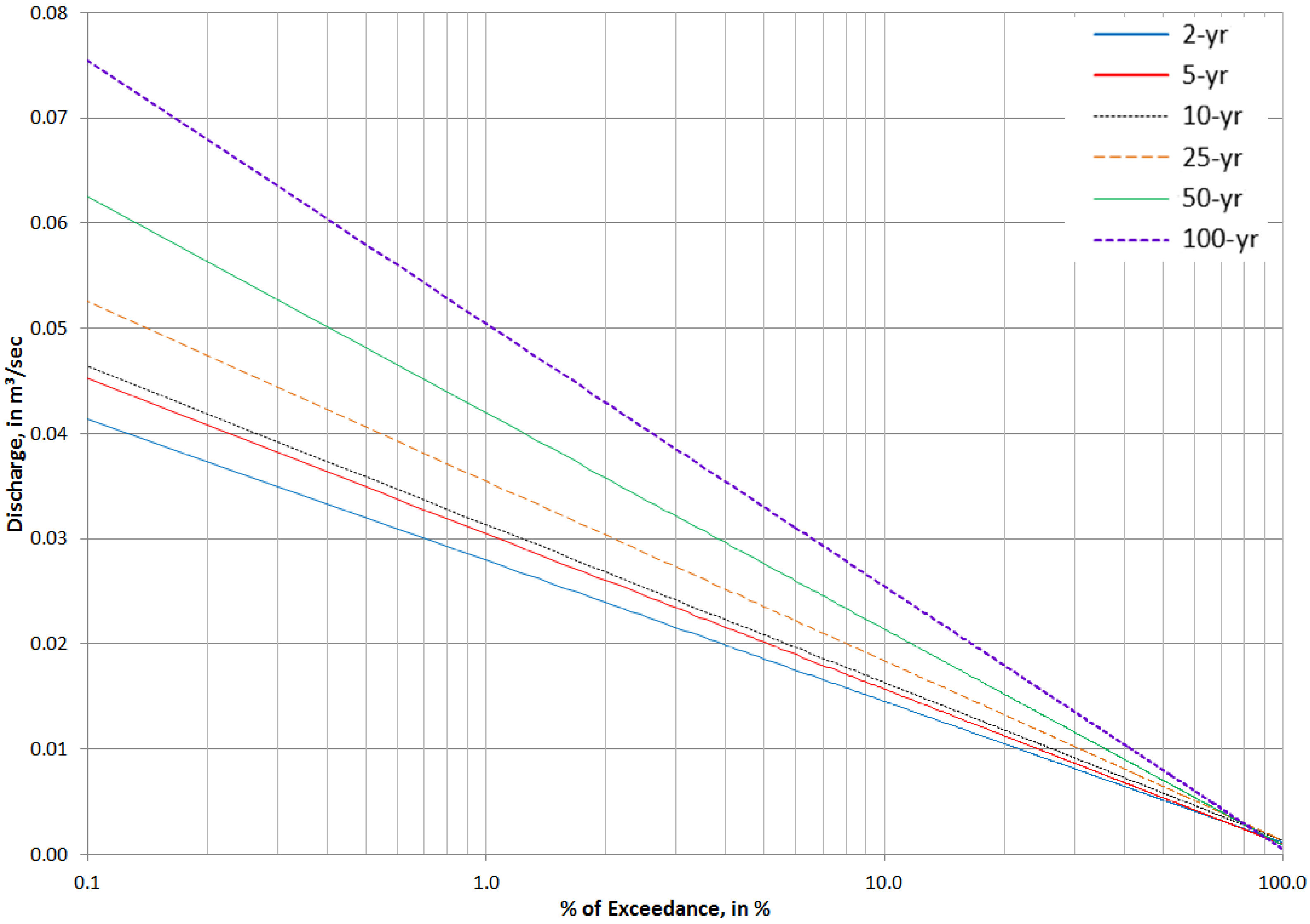


Figure I.10 Flow Duration Curves of Subwatershed #9

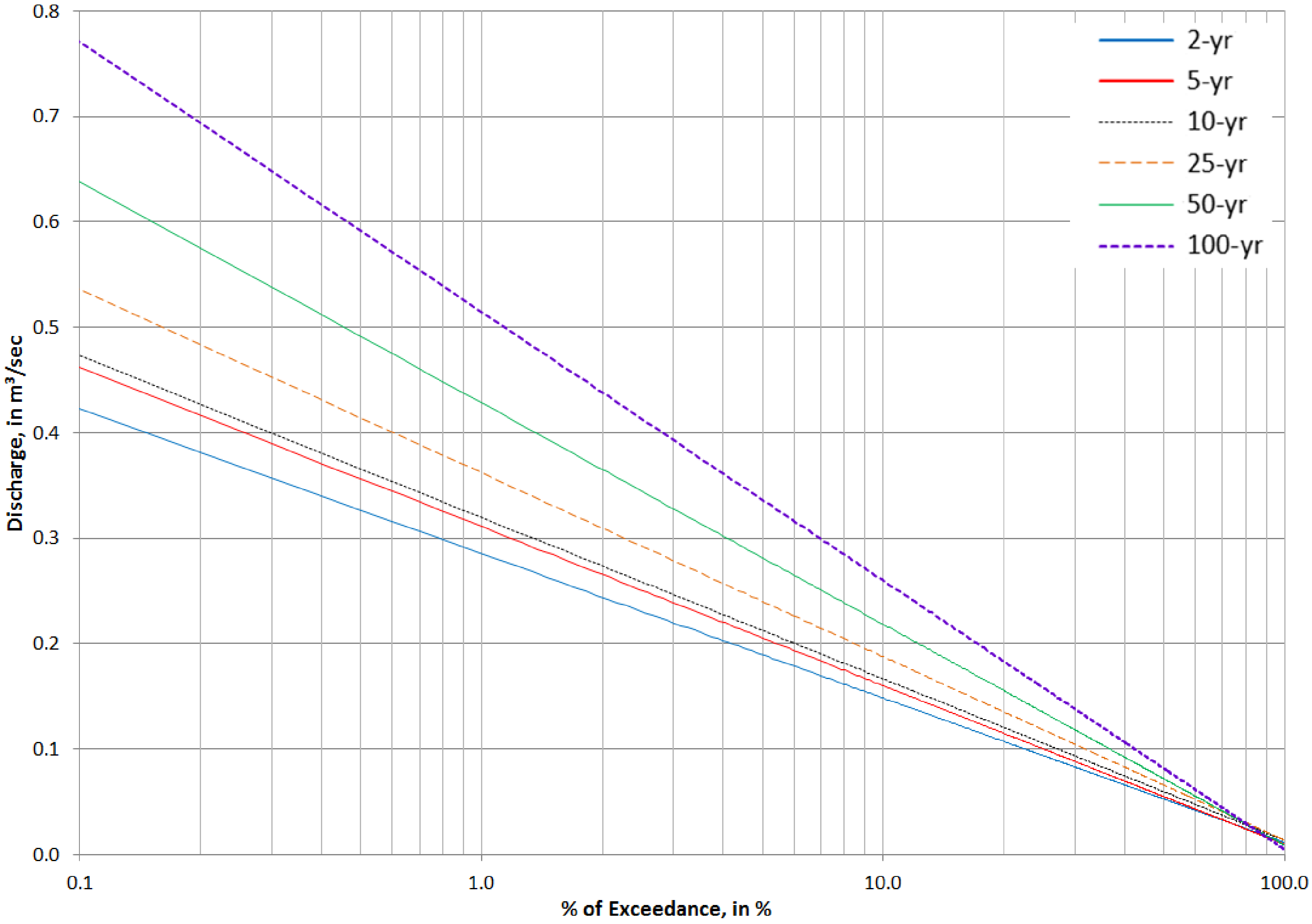


Figure I.11 Flow Duration Curves of Subwatershed #10

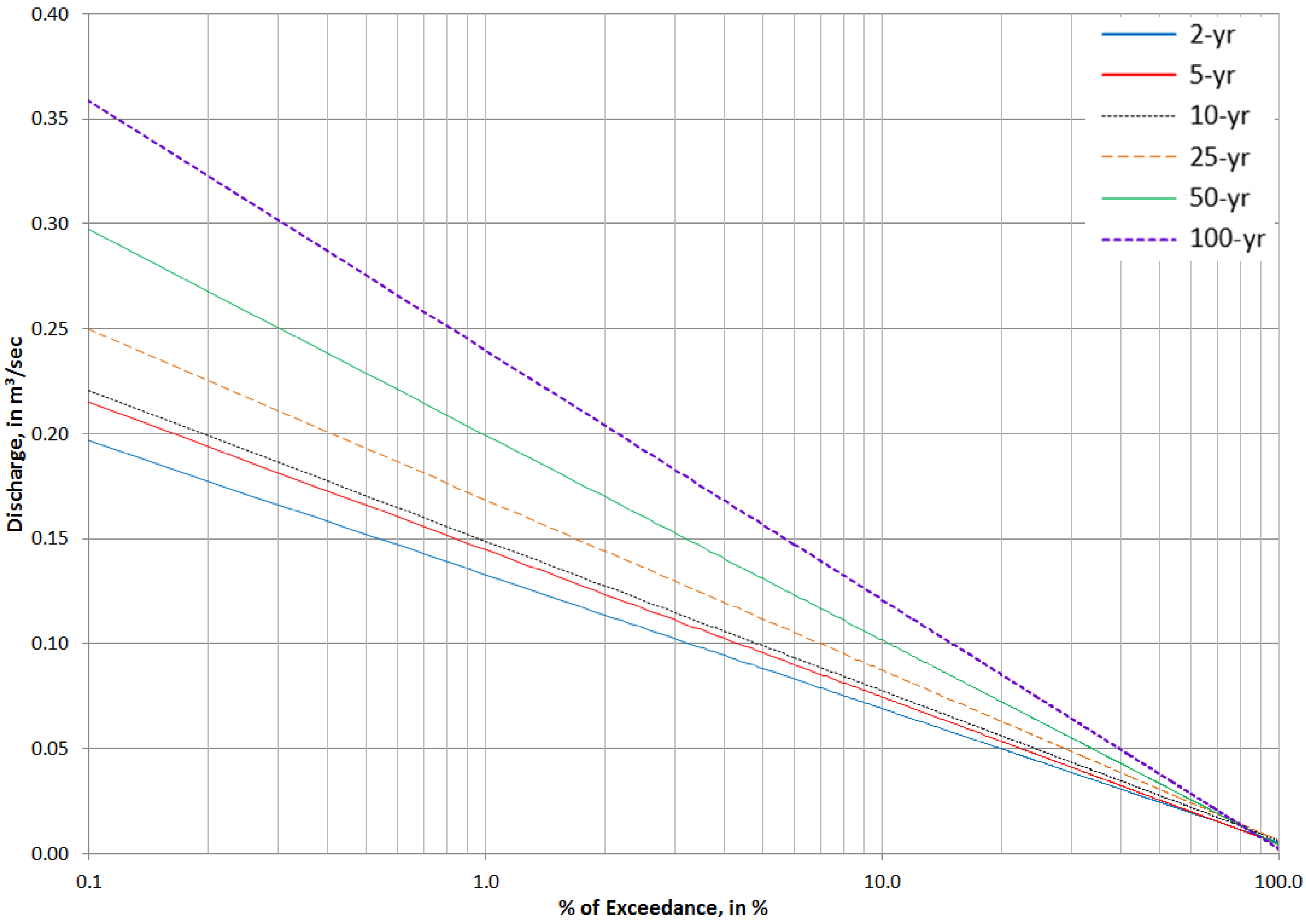


Figure I.12 Flow Duration Curves of Subwatershed #11

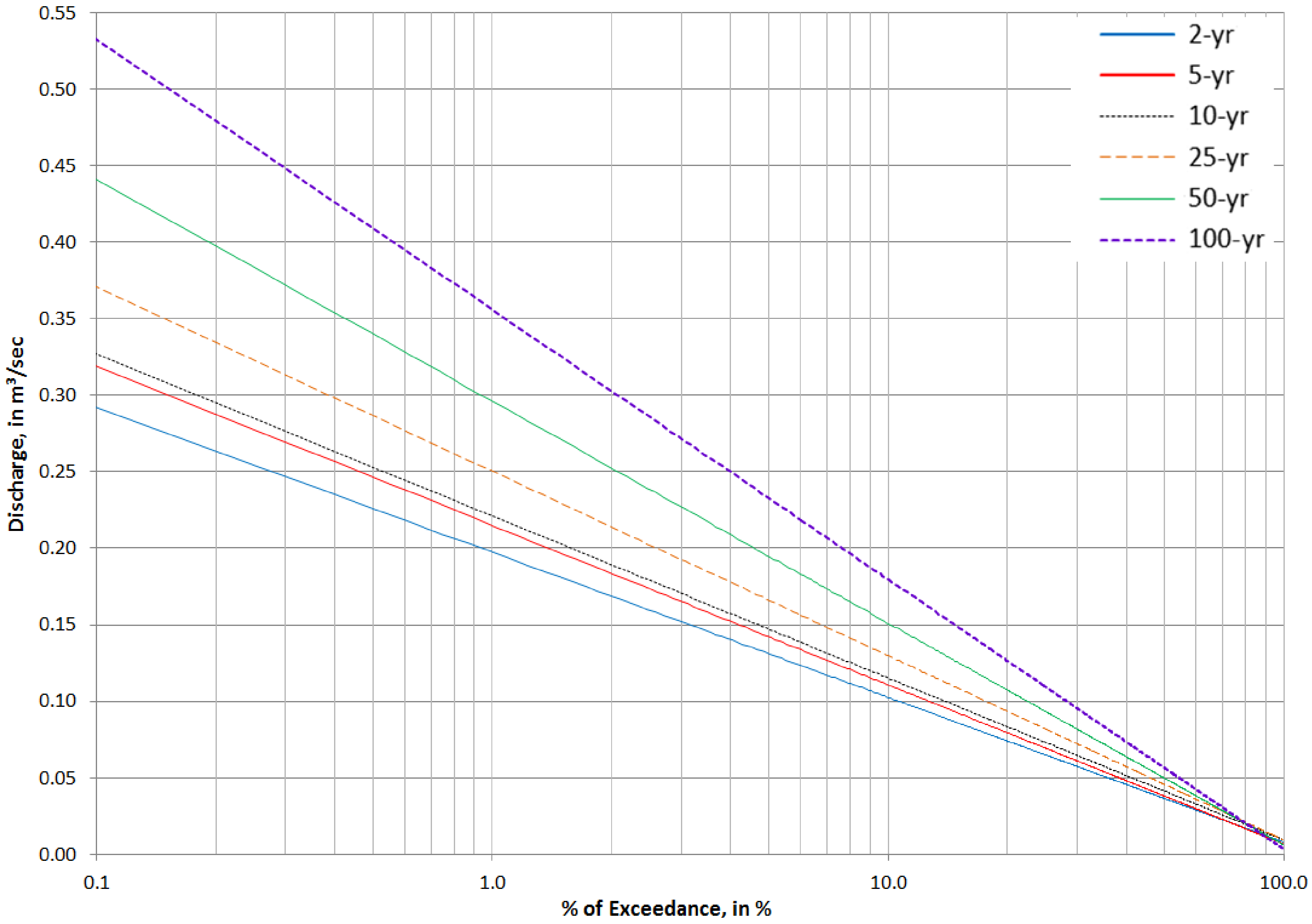


Figure I.13 Flow Duration Curves of Subwatershed #12

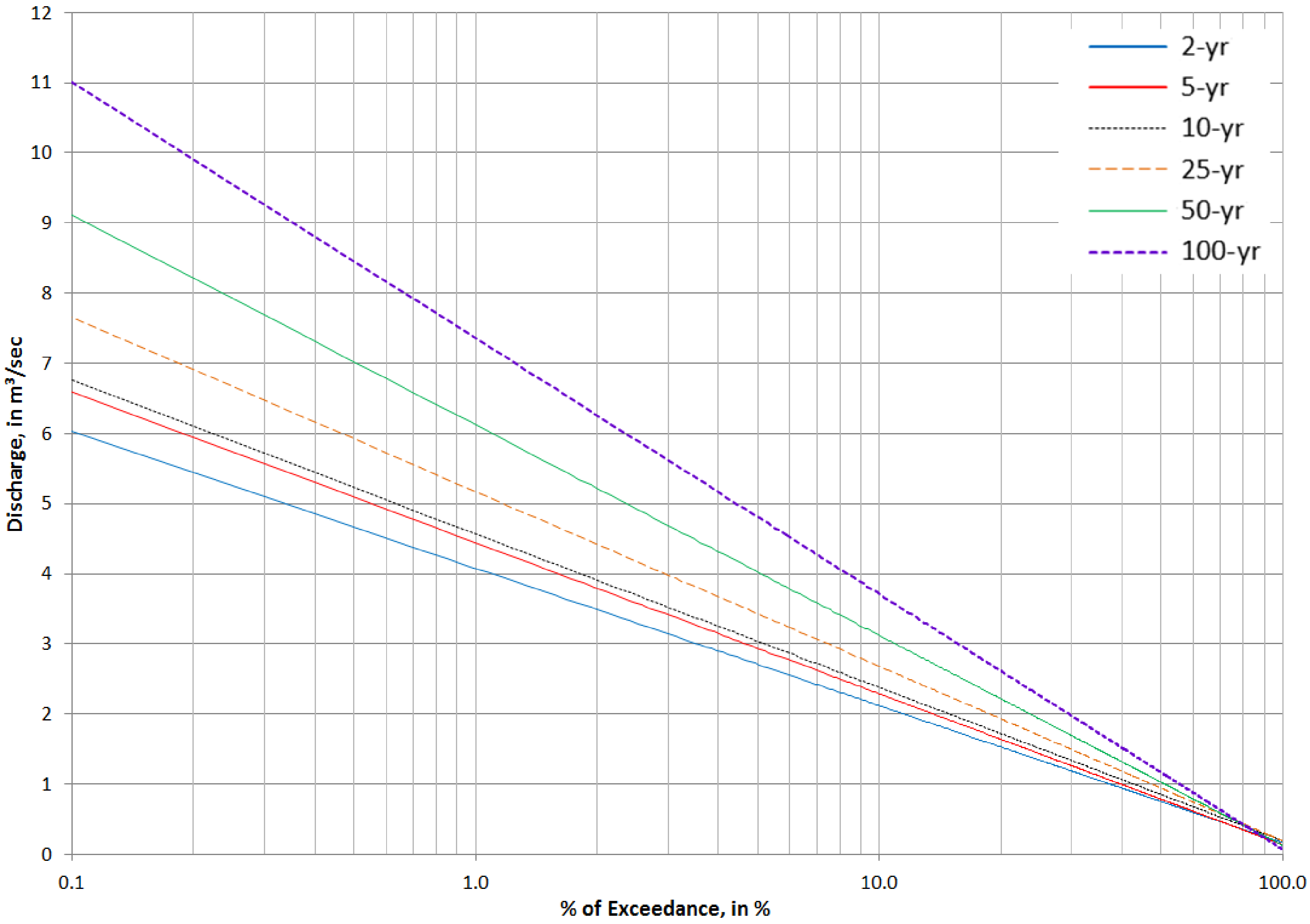


Figure I.14 Flow Duration Curves of Subwatershed #13

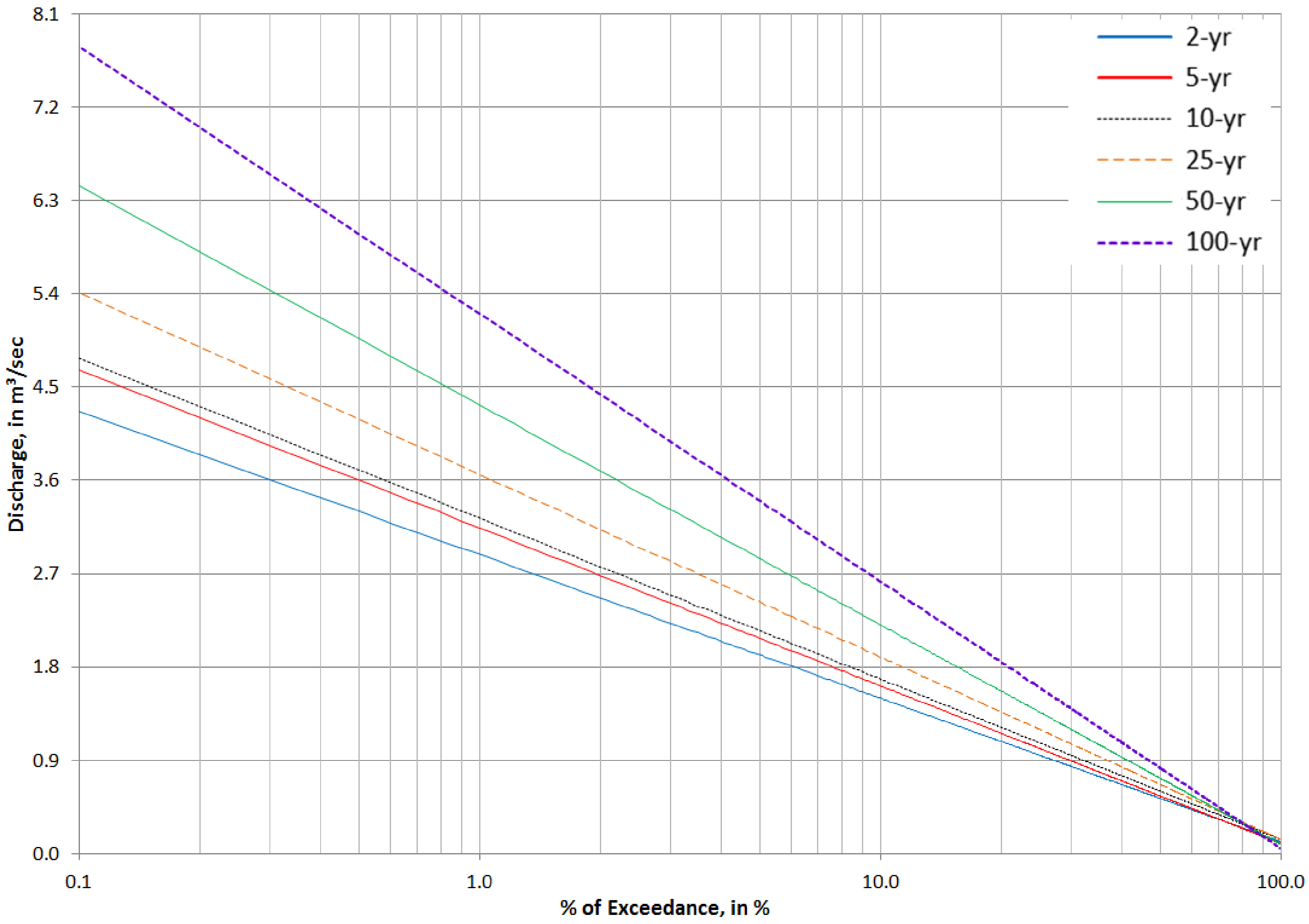


Figure I.15 Flow Duration Curves of Subwatershed #14

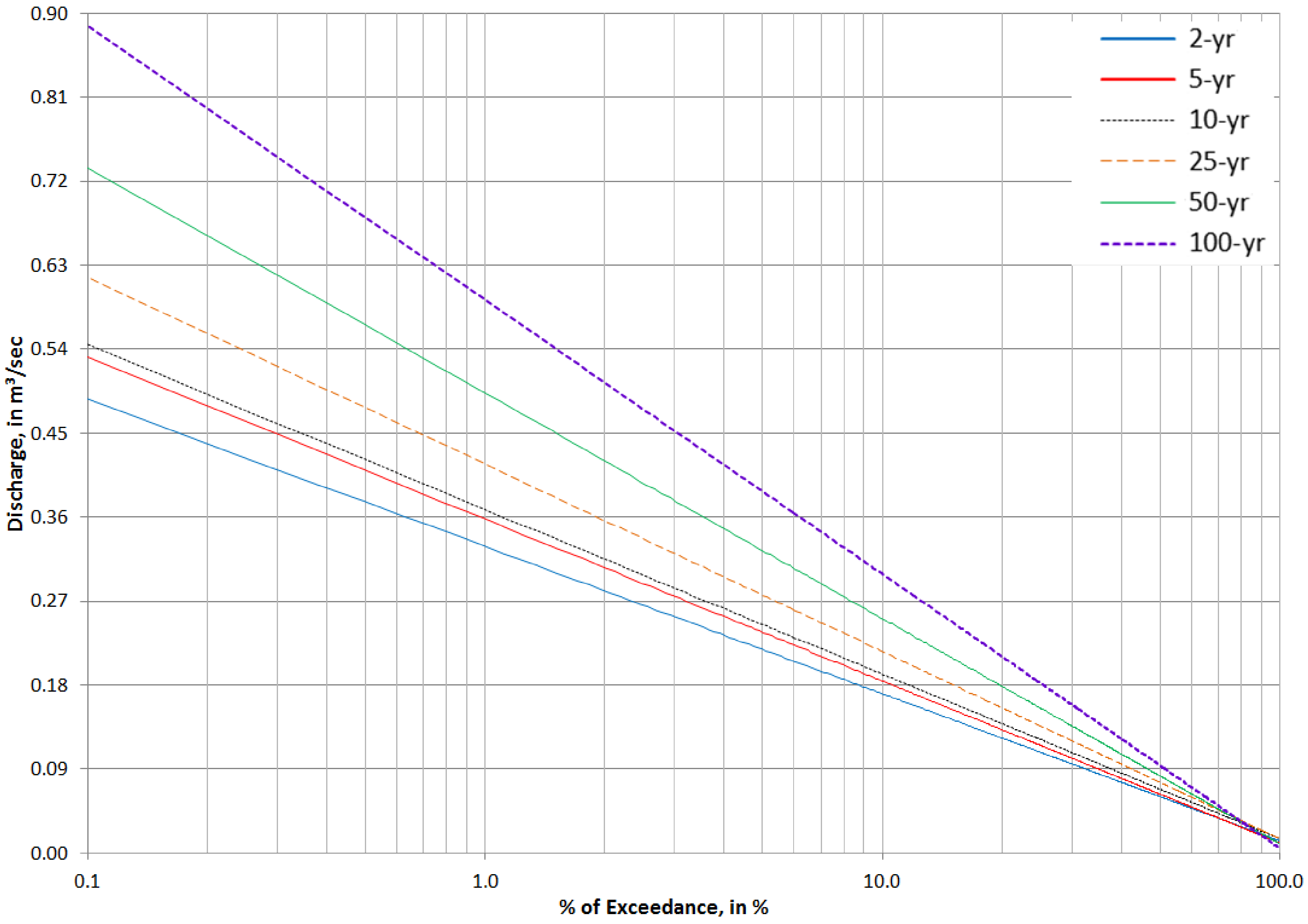


Figure I.16 Flow Duration Curves of Subwatershed #15

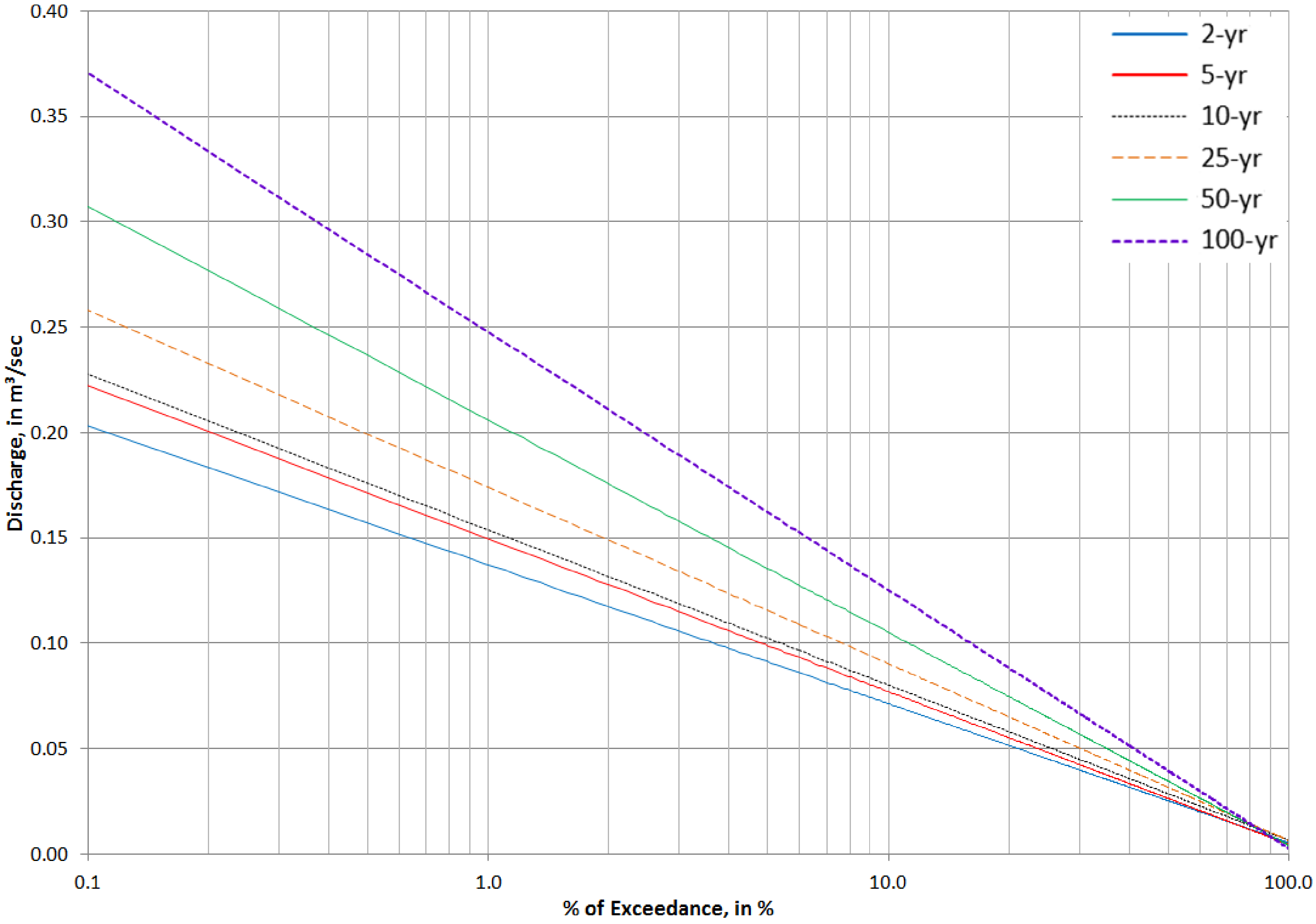


Figure I.17 Flow Duration Curves of Subwatershed #16

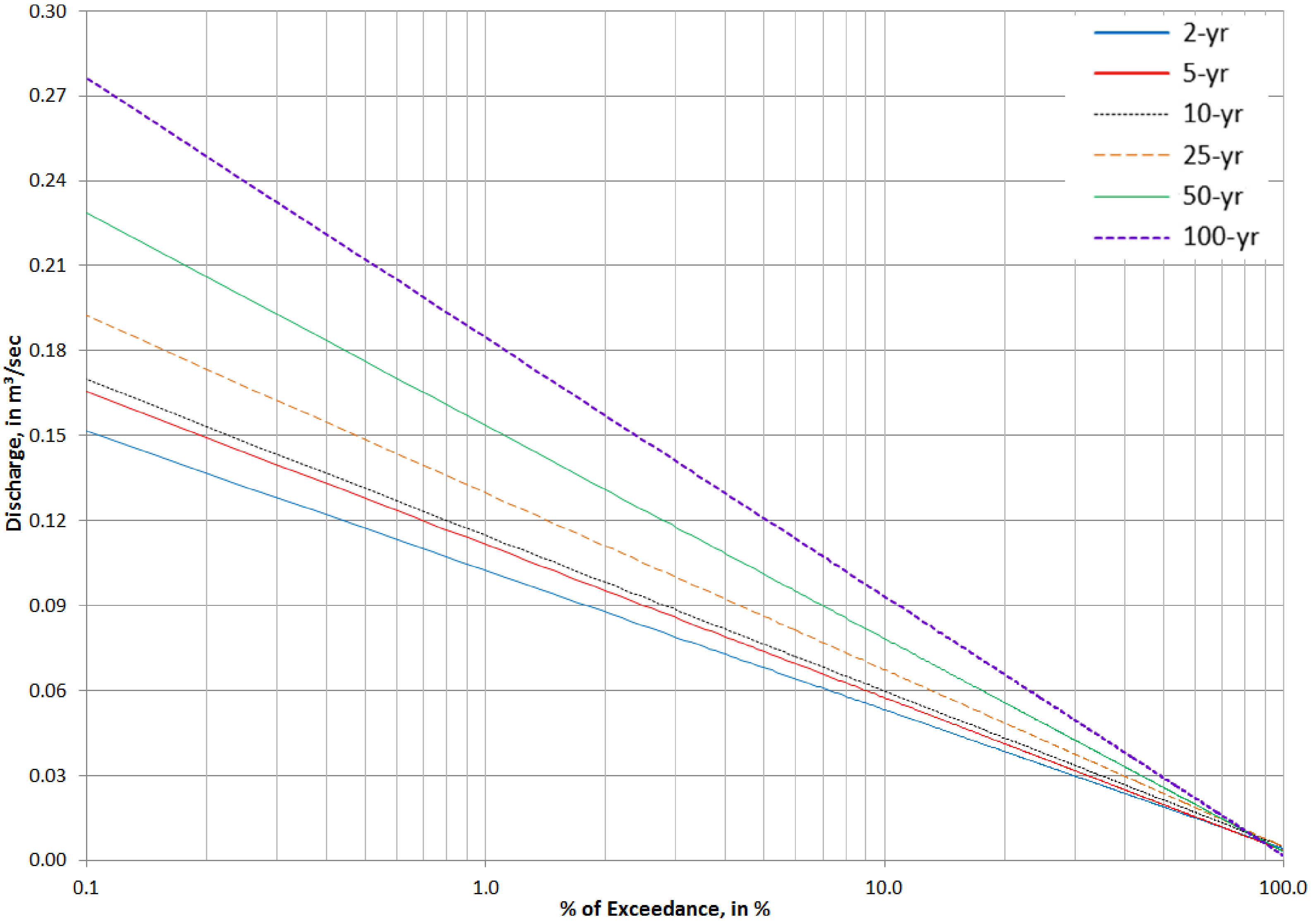


Figure I.18 Flow Duration Curves of Subwatershed #17

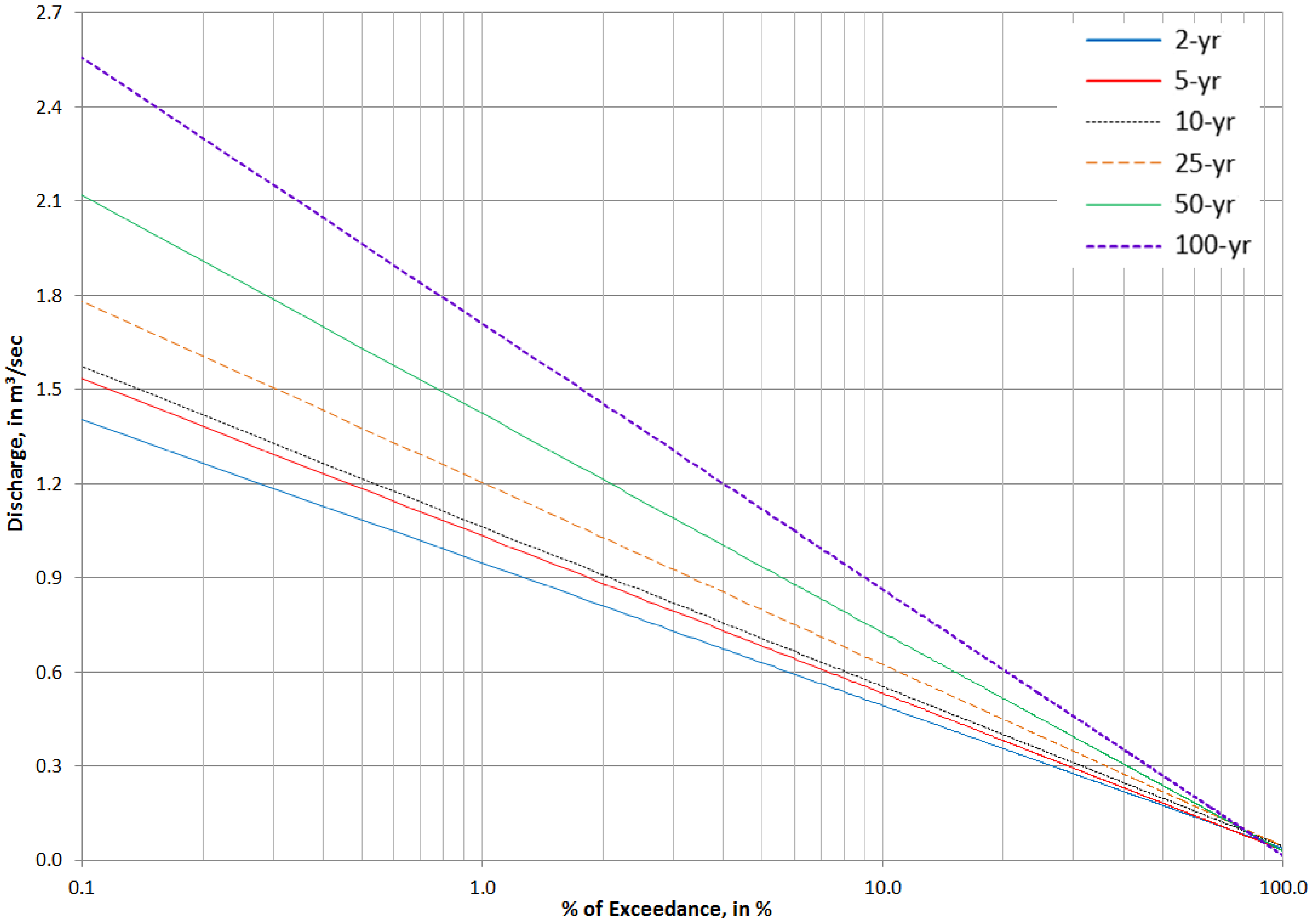


Figure I.19 Flow Duration Curves of Subwatershed #18

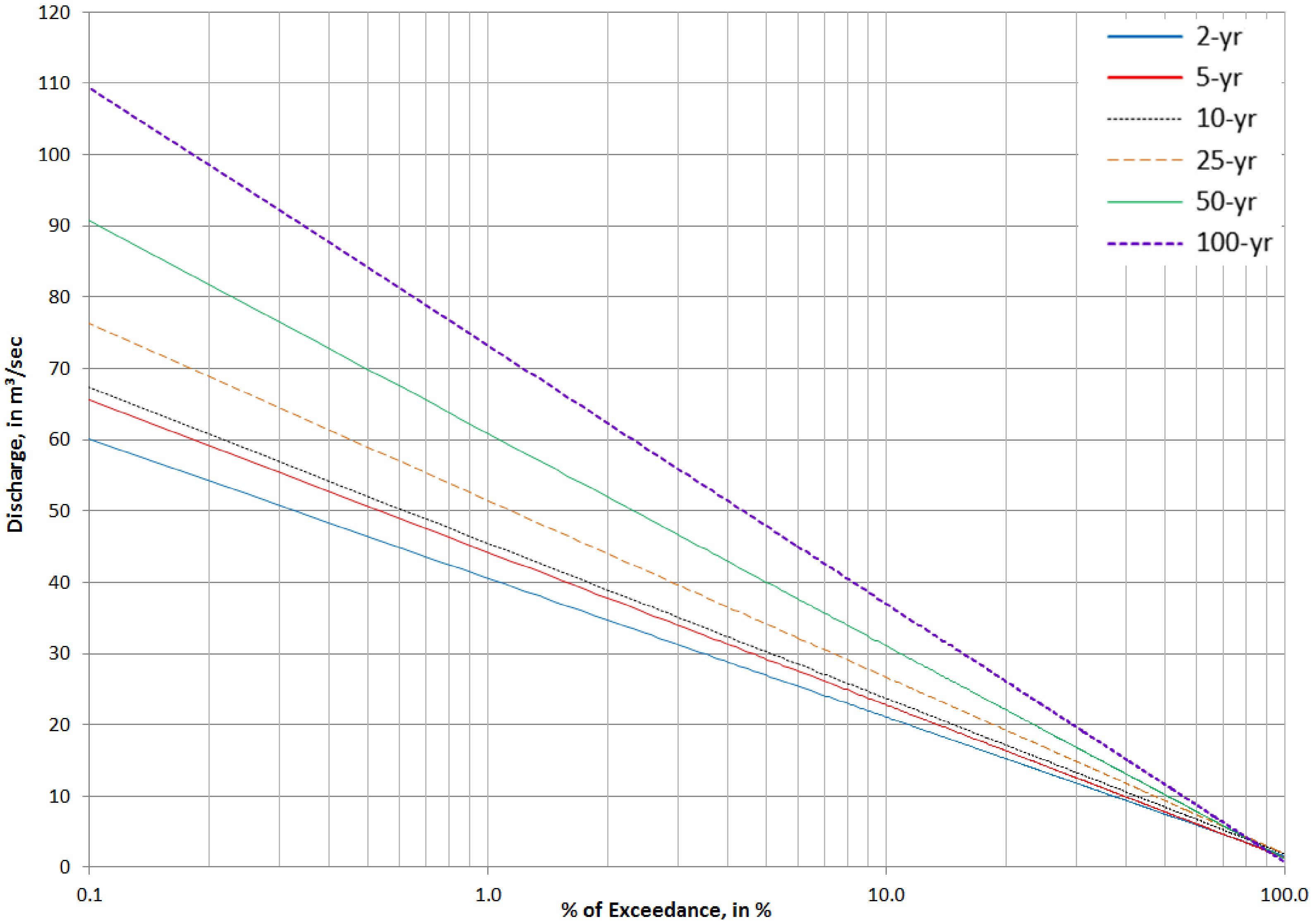


Figure I.20 Flow Duration Curves of Subwatershed #19

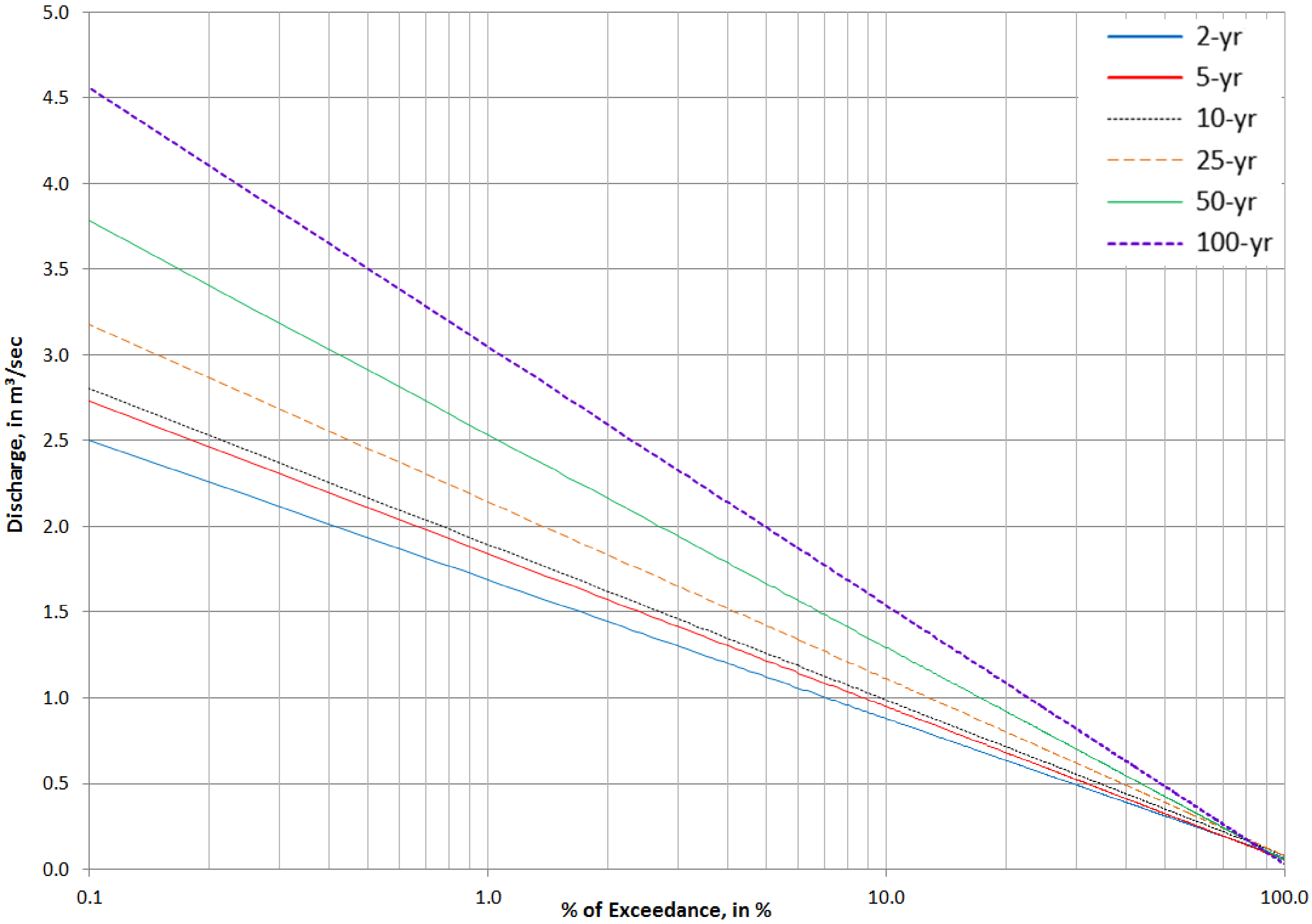


Figure I.21 Flow Duration Curves of Subwatershed #19A

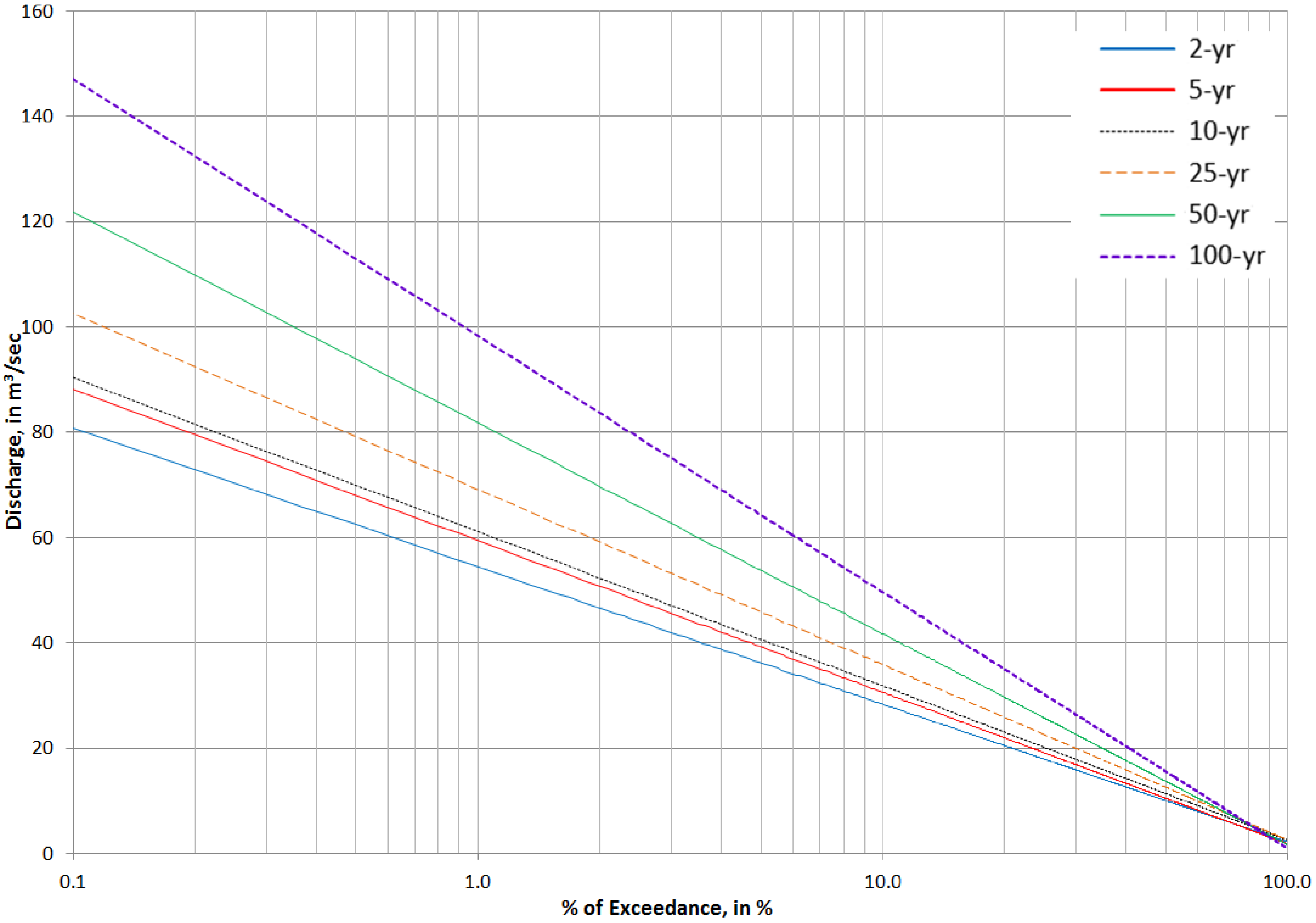


Figure I.22 Flow Duration Curves of Subwatershed #20

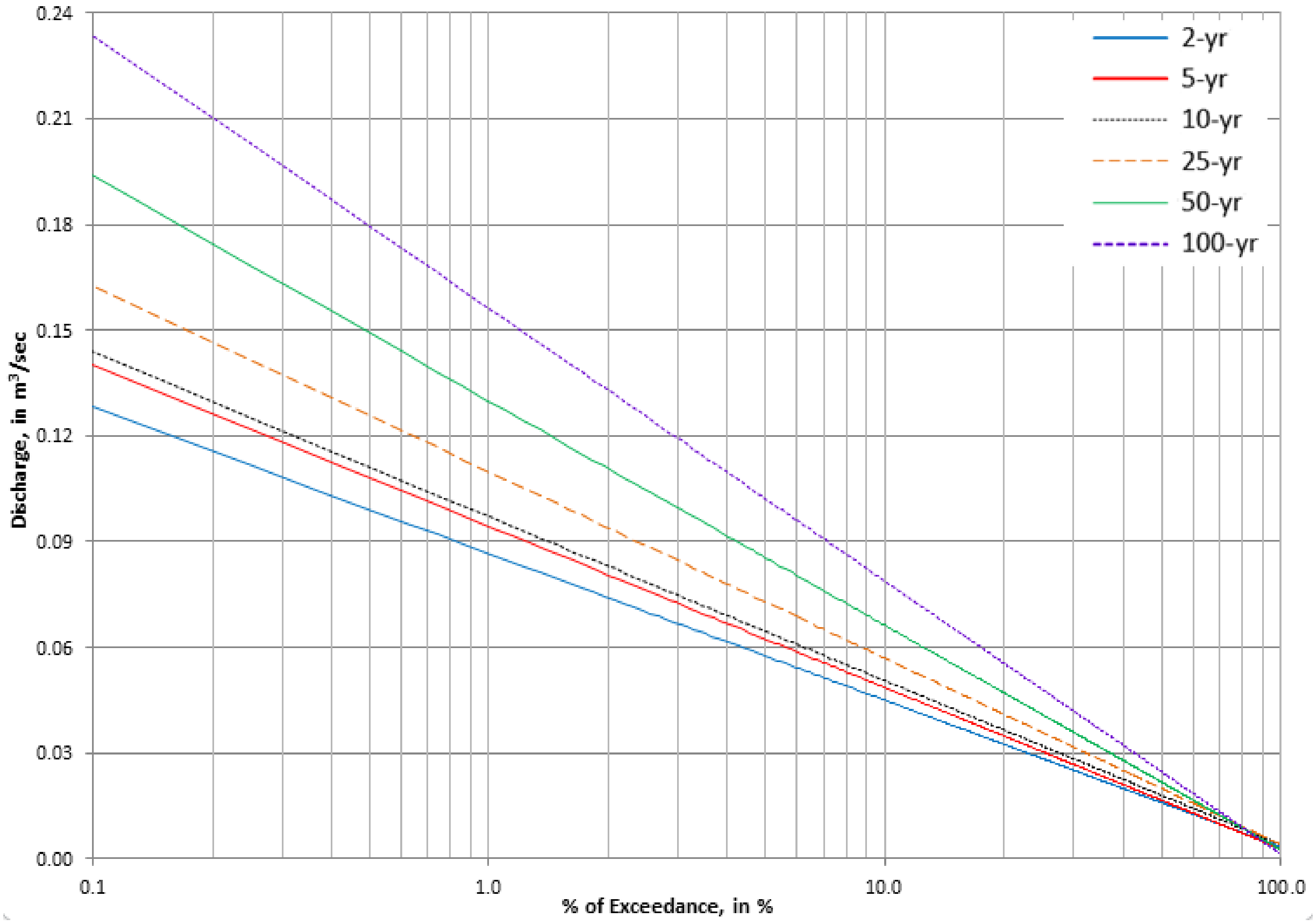


Figure I.23 Flow Duration Curves of Subwatershed #21

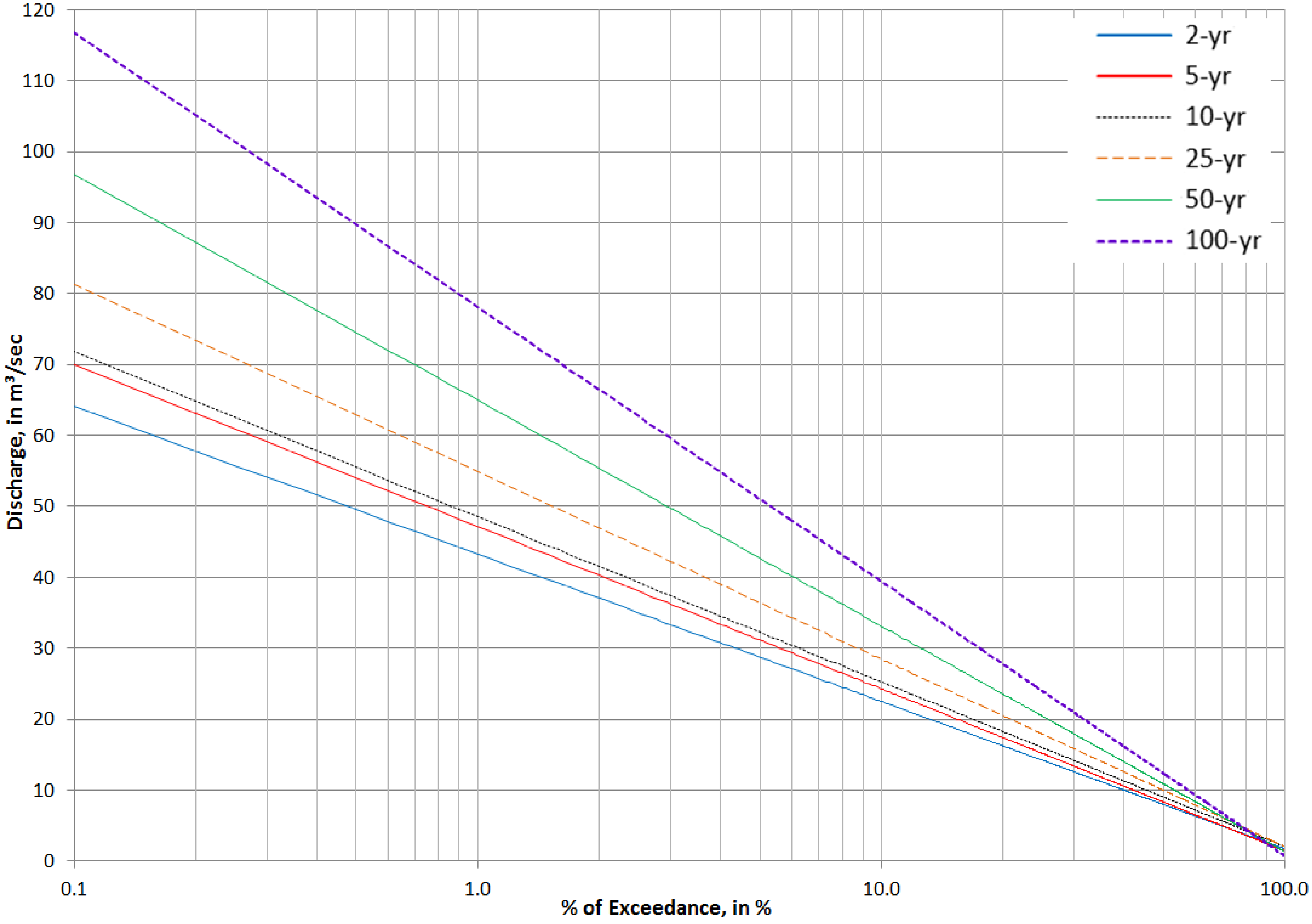


Figure I.24 Flow Duration Curves of Subwatershed #22

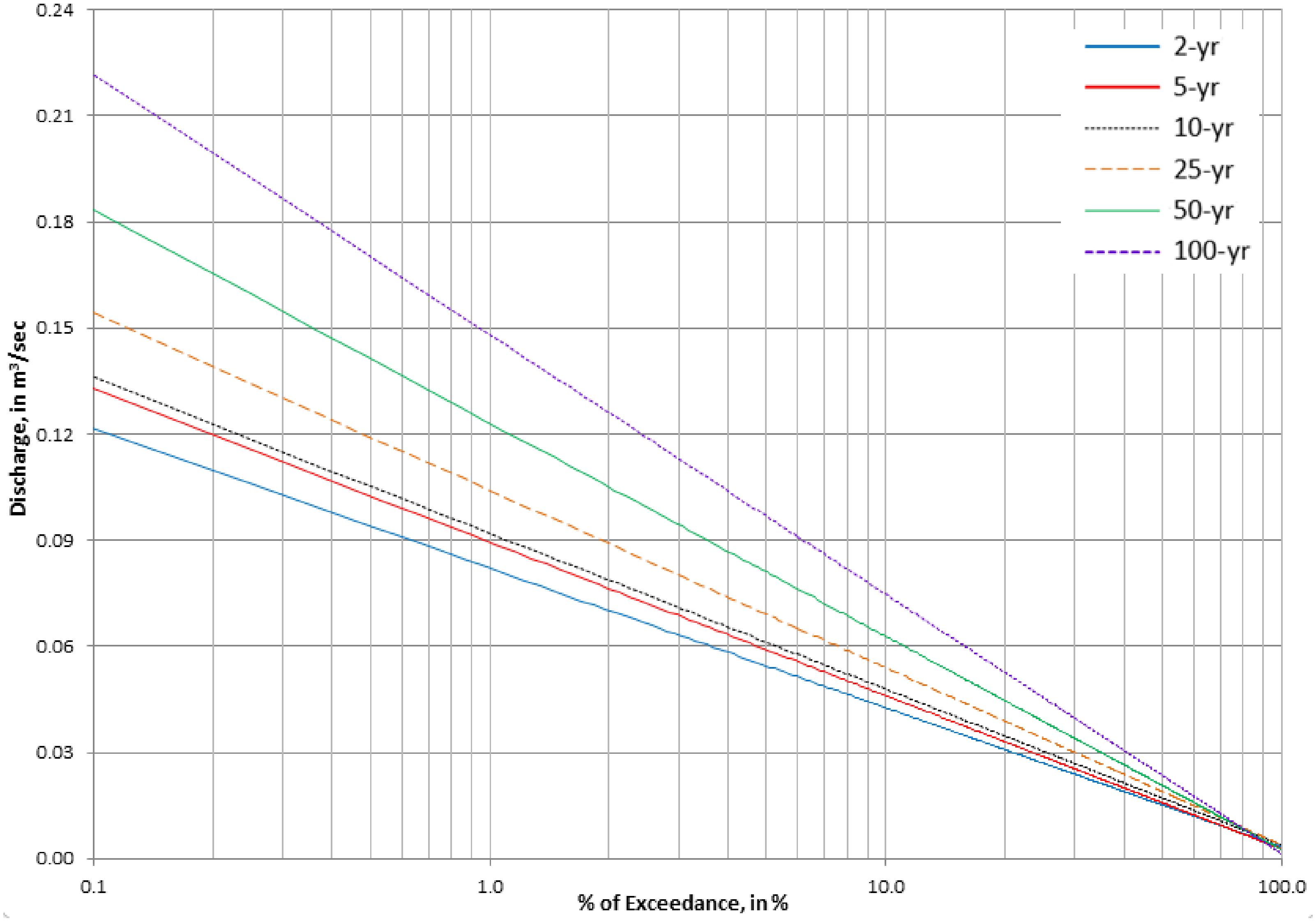


Figure I.25 Flow Duration Curves of Subwatershed #23

Appendix J

Low Flow Curves

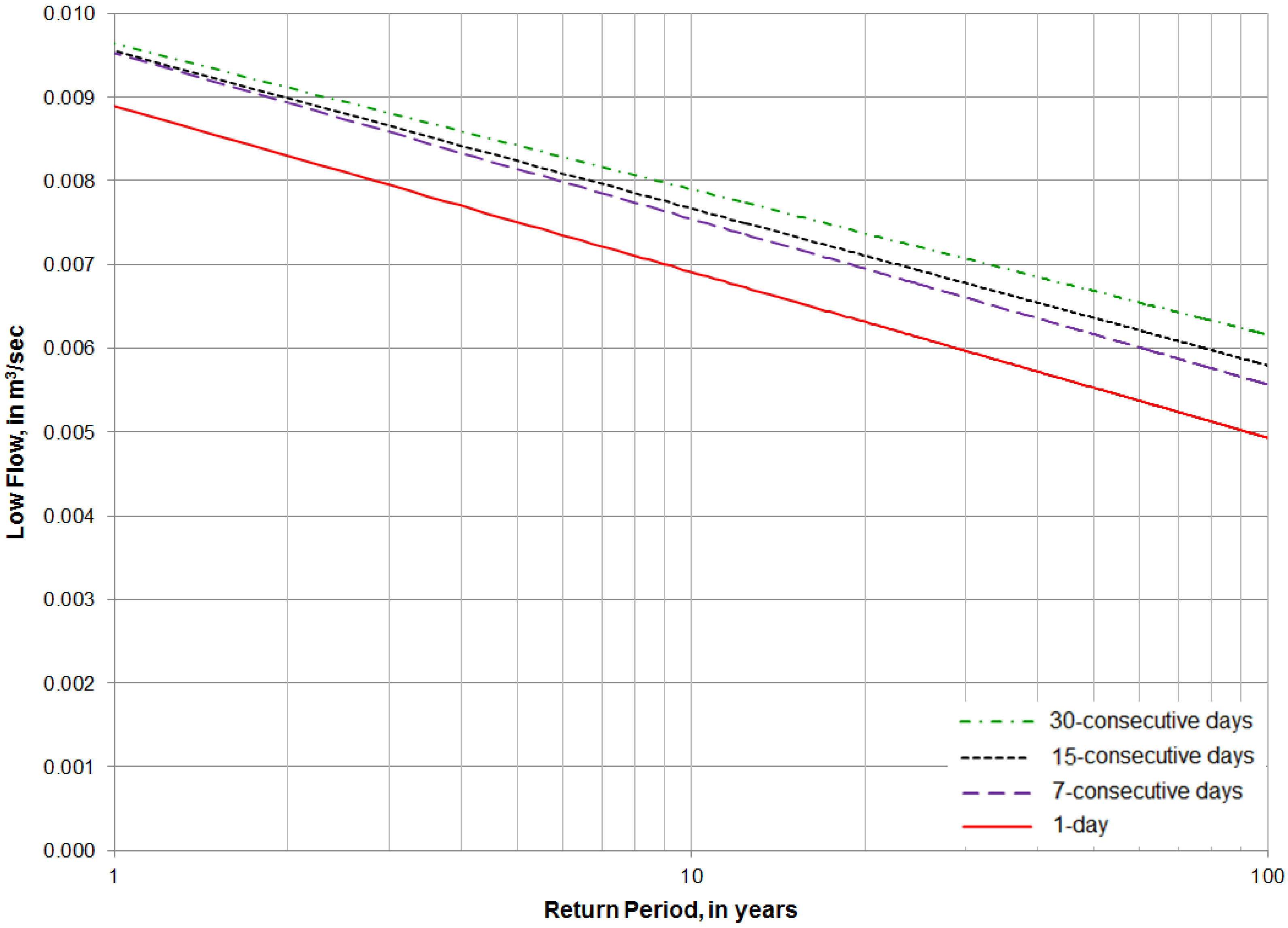


Figure J.1 Low Flow Curves of Subwatershed #1.

