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Joyce Lake Direct Shipping Iron Ore Project:

Chapter 11:

Water Resources

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11.0 WATER RESOURCES

As detailed in chapter 1, Joyce Direct Iron Inc. succeeded Labec Century Iron Ore Inc. ("Labec Century") as the Project Proponent on February 18, 2021 following an internal reorganization. All references to Labec Century as the Project proponent may be interpreted as now referring to Joyce Direct Iron Inc.

11.1 VC Definition and Rationale for Selection

The Water Resources VC includes the surface water component of fresh water resources, including the lacustrine environment. Water Resources interacts with other VCs such as groundwater, terrestrial environment, wetlands, fish and fish habitat, birds, wildlife and their habitat, and other current uses of land and resources, which are assessed in Chapters 12, 13, 14, 15, 16, and 20, respectively. Water Resources has been selected as a VC because:

- Surface water related to the Project in Labrador is the freshwater habitat for fish, aquatic organisms and vegetation and both facultative and obligate wetland vegetation and therefore is critical to the life function of these biota in that it provides the habitat component of the aquatic ecosystem;

- Changes to surface water drainage patterns, quantity, quality and sediment quality arising from Project activities, as well as the release of hazardous and deleterious substances during upset conditions, can affect the form and function of the aquatic environment and therefore directly affect the quality, nature and sustainability of aquatic ecosystems. Project effluent quality is specifically regulated through the provisions of the NL *Water Resources Act* and federal *Fisheries Act*;

- Surface water is critical in the hydrologic cycle because it is the interface for evaporation, transpiration and sublimation to provide atmospheric moisture and the outlet of the earth's groundwater regime;

- Changes to surface water quantity and availability can affect infiltration, evaporation, transpiration and sublimation potential and therefore plays a critical role in preserving groundwater and evapotranspiration (ET) in the environmental water balance;

- Project effects and interactions with local surface water features used as human drinking water sources have the potential to affect water quantity and quality, and therefore must be assessed to ensure the sustainability of the water supply and the preservation of water quality;

- Surface water is important for its recreational and subsistence value for fishing, boating and navigation, snowmobiling, bathing and other uses; and

- Surface water is important to society aesthetically for its visual place within the natural environment.

11.1.1 Approach to Assessment of Effects

Existing information, field data collected for the Project and technical studies conducted for the Project were used to develop this assessment, including results from the Surface Water Baseline Study (Stassinu Stantec 2014a), Determination of Mixing Zone Impacted by Blasting Residues (Stassinu Stantec 2014b), Hydrotechnical Assessment of the Iron Arm Causeway (Stassinu Stantec 2014c), Nitrogen Leaching Assessment for Joyce lake Iron Ore Project (Stassinu Stantec 2014d) Hydraulic Assessment of the Proposed Bridge at Gilling River (Stassinu Stantec 2014e), Stream Crossing Design (Stassinu Stantec 2014f), Sediment Pond Design Joyce Lake Direct Shipping Iron Ore Project (Stassinu Stantec 2014g), Lacustrine Ice Environment in the RSA (Stassinu Stantec 2013), Joyce Lake and area DSO Project Hydrogeological Study (WESA 2014) and Fish and Fish Habitat Baseline Study (WSP 2013).

11.2 Scope of the Assessment

11.2.1 Regulatory Setting

The CEAA's EIS guidelines for the Project specifically require an assessment of the environmental effects of the Project on water resources and the lacustrine environment.

The Newfoundland and Labrador *Environmental Control Water and Sewage Regulations*, 2003 (ECWSR) pursuant to the province's *Water Resources Act* sets maximum levels for several parameters including metals, organic compounds, hydrocarbons and other potential contaminants. An amendment was enacted in 2009 that states:

> *"Schedule C – A person primarily in the Metal Mining Industry shall comply with sections 3, 19.1 and 20 and Schedule 4 of the Metal Mining Effluent Regulations (Canada) SOR/2002-22, including any changes or amendments to those sections of and that schedule to those regulations over time."*

MDMER pursuant to the federal *Fisheries Act*, comes into force on the first day that a mine releases more than 50 m^3 in a single day. The MDMER sets maximum allowable limits for specific metals as sampled by a prescribed schedule. MDMER also sets Environmental Effects Monitoring (EEM) criteria including operational phase surface water monitoring criteria.

Though not a regulation, the *Certificate of Approval* (C of A) issued by NLDOECC sets concentration limits for specific parameters in the discharged effluent. A provincial C of A usually sets concentration limits that are the same as the MDMER, when they apply to a project as they do in this Project. The C of A is issued pursuant to the *Environmental Protection Act*. The certificate grants approval for the construction and operation of a mill complex and its associated works. The C of A provides terms and conditions for satisfying various requirements for the Acts, regulations and policies under which the Project falls, including:

- *Environment Protection Act;*
- *Water Resources Act;*
- *Environmental Control Water and Sewage Regulations, 2003;*
- *Halocarbon Regulations, 2005;*
- *Storage and Handling of Gasoline and Associated Products Regulations, 2003;*
- *Used Oil Control Regulations; and*
- *Accredited and Certified Laboratory Policy.*

Water use is regulated by NLDOECC through permitting requirements for activities within 15 m of a water body related to withdrawal of water, installation of intake structures, dams and culverts and discharge of wastewater. Water is enshrined in Part 1 of the NL *Water Resources Act* and licenses and applications are prioritized in the following manner: domestic, municipal, agricultural, commercial, institutional, and industrial, water and thermal power generation, and other purposes, prescribed by regulation. Other relevant surface water regulations relate to local watershed management units, regulations and provincial policy related to dam construction, operations, maintenance and surveillance.

The sustainability of water supply and preservation of water quality are critical to maintain and are protected in Newfoundland and Labrador public water supply regulation. In Newfoundland and Labrador, 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 within the mandate of NLDOECC (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, reduce the risk of accidental spill and leaks as well as contingency plans. 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 reduce adverse effects on water quality and proposed measures for site closure, restoration and rehabilitation.

11.2.2 Influence of Consultation and Engagement on the Assessment

Labec Century has engaged and consulted with a variety of stakeholders, Indigenous groups, and members of the public throughout the EA process, and is committed to being responsive to questions and concerns that arise. Details on the issues raised by stakeholders in relation to Water Resources are provided in Table 11.1.

Table 11.1 Issues Raised by Indigenous Groups and Stakeholders

Question / Issue	Community/ Organization	Summary of Comments	Response
Water Quality	Naskapi of Kawawachikamach	Will there be any red lakes?	Red water is a specific water quality effect associated with iron ore tailings effluent. This DSO Project will use dry crushing and screening and will not generate tailings, so no red water is expected.
Water quality	Naskapi of Kawawachikamach Elders and Band Council	Some of the elders who were at the meeting used to work for IOC and had concerns related to their history with that operation.	Water will be captured and cleaned before discharge to the environment
Water Quality	Naskapi of Kawawachikamach	Weather changes a lot in that area, how are they planning to secure the waste so that it will not leak into the lake, the soil, the groundwater, etc.?	Overburden, waste rock and low grade ore stock piles will be graded (sloped at 22º) to avoid issues with erosion and gullying. These stockpiles will also have perimeter ditches to collect runoff and groundwater seepage and direct it to sedimentation ponds before release to the environment..
Waste Water	Naskapi of Kawawachikamach	Can the plant be placed further than 200m from lake? It seems very close and will create dust. Water runoff will bring oil and waste into lake.	Dust suppression will be an ongoing maintenance activity to reduce impacts to soil and water quality. Also oil and fuel potentially collected in runoff will be trapped in sediment ponds. The 200m between the plant and Attikamagan Lake will be a buffer zone and is considered adequate to ensure there is no impact on the lake.

Table 11.1 Issues Raised by Indigenous Groups and Stakeholders

Question / Issue	Community/ Organization	Summary of Comments	Response
Dewatering/ Water Quality	Naskapi of Kawawachikamach	Will water being pumped out be of same quality as lake water?	Water drained from Joyce Lake will be naturally-occurring water, the same water that is currently in Joyce Lake, This water will not be used for any purpose but will simply be drained by pumping to Attikamagen Lake.
Dewatering	Naskapi of Kawawachikamach	How will you prevent flooding from occurring once the mine is closed?	To prevent flooding once the mine is closed Joyce Lake and the open pit will refill with water naturally from precipitation and ground water recharge. When water levels reach the current elevation of Joyce Lake today, water in the lake and open pit will spill out through the existing outlet system, mitigating potential flooding, as it is doing today. To prevent flooding on other areas of the Project site including the haul road and rail loop after closure, mine features will be removed/rehabilitated to eliminate potential barriers to water flow (e.g., culverts and bridges) and to maintain flooding conditions that currently exist.
Closure and Decommissioning	Naskapi of Kawawachikamach	What will happen with the mine once you are done mining the iron ore?	A detailed Closure and Reclamation Plan will be prepared for the Project, as required by the Newfoundland and Labrador Mining Act. The Plan will provide a final closure strategy for the open pit, waste piles, mine roads, and other mine facilities, and will incorporate progressive rehabilitation during all stages of the Project. to limit the work required after cessation of Operations and to limit the environmental effects during the Project life. A preliminary plan for the closure of the mine includes erosion control by revegetation wherever possible, stabilized slopes, and barricades around the open pit.
Effects on water and aquatic environment	Naskapi of Kawawachikamach	What are the impacts on water and on the environment?	Overburden, waste rock and low grade ore piles will be graded (sloped and stable) to avoid issues with erosion and gullying. The overburden, waste rock and low grade ore stockpiles will also have perimeter ditches to collect runoff and groundwater seepage and direct it to sedimentation ponds before release to the environment. The primary potential effects of the quarried rock for causeway construction on Iron Arm water will arise from some explosives residue on the surface of the blasted rock. The explosives residue may cause elevated ammonia or nitrogen concentration for a short and temporary period, however the concentrations are not expected to exceed the long term exposure limits of the Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life (PAL)

Table 11.1 Issues Raised by Indigenous Groups and Stakeholders

Question / Issue	Community/ Organization	Summary of Comments	Response
Rock Causeway on Iron Arm	Naskapi of Kawawachikamach	How will the year-round bridge and rock causeway affect the fish and the lake? (we fish in that area near those islands).	Stantec has assessed fish passage through the causeway bridges and their recommendations to reduce water velocities for resident species such as Northern Pike and Lake Trout to pass has been adopted and incorporated into the bridges and causeway designs by increasing the width of both bridges from 4m to 8m. The causeway bridge designs also allow for easy passage of fishers and others in small boats under both of the bridges..
Water Quality/ Fish and Fish Habitat	DFO	Would like to know plans for crossing structures. Project design should try to stay out of water to avoid issues with fish and fish habitat. Consider bottomless culverts or bridge with no in-water footprint. Flow data required for stream crossings as it is important for determining impacts on existing fish habitats at potential impact areas and any areas downstream that may rely on them. Potential impacts of pit drainage on Joyce Lake.	There are four bridge structures proposed at this point. Two along the access road and two in the causeway. All bridges and culverts are designed for fish passage which for culverts means culvert embedment as per DFO recommendations. Regional flow data will be gathered to size all culverts and bridge openings The Joyce Lake and open pit water management plan provides details regarding the recommended Joyce Lake dewatering strategy and the approach to draining non-contact water from the Joyce Lake watershed to the downstream receiving water system during operations.
Water quality/Fish and Fish Habitat	Kawawachikamach Band Council (Paul Mameanskum, George Guanish, Ken Lam, Léonard McKenzie)	Concern about potential Project effects of Iron Arm on water quality and fish populations	Mine contact water will be treated to regulatory effluent criteria in sediment ponds to meet CWQG-PAL

11.2.3 Temporal and Spatial Boundaries

The temporal boundaries for the environmental assessment include the Project phases of Construction, Operation and Maintenance, and Closure and Decommissioning. The temporal boundary for Construction is one year (pre-operation), for Operation and Maintenance is approximately seven years, and for Closure and Decommissioning is approximately one year.

The spatial boundaries for the environmental effects assessment on Water Resources are defined below.

Project Development Area (PDA): The PDA is the area represented by the physical Project footprint as defined in Chapter 2: Project Description. The PDA includes the area of physical disturbance for the Project, including the physical area planned for the open pit, waste rock, low grade ore, and overburden stockpile areas, processing plant area, magazine explosive area, main fuel depot and power plant, causeway access roads, rail yard and accommodation camp.

Local Study Area (LSA): The LSA is the spatial area within which local effects are assessed (*i.e.,* within close proximity to the action where direct effects are anticipated). The LSA includes the PDA and any adjacent area where Project-related environmental effects may reasonably be expected to occur, including downstream lakes and wetlands, and rail yard and access road (Figure 11.1).

Regional Study Area (RSA): The RSA is the spatial area within which cumulative effects are assessed (*i.e.,* extending a distance from the Project footprint in which both direct and indirect effects are anticipated to occur). The RSA encompasses several sub-watersheds of the Churchill River including Attikamagen Lake, Petitsikapau Lake, Astray Lake, and several unnamed lakes and rivers (Figure 11.1).

11.2.4 Selection of Environmental Effects and Measurable Parameters

This section focuses on selection of potential environmental effects and measurable parameters associated with Water Resources. The amount of water moving on the land as surface runoff or temporarily stored in waterbodies depends on the net amount of precipitation, *i.e.,* snowfall and rainfall, evaporation into the atmosphere, transpiration by plants and infiltration into the ground. Water runoff is an important contributor to water flow in streams. Surface runoff can also carry sediment generated by erosion of the land surfaces into streams. The interaction between water flow in streams, defined in terms of water depth and velocity, and sediment determines the physical characteristics or morphology of the stream.

Construction, Operation and Maintenance, and closure and decommissioning of the various Project components can disrupt the natural balance between water flow and sediment concentration in waterbodies. Project activities that could cause these disruptions include land disturbance, disturbance to stream beds and banks, flow obstruction, and water withdrawals and disposals. These activities can affect natural drainage patterns, runoff amount, stream flow depth and velocity, and sediment supply.

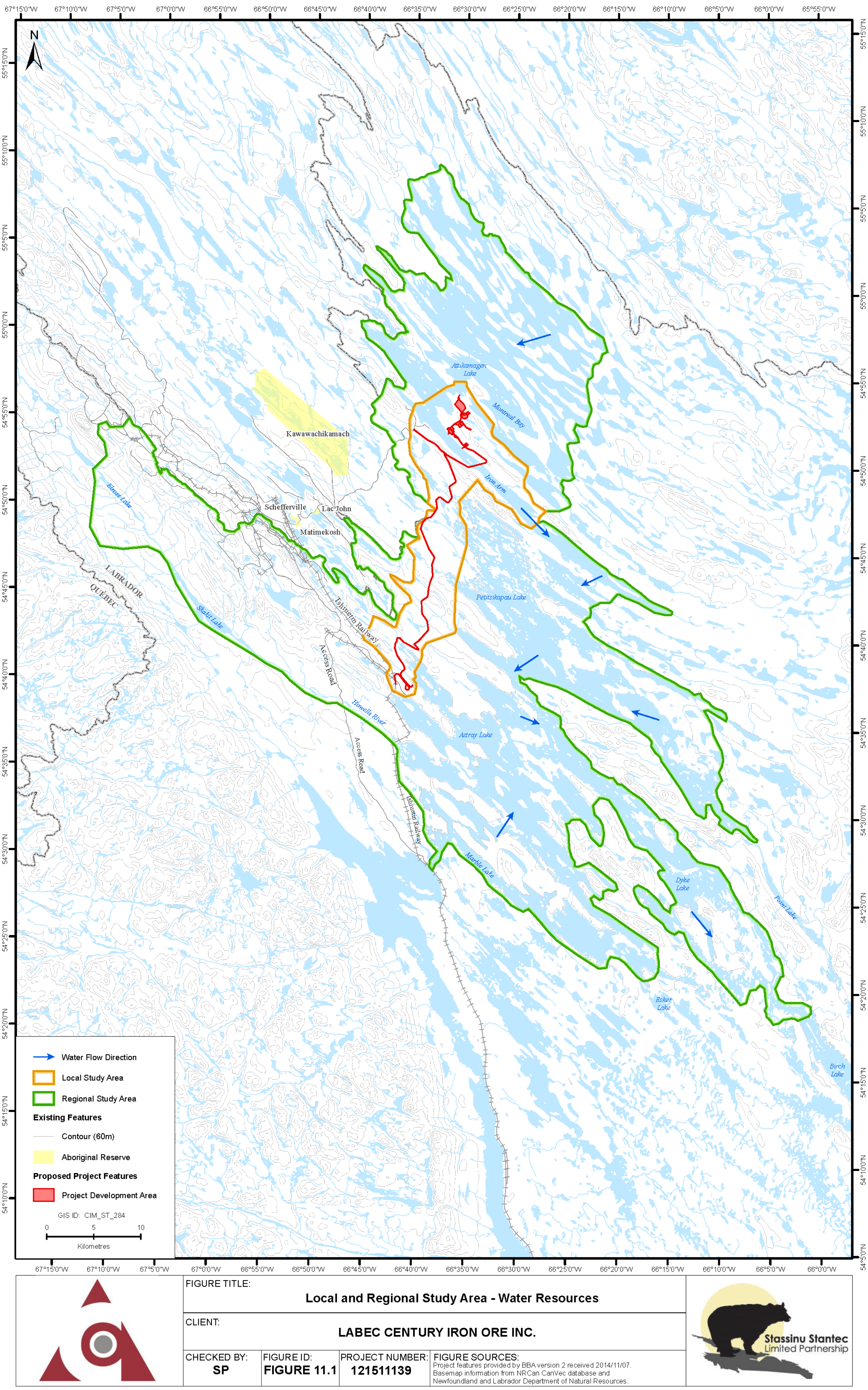

Figure 11.1 Local and Regional Study Area

Construction, operation and maintenance, and Closure and Decommissioning of the various Project components might alter water quality in waterbodies. Project activities that might cause these effects include:

- Construction of causeway;
- Mine water releases;
- Wastewater releases;
- Use of explosive material in open pit mining,
- Land disturbance; and
- Leaks and spills.

Therefore, the environmental assessment for Water Resources is focused on the following environmental effects:

- Change in surface water quantity;
- Change in surface water quality; and
- Change in surface water drainage patterns.

The environmental effects and associated measurable parameters, with rationale, are summarized in Table 11.2.

Table 11.2 Measurable Parameters for Water Resources

Environmental Effect	Measurable Parameter	Rationale for Selection of the Measurable Parameter
Change in Surface Water Quantity	Surface water levels of and flows in water bodies	Project interactions with, and uses of, surface water have the potential to alter runoff characteristics and thereby affect local streamflows and lake levels. This in turn may affect aquatic habitat quality
Change in Surface Water Quality	Total suspended solids (TSS), pH, ammonia, and metals concentrations of receiving water bodies.	The Project has the potential to affect receiving water quality through discharge of effluent high in TSS, ammonia, metals and low in pH
Change in Surface Water Drainage Patterns	Watercourse alteration/realignment	Project facilities and infrastructure will interfere with the existing upstream watershed area and alignment of some watercourses, potentially affecting streamflows and drainage patterns.

11.3 Standards or Thresholds for Determining the Significance of Residual Environmental Effects

Terms that will be used to characterize residual environmental effects for Water Resources are in accordance with guidance provided by IAAC.

- Direction:
  - Adverse: condition of surface water is declining in comparison to baseline condition and trends;
  - Positive: condition of surface water is improving in comparison to baseline condition and trends; or
  - Neutral: no change in the condition of surface water compared to baseline conditions and trends.
- Magnitude:
  - Negligible: no measurable adverse effect anticipated;
  - Low: effect occurs that is detectable, but is within normal variability of baseline conditions;
  - Moderate: effect occurs that would cause an increase (or decrease) with regard to baseline, but is within regulatory limits and objectives; or
  - High: effect occurs that would singly or as a substantial contribution in combination with other sources cause exceedances of objectives or standards.
- Geographic Extent:
  - Site-specific: effect is restricted to the PDA;
  - Local: effect restricted to the LSA; or
  - Regional: effect restricted to the RSA.
- Frequency:
  - Occasionally: effect occurs once per month or less;
  - Sporadic: effect occurs sporadically at irregular intervals;
  - Regularly: effect occurs on a regular basis and at regular intervals; or
  - Continuous: effect occurs continuously throughout the Project life.

- Duration:
  - Short term - Effect does not extend beyond one year;
  - Medium term - Effect does not extend beyond seven years;
  - Long term - Effects are measurable and extend beyond seven years;
  - Permanent - Effects persistent and measurable parameter unlikely to recover to baseline conditions.
- Reversibility:
  - Reversible - Will likely recover to baseline conditions after the end of Project decommissioning;
  - Irreversible - Unlikely to recover to baseline conditions after the end of Project decommissioning (i.e., Permanent).
- Ecological/Socio-economic Context:
  - Undisturbed: effect takes place within an area that is relatively or not adversely affected by human activity; or
  - Disturbed: effect takes place within an area with human activity. Area has been substantially previously disturbed by human development or human development is still present.
- Prediction Confidence:
  - Low: Insufficient data or information to reliably predict effect;
  - Moderate: Sufficient site-specific information or experience in similar surface water to predict possible effect; or
  - High: Sufficient site-specific information or experience in similar surface water to reliably determine an effect.

A significant adverse residual environmental effect on Water Resources is defined as a Project-related environmental effect that results in:

- Changes in surface water quantity, such that maintenance flow in a fish-bearing watercourse is not sustained, fish are no longer able to pass in a flowing water body, the sustainability of public water supplies are affected, changes in watercourse flow increases the erosion and sedimentation potential of a receiving water body or changes to wetland, pond and lake levels affects their ability to continue to support all the existing condition life phases of fish;

- Changes in surface water quality such that its potability is affected as defined by the Guidelines for Canadian Drinking Water Quality (Health Canada, 2020), effluent quality exceeds MDMER criteria, effluent mixing zones exceed acute toxicity criteria, the boundary of effluent mixing zones exceed chronic toxicity criteria or exceeds baseline or Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) for the Protection of Aquatic Life (PAL), the assimilative capacity of effluent receiving waters is exceeded; or

- Sediment quality is degraded below baseline quality or the CCME Canadian Sediment Quality Guidelines (CSQG), such that aquatic life is significantly affected.

11.4 Potential Project-VC Interactions

Alterations to the land surface resulting from Project facilities (*e.g.,* open pit) and activities affecting surface water (*e.g.,* water withdrawal, treated effluent discharge and dewatering) will be the primary drivers of effects to Surface Water. The effects assessment will include an analysis of effects on local receiving water bodies and watersheds. Surface water effects relate to potential changes in receiving water hydrology, water quality and sediment quality. Changes to flow and water quality relate to changes to the drainage, infiltration and groundwater discharge characteristics, as well as Project water withdrawal and uses and how treated effluent is returned to receiving waters. Water quality effects relate to erosion and sedimentation potential and effluent quality and how effluent mixes and effects receiving waters.

In Table 11.3 below, each Project activity and physical work for the Project is listed, and each interaction rated as 0, 1, or 2 based on the level of interaction associated with each activity or physical work.

Table 11.3 Potential Project Environmental Effects to Water Resources

Project Activities and Physical Works	Potential Environmental Effects		
	Change in Surface Water Quantity	Change in Surface Water Quality	Change in Surface Water Drainage Patterns
Construction			
Site Preparation (including clearing, grubbing, excavation, material haulage, grading, removal of overburden, ditching, and stockpiling)	2	2	2
Construction of Roads	2	2	2
Construction of Causeway	2	2	2
Construction of Site Buildings and Associated Infrastructure	2	2	2
Construction of Rail loop and Associated Infrastructure	2	2	2
Construction of Stream Crossings	1	1	1
Installation of Water Supply Infrastructure (wells, pumps, pipes)	1	1	1
Onsite Vehicle / Equipment Operation	1	1	1
Waste Management	0	1	0
Transportation of Personnel and Goods to Site	0	1	0

Table 11.3 Potential Project Environmental Effects to Water Resources

Project Activities and Physical Works	Potential Environmental Effects		
	Change in Surface Water Quantity	**Change in Surface Water Quality**	**Change in Surface Water Drainage Patterns**
Expenditures	0	0	0
Employment	0	0	0
Operation and Maintenance			
Maintenance of Causeway	2	2	0
Open Pit Mining (including drilling, blasting, ore and waste haulage, stockpiling, dewatering)	2	2	2
Dewatering Joyce Lake	2	2	2
Ore Processing (including crushing, conveying, storage, grinding, screening)	2	2	2
Waste Rock Disposal on Surface	2	2	2
Water Treatment (including mine water and surface runoff) and Discharge	2	2	2
Rail Load-Out and Transport	1	1	0
Onsite Vehicle / Equipment Operation and Maintenance	1	1	0
Waste Management	1	1	0
Transportation of Personnel and Goods to Site	0	1	0
Fuel Transport	0	1	0
Fuel Storage and Dispensing	0	0	0
Progressive Rehabilitation	1	1	1
Expenditures	0	0	0
Employment	0	0	0
Closure and Decommissioning			
Site Decommissioning	2	2	2
Site Reclamation (building demolition, grading, scarifying)	2	2	2
Accidents and Malfunctions			
Hydrocarbon Spill	0	2	0
Train Derailment	0	2	2
Forest Fire	2	2	2
Sedimentation / Settling Pond Overflow	2	2	2
Premature / Permanent Shutdown	0	0	0

Key:
0 No interaction (i.e., no potential for activity to result in the effect).
1 Interaction may occur; however, based on past experience and professional judgment, the resulting effect is well understood and can be managed to negligible or acceptable levels through standard operating procedures or through the application of management or codified practices. No further assessment is warranted.
2 interaction may occur and the resulting effect may exceed negligible or acceptable levels without implementation of project-specific mitigation. Further assessment is warranted.

The rating takes a precautionary approach, whereby interactions with a meaningful degree of uncertainty have been rated as 2, ensuring that a detailed environmental effects assessment is conducted.

11.4.1 Interactions Rated as 0

During Construction, waste management and transportation of personnel and goods to site are not predicted to have any interaction with surface water quantity or surface water drainage patterns as these two activities will not require any ground disturbance or use of surface water. Expenditures and employment will also not have any interaction with surface water during either Construction or Operation and Maintenance.

During Operations and Maintenance, maintenance of the causeway, rail load-out, onsite vehicle and equipment operation, and waste management will not affect drainage patterns or require watercourse alterations. Transportation of personnel and goods to site, fuel storage and dispensing will also not interact with surface water quantity or drainage patterns.

Hydrocarbon spill and train derailment will not affect surface water quantity. Hydrocarbon spill will also not affect drainage patterns, as the main concern is surface water quality, which is rated as a 2 and fully assessed.

With respect to premature of permanent shutdown, it is currently planned that the mine will be operational for seven years, at which time decommissioning and rehabilitation will commence. However, should market conditions change or other factors arise that result in the premature shutdown of the mine, regulatory requirements include provision for financial assurance from Labec Century. Rehabilitative measures may be implemented by the NL Minister of Industry, Energy and Technology, in which case costs incurred by the Crown in implementing these measures may be recovered by drawing on the financial assurance provided by the proponent. Any required cost expenditures over and above the financial assurance provided would be considered debt by Labec Century to the Crown. As rehabilitation would occur regardless of the timing of the shutdown, premature or permanent shutdown will not have any additional or different interactions with water resources other than those currently assessed under Closure and Decommissioning.

11.4.2 Interactions Rated as 1

During Construction, construction of stream crossings, installation of water supply infrastructure, on-site vehicle and equipment operation, may interact with surface water quantity, quality and surface water drainage patterns. Waste management and the transportation of personnel and goods may also interact with surface water quality. These environmental effects will be mitigated through the establishment of riparian set back limits within the PDA, adherence to Best Management Practices (BMPs), such as clearing only the required right-of-way, limiting the use of machinery within 3 m of the watercourse, restricting use of heavy machinery and vehicles to designated areas and progressive rehabilitation of riparian areas. The progressive rehabilitation program will be implemented to rehabilitate disturbed riparian areas with native grasses and shrubs. Potential alterations of water and sediment quality will be mitigated through erosion and sediment control measures, spill prevention and cleanup procedures, a dust suppression program, adherence to riparian set back limits, progressive reclamation of disturbed surfaces, a site waste management plan, ongoing monitoring of erosion control measures, and adherence to Project-specific protection plans.

During Operations and Maintenance, rail load-out, rail transport, vehicle and equipment operation and maintenance, waste management and progressive rehabilitation may interact with surface water quality through change in ground surface runoff characteristics, water balance and runoff/effluent quality. A number of access roads, haulage roads and a rail track loop will be constructed for the Project and will require approximately 15 water crossings. During periods when dust suppression on access roads is required, up to 100 m^3/d of water may be applied. Due to the relatively narrow and linear nature of the access road and rail track their effect on the drainage characteristics of their footprints will be distributed over their lengths. Therefore, changes to surface water quantity are considered to be negligible. Any potential changes in surface water quality from sedimentation can be managed with standard mitigation measures in place.

The access roads and rail tracks will require side ditches and culverts to convey cross-drainage. Intermittent and perennial watercourse crossings will require large steel pipe or arch-type culverts. The 100 year return period flow will be used to size culvert conveyance capacity without access roads and rail track inundation. Rail track drainage works will be designed in accordance with the AREMA guidelines. Specific additional measures are recommended to mitigate erosion and sedimentation and water quality effects.

Stormwater runoff from aggregate surfaced roads can contain high total suspended solids (TSS) concentrations, especially under high melting and intense rainfall conditions. Further, TSS loading may result from road surface dust suppression watering. Water will be used for dust suppression during summer and sand used to increase tire traction of access roads during cold season. All access roads and rail infrastructure will incorporate roadside and railside ditches and stormwater ponds.

The transport of diesel fuel and lubricants via rail, as well as access vehicle traffic, increase the potential for hydrocarbon release to the environment. Road and rail design, traffic management and runoff controls will therefore require spill containment, collection and management controls to mitigate potential hydrocarbon release. The effects of a hydrocarbon spill are fully assessed under Accidents and Malfunctions.

The potential effects of the activities rated 1 are well understood and can be addressed through the standard mitigation measures described above and will not result in any significant residual effects. No further assessment is required.

11.4.3 Interactions Rated as 2

Site preparation, construction of roads, causeway, site buildings and associated infrastructure, and rail loop and associated infrastructure have the potential to affect surface water including increased runoff from disturbed areas, increased TSS from disturbed areas, change in water and sediment quality, change in drainage patterns and increased erosion, scour and sediment in water courses. Therefore, the environmental effects of these activities require further assessment and are addressed in Section 11.6.1.

During Operation and Maintenance, maintenance of causeway, open pit mining, dewatering of Joyce Lake, ore processing, waste rock disposal and water treatment and discharge have the potential to affect surface water. Open pit mine and Joyce Lake dewatering may affect surface water quantity. Surface disturbance and use of explosives in open pit mining may affect water quality. Runoff from waste rock, low grade ore and overburden stockpiles area may affect water quality of receiving waterbodies. Therefore, the environmental effects of these activities require further assessment and are addressed in Section 11.6.2.

During Closure and Decommissioning, site decommissioning and site reclamation have the potential to affect surface water quantity, quality and drainage patterns. Therefore, the environmental effects of these activities require further assessment and are addressed in Section 11.6.3.

Hydrocarbon spill may affect the surface water quality of receiving streams. Train derailment and associated fuel spills may affect surface water quality and drainage patterns if watercourses are blocked by a derailment or if surface drainage must be blocked or re-routed to support remediation and mitigate downstream effects. Forest fires may also affect surface water quantity, quality and drainage patterns by the change they produce in vegetation cover and soil stabilization; however deployment of a fire containment and management plan, as well as burn reforestation can largely mitigate effects. Sediment pond overflow/ breach would affect water quality and drainage patterns via the altering of downstream drainage route in an overflow/breach. Therefore, the environmental effects of these activities require further assessment and are addressed in Section 11.8.

11.5 Existing Environment

11.5.1 Information Sources

The sources of information used to describe existing surface water conditions in the LSA and RSA include:

- field surveys/data collected by Stantec (Stantec 2014a) and WSP (WSP 2013) in support of the Project;
- Environment and Climate Change Canada climate data;
- Environment and Climate Change Canada hydrometric data; and
- Other supporting government and scientific information.

While traditional knowledge pertaining specifically to Water Resources was not identified, the traditional knowledge results identified in Chapter 3: Engagement and Traditional Knowledge have been considered and integrated throughout the assessment. Traditional knowledge related to fish and fish habitat is provided in Chapter 15: Fish and Fish Habitat.

11.5.2 Methodology for Characterization of Baseline Conditions

11.5.2.1 Data Collection

The field monitoring program included the installation of eight (8) hydrometric monitoring stations in the LSA to monitor water levels continuously and to estimate flow rates at stream hydrometric monitoring locations (these stations were also used as sampling locations for the water quality monitoring program). Hydrometric monitoring stations were installed in August 2012. The details of hydrometric monitoring stations are provided in Table 11.4 and the monitoring locations are shown in Figure 11.2.