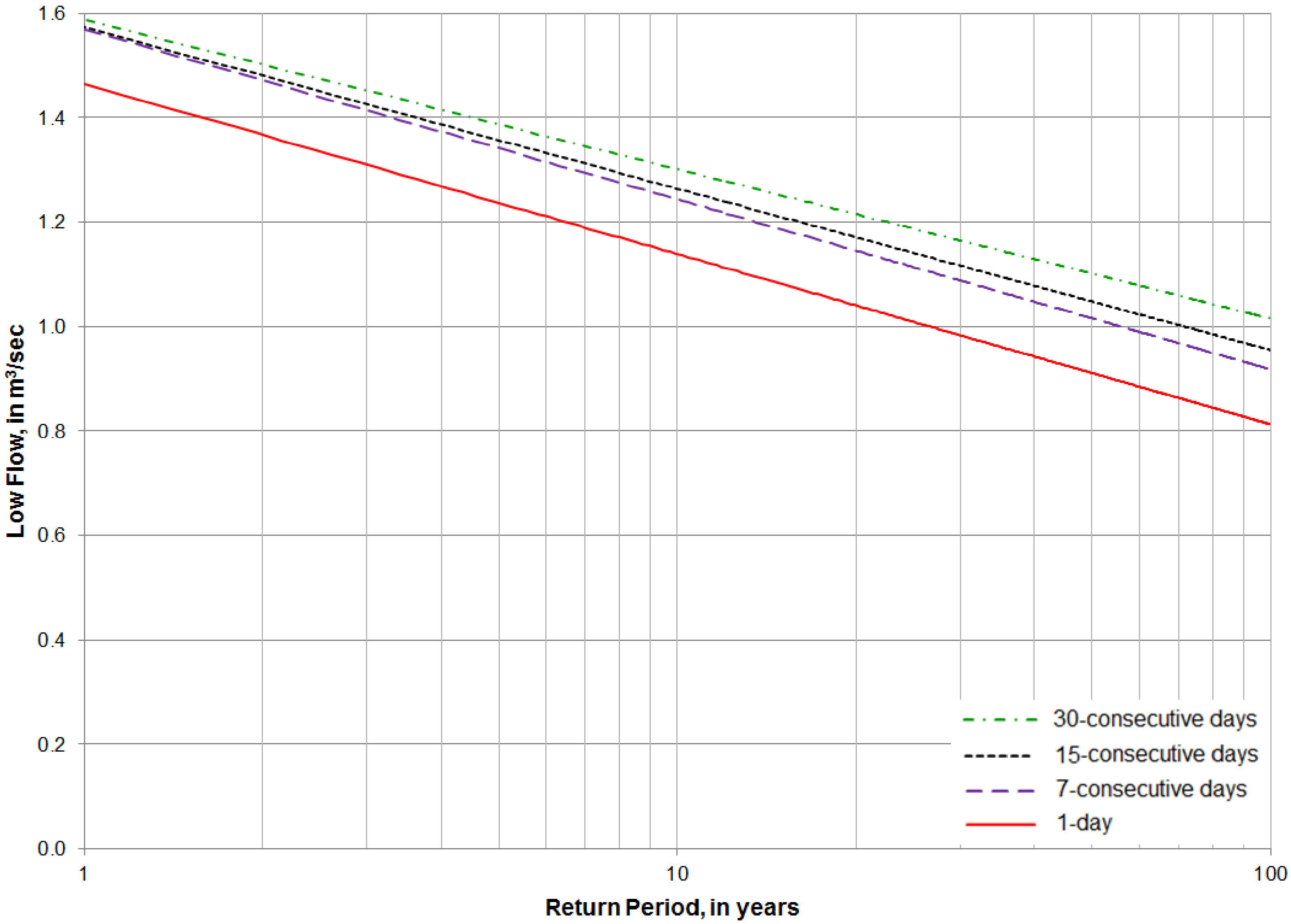


Figure J.2 Low Flow Curves of Subwatershed #2.

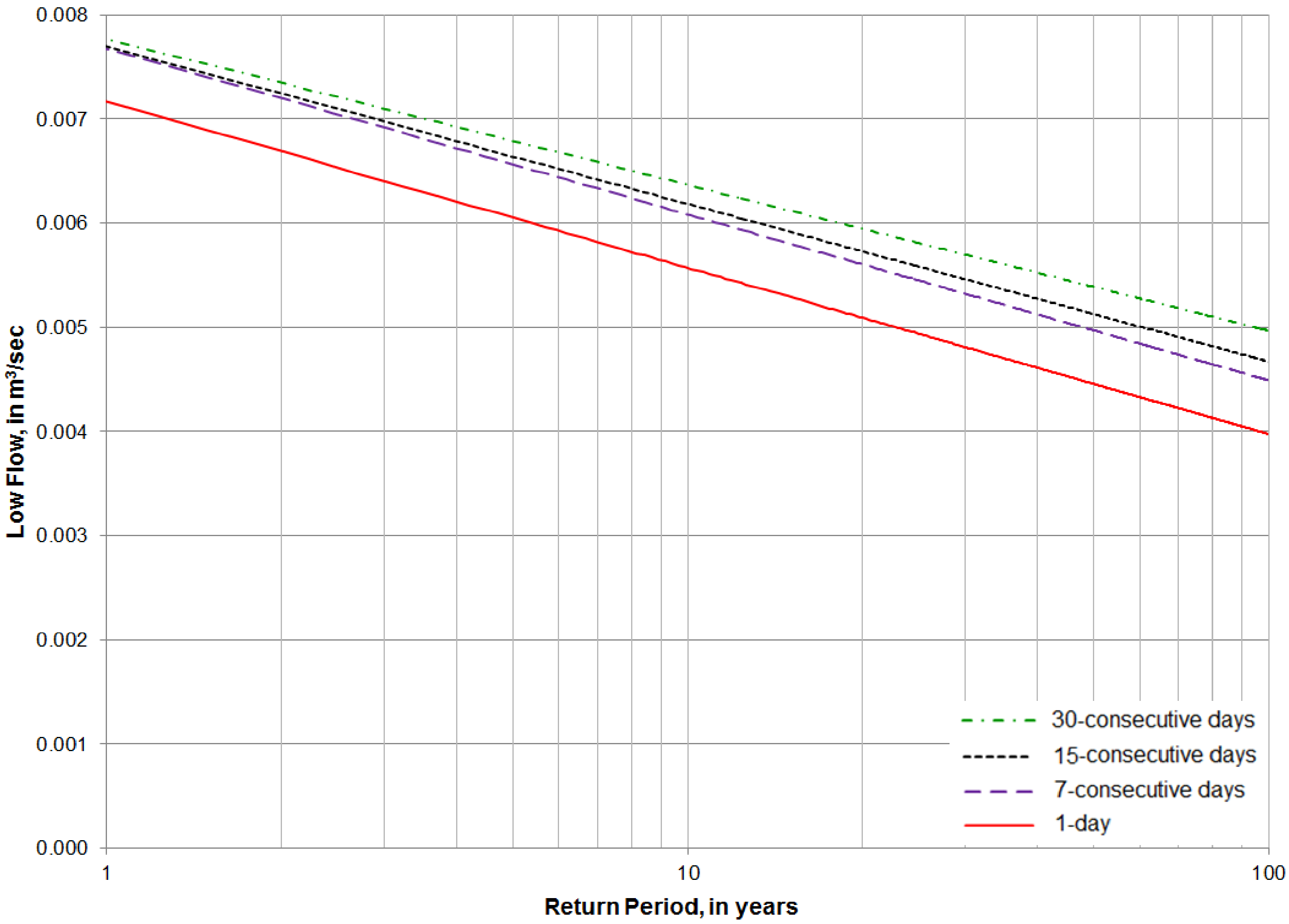


Figure J.3 Low Flow Curves of Subwatershed #3.

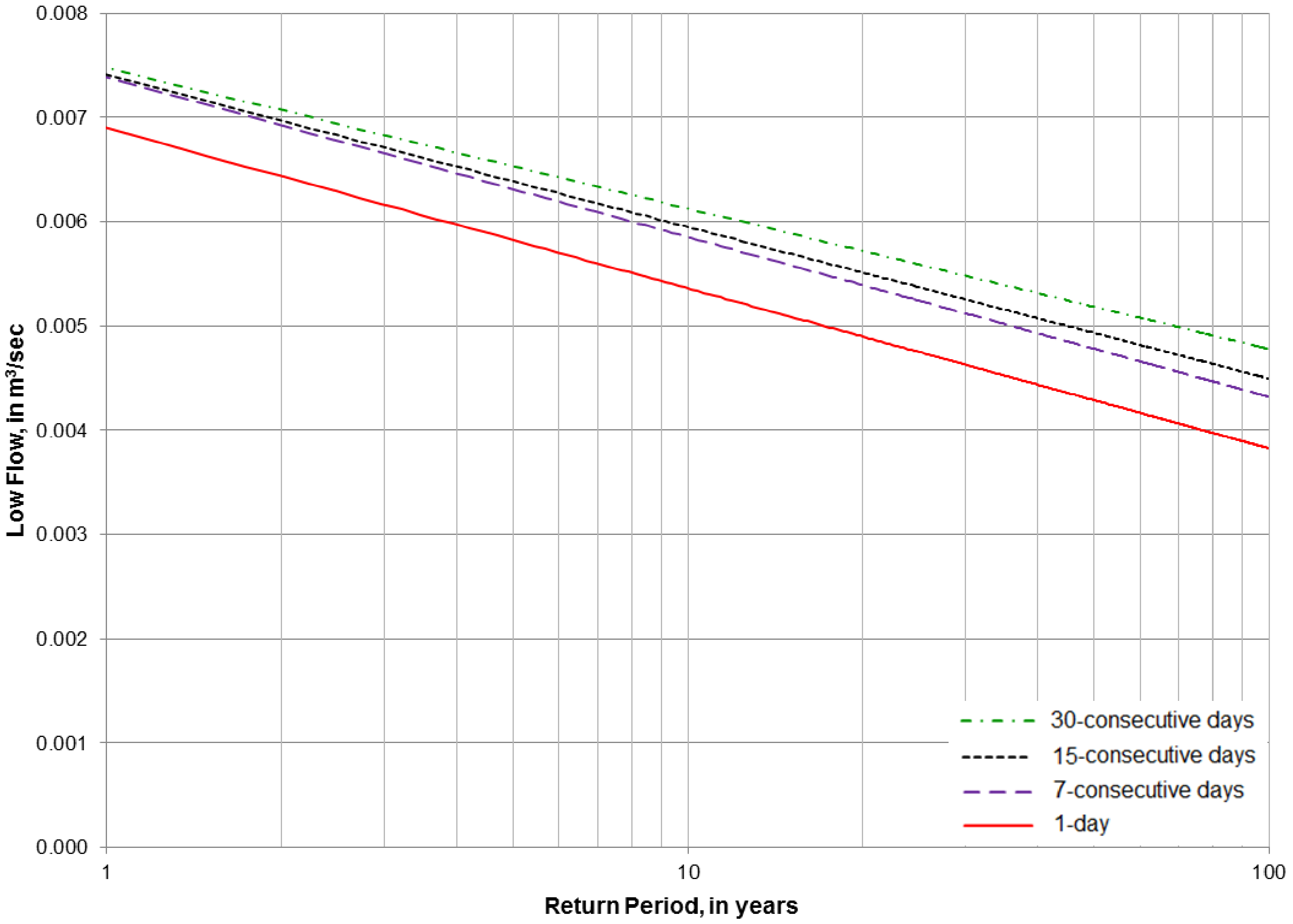


Figure J.4 Low Flow Curves of Subwatershed #3A.

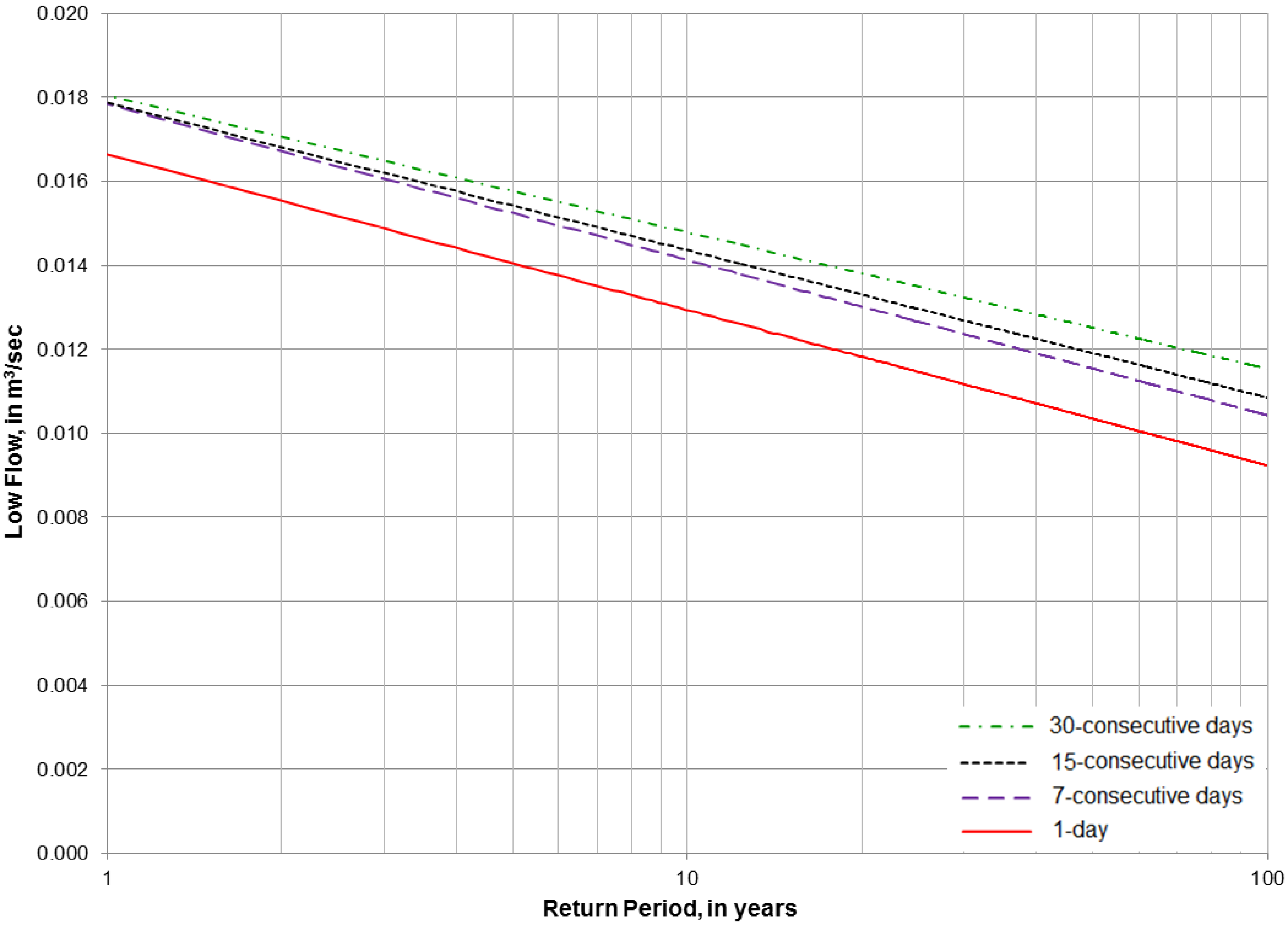


Figure J.5 Low Flow Curves of Subwatershed #4.

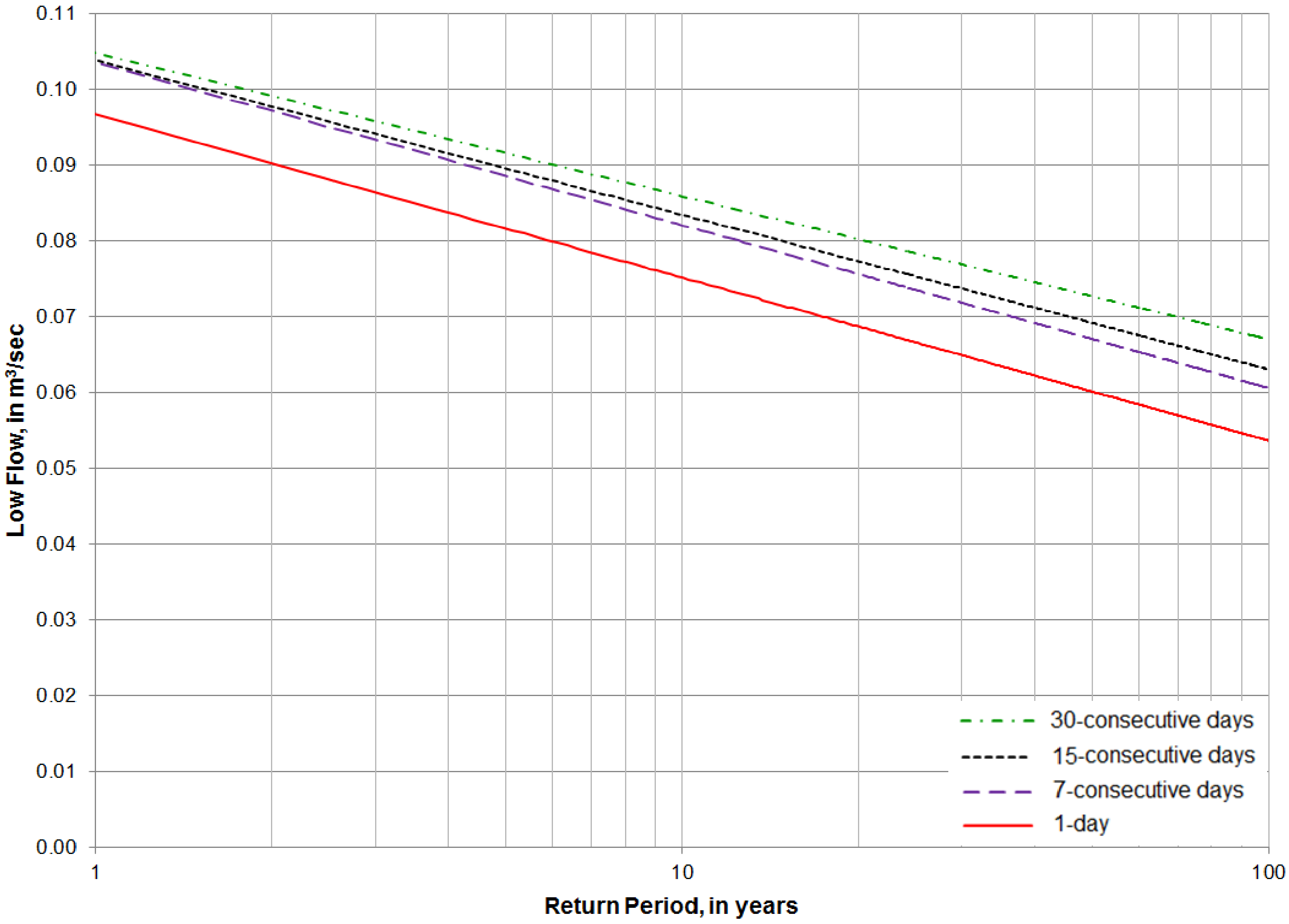


Figure J.6 Low Flow Curves of Subwatershed #5.

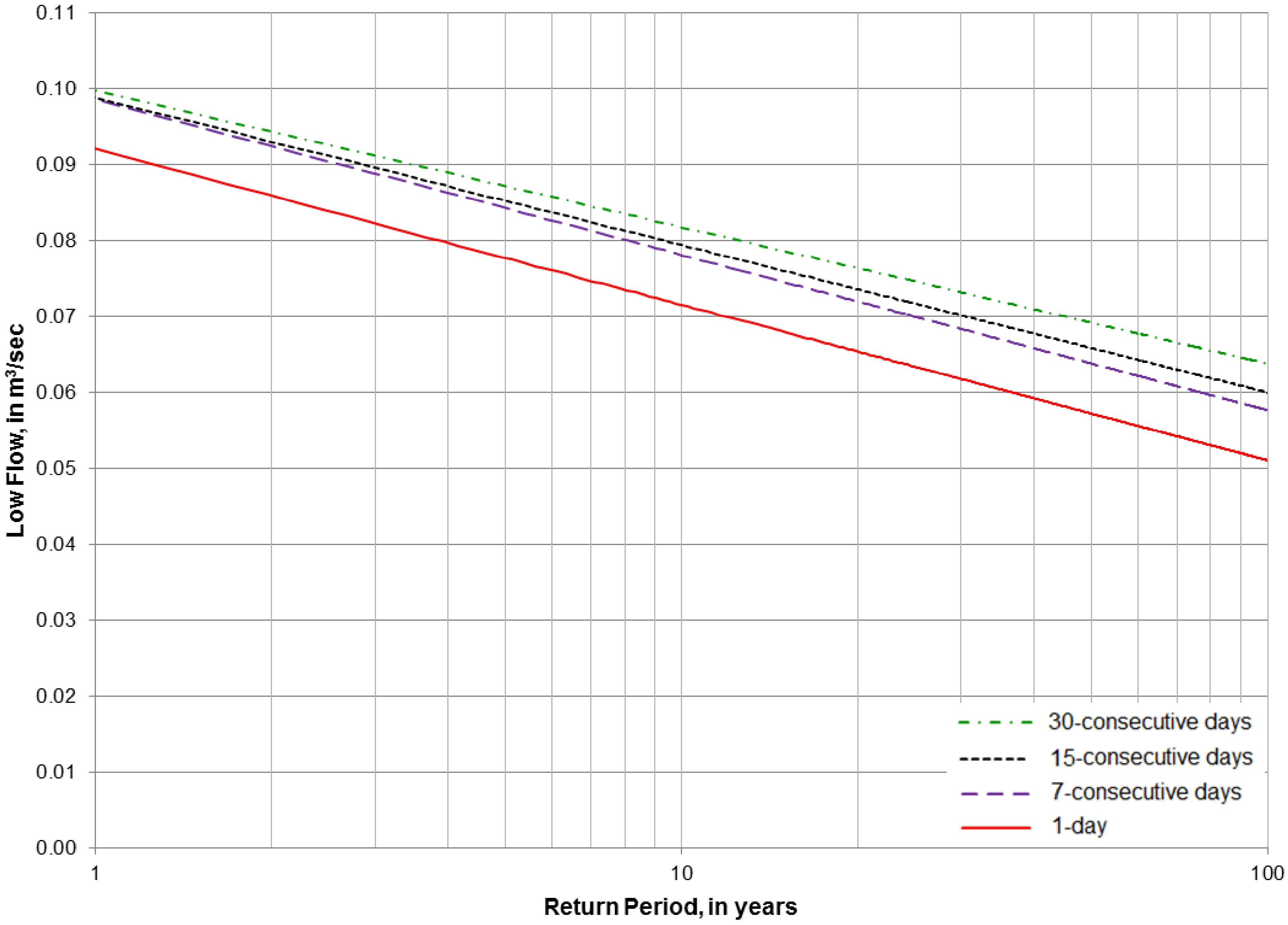


Figure J.7 Low Flow Curves of Subwatershed #6.

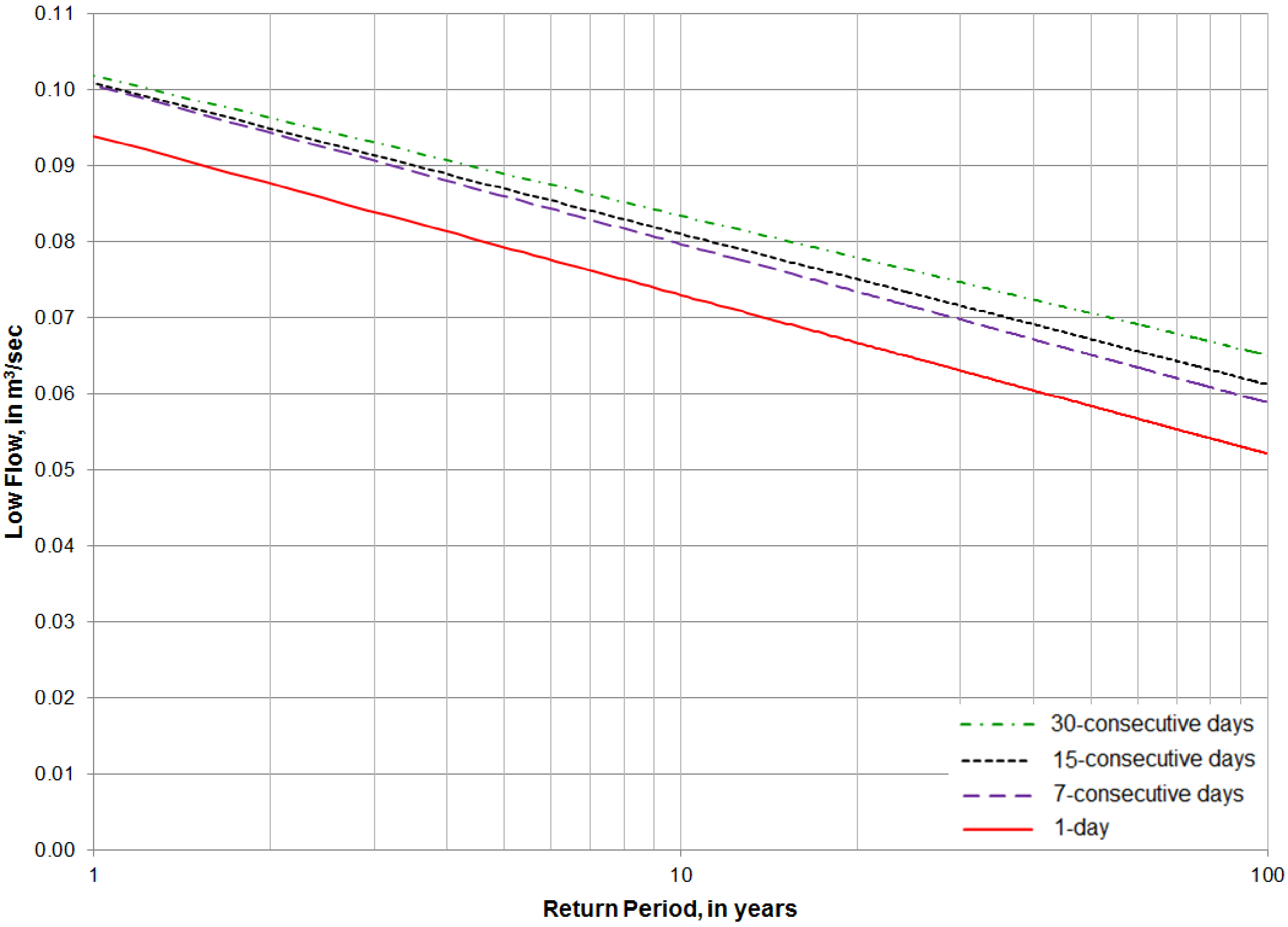


Figure J.8 Low Flow Curves of Subwatershed #7.

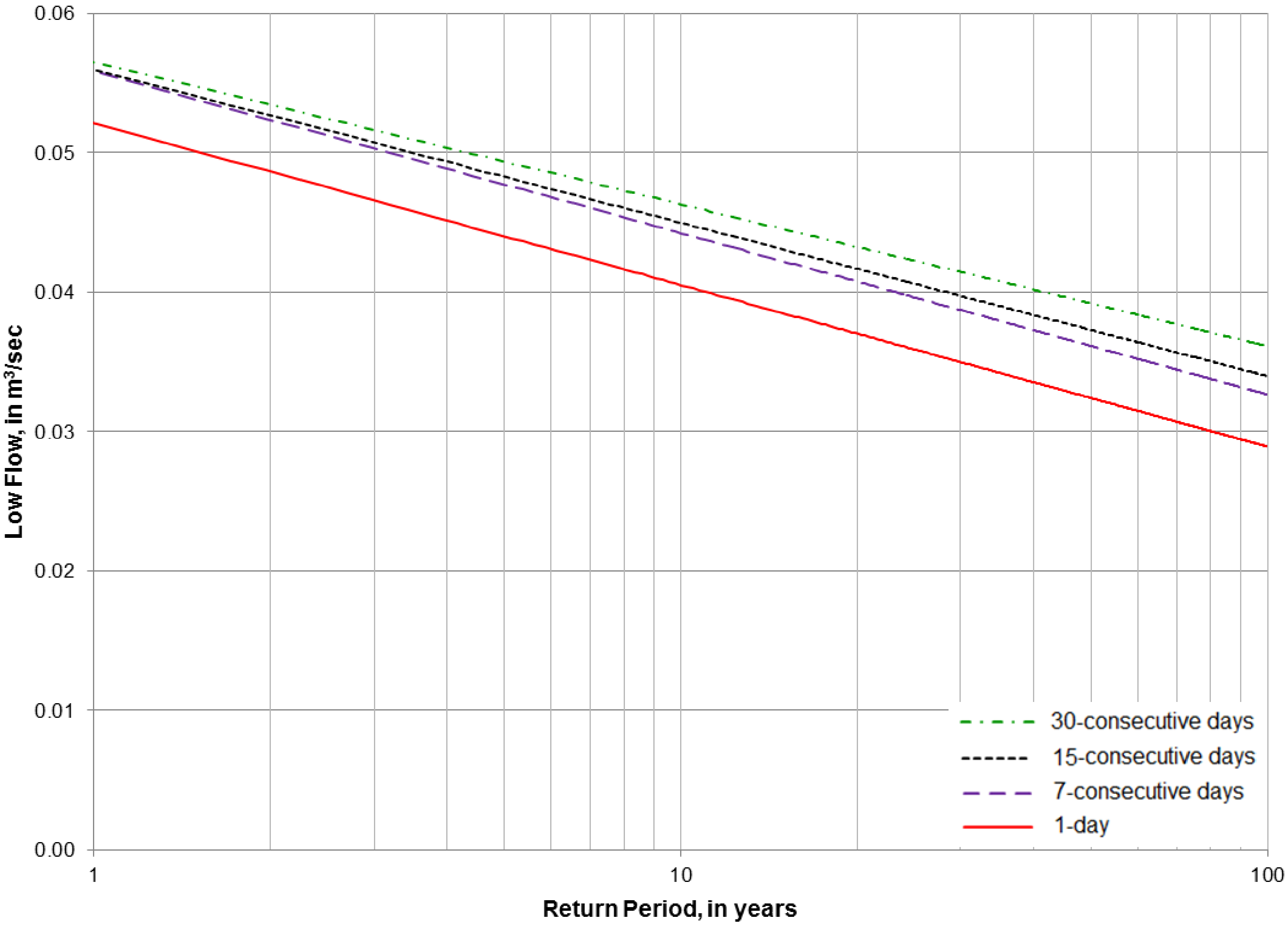


Figure J.9 Low Flow Curves of Subwatershed #8.

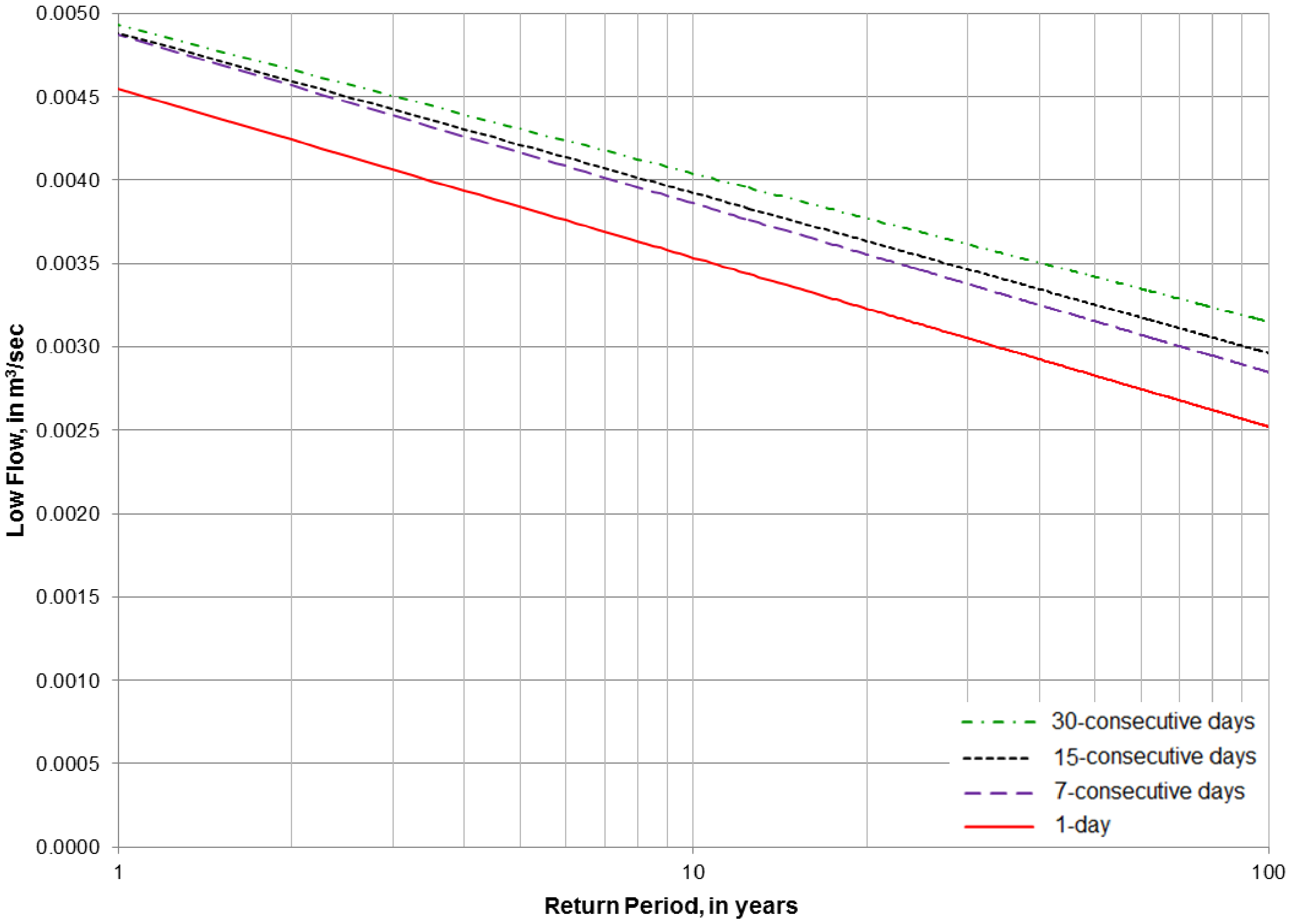


Figure J.10 Low Flow Curves of Subwatershed #9.

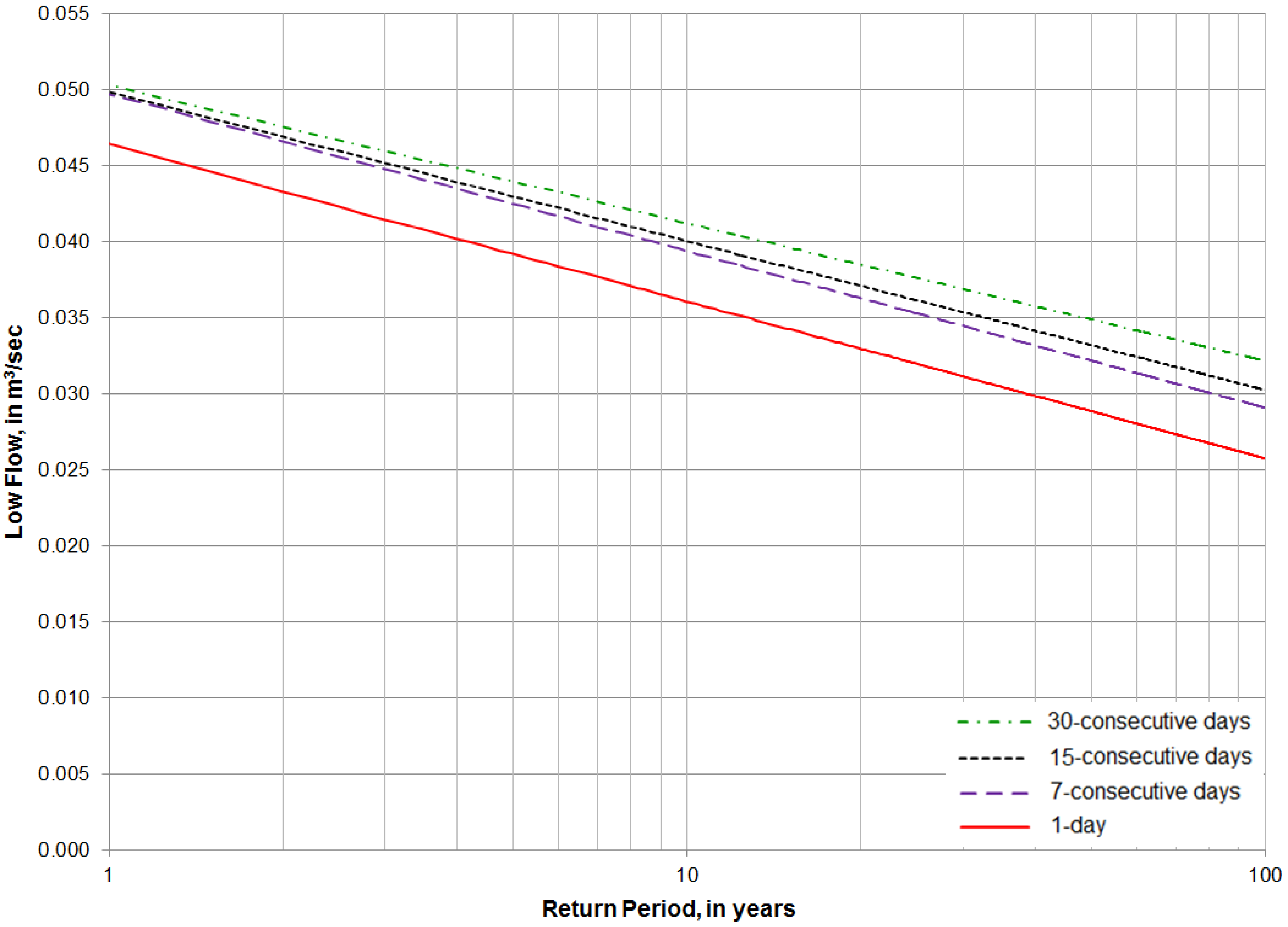


Figure J.11 Low Flow Curves of Subwatershed #10.

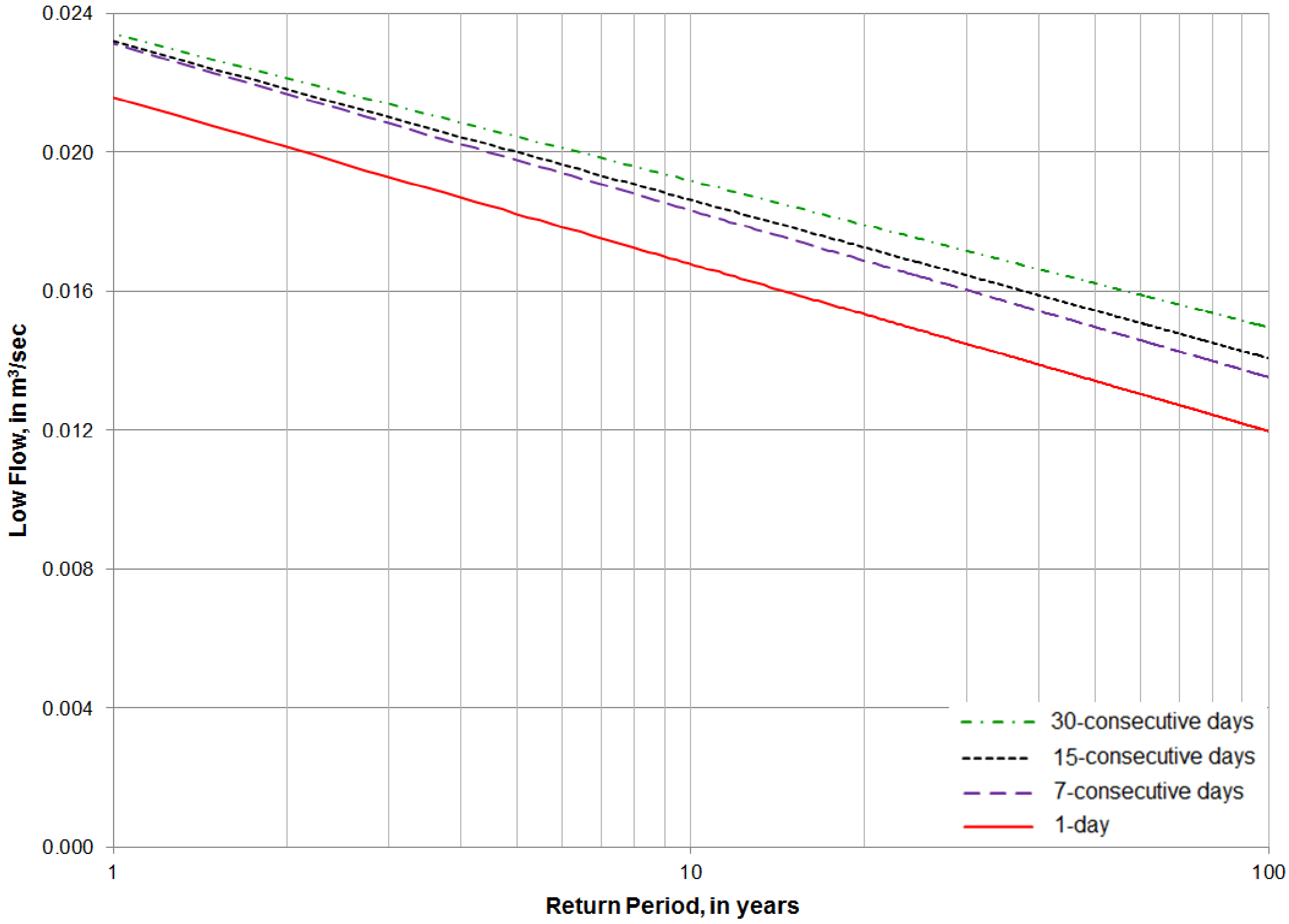


Figure J.12 Low Flow Curves of Subwatershed #11.

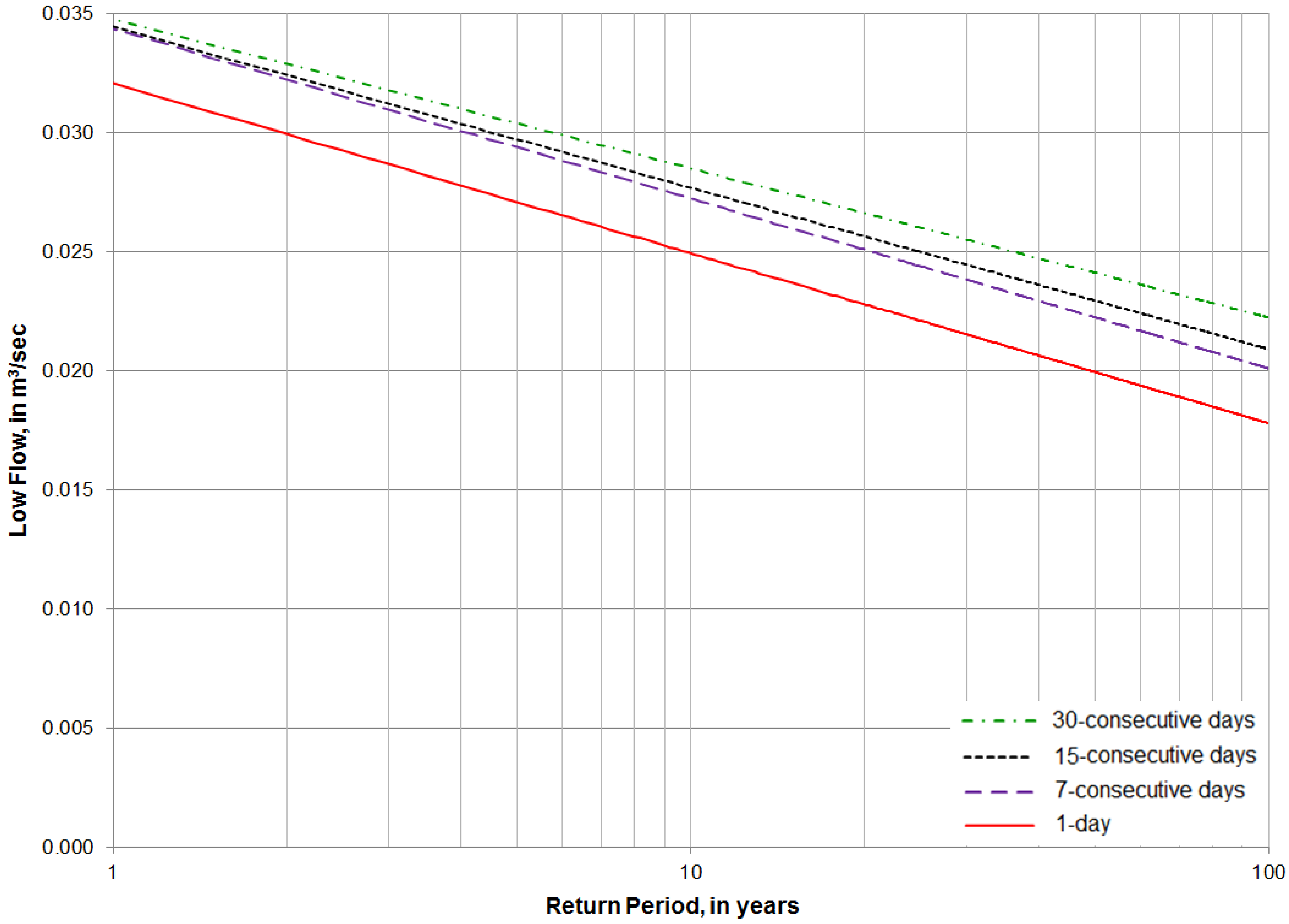


Figure J.13 Low Flow Curves of Subwatershed #12.

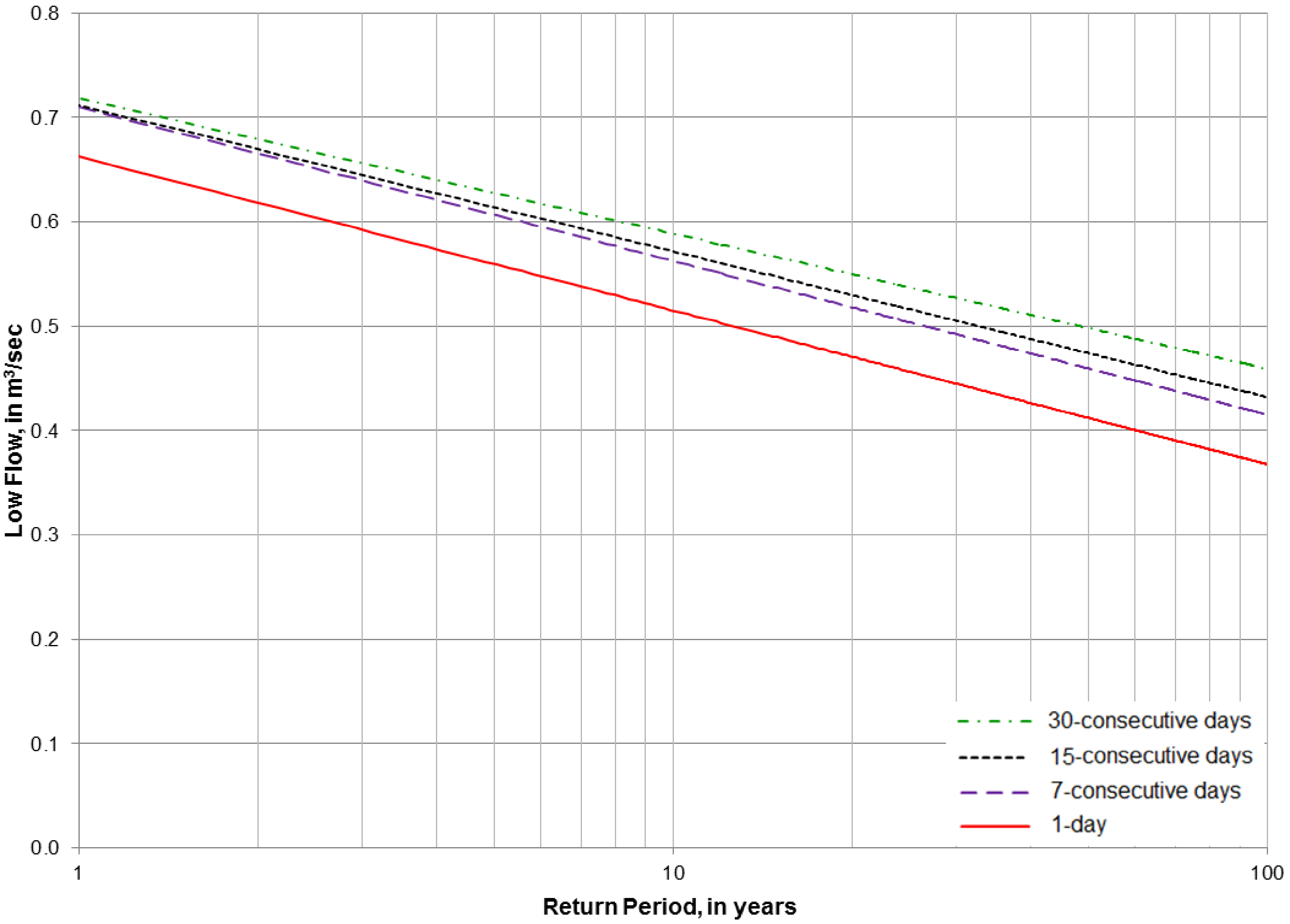


Figure J.14 Low Flow Curves of Subwatershed #13.