Table 11.4 Monitoring Station Details

Station ID	Location*	Function	Instrumentation
S1	6059334.9 N, 651828.9 E	Monitor baseline water quality and flow data in the Gilling River near the proposed road crossing and water quality and flow data during construction and operation of the road.	Levelogger and barologger were installed on August 24, 2012 in a stilling well for water level and atmospheric pressure monitoring with a 10-minutre recording interval. The stilling well was installed near the south bank.
S2	6076159.9 N, 656166.9 E	Monitor baseline water quality and flow data for an unnamed creek (drains to Petitsikapau Lake) near the proposed road crossing and water quality and flow data during construction and operation of the road.	A levelogger was installed on August 24, 2012 in a stilling well for water level monitoring with a 10-minute recording interval. The stilling well was installed on the north bank.
S3	6079417.5 N, 656365.3 E	Monitor baseline water quality and flow data for an unnamed creek (drains to Petitsikapau Lake) and water quality and flow data during the construction, operation and decommissioning of the processing plant which is located in this watershed.	A levelogger was installed on August 24, 2012 in a stilling well for water level monitoring with a 10-minutre recording interval. The stilling well was installed on the east bank.
S4	6084123.3 N, 660544.7 E	Monitor baseline water quality and flow data in the channel outleting Joyce Lake and water quality and flow data during the construction, operation and rehabilitation of the mine pit.	Levelogger and barologger were installed on August 23, 2012 in a stilling well for water level and atmospheric pressure monitoring with a 10-minute recording interval. The stilling well was installed on the north bank.
L1	6077322.2 N, 658147.2 E	Monitor baseline water quality and water levels in Petitsikapau Lake and water quality and level data during the construction, operation and decommissioning of the processing plant.	A levelogger was installed on August 23, 2012 in a stilling well for water level monitoring with a 10-minute recording interval.
L2	6082196.0 N, 659177.5 E	Monitor baseline water quality and water levels in Unnamed Lake F and water quality and level data during construction, operation and rehabilitation of low grade ore stock pile and crusher. Lake F is drains to Iron Arm via a small channel and is a potential receiving water body for runoff from the proposed low grade ore stockpile and crusher.	A levelogger was installed on August 24, 2012 in a stilling well in the lake for water level monitoring with a 10-minute recording interval.

Table 11.4 Monitoring Station Details

Station ID	Location*	Function	Instrumentation
L3	6086062.9 N, 658970.9 E	Monitor baseline water quality and water levels in Joyce Lake and water quality and water levels during the construction, operation and rehabilitation of the mine pit.	A levelogger was installed on August 23, 2012 in a stilling well for water level monitoring with a 10-minute recording interval.
L4	6088835.4 N, 656837.4 E	Monitor baseline water quality and water levels in Attikamagen Lake and water quality and water levels during the construction, operation and rehabilitation of waste rock and overburden stockpiles.	A levelogger was installed on August 23, 2012 in a stilling well for water level monitoring with a 10-minute recording interval.
Notes: * NAD83			

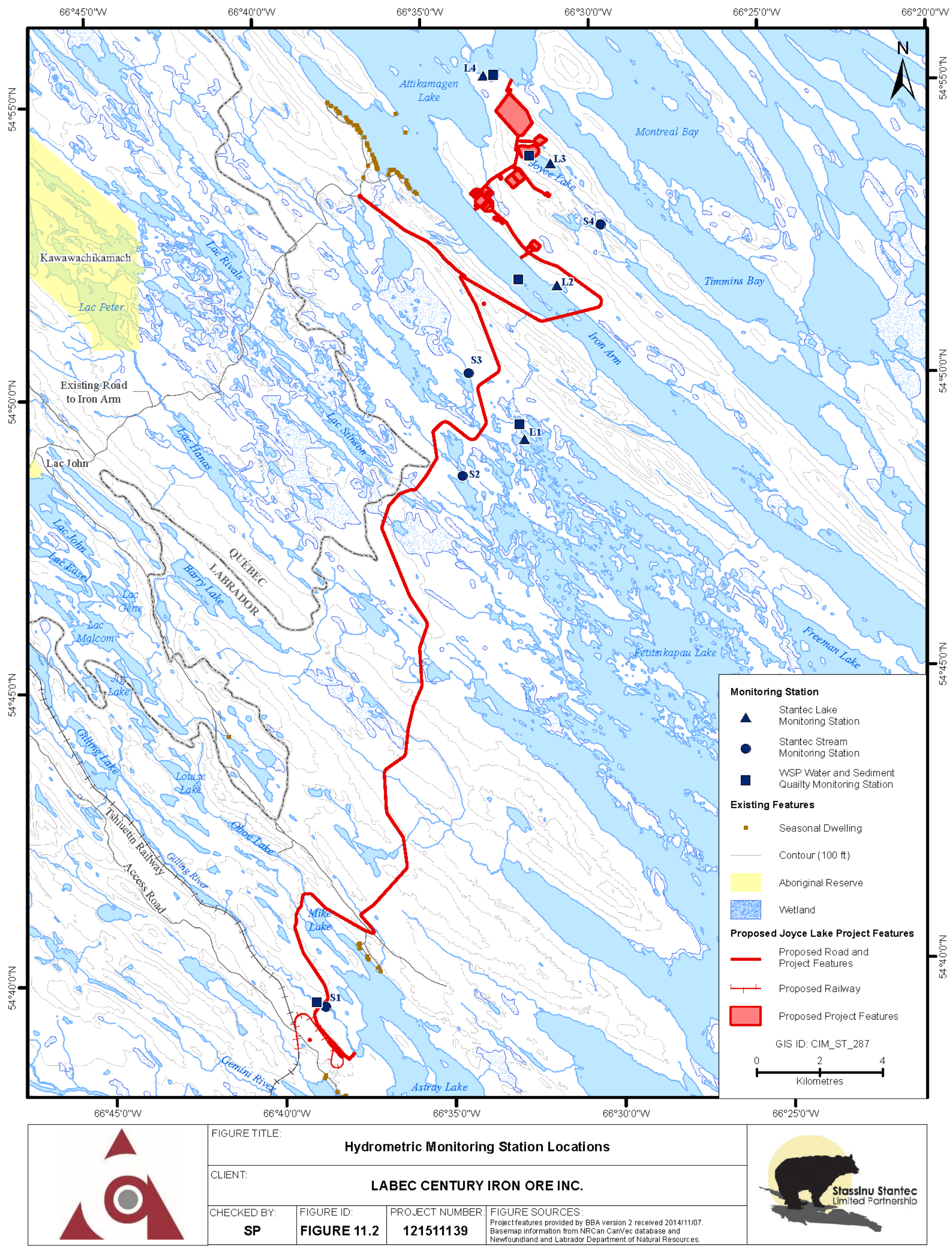

Figure 11.2 Hydrometric Monitoring Station Locations

Lake Level Monitoring

Lake level monitoring was accomplished through the installation of Solinst Leveloggers™ in stilling wells at four lakes: Petitsikapau Lake (L1), Lake F (L2), Joyce Lake (L3) and Attikamagen Lake (L4), as shown in Figure 11.2. These Leveloggers were installed on an arbitrary datum and at a depth that was anticipated to cover the entire range of lake elevation fluctuation during all climatic conditions including high precipitation events. Levelogger data were downloaded seasonally at all stations. Monitored lake level data were used to assess water level fluctuation, hydraulic connection to potentially connected waterbodies, lake volume fluctuations, and ice effects.

Lake Level Monitoring

Lake level monitoring was accomplished through the installation of Solinst Leveloggers™ in stilling wells at four lakes: Petitsikapau Lake (L1), Lake F (L2), Joyce Lake (L3) and Attikamagen Lake (L4), as shown in Figure 11.2. These Leveloggers were installed on an arbitrary datum and at a depth that was anticipated to cover the entire range of lake elevation fluctuation during all climatic conditions including high precipitation events. Levelogger data were downloaded seasonally at all stations. Monitored lake level data were used to assess water level fluctuation, hydraulic connection to potentially connected waterbodies, lake volume fluctuations, and ice effects.

Stream Level Monitoring

Leveloggers were installed in stilling wells in watercourses at locations S1, S2, S3, and S4 as shown in Figure 11.2 and details are provided in Table 11.4. A typical Levelogger installation in a watercourse is depicted in Figure 11.3. Photo 11.1 shows monitoring station installation at Station S2.

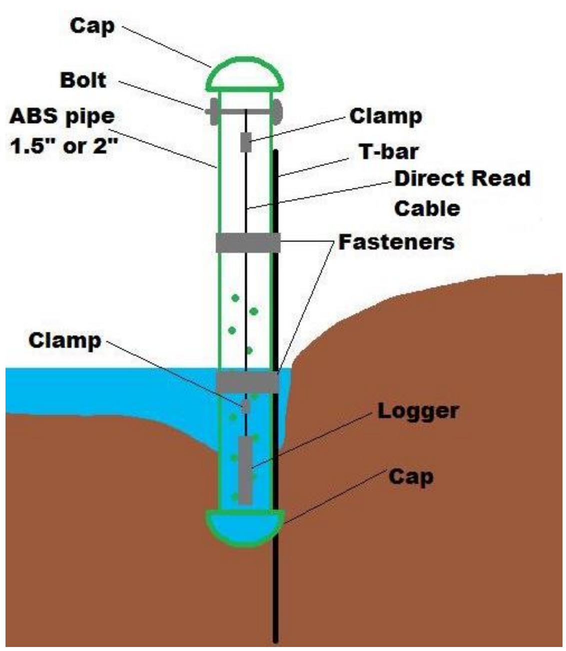

Figure 11.3 Typical Stilling Well Installation

Photo 11.1 Monitoring Station Installation at Station S2

Leveloggers were downloaded in fall, 2012 and again in fall, 2013. Barologgers were also deployed to collect barometric pressure at two hydrometric monitoring locations (S1 and S4). Monitored atmospheric pressure and ambient temperature were used to barometrically compensate Levelogger water level data. Levelogger data were also offset to compensate for differences between its installed depth and the channel thalweg to subsequently enable conversion of level data to flow using rating curves.

Stream Flow Data

Manual water level and velocity measurements were collected seasonally at the four stream hydrometric monitoring stations (S1, S2, S3, and S4) when water / ice conditions permitted. Velocity measurements were collected using a portable Marsh-McBirney Flo-Mate™ flow meter 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 (minimum of 10) and the velocity was measured at the depth that corresponds to 60% of the total depth. The measured velocity at each section and corresponding water depths were used to estimate the total stream flow using the Mid-Section Method recommended and used by the Water Survey of Canada. Flow data were used to develop a rating curve for each stream hydrometric monitoring station. Rating curves for each stream hydrometric station were developed using Manning's equation along with two measured flow data. The channel slope and manning's n were selected based on field observation. The rating curves are expected to remain valid as long as channel properties such as cross-sectional shape and manning's n, remain the same. Flow hydrographs for each stream monitoring locations were developed based on monitored water level data and rating curves.

Water and Sediment Quality

Stantec collected water quality samples at eight hydrometric monitoring locations (Figure 11.2) during the site visits in August 2012, October 2012 and July 2013. Additionally, water and sediment quality samples were collected at five locations (Figure 11.2) in August 2012 by WSP. Water and sediment quality parameters at these locations were expected to provide a sufficient amount of information for the purposes of this Project.

At the time of water quality sample collection, in situ water quality measurements were taken with a multi-parameter sonde such as YSI or Hydrolab sondes at each hydrometric monitoring station. These in-situ water quality measurements consist of temperature, pH, electrical conductivity, dissolved oxygen (DO) and total dissolved solids. These were collected due to laboratory requirements for field in-situ parameter records and also for determination of derived water quality parameters requiring field constituent concentrations.

Water quality sample collection was performed according to approved methods for grab sampling, including sample vial labeling, sample storage in coolers to avoid thermal sample integrity breaches and completion of Chain of Custody sample submission documentation. Sampling was conducted in accordance with and referenced to the CWQG-PAL.

Sediment sampling was undertaken at five locations (Figure 11.2) in August, 2012 by WSP in accordance with and referenced against the CSQG for the Protection of Aquatic Life (pPAL).

Bathymetry Survey

In addition to hydrometric monitoring, water quality and sediment quality sampling, bathymetric and LiDAR (Light Detection and Ranging) topography surveys were conducted at areas where Project features are located or may have impacts from the Project. Figure 11.4 shows the extent of bathymetry and LiDAR topography survey coverage.

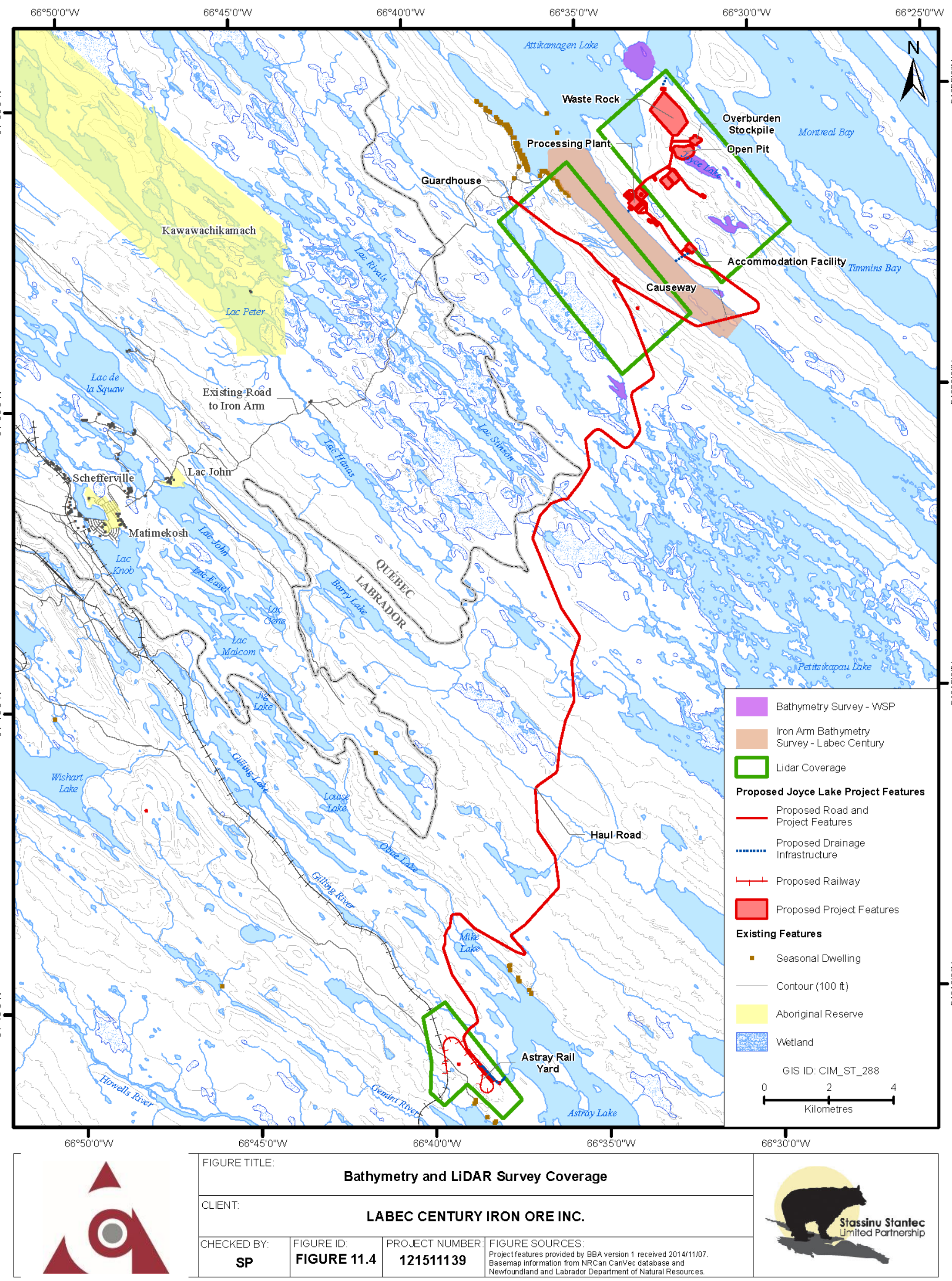

Figure 11.4 Bathymetry and LiDAR Survey Coverage

11.5.2.2 Data Analysis

The surface water baseline study is intended to characterize the climate, hydrology and water quality baseline conditions in watersheds potentially affected by the proposed development of the Project. Figure 11.1 shows the PDA, LSA, RSA and local features. The surface water study was designed to gain a better understanding of potential surface water impacts arising from the Project, sources of water for mine operations and the assimilative capacity of the various waterbodies under study to receive mine effluent. This surface water baseline study included the completion of:

- a climate assessment;
- a regional hydrological assessment;
- a local hydrological assessment;
- a water balance assessment;
- a water supply assessment;
- a regional water quality assessment;
- a local water quality assessment;
- a regional sediment quality assessment;
- a local sediment quality assessment; and
- a local receiving water assimilative capacity assessment.