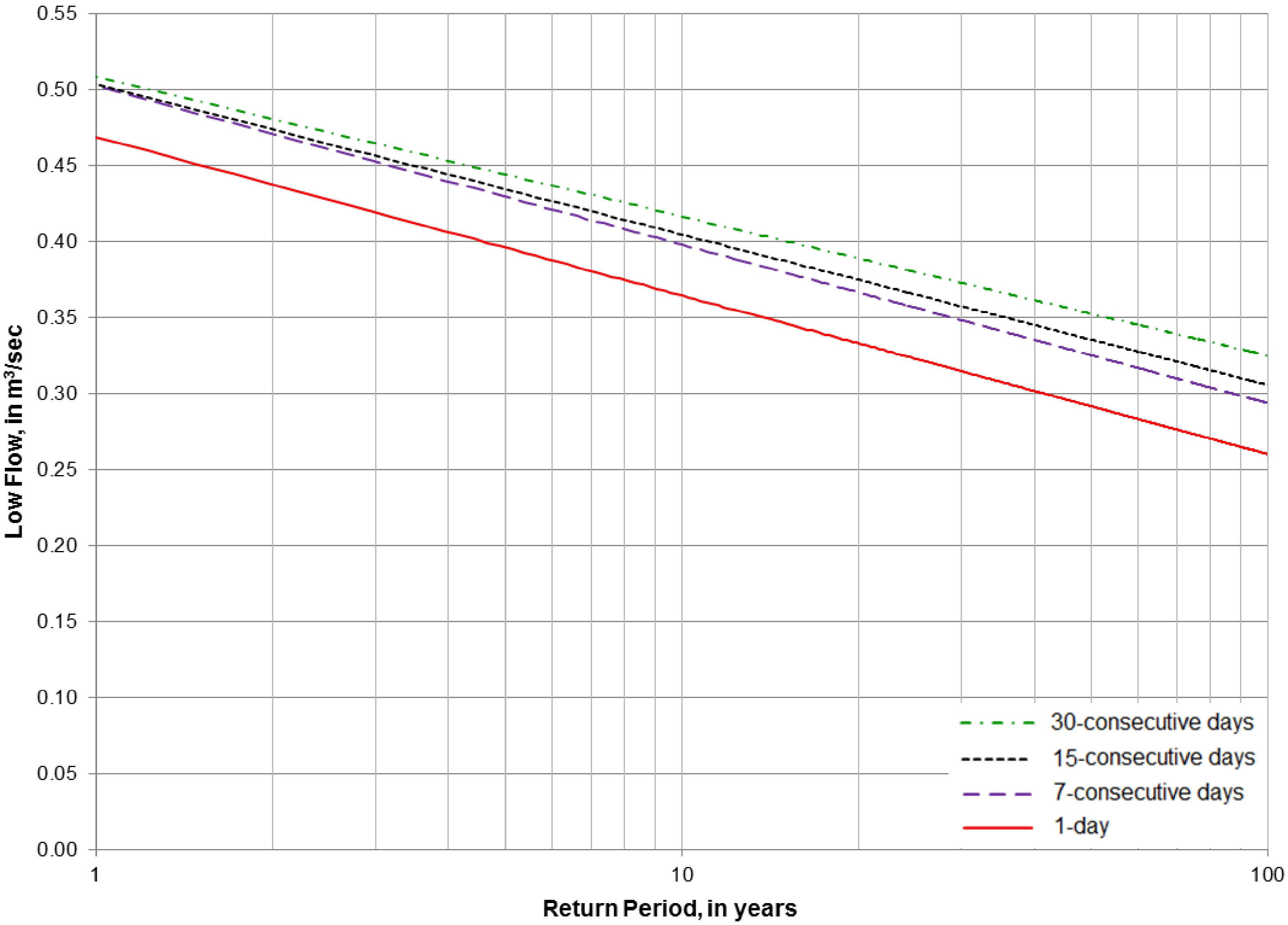


Figure J.15 Low Flow Curves of Subwatershed #14.

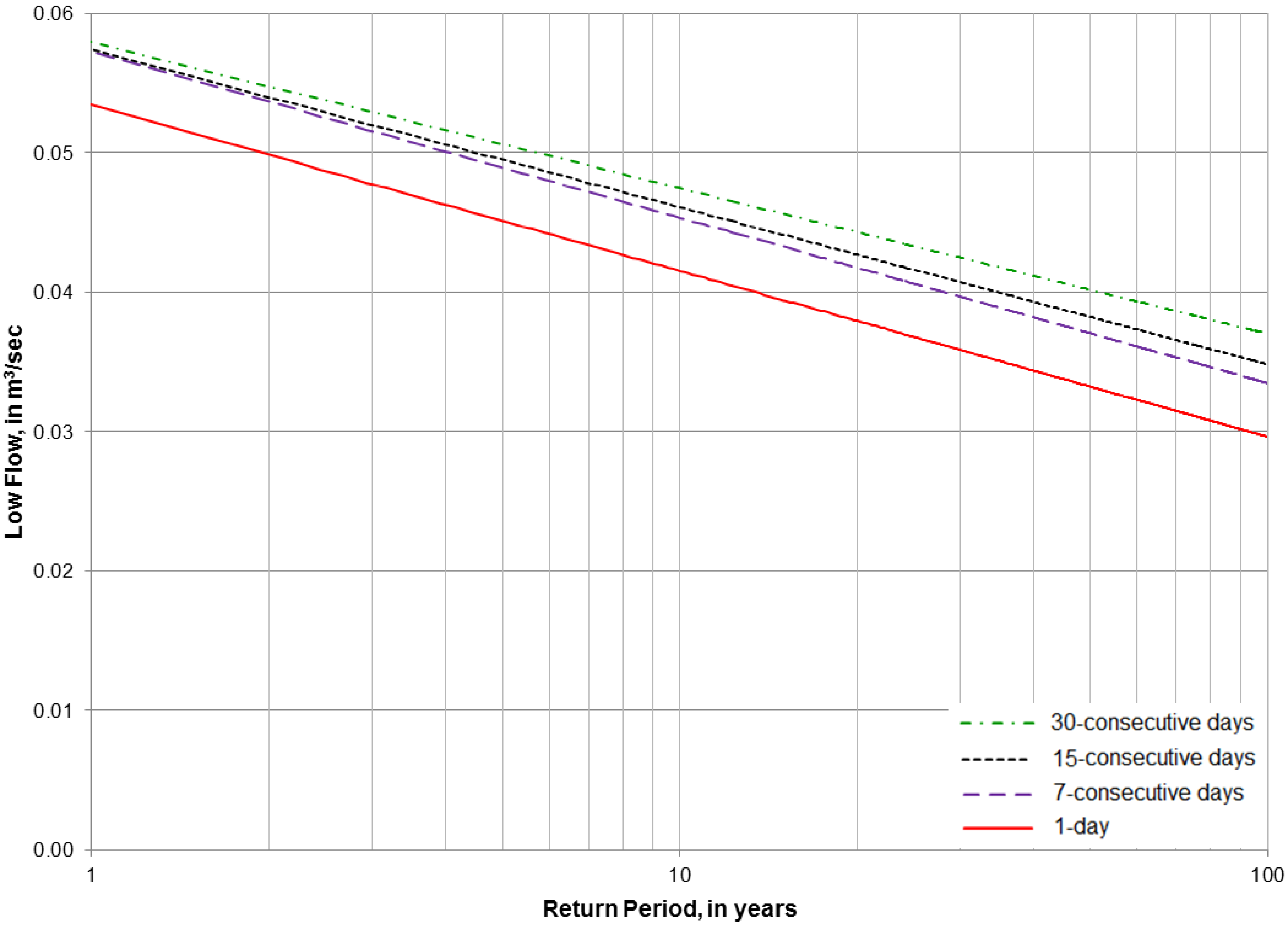


Figure J.16 Low Flow Curves of Subwatershed #15.

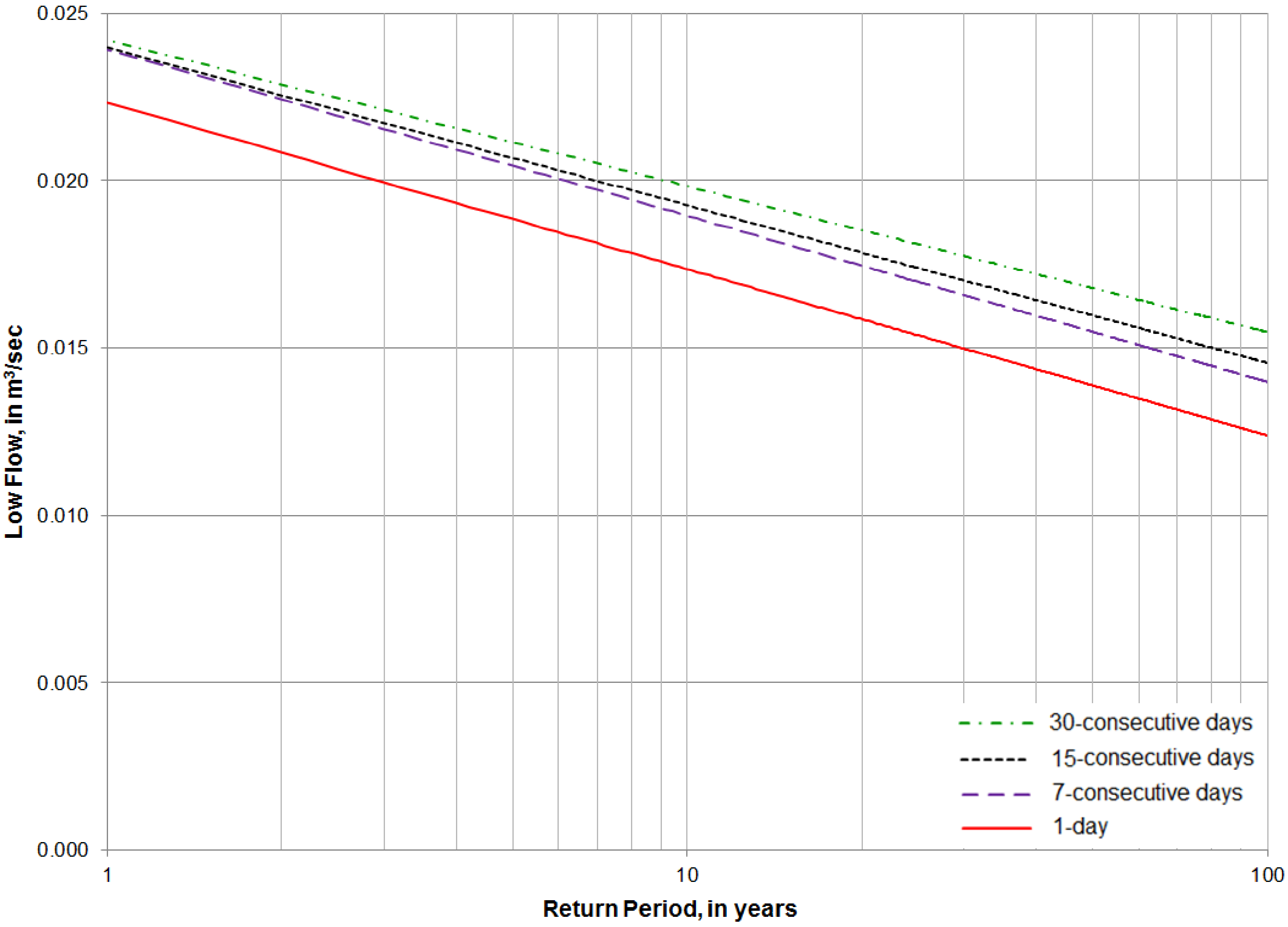


Figure J.17 Low Flow Curves of Subwatershed #16.

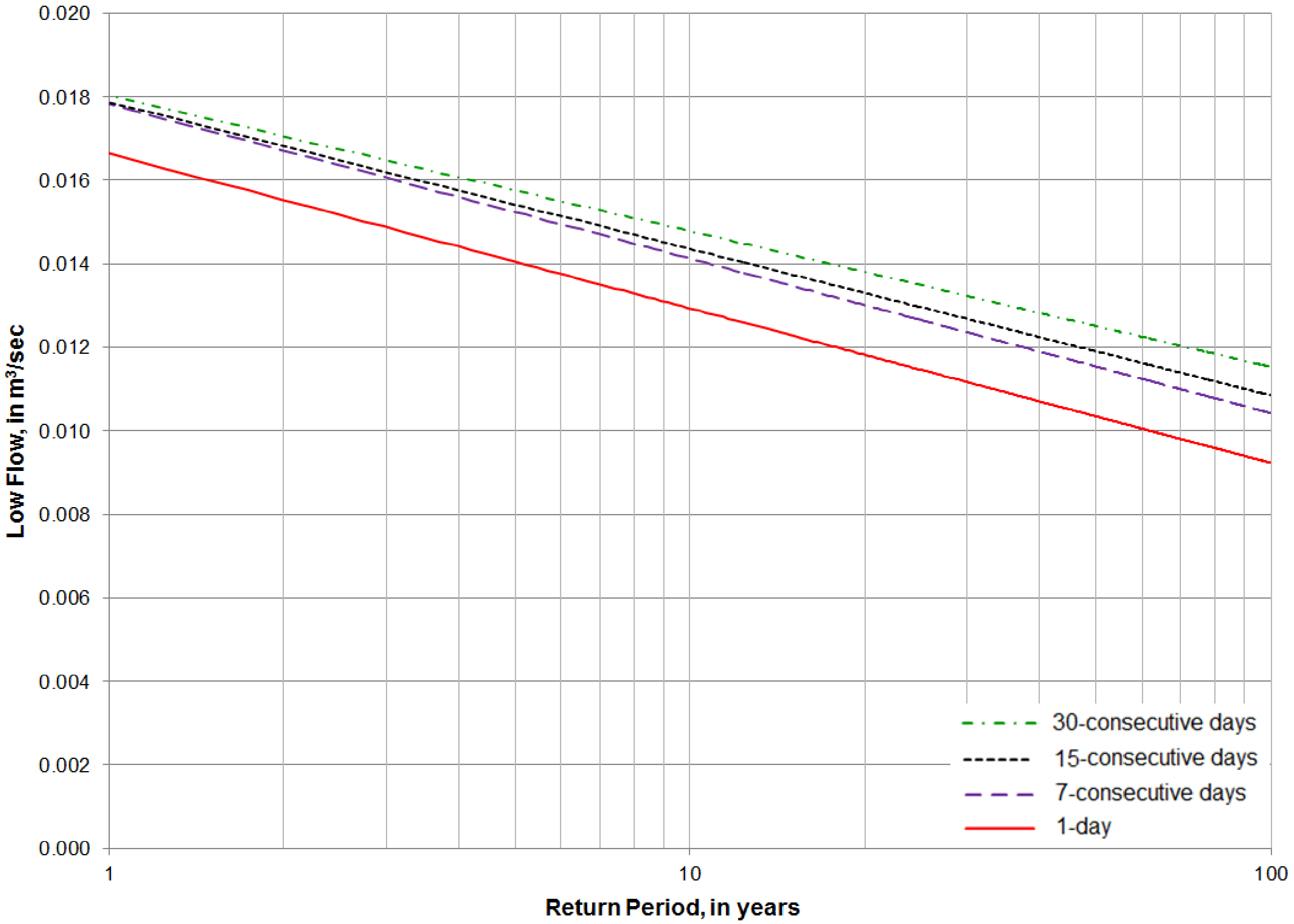


Figure J.18 Low Flow Curves of Subwatershed #17.

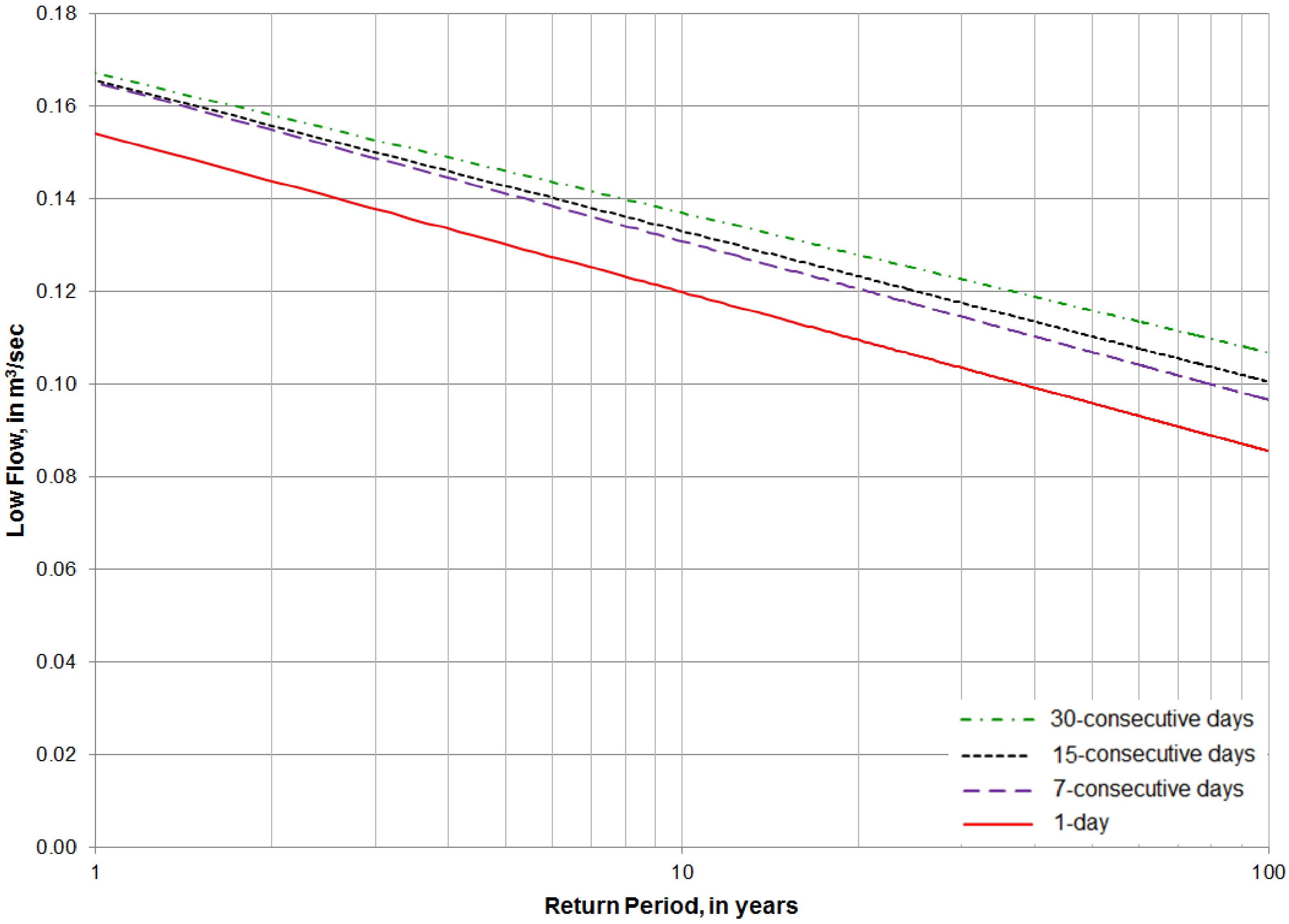


Figure J.19 Low Flow Curves of Subwatershed #18.

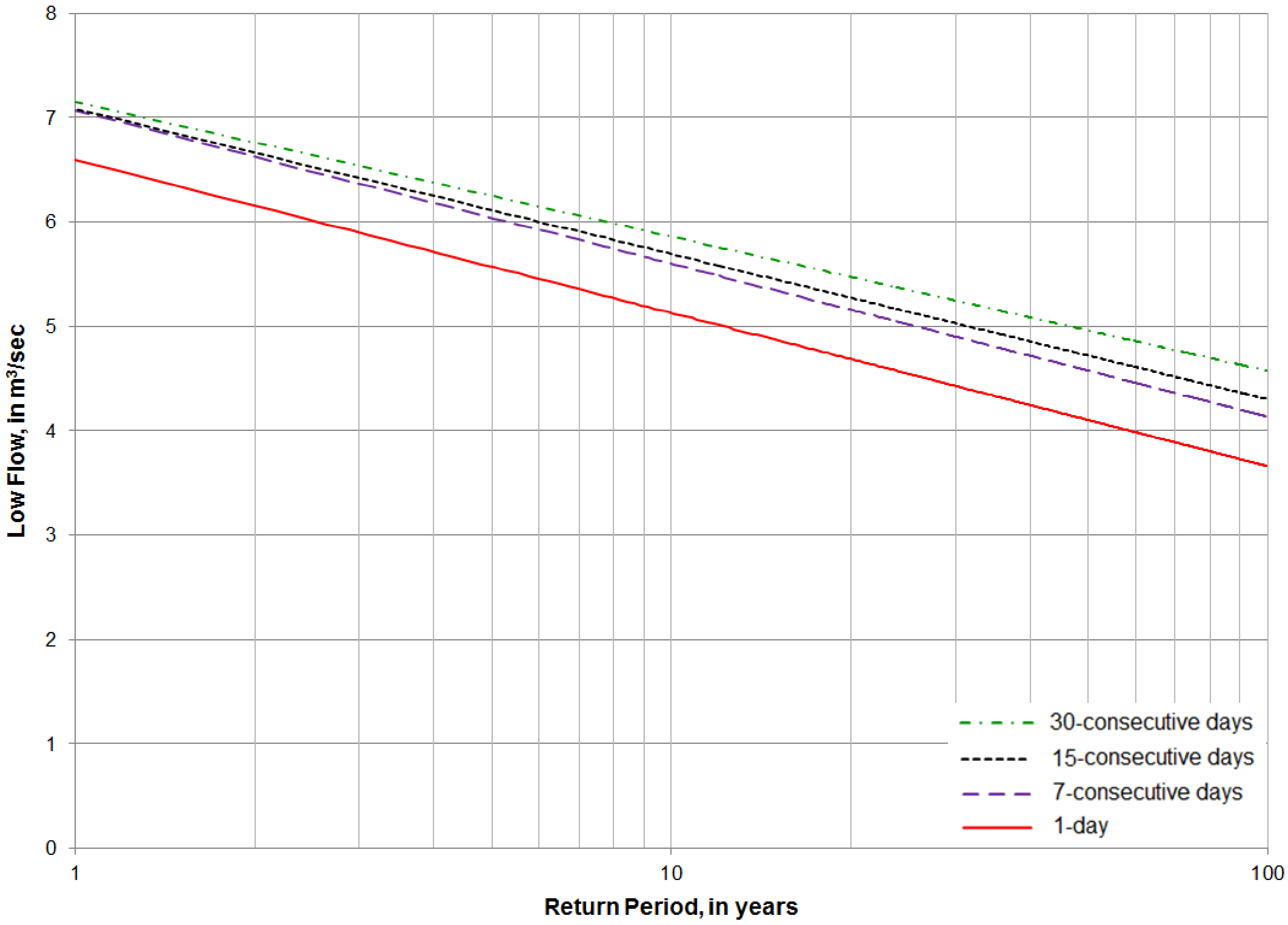


Figure J.20 Low Flow Curves of Subwatershed #19.

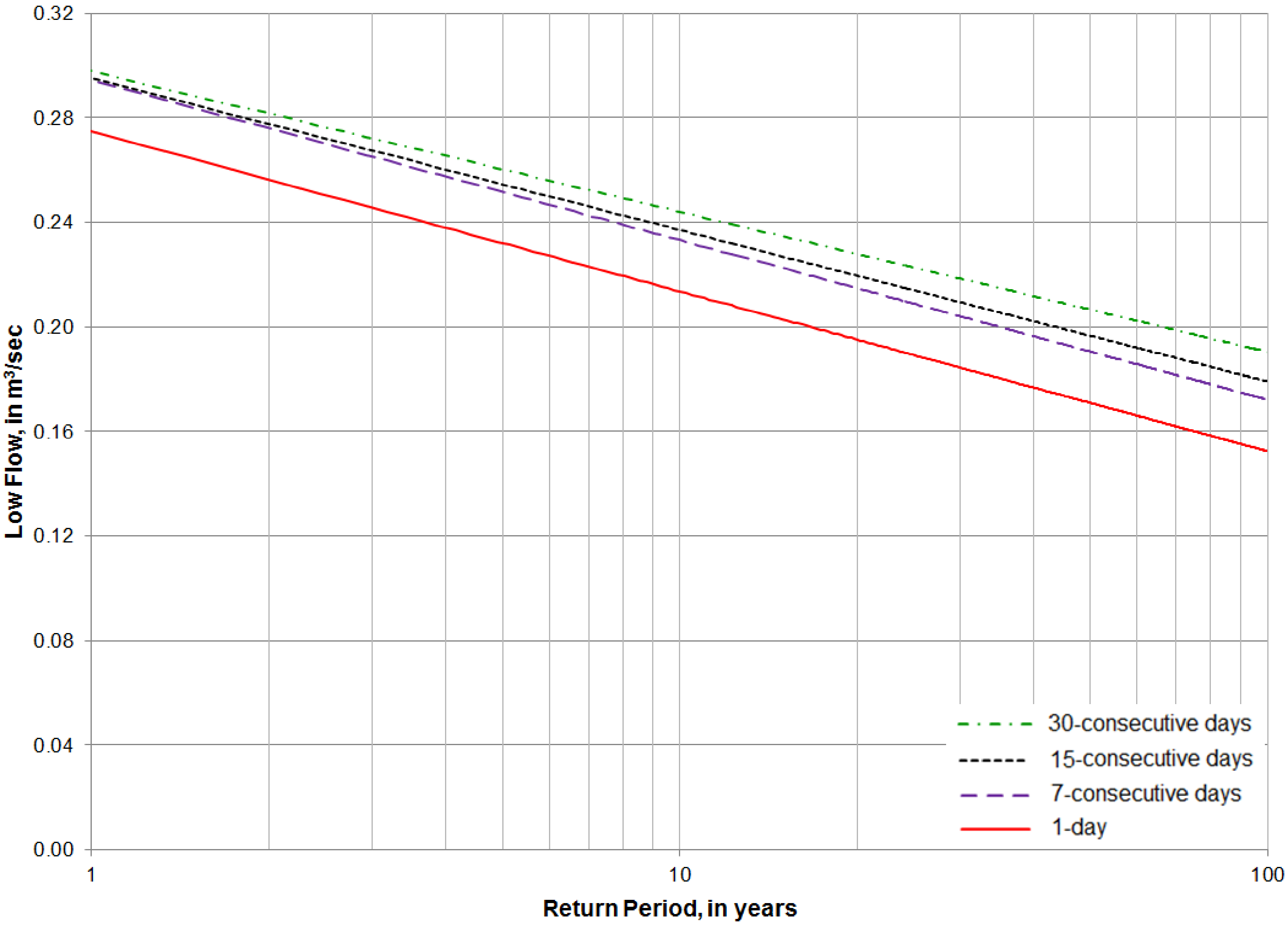


Figure J.21 Low Flow Curves of Subwatershed #19A.

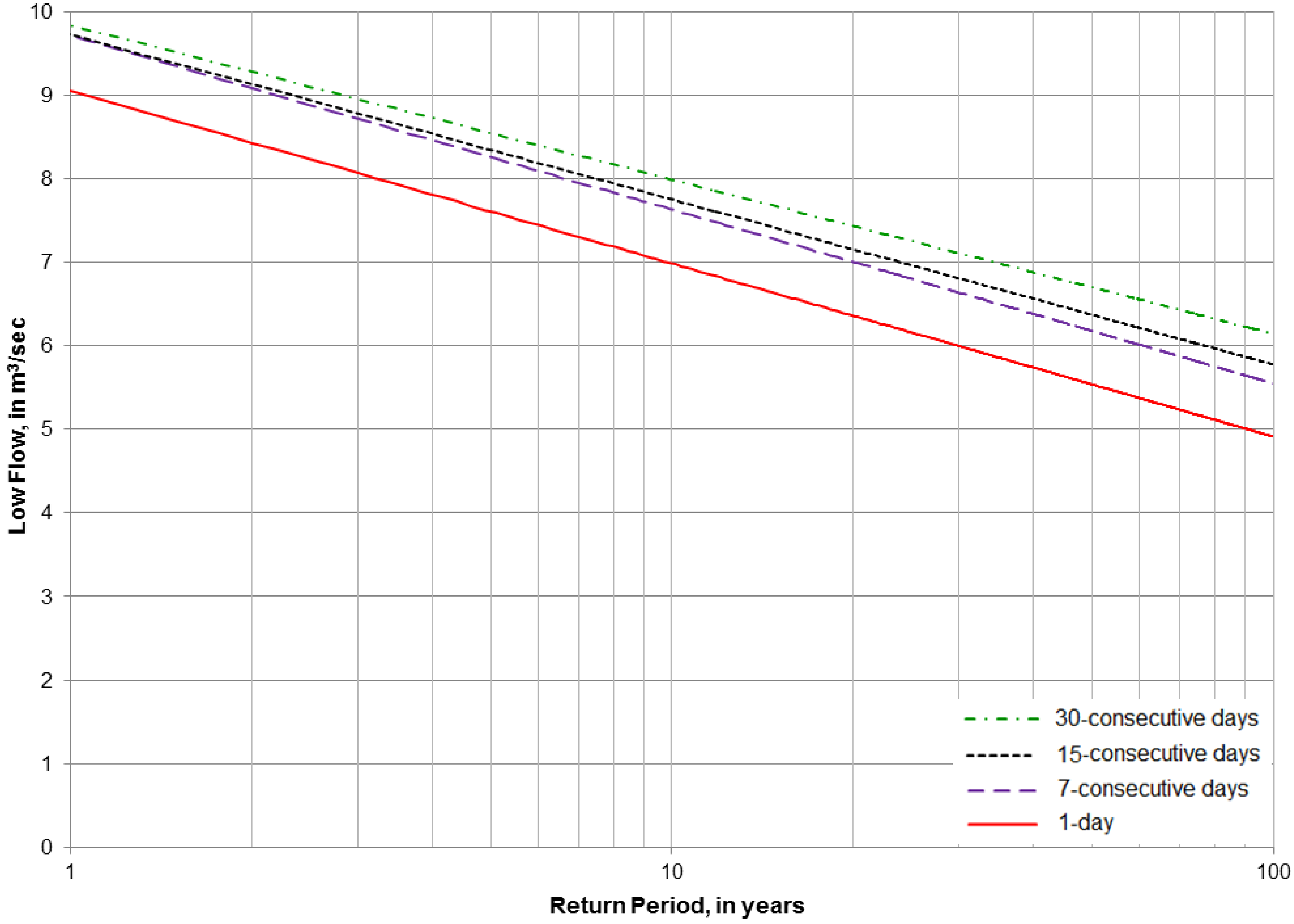


Figure J.22 Low Flow Curves of Subwatershed #20.

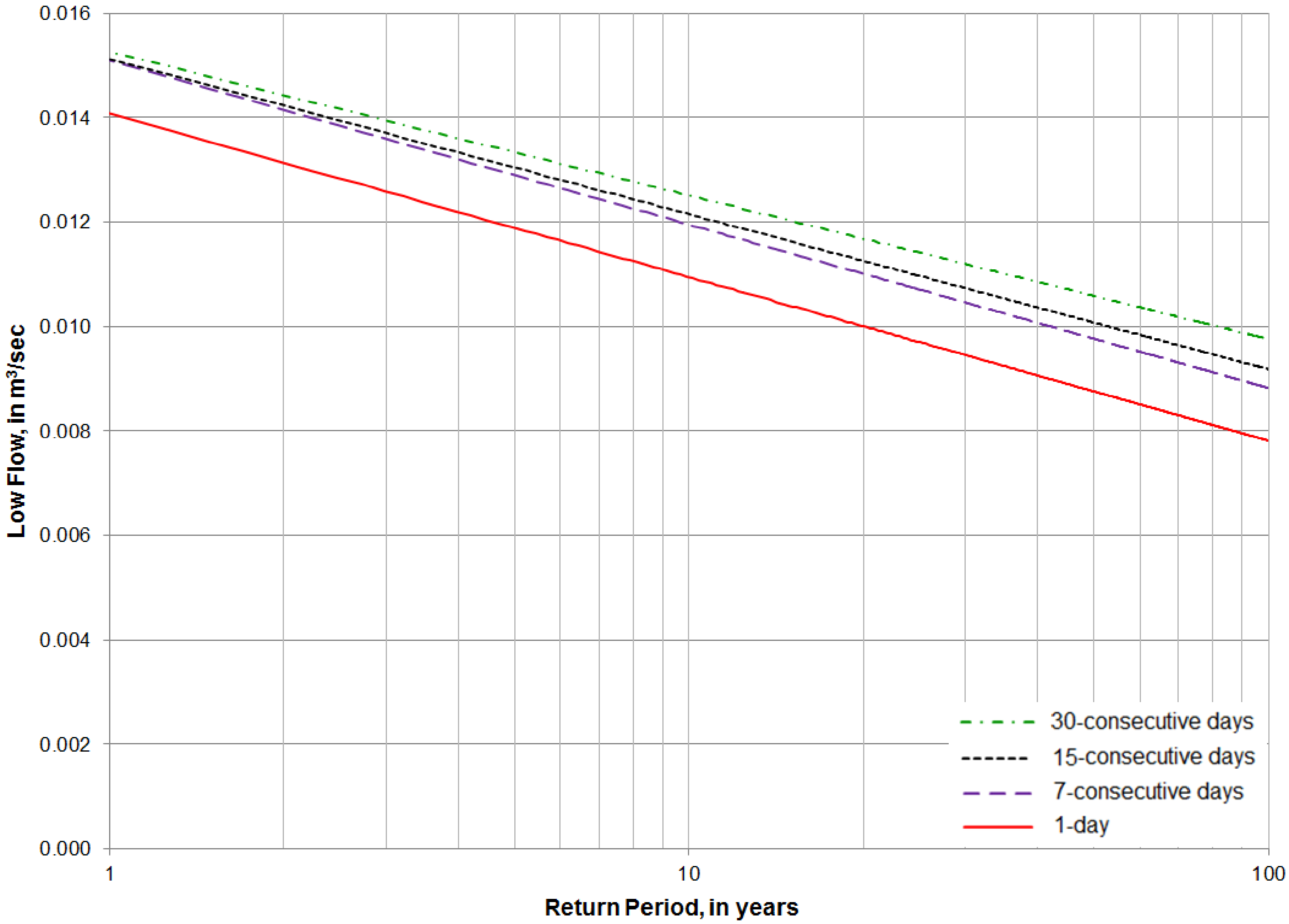


Figure J.23 Low Flow Curves of Subwatershed #21.

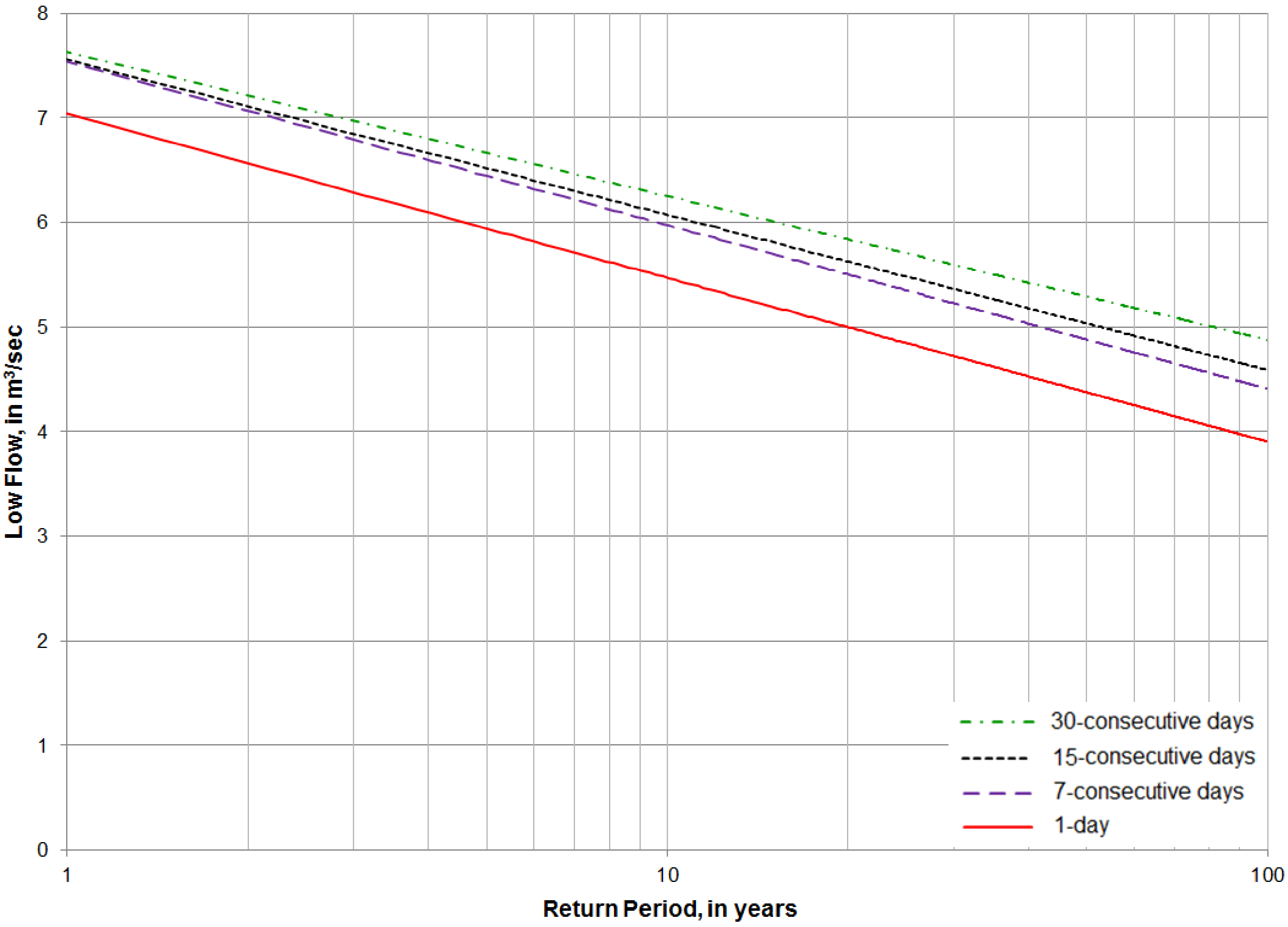


Figure J.24 Low Flow Curves of Subwatershed #22.

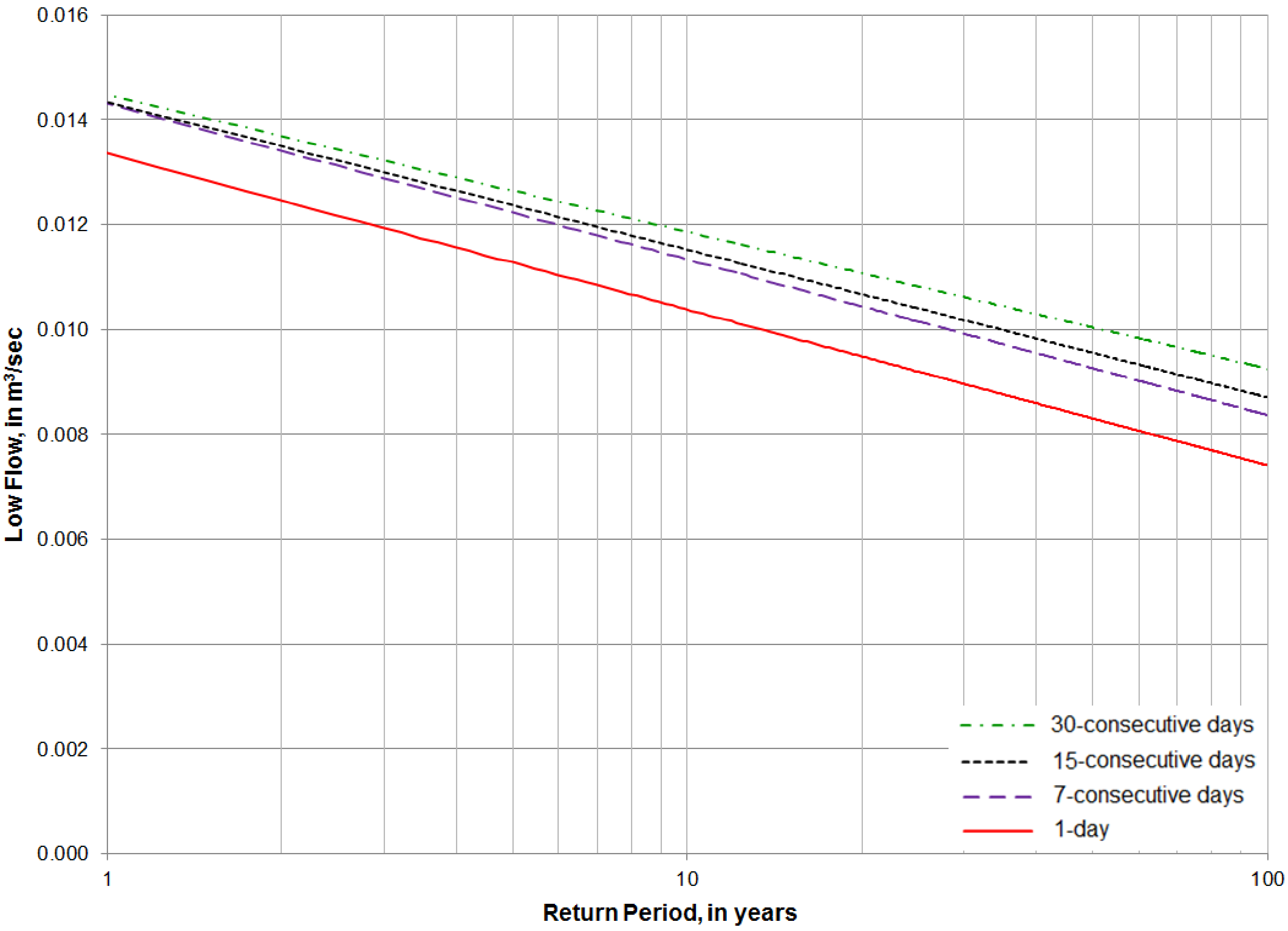


Figure J.25 Low Flow Curves of Subwatershed #23.

Appendix K

Flood Flow Assessment

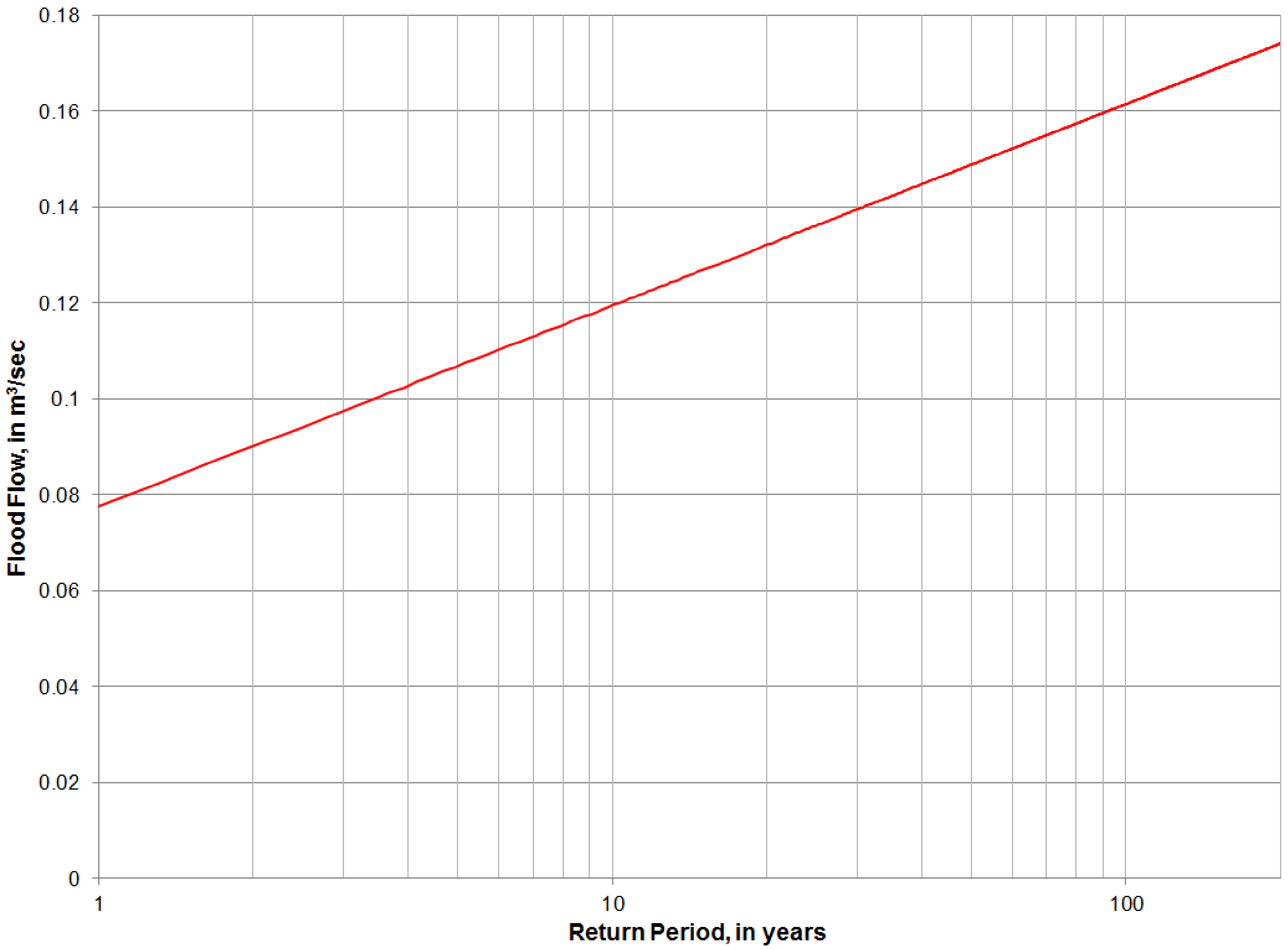


Figure K.1 Flood Flow Curve of Subwatershed #1.

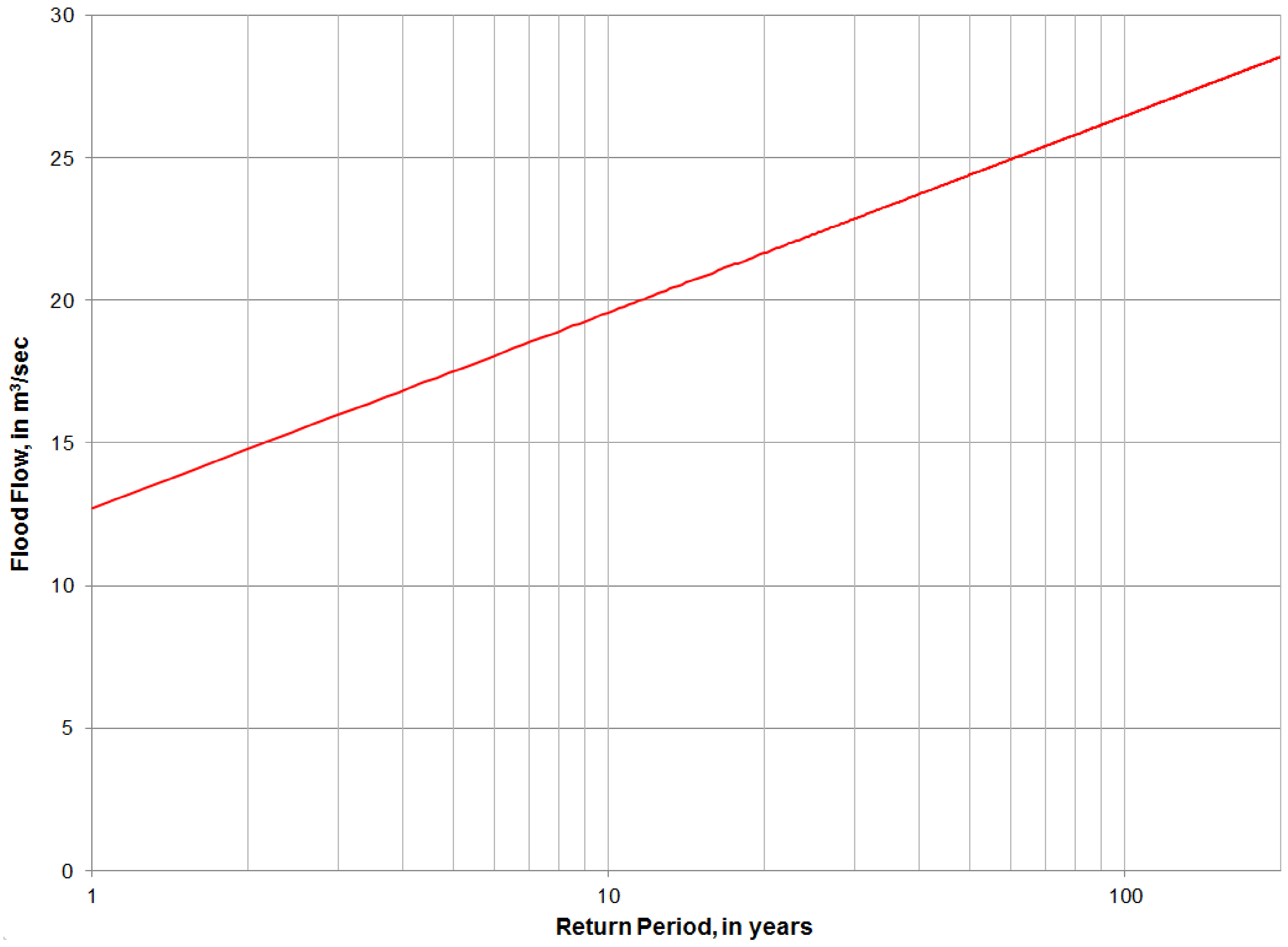


Figure K.2 Flood Flow Curve of Subwatershed #2.

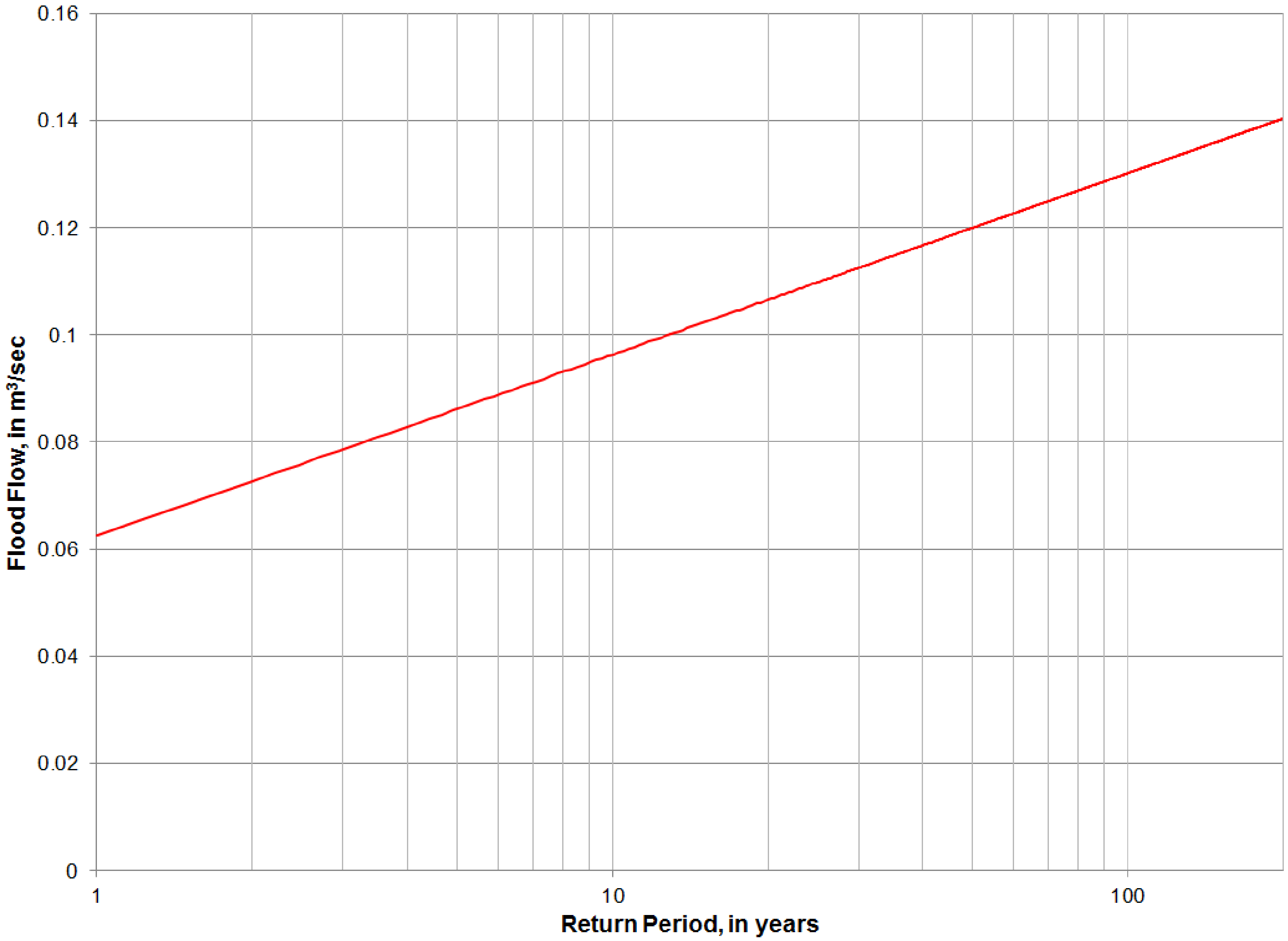


Figure K.3 Flood Flow Curve of Subwatershed #3.

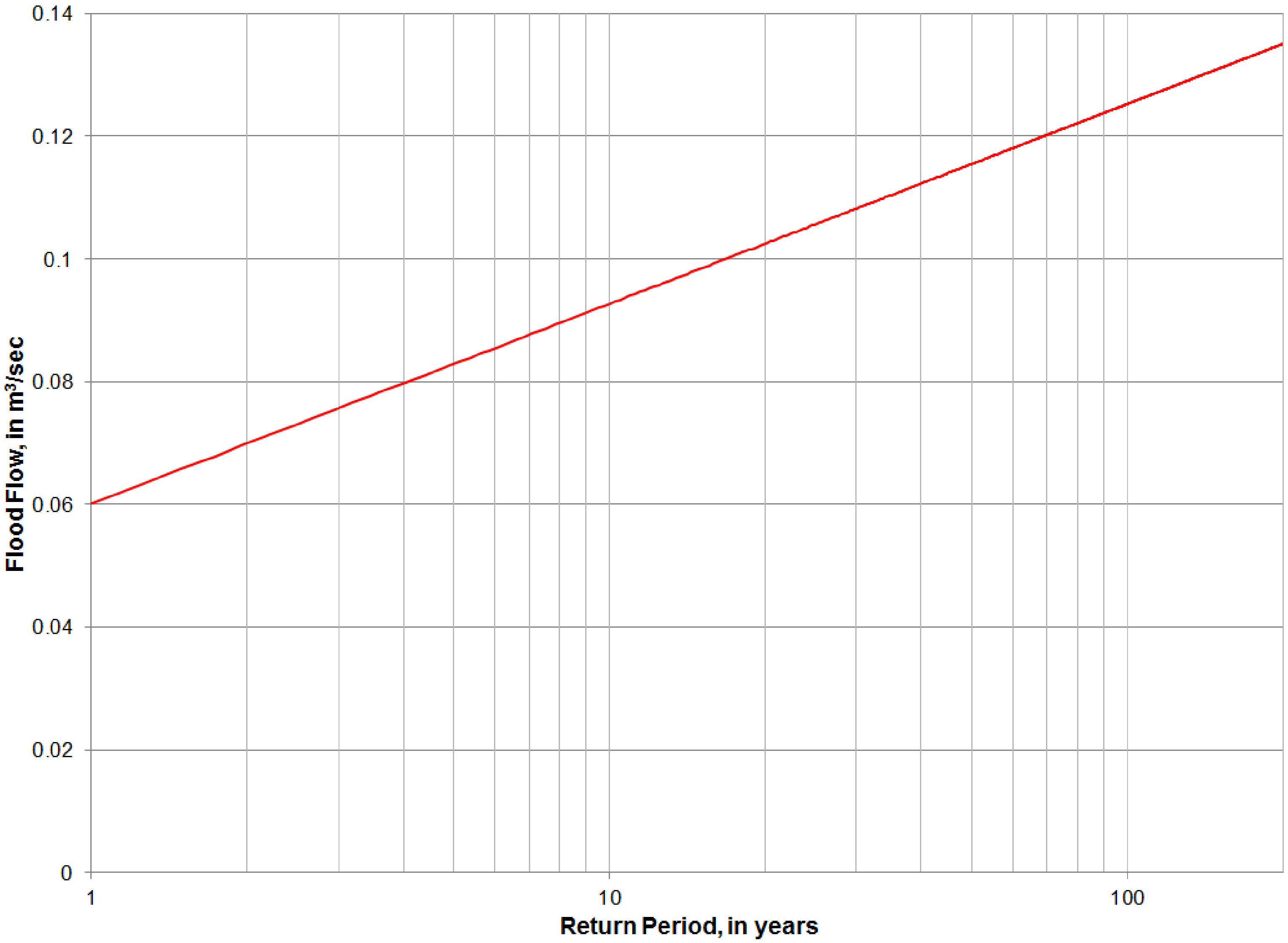


Figure K.4 Flood Flow Curve of Subwatershed #3A.

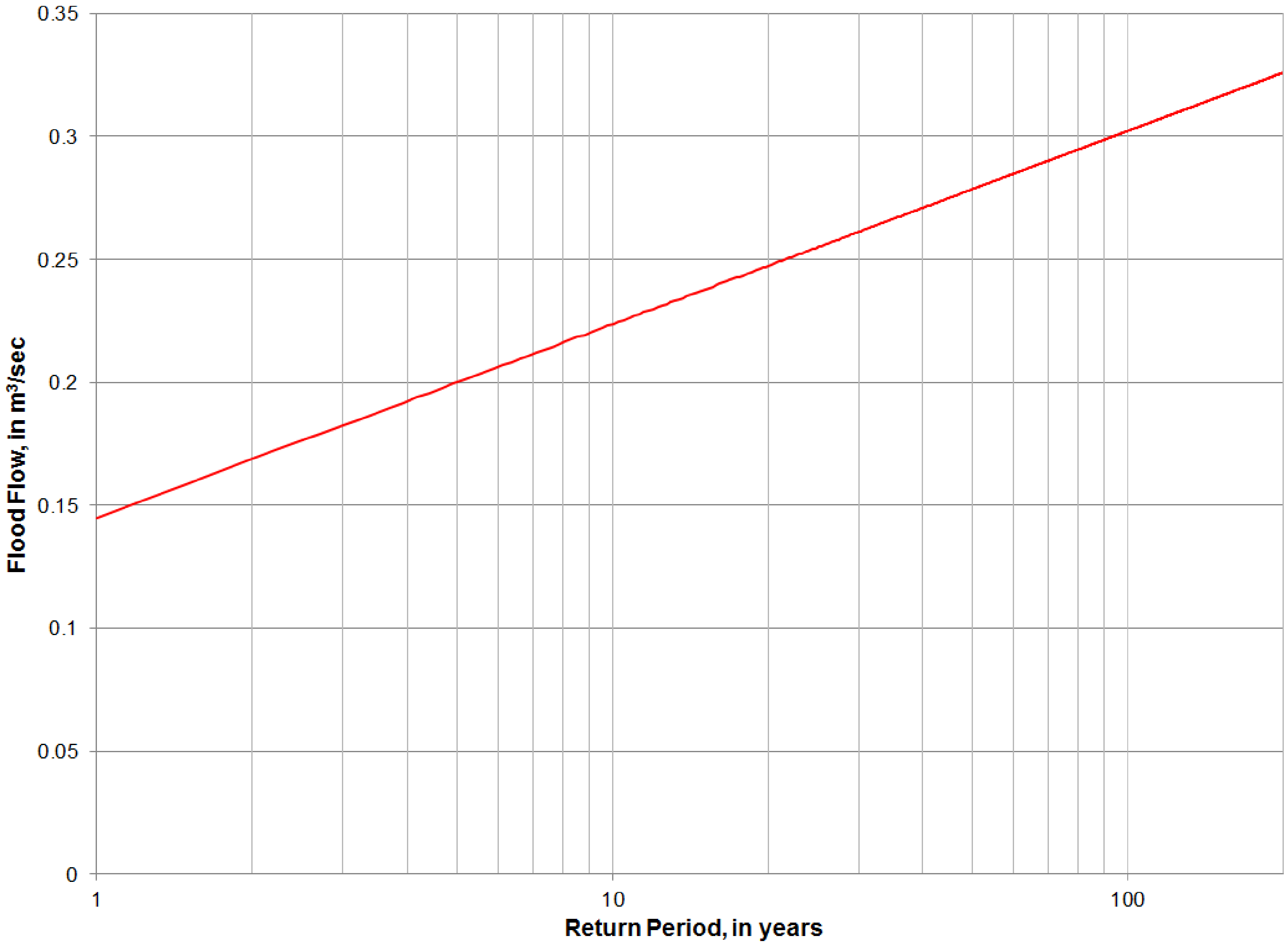


Figure K.5 Flood Flow Curve of Subwatershed #4.

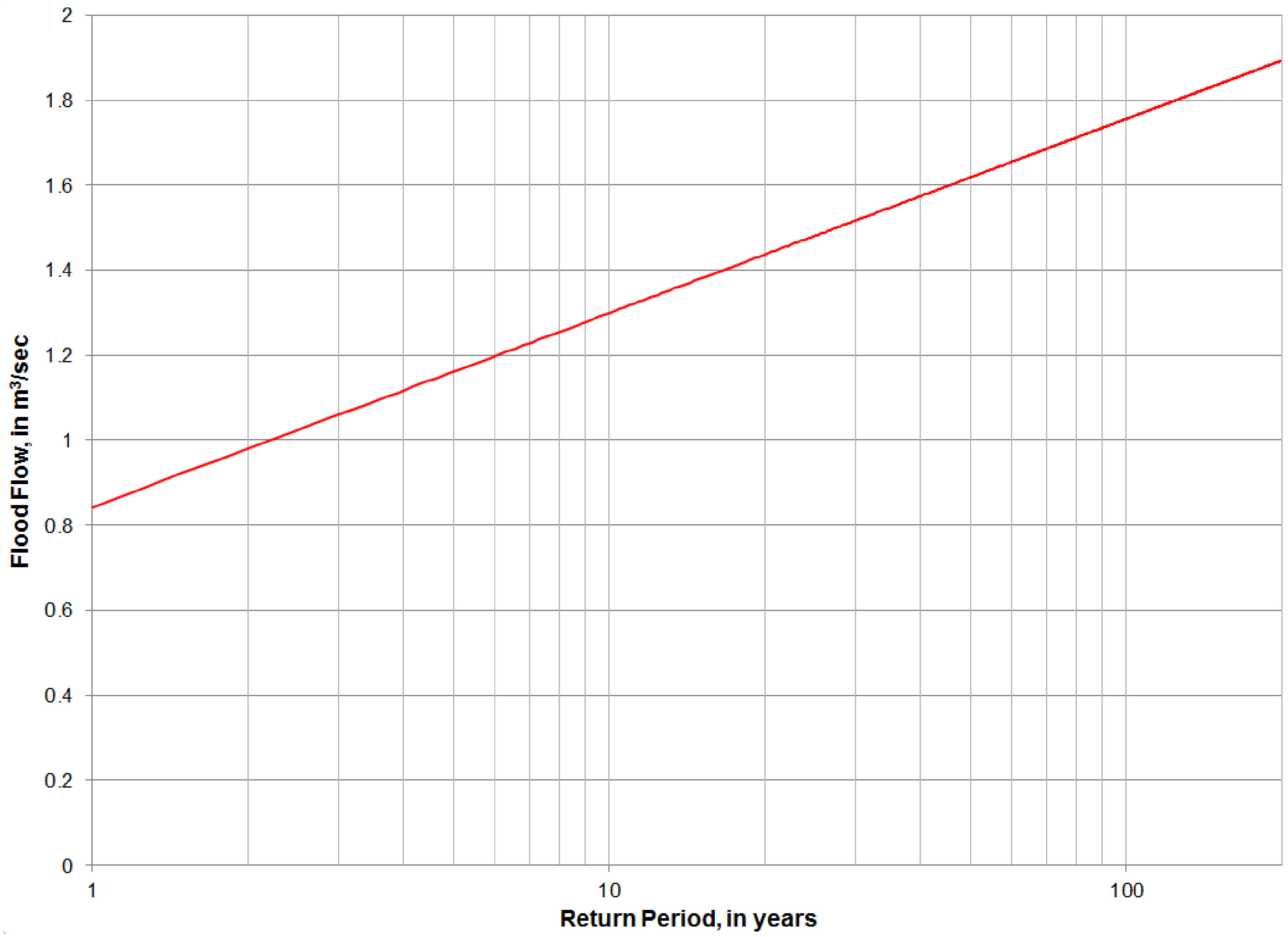


Figure K.6 **Flood Flow Curve of Subwatershed #5.**

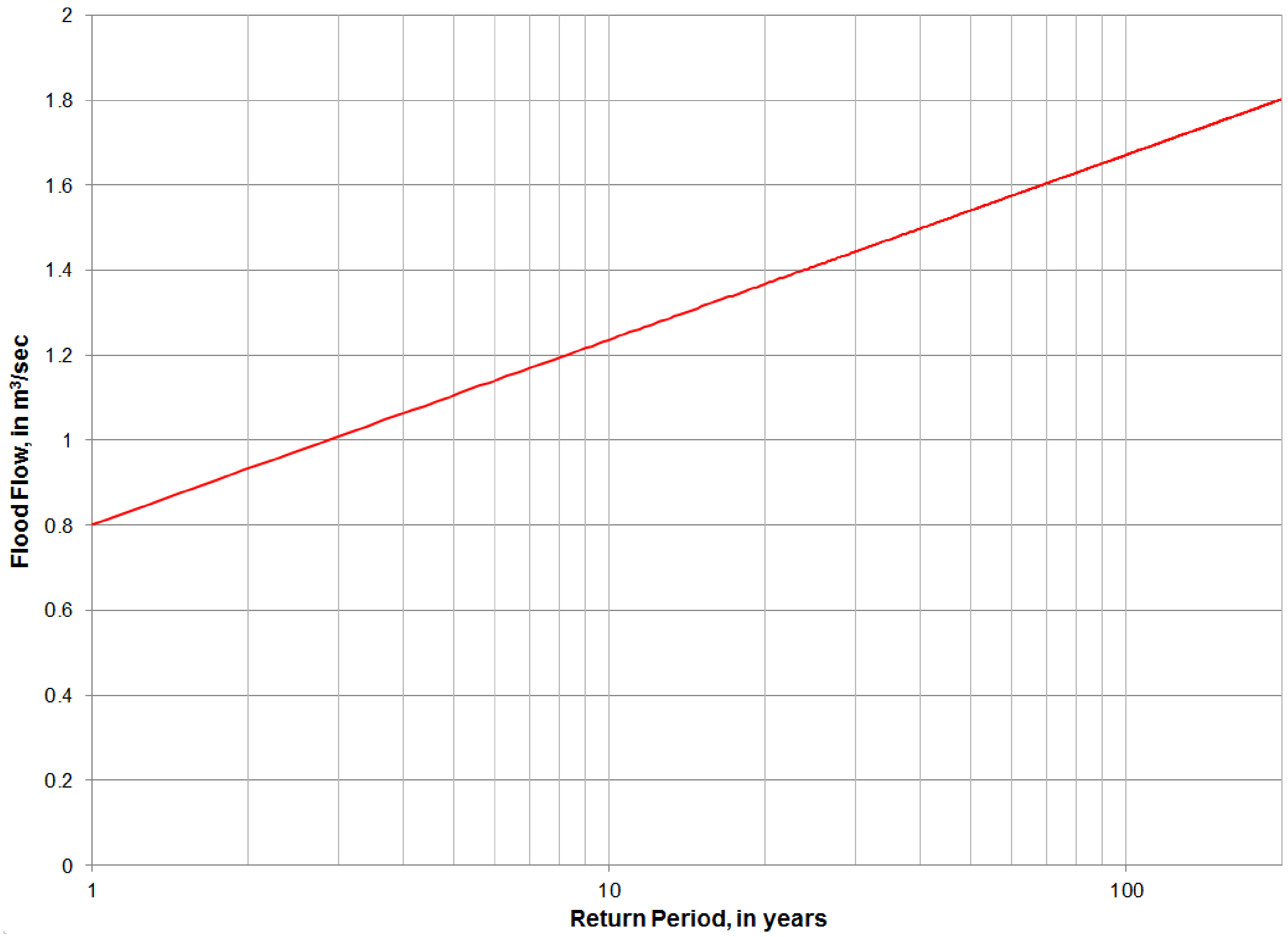


Figure K.7 **Flood Flow Curve of Subwatershed #6.**

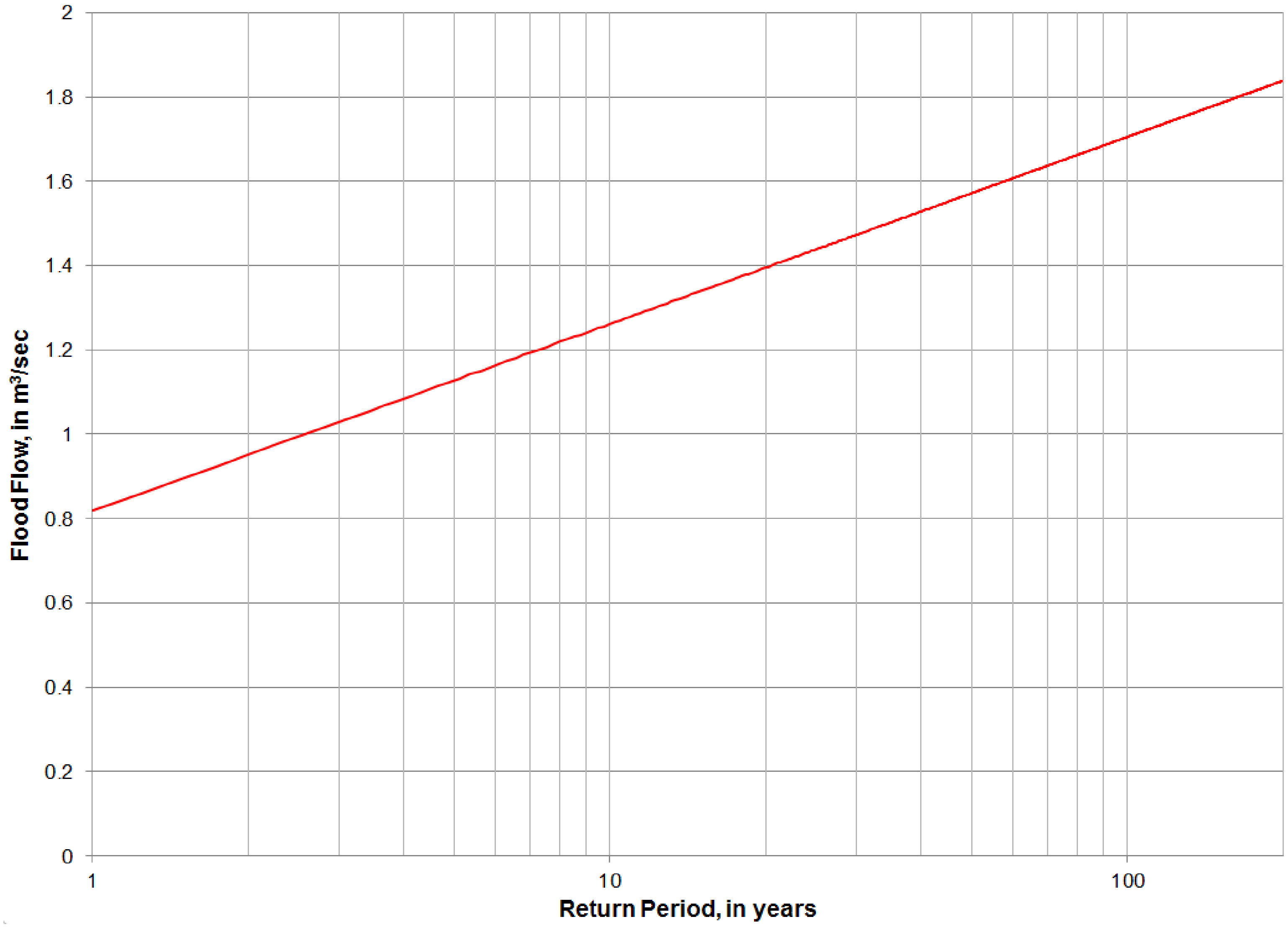


Figure K.8 **Flood Flow Curve of Subwatershed #7.**

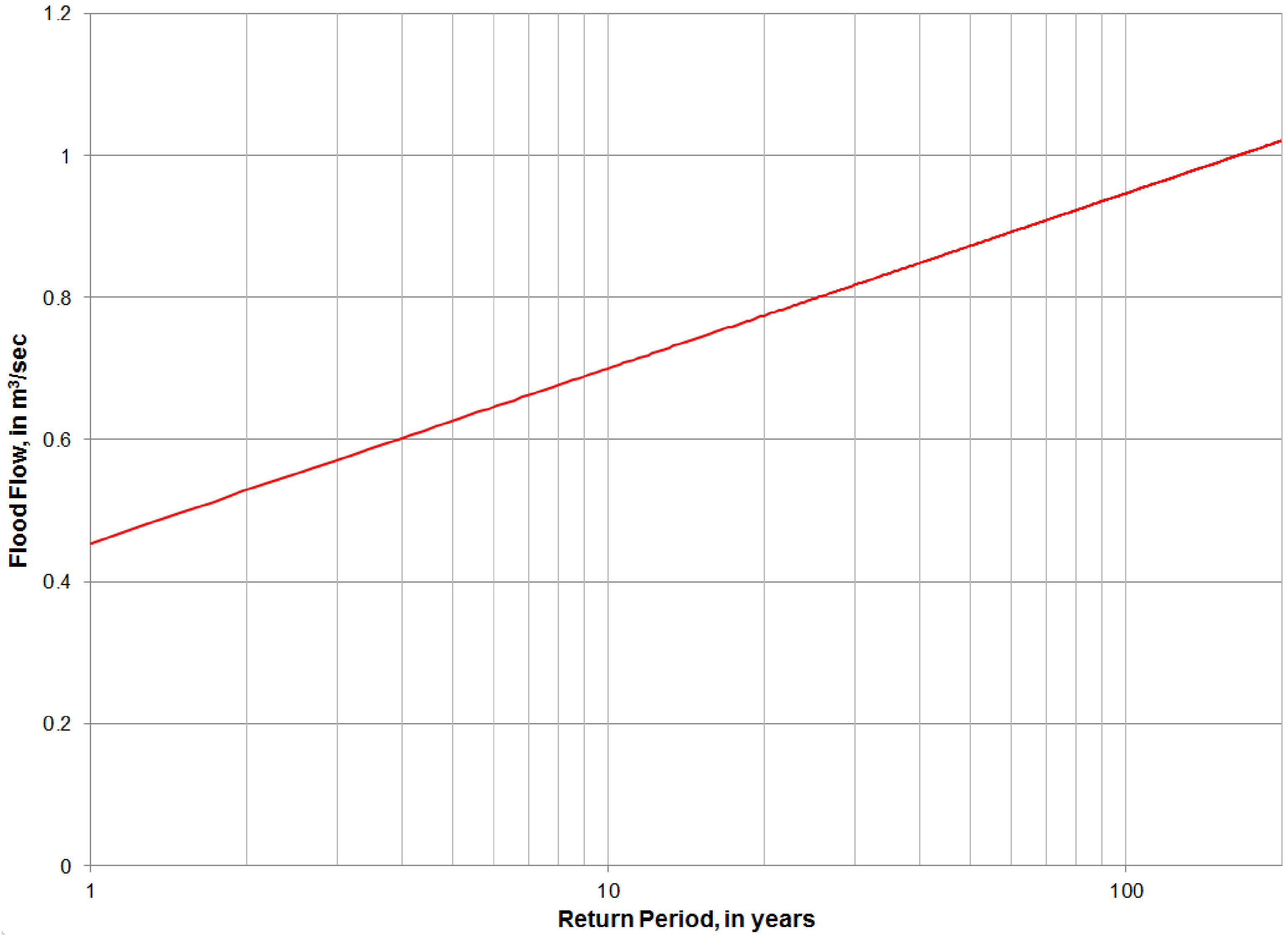


Figure K.9 **Flood Flow Curve of Subwatershed #8.**

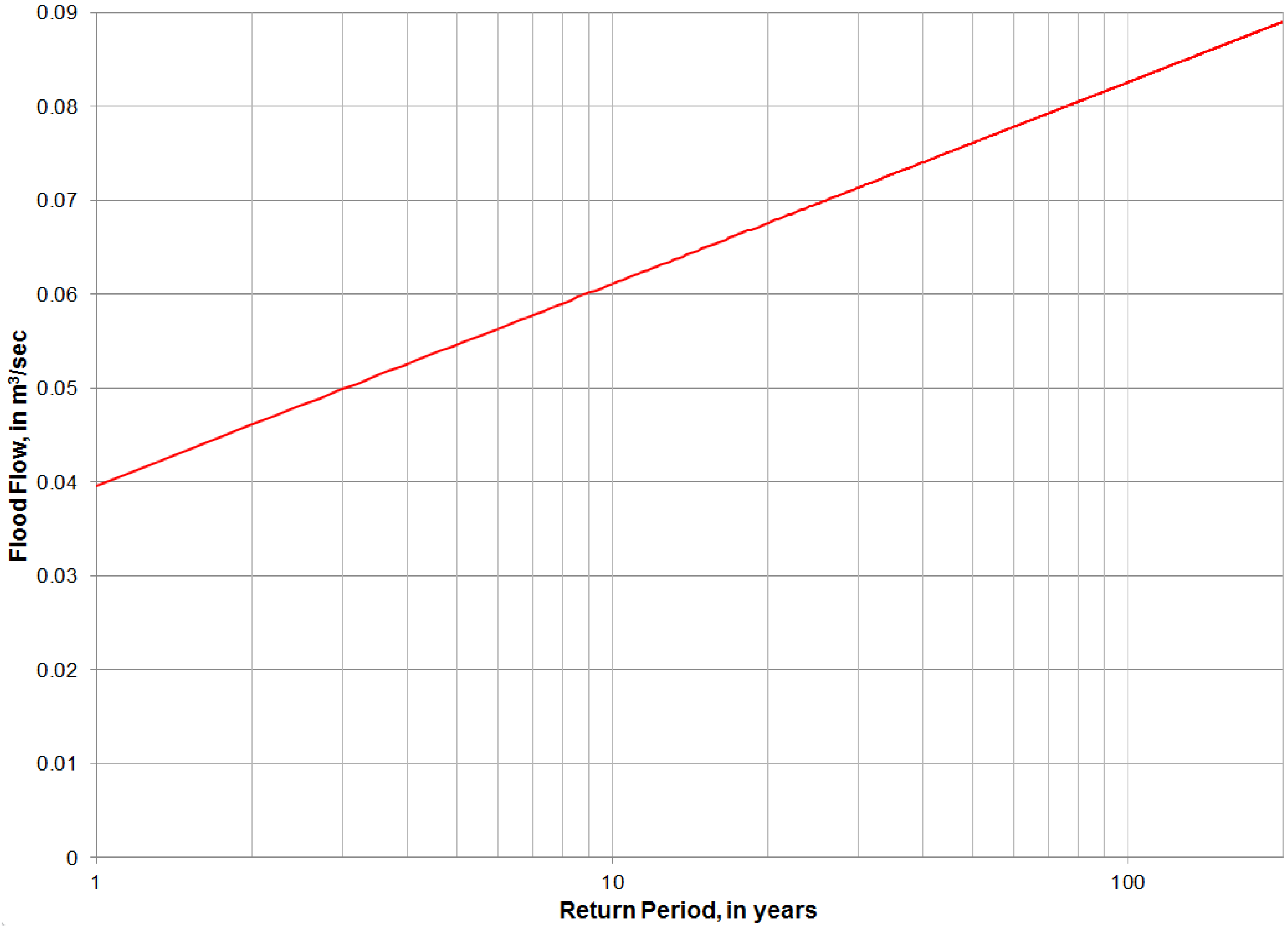


Figure K.10 Flood Flow Curve of Subwatershed #9.

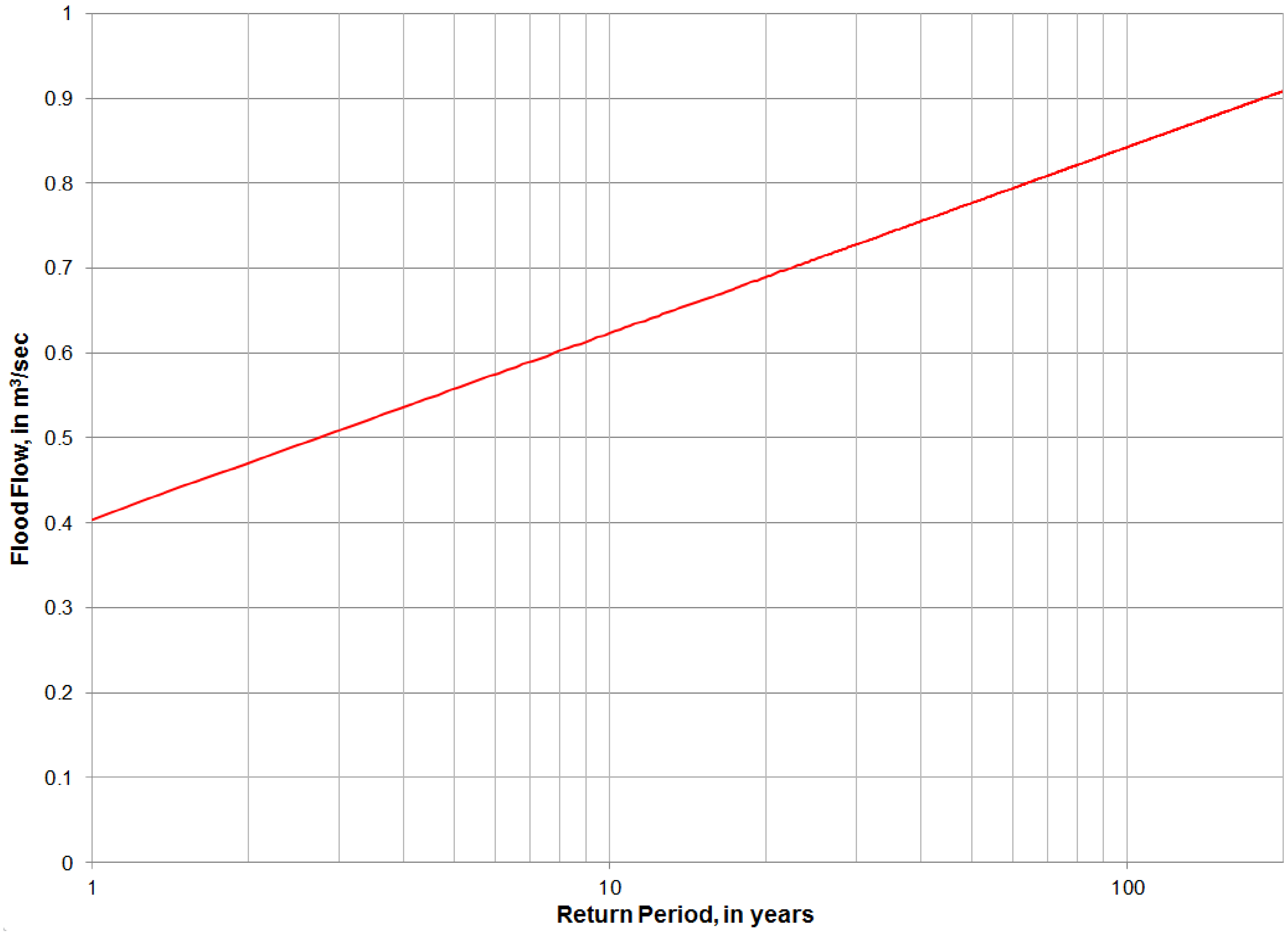


Figure K.11 Flood Flow Curve of Subwatershed #10.

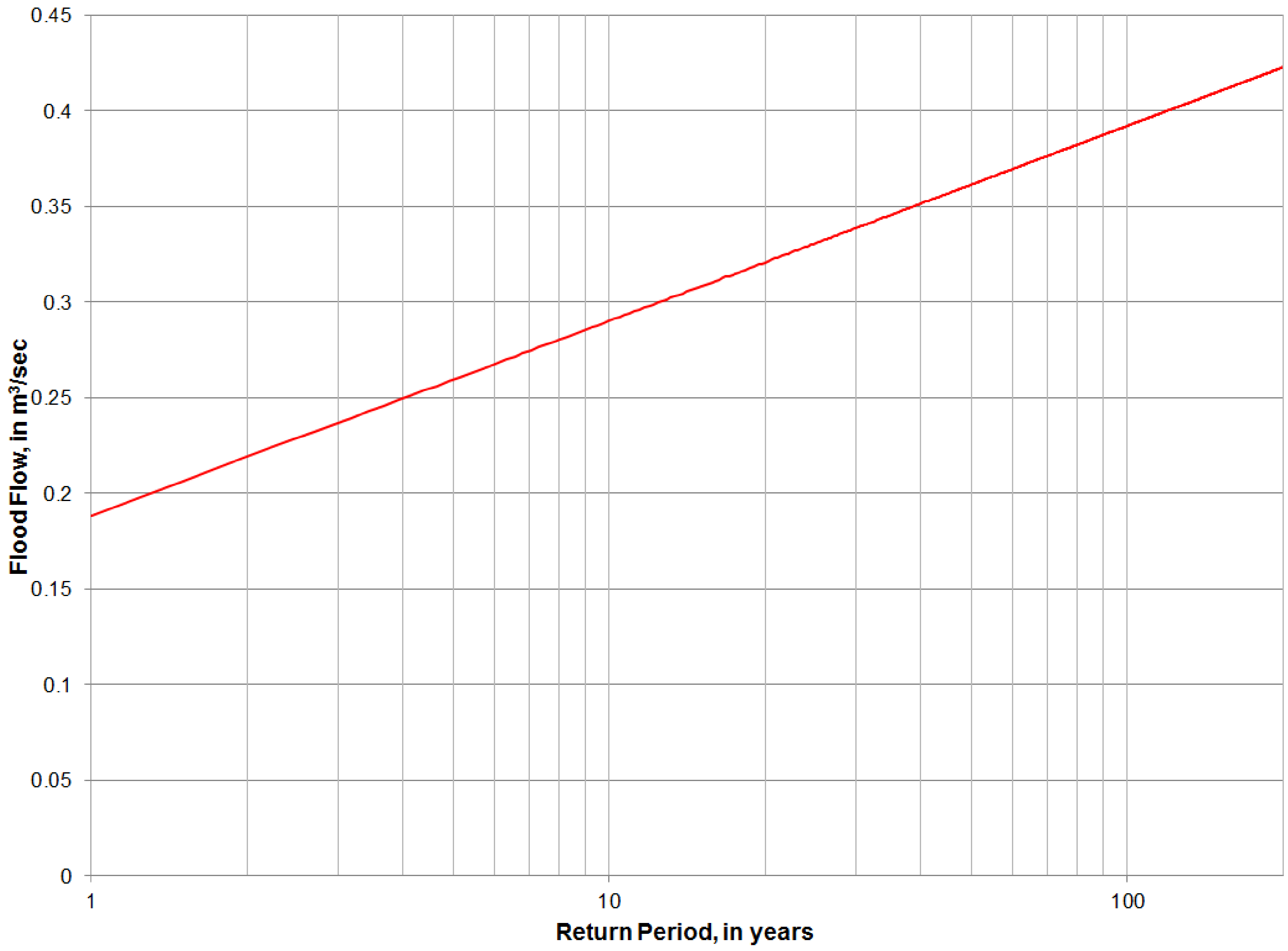


Figure K.12 Flood Flow Curve of Subwatershed #11.

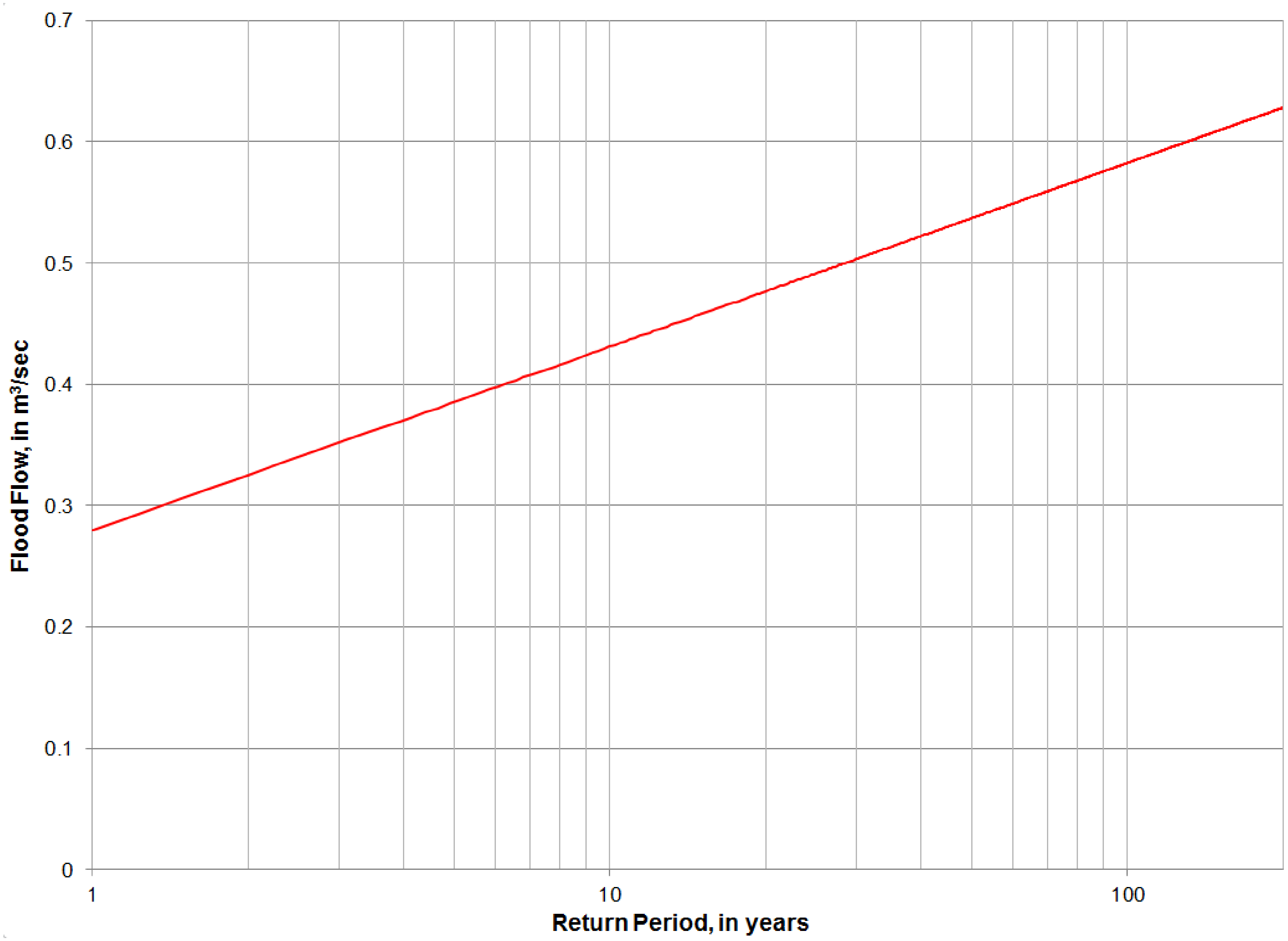


Figure K.13 Flood Flow Curve of Subwatershed #12.

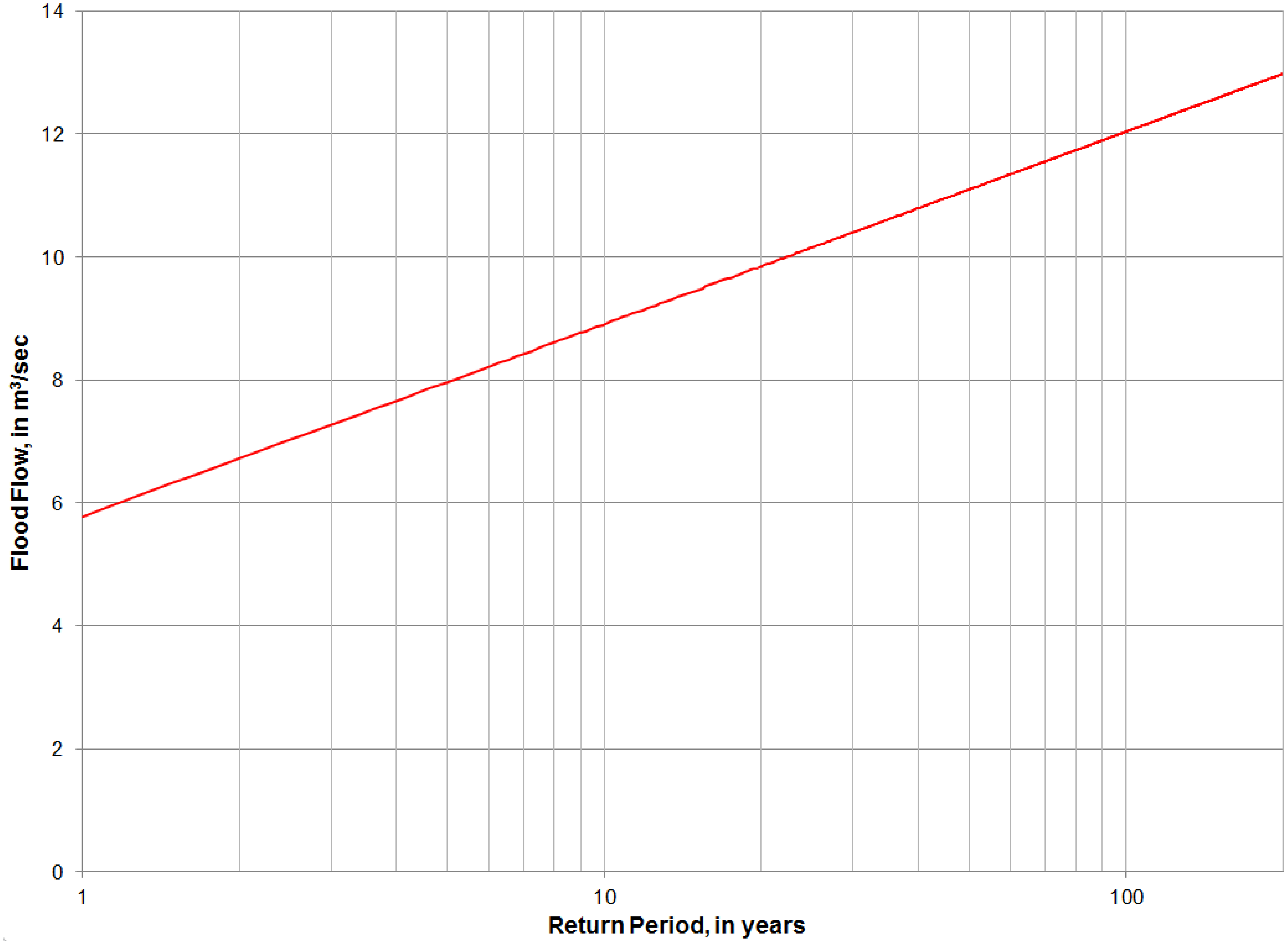


Figure K.14 Flood Flow Curve of Subwatershed #13.

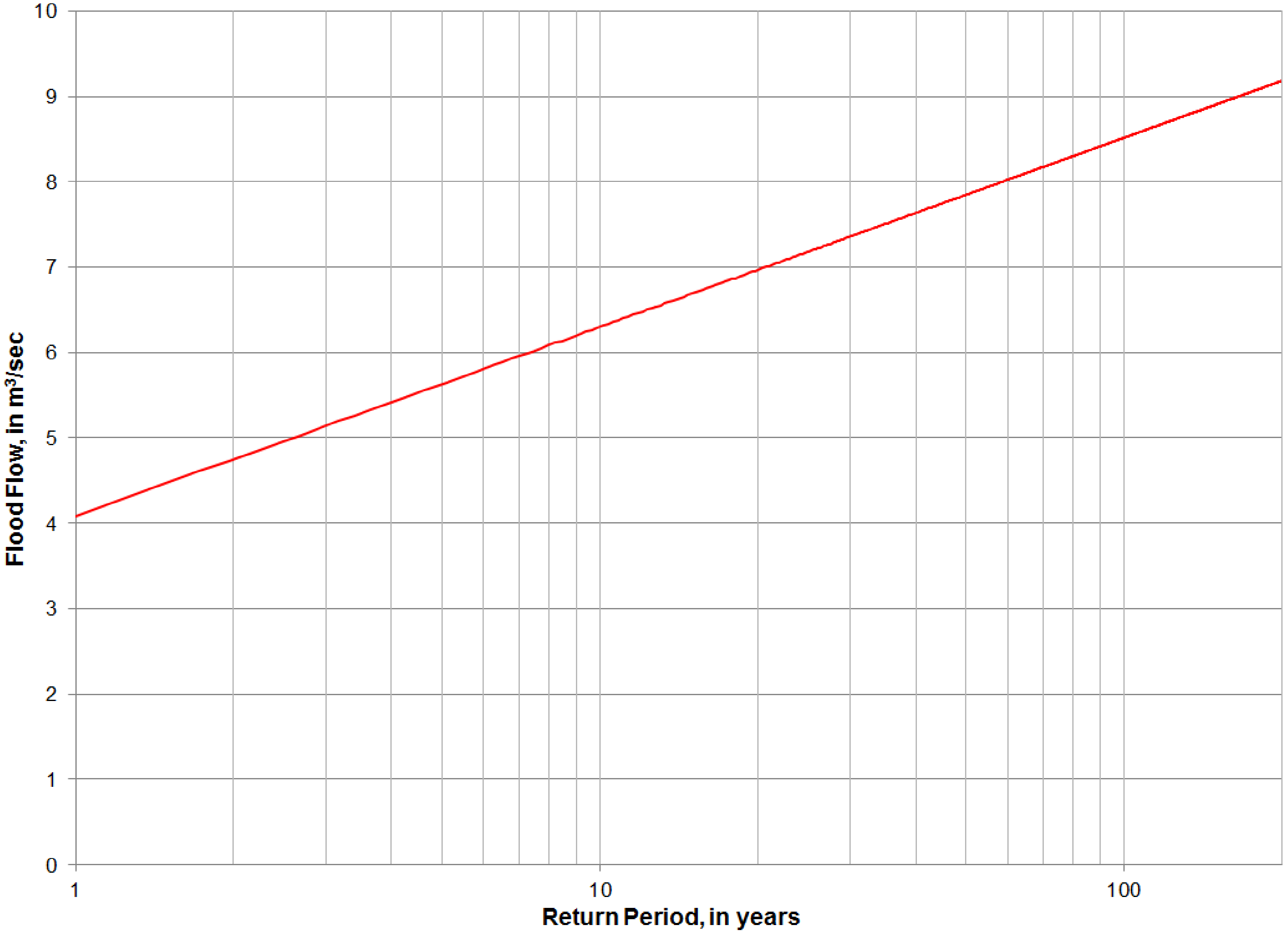


Figure K.15 Flood Flow Curve of Subwatershed #14.

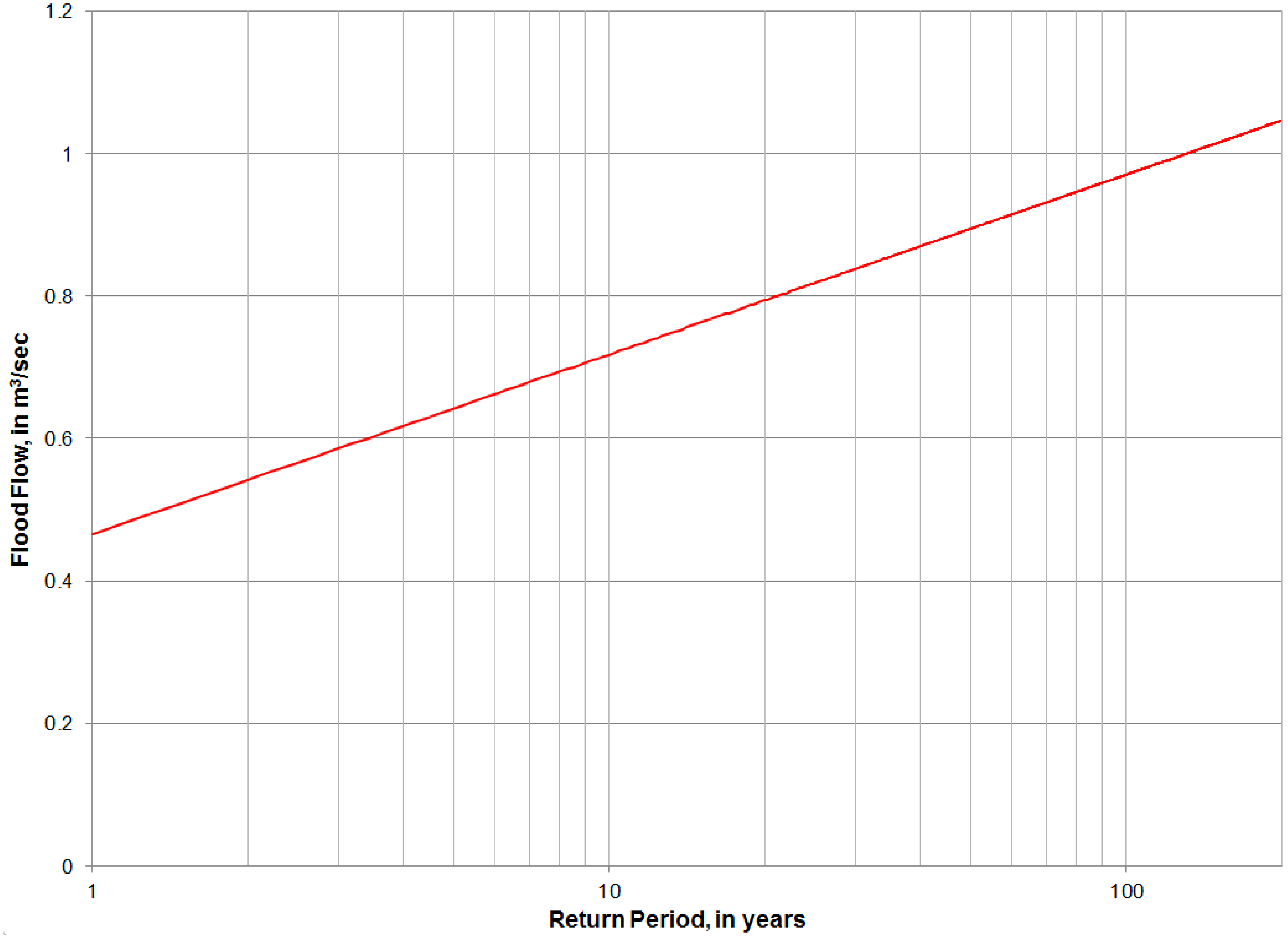


Figure K.16 Flood Flow Curve of Subwatershed #15.

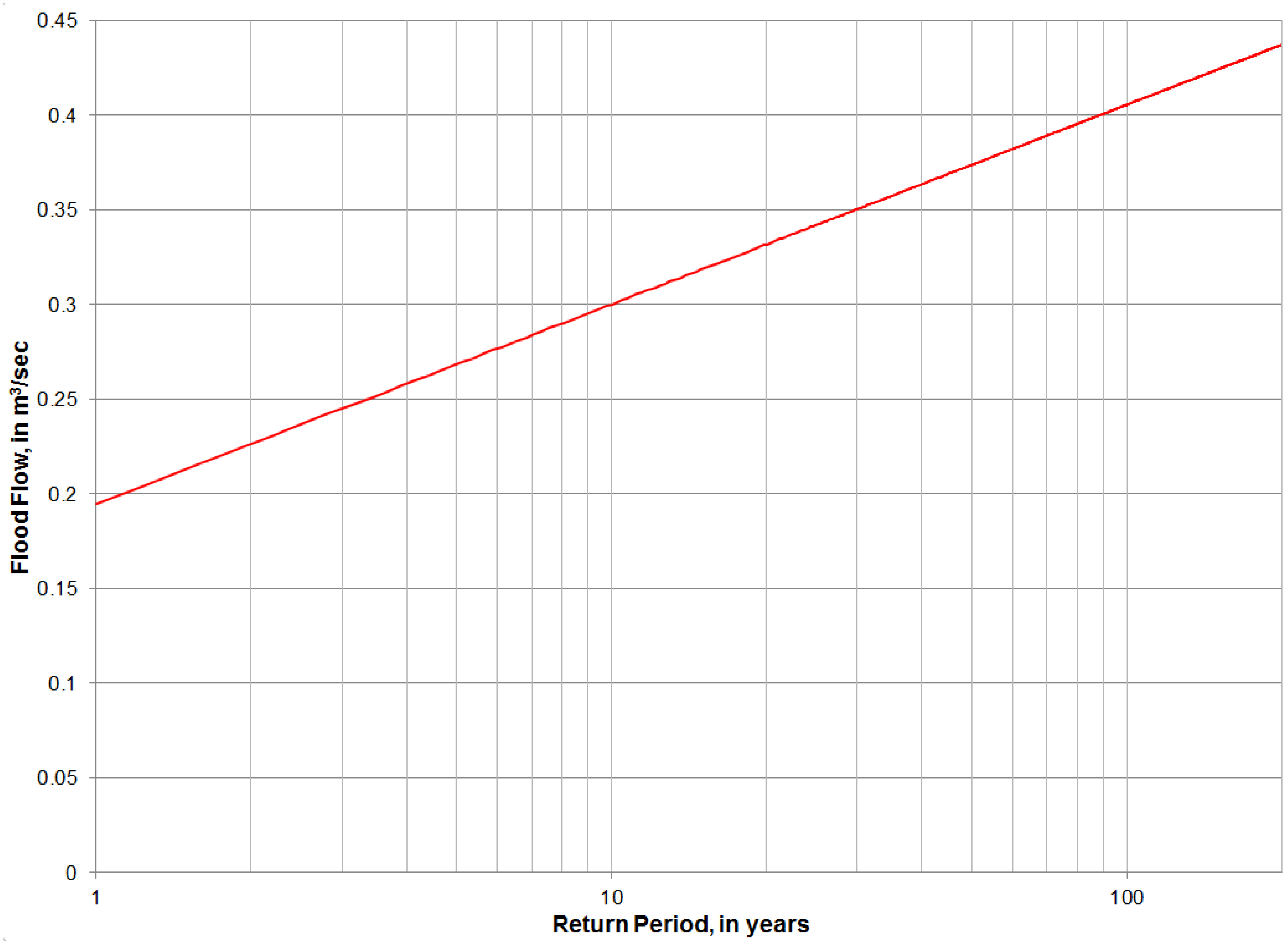


Figure K.17 Flood Flow Curve of Subwatershed #16.

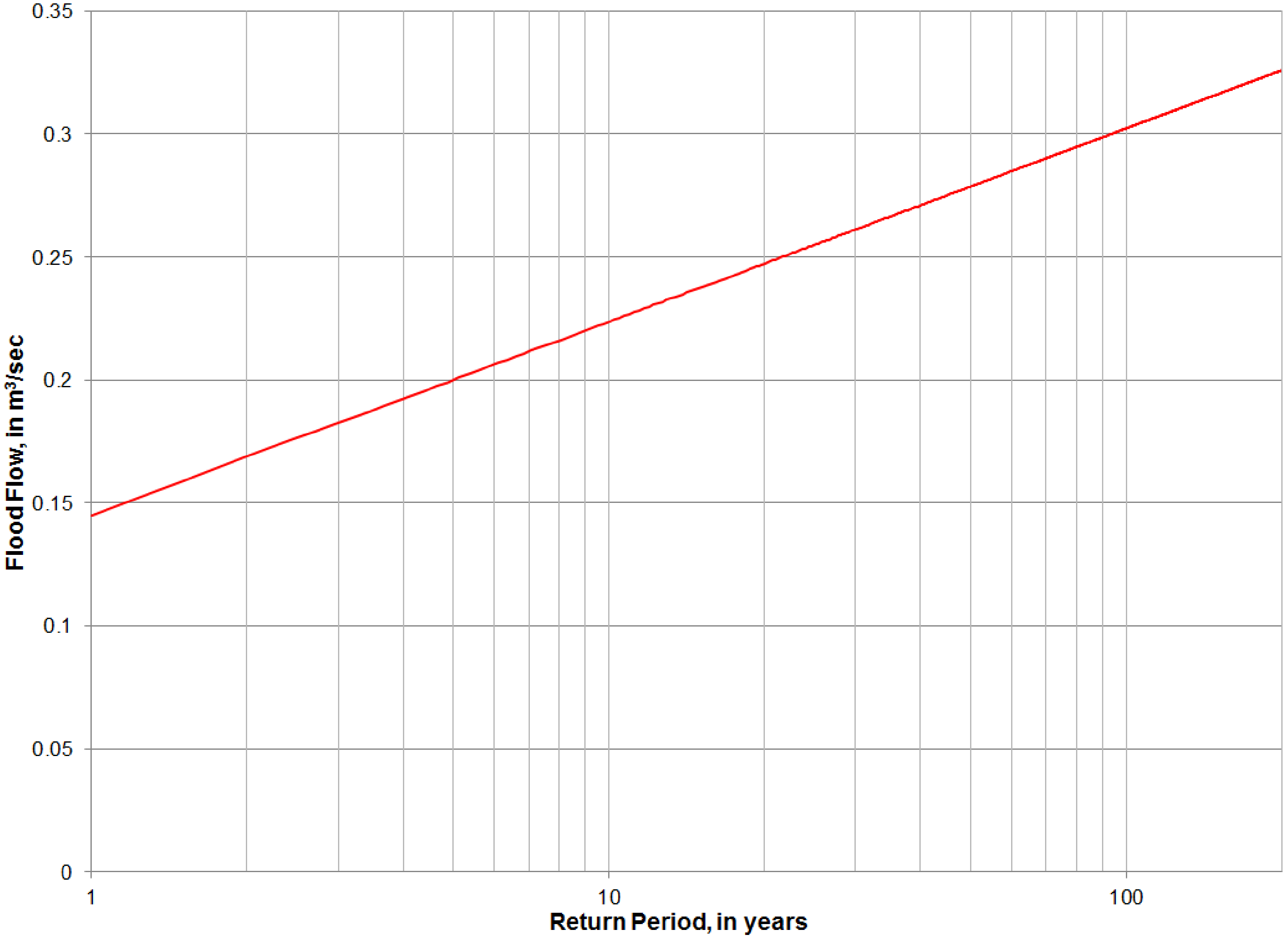


Figure K.18 **Flood Flow Curve of Subwatershed #17.**

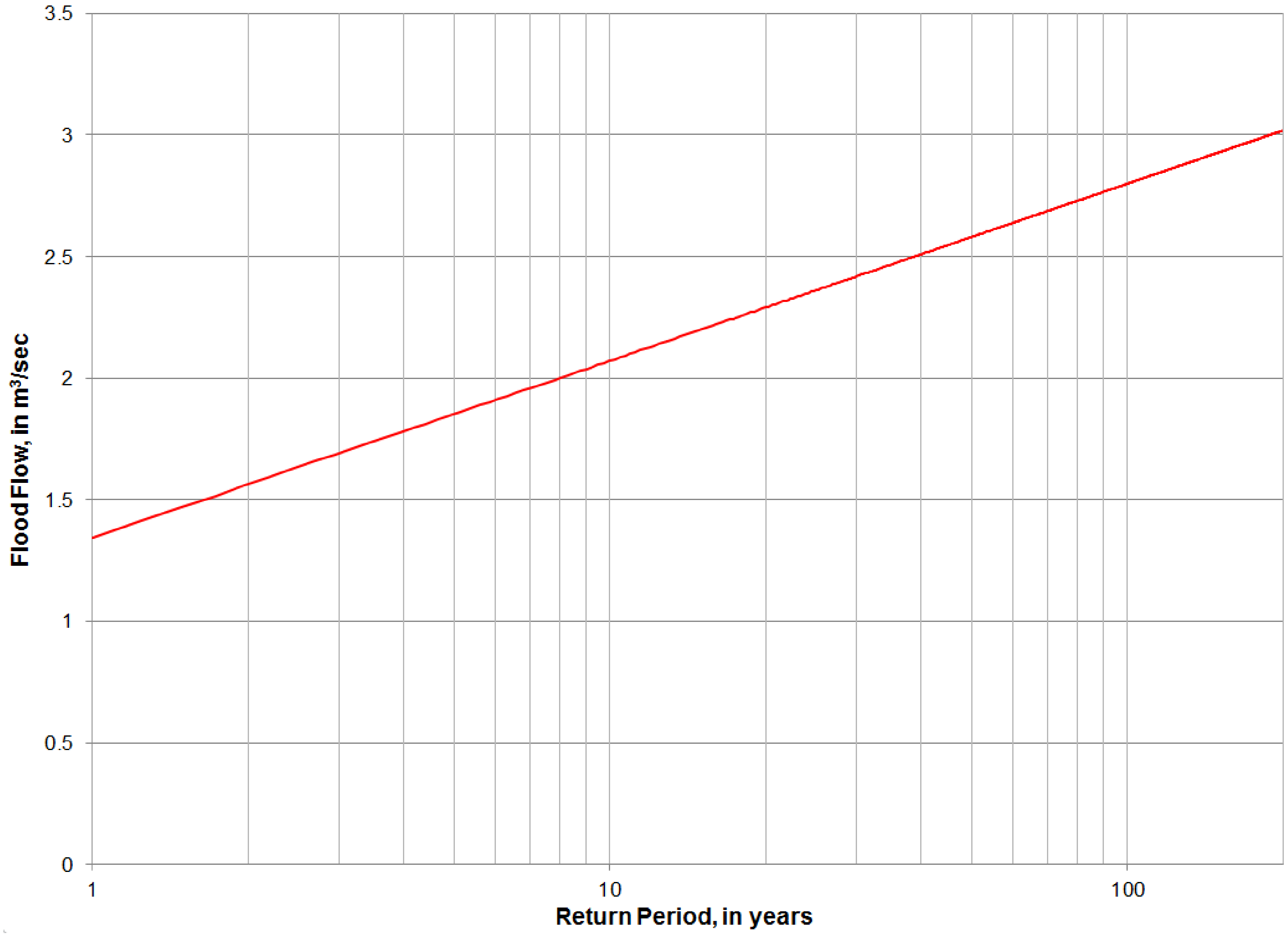


Figure K.19 Flood Flow Curve of Subwatershed #18.