The methodology used for each of the aforementioned components is discussed in detail throughout this section.

Climate and Climate Change

Climatic factors are important for defining the hydrologic conditions in the LSA and RSA because precipitation and temperature significantly affect basin runoff characteristics and streamflows. A number of regional climate monitoring stations in and around the RSA are listed in Table 11.5. Of these stations, only the Schefferville Airport and Wabush Airport station provides comprehensive year-round monitoring with a period of record that is sufficient for characterizing long-term climate conditions in the RSA and LSA. The Schefferville Airport station data will be used to characterize the climate conditions at the Project site as it is closest to the Project site.

Table 11.5 Environment and Climate Change Canada Climate Stations

Name	Station ID	Location		Elevation (m)	Period
Indian House Lake, QC	7113280	56º14’00”N	64º44’00”W	310.9	1944-1964
Border Airport, QC	7110830	55º20’00”N	63º13’00”W	464.8	1965-1979
Border (AUT), QC	7110831	56º14’00”N	64º44’00”W	464.8	1993-1998
Schefferville, QC	7117821	54º48’00”N	66º48’00”W	518.2	1992-1993
Schefferville, QC	7117823	54º48’19”N	66º48’19”W	520.9	2012
Schefferville Airport, QC	7117825	54º48’00”N	66º49’00”W	521.8	1948-2010
Schefferville Airport, QC	7117827	54º48’00”N	66º48’00”W	521.0	2005-2012
Nitchequon, QC	7095480	53º12’00”N	70º54’00”W	536.1	1953-2012
Menihek Rapids, NL	8501548	54º28’00”N	66º37’00”W	489.2	1952-1961
Esker 2, NL	8501548	53º52’00”N	66º25’00”W	487.7	1972-1978
Sandgirt, NL	8503630	53º50’00”N	65º30’00”W	452.6	1939-1948
Twin Falls, NL	8504050	53º30’00”N	64º31’00”W	483.1	1960-1967
Twin Falls, NL	8504060	53º38’00”N	64º29’00”W	456.9	1967-1968
Churchill Falls, NL	850A131	53º32’00”N	63º58’00”W	488.5	1993-1998
Churchill Falls Airport, NL	8501132	53º33’00”N	64º06’00”W	439.5	1969-1993
Churchill Falls, NL	8501130	53º33’28”N	64º05’38”W	439.5	2006-2007
Churchill Falls, NL	8501131	53º33’43”N	64º06’23”W	439.5	2011-2012
Wabush Airport, NL	8504175	52º55’38”N	66º52’27”W	551.0	1961-2012

Schefferville Airport climate data were analyzed using standard statistical methods to characterize climate conditions using long-term averages, climate normals, extremes and probability of occurrence of extreme events. Wet year and dry year climatic conditions were also selected based on period of 1948 to 2012.

Precipitation data for 24-hour storm events were derived from the available intensity-duration-frequency (IDF) curves at Schefferville Airport station (Climate ID: 7117825) for 2 to 100 year return periods. Precipitation for return periods higher than 100 year was determined by extrapolating the 2 to 100 year storm events precipitation. Since there are limited sources of probable maximum precipitation (PMP) determination in Labrador, a common practice of using the return period of the 10,000-year storm event is applied in determining the PMP precipitation (Ponce 1989).

Daily lake evaporation was obtained from the Churchill Falls A station (climate ID: 8501132) and Nitchequon station (Climate ID: 7095480) data. The Churchill Falls A station has daily data from 1972 to 1992 and Nitchequan A station has daily data from 1966 to 1985. Monthly and annual evaporation rates were estimated from available daily data. A frequency analysis was carried out based on available evaporation data to determine the evaporation rate for various wet and dry year return periods.

The potential effects of climate change on the Project can be assessed with respect to temperature and precipitation change effects on surface water. The climate change assessment was conducted through a review of Labrador climate change literature.

Hydrology

The hydrology baseline study was conducted through the application of hydrologic principles and methods. Available streamflow data were analyzed using standard statistical methods to characterize baseline conditions using long-term averages, extremes and probability of occurrence of extreme events. Flood frequency analysis was conducted using the annual maximum series of flows to estimate the flood flows for various return periods (2, 5, 10, 20, 50 and 100 years) for selected hydrometric stations. Low flow frequency analysis also was conducted using low flow indices (7 day average and 30 day average) for various return periods. The SSP software package developed by the US Army Corps of Engineers was used to predict the peak flow and low flow frequencies. Regional equations were developed for annual flows, monthly flows, low flows and flood flows to extend the recorded flow data to smaller watersheds. Flow duration curves (FDCs) for wet and dry years were developed as described by Vogel and Fennessey (1994).

There are limited streamflow monitoring stations available in Labrador and northern Quebec and no streamflow monitoring stations are within the LSA and RSA to characterize hydrologic conditions. Therefore, streamflow monitoring stations operated by Environment and Climate Change Canada in Labrador and Quebec were selected to characterize the hydrologic conditions in LSA and RSA. Some of these stations have short-term or discontinuous records and are therefore of limited value in defining regional hydrologic characteristics. The recommended minimum stream flow record length to estimate the flood flows for various return periods comes from United States Geological Survey (USGS) practice and are listed in Table 11.6. However, more years of data will increase confidence in the estimated flows. There are also streamflow monitoring stations which have very large drainage basins and therefore have limited representativity for basins within the RSA.

Table 11.6 Recommended Minimum Stream Flow Record Lengths (Dalrymple and Benson 1960)

Return Period (Years)	Minimum Record Length (Years)
10-Year	8
25-Year	10
50-Year	15
100-Year	20

The selected Water Survey Canada Hydrometric Stations in the proximity of the RSA are listed in Table 11.7 and shown in Figure 11.5 and were used to define the hydrologic characteristics in the RSA. The selected streamflow monitoring stations in Labrador are located in the same interior Labrador climate zone as the Project site (refer to section 11.5.3.1 for further details). Two streamflow monitoring stations were selected in Quebec and their watersheds located adjacent to the RSA.

Table 11.7 Environment and Climate Change Canada Hydrometric Stations

Station ID	Name	Province	Location		Period of Record			Drainage Area (km²)
			Lat	Long	Year From	Year To	Years of Record	
03LD004	Swampy Bay Riviere	QC	56.64	-68.56	1972	1993	21	8,990
03MB001	False Riviere	QC	57.67	-68.27	1972	1993	18	2,140
03MC001	Tunulic Riviere Pres de L'embouchure	QC	57.91	-66.37	1972	1993	20	3,680
03NF001	Ugjoktok River Below Harp Lake	NL	55.23	-61.30	1978	2012	31	7,570
03NG001	Kanairiktok River Below Snegamook Lake	NL	54.62	-60.98	1977	1996	17	8,930
03PB002	Naskaupi River Below Naskaupi Lake	NL	54.13	-61.43	1977	2012	29	4,480
03OE010	Big Pond Brook Below Big Pond	NL	53.63	-60.38	1994	2010	17	71.4
03NE001	Reid Brook at Outlet of Reid Pond	NL	56.43	-62.26	1995	2010	12	75.7
03NE002	Camp Pond Brook Below Camp Pond	NL	56.41	-62.20	1995	2010	12	24.3
02XA004	Riviere Joir Near Provincial Border	NL	52.29	-60.14	1980	1996	15	2,060
03OD007	East Metchin River	NL	53.45	-63.24	1998	2008	13	1,750
03PB001	Naskupi River at Fermont Lake	NL	54.26	-63.30	1995	1970	16	8,990
03QC002	Alexis River Near Port Hope Simpson	NL	52.79	-56.91	1978	2008	34	2,310

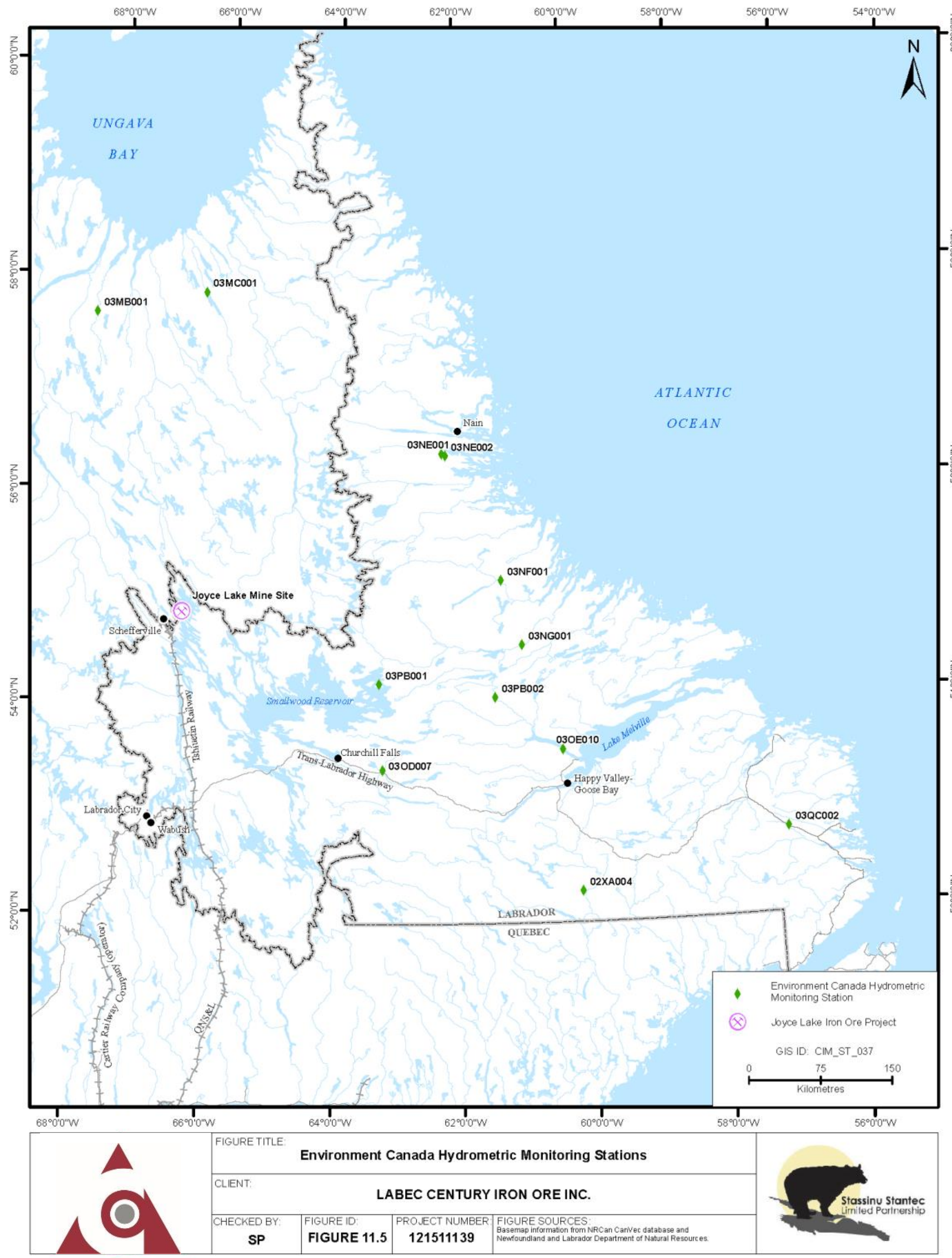

Figure 11.5 Environment and Climate Change Canada Hydrometric Monitoring Stations

The following criteria were considered in selecting the hydrometric stations for the hydrologic analysis:

- stations with drainage area less than 10,000 km^2;
- stations with natural flow regimes; and
- stations with periods of record more than 9 years.

To augment the available regional streamflow data, Stantec installed four stream hydrometric monitoring stations and four lake level monitoring stations within the LSA as discussed in Section 11.5.2.1.

Environmental Water Balance

The LSA/PDA water balance can be presented by the following relationship:

(Equation 1) $P = ET + R + I$

Where: P = precipitation;

ET = evapotranspiration;

R = surface runoff; and

I = infiltration and storage.

A spreadsheet-based monthly water balance model for the PDA and LSA based on the Thornthwaite and Mather (1957) monthly water balance model was developed to estimate ET, surface runoff, infiltration, and streamflow (Mather 1969, 1978 and 1979; Black 1996).

The spreadsheet model calculates monthly potential evapotranspiration (PET) using the Malmstrom equation (Malmstrom 1969) and is given by:

(Equation 2) $PET = 40.9 \times ea^*$

$ea^* = 0.611 \times \exp[(17.3 \times T)/(T+237.3)]$

Where: PET = potential evapotranspiration (mm/month)

ea* = saturation vapour pressure (KPa)

T = mean monthly temperature (^oC)

Actual evapotranspiration (AET) is derived from PET and soil-moisture. When P for a month is less than PET, then AET is equal to P plus the amount of soil moisture that can be withdrawn from storage in the soil. If P for a month is greater than PET, then AET is equal to PET.

The Infiltration factor described in OMOE (1995 and 2003) is used to determine the fraction of water surplus (excess of precipitation over evapotranspiration, P-ET) that infiltrates into the ground and the fraction that runs off to nearby streams. The “infiltration factor- i” is determined from average landscape topographic slope, hydrologic soil type and vegetation cover type and is used to determine the proportion of P-ET routed to infiltration. Infiltrated water recharges aquifers and also routes via interflow to waterbodies and watercourses. In the long term, all net infiltrated water recharging aquifers is discharged as a component of baseflow. Thus, an additional line row in the monthly water balance estimates streamflow which integrates both overland runoff and infiltration routing back to the “stream” as groundwater discharge and interflow components of baseflow.

Although within the temporal confines of a climate year, groundwater recharge and groundwater discharge 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 case, as all groundwater is assumed to flow in relatively localized groundwater watersheds 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 groundwater discharge. It was assumed that runoff, ET and infiltration are negligible in months with average monthly temperatures below 0^{o}C.

The water balance model was applied to climate normal, wet and dry year climate conditions to estimate the existing condition environmental water balance over a temporal scale compatible with the Project life cycle.

Water Quality

Water quality monitoring is a requirement for development of resource extraction projects. Comprehensive water quality data, including levels of contaminants, is needed to characterize baseline water quality conditions, 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 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 CWQG-PAL and the MDMER;
- characterize 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;
- establish a summary of baseline 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 MDMER 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, sedimentation pond design and sizing and the timing, duration, flow rate and seasonality of water discharges; and
- calibrate and develop water quality models.

Eight (8) routine seasonal surface water quality monitoring locations were monitored in 2012 and are identified in Figure 11.2. Water quality monitoring station was selected based on the following considerations:

- representative 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.

Water quality sampling analytical parameters are listed in Table 11.8. The analytical constituents included parameters listed in Schedule 4 of the MDMER SOR/2002/222. Metals analysis included both total and dissolved concentrations. The CWQG-PAL are used to assess baseline water quality. The CWQGs for metals are based on total metals concentrations. Water quality samples were collected by grab sample.

Table 11.8 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 (DOC), Hardness, pH, Total Organic Carbon, Suspended Solids	Acidity, Ammonium, Color, Strong Acid Dissociation Cyanide, Total Dissolved Solids (TDS), Total Phosphorus (TP), 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

11.5.3 Baseline Conditions

The existing environment for Water Resources includes a description and discussion of local climate, topography, surficial geology, vegetation, drainage patterns, environmental water balance, watershed delineation, hydrological characteristics, water and sediment quality, local water supplies and local receiving water assimilative capacity.

11.5.3.1 Climate

Labrador is divided into three climate zones in the Atlas of Newfoundland and Labrador, shown in Figure 11.6. The Project site is located within the Interior Labrador climate zone. The Interior of Labrador has a continental climate with lengthy, very cold winters with deep snow cover, but relatively more settled weather patterns.