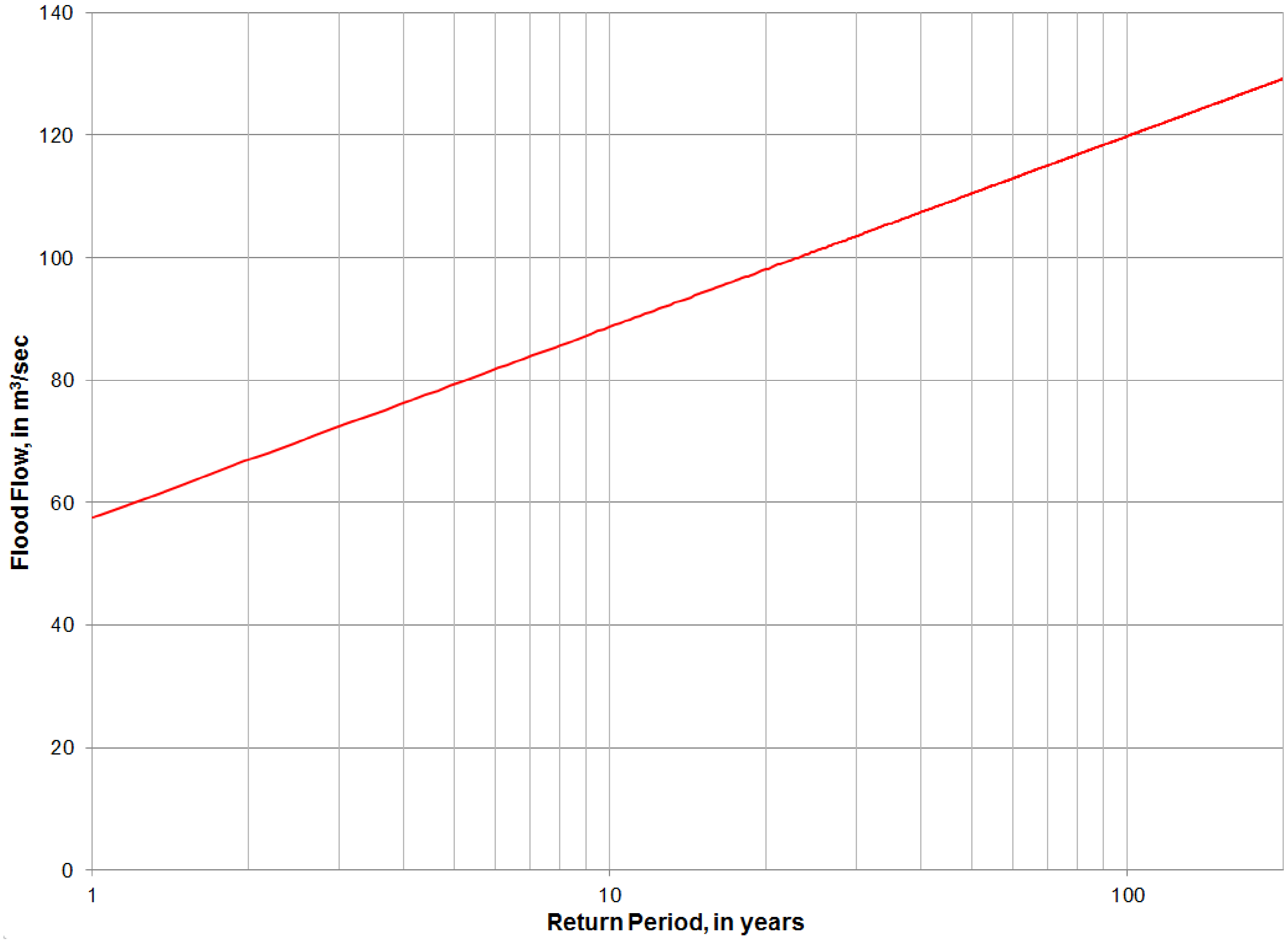


Figure K.20 Flood Flow Curve of Subwatershed #19.

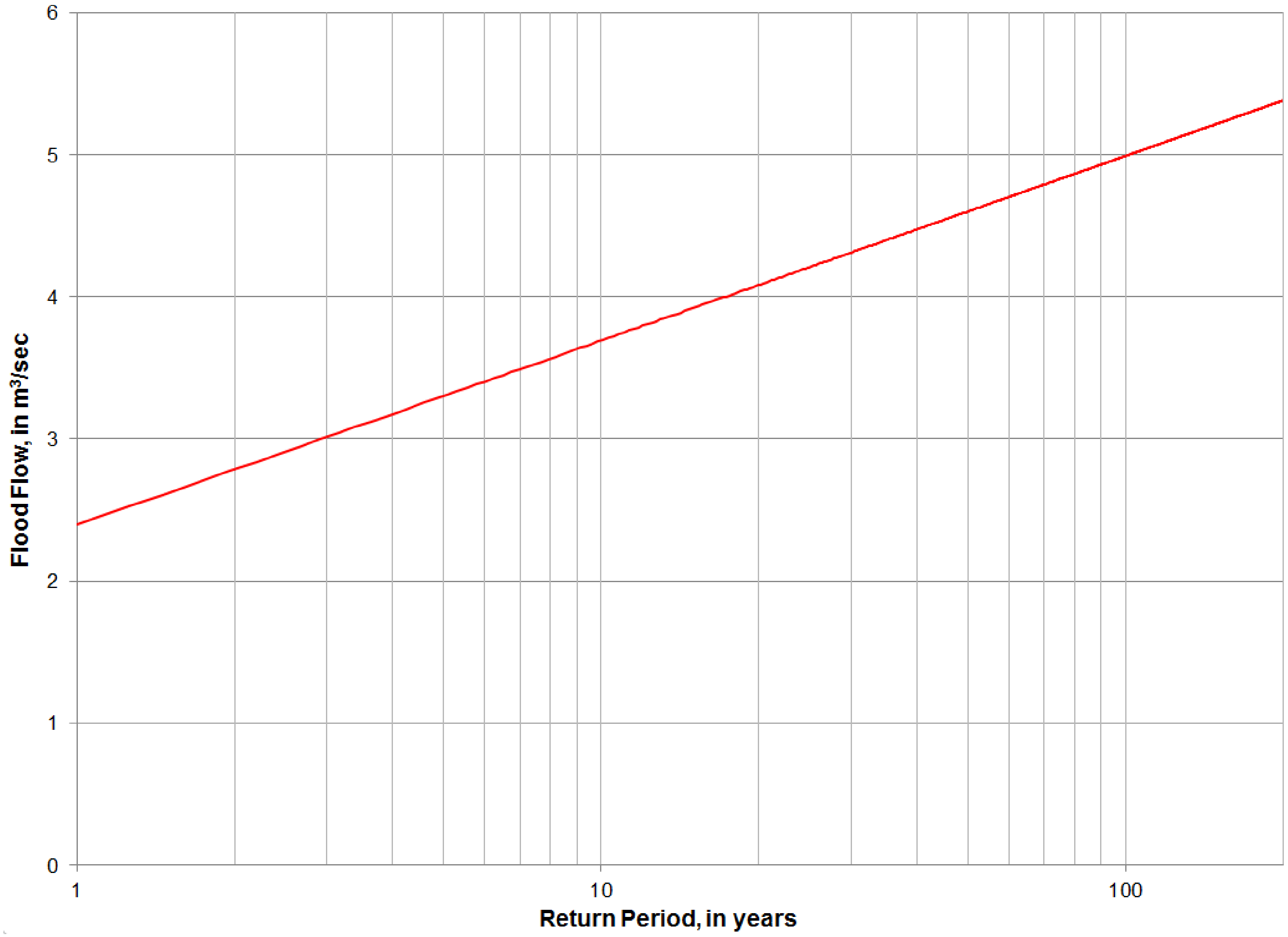


Figure K.21 Flood Flow Curve of Subwatershed #19A.

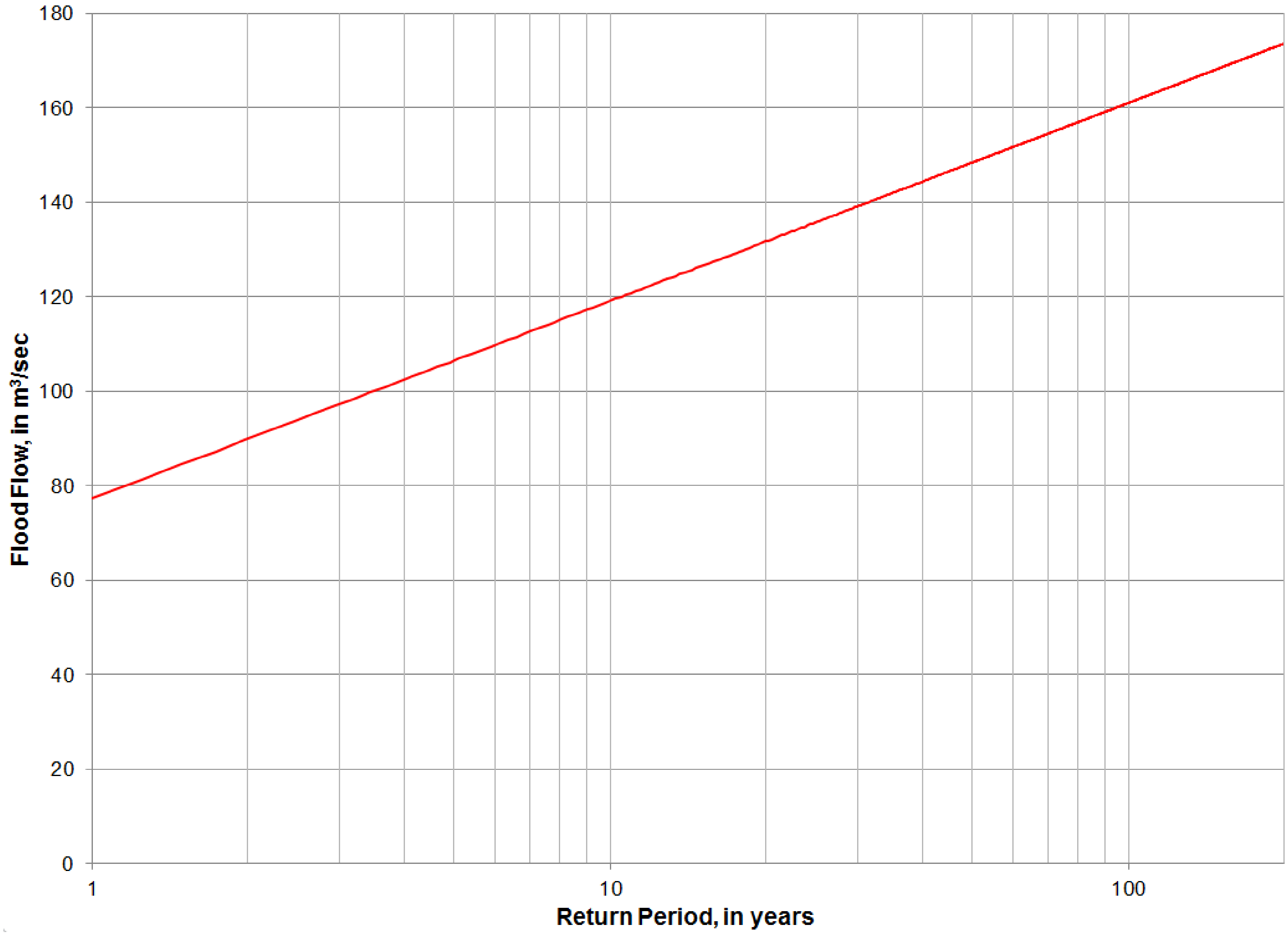


Figure K.22 **Flood Flow Curve of Subwatershed #20.**

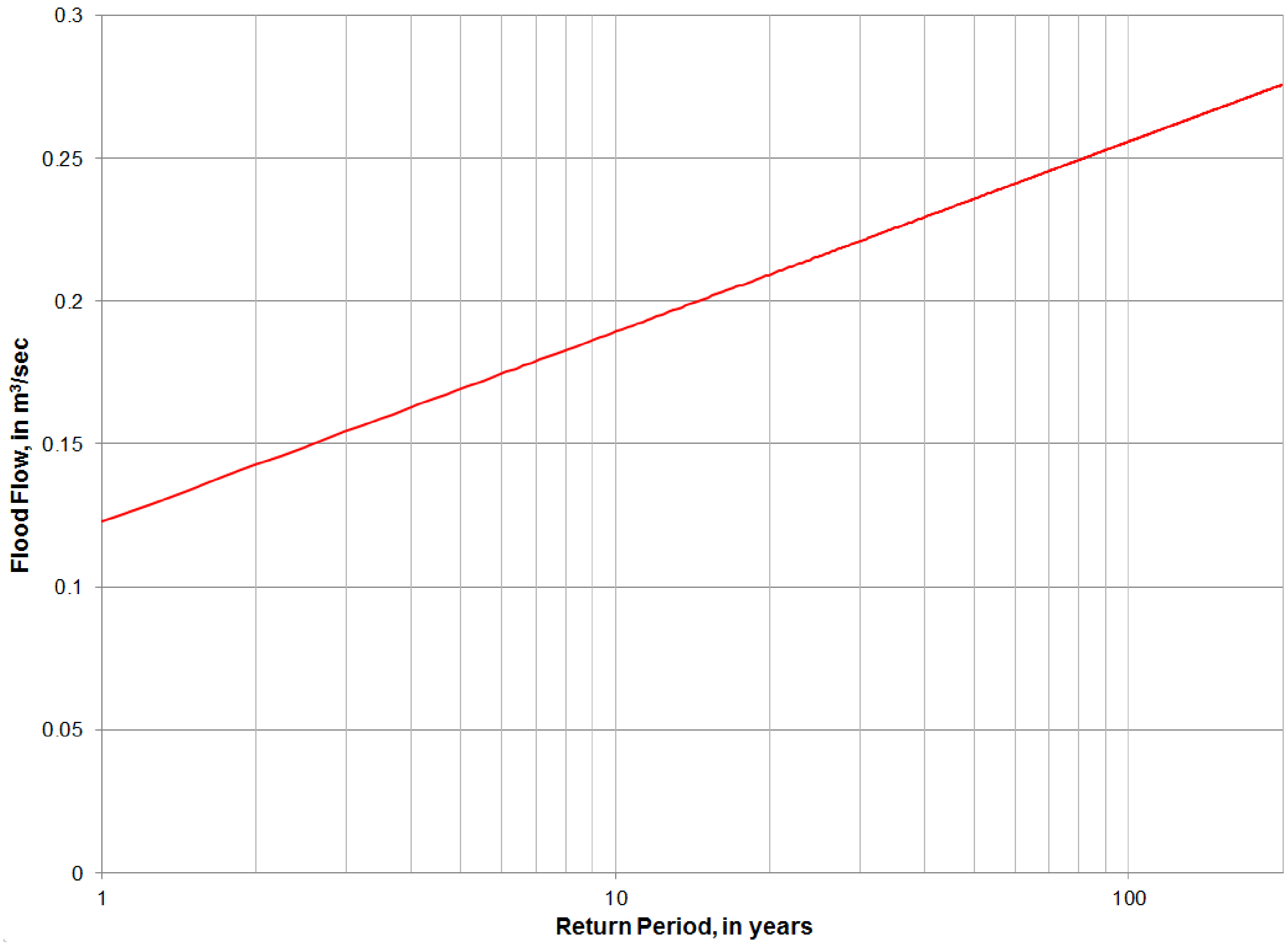


Figure K.23 Flood Flow Curve of Subwatershed #21.

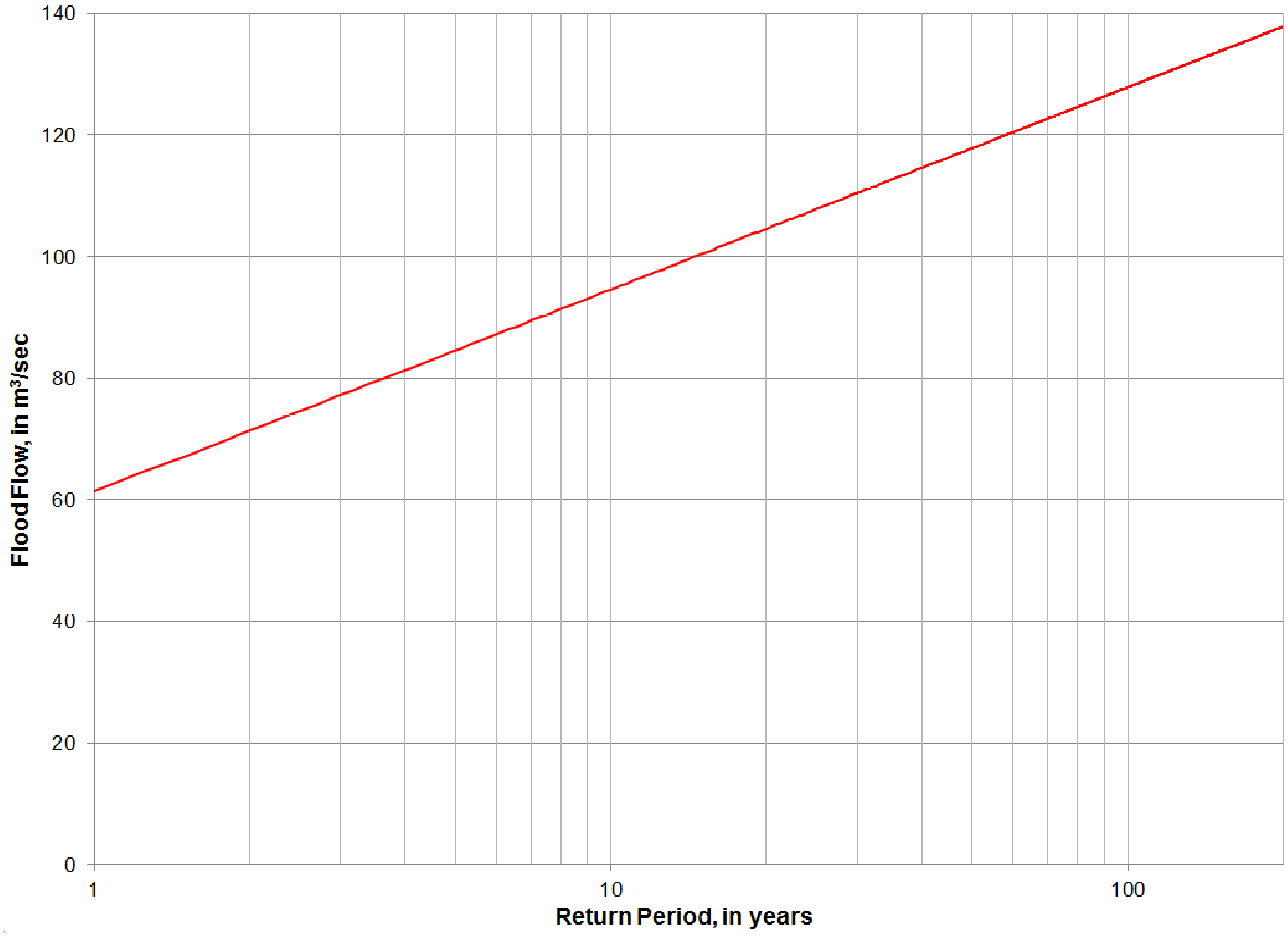


Figure K.24 Flood Flow Curve of Subwatershed #22.

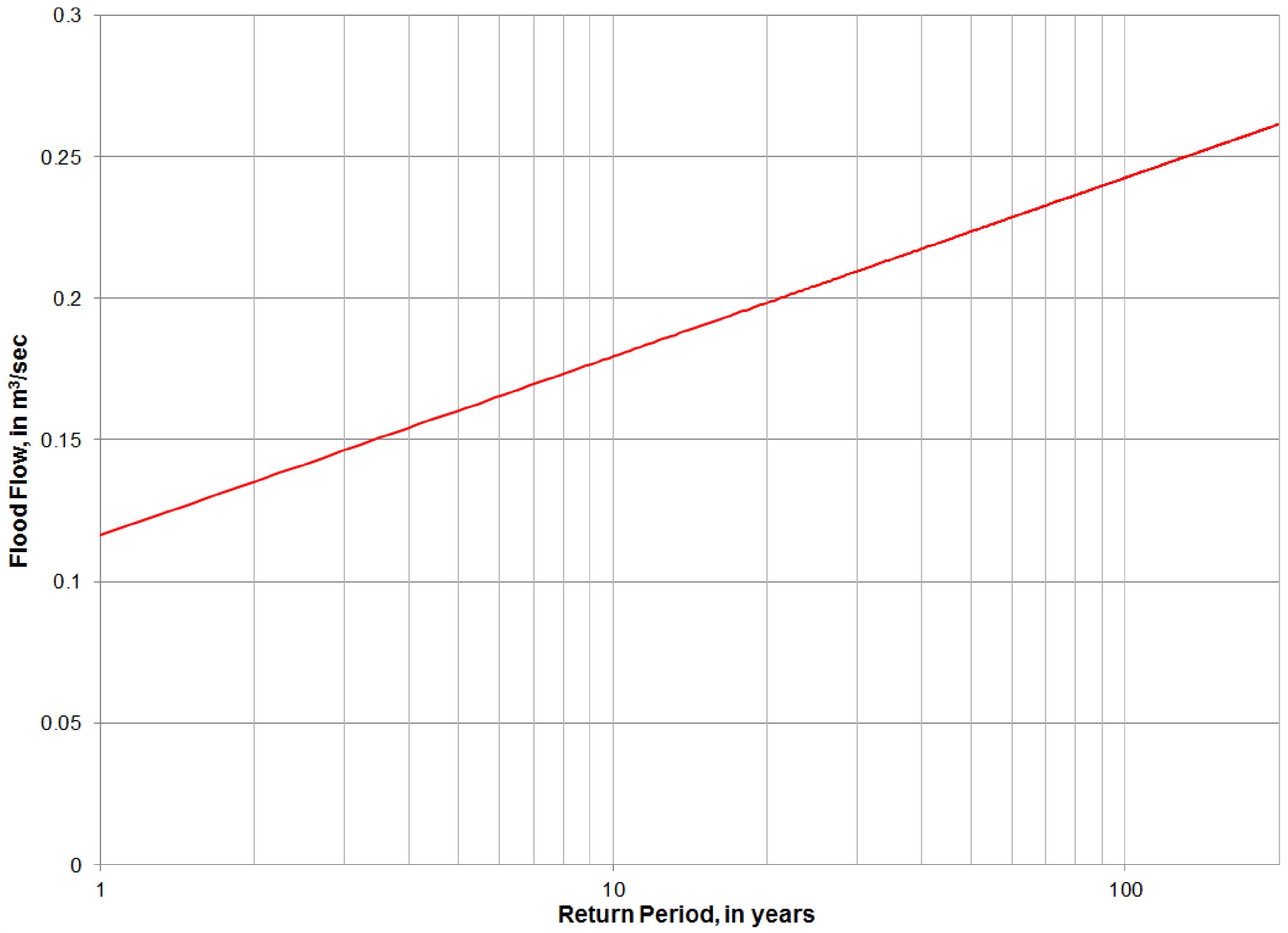
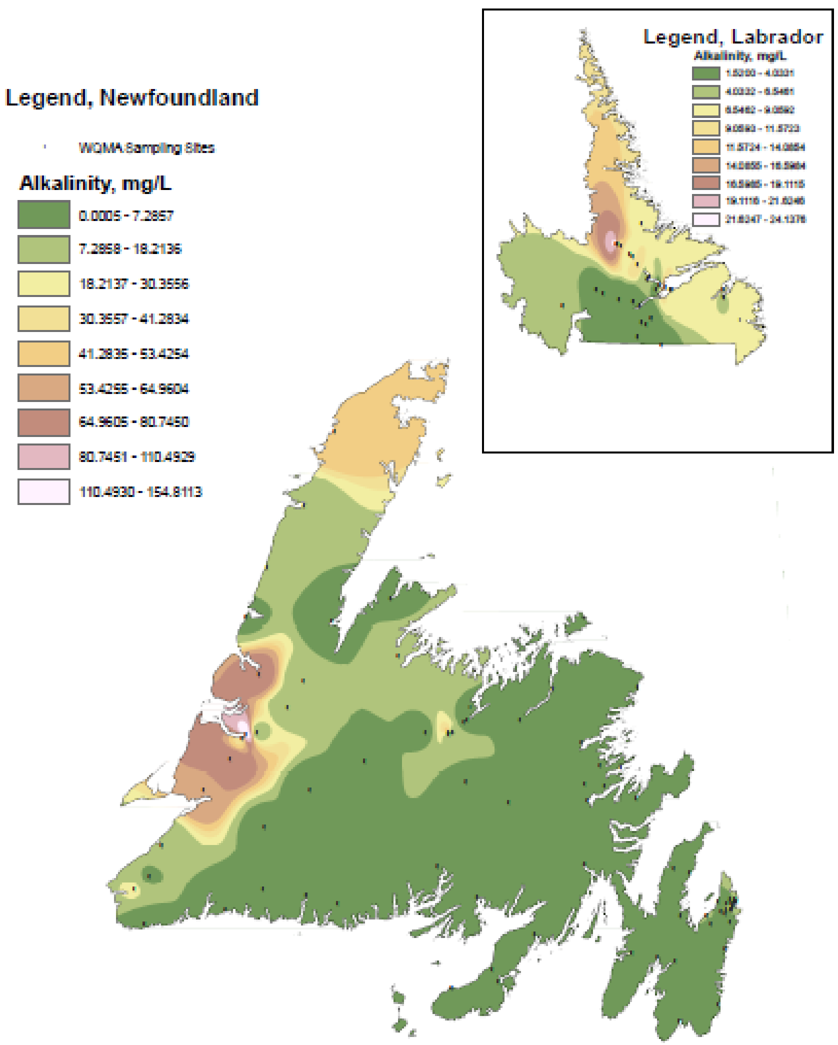


Figure K.25 Flood Flow Curve of Subwatershed #23.

Appendix L

Water Quality Concentration Contour Maps from Newfoundland Department of Environment and Conservation

Alkalinity Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
Alkalinity, mg/L
1.5200 - 4.0331
4.0332 - 6.5461
6.5462 - 9.0592
9.0593 - 11.5723
11.5724 - 14.0854
14.0855 - 16.5984
16.5985 - 19.1115
19.1116 - 21.6246
21.6247 - 24.1376
Legend, Newfoundland
WQMA Sampling Sites
Alkalinity, mg/L
0.0005 - 7.2857
7.2858 - 18.2136
18.2137 - 30.3556
30.3557 - 41.2834
41.2835 - 53.4254
53.4255 - 64.9604
64.9605 - 80.7450
80.7451 - 110.4929
110.4930 - 154.8113

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Alkalinity refers to water's ability, or inability, to neutralize acids. It is primarily a function of the carbonate, bicarbonate, and hydroxide content in water. The lower the alkalinity, the less capacity the water has to absorb acids without becoming more acidic. It is increased by urban drainage, as well as leachate from waste disposal sites, and activities such as pulp and paper mills and agriculture. There is no alkalinity guideline for the Protection of Aquatic Life.

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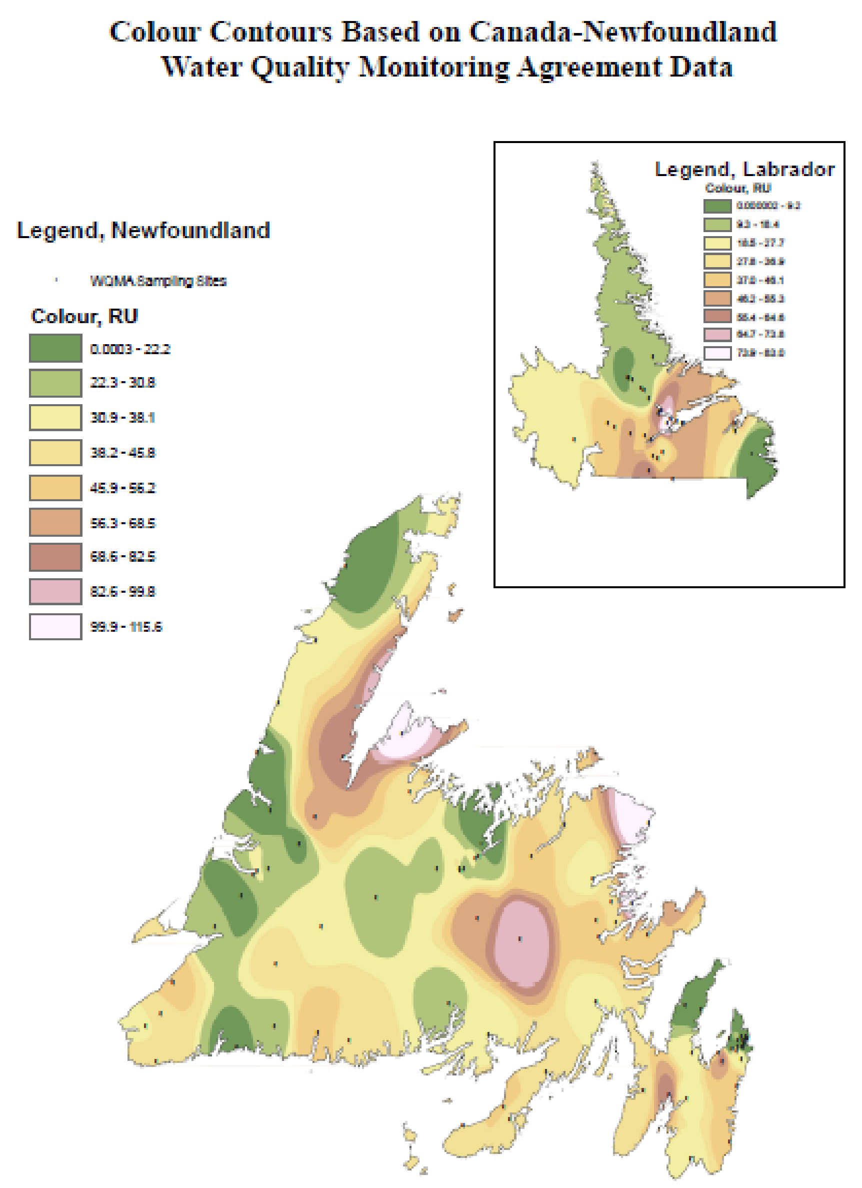
Department of Environment and Conservation
Water Resources Management Division

Environment Canada   Environnement Canada

Figure L.1 **Alkalinity Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data**


Colour Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data
Legend, Labrador
Colour, RU
0.000000 - 9.2
9.3 - 18.4
18.5 - 27.7
27.8 - 36.9
37.0 - 46.1
46.2 - 55.3
55.4 - 64.6
64.7 - 73.8
73.9 - 83.0
Legend, Newfoundland
WQMA Sampling Sites
Colour, RU
0.0003 - 22.2
22.3 - 30.8
30.9 - 38.1
38.2 - 45.8
45.9 - 56.2
56.3 - 68.5
68.6 - 82.5
82.6 - 99.8
99.9 - 115.6

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

A water body may be perceived as being unclean due to high colour (i.e. brown or green), but this is not necessarily the case. Large amount of bogs and marshes in this province result in a high organic content in most waterbodies, which can cause high colour. In addition, geology can influence water colour (i.e. if there is a high iron or copper content in surrounding bedrock). Industrial waste from pulp and paper production and mining operations can also add substantial colour to water. There is no colour guideline for the Protection of Aquatic Life.

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Water Resources Management Division

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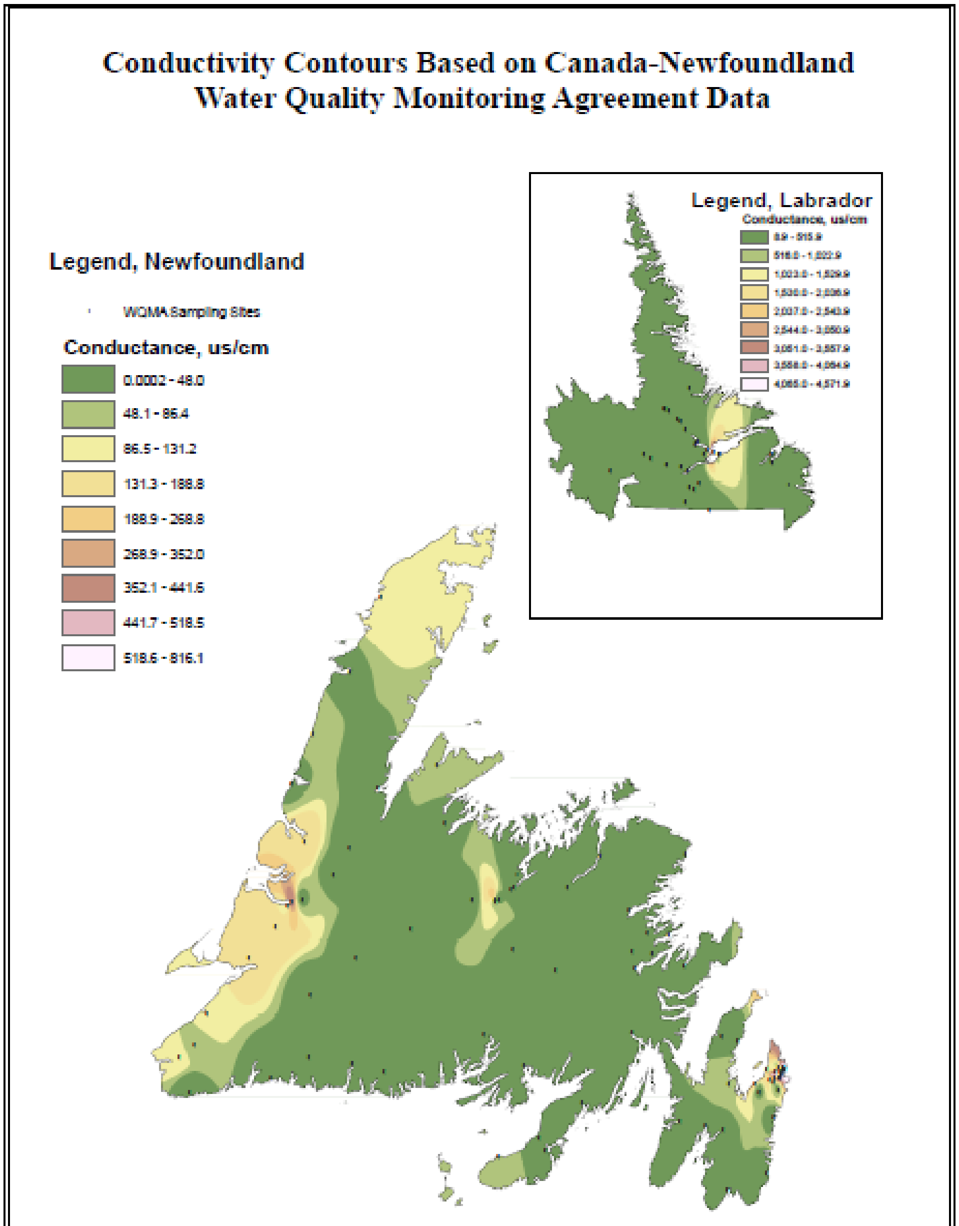
Figure L.2 **Colour Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data**


Conductivity Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data
Legend, Newfoundland
WQMA Sampling Sites
Conductance, us/cm
0.0002 - 48.0
48.1 - 86.4
86.5 - 131.2
131.3 - 188.8
188.9 - 268.8
268.9 - 352.0
352.1 - 441.6
441.7 - 518.5
518.6 - 816.1
Legend, Labrador
Conductance, us/cm
8.9 - 515.9
516.0 - 1,022.9
1,023.0 - 1,529.9
1,530.0 - 2,036.9
2,037.0 - 2,543.9
2,544.0 - 3,050.9
3,051.0 - 3,557.9
3,558.0 - 4,064.9
4,065.0 - 4,571.9

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Conductance or conductivity is defined as the amount of ionic material (i.e. salts) dissolved in the water. Conductivity of waterbodies tends to be higher in urban areas and near highways, as it is influenced by road salt and fertilizer application. In addition, conductivity of a water body can be influenced by the conductivity of rainwater (i.e. if the clouds form over the ocean they have a higher salt content). There is no conductivity guideline for the Protection of Aquatic Life.

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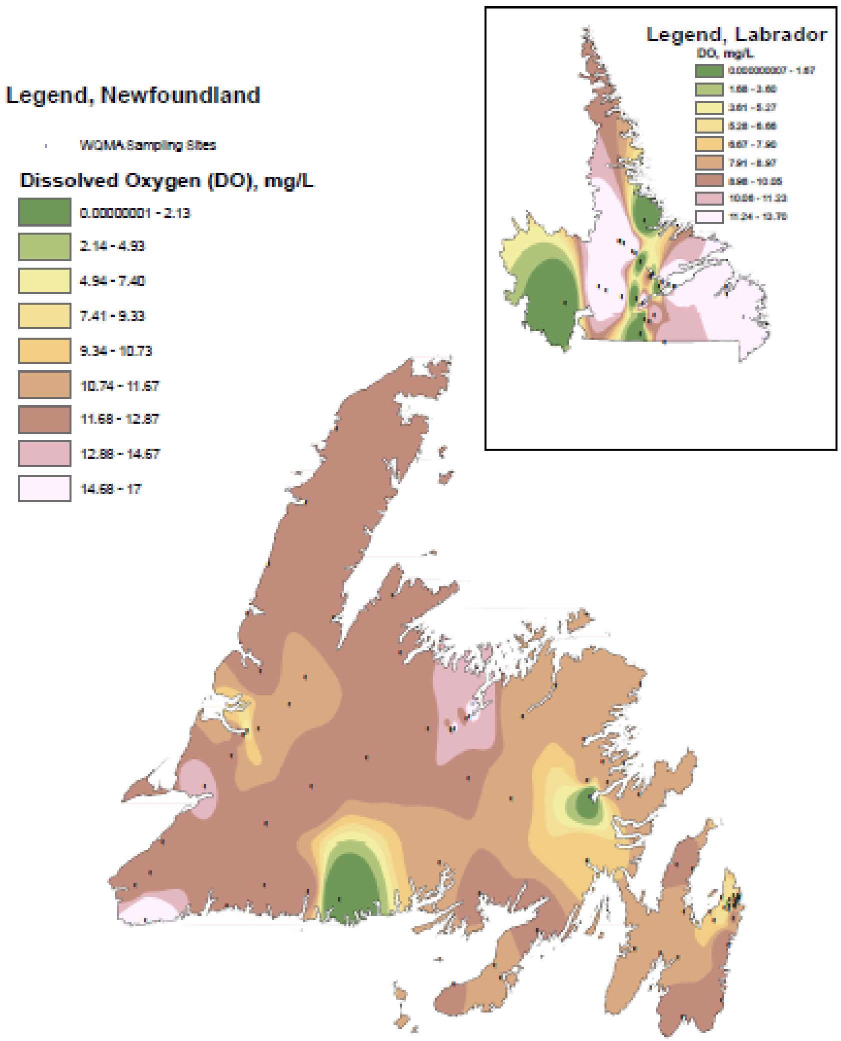
Water Resources Management Division

Environment Canada Environnement Canada

Figure L.3 Conductivity Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Dissolved Oxygen Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
DO, mg/L
🟩 0.000000007 - 1.67
1.68 - 3.60
3.61 - 5.27
5.28 - 6.66
6.67 - 7.90
7.91 - 8.97
8.98 - 10.05
10.06 - 11.23
11.24 - 12.70
Legend, Newfoundland
WQMA Sampling Sites
Dissolved Oxygen (DO), mg/L
0.00000001 - 2.13
2.14 - 4.93
4.94 - 7.40
7.41 - 9.33
9.34 - 10.73
10.74 - 11.67
11.68 - 12.87
12.88 - 14.67
14.68 - 17

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Dissolved Oxygen (DO) is oxygen dissolved in water that is required by aquatic life for metabolism (i.e. breathing). The concentration of DO depends on pressure, temperature, and turbulence. Organics in the water can decrease DO concentrations. It tends to be lower in small shallow rivers, which are generally found in urban areas. The DO guideline for the Protection of Aquatic Life is a minimum of 9.5mg/L.

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Department of Environment and Conservation
Water Resources Management Division

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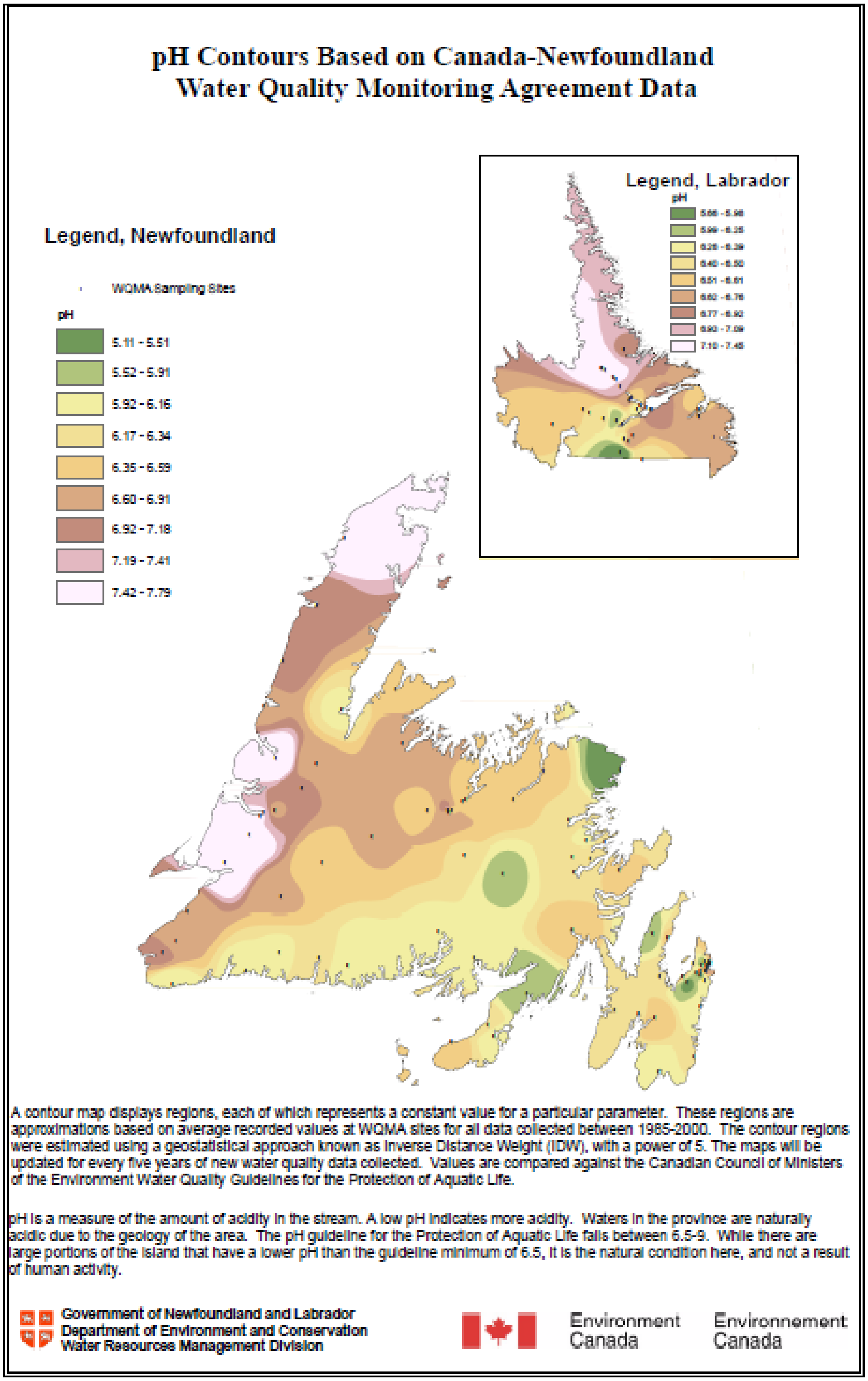
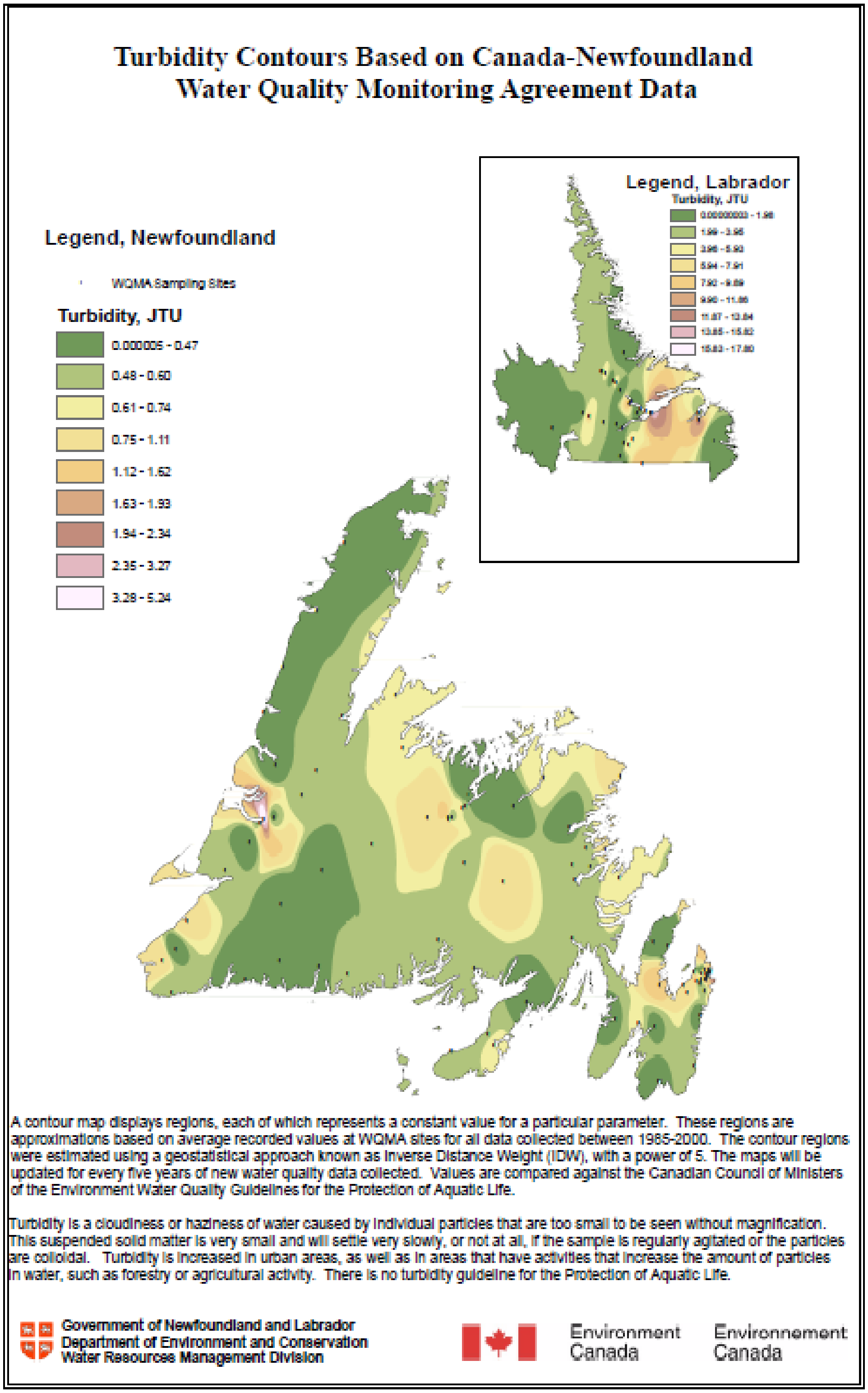
Figure L.4 **Dissolved Oxygen Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data**


pH Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data
Legend, Labrador
pH
5.66 - 5.98
5.99 - 6.25
6.26 - 6.39
6.40 - 6.50
6.51 - 6.61
6.62 - 6.76
6.77 - 6.92
6.93 - 7.09
7.10 - 7.45
Legend, Newfoundland
WQMA Sampling Sites
pH
5.11 - 5.51
5.52 - 5.91
5.92 - 6.16
6.17 - 6.34
6.35 - 6.59
6.60 - 6.91
6.92 - 7.18
7.19 - 7.41
7.42 - 7.79
Government of Newfoundland and Labrador
Department of Environment and Conservation
Water Resources Management Division
Environment Canada
Environnement Canada

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

pH is a measure of the amount of acidity in the stream. A low pH indicates more acidity. Waters in the province are naturally acidic due to the geology of the area. The pH guideline for the Protection of Aquatic Life falls between 6.5-9. While there are large portions of the island that have a lower pH than the guideline minimum of 6.5, it is the natural condition here, and not a result of human activity.

Figure L.5 pH Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Turbidity Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data
Legend, Newfoundland
WQMA Sampling Sites
Turbidity, JTU
0.000005 - 0.47
0.48 - 0.60
0.61 - 0.74
0.75 - 1.11
1.12 - 1.62
1.63 - 1.93
1.94 - 2.34
2.35 - 3.27
3.28 - 5.24
Legend, Labrador
Turbidity, JTU
0.00000003 - 1.98
1.99 - 3.95
3.96 - 5.93
5.94 - 7.91
7.92 - 9.89
9.90 - 11.86
11.87 - 13.84
13.85 - 15.82
15.83 - 17.80

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Turbidity is a cloudiness or haziness of water caused by individual particles that are too small to be seen without magnification. This suspended solid matter is very small and will settle very slowly, or not at all, if the sample is regularly agitated or the particles are colloidal. Turbidity is increased in urban areas, as well as in areas that have activities that increase the amount of particles in water, such as forestry or agricultural activity. There is no turbidity guideline for the Protection of Aquatic Life.

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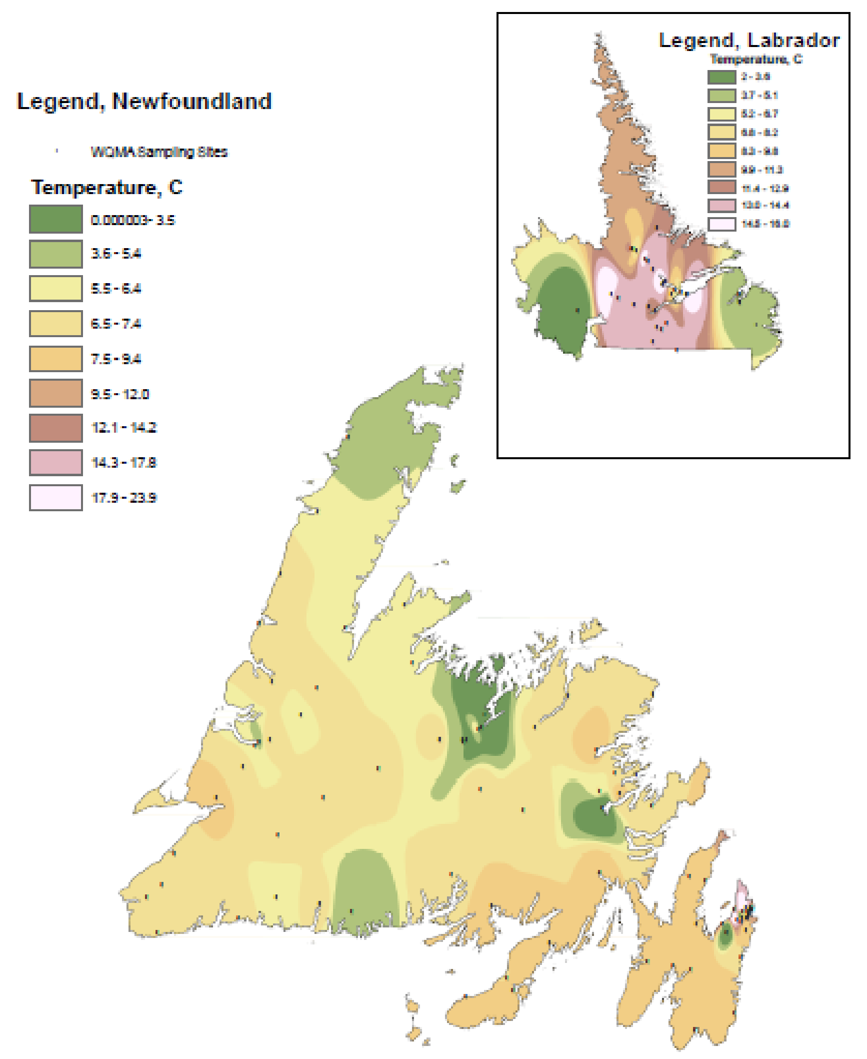
Figure L.6 Turbidity Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Temperature Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
Temperature, C
2 - 3.6
3.7 - 5.1
5.2 - 6.7
6.8 - 8.2
8.3 - 9.8
9.9 - 11.3
11.4 - 12.9
13.0 - 14.4
14.5 - 15.9
Legend, Newfoundland
WQMA Sampling Sites
Temperature, C
0.000003- 3.5
3.6 - 5.4
5.5 - 6.4
6.5 - 7.4
7.5 - 9.4
9.5 - 12.0
12.1 - 14.2
14.3 - 17.8
17.9 - 23.9

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Water temperature is affected by many factors, such as water depth and air temperature. Temperatures are higher in urban settings where rivers tend to be shallower and smaller than those found in other areas. Average temperatures in Labrador are artificially high, as most sites are measured only once or twice a year, usually in the summer, when the water temperatures are at their warmest. There is no temperature guideline for the Protection of Aquatic Life.

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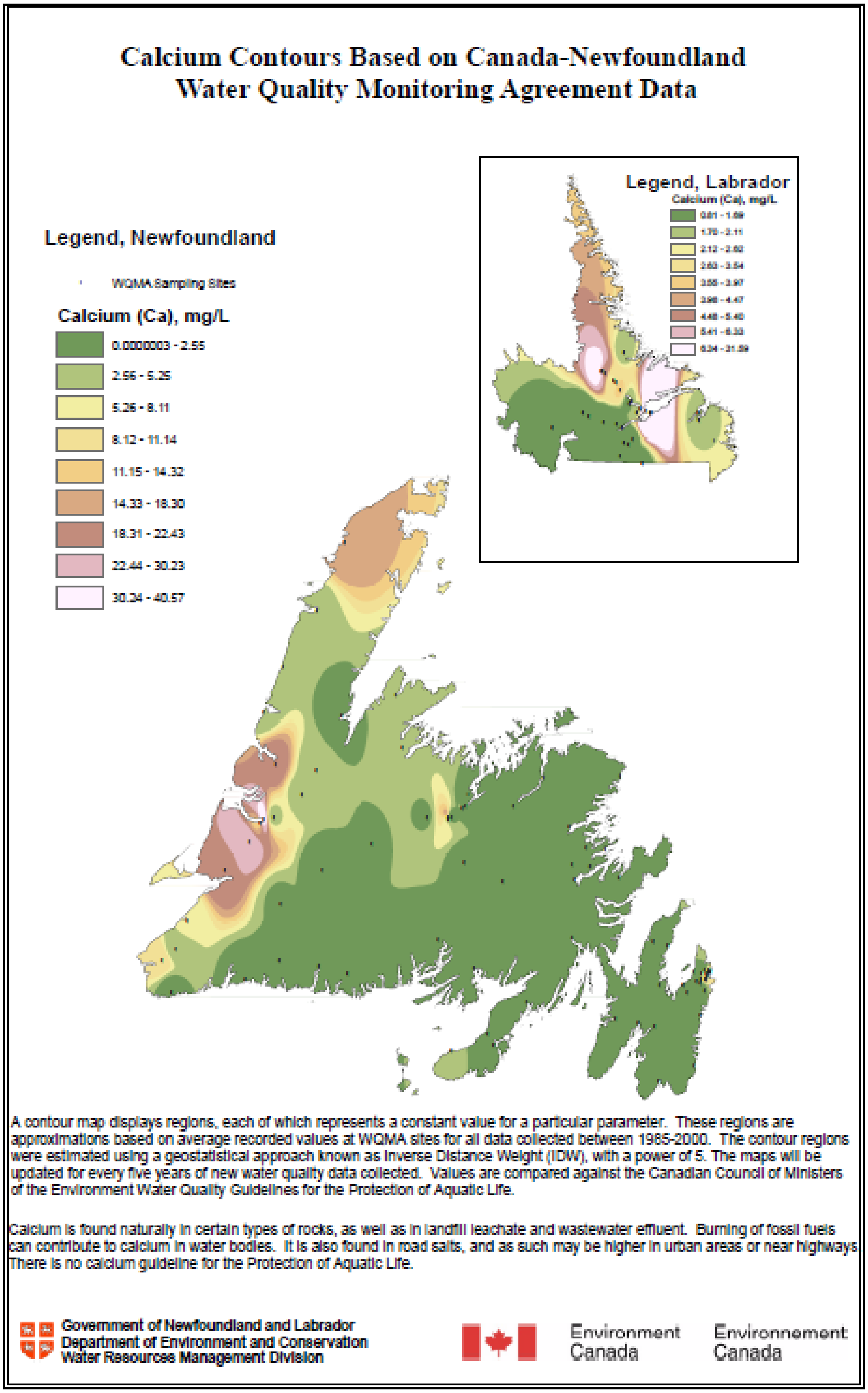
Figure L.7 Temperature Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Calcium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Legend, Labrador
Calcium (Ca), mg/L
0.61 - 1.69
1.70 - 2.11
2.12 - 2.62
2.63 - 3.54
3.55 - 3.97
3.98 - 4.47
4.48 - 5.40
5.41 - 6.33
6.34 - 31.59
Legend, Newfoundland
WQMA Sampling Sites
Calcium (Ca), mg/L
0.0000003 - 2.55
2.56 - 5.25
5.26 - 8.11
8.12 - 11.14
11.15 - 14.32
14.33 - 18.30
18.31 - 22.43
22.44 - 30.23
30.24 - 40.57

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Calcium is found naturally in certain types of rocks, as well as in landfill leachate and wastewater effluent. Burning of fossil fuels can contribute to calcium in water bodies. It is also found in road salts, and as such may be higher in urban areas or near highways There is no calcium guideline for the Protection of Aquatic Life.

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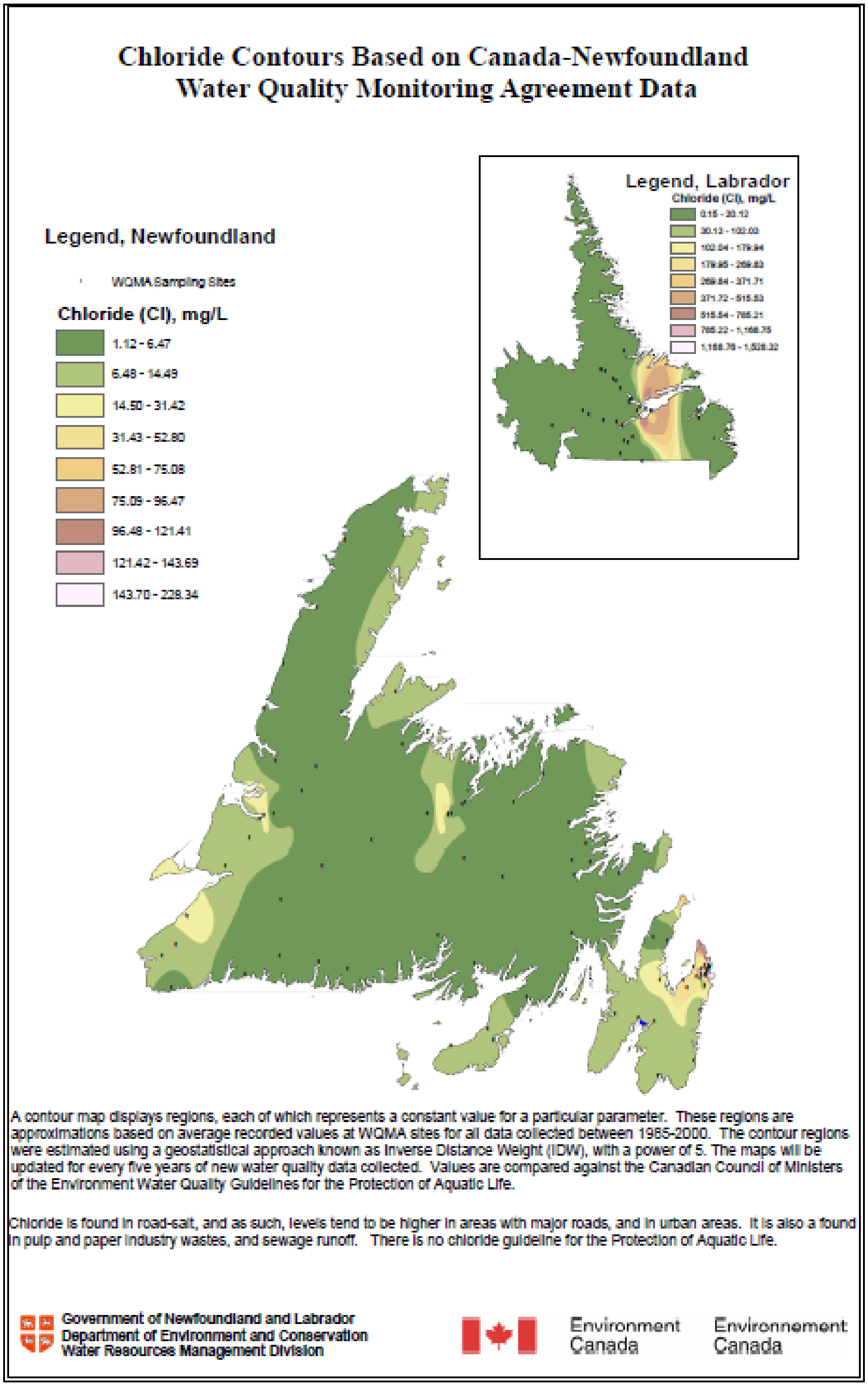
Figure L.8 **Calcium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data**



Chloride Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Legend, Labrador
Chloride (Cl), mg/L
0.15 - 30.12
30.13 - 102.03
102.04 - 179.94
179.95 - 269.83
269.84 - 371.71
371.72 - 515.53
515.54 - 765.21
765.22 - 1,168.75
1,168.76 - 1,528.32
Legend, Newfoundland
WQMA Sampling Sites
Chloride (Cl), mg/L
1.12 - 6.47
6.48 - 14.49
14.50 - 31.42
31.43 - 52.80
52.81 - 75.08
75.09 - 96.47
96.48 - 121.41
121.42 - 143.69
143.70 - 228.34

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Chloride is found in road-salt, and as such, levels tend to be higher in areas with major roads, and in urban areas. It is also a found in pulp and paper industry wastes, and sewage runoff. There is no chloride guideline for the Protection of Aquatic Life.

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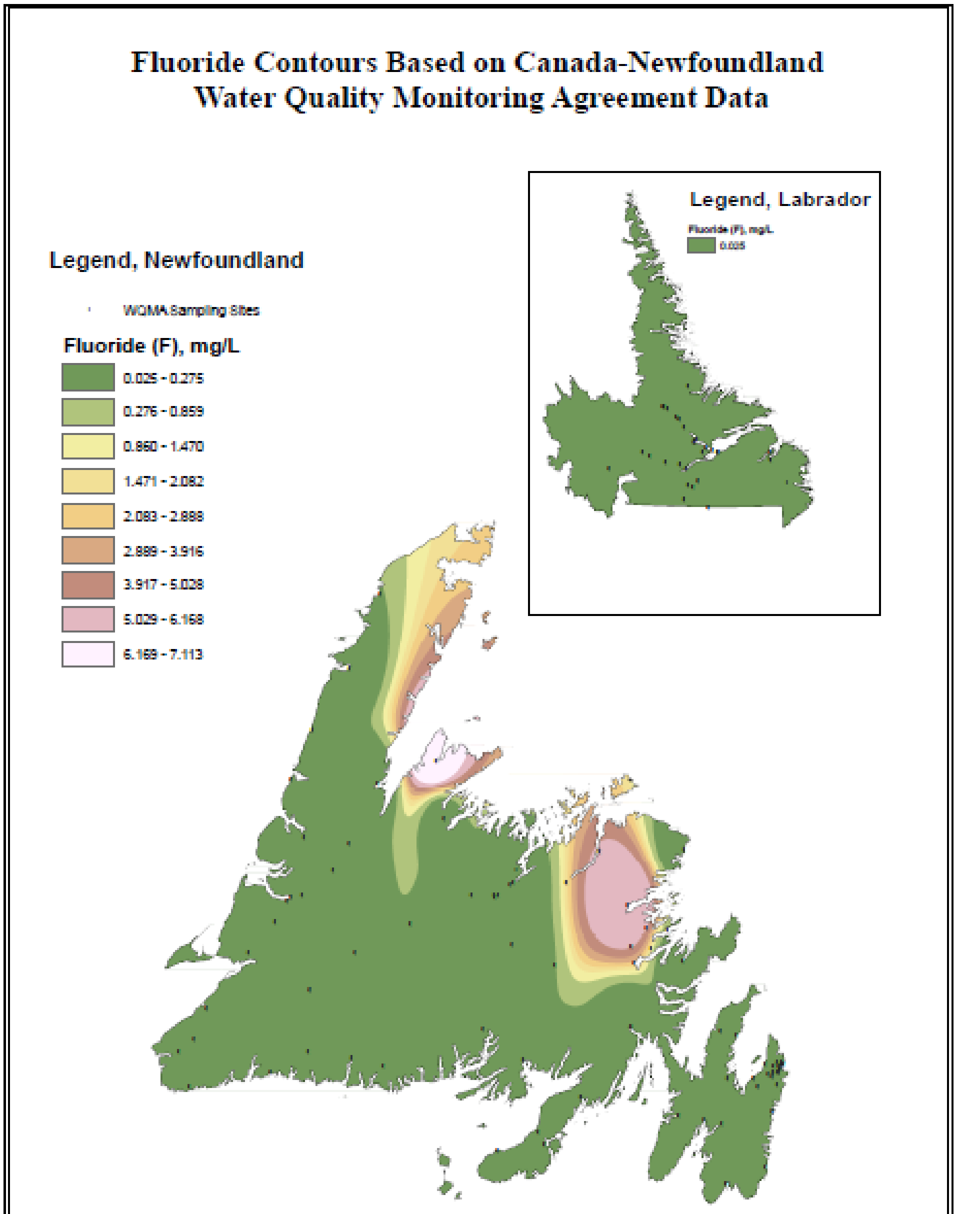
Figure L.9 **Chloride Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data**


Fluoride Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data
Legend, Labrador
Fluoride (F), mg/L
0.025
Legend, Newfoundland
WQMA Sampling Sites
Fluoride (F), mg/L
0.025 - 0.275
0.276 - 0.859
0.860 - 1.470
1.471 - 2.082
2.083 - 2.888
2.889 - 3.916
3.917 - 5.028
5.029 - 6.168
6.169 - 7.113

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Fluoride occurs naturally in the earth's crust where it can be found in rocks, coal and clay. Fluorides can also be released into the air in wind-blown soil. Hydrogen fluorides are a byproduct of combustion processes of industry. Fluorides that are found in air will eventually drop onto land or into water. The fluoride guideline for the Protection of Aquatic Life is 1.2mg/L, which is significantly higher than values found in the waters of Newfoundland and Labrador. Values in Labrador are artificially uniform as only two sites were tested for fluoride concentrations.

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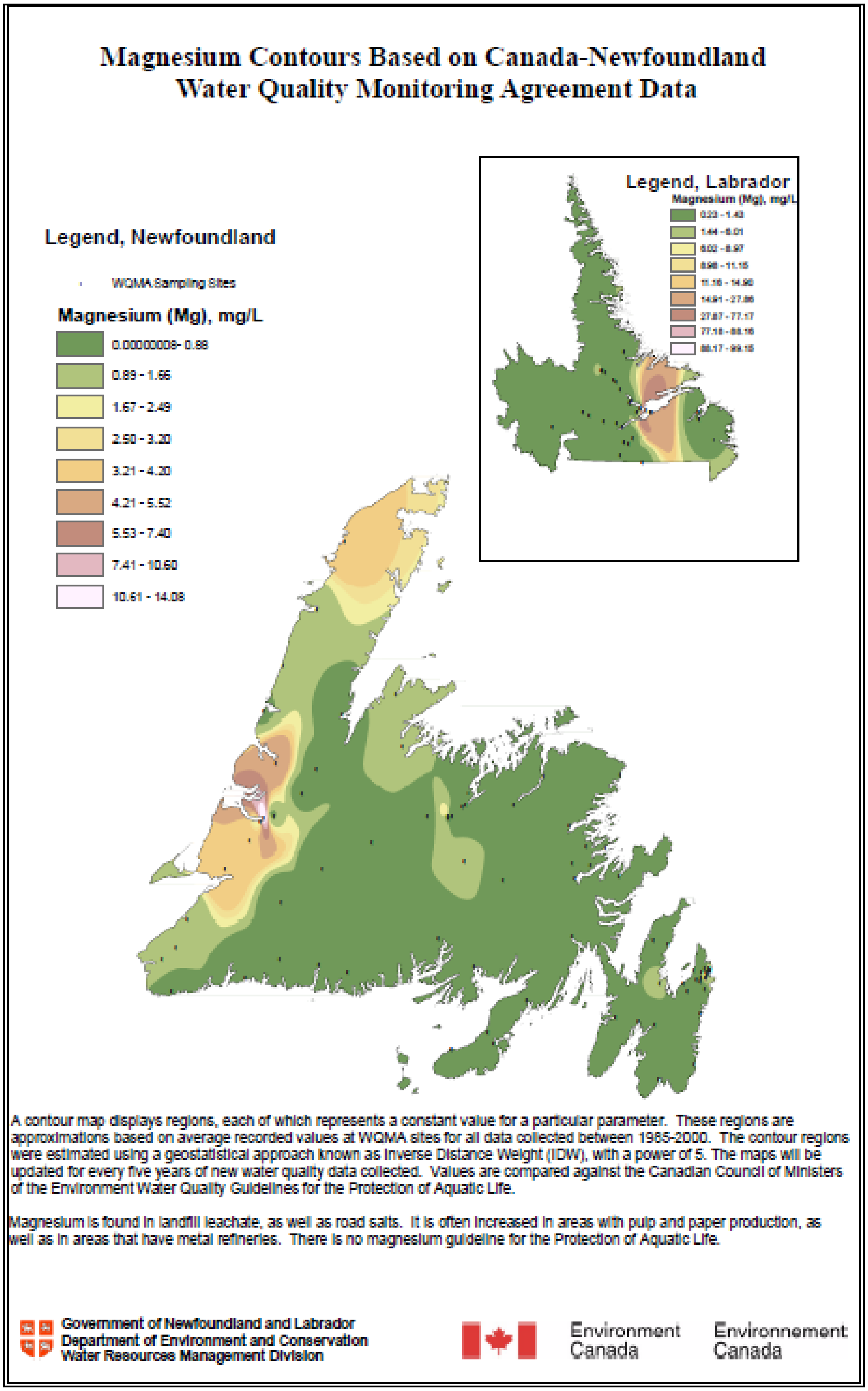
Figure L.10 Fluoride Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Magnesium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data
Legend, Labrador
Magnesium (Mg), mg/L
0.23 - 1.43
1.44 - 6.01
6.02 - 8.97
8.98 - 11.15
11.16 - 14.90
14.91 - 27.86
27.87 - 77.17
77.18 - 88.16
88.17 - 99.15
Legend, Newfoundland
WQMA Sampling Sites
Magnesium (Mg), mg/L
0.00000008- 0.88
0.89 - 1.66
1.67 - 2.49
2.50 - 3.20
3.21 - 4.20
4.21 - 5.52
5.53 - 7.40
7.41 - 10.60
10.61 - 14.08

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Magnesium is found in landfill leachate, as well as road salts. It is often increased in areas with pulp and paper production, as well as in areas that have metal refineries. There is no magnesium guideline for the Protection of Aquatic Life.

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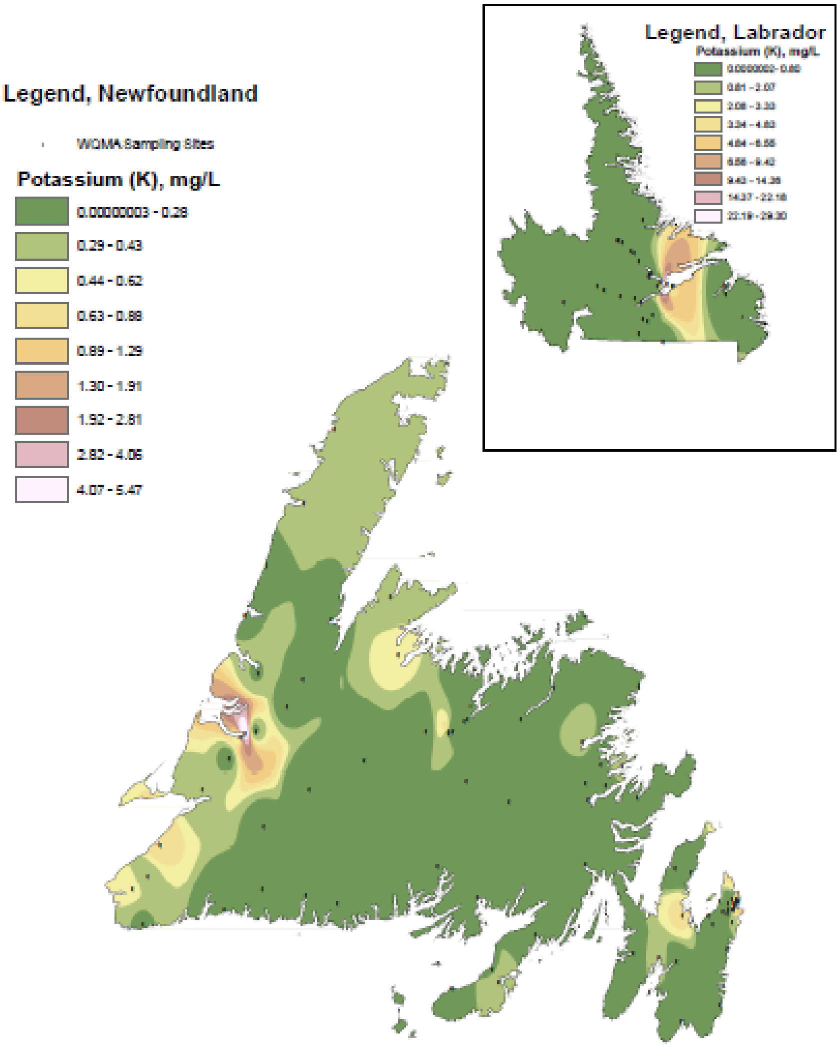
Figure L.11 **Magnesium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data**

Potassium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
Potassium (K), mg/L
🟩 0.0000002 - 0.80
🟩 0.81 - 2.07
🟨 2.08 - 3.33
🟨 3.34 - 4.83
🟧 4.84 - 6.58
🟧 6.58 - 9.42
🟫 9.43 - 14.36
🟪 14.37 - 22.18
⬜ 22.19 - 29.30
Legend, Newfoundland
· WQMA Sampling Sites
Potassium (K), mg/L
🟩 0.00000003 - 0.28
🟩 0.29 - 0.43
🟨 0.44 - 0.62
🟨 0.63 - 0.88
🟧 0.89 - 1.29
🟧 1.30 - 1.91
🟫 1.92 - 2.81
🟪 2.82 - 4.06
⬜ 4.07 - 5.47

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Potassium is found in fertilizers, and as such, levels are increased by agricultural activities. There is no potassium guideline for the Protection of Aquatic Life.

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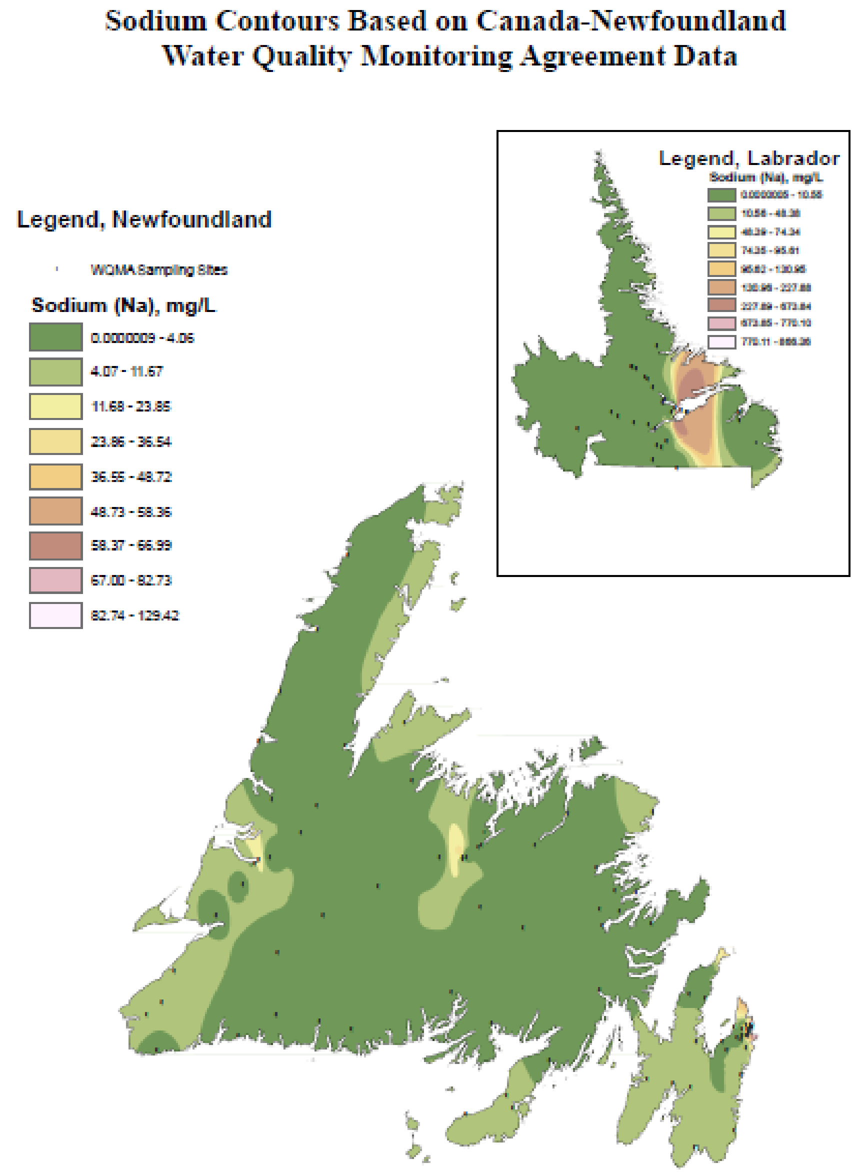
Figure L.12 Potassium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Sodium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data
Legend, Newfoundland
WQMA Sampling Sites
Sodium (Na), mg/L
0.0000009 - 4.06
4.07 - 11.67
11.68 - 23.85
23.86 - 36.54
36.55 - 48.72
48.73 - 58.36
58.37 - 66.99
67.00 - 82.73
82.74 - 129.42
Legend, Labrador
Sodium (Na), mg/L
0.0000005 - 10.55
10.56 - 48.38
48.39 - 74.34
74.35 - 95.61
95.62 - 130.95
130.96 - 227.88
227.89 - 673.84
673.85 - 770.10
770.11 - 888.38

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Sodium (salt) is generally higher in urban areas where roads are salted extensively in winter. It is a also a product of weathering of natural salt deposits (geology). There is no sodium guideline for the Protection of Aquatic Life.

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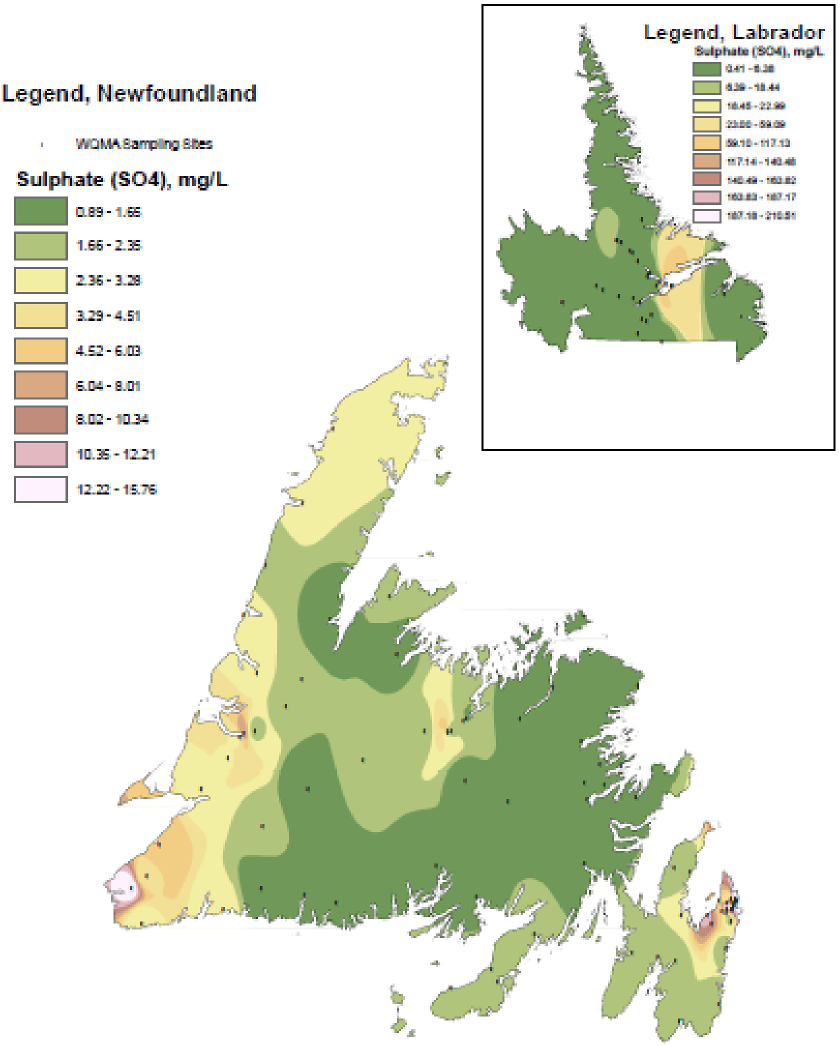
Figure L.13 Sodium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Sulphate Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Newfoundland
WQMA Sampling Sites
Sulphate (SO4), mg/L
0.89 - 1.65
1.66 - 2.35
2.36 - 3.28
3.29 - 4.51
4.52 - 6.03
6.04 - 8.01
8.02 - 10.34
10.35 - 12.21
12.22 - 15.76
Legend, Labrador
Sulphate (SO4), mg/L
0.41 - 6.38
6.39 - 18.44
18.45 - 22.99
23.00 - 59.09
59.10 - 117.13
117.14 - 140.48
140.49 - 163.82
163.83 - 187.17
187.18 - 210.51

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Sulphate is a known emission from thermal generation plants, and tends to be higher in areas near these plants. They can also be a result of long-range transport of pollutants, and have an acidifying affect. A natural source of sulphate is weathering of gypsum. Pulp and paper mills also produce sulphate in their wastes. There is no sulphate guideline for the Protection of Aquatic Life.

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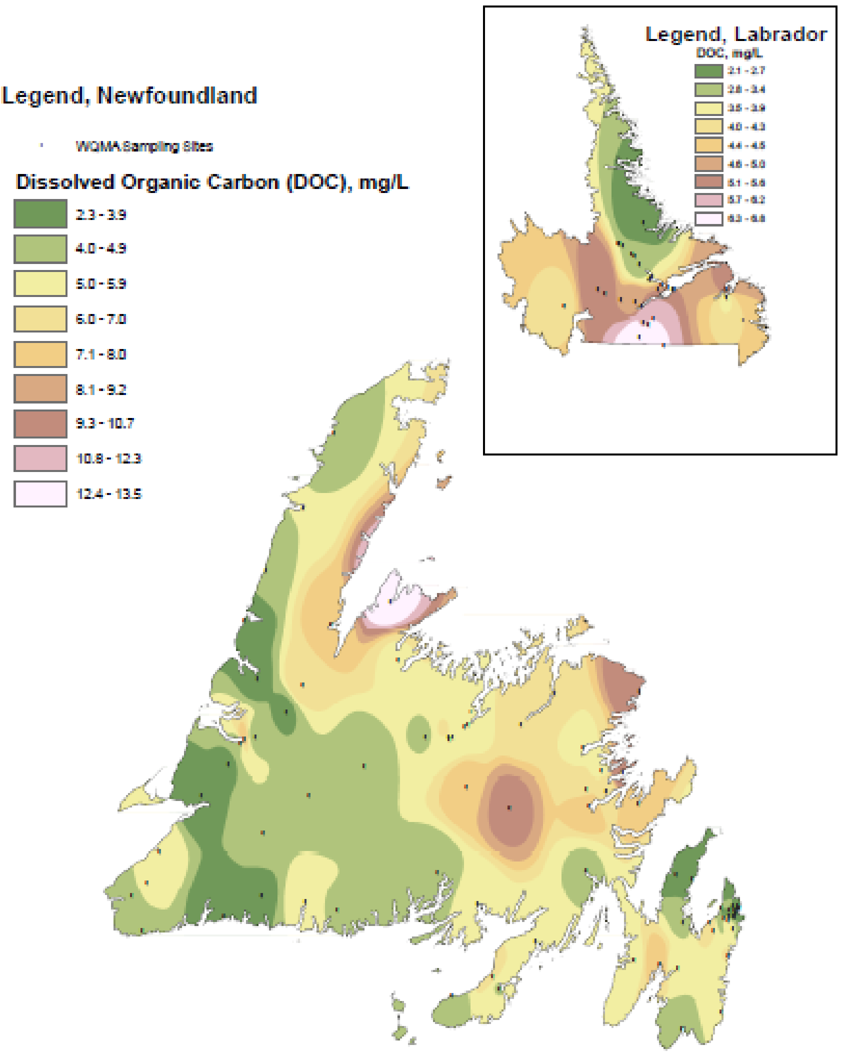
Figure L.14 Sulphate Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Dissolved Organic Carbon Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
DOC, mg/L
2.1 - 2.7
2.8 - 3.4
3.5 - 3.9
4.0 - 4.3
4.4 - 4.5
4.6 - 5.0
5.1 - 5.6
5.7 - 6.2
6.3 - 6.8
Legend, Newfoundland
WQMA Sampling Sites
Dissolved Organic Carbon (DOC), mg/L
2.3 - 3.9
4.0 - 4.9
5.0 - 5.9
6.0 - 7.0
7.1 - 8.0
8.1 - 9.2
9.3 - 10.7
10.8 - 12.3
12.4 - 13.5

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Dissolved Organic Carbon (DOC) includes soluble carbohydrates, amino acids, and other acids whose sources include photosynthesis, leaching from plant leaves and roots, and soil organic matter. Levels are naturally high in the province due to the abundance of bogs and marshes. Increased levels of DOC can be a result of forest harvesting or the discharge of sewage. There is no DOC guideline for the Protection of Aquatic Life.

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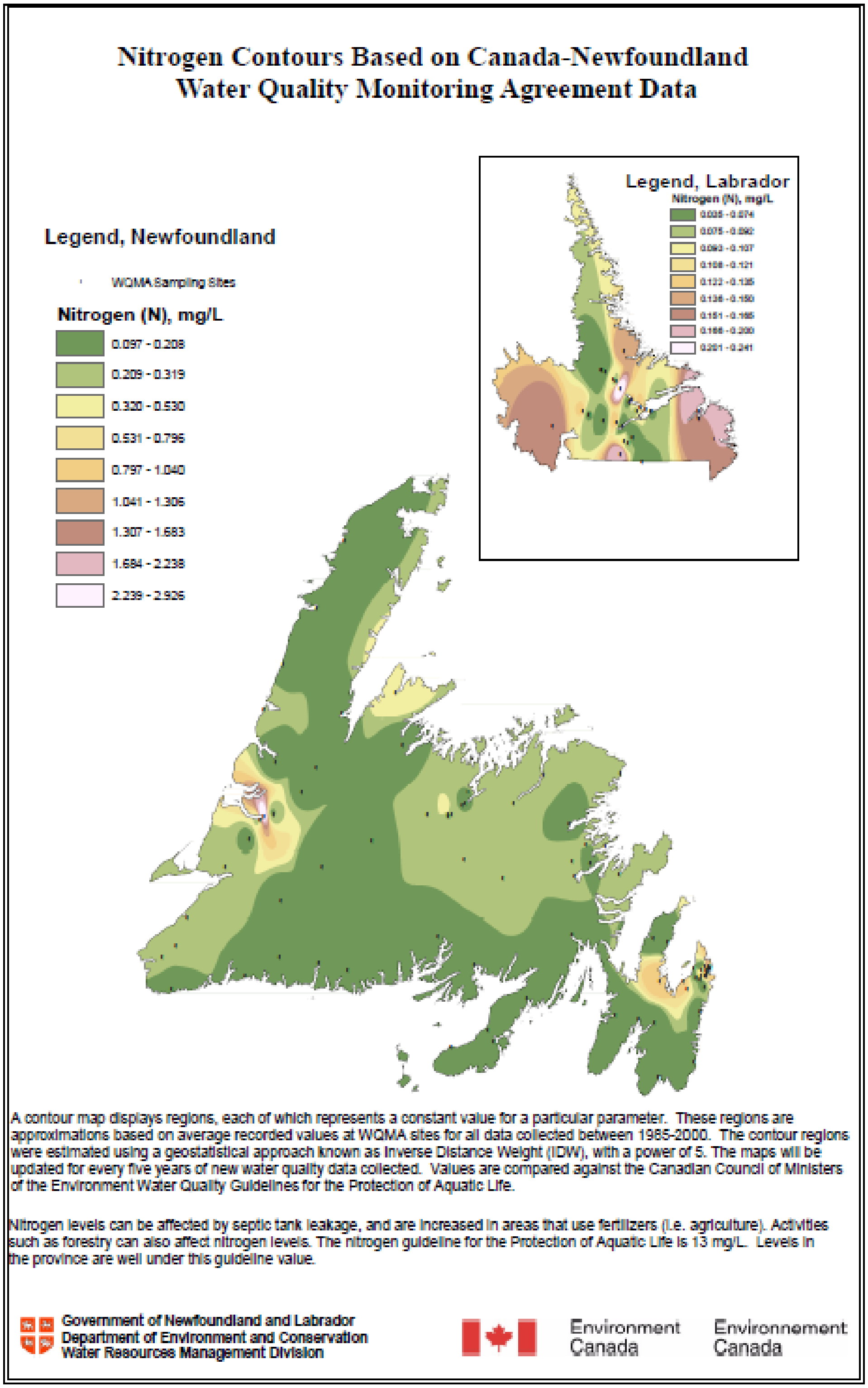
Figure L.15 Dissolved Organic Carbon Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Nitrogen Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Legend, Labrador
Nitrogen (N), mg/L
0.035 - 0.074
0.075 - 0.092
0.093 - 0.107
0.108 - 0.121
0.122 - 0.135
0.136 - 0.150
0.151 - 0.165
0.166 - 0.200
0.201 - 0.241
Legend, Newfoundland
WQMA Sampling Sites
Nitrogen (N), mg/L
0.097 - 0.208
0.209 - 0.319
0.320 - 0.530
0.531 - 0.796
0.797 - 1.040
1.041 - 1.306
1.307 - 1.683
1.684 - 2.238
2.239 - 2.926

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Nitrogen levels can be affected by septic tank leakage, and are increased in areas that use fertilizers (i.e. agriculture). Activities such as forestry can also affect nitrogen levels. The nitrogen guideline for the Protection of Aquatic Life is 13 mg/L. Levels in the province are well under this guideline value.

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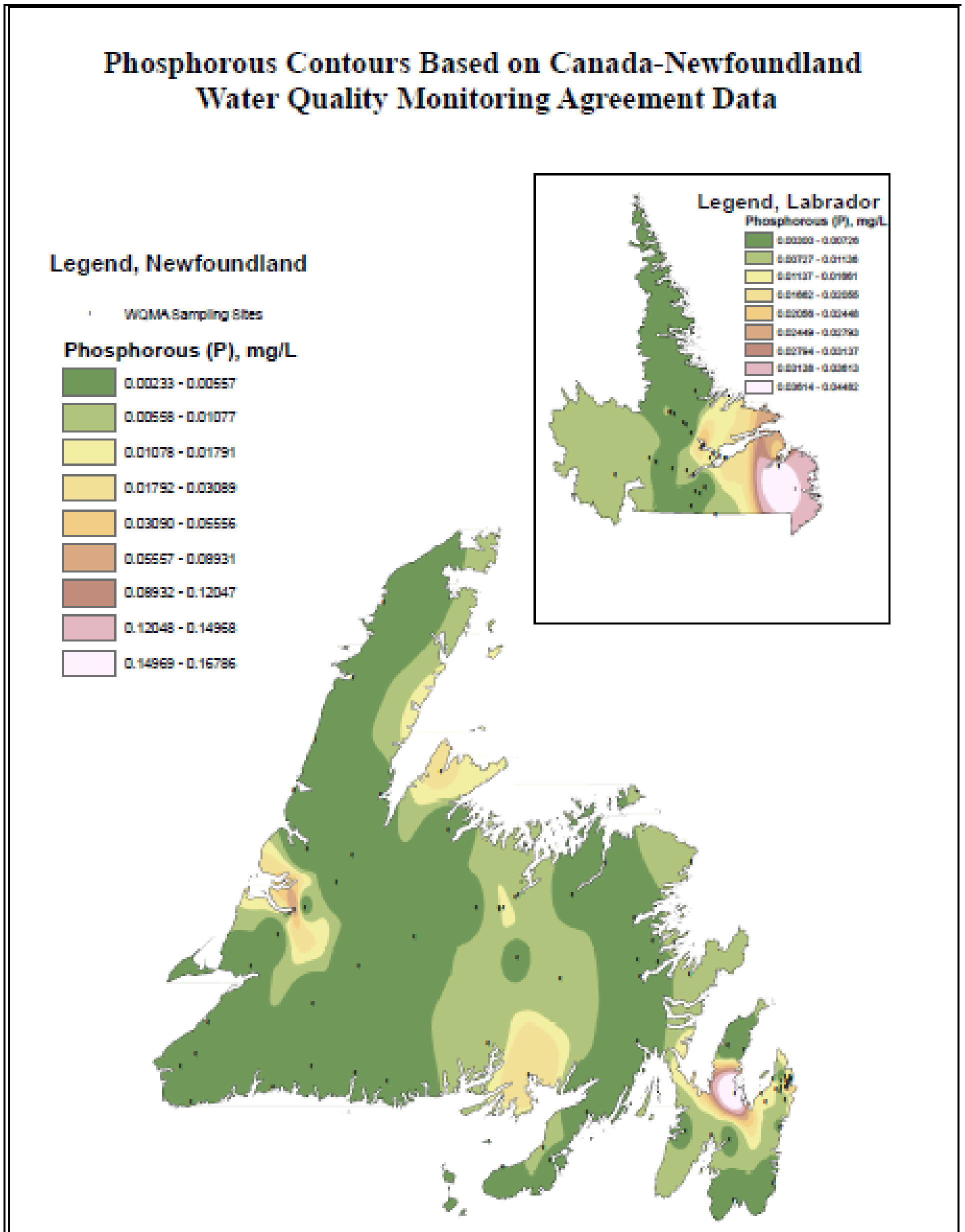
Figure L.16 Nitrogen Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Phosphorous Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data
Legend, Labrador
Phosphorous (P), mg/L
0.00303 - 0.00726
0.00727 - 0.01136
0.01137 - 0.01661
0.01662 - 0.02055
0.02056 - 0.02448
0.02449 - 0.02793
0.02794 - 0.03137
0.03138 - 0.03613
0.03614 - 0.04482
Legend, Newfoundland
WQMA Sampling Sites
Phosphorous (P), mg/L
0.00233 - 0.00557
0.00558 - 0.01077
0.01078 - 0.01791
0.01792 - 0.03089
0.03090 - 0.05556
0.05557 - 0.08931
0.08932 - 0.12047
0.12048 - 0.14968
0.14969 - 0.16786

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Phosphorous levels are generally increased in areas with agricultural activity and residential runoff. However, it is a part of the natural water column as a major element in all flora and fauna and their by products. The phosphorous guideline for the protection of Aquatic Life is 0.03mg/L for rivers and 0.02 mg/L for impacted lakes. There are localized areas of exceedance in the province, mainly near urban areas.

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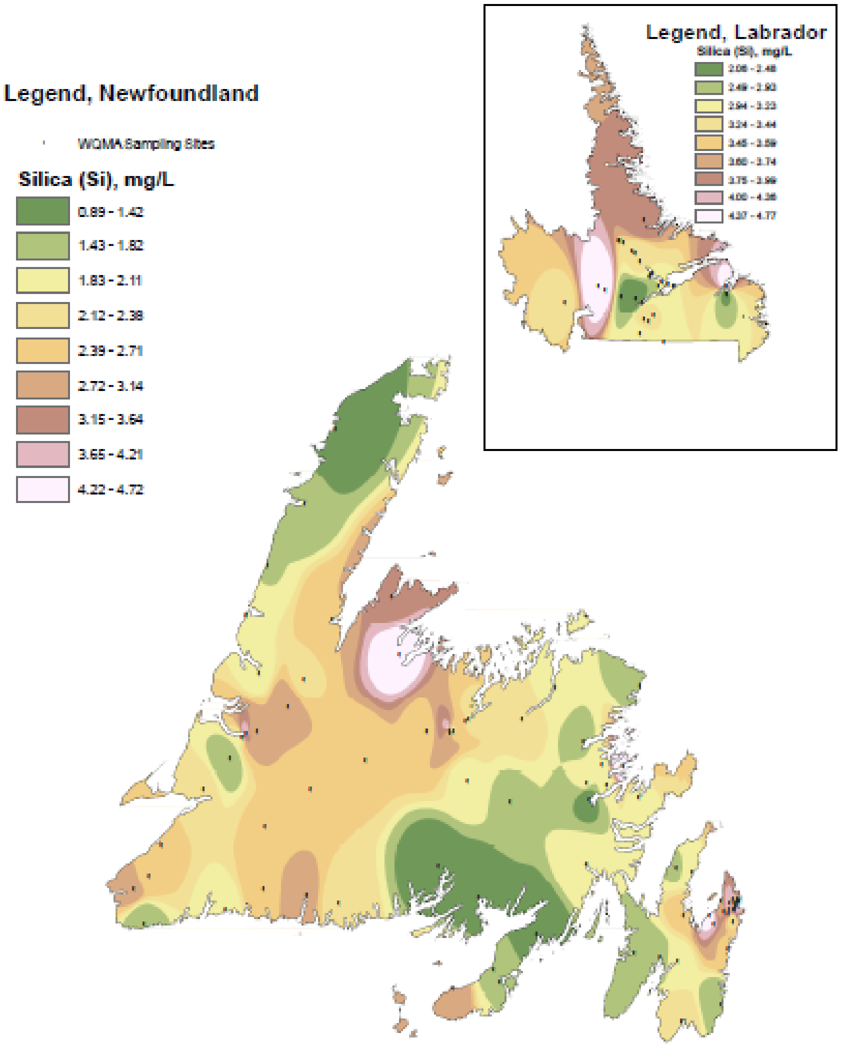
Figure L.17 Phosphorous Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Silica Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Newfoundland
WQMA Sampling Sites
Silica (Si), mg/L
0.89 - 1.42
1.43 - 1.82
1.83 - 2.11
2.12 - 2.38
2.39 - 2.71
2.72 - 3.14
3.15 - 3.64
3.65 - 4.21
4.22 - 4.72
Legend, Labrador
Silica (Si), mg/L
2.06 - 2.48
2.49 - 2.93
2.94 - 3.23
3.24 - 3.44
3.45 - 3.59
3.60 - 3.74
3.75 - 3.99
4.00 - 4.36
4.37 - 4.77

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Silica is the most abundant element in the earth's crust. It is naturally occurring, and no negative environmental effects have been reported. There is no silica guideline for the Protection of Aquatic Life.

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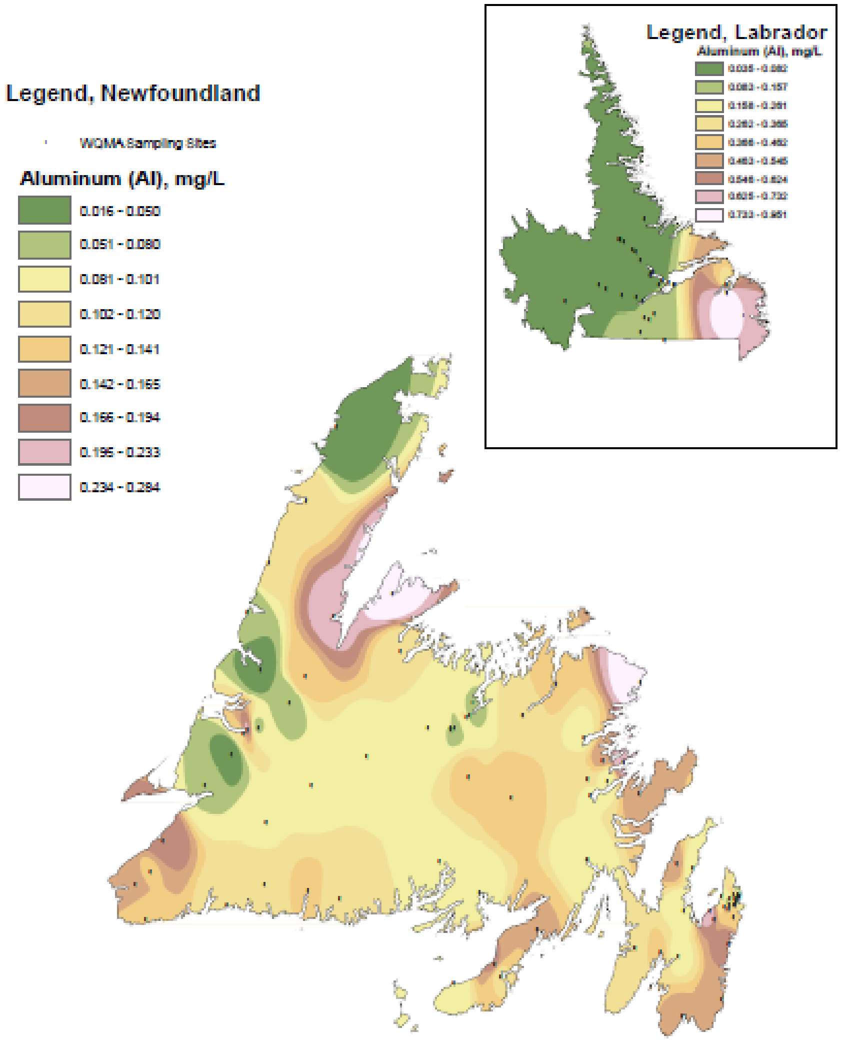
Figure L.18 Silica Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Aluminum Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
Aluminum (Al), mg/L
0.035 - 0.082
0.083 - 0.157
0.158 - 0.261
0.262 - 0.365
0.366 - 0.462
0.463 - 0.545
0.546 - 0.624
0.625 - 0.732
0.733 - 0.951
Legend, Newfoundland
WQMA Sampling Sites
Aluminum (Al), mg/L
0.016 - 0.050
0.051 - 0.080
0.081 - 0.101
0.102 - 0.120
0.121 - 0.141
0.142 - 0.165
0.166 - 0.194
0.195 - 0.233
0.234 - 0.284

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Variation in the amount of aluminum in water is primarily dictated by geology in this province. The aluminum guideline for the Protection of Aquatic Life guideline is 0.005-0.100 mg/L. The guideline value is presented as a range because aluminum is dependent on the values of other water quality parameters such as pH, and needs to be adjusted for site specific conditions. Most of the province falls under this guideline.

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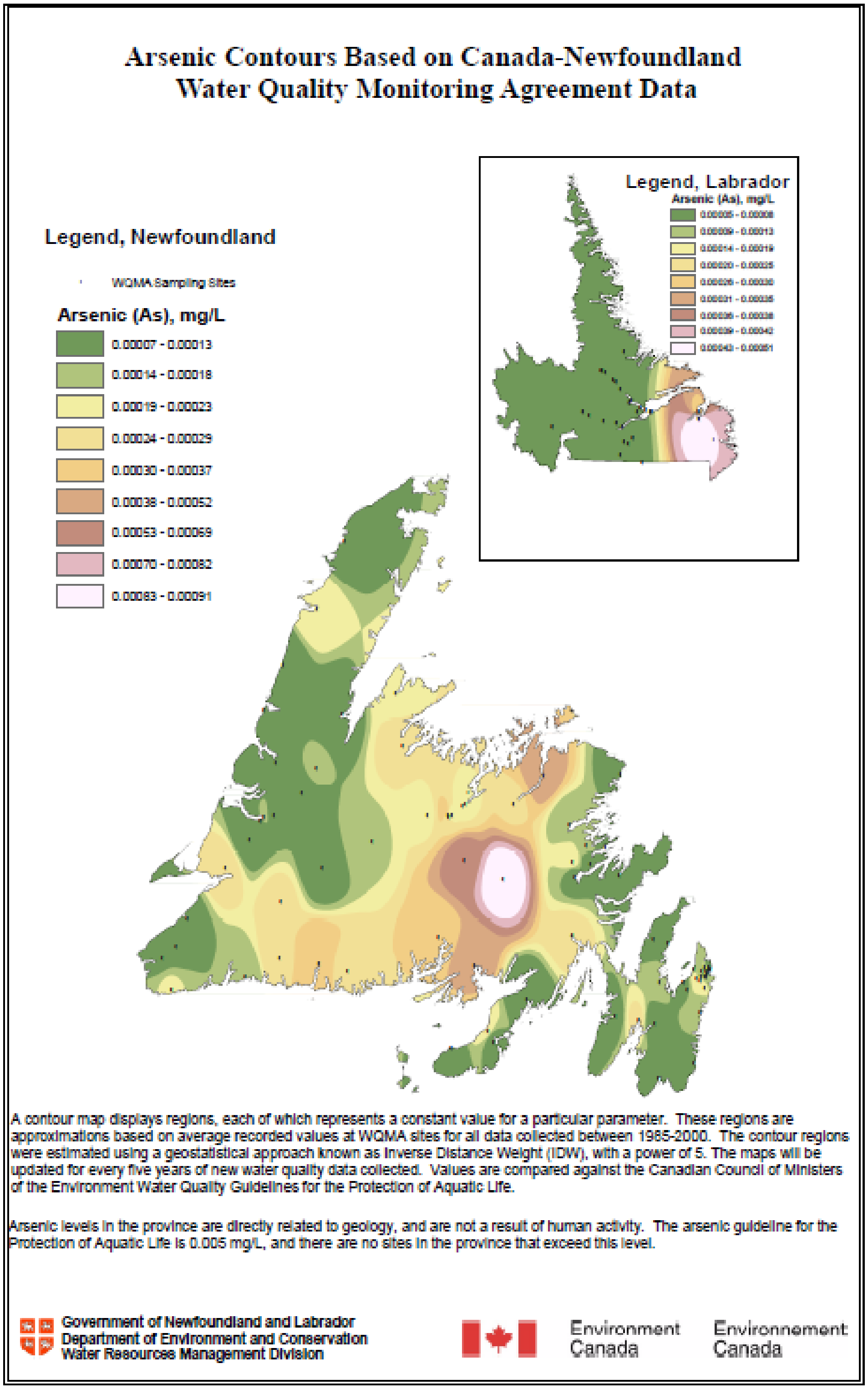
Figure L.19 Aluminum Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Arsenic Contours Based on Canada-Newfoundland
Water Quality Monitoring Agreement Data
Legend, Newfoundland
WQMA Sampling Sites
Arsenic (As), mg/L
0.00007 - 0.00013
0.00014 - 0.00018
0.00019 - 0.00023
0.00024 - 0.00029
0.00030 - 0.00037
0.00038 - 0.00052
0.00053 - 0.00069
0.00070 - 0.00082
0.00083 - 0.00091
Legend, Labrador
Arsenic (As), mg/L
0.00005 - 0.00008
0.00009 - 0.00013
0.00014 - 0.00019
0.00020 - 0.00025
0.00026 - 0.00030
0.00031 - 0.00035
0.00036 - 0.00038
0.00039 - 0.00042
0.00043 - 0.00051
Environment Canada
Environnement Canada

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Arsenic levels in the province are directly related to geology, and are not a result of human activity. The arsenic guideline for the Protection of Aquatic Life is 0.005 mg/L, and there are no sites in the province that exceed this level.

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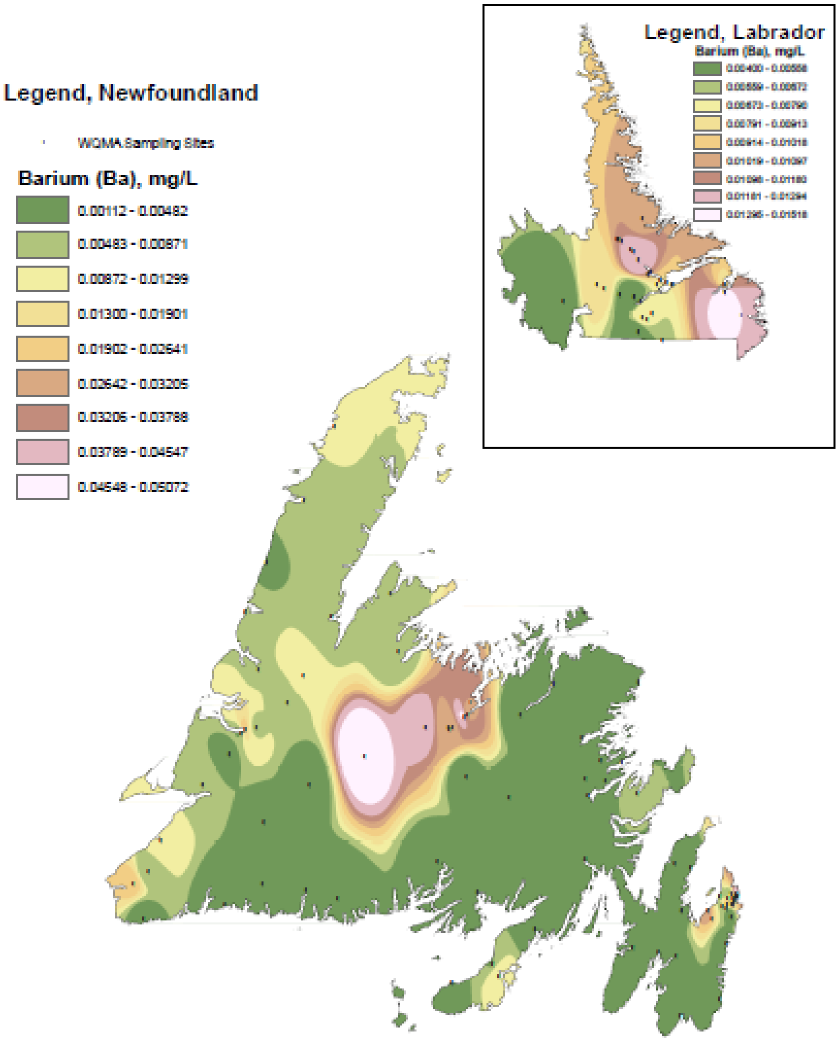
Department of Environment and Conservation
Water Resources Management Division

Figure L.20 Arsenic Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Barium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
Barium (Ba), mg/L
🟩 0.00400 - 0.00558
🟩 0.00559 - 0.00672
🟨 0.00673 - 0.00790
🟨 0.00791 - 0.00913
🟧 0.00914 - 0.01018
🟫 0.01019 - 0.01097
🟫 0.01098 - 0.01180
▨ 0.01181 - 0.01294
☐ 0.01295 - 0.01518
Legend, Newfoundland
· WQMA Sampling Sites
Barium (Ba), mg/L
🟩 0.00112 - 0.00482
🟩 0.00483 - 0.00871
🟨 0.00872 - 0.01299
🟨 0.01300 - 0.01901
🟧 0.01902 - 0.02641
🟫 0.02642 - 0.03205
🟫 0.03206 - 0.03788
▨ 0.03789 - 0.04547
☐ 0.04548 - 0.05072

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Barium is found naturally in rock, and is also a mining by-product. Levels in the province are primarily affected by natural geology rather than mining activity. There is no barium guideline for the Protection of Aquatic Life.

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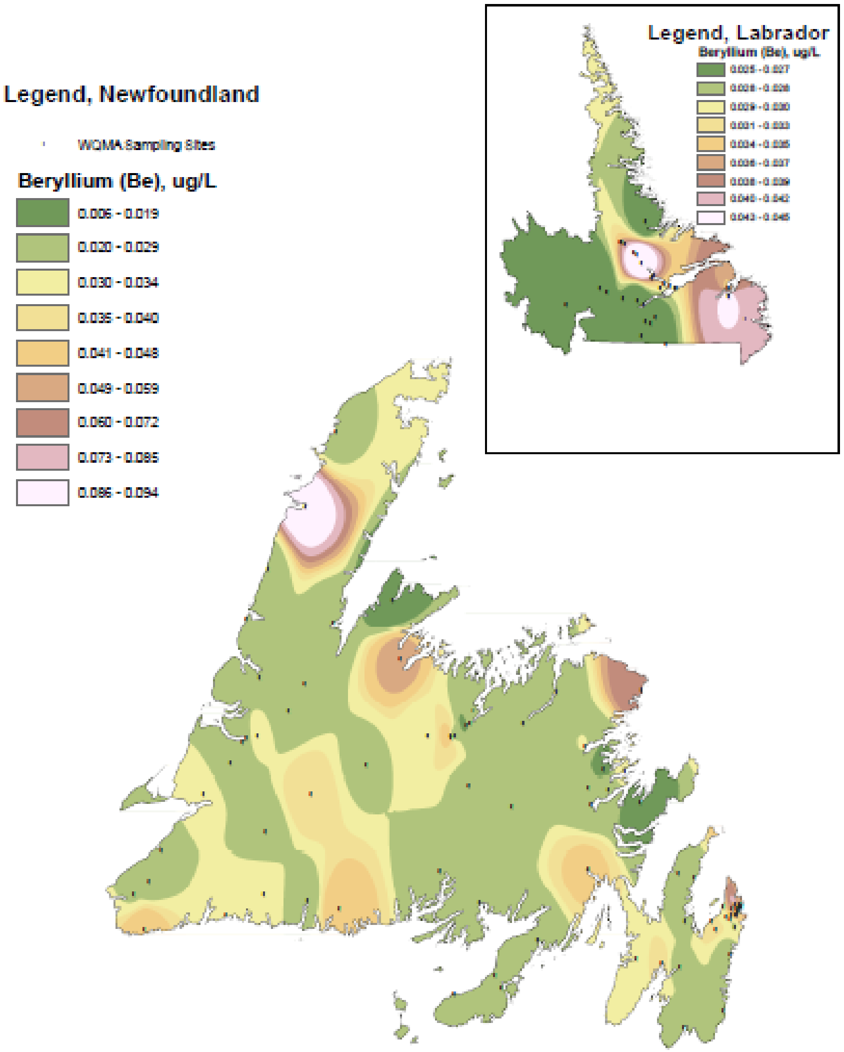
Water Resources Management Division

Environment Canada Environnement Canada

Figure L.21 **Barium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data**

Beryllium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
Beryllium (Be), ug/L
🟩 0.005 - 0.027
🟩 0.028 - 0.028
🟨 0.029 - 0.030
🟨 0.031 - 0.033
🟧 0.034 - 0.035
🟧 0.036 - 0.037
🟫 0.038 - 0.039
🟪 0.040 - 0.042
⬜ 0.043 - 0.045
Legend, Newfoundland
WQMA Sampling Sites
Beryllium (Be), ug/L
🟩 0.006 - 0.019
🟩 0.020 - 0.029
🟨 0.030 - 0.034
🟨 0.035 - 0.040
🟧 0.041 - 0.048
🟧 0.049 - 0.059
🟫 0.060 - 0.072
🟪 0.073 - 0.085
⬜ 0.086 - 0.094

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Beryllium does occur as a chemical component of certain rocks, coal and oil, soil, and volcanic dust. Levels in waterbodies are influenced by the weathering of rocks and soil. Most of the man-made beryllium that enters waterways is a result of industry dumping waste water and when beryllium dust in the air from industrial activities settles over water. There is no beryllium guideline for the Protection of Aquatic Life.