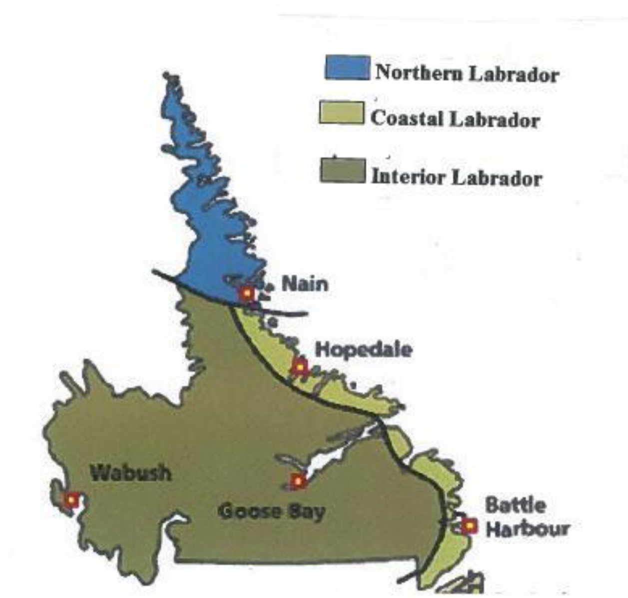

Figure 11.6 Climate Zones of Labrador (Atlas of Newfoundland and Labrador, 1991)

The nearest Environment and Climate Change Canada's climate station with long-term record is located at the Schefferville Airport located 20 km southwest and west of the PDA. It was therefore selected to provide the basis for characterizing climate conditions in the LSA and RSA.

Temperature

The Project Area has a continental climate with significant seasonal variations in temperature. A summary of the monthly temperature distribution throughout the year is presented in Table 11.9 and Figure 11.7. The average daily temperatures typically drop below freezing by the end of October and remain below zero until April. Monthly mean temperature extremes in the area can range from -29°C in the winter to 17°C in the summer, with a mean annual temperature of -5.3°C.

Table 11.9 Air Temperature Statistics for LSA and RSA

Month	Temperature (°C)[1]		
	Maximum	Mean	Minimum
January	-19.0	-24.1	-29.2
February	-16.9	-22.6	-28.1
March	-9.8	-16.0	-22.2
April	-1.5	-7.3	-13.1
May	6.0	1.2	-3.6
June	13.7	8.5	3.3
July	17.2	12.4	7.6
August	15.8	11.2	6.5
September	8.9	5.4	1.7
October	1.3	-1.7	-4.6
November	-6.1	-9.8	-13.5
December	-15.9	-20.6	-25.2

Note:
[1] Based on period of record 1948 – 2010.

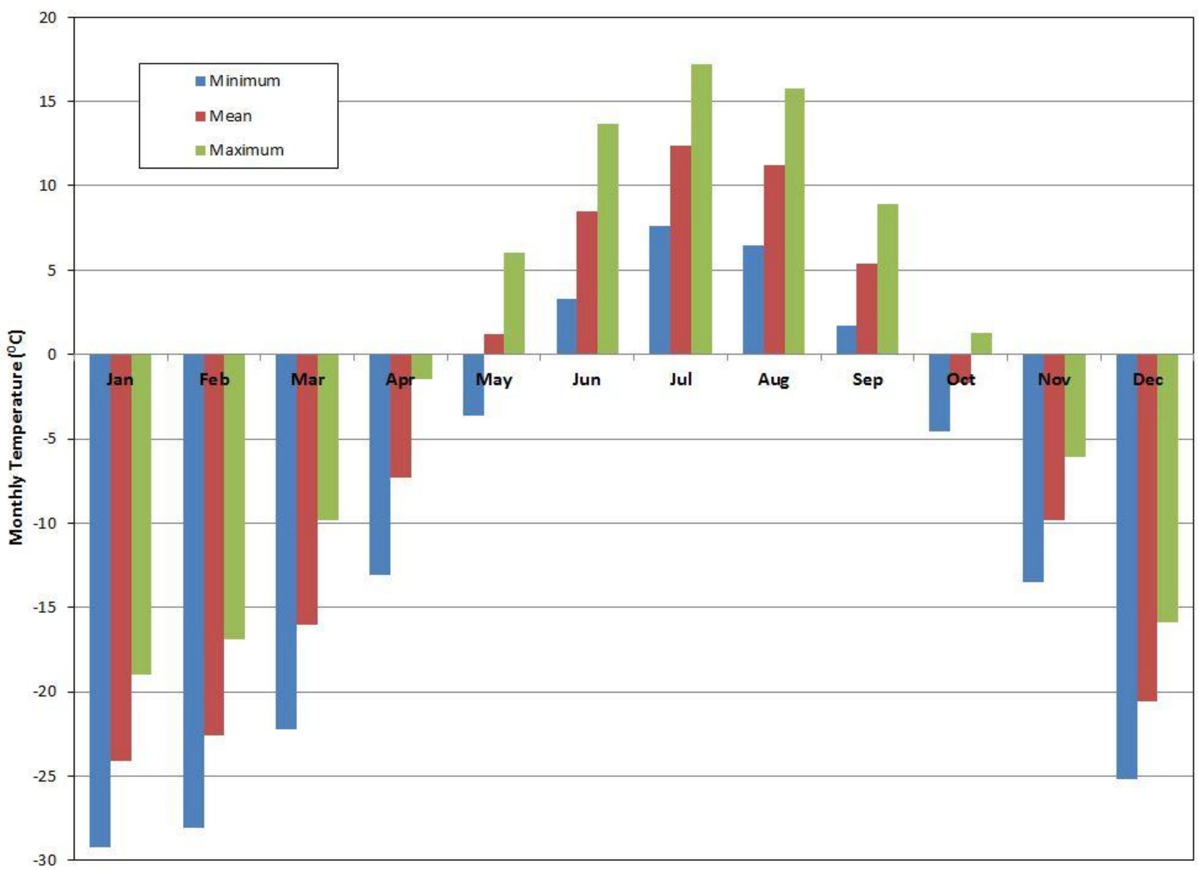

Figure 11.7 Monthly Air Temperature for LSA and RSA

Precipitation

Mean and extreme monthly precipitation estimates for the LSA and RSA are presented in Table 11.10. The temporal variation in monthly precipitation is shown in Figure 11.8. Average annual precipitation is approximately 780 mm based on period of record 1948 to 2010 and 823 mm based on period of record 1971 to 2000 (climate normal). The climate normal was estimated for the period of record 1971 to 2000 since the rainfall and snowfall data are not available for the period of 2000 to 2010. These annual precipitations are typical of western Labrador. Based on climate normal data, annual precipitation occurs approximately 49.5% (408 mm) as rainfall and 50.5% (415 mm) as snow. The annual snowfall is estimated to be 440 cm/year, occurring mainly between October and May. The 10-Year and 100-Year wet annual precipitation amounts are estimated to be 948 mm and 1074 mm, respectively. The 10-Year and 100-Year dry annual precipitation amounts are estimated to be 564 mm and 448 mm, respectively. Monthly precipitation and annual precipitation for various return periods are presented in Tables 11.11 and 11.12 respectively.

Table 11.10 Monthly Precipitation

Month	Precipitation (mm)[1]		
	Maximum	Mean	Minimum
January	136.4	45.4	9.2
February	92.9	37.5	1.8
March	121.5	45.1	6.7
April	144.4	46.2	8.4
May	107	51.0	12.5
June	159.5	73.5	22.1
July	189.4	100.2	27.0
August	170.8	93.6	42.6
September	194	91.6	46.1
October	150.4	77.8	21.9
November	151.7	69.4	23.2
December	117.1	48.1	15.0

Note:
[1] Based on period of record 1948 – 2010.

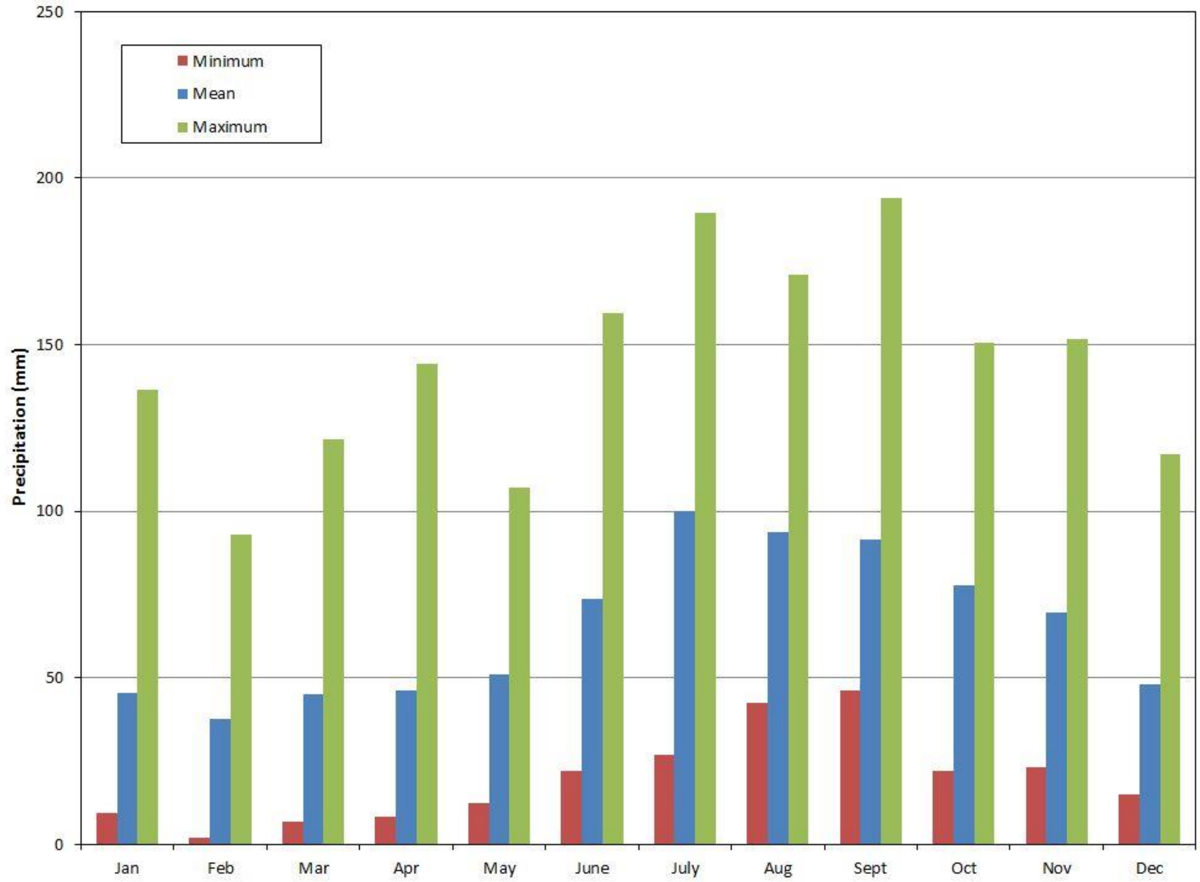

Figure 11.8 Monthly Precipitation

Table 11.11 Monthly and Annual Precipitation Statistics for LSA and RSA

Month	Total Precipitation (mm)[1]				
	100 Year Dry	10 Year Dry	Average Year	10 Year Wet	100 Year Wet
January	7.6	15.7	45.4	106.1	168.1
February	7.0	1.6	37.8	75.4	100.2
March	6.2	14.4	45.3	89.9	134.6
April	6.4	13.0	46.8	100.8	166.3
May	10.6	19.6	51.1	96.7	119.5
June	19.4	31.7	73.5	132.9	195.0
July	25.4	49.0	99.8	164.4	212.7
August	34.2	46.0	92.7	151.7	191.8
September	39.7	51.3	91.7	165.5	230.2
October	21.5	38.1	77.5	133.2	163.6
November	21.3	30.8	70.0	114.9	164.2
December	13.5	20.8	48.4	88.2	88.2
Annual	448	564	780	948	1074

Note:
[1] Based on period of record 1948 – 2010.

Table 11.12 Annual Precipitation for Range of Return Periods

Return Period (Year)	Annual Precipitation (mm)[1]	
	Wet Year	Dry Year
Mean	780	
5	910	598
10	948	564
25	998	518
50	1036	483
100	1074	448
200	1112	413
500	1162	367
1000	1200	332

Note:
[1] Based on period of record 1948 – 2010.

IDF curves for the Schefferville Airport were obtained from Environment and Climate Change Canada and are presented in Table 11.13 and Figure 11.9.

Table 11.13 Rainfall IDF Statistics for LSA and RSA

Duration	Total Rainfall (mm)					
	2 year	5 Year	10 year	25 Year	50 Year	100 Year
5 minutes	3.7	5.8	7.3	9.0	10.4	11.7
10 minutes	5.3	7.7	9.3	11.4	12.9	14.4
15 minutes	6.1	8.8	10.6	12.8	14.5	16.2
30 minutes	7.5	10.6	12.7	15.4	17.3	19.3
1 hour	10.0	13.5	15.8	18.8	20.9	23.1
2 hour	13.4	17.1	19.5	22.6	24.9	27.2
6 hour	22.3	28.0	31.7	36.5	40.0	43.5
12 hour	29.0	37.7	43.4	50.7	56.1	61.5
24 hour	36.8	49.7	58.2	69.0	77.1	85.0

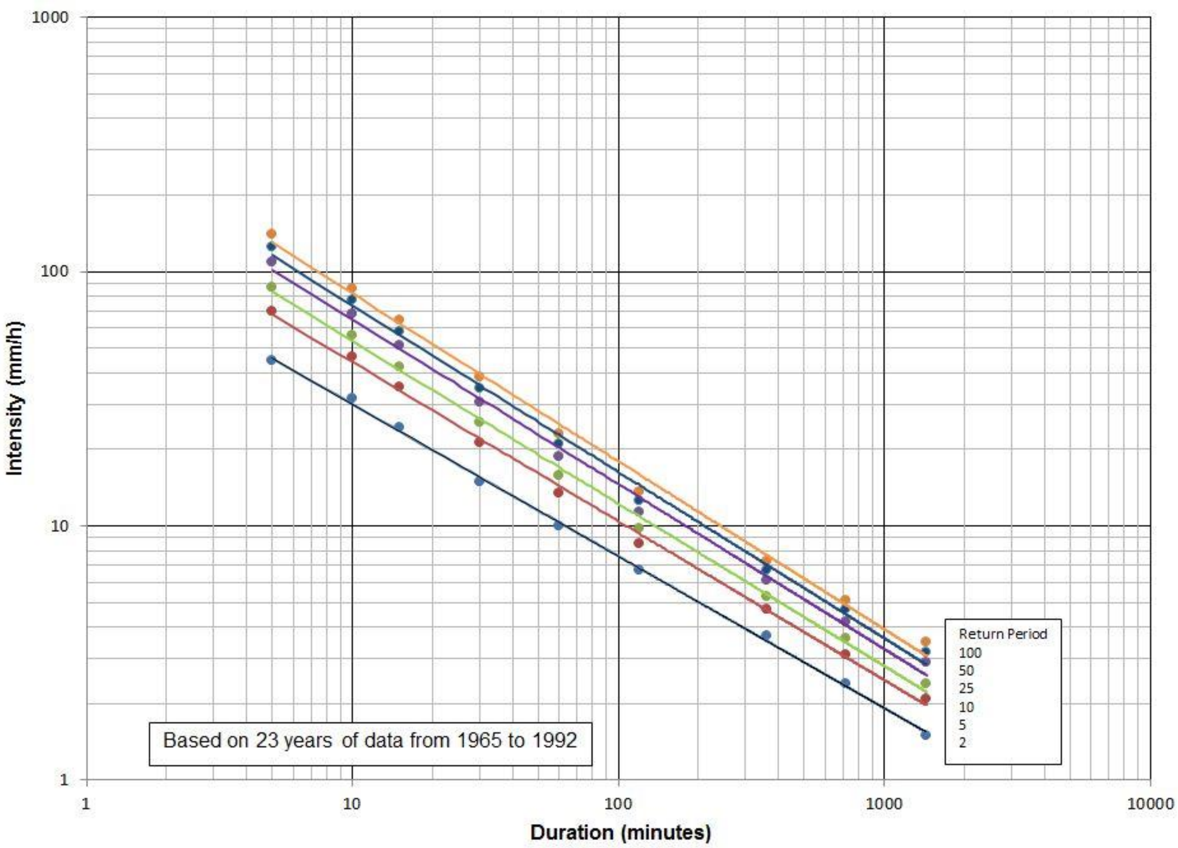

Figure 11.9 IDF Curves for LSA and RSA

Rainfall intensity for the Project area can be estimated from the following equation:

(Equation 3) $I = A\ TB$

Where: I = Rainfall intensity (mm/hr);

T = Duration (hour); and

A&B = constants and are provided in Table 11.14 for various storm events.