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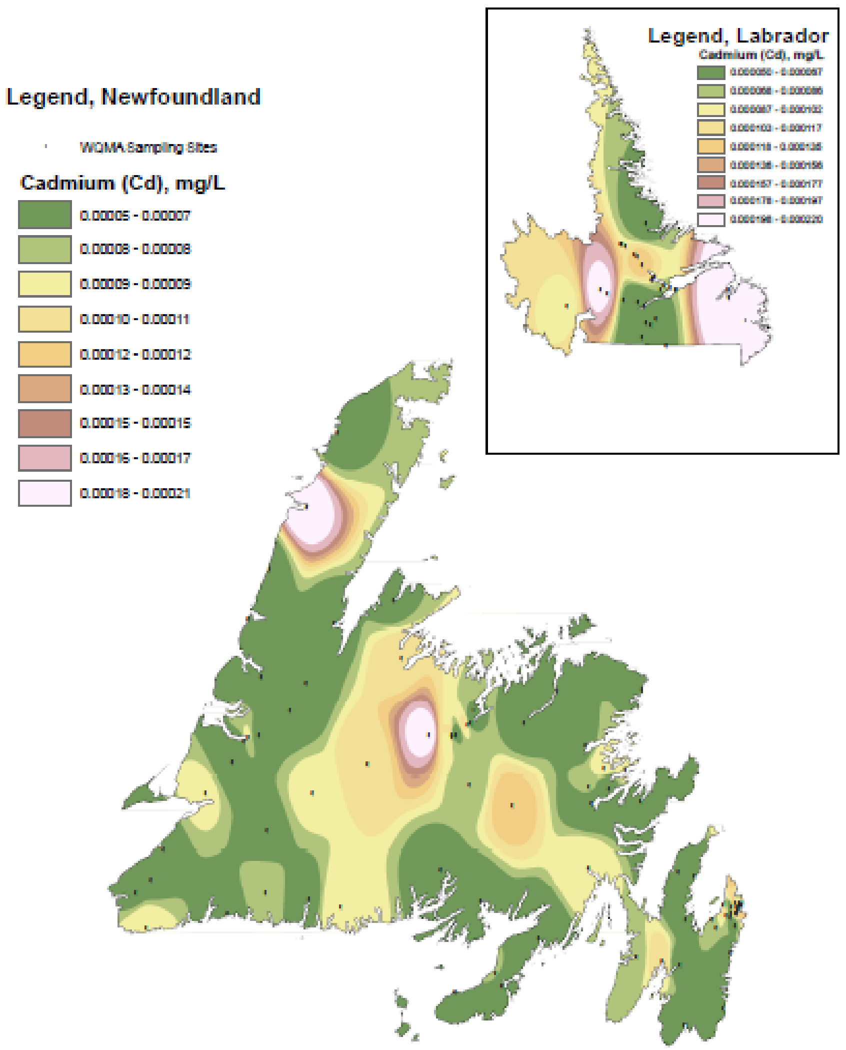
Figure L.22 Beryllium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Cadmium Contours Based on Canada-Newfoundland
Water Quality Monitoring Agreement Data


Legend, Labrador
Cadmium (Cd), mg/L
0.000050 - 0.000067
0.000068 - 0.000086
0.000087 - 0.000102
0.000103 - 0.000117
0.000118 - 0.000135
0.000136 - 0.000156
0.000157 - 0.000177
0.000178 - 0.000197
0.000198 - 0.000220
Legend, Newfoundland
WQMA Sampling Sites
Cadmium (Cd), mg/L
0.00005 - 0.00007
0.00008 - 0.00008
0.00009 - 0.00009
0.00010 - 0.00011
0.00012 - 0.00012
0.00013 - 0.00014
0.00015 - 0.00015
0.00016 - 0.00017
0.00018 - 0.00021

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

The cadmium guideline for the Protection of Aquatic Life is 0.017 ug/L (0.000017 mg/L), which is currently below the level of detection possible with modern laboratory tests. The cadmium levels in the WQMA ambient water sites are well below the level considered hazardous to human health.

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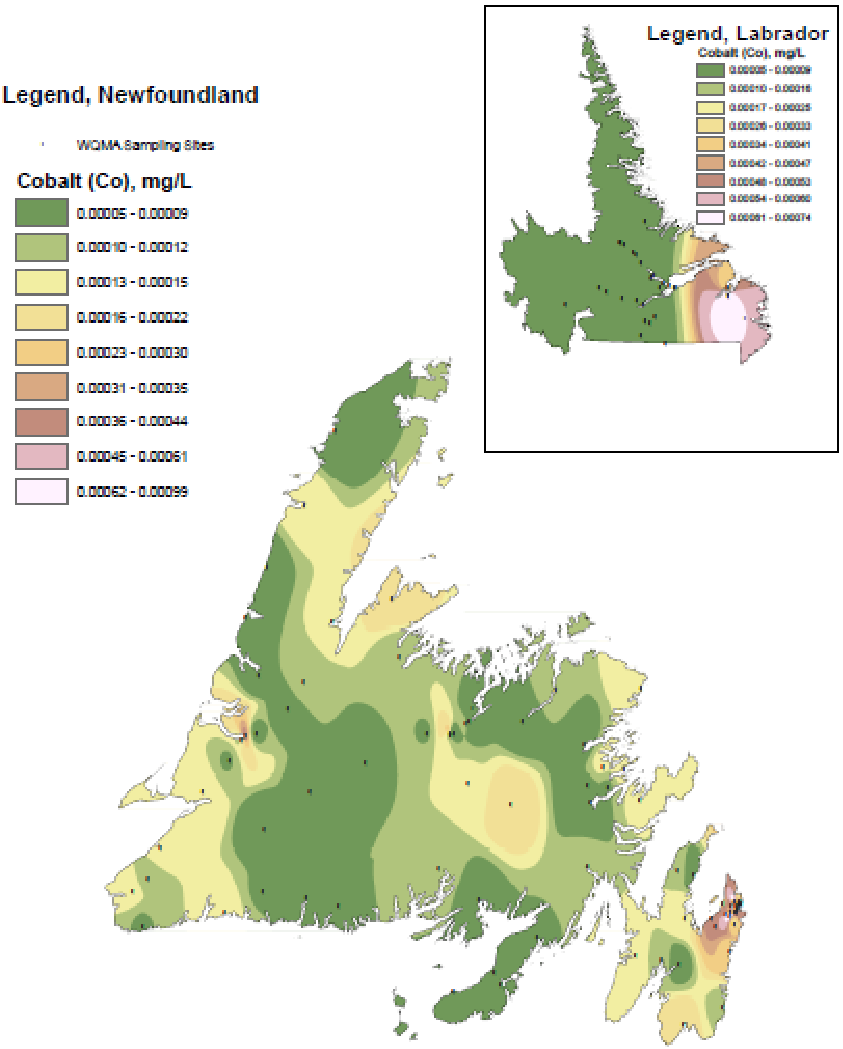
Figure L.23 Cadmium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Cobalt Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
Cobalt (Co), mg/L
0.00005 - 0.00009
0.00010 - 0.00016
0.00017 - 0.00025
0.00026 - 0.00033
0.00034 - 0.00041
0.00042 - 0.00047
0.00048 - 0.00053
0.00054 - 0.00060
0.00061 - 0.00074
Legend, Newfoundland
WQMA Sampling Sites
Cobalt (Co), mg/L
0.00005 - 0.00009
0.00010 - 0.00012
0.00013 - 0.00015
0.00016 - 0.00022
0.00023 - 0.00030
0.00031 - 0.00035
0.00036 - 0.00044
0.00045 - 0.00061
0.00062 - 0.00099

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Cobalt is found in leachate from waste disposal, raw sewage, and can be found in mine drainage. Small amounts are released into the atmosphere by coal combustion and mining, as well as by processing of cobalt-containing ores and the production and use of cobalt chemicals. There is no cobalt guideline for the Protection of Aquatic Life.

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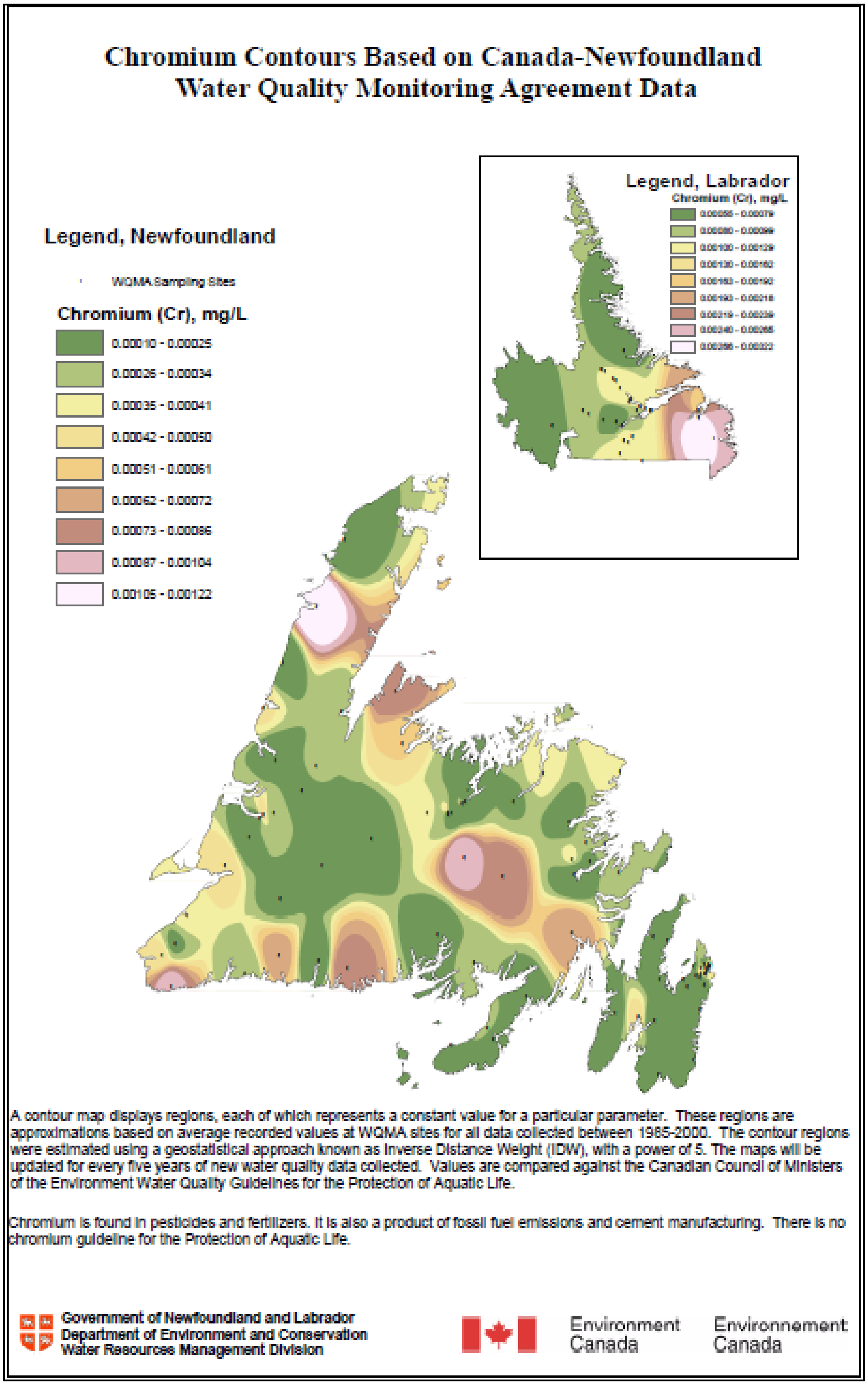
Figure L.24 Cobalt Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Chromium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Legend, Labrador
Chromium (Cr), mg/L
0.00055 - 0.00079
0.00080 - 0.00099
0.00100 - 0.00129
0.00130 - 0.00162
0.00163 - 0.00190
0.00193 - 0.00218
0.00219 - 0.00239
0.00240 - 0.00265
0.00266 - 0.00322
Legend, Newfoundland
WQMA Sampling Sites
Chromium (Cr), mg/L
0.00010 - 0.00025
0.00026 - 0.00034
0.00035 - 0.00041
0.00042 - 0.00050
0.00051 - 0.00061
0.00062 - 0.00072
0.00073 - 0.00086
0.00087 - 0.00104
0.00105 - 0.00122

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Chromium is found in pesticides and fertilizers. It is also a product of fossil fuel emissions and cement manufacturing. There is no chromium guideline for the Protection of Aquatic Life.

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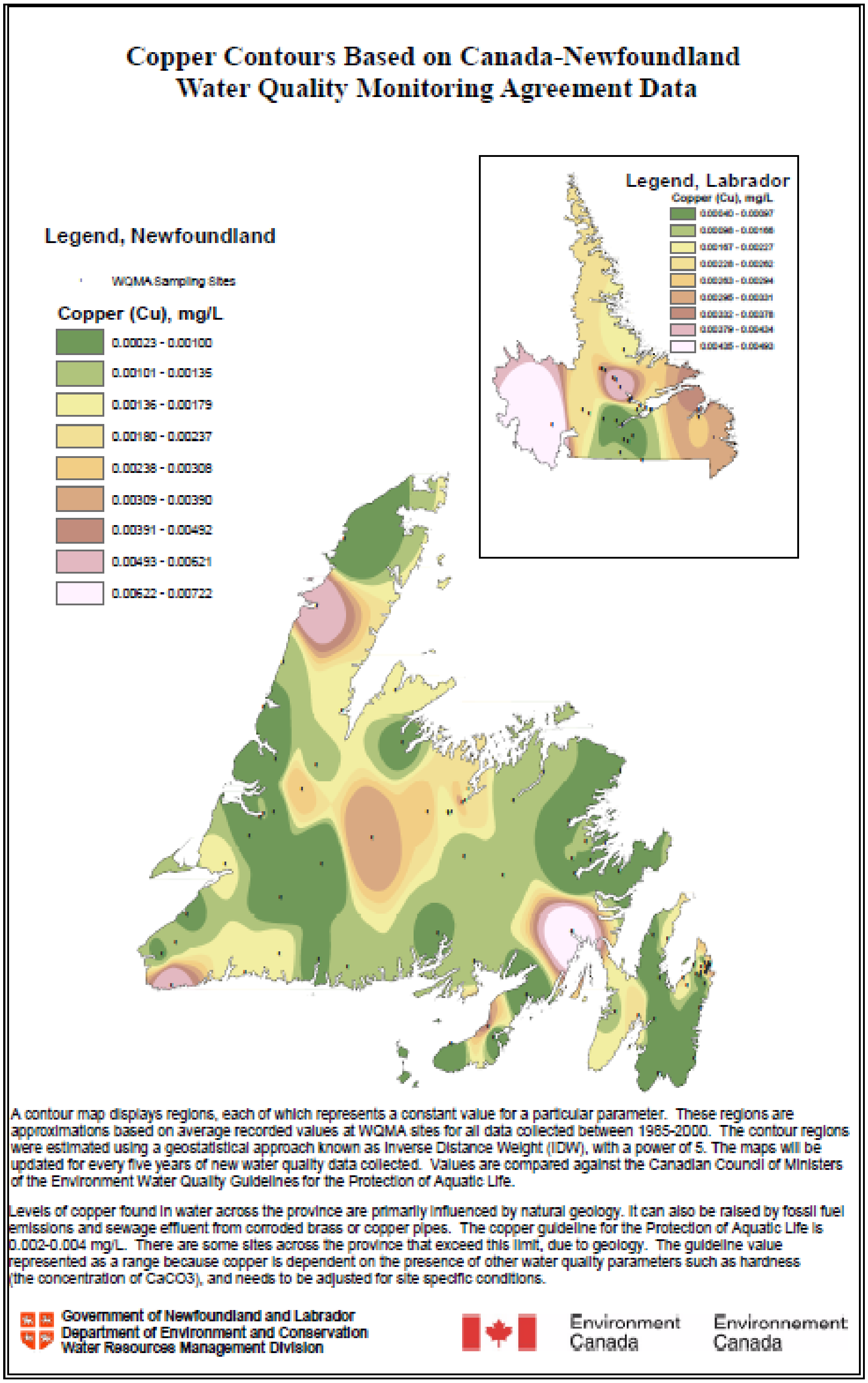
Figure L.25 Chromium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Copper Contours Based on Canada-Newfoundland
Water Quality Monitoring Agreement Data

Legend, Newfoundland
WQMA Sampling Sites
Copper (Cu), mg/L
0.00023 - 0.00100
0.00101 - 0.00135
0.00136 - 0.00179
0.00180 - 0.00237
0.00238 - 0.00308
0.00309 - 0.00390
0.00391 - 0.00492
0.00493 - 0.00621
0.00622 - 0.00722
Legend, Labrador
Copper (Cu), mg/L
0.00040 - 0.00097
0.00098 - 0.00166
0.00167 - 0.00227
0.00228 - 0.00262
0.00263 - 0.00294
0.00295 - 0.00331
0.00332 - 0.00378
0.00379 - 0.00424
0.00425 - 0.00493

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Levels of copper found in water across the province are primarily influenced by natural geology. It can also be raised by fossil fuel emissions and sewage effluent from corroded brass or copper pipes. The copper guideline for the Protection of Aquatic Life is 0.002-0.004 mg/L. There are some sites across the province that exceed this limit, due to geology. The guideline value represented as a range because copper is dependent on the presence of other water quality parameters such as hardness (the concentration of CaCO3), and needs to be adjusted for site specific conditions.

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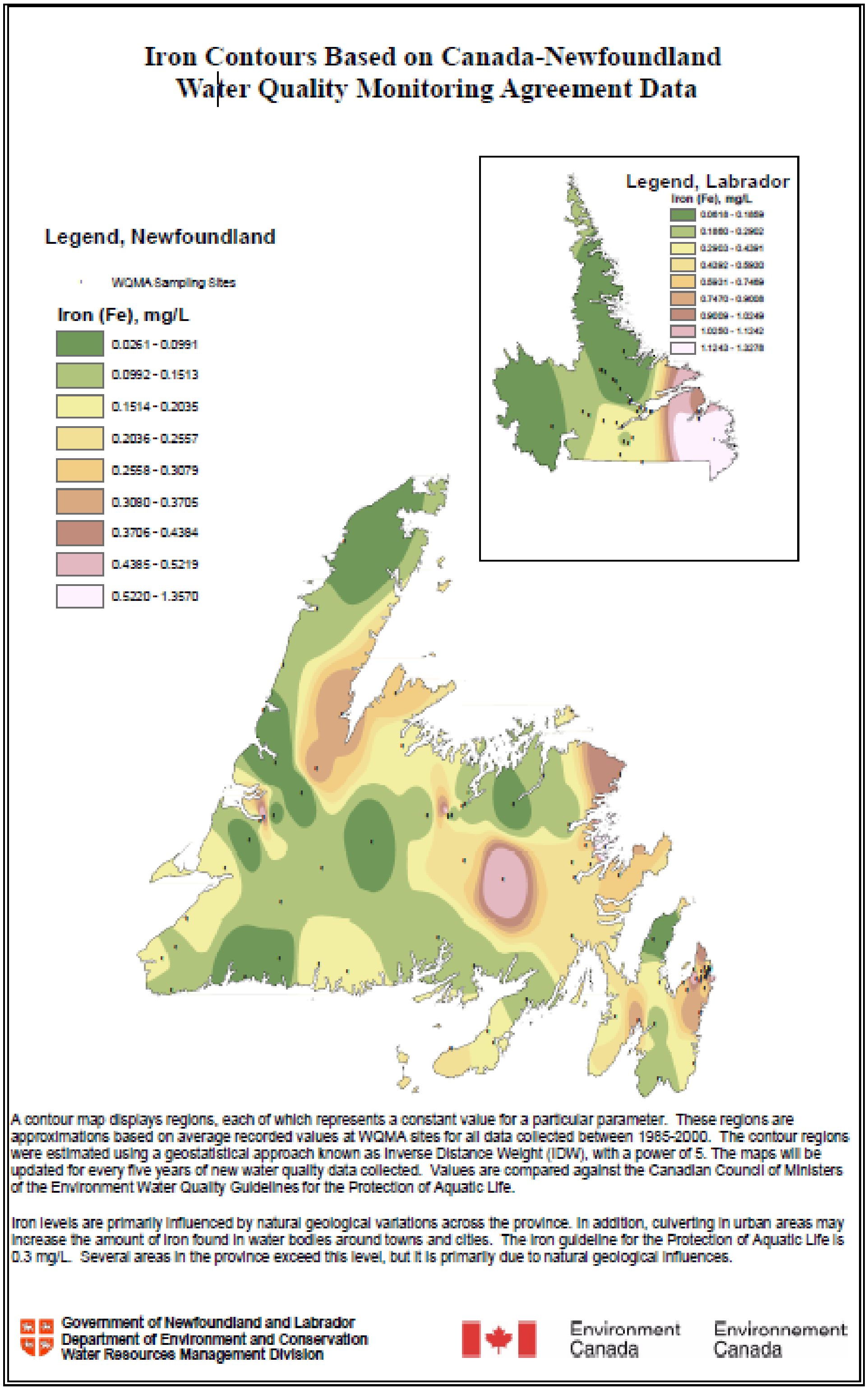
Figure L.26 Copper Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Iron Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Legend, Labrador
Iron (Fe), mg/L
🟩 0.0618 - 0.1859
🟩 0.1860 - 0.2902
🟨 0.2903 - 0.4391
🟨 0.4392 - 0.5930
🟧 0.5931 - 0.7469
🟧 0.7470 - 0.9008
🟫 0.9009 - 1.0249
🟪 1.0250 - 1.1242
⬜ 1.1243 - 1.3278
Legend, Newfoundland
· WQMA Sampling Sites
Iron (Fe), mg/L
🟩 0.0261 - 0.0991
🟩 0.0992 - 0.1513
🟨 0.1514 - 0.2035
🟨 0.2036 - 0.2557
🟧 0.2558 - 0.3079
🟧 0.3080 - 0.3705
🟫 0.3706 - 0.4384
🟪 0.4385 - 0.5219
⬜ 0.5220 - 1.3570

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Iron levels are primarily influenced by natural geological variations across the province. In addition, culverting in urban areas may increase the amount of iron found in water bodies around towns and cities. The iron guideline for the Protection of Aquatic Life is 0.3 mg/L. Several areas in the province exceed this level, but it is primarily due to natural geological influences.

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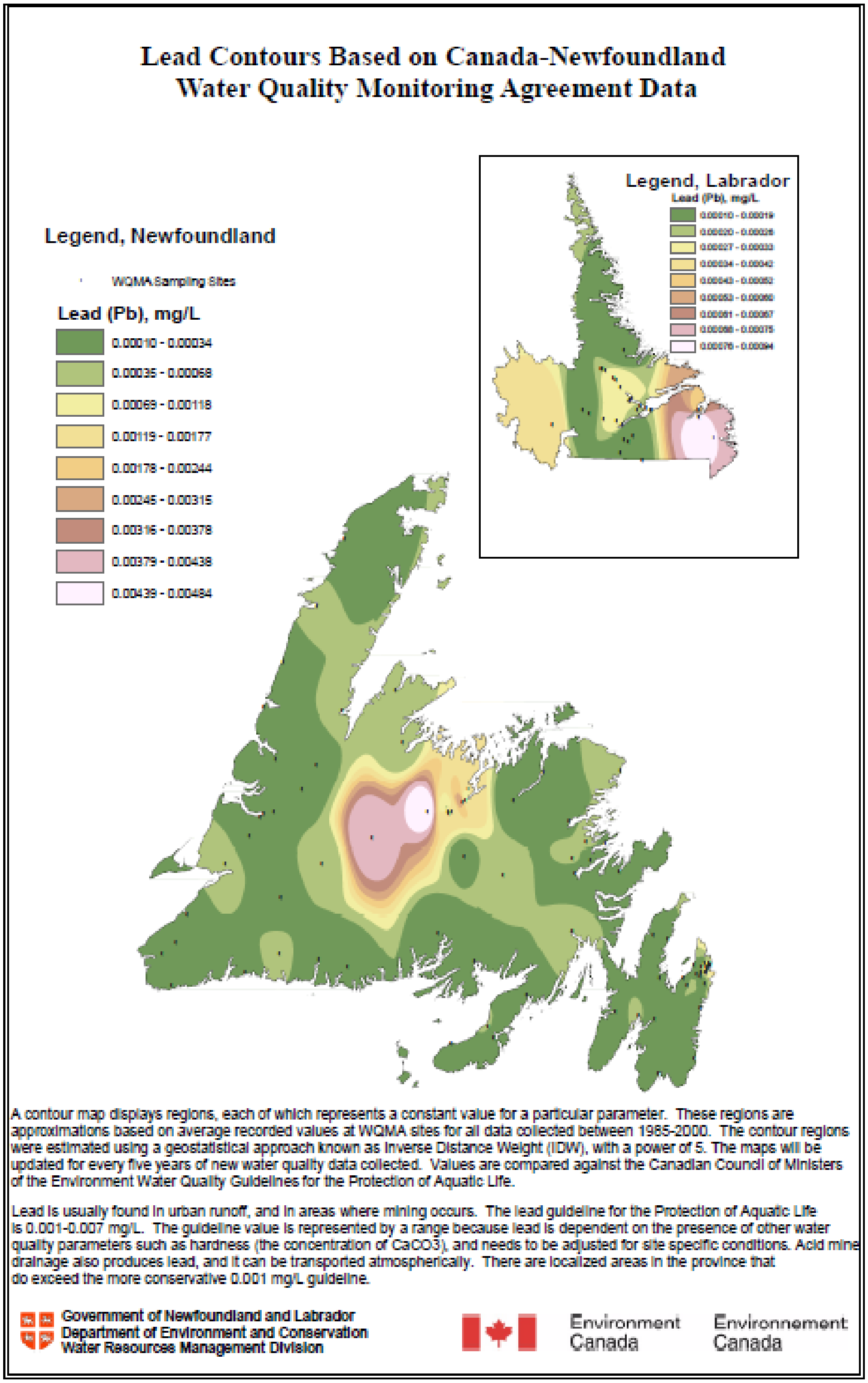
Figure L.27 Iron Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
Lead (Pb), mg/L
0.00010 - 0.00019
0.00020 - 0.00026
0.00027 - 0.00033
0.00034 - 0.00042
0.00043 - 0.00052
0.00053 - 0.00060
0.00061 - 0.00067
0.00068 - 0.00075
0.00076 - 0.00084
Legend, Newfoundland
WQMA Sampling Sites
Lead (Pb), mg/L
0.00010 - 0.00034
0.00035 - 0.00068
0.00069 - 0.00118
0.00119 - 0.00177
0.00178 - 0.00244
0.00245 - 0.00315
0.00316 - 0.00378
0.00379 - 0.00438
0.00439 - 0.00484

Lead Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Lead is usually found in urban runoff, and in areas where mining occurs. The lead guideline for the Protection of Aquatic Life is 0.001-0.007 mg/L. The guideline value is represented by a range because lead is dependent on the presence of other water quality parameters such as hardness (the concentration of CaCO3), and needs to be adjusted for site specific conditions. Acid mine drainage also produces lead, and it can be transported atmospherically. There are localized areas in the province that do exceed the more conservative 0.001 mg/L guideline.

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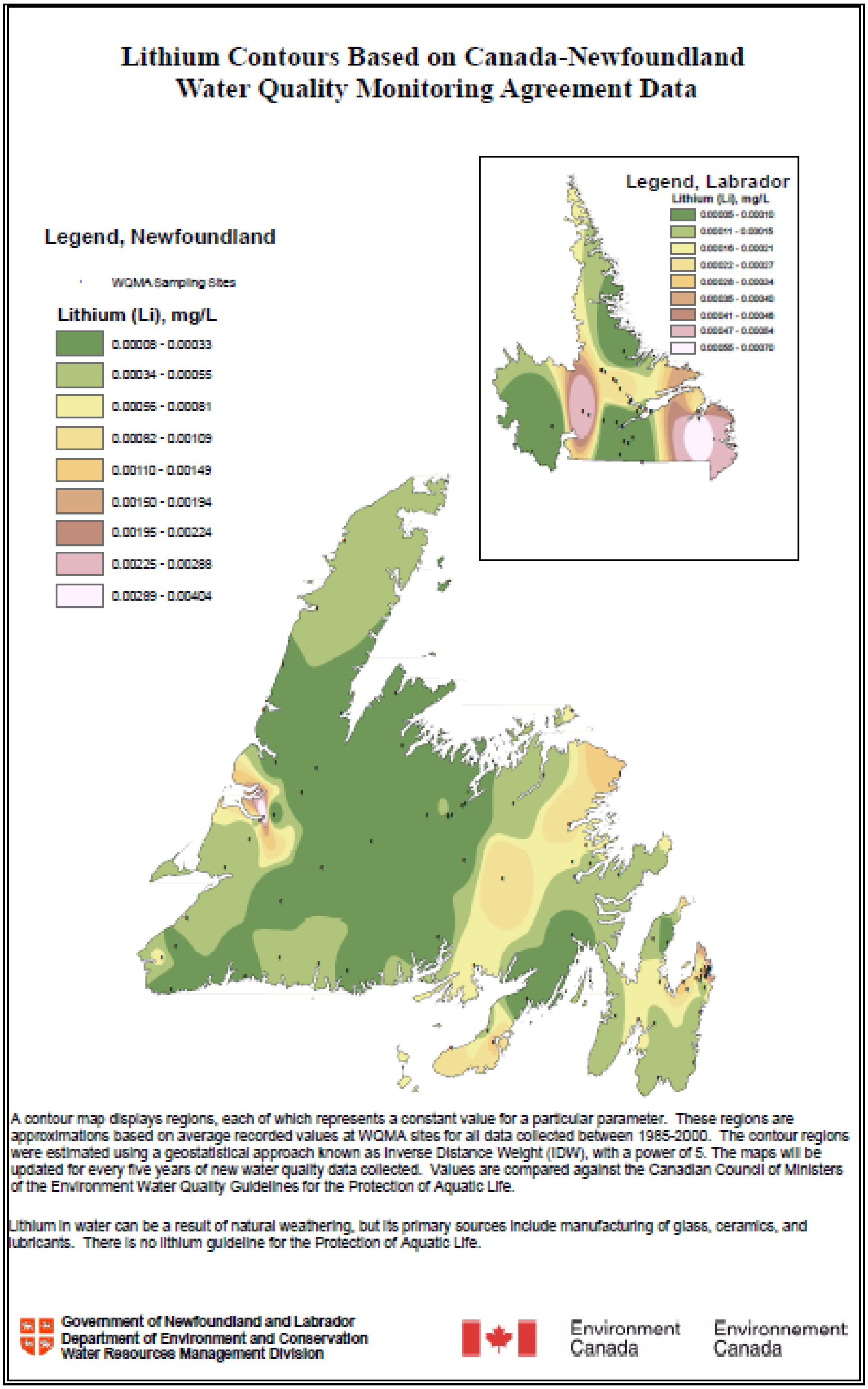
Figure L.28 Lead Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Lithium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Legend, Newfoundland
WQMA Sampling Sites
Lithium (Li), mg/L
0.00008 - 0.00033
0.00034 - 0.00055
0.00056 - 0.00081
0.00082 - 0.00109
0.00110 - 0.00149
0.00150 - 0.00194
0.00195 - 0.00224
0.00225 - 0.00288
0.00289 - 0.00404
Legend, Labrador
Lithium (Li), mg/L
0.00005 - 0.00010
0.00011 - 0.00015
0.00016 - 0.00021
0.00022 - 0.00027
0.00028 - 0.00034
0.00035 - 0.00040
0.00041 - 0.00046
0.00047 - 0.00054
0.00055 - 0.00070

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Lithium in water can be a result of natural weathering, but its primary sources include manufacturing of glass, ceramics, and lubricants. There is no lithium guideline for the Protection of Aquatic Life.

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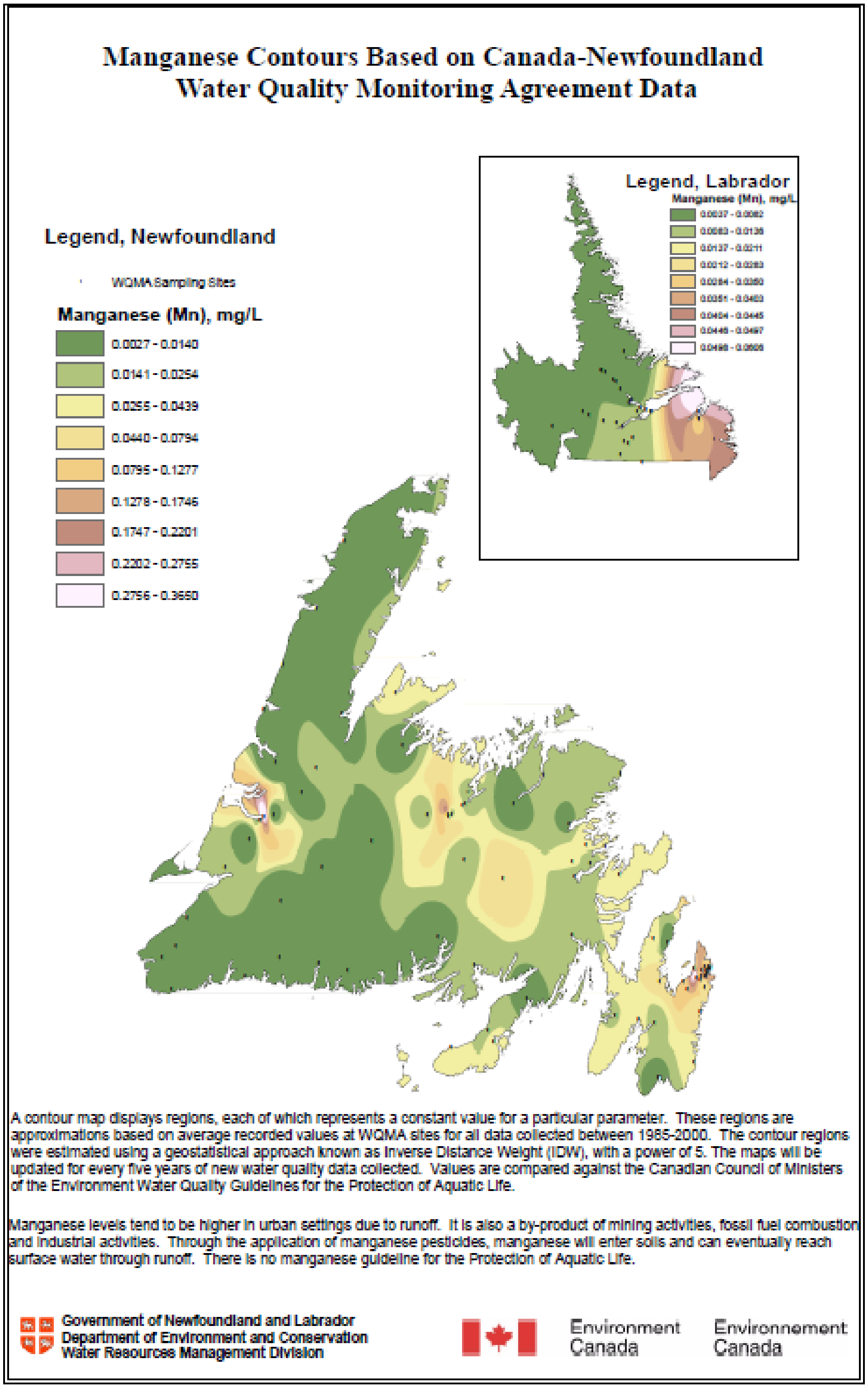
Figure L.29 Lithium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Manganese Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Legend, Labrador
Manganese (Mn), mg/L
0.0037 - 0.0082
0.0083 - 0.0136
0.0137 - 0.0211
0.0212 - 0.0283
0.0284 - 0.0350
0.0351 - 0.0403
0.0404 - 0.0445
0.0446 - 0.0497
0.0498 - 0.0606
Legend, Newfoundland
WQMA Sampling Sites
Manganese (Mn), mg/L
0.0027 - 0.0140
0.0141 - 0.0254
0.0255 - 0.0439
0.0440 - 0.0794
0.0795 - 0.1277
0.1278 - 0.1746
0.1747 - 0.2201
0.2202 - 0.2755
0.2756 - 0.3650

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Manganese levels tend to be higher in urban settings due to runoff. It is also a by-product of mining activities, fossil fuel combustion and industrial activities. Through the application of manganese pesticides, manganese will enter soils and can eventually reach surface water through runoff. There is no manganese guideline for the Protection of Aquatic Life.

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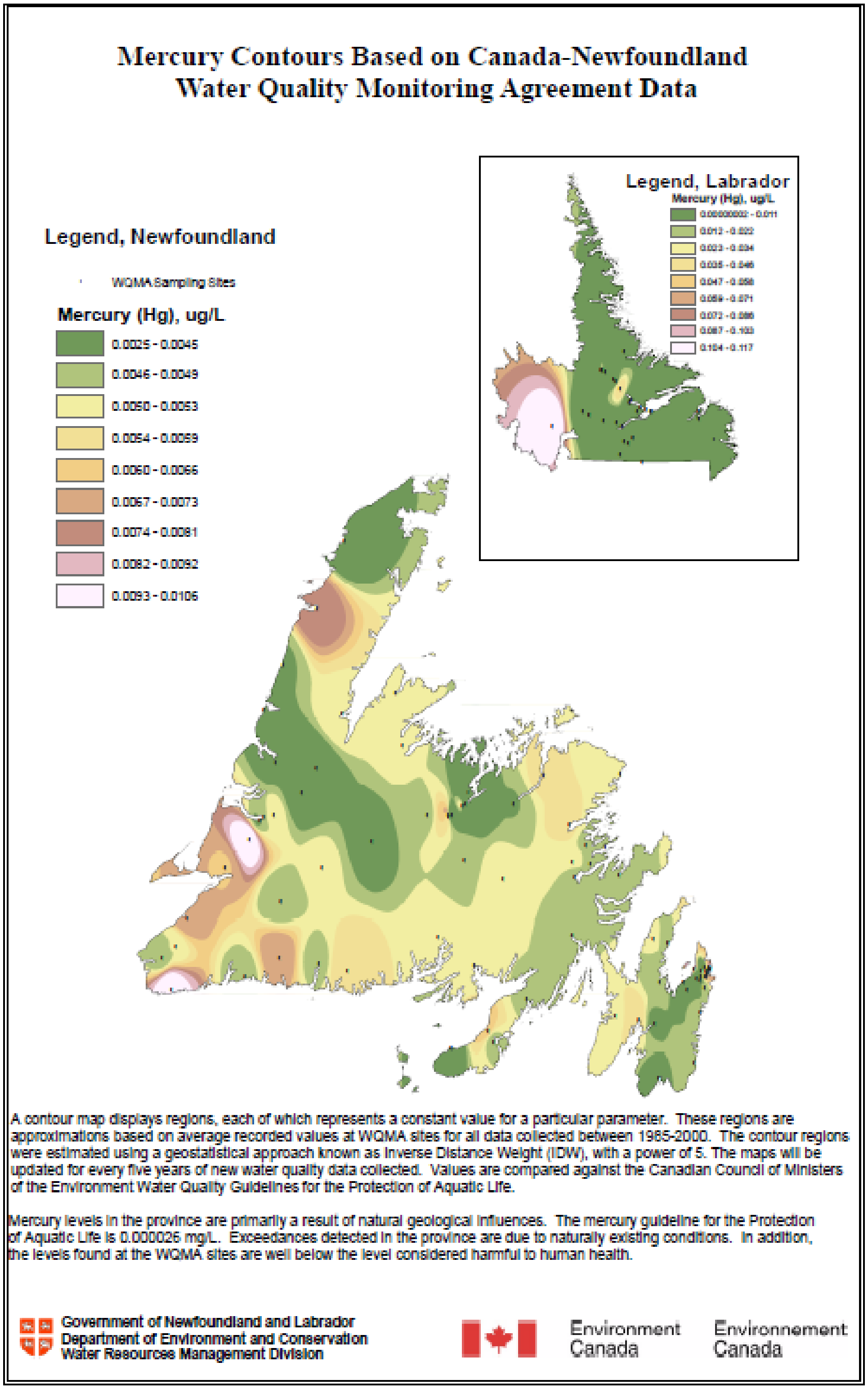
Figure L.30 Manganese Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Mercury Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Legend, Labrador
Mercury (Hg), ug/L
🟩 0.00000002 - 0.011
🟩 0.012 - 0.022
🟨 0.023 - 0.034
🟨 0.035 - 0.046
🟧 0.047 - 0.058
🟫 0.059 - 0.071
🟫 0.072 - 0.086
▭ 0.087 - 0.103
▭ 0.104 - 0.117
Legend, Newfoundland
WQMA Sampling Sites
Mercury (Hg), ug/L
🟩 0.0025 - 0.0045
🟩 0.0046 - 0.0049
🟨 0.0050 - 0.0053
🟨 0.0054 - 0.0059
🟧 0.0060 - 0.0066
🟫 0.0067 - 0.0073
🟫 0.0074 - 0.0081
▭ 0.0082 - 0.0092
▭ 0.0093 - 0.0106

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1965-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Mercury levels in the province are primarily a result of natural geological influences. The mercury guideline for the Protection of Aquatic Life is 0.000026 mg/L. Exceedances detected in the province are due to naturally existing conditions. In addition, the levels found at the WQMA sites are well below the level considered harmful to human health.

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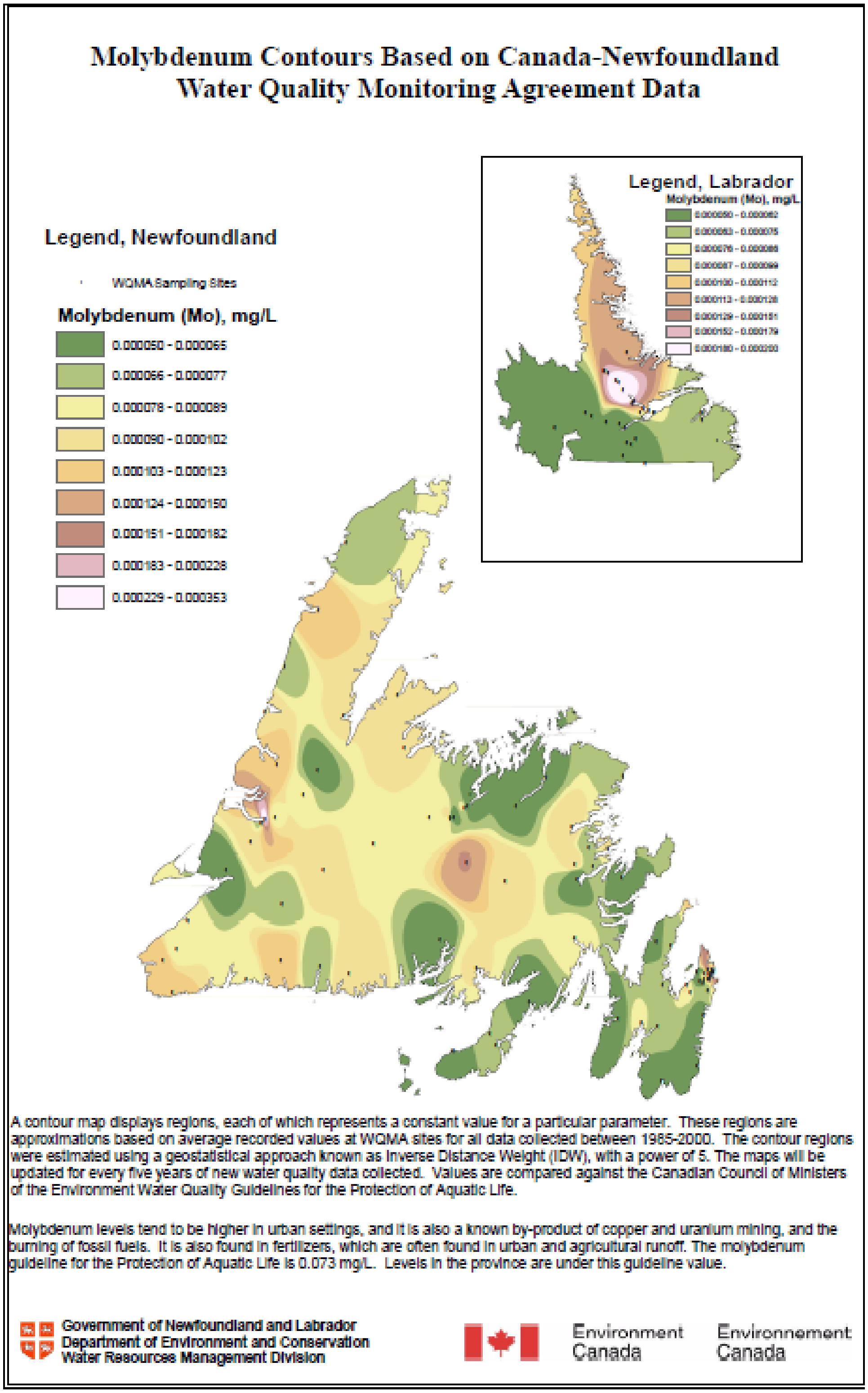
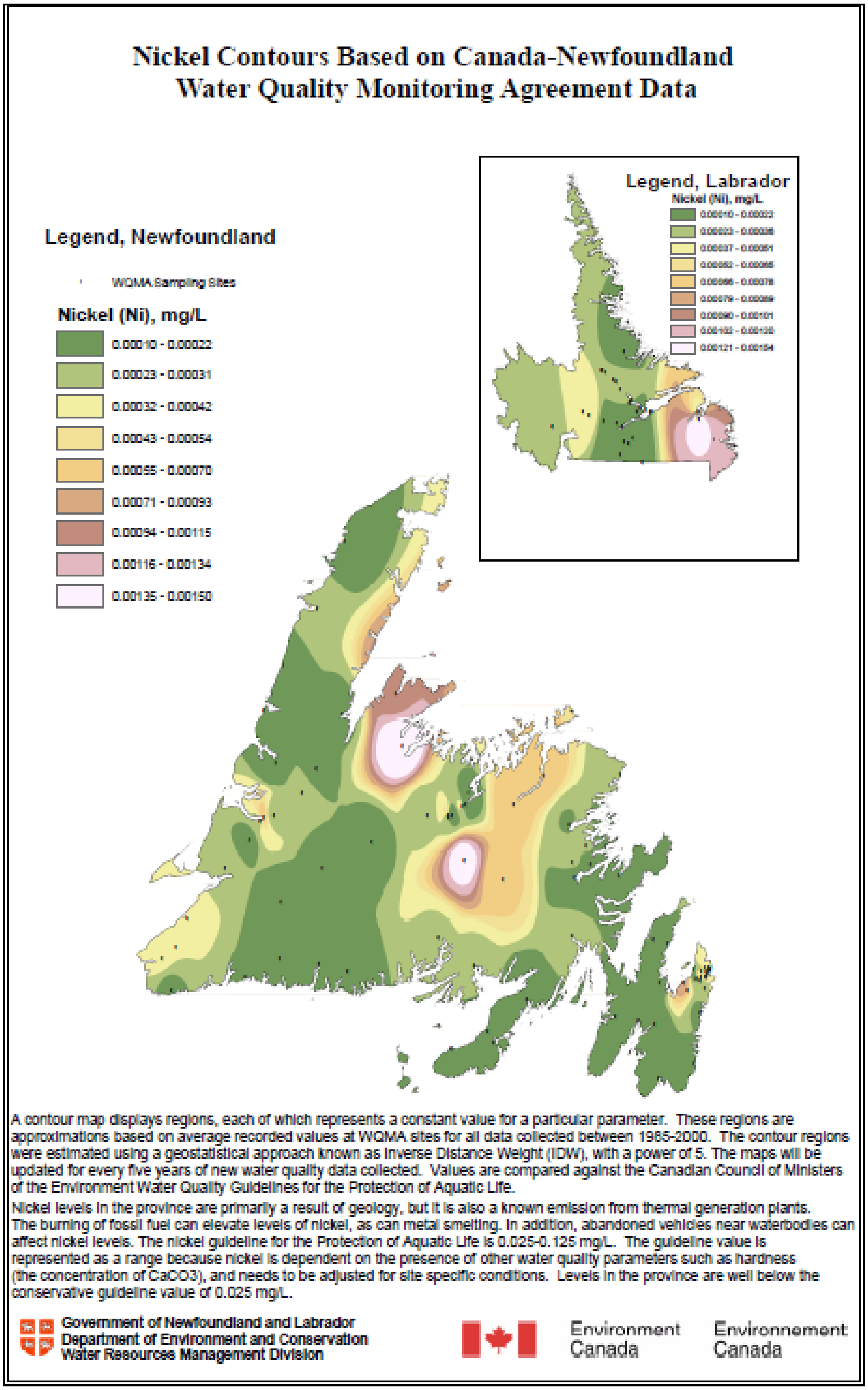
Figure L.31 Mercury Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Molybdenum Contours Based on Canada-Newfoundland
Water Quality Monitoring Agreement Data
Legend, Labrador
Molybdenum (Mo), mg/L
0.000050 - 0.000062
0.000063 - 0.000075
0.000076 - 0.000086
0.000087 - 0.000099
0.000100 - 0.000112
0.000113 - 0.000128
0.000129 - 0.000151
0.000152 - 0.000179
0.000180 - 0.000200
Legend, Newfoundland
WQMA Sampling Sites
Molybdenum (Mo), mg/L
0.000050 - 0.000065
0.000066 - 0.000077
0.000078 - 0.000089
0.000090 - 0.000102
0.000103 - 0.000123
0.000124 - 0.000150
0.000151 - 0.000182
0.000183 - 0.000228
0.000229 - 0.000353
Government of Newfoundland and Labrador
Department of Environment and Conservation
Water Resources Management Division
Environment Canada
Environnement Canada

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Molybdenum levels tend to be higher in urban settings, and it is also a known by-product of copper and uranium mining, and the burning of fossil fuels. It is also found in fertilizers, which are often found in urban and agricultural runoff. The molybdenum guideline for the Protection of Aquatic Life is 0.073 mg/L. Levels in the province are under this guideline value.

Figure L.32 Molybdenum Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Nickel Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Legend, Labrador
Nickel (Ni), mg/L
0.00010 - 0.00022
0.00023 - 0.00036
0.00037 - 0.00051
0.00052 - 0.00065
0.00066 - 0.00078
0.00079 - 0.00089
0.00090 - 0.00101
0.00102 - 0.00120
0.00121 - 0.00184
Legend, Newfoundland
WQMA Sampling Sites
Nickel (Ni), mg/L
0.00010 - 0.00022
0.00023 - 0.00031
0.00032 - 0.00042
0.00043 - 0.00054
0.00055 - 0.00070
0.00071 - 0.00093
0.00094 - 0.00115
0.00116 - 0.00134
0.00135 - 0.00150

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Nickel levels in the province are primarily a result of geology, but it is also a known emission from thermal generation plants. The burning of fossil fuel can elevate levels of nickel, as can metal smelting. In addition, abandoned vehicles near waterbodies can affect nickel levels. The nickel guideline for the Protection of Aquatic Life is 0.025-0.125 mg/L. The guideline value is represented as a range because nickel is dependent on the presence of other water quality parameters such as hardness (the concentration of CaCO3), and needs to be adjusted for site specific conditions. Levels in the province are well below the conservative guideline value of 0.025 mg/L.

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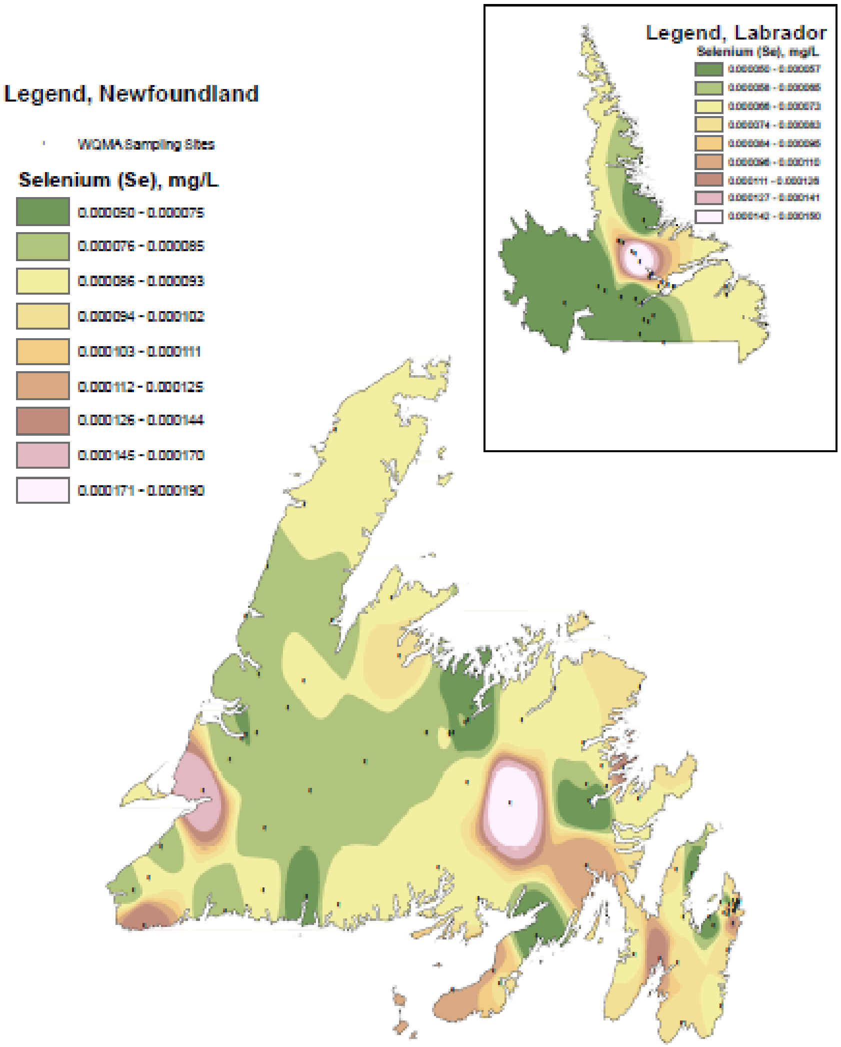
Figure L.33 Nickel Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Selenium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
Selenium (Se), mg/L
0.000050 - 0.000057
0.000058 - 0.000065
0.000066 - 0.000073
0.000074 - 0.000083
0.000084 - 0.000095
0.000096 - 0.000110
0.000111 - 0.000126
0.000127 - 0.000141
0.000142 - 0.000150
Legend, Newfoundland
WQMA Sampling Sites
Selenium (Se), mg/L
0.000050 - 0.000075
0.000076 - 0.000085
0.000086 - 0.000093
0.000094 - 0.000102
0.000103 - 0.000111
0.000112 - 0.000125
0.000126 - 0.000144
0.000145 - 0.000170
0.000171 - 0.000190

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Low levels of selenium can end up in soils or water through weathering of rocks. Selenium can also settle in soil and water from the air after being released by coal and oil combustion. Agricultural activity can increase the selenium content in surface water, and levels are also influenced by urbanization. The selenium guideline for the Protection of Aquatic Life is 0.001 mg/L. Levels in the province are below this guideline.

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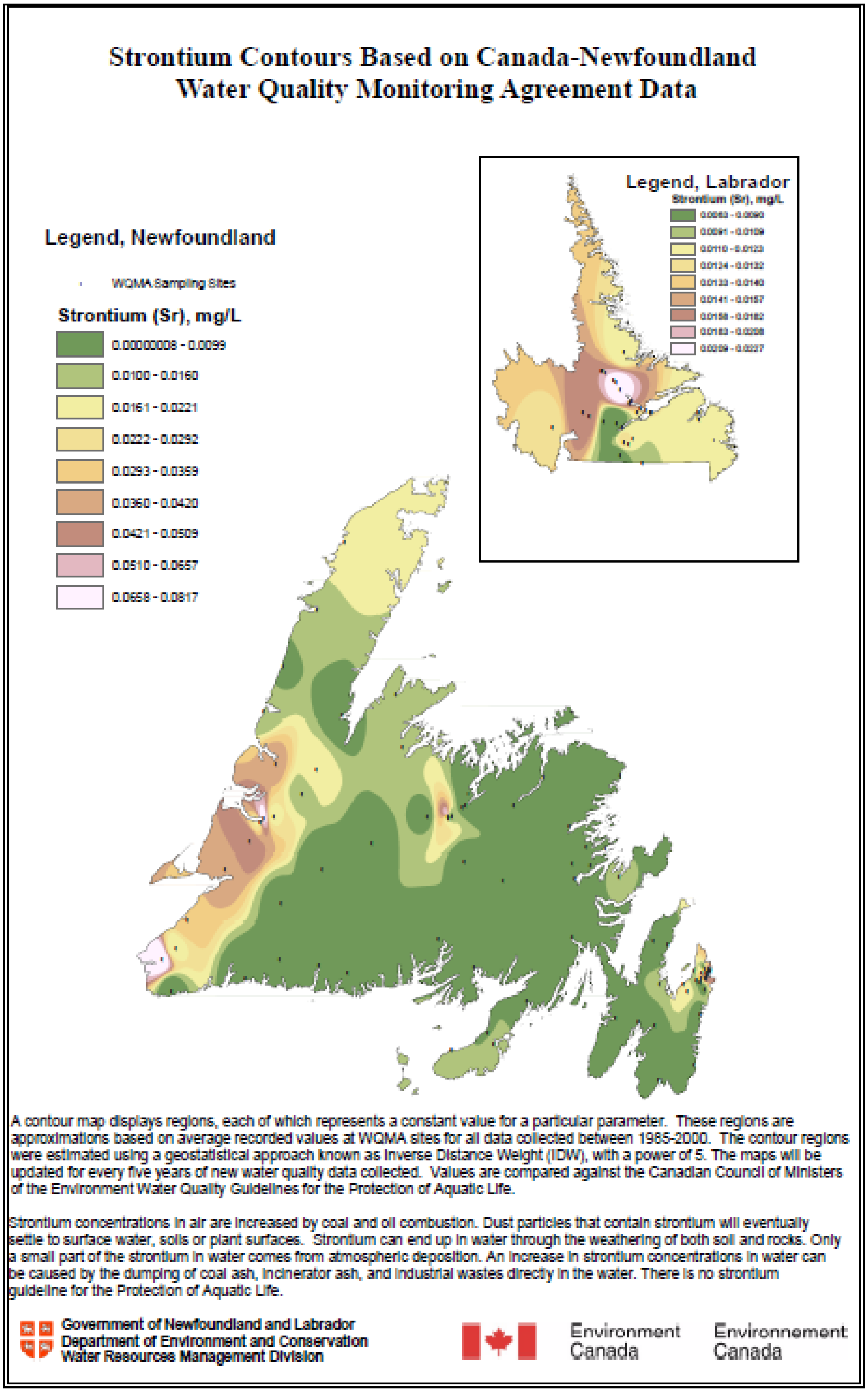
Figure L.34 Selenium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Strontium Contours Based on Canada-Newfoundland
Water Quality Monitoring Agreement Data

Legend, Labrador
Strontium (Sr), mg/L
🟩 0.0063 - 0.0090
🟩 0.0091 - 0.0109
🟨 0.0110 - 0.0123
🟨 0.0124 - 0.0132
🟧 0.0133 - 0.0140
🟫 0.0141 - 0.0157
🟫 0.0158 - 0.0182
🟪 0.0183 - 0.0208
⬜ 0.0209 - 0.0227
Legend, Newfoundland
WQMA Sampling Sites
Strontium (Sr), mg/L
🟩 0.00000008 - 0.0099
🟩 0.0100 - 0.0160
🟨 0.0161 - 0.0221
🟨 0.0222 - 0.0292
🟧 0.0293 - 0.0359
🟫 0.0360 - 0.0420
🟫 0.0421 - 0.0509
🟪 0.0510 - 0.0657
⬜ 0.0658 - 0.0817

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Strontium concentrations in air are increased by coal and oil combustion. Dust particles that contain strontium will eventually settle to surface water, soils or plant surfaces. Strontium can end up in water through the weathering of both soil and rocks. Only a small part of the strontium in water comes from atmospheric deposition. An increase in strontium concentrations in water can be caused by the dumping of coal ash, incinerator ash, and industrial wastes directly in the water. There is no strontium guideline for the Protection of Aquatic Life.