Table 11.14 Constants A and B (Environment and Climate Change Canada)

Return Period (Year)	2	5	10	25	50	100
A	10.4	14.4	17.0	20.3	22.7	25.2
B	-0.595	-0.625	-0.637	-0.648	-0.654	-0.659

The estimated PMP based on 10,000 year return period is 142 mm for 24-hour storm duration. This is a preliminary value based on statistical estimates using limited data and is considered suitable for feasibility studies, but not necessarily for detailed design.

Climate Normals

Climate normals for the 30-year period (1971 to 2000) were obtained from Schefferville Airport weather station and are presented in Table 11.15. The climate normal precipitation is approximately 823 mm/year. The annual snowfall is estimated to be 441 cm/year occurring mainly between October and May.

Table 11.15 Climate Normals for the 30-year Period (1971 to 2000) at Schefferville Airport Station (Station # 7117825)

Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-24.1	-22.6	-16.0	-7.3	1.2	8.5	12.4	11.2	5.4	-1.7	-9.8	-20.6	-5.3
Rainfall (mm)	0.2	0.2	1.6	8.4	27.7	65.4	106.8	82.8	85.3	24.4	4.5	0.9	408
Snowfall (cm)	57.4	42.6	56.6	54.8	22.9	8	0.5	1.7	12.7	57.2	70.7	55.4	441
Precipitation (mm)	53.2	38.7	53.3	61.4	52.1	73.7	107.2	84.5	98.4	80.5	69.4	50.7	823
Snow on Ground (cm)	62.0	70.0	71.0	69.0	18.0	0.0	0.0	0.0	0.0	7.0	26.0	49.0	31.0

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 in February, March and April. The snow cover is usually melted by the end of May and returns in October with a mean monthly value of 7 cm.

Dry Year

A review of annual climate conditions at the Schefferville Airport climate station indicated that 1997 was the driest year in 30-years of record from 1971 to 2000. Table 11.16 presents the monthly climate values for 1997. Dry year 1997 had 521 mm of total precipitation which was 37% less precipitation than the climate normal condition. Statistically, 1997 is in the range of the 1:25 year dry year.

Table 11.16 Climate Values for a Dry Year (1997) at Schefferville Airport Station (Station # 7117825)

Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-21.0	-25.0	-19.5	-8.7	-0.5	8.4	10.9	10.8	6.9	-0.6	-9.5	-17.0	-5.3
Rainfall (mm)[1]	-	-	-	-	-	-	-	-	-	-	-	-	-
Snowfall (cm)[1]	-	-	-	-	-	-	-	-	-	-	-	-	-
Precipitation (mm)	17.6	1.8	9.7	23.9	67.0	33.2	168	42.6	67.4	21.9	41.3	26.5	521
Snow on Ground (cm)[1]	-	-	-	-	-	-	-	-	-	-	-	-	-

Note:
[1] Rainfall, snow fall and snow on ground data are not available for year 1997

Wet Year

A review of annual climate conditions at the Schefferville Airport climate station indicated that 1983 was the wettest year in the 30 years of record from 1971 to 2000. Table 11.17 presents the monthly climate values for 1983. Wet year 1983 had 1038 mm of total precipitation which was 26% more precipitation than the climate normal condition. Statistically, 1983 is in the range of the 1:50 year wet year.

Table 11.17 Climate Values for a Wet Year (1983) at Schefferville Airport Station (Station # 7117825)

Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Temperature (°C)	-24.7	-23.4	-16.7	-2.9	1.7	10.6	11.7	10.4	7.2	-0.9	-9.3	-21.7	-4.8
Rainfall (mm)	0.0	0.0	0.0	28.3	8.0	85.6	144.4	98.1	152.0	49.1	0.2	0.0	566
Snowfall (cm)	67.7	50.1	133.2	37.4	19.0	5.9	0.0	0.0	0.0	54.6	101.1	87.3	556
Precipitation (mm)	51.2	37.8	110.2	61.3	28.3	91.5	144.4	98.1	151.8	102.6	82.7	77.7	1,038
Snow on Ground (cm)	46.4	54.3	74.4	68.5	8.3	0.0	0.0	0.0	0.0	1.7	21.8	59.2	27.9

The dry-wet climate year assessment indicates that considerable precipitation variability occurs year over year within the LSA.

Evaporation and Transpiration

Monthly lake evaporation rates for Churchill Falls A and Nitchequon A climate stations are provided in Table 11.18. Lake evaporation rates estimated by Rollings (1997) for Labrador based on the Goose Bay A, Churchill Falls A, and Schefferville A climate stations data are also presented in Table 11.18. The mean annual calculated lake evaporation is about 350 mm. Evaporation is negligible from November to April. The maximum monthly lake evaporation is 100 mm and occurs in July. Mean annual PET for Labrador is shown in Figure 11.10.

Table 11.18 Monthly Lake Evaporation for LSA and RSA

Month	Evaporation (mm)		
	Rollings (1997)	Churchill Falls A[1]	Nitcheqon A[2]
May	20	-	-
June	95	96	91
July	100	104	96
August	80	84	76
September	45	39	45
October	10	10[3]	-
Annual	**350**	**323**	**308**

Notes:
1 Based on period of record 1972 – 1992.
2 Based on period of record 1966 – 1985.
3 Based on two years of data.

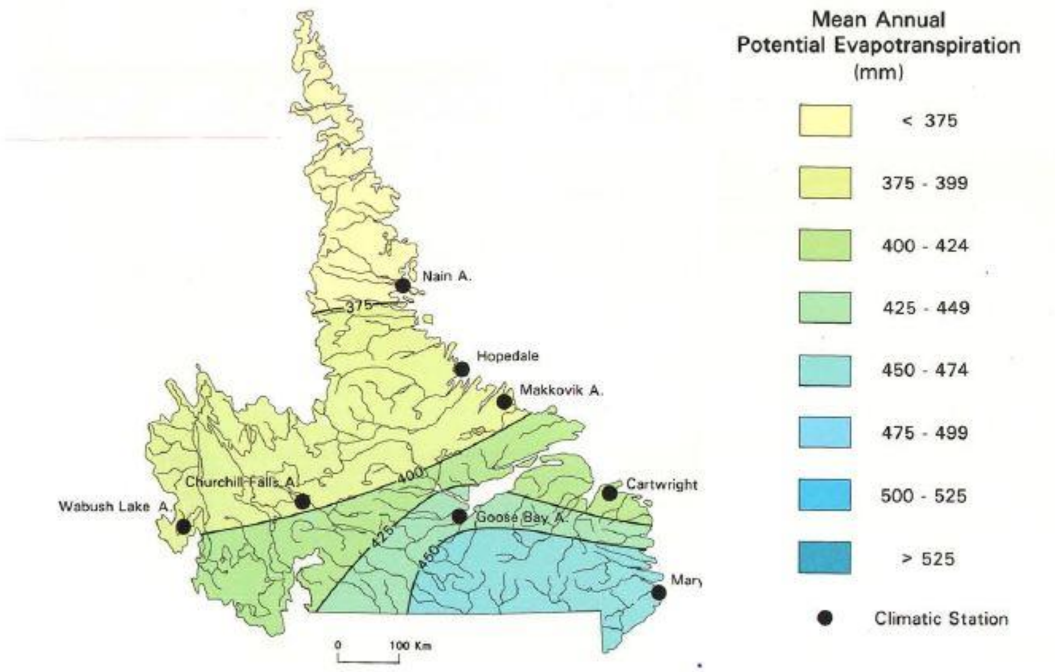

Figure 11.10 Potential Mean Annual Evaporation for Labrador (Water Resources Atlas of Newfoundland and Labrador, 1992)

Permafrost

Permafrost is defined on the basis of the temperature within the ground. The National Research Council of Canada defines permafrost as ground which is continuously below 0°C for two or more years. Permafrost conditions in northern Quebec and Labrador are shown in Figure 11.11 from Brown 1979. Nicholson's (1978) research on permafrost distribution in the Schefferville area indicates that deep permafrost underlies areas of exposed high elevation, where vegetation cover consisted of tundra. The depth of the permafrost ranged from 60 to 100 m, and entirely unfrozen areas occurred in the valleys and within 30 m from permanently covered shoreline. Earlier research found that permafrost was not expected to exist beneath waterbodies that are too deep to freeze solid during the winter (Nicholson and Lewis 1976).

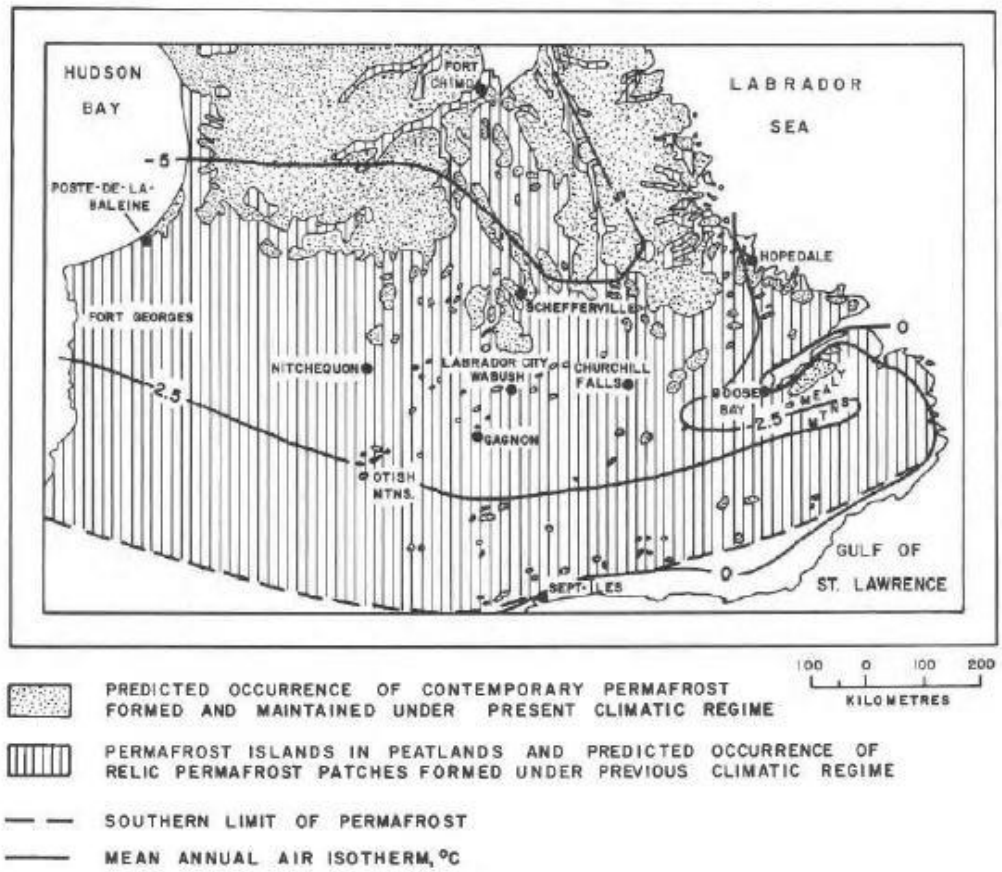

Figure 11.11 Permafrost Distribution in Northern Quebec and Labrador (Brown, 1979)

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 30°C in the summer to -30°C in the winter. The average daily maximum temperatures are similar to the rest of Atlantic Canada (~21°C). Labrador is the coldest region in Atlantic Canada during the winter with an average daily minimum of -22°C. 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 IPCC is between 2°C and 3°C and up to more than 5°C 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 10° increase in temperature. The winter temperature in the northern part of the continent is projected to be higher by 7° in the winter and 2° 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 and Climate Change Canada predicts for Newfoundland and Labrador an increase in mean temperature of 2°C 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 and Climate Change Canada, as well as warmer winters (Vasseur and Catto 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 70s 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 and Climate Change Canada agree with those of the IPCC of an overall increase in precipitation. Over the next 70 years, Environment and Climate Change 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 and Catto 2008).

11.5.3.2 Hydrology

Regional Hydrology

Naturally flowing rivers in Labrador enter their baseflow recession phase in fall when the ambient temperatures drop below 0°C and a permanent snow cover is established (Rollings 1997). Baseflow recession lasts as long as 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. A secondary annual hydrograph peak typically occurs in October.

Annual Flows

The mean annual flow (MAF) was calculated for the hydrometric stations listed in Table 11.7. The results are provided in Appendix G. The MAF per unit area was 0.0205 $m^3/s/km^2$ with standard deviation of 0.0042 $m^3/s/km^2$ and ranged from 0.0122 $m^3/s/km^2$ to 0.0289 $m^3/s/km^2$. The mean peak flow per unit area was 0.1539 $m^3/s/km^2$ with standard deviation of 0.0493 $m^3/s/km^2$ and ranged from 0.0974 $m^3/s/km^2$ to 0.2523 $m^3/s/km^2$. Figure 11.12 presents mean annual runoff for Labrador. The relationship between MAFs and drainage area is presented in Figure 11.13.

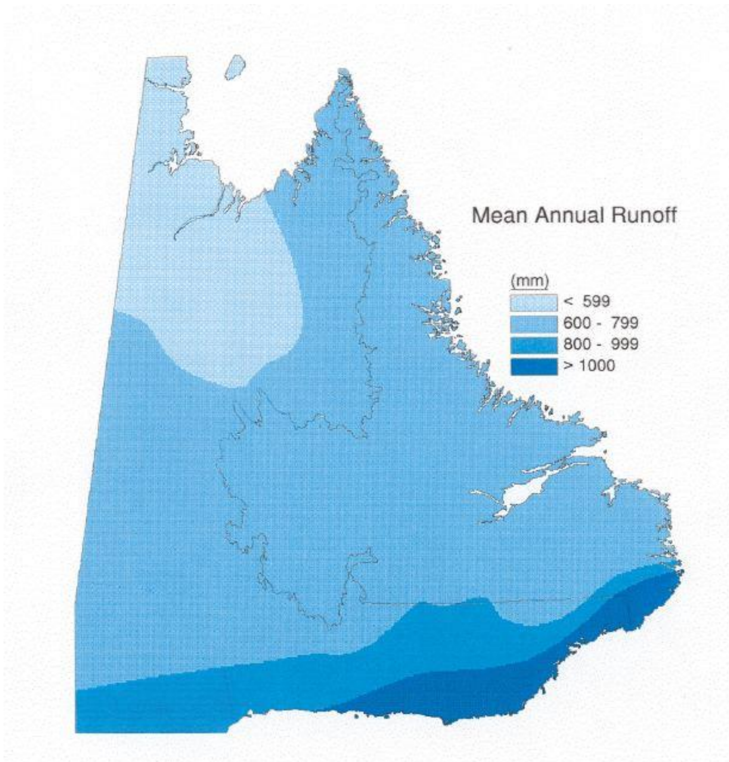

Figure 11.12 Mean Annual Runoff for Labrador (Rollings, 1997)

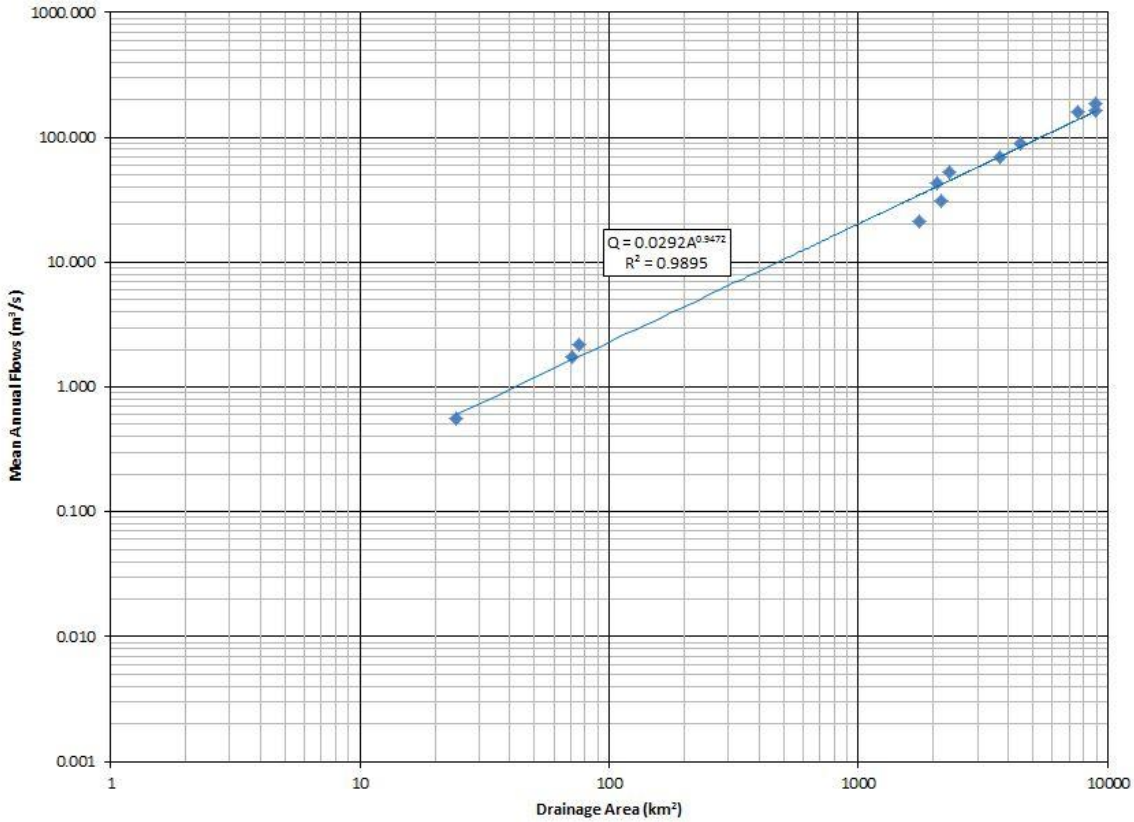

Figure 11.13 Annual Flows Versus Drainage Area

Monthly Flows

The mean, minimum and maximum monthly flows for selected hydrometric stations in Labrador are presented in Figure 11.14. Low flow occurs from January to April. Streamflows peak in May or June due to spring freshet and then gradually decrease until August or September and remain uniform for most of the remainder of the year.

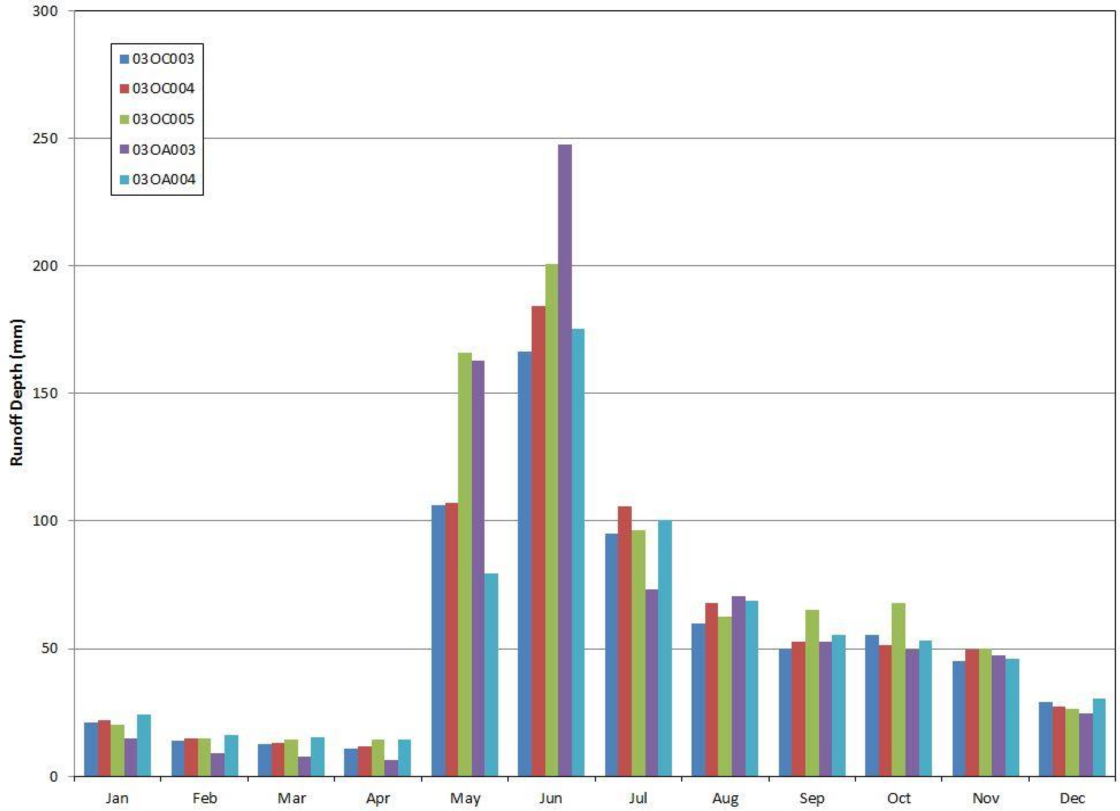

Figure 11.14 Monthly Runoff from Selected Hydrometric Stations in Labrador

Three hydrological seasons can be identified in the monthly hydrograph and are described below (Rollings 1997):

- Spring – period of peak streamflows corresponds to the spring freshet, which can run with recession continuing up to August;
- Fall – period of uniform streamflows corresponds to rainfall-runoff events, which can run from September to December; and
- Winter – period of base flow, which can run from January to April.

A regional analysis of monthly flows was carried out using the hydrometric stations listed in Table 11.7. Monthly flows can be related to the drainage area as follows:

(Equation 4) $Q = \alpha A^{\beta}$

Where Q = monthly flows (m^3/s);

A = Drainage Area (km^2); and

α and β = constants.

The derived constants for regional relationships between monthly flows and drainage area are presented in Table 11.19. Figures 11.15 and 11.16 show the relationships between monthly flows and drainage area for August and December respectively.

Table 11.19 Constants for Regional Relationship between Monthly Flows and Drainage Area

Month	Minimum Flows			Mean Flows			Maximum Flows		
	α	β	R^2	α	β	R^2	α	β	R^2
January	0.0003	1.2486	0.98	0.0043	0.9984	0.97	0.0243	0.8504	0.90
February	7E-05	1.3981	0.96	0.0052	0.9392	0.96	0.0440	0.7402	0.84
March	5E-05	1.4021	0.93	0.0048	0.9245	0.94	0.0301	0.7546	0.80
April	0.0004	1.1437	0.92	0.0105	0.8869	0.88	0.0453	0.8556	0.68
May	0.1110	0.8345	0.57	0.1469	0.8513	0.96	0.1887	0.8813	0.77
June	0.0149	1.0554	0.96	0.0673	0.9849	0.97	0.1141	0.9744	0.93
July	0.0100	1.0199	0.95	0.0350	0.9652	0.97	0.0900	0.9069	0.91
August	0.0064	1.0174	0.97	0.0161	1.0119	0.99	0.0348	0.9954	0.92
September	0.0037	1.0774	0.98	0.0164	1.0068	0.99	0.0570	0.9274	0.91
October	0.0026	1.1457	0.99	0.0232	0.9844	0.99	0.0566	0.9344	0.93
November	0.0038	1.0601	0.99	0.0166	0.9773	0.99	0.0518	0.8901	0.92
December	0.0009	1.1778	0.99	0.0089	0.9740	0.99	0.0417	0.8558	0.89

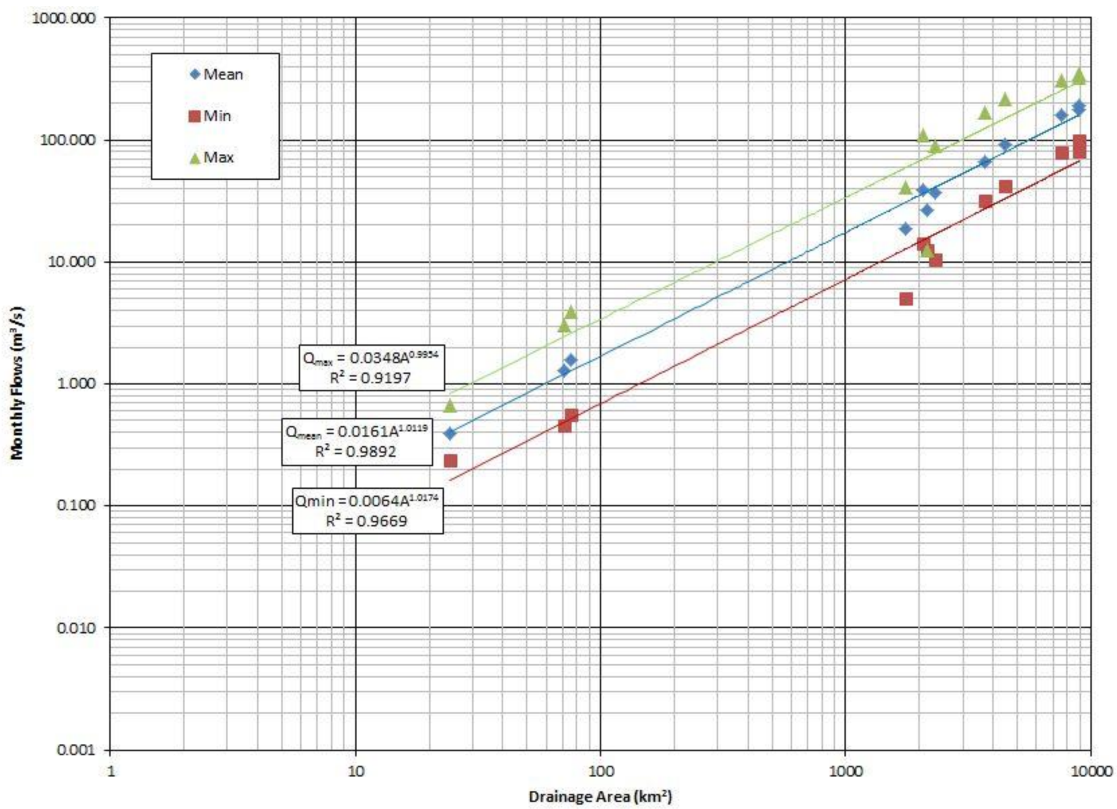

Figure 11.15 Monthly Flows Versus Drainage Area - August

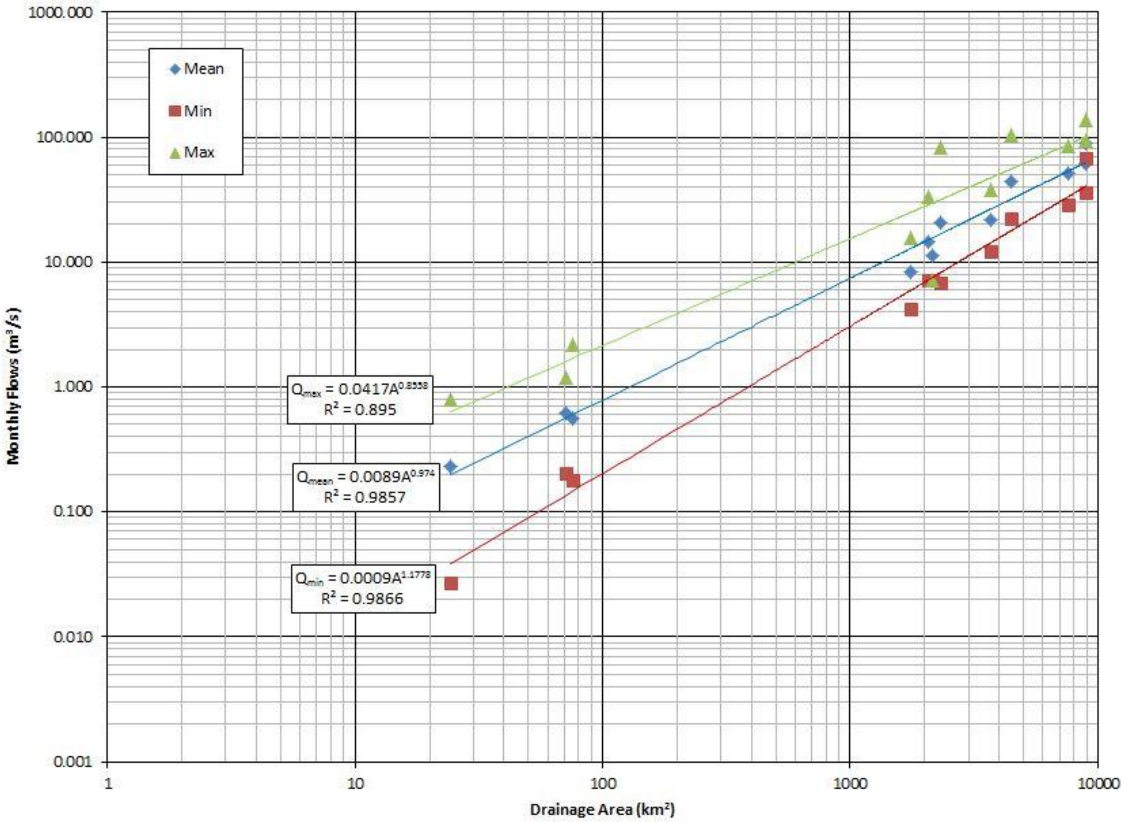

Figure 11.16 Monthly Flows Versus Drainage Area - December

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 500-year return periods suggested by Newfoundland and Labrador Department of Environment, Climate Change and Municipalities (Rollings 1999) was used for the flood flow assessment of the Environment and Climate Change Canada hydrometric stations listed in Table 11.7. Regional frequency analysis was carried out using the single station frequency analysis results for the hydrometric stations listed in Table 11.7. The following relationship was developed between peak flows and drainage area:

(Equation 5) $Q_T = \mu A^{\lambda}$

Where: Q_T = Peak flow for T year return period (m^3/s);

A = Drainage Area (km^2); and

μ and λ = constants.

The regional relationships for flood flows are based on daily peak flows since many instantaneous peak flows are missing for most of the hydrometric stations considered. An assessment based on the daily peak flow to available instantaneous peak flows indicated that the ratio between instantaneous peak flows to daily peak flows ranged from 1.01 to 1.06 on average. It is recommended that a factor of 1.06 needs to be applied to the predicted flood flow using regional relationship Equation 4 to estimate the instantaneous peak flows. Figures 11.17 and 11.18 show the relationship between peak flows and drainage area for 10 and 100 year return periods. The flood flows estimated using the Rollings (1997) regional relationship are also shown in Figures 11.17 and 11.18 for 10 and 100 year return periods and they are in good agreement with the present results. Table 11.20 presents the constants used in the regional relationship for peak flows.

Table 11.20 Relationship between Peak Flows and Drainage Area

Return Period	μ	λ	R^2
2	0.2885	0.9026	0.98
5	0.3372	0.9107	0.98
10	0.3600	0.9169	0.98
20	0.3776	0.9229	0.98
50	0.3939	0.9309	0.98
100	0.4077	0.9356	0.98
200	0.4151	0.9414	0.98
500	0.4231	0.9489	0.98