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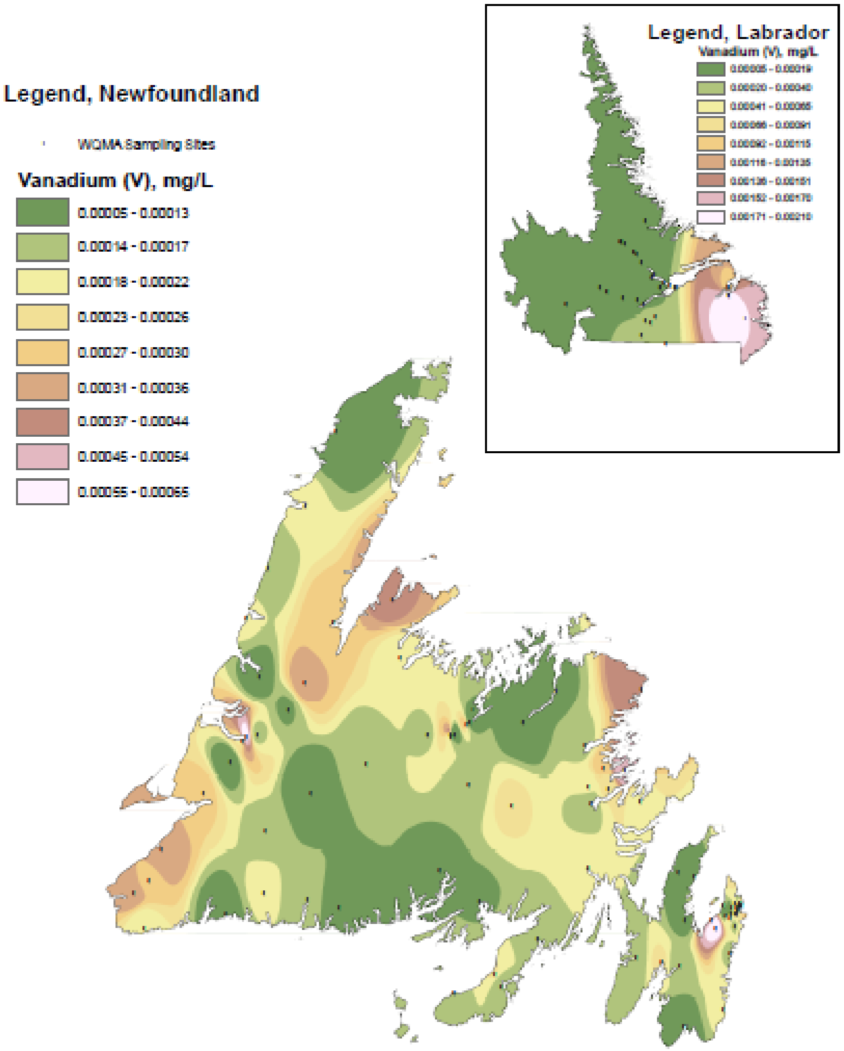
Figure L.35 Strontium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Vanadium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data


Legend, Labrador
Vanadium (V), mg/L
🟩 0.00005 - 0.00019
🟩 0.00020 - 0.00040
🟨 0.00041 - 0.00065
🟨 0.00066 - 0.00091
🟧 0.00092 - 0.00115
🟧 0.00116 - 0.00135
🟫 0.00136 - 0.00151
🟪 0.00152 - 0.00170
⬜ 0.00171 - 0.00210
Legend, Newfoundland
WQMA Sampling Sites
Vanadium (V), mg/L
🟩 0.00005 - 0.00013
🟩 0.00014 - 0.00017
🟨 0.00018 - 0.00022
🟨 0.00023 - 0.00026
🟧 0.00027 - 0.00030
🟧 0.00031 - 0.00036
🟫 0.00037 - 0.00044
🟪 0.00045 - 0.00054
⬜ 0.00055 - 0.00065

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Vanadium is found in landfill leachate, as well as in emissions from thermal generation plants, and tend to be increased in areas around them. There is no vanadium guideline for the Protection of Aquatic Life.

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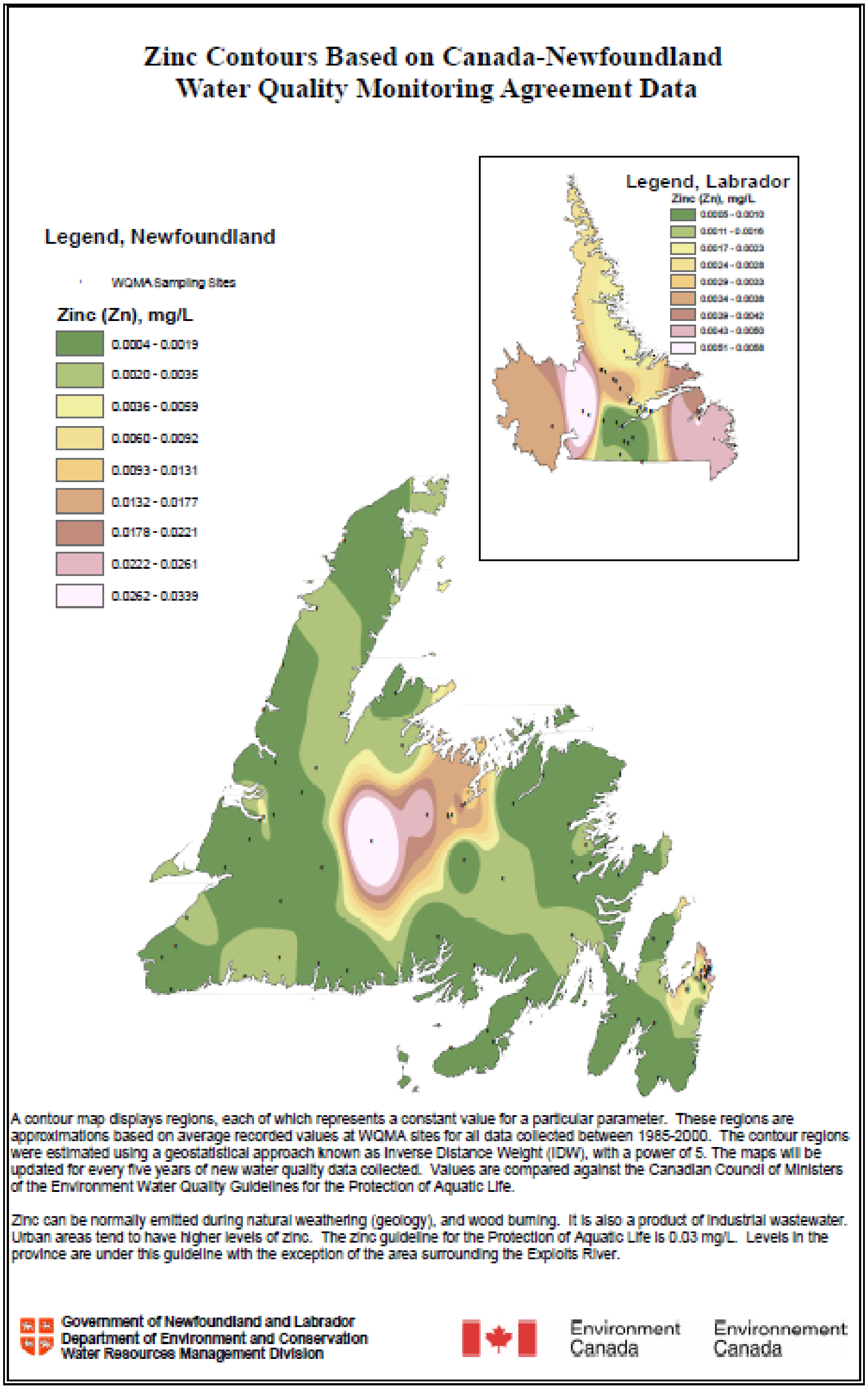
Figure L.36 Vanadium Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data



Zinc Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Legend, Labrador
Zinc (Zn), mg/L
🟩 0.0005 - 0.0010
🟩 0.0011 - 0.0016
🟨 0.0017 - 0.0023
🟨 0.0024 - 0.0028
🟧 0.0029 - 0.0033
🟧 0.0034 - 0.0038
🟫 0.0039 - 0.0042
▭ 0.0043 - 0.0050
▭ 0.0051 - 0.0058
Legend, Newfoundland
· WQMA Sampling Sites
Zinc (Zn), mg/L
🟩 0.0004 - 0.0019
🟩 0.0020 - 0.0035
🟨 0.0036 - 0.0059
🟨 0.0060 - 0.0092
🟧 0.0093 - 0.0131
🟧 0.0132 - 0.0177
🟫 0.0178 - 0.0221
▭ 0.0222 - 0.0261
▭ 0.0262 - 0.0339
Environment Canada
Environnement Canada

A contour map displays regions, each of which represents a constant value for a particular parameter. These regions are approximations based on average recorded values at WQMA sites for all data collected between 1985-2000. The contour regions were estimated using a geostatistical approach known as Inverse Distance Weight (IDW), with a power of 5. The maps will be updated for every five years of new water quality data collected. Values are compared against the Canadian Council of Ministers of the Environment Water Quality Guidelines for the Protection of Aquatic Life.

Zinc can be normally emitted during natural weathering (geology), and wood burning. It is also a product of industrial wastewater. Urban areas tend to have higher levels of zinc. The zinc guideline for the Protection of Aquatic Life is 0.03 mg/L. Levels in the province are under this guideline with the exception of the area surrounding the Exploits River.

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Water Resources Management Division

Figure L.37 Zinc Contours Based on Canada-Newfoundland Water Quality Monitoring Agreement Data

Appendix M

Seasonal Monitoring Water and Sediment Quality Results

Parameter	Units	RDL	CWQG Guideline	MMER	S1				S2				S3			S4			S5			L1			L2	Long Lake
				Guideline	8-Oct-11	Lab. Dup.	2-Mar-12	Lab. Dup.	7-Oct-11	Lab. Dup.	2-Mar-12	Lab. Dup.	8-Oct-11	2-Mar-12	Lab. Dup.	7-Oct-11	2-Mar-12	Lab. Dup.	8-Oct-11	Lab. Dup.	2-Mar-12	7-Oct-11	2-Mar-12	Lab. Dup.	8-Oct-11	2-Mar-12
Anion Sum	me/L	N/A			0.67		1.06		1.21		1.75		0.55	0.960		0.61	0.690		1.79		2.32	0.68	0.710		1.83	0.81
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	1			33		49		56		78		27	42		28	32		86		110	34	33		88	37
Calculated TDS	mg/L	1			38		58.0		67		93.0		36	56.0		34	37.0		90		116	37	38.0		91	43
Carb. Alkalinity (calc. as CaCO3)	mg/L	1			<1		<1.0		<1		<1.0		<1	<1.0		<1	<1.0		<1		1.2	<1	<1.0		<1	<1.0
Cation Sum	me/L	N/A			0.76		0.970		1.23		1.57		0.65	0.890		0.65	0.630		1.84		2.22	0.76	0.670		1.85	0.76
Hardness (CaCO3)	mg/L	1			34		43		56		69		29	40		29	29		89		110	36	31		90	36
Ion Balance (% Difference)	%	N/A			6.29		4.43		0.82		5.42		8.33	3.78		3.17	4.55		1.38		2.20	5.56	2.90		0.54	3.18
Langelier Index (@ 20C)	N/A				-1.34		-1.07		-0.54		-0.421		-1.53	-1.10		-1.36	-1.37		-0.075		0.152	-1.11	-1.19		-0.087	-1.08
Langelier Index (@ 4C)	N/A				-1.59		-1.32		-0.792		-0.672		-1.78	-1.36		-1.61	-1.63		-0.326		-0.0990	-1.36	-1.45		-0.338	-1.33
Nitrate (N)	mg/L	0.05	13		<0.05		0.27		<0.05		0.053		<0.05	0.080		<0.05	<0.050		<0.05		0.11	<0.05	<0.050		<0.05	0.11
Saturation pH (@ 20C)	N/A				8.86		8.58		8.41		8.18		9.03	8.66		8.99	8.92		8.11		7.91	8.88	8.85		8.13	8.76
Saturation pH (@ 4C)	N/A				9.11		8.83		8.66		8.43		9.28	8.92		9.24	9.18		8.36		8.16	9.13	9.11		8.38	9.01
Acidity	mg/L	5			<5		5.6		<5		6.4		5	<5.0		<5	<5.0		<5	<5	<5.0	<5	<5.0		<5	<5.0
Total Alkalinity (Total as CaCO3)	mg/L	5			33		49		56		78		27	43		29	32	31	87		110	34	33	32	89	38
Dissolved Chloride (Cl)	mg/L	1			<1		<1.0		<1		2.2		<1	<1.0		<1	<1.0	<1.0	<1		<1.0	<1	<1.0	<1.0	<1	<1.0
Colour	TCU	5	Narrative		23		22		20		11		44	14		13	12	11	13		7.9	10	11	10	12	9.9
Strong Acid Dissoc. Cyanide (CN)	mg/L	0.002	0.005 (as free CN)	2	<0.002		<0.0020		<0.002		<0.0020		<0.002	<0.0020		<0.002	<0.0020		<0.002		<0.0020	<0.002	<0.0020		<0.002	<0.0020
Total Dissolved Solids	mg/L	10			47		64		64	54	82		46	48		31	32		81		110	34	27		100	30
Dissolved Fluoride (F-)	mg/L	0.1	0.120 (inorganic F)		<0.1	<0.1	<0.10	<0.10	<0.1		0.11		<0.1	<0.10		<0.1	<0.10		<0.1		<0.10	<0.1	<0.10		<0.1	<0.10
Nitrate + Nitrite	mg/L	0.05			<0.05		0.27		<0.05		0.053		<0.05	0.080		<0.05	<0.050	<0.050	<0.05		0.11	<0.05	<0.050	0.052	<0.05	0.11
Nitrite (N)	mg/L	0.01	0.06		<0.01		<0.010		<0.01		<0.010		<0.01	<0.010		<0.01	<0.010	<0.010	<0.01		<0.010	<0.01	<0.010	<0.010	<0.01	<0.010
Nitrogen (Ammonia Nitrogen)	mg/L	0.05	See Table		0.06		<0.050	<0.050	0.11		<0.050		0.08	<0.050		0.06	<0.050		0.16		<0.050	<0.05	<0.050	<0.050	<0.05	<0.050
Dissolved Organic Carbon (C)	mg/L	0.5			5.3	5.4	5.0	4.8	3.7		3.5		6.7	2.5		3.2	3.3		3.2		1.5	3.1	3.3		3	3.2
Total Organic Carbon (C)	mg/L	0.5			5		4.4	4.3	3.5		3.8		6.7	2.1		3.1	2.9		3		1.2	2.9	2.7		2.9	2.8
Orthophosphate (P)	mg/L	0.01			<0.01		<0.010		<0.01		<0.010		<0.01	<0.010		<0.01	<0.010	<0.010	<0.01		<0.010	<0.01	<0.010	<0.010	0.01	<0.010
pH	pH	N/A	6.5-9		7.52		7.51		7.87		7.76	7.78	7.5	7.56		7.63	7.55		8.03		8.06	7.77	7.66		8.04	7.68
Total Phosphorus	mg/L						0.016				0.005			0.012			0.012				0.004		0.003			0.018
Reactive Silica (SiO2)	mg/L	0.5			4.2		6.7		6.6		8.8		7.4	9.4		3.2	3.6	3.5	4.3		6.7	3.4	3.7	3.7	4.3	4
Total Suspended Solids	mg/L	1	Narrative	30	2		2.7		1		<2.0		<1	5.2		1	2.4		<1		<1.0	1	1.6		2	<1.0
Dissolved Sulphate (SO4)	mg/L	2			<2		2.7		4		5.4		<2	4.8		2	2.2	2.1	2		5.8	<2	2.2	2.3	2	2.3
Turbidity	NTU	0.1	Narrative		0.2		0.60		0.1		1.3		0.2	0.70	0.78	0.1	0.37		<0.1		0.40	0.2	0.18		<0.1	0.61
Conductivity	uS/cm	1			67		95		110		160	160	56	87		58	62		160		210	68	67		160	76
Dissolved Mercury (Hg)	μg/L	0.01	0.026		<0.01	<0.01	<0.013	<0.013	0.01		<0.013		<0.01	<0.013		<0.01	<0.013		<0.01		<0.013	<0.01	<0.013		<0.01	<0.013
Dissolved Aluminum (Al)	μg/L	5.0			14.3		12.9		10.3		7.8		79.8	22.1		17.9	11.5	12.1	<5		<5.0	16.1	<5.0		12.3	7.2
Total Aluminum (Al)	μg/L	5.0	5 if pH <6.5, 100 if pH > 6.5		13.1		19.9		14.4		14.7		72.8	41.9		20.1	73.6		<5		8.2	47.7	8.2		19.2	16.5
Total Antimony (Sb)	μg/L	1.0			<1		<1.0		<1		<1.0		<1	<1.0		<1	<1.0		<1		<1.0	<1	<1.0		<1	<1.0
Total Arsenic (As)	μg/L	1.0	5	1000	<1		<1.0		<1		<1.0		<1	<1.0		<1	<1.0		<1		<1.0	<1	<1.0		<1	<1.0
Total Barium (Ba)	μg/L	1.0			12.5		18.2		14.3		18.6		12.2	15.3		8.6	10.4		18.3		30.6	9.6	30.6		18.5	10.3
Total Beryllium (Be)	μg/L	1.0			<1		<1.0		<1		<1.0		<1	<1.0		<1	<1.0		<1		<1.0	<1	<1.0		<1	<1.0
Total Bismuth (Bi)	μg/L	2.0			<2		<2.0		<2		<2.0		<2	<2.0		<2	<2.0		<2		<2.0	<2	<2.0		<2	<2.0
Total Boron (B)	μg/L	50	1500		<50		<50		<50		<50		<50	<50		<50	<50		<50		<50	<50	<50		<50	<50
Total Cadmium (Cd)	μg/L	0.017	*Cadmium concentration =* $10^{0.86[\log10(hardness)]-3.2}$		0.048		<0.017		<0.017		<0.017		<0.017	<0.017		<0.017	<0.017		<0.017		<0.017	<0.017	<0.017		<0.017	<0.017
Total Calcium (Ca)	μg/L	100			8490		11100		14500		18200		6860	10400		7110	7280		19500		25300	7690	25300		18700	9090
Total Chromium (Cr)	μg/L	1.0			<1		<1.0		<1		<1.0		<1	<1.0		<1	<1.0		<1		<1.0	<1	<1.0		<1	<1.0
Total Cobalt (Co)	μg/L	0.40			<0.4		<0.40		<0.4		<0.40		<0.4	<0.40		<0.4	<0.40		<0.4		<0.40	<0.4	<0.40		<0.4	<0.40
Total Copper (Cu)	μg/L	2.0	*Copper concetration =* $e^{0.8545[\ln(hardness)]-1.465} * 0.2$ *μg/L*	600	<2		<2.0		<2		<2.0		<2	<2.0		<2	<2.0		<2		<2.0	2.4	<2.0		<2	<2.0
Total Iron (Fe)	μg/L	50	300		77		297		112		493		123	123		<50	140		54		167	76	167		109	<50
Total Lead (Pb)	μg/L	0.50	*Lead concetration =* $e^{1.273[\ln(hardness)]-4.705}$	400	<0.5		<0.50		<0.5		<0.50		<0.5	<0.50		<0.5	<0.50		<0.5		<0.50	<0.5	<0.50		<0.5	<0.50
Total Magnesium (Mg)	μg/L	100			3120		4030		5580		7080		2870	4250		2930	3040		9780		13000	3590	13000		9770	3840
Total Manganese (Mn)	μg/L	2.0			27.2		87.0		26.1		185		28.4	62.9		4	21.4		29.5		50.8	12.8	50.8		45	7.7
Total Molybdenum (Mo)	μg/L	2.0	73		<2		<2.0		<2		<2.0		<2	<2.0		<2	<2.0		<2		<2.0	<2	<2.0		<2	<2.0
Total Nickel (Ni)	μg/L	2.0	*Nickel concentration =* $e^{0.76[\ln(hardness)]+1.06}$	1000	<2		<2.0		<2		<2.0		<2	<2.0		<2	<2.0		<2		<2.0	<2	<2.0		<2	<2.0
Total Phosphorus (P)	μg/L	100	ultra-oligotrophic <4,oligotrophic 4-10, mesotrophic 10-20, meso-eutrophic 20-35, eutrophic 35-100, hyper-eutrophic >100		<100		<100		<100		<100		<100	<100		<100	<100		<100		<100	<100	<100		<100	<100
Total Potassium (K)	μg/L	100			1330		1640		2060		2690		1040	1570		1060	1120		971		1410	849	1410		908	1050
Total Selenium (Se)	μg/L	1.0	1		<1		<1.0		<1		<1.0		<1	<1.0		<1	<1.0		<1		<1.0	<1	<1.0		<1	<1.0
Total Silicon (Si)	μg/L	500			2050		3460		3220		4800		3470	4940		1560	1940		2040		3590	1650	3590		2020	2090
Total Silver (Ag)	μg/L	0.10	0.1		<0.1		<0.10		<0.1		<0.10		<0.1	<0.10		<0.1	<0.10		<0.1		<0.10	<0.1	<0.10		<0.1	<0.10
Total Sodium (Na)	μg/L	100			940		1440		1200		3040		925	1300		706	808		599		946	538	946		597	762
Total Strontium (Sr)	μg/L	2.0			17.7		22.5		24.2		29.9		16.7	23.5		12.9	13.3		15.5		23.2	12.4	23.2		16	12.6
Total Sulphur (S)	μg/L	5000			<5000		<5000		<5000		<5000		<5000	<5000		<5000	<5000		<5000		<5000	<5000	<5000		<5000	<5000
Total Tellurium (Te)	μg/L	2.0			<2		<2.0		<2		<2.0		<2	<2.0		<2	<2.0		<2		<2.0	<2	<2.0		<2	<2.0
Total Thallium (Tl)	μg/L	0.10	0.8		<0.1		<0.10		<0.1		<0.10		<0.1	<0.10		<0.1	<0.10		<0.1		<0.10	<0.1	<0.10		<0.1	<0.10
Total Tin (Sn)	μg/L	2.0			<2		<2.0		<2		<2.0		<2	<2.0		<2	<2.0		<2		<2.0	<2	<2.0		<2	<2.0
Total Titanium (Ti)	μg/L	2.0			<2		<2.0		<2		<2.0		<2	<2.0		<2	4.1		<2		<2.0	2.5	<2.0		<2	2.2
Total Uranium (U)	μg/L	0.10	33 (short term), 15 (long term)		<0.1		<0.10		0.16		0.15		<0.1	<0.10		<0.1	0.16		0.39		0.96	<0.1	0.96		0.37	<0.10
Total Vanadium (V)	μg/L	2.0			<2		<2.0		<2		<2.0		<2	<2.0		<2	<2.0		<2		<2.0	<2	<2.0		<2	<2.0
Total Zinc (Zn)	μg/L	5.0	30	1000	<5		24.7		<5		<5.0		<5	5.2		<5	<5.0		<5		7.0	<5	7.0		<5	30.7
Radium 226	Bq/L			1.11	<0.005				0.02				<0.005			0.006			<0.005			0.008			<0.005	

Table M.1 Water Quality Laboratory Analytical Resutls for Routine Monitoring Stations from October 2011 and March 2012 visits

Parameter	Units	RDL	CWQG Guideline	MMER Guideline	LL1-M		LL2-T		LL3-T		LL4-T	WDR-1	MI1-T	JLC-T	WALSH-T		PL1-T	MOL-1-C	
					16-Apr-12	Lab.Dup.	16-Apr-12	Lab.Dup.	17-Apr-12	Lab.Dup.	17-Apr-12	17-Apr-12	17-Apr-12	18-Apr-12	18-Apr-12	Lab.Dup.	18-Apr-12	18-Apr-12	Lab.Dup.
Anion Sum	me/L	N/A			0.930		1.13		0.940		1.62	1.54	0.840	0.910	0.660		1.37	0.620	
Bicarb. Alkalinity (calc. as CaCO3)	mg/L	1			42		52		43		76	72	39	41	27		61	29	
Calculated TDS	mg/L	1			49.0		60.0		50.0		79.0	78.0	45.0	49.0	40.0		75.0	35.0	
Carb. Alkalinity (calc. as CaCO3)	mg/L	1			ND		ND		ND		ND	ND	ND	ND	ND		ND	ND	
Cation Sum	me/L	N/A			0.880		1.11		0.920		1.40	1.49	0.820	0.890	0.680		1.24	0.660	
Hardness (CaCO3)	mg/L	1			41		52		43		67	71	38	42	29		55	30	
Ion Balance (% Difference)	%	N/A			2.76		0.890		1.08		7.28	1.65	1.20	1.11	1.49		4.98	3.13	
Langelier Index (@ 20C)	N/A				-0.871		-0.880		-0.897		-0.542	-0.399	-1.10	-0.951	-1.46		-0.768	-3.28	
Langelier Index (@ 4C)	N/A				-1.12		-1.13		-1.15		-0.793	-0.650	-1.35	-1.20	-1.71		-1.02	-3.53	
Nitrate (N)	mg/L	0.05	13		0.083		0.094		ND		0.070	0.066	ND	0.11	0.11		ND	ND	
Saturation pH (@ 20C)	N/A				8.71		8.50		8.67		8.27	8.31	8.75	8.68	9.00		8.43	8.95	
Saturation pH (@ 4C)	N/A				8.96		8.75		8.92		8.52	8.56	9.00	8.93	9.25		8.68	9.20	
Acidity	mg/L	5			5.2		ND		ND		5.0	ND	ND	ND	ND	ND	5.2	12	
Total Alkalinity (Total as CaCO3)	mg/L	5			43		52		44		76	72	40	42	27		61	29	
Dissolved Chloride (Cl)	mg/L	1			ND		ND		ND		ND	ND	ND	ND	2.2		1.6	ND	
Colour	TCU	5	Narrative		10		9.8		11		9.9	8.3	11	12	22		15	9.6	
Strong Acid Dissoc. Cyanide (CN)	mg/L	0.002	0.005 (as free CN)	2	ND		ND		ND		ND	ND	ND	ND	ND		ND	ND	
Total Dissolved Solids	mg/L	10			52		48		49		90	74	36	46	41	41	69	29	
Dissolved Fluoride (F-)	mg/L	0.1	0.120 (inorganic F)		ND	ND	ND		ND		ND	ND	ND	ND	ND		ND	ND	
Nitrate + Nitrite	mg/L	0.05			0.083		0.094		ND		0.070	0.066	ND	0.11	0.11		ND	ND	
Nitrite (N)	mg/L	0.01	0.06		ND		ND		ND		ND	ND	ND	ND	ND		ND	ND	
Nitrogen (Ammonia Nitrogen)	mg/L	0.05	See Table		ND	ND	ND		ND		ND	ND	ND	ND	ND		ND	ND	
Dissolved Organic Carbon (C)	mg/L	0.5					7.3	7.4	3.9		6.2	3.8	4.3	3.7	4.7		4.7	20	
Total Organic Carbon (C)	mg/L	0.5			2.6	2.8	6.7		3.4		6.3	3.2	4.2	3.7	4.2		4.2	20	
Orthophosphate (P)	mg/L	0.01			ND		ND		ND		ND	ND	ND	ND	ND		ND	ND	
pH	pH	N/A	6.5-9		7.84	7.85	7.62		7.77		7.73	7.91	7.65	7.73	7.54		7.66	5.67	5.64
Total Phosphorus	mg/L				0.005		0.006		0.014		0.011	0.007	0.011	0.011	0.009		0.013	0.007	
Reactive Silica (SiO2)	mg/L	0.5			4.4		4.8		4.4		4.7	4.7	4.2	4.5	5.7		8.2	3.8	
Total Suspended Solids	mg/L	1	Narrative	30	ND		1.4		1.0		2.0	ND	1.0	ND	ND		1.6	1.0	
Dissolved Sulphate (SO4)	mg/L	2			3.4		3.7		3.1		4.4	4.4	2.4	3.1	2.2		5.3	2.3	
Turbidity	NTU	0.1	Narrative		0.33	0.36	0.43		0.40		0.53	0.60	0.31	0.20	0.45		0.96	0.17	
Conductivity	uS/cm	1			87	89	110		88		140	140	79	86	67		120	66	66
Dissolved Mercury (Hg)	µg/L	0.01	0.026		0.073	0.073	ND		ND		ND	ND	ND	ND	ND		ND	0.022	
Dissolved Aluminum (Al)	µg/L	5.0			7.2		5.9	5.9	7.7		ND	ND	9.4	ND	36.7		10.8	18	
Total Aluminum (Al)	µg/L	5.0	5 if pH <6.5, 100 if pH > 6.5		18.6		14		15.5	15.1	12.5	13.8	17.4	8.7	45.8		15.2	18.5	
Total Antimony (Sb)	µg/L	1.0			ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Arsenic (As)	µg/L	1.0	5	1000	ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Barium (Ba)	µg/L	1.0			10.9		14.4		11.7	11.8	17.2	17.9	10.1	12.2	12.5		15.2	8.6	
Total Beryllium (Be)	µg/L	1.0			ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Bismuth (Bi)	µg/L	2.0			ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Boron (B)	µg/L	50	1500		ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Cadmium (Cd)	µg/L	0.017	Cadmium concentration = $10^{0.86[log10(hardness)]-3.2}$ µg/L		ND		0.056		0.045	0.039	0.022	0.035	ND	ND	ND		ND	ND	
Total Calcium (Ca)	µg/L	100			9410		12300		10000	9860	15300	14500	8870	10200	7280		12900	7550	
Total Chromium (Cr)	µg/L	1.0			ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Cobalt (Co)	µg/L	0.40			ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Copper (Cu)	µg/L	2.0	Copper concetration = $e^{0.8545[\ln(hardness)]-1.465}$ * 0.2 µg/L	600	ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Iron (Fe)	µg/L	50	300		ND		52		ND	ND	128	136	ND	ND	180		160	ND	
Total Lead (Pb)	µg/L	0.50	Lead concetration = $e^{1.273[\ln(hardness)]-4.705}$ µg/L	400	0.60		0.84		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Magnesium (Mg)	µg/L	100			4560		5890		4770	4740	7480	7790	4070	4490	2580		5220	3050	
Total Manganese (Mn)	µg/L	2.0			4.6		21.3		7.5	7.3	19.5	17.8	4.8	7.6	15.8		75.2	ND	
Total Molybdenum (Mo)	µg/L	2.0	73		ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Nickel (Ni)	µg/L	2.0	Nickel concentration = $e^{0.76[\ln(hardness)]+1.06}$ µg/L	1000	ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Phosphorus (P)	µg/L	100	ultra-oligotrophic <4,oligotrophic 4-10, mesotrophic 10-20, meso-eutrophic 20-35, eutrophic 35-100, hyper-eutrophic >100		ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Potassium (K)	µg/L	100			1000		1270		1080	1080	1300	1420	1010	954	1210		2100	1020	
Total Selenium (Se)	µg/L	1.0	1		ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Silicon (Si)	µg/L	500			1860		2150		1890	1880	1930	1890	1830	1970	2380		3410	1630	
Total Silver (Ag)	µg/L	0.10	0.1		ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Sodium (Na)	µg/L	100			651		814		770	752	658	771	748	654	1540		1990	893	
Total Strontium (Sr)	µg/L	2.0			14.0		17.6		14.8	13.9	19.3	20.5	13.4	15.6	18.4		22.5	13.7	
Total Sulphur (S)	µg/L	5000			ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Tellurium (Te)	µg/L	2.0			ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Thallium (Tl)	µg/L	0.10	0.8		ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Tin (Sn)	µg/L	2.0			ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Titanium (Ti)	µg/L	2.0			ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Uranium (U)	µg/L	0.10	33 (short term), 15 (long term)		0.13		0.22		0.15	0.14	0.39	0.4	ND	ND	ND		ND	ND	
Total Vanadium (V)	µg/L	2.0			ND		ND		ND	ND	ND	ND	ND	ND	ND		ND	ND	
Total Zinc (Zn)	µg/L	5.0	30	1000	6.9		ND		ND	ND	ND	ND	ND	ND	ND		22.3	ND	
Radium 226	Bq/L			1.11															

Table M.2 Water Quality Laboratory Analytical Resutls for Additional Lake Samples from April 2012 Field Visit

Station	Date	Temperature (deg. C)	Specific Conductance (µS/cm)	Conductivity (µS/cm)	TDS (g/L)	Salinity	DO (%)	DO (mg/L)	pH	pH mV
October 2011 Field Visit										
S1	8-Oct-11	3.57	65	38	0.042	0.03	90.1	11.93	9.00	-85.0
S2	7-Oct-11	1.85	111	62	0.072	0.05	103.4	14.36	8.90	-81.7
S3	8-Oct-11	3.64	56	33	0.037	0.03	87.6	11.59	9.10	-90.0
S4	7-Oct-11	7.00	57	38	0.037	0.03	100.5	12.18	8.94	-83.2
S5	8-Oct-11	4.72	156	95	0.101	0.07	87.8	11.29	9.07	-88.8
L1	7-Oct-11	6.73	66	43	0.043	0.03	101.1	12.35	9.13	-93.0
L2	8-Oct-11	5	157	57	0.102	0.07	93.2	11.91	9.06	-88.4
March 2012 Field Visit										
S1	2-Mar-12	4.27	100	72	0.065	0.05	121.3	15.44	7.60	-82.0
S2	3-Mar-12	3.40	158	123	0.103	0.08	127	17.1	7.70	-92.1
S3	2-Mar-12	5.53	87	54	0.057	0.04	98.8	12.46	7.81	-100.9
S4	2-Mar-12	4	48	38	0.032	0.02	127.7	16.6	8.62	-128
S5	2-Mar-12	4.5	245	155	0.158	0.12	98.8	12.55	7.59	-89.3
L1	2-Mar-12	3.42	104	62	0.068	0.05	131	17.44	7.45	-84.2
L2	2-Mar-12	2.65	85	49	0.055	0.04	94.1	12.67	8.08	-111.1

Table M.3 In-situ Water Quality Measurements Results for October and March Field Visit

Station	Date	Water Temperature (deg. C)	Air Temperature (deg.C)	Water Depth (m)	Depth of Sample (m)	Thickness of Ice (m)	Conductivity (µS/cm)	DO (mg/L)	pH
April 2012 Field Visit									
LL1-M	16-Apr-12	2.18	0	7.7	4.00	0.82	181	10.91	6.30
LL2-T	17-Apr-12	0.06	-7	2.4	1.20	0.85	265	12.06	7.03
LL3-T	17-Apr-12	0.15	-8	2.4	1.20	0.82	221	12.92	7.22
LL4-T	17-Apr-12	0.01	-8	1.0	0.90	0.82	299	12.13	7.42
WDR-1	17-Apr-12	0.04	-6	1.3	0.60	0.4	351	12.09	7.60
MI1-T	17-Apr-12	0.01	-5	12.4	1.00	0.85	200	12.84	7.69
JLC-T	18-Apr-12	1.24	-4	0.2	0.15		219	12.24	7.28
WALSH-T	41017	0.07	-2	0.5	0.15	0.1	171	12.39	7.5
PL-1-T	18-Apr-12	0.11	0	1.2	0.50	0.8	308	11.29	7.49
MOL1-C	18-Apr-12	0.41	0	17.6	1.00	0.8	167	12.15	7.77
May 2012 Field Visit									
S1	29-May-12	6.35	3	0.75	0.30	0.47	72	10.21	7.96
S2	29-May-12	7.02	3	0.4	0.40	0.67	81	9.92	7.90
S3	28-May-12	1.65	2	0.8	0.10	0.4	34	11.09	8.02
S4	28-May-12	3.36	2	0.3	0.10	0.91	45	11.06	7.84
S5	28-May-12	4.1	4	0.7	0.30		125	12.02	8.06
L1	28-May-12	3.88	2	Lake	0.20	0.58	68	11.71	7.79
L2	28-May-12	5.52	4	0.8	0.10	0.55	81	11.46	7.88

Table M.4 In-situ Water Quality Measurements Results for April and May 2012 Field Visit

Parameter	Units	RDL(Nov_11)	CCME Guidelines		S3			S4			S5			MS8125 (5-Mar-12)			L2			LV4062		LL1-S			PL 1-S			MOL-1-S	
			ISQG	PEL	5-Mar-12	Lab. Dup.		3-Mar-12	Lab. Dup.		2-Mar-12	Lab. Dup.		(Field Dup.5-Mar-12)	Field Dup. -Lab.Dup.		28-Nov-11	Lab. Dup.		28-Nov-11(DUP)		16-Apr-12	Lab. Dup.	RDL	18-Apr-12	Lab. Dup.	RDL	18-Apr-12	RDL
Inorganics																													
Chloride (Cl)	mg/kg	5.0			65			<5.0			29			6.5			7			7		8.9		5.0	29		5.0	36	5.0
Moisture	%	1			88			18			62			15			38	33		36		86		1	88		1	91	1
Organic Carbon (TOC)	g/kg	0.20			210			1.8			70			1.9			27			27		74		0.40	99		1	79	0.50
Total Kjeldahl Nitrogen	µg/g	10			6810			92			2870			122			1540			1310		5810		50	6710		50	6060	50
< -4 Phi (16 mm)	%	0.10			100			100			100			100			100			100		100		0.10	100		0.10	100	0.10
< -3 Phi (8 mm)	%	0.10			100			100			100			100			100			100		100		0.10	100		0.10	100	0.10
< -2 Phi (4 mm)	%	0.10			100			100			100			100			100			100		100		0.10	100		0.10	100	0.10
< -1 Phi (2 mm)	%	0.10			95 (2)			67			98 (1)			58			73 (1)			90 (2)		100		0.10	100		0.10	100	0.10
< 0 Phi (1 mm)	%	0.10			81 (3)			40			93			31			65			81		73		0.10	74		0.10	74	0.10
< +1 Phi (0.5 mm)	%	0.10			67 (4)			20			87			14			52			65		65		0.10	62		0.10	62	0.10
< +2 Phi (0.25 mm)	%	0.10			53			5.4			70			4.0			26			32		60		0.10	48		0.10	55	0.10
< +3 Phi (0.12 mm)	%	0.10			40			1.5			45			1.3			13			16		55		0.10	33		0.10	49	0.10
< +4 Phi (0.062 mm)	%	0.10			33			0.93			26			0.85			6.1			6.8		49		0.10	25		0.10	45	0.10
< +5 Phi (0.031 mm)	%	0.10			28			0.68			17			0.65			5.5			6.0		39		0.10	23		0.10	43	0.10
< +6 Phi (0.016 mm)	%	0.10			20			0.47			9.9			0.47			4.6			5.4		31		0.10	17		0.10	35	0.10
< +7 Phi (0.0078 mm)	%	0.10			11			0.28			3.6			0.38			3.4			4.3		18		0.10	11		0.10	20	0.10
< +8 Phi (0.0039 mm)	%	0.10			10			0.29			2.5			0.45			3.3			4.1		15		0.10	11		0.10	16	0.10
< +9 Phi (0.0020 mm)	%	0.10			11			0.3			1.8			0.29			3.2			3.9		14		0.10	9.4		0.10	14	0.10
Gravel	%	0.10			5.2			33			2.1			42			27			9.6		ND		0.10	ND		0.10	ND	0.10
Sand	%	0.10			61			66			72			57			67			84		51		0.10	75		0.10	55	0.10
Silt	%	0.10			23			0.63			23			0.40			2.8			2.7		34		0.10	14		0.10	29	0.10
Clay	%	0.10			10			0.29			2.5			0.45			3.3	4.1		4.1		15		0.10	11		0.10	16	0.10

Table M.5 Sediment Quality General Constituents Laboratory Analytical Resutls for Routine Monitoring Stations and Selected Lakes

Parameter	Units	RDL	CCME Guidelines		S3			S4			S5			MS8125 (5-Mar-12)			L2			LV4062		LL1-S			PL 1-S			MOL-1-S	
			ISQG	PEL	5-Mar-12	Lab. Dup.		3-Mar-12	Lab. Dup.		2-Mar-12	Lab. Dup.		(Field Dup.5-Mar-12)	Field Dup. -Lab.Dup.		28-Nov-11	Lab. Dup.		28-Nov-11(DUP)		16-Apr-12	Lab. Dup.	RDL	18-Apr-12	Lab. Dup.	RDL	18-Apr-12	RDL
Metals																													
Acid Extractable Aluminum (Al)	µg/g	50			13000			3500						3300	3300														
Available Aluminum (Al)	mg/kg	10			13000			2300			4500	4700		2300			1500			1500		16000		10	10000		10	23000	10
Available Antimony (Sb)	mg/kg	2.0			<2.0			<2.0			<2.0	<2.0		<2.0			ND			ND		ND		2.0	ND		2.0	ND	2.0
Available Arsenic (As)	mg/kg	2.0	5.9	17	<2.0			<2.0			2.3	2.6		<2.0			ND			ND		2.2		2.0	ND		2.0	ND	2.0
Acid Extractable Barium (Ba)	µg/g	0.5			150			43						39	38														
Available Barium (Ba)	mg/kg	5.0			120			23			290	240		17			46			47		350		5.0	140		5.0	860	5.0
Acid Extractable Beryllium (Be)	µg/g	0.5			<0.5			<0.5						<0.5	<0.5														
Available Beryllium (Be)	mg/kg	2.0			<2.0			<2.0			<2.0	<2.0		<2.0			ND			ND		ND		2.0	ND		2.0	ND	2.0
Acid Extractable Bismuth (Bi)	µg/g	5			<5			<5						<5	<5														
Available Bismuth (Bi)	mg/kg	2.0			<2.0			<2.0			<2.0	<2.0		<2.0			ND			ND		ND		2.0	ND		2.0	ND	2.0
Available Boron (B)	mg/kg	5.0			<5.0			<5.0			<5.0	<5.0		<5.0			ND			ND		ND		5.0	ND		5.0	ND	5.0
Acid Extractable Cadmium (Cd)	µg/g	0.3			0.6			<0.3						<0.3	<0.3														
Available Cadmium (Cd)	mg/kg	0.30	0.6	3.5	0.5			<0.30			0.32	0.35		<0.30			ND			ND		0.59		0.30	ND		0.30	0.65	0.30
Acid Extractable Calcium (Ca)	µg/g	50			7800			2100						1700	1600														
Acid Extractable Chromium (Cr)	µg/g	0.5			49			26						23	22														
Available Chromium (Cr)	mg/kg	2.0	37.3	90	48			15			22	23		11			11			9		65		2.0	31		2.0	71	2.0
Acid Extractable Cobalt (Co)	µg/g	0.5			9.1			3						2.5	3.2														
Available Cobalt (Co)	mg/kg	1.0			9.8			1.7			5.8	6.4		1.7			2			2		13		1.0	11		1.0	17	1.0
Acid Extractable Copper (Cu)	µg/g	0.5			36			3.9						2.7	19 (1)														
Available Copper (Cu)	mg/kg	2.0	35.7	197	14			<2.0			9.6	8.7		<2.0			2			2		25		2.0	16		2.0	37	2.0
Acid Extractable Iron (Fe)	µg/g	50			23000			11000						9400	9200														
Available Iron (Fe)	mg/kg	50			21000			5500			52000	54000		6400			31000			25000		71000		50	23000		50	44000	50
Acid Extractable Lead (Pb)	µg/g	1			5			3						2	2														
Available Lead (Pb)	mg/kg	0.50	35	91.3	5.3			1.7			2.1	2.2		1.5			1.1			1.1		16		0.50	2.3		0.50	7.8	0.50
Available Lithium (Li)	mg/kg	2.0			16			4.1			3.4	3.6		3.5			ND			ND		11		2.0	7.7		2.0	14	2.0
Acid Extractable Magnesium (Mg)	µg/g	50			4100			2600						2400	2400														
Acid Extractable Manganese (Mn)	µg/g	10			2800			390						290	310														
Available Manganese (Mn)	mg/kg	2.0			650			220			15000	16000		110			400			390		4100		2.0	1100		2.0	16000	2.0
Available Mercury (Hg)	mg/kg	0.10	0.17	0.486	0.17			<0.10			<0.10	<0.10		<0.10			ND			ND		0.11		0.10	ND		0.10	0.15	0.10
Acid Extractable Molybdenum (Mo)	µg/g	0.5			14			0.8						0.6	0.8														
Available Molybdenum (Mo)	mg/kg	2.0			14			<2.0			14	14		<2.0			ND			ND		4.1		2.0	5.9		2.0	14	2.0
Acid Extractable Nickel (Ni)	µg/g	0.5			19			7.9						7.1	7.9														
Available Nickel (Ni)	mg/kg	2.0			20			5.3			18	20		5.5			4			4		40		2.0	35		2.0	49	2.0
Acid Extractable Phosphorus (P)	µg/g	20			770			560			950			460	450		700	700		670		1100		20	570		20	3900	200
Acid Extractable Potassium (K)	µg/g	200			330			950						910	900														
Available Rubidium (Rb)	mg/kg	2.0			3.9			4.8			2.9	3.1		5.1			ND			ND		19		2.0	4.5		2.0	15	2.0
Available Selenium (Se)	mg/kg	2.0			<2.0			<2.0			<2.0	<2.0		<2.0			ND			ND		ND		2.0	ND		2.0	ND	2.0
Acid Extractable Silver (Ag)	µg/g	0.3			<0.3			<0.3						<0.3	<0.3														
Available Silver (Ag)	mg/kg	0.50			<0.50			<0.50			<0.50	<0.50		<0.50			ND			ND		ND		0.50	ND		0.50	ND	0.50
Acid Extractable Sodium (Na)	µg/g	100			<100			<100						<100	<100														
Available Strontium (Sr)	mg/kg	5.0			25			8.6			13	13		8.6			5			5		23		5.0	18		5.0	39	5.0
Acid Extractable Strontium (Sr)	µg/g	1			23			7						6	6														
Available Thallium (Tl)	mg/kg	0.10			0.24			<0.10			0.71	0.81		<0.10			ND			ND		0.41		0.10	0.48		0.10	0.44	0.10
Acid Extractable Sulphur (S)	µg/g	50			1800			87						100	180														
Available Tin (Sn)	mg/kg	2.0			<2.0			<2.0			<2.0	<2.0		<2.0			ND			ND		ND		2.0	ND		2.0	ND	2.0
Acid Extractable Tin (Sn)	µg/g	1			<1			<1						<1	2														
Available Uranium (U)	mg/kg	0.10			4.8			0.35			9.7	11		0.23			1.3			1.2		12		0.10	6		0.10	28	0.10
Acid Extractable Titanium (Ti)	µg/g	5			450			350						330	330														
Available Vanadium (V)	mg/kg	2.0			32			8.3			16	17		7.4			9			7		39		2.0	17		2.0	42	2.0
Available Zinc (Zn)	mg/kg	5.0	123	315	91			8.2			49	51		8.8			8			9		110		5.0	70		5.0	130	5.0
Acid Extractable Vanadium (V)	µg/g	0.5			40			15						14	13														
Acid Extractable Zinc (Zn)	µg/g	3			100			16						13	13														
Acid Extractable Zirconium (Zr)	µg/g	5			<5			<5						<5	<5														

Table M.6 Sediment Quality Metals Laboratory Analytical Resutls for Routine Monitoring Stations and Selected Lakes

Parameter	Units	RDL	CCME Guidelines		S3			S4			S5			MS8125 (5-Mar-12)			L2			LV4062		LL1-S			PL 1-S			MOL-1-S	
			ISQG	PEL	5-Mar-12	Lab. Dup.		3-Mar-12	Lab. Dup.		2-Mar-12	Lab. Dup.		(Field Dup.5-Mar-12)	Field Dup. -Lab.Dup.		28-Nov-11	Lab. Dup.		28-Nov-11(DUP)		16-Apr-12	Lab. Dup.	RDL	18-Apr-12	Lab. Dup.	RDL	18-Apr-12	RDL
Polyaromatic Hydrocarbons																													
1-Methylnaphthalene	mg/kg	0.0050			<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
2-Methylnaphthalene	mg/kg	0.0050	0.0202	0.2010	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Acenaphthene	mg/kg	0.0050	0.0067	0.0889	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Acenaphthylene	mg/kg	0.0050	0.0059	0.1280	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Anthracene	mg/kg	0.0050	0.0469	0.2450	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Benzo(a)anthracene	mg/kg	0.0050	0.0317	0.3850	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Benzo(a)pyrene	mg/kg	0.0050	0.0319	0.7820	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Benzo(b)fluoranthene	mg/kg	0.0050			<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Benzo(g,h,i)perylene	mg/kg	0.0050			<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Benzo(j)fluoranthene	mg/kg	0.0050			<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Benzo(k)fluoranthene	mg/kg	0.0050			<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Chrysene	mg/kg	0.0050	0.0571	0.8620	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Dibenz(a,h)anthracene	mg/kg	0.0050	0.0062	0.1350	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Fluoranthene	mg/kg	0.0050	0.1110	2.3550	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Fluorene	mg/kg	0.0050	0.0212	0.1440	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Indeno(1,2,3-cd)pyrene	mg/kg	0.0050			<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Naphthalene	mg/kg	0.0050	0.0346	0.3910	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Perylene	mg/kg	0.0050			<0.0050			<0.0050			1.3			<0.0050	<0.0050		0.19			0.16		1.4	1.5	0.0050	2.3		0.0050	1.6	0.0050
Phenanthrene	mg/kg	0.0050	0.0419	0.5150	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Pyrene	mg/kg	0.0050	0.0530	0.8750	<0.0050			<0.0050			<0.0050			<0.0050	<0.0050		ND			ND		ND	ND	0.0050	ND		0.0050	ND	0.0050
Surrogate Recovery (%)																													
D10-Anthracene	%				86			82			86			83	92		79			81		84	85		86			79	
D14-Terphenyl	%				92			94			130			91	97		121			109		96	99		100			95	
D8-Acenaphthylene	%				82			76			82			77	80		78			77		80	80		78			77	
BTEX & F1 Hydrocarbons																													
Benzene	µg/g	0.020			<0.20			<0.020			<0.060			<0.020			ND			ND		ND		0.14	ND		0.20	ND	0.20
Toluene	µg/g	0.020			<0.20			<0.020			<0.060			<0.020			ND			ND		ND		0.14	ND		0.20	ND	0.20
Ethylbenzene	µg/g	0.020			<0.20			<0.020			<0.060			<0.020			ND			ND		ND		0.14	ND		0.20	ND	0.20
o-Xylene	µg/g	0.020			<0.20			<0.020			<0.060			<0.020			ND			ND		ND		0.14	ND		0.20	ND	0.20
p+m-Xylene	µg/g	0.040			<0.40			<0.040			<0.12			<0.040			ND			ND		ND		0.28	ND		0.40	ND	0.40
Total Xylenes	µg/g	0.040			<0.40			<0.040			<0.12			<0.040			ND			ND		ND		0.28	ND		0.40	ND	0.40
F1 (C6-C10)	µg/g	10			<100			<10			<30			<10			ND			ND		ND		70	ND		100	ND	100
F1 (C6-C10) - BTEX	µg/g	10			<100			<10			<30			<10			ND			ND		ND		70	ND		100	ND	100
F2-F4 Hydrocarbons																													
F4G-sg (Grav. Heavy Hydrocarbons)																	1200			440	590								
F2 (C10-C16 Hydrocarbons)	µg/g	10			<100			<10			46			<10			ND			ND		ND		70	ND		100	500	100
F3 (C16-C34 Hydrocarbons)	µg/g	10			720			<10			140			<10			71			67		ND		70	ND		100	180	100
F4 (C34-C50 Hydrocarbons)	µg/g	10			240			<10			<30			<10			13			16		ND		70	ND		100	ND	100
Reached Baseline at C50	µg/g				Yes			Yes			Yes			Yes			Yes			Yes		Yes			Yes			Yes	
Surrogate Recovery (%)																													
1,4-Difluorobenzene	%				97			97			97			99			101			102		99			102			103	
4-Bromofluorobenzene	%				109			108			108			108			98			100		96			99			85	
D10-Ethylbenzene	%				98			99			98			98			87			92		97			105			110	
D4-1,2-Dichloroethane	%				93			92			92			93			96			98		95			95			98	
o-Terphenyl	%				90			84			86			88			127			116		113			113			115	

Table M.7 Sediment Quality Hydrocarbons Laboratory Analytical Resutls for Routine Monitoring Stations and Selected Lakes

Appendix N

In-situ Water Quality Sonde Records

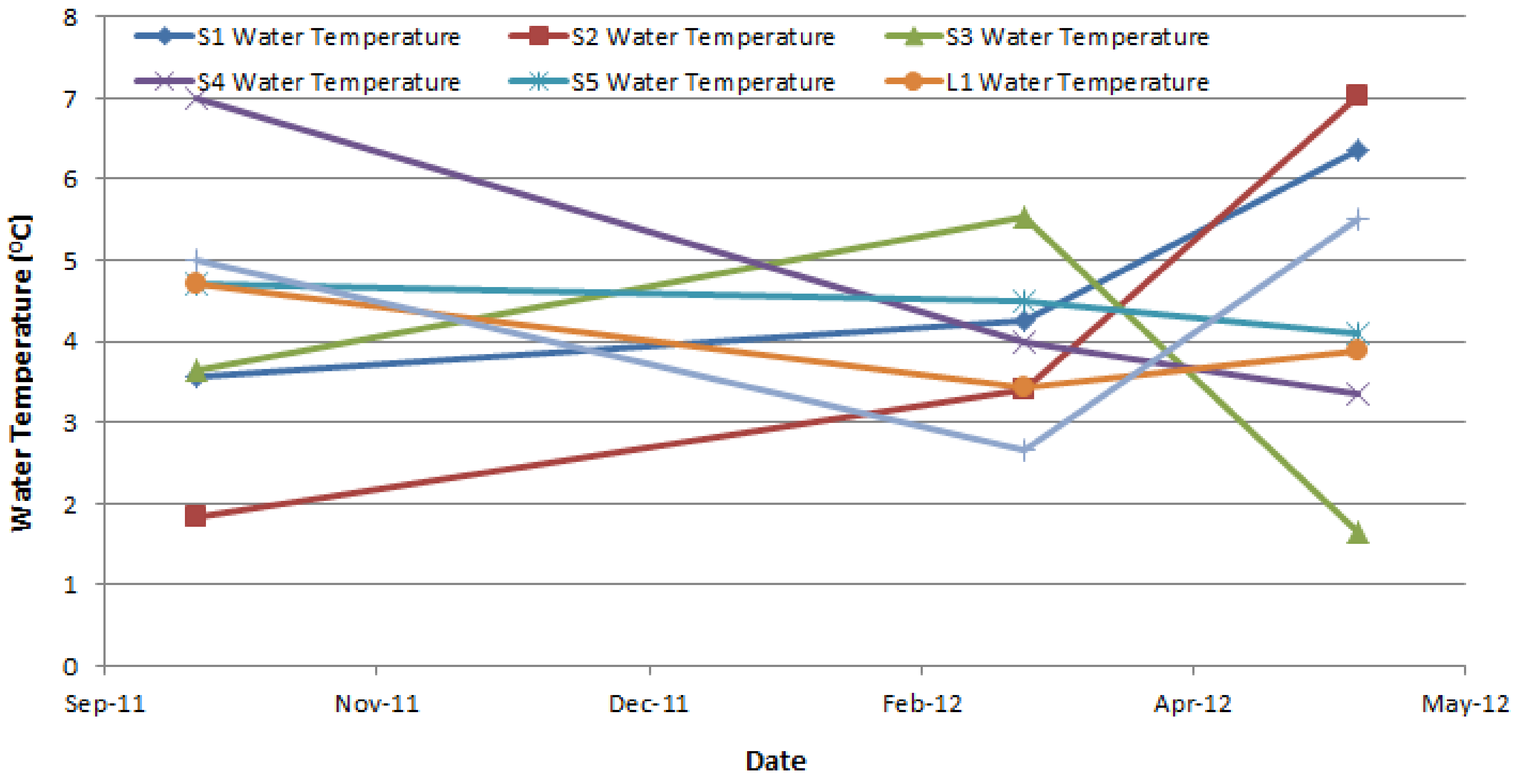

Figure N.1 *In-situ* **Water Temperature Sonde Records at Different Monitoring Stations**