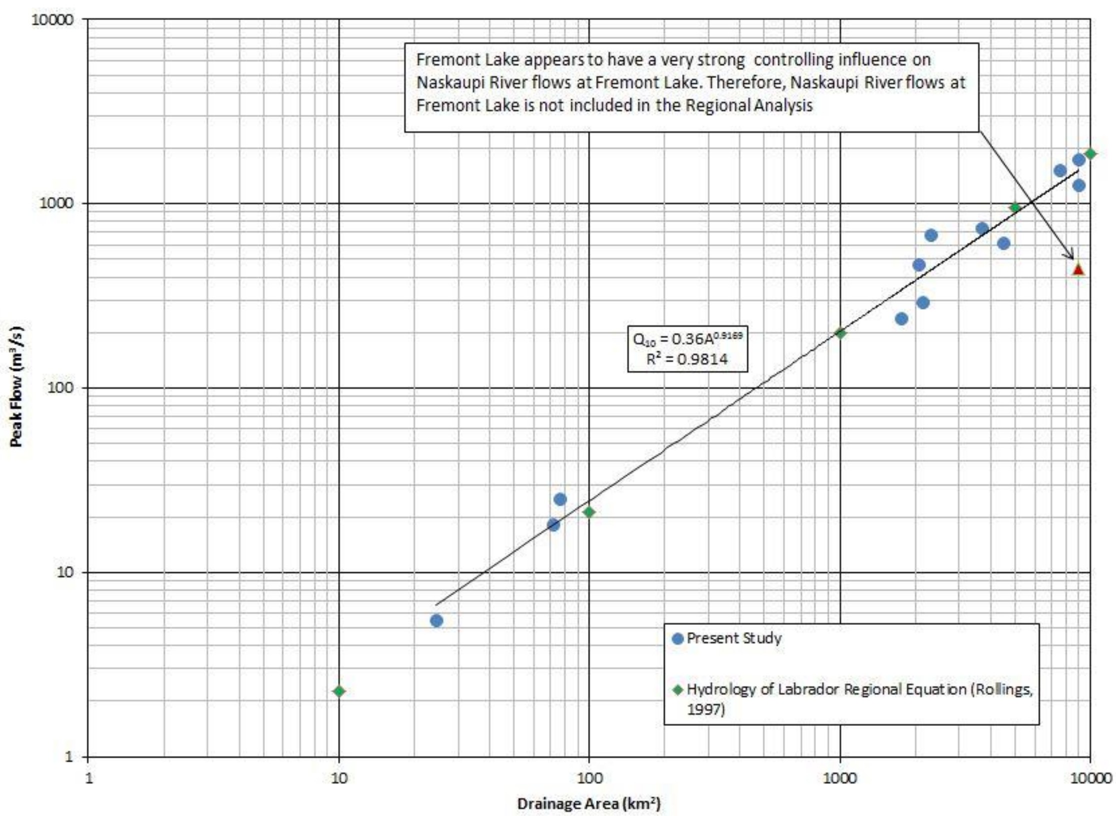

Figure 11.17 Peak Flows Versus Drainage Area – 1:10 Year Period

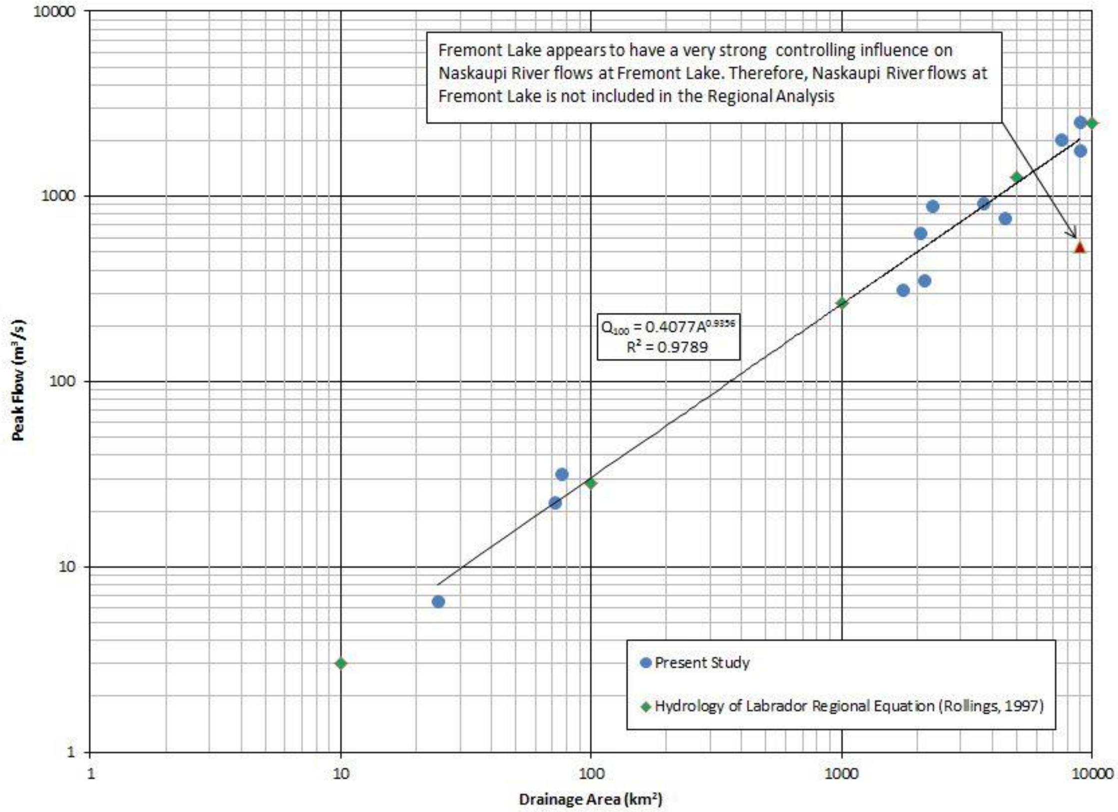

Figure 11.18 Peak Flows Versus Drainage Area – 1:100 Year Period

Ice jam floods are not considered in this analysis; however, they may have significant impacts on design of conveyance and water crossing infrastructure. The shape of a river influences the locations where ice jams are most probable. Ice dam flooding potential and mitigation alternatives should be investigated depending on the type of infrastructure and its location within the watercourse.

Low and Environmental Flows

Low flow indices are required to assess the water withdrawal capacity and instream flow needs or environmental (maintenance) flow requirements for watercourses throughout the PDA and LSA. 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 can be achieved (eFlowNet 2007).

The most widely used hydrological method to estimate the low flow indices include various flow duration exceedance percentiles (e.g., Q95, Q75), single low flow indices (e.g., $7Q_{10}$, $7Q_2$) and the Tennant Method (1976). A regional frequency analysis for low flows was carried out for hydrometric stations listed in Table 11.7 for $7Q_2$, $7Q_{10}$, $7Q_{20}$ and $30Q_{50}$. The low flow relationship with drainage area is shown in Figures 11.19 and 11.20 for $7Q_2$ and $7Q_{10}$ respectively. Flow exceedance values can be obtained from Figures 11.21 and 11.22 provided in the following section.

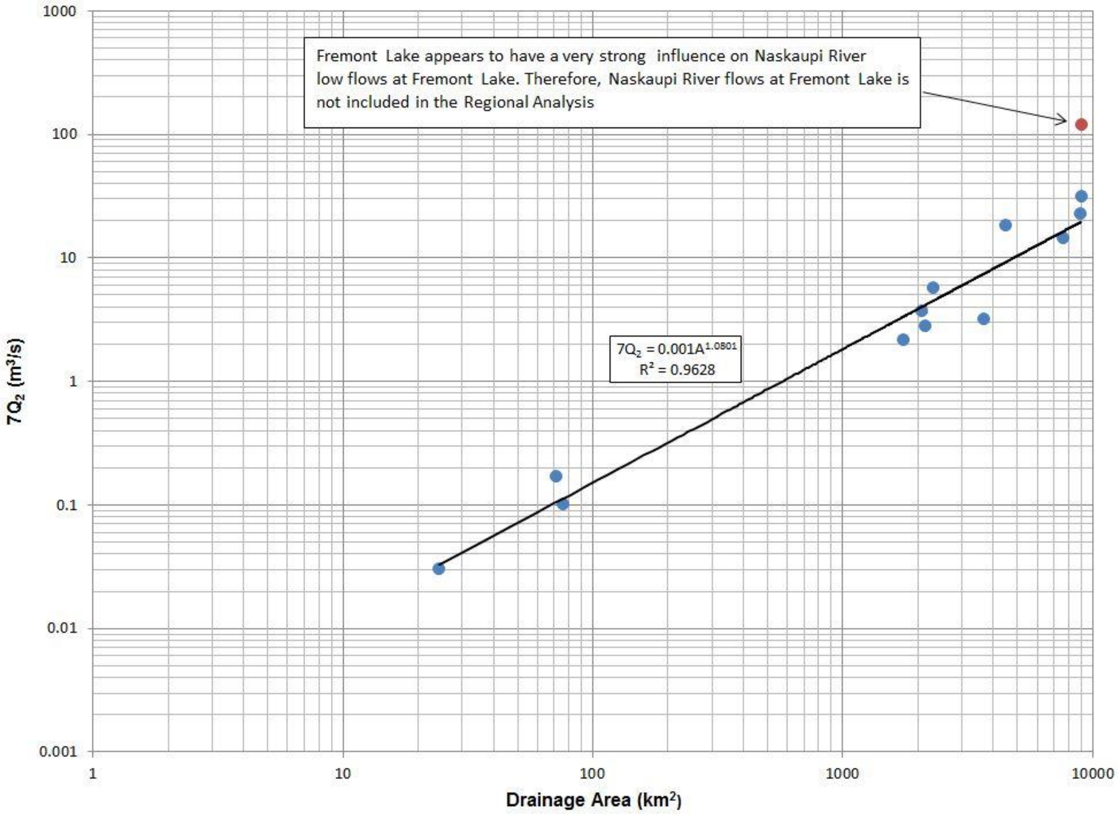

Figure 11.19 Low Flow $7Q_2$ Versus Drainage Area

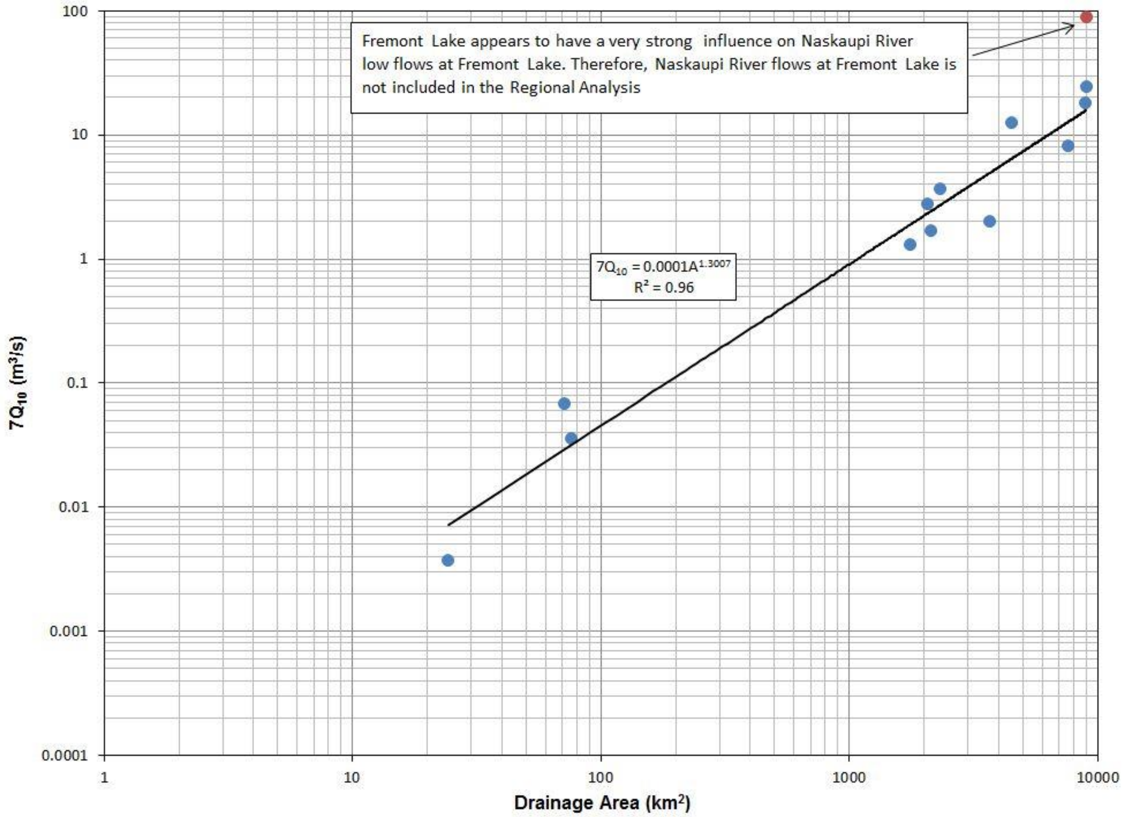

Figure 11.20 Low Flow $7Q_{10}$ Versus Drainage Area

For this study, Tennant's method suggested by DFO was used to estimate the environmental flows (Stoneman 2005; Maunder and Hindley 2005). The Tennant method uses a percentage of the MAF for two different six month periods to define conditions of flow regarding "instream flow regimens for fish, wildlife, recreation, and related environmental resources" (Table 11.21). The low or maintenance flow requirement for the summer period (April to September) is 40% of the MAF and for the winter period (October to March) is 20% of the MAF. The maintenance flows for the streams in the Project area can be estimated from the following equations:

(Equation 6) Summer: $Q_{MFS} = 0.0117A^{0.9472}$

(Equation 7) Winter: $Q_{MFW} = 0.0058A^{0.9472}$

Where: Q_{MFS} and Q_{MFW} = summer and winter maintenance flow in m^3/s; and

A = drainage area in km^2.

Table 11.21 The Tennant Method (1976)

Narrative Description of General Condition of Flow	Recommended Flow Regimens (%MAF) – October to March	Recommended Flow Regimens (% MAF) – April to September
Flushing or Maximum	200%	200%
Optimum Range	60-100%	60-100%
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair or Degrading	10%	30%
Poor or Minimum	10%	10%
Severe Degradation	<10%	<10%

Flow Duration Curves

Flow Duration Curves indicate which percentage of time during the entire record a flow was equaled or exceeded over a historical period. Stream FDCs are used in the determination of water use, water quality management, river sedimentation, flood control and instream flow requirements. An annual flow duration curve (AFDC) represents the relationship between magnitude and frequency of flow was equaled or exceeded over a water year or calendar year. AFDCs have been shown to be quite useful for making probabilistic statements about wet, typical and dry years, for computing confidence intervals associated with the AFDC representing the typical hydrologic conditions and for assigning return periods to individual AFDCs (Vogel and Fennessey 1994).

Normalized (Q_{Daily}/Q_{Annual}) period-of-Record FDCs are shown in Figure 11.21 for the hydrometric stations listed in Table 11.7. The FDCs have similar characteristics and are closely overlapping each other except for the Naskaupi River at Fremont Lake. Flows in the Naskaupi River appear to be significantly controlled by Fremont Lake.

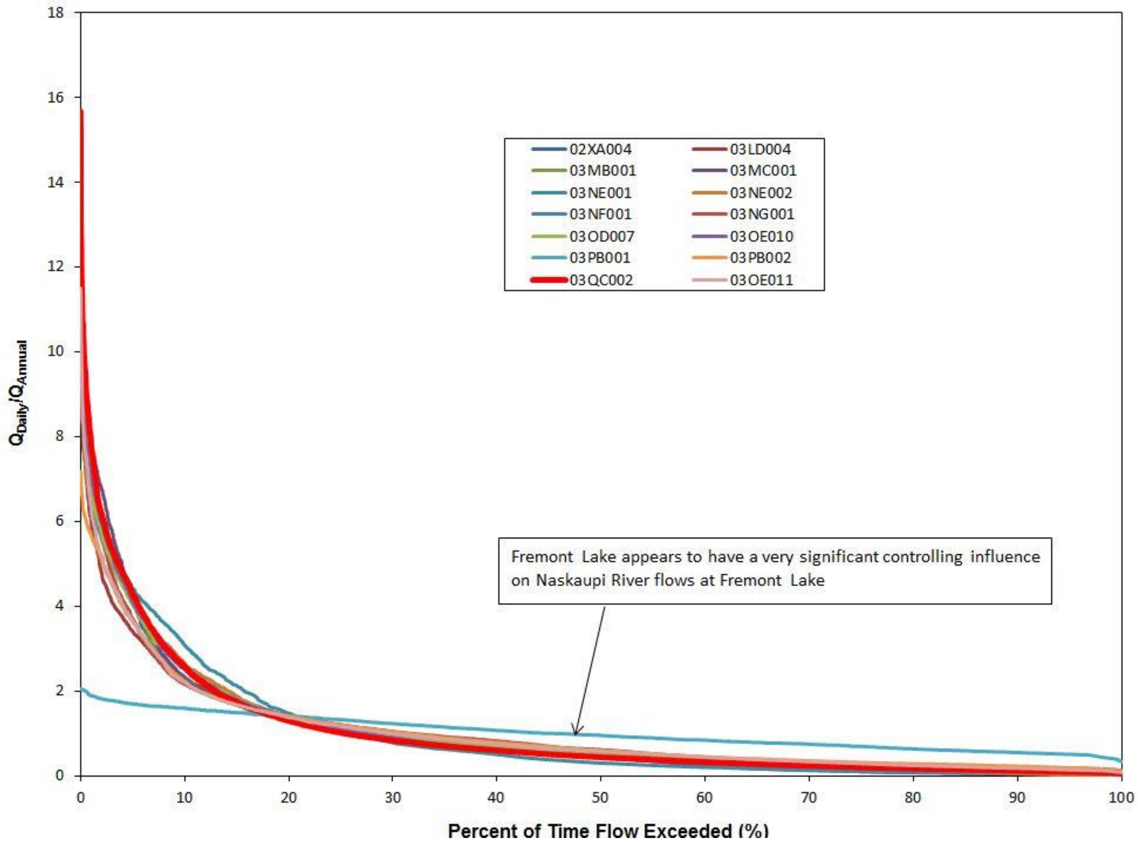

Figure 11.21 Period-of-Record Duration Curves for Selected Hydrometric Stations

The Alexis River near Port Hope Simpson was selected to develop the regional FDC curves since it has the longest flow record. The period-of-record, mean and median FDCs for the RSA is presented in Figure 11.22 and Wet and Dry year FDCs are presented in Figure 11.23. One can estimate FDC curves for a particular watershed using the normalized FDC curves in Figures 11.22 and 11.23 for the RSA and MAFs estimated using relationship provided in Figure 11.13.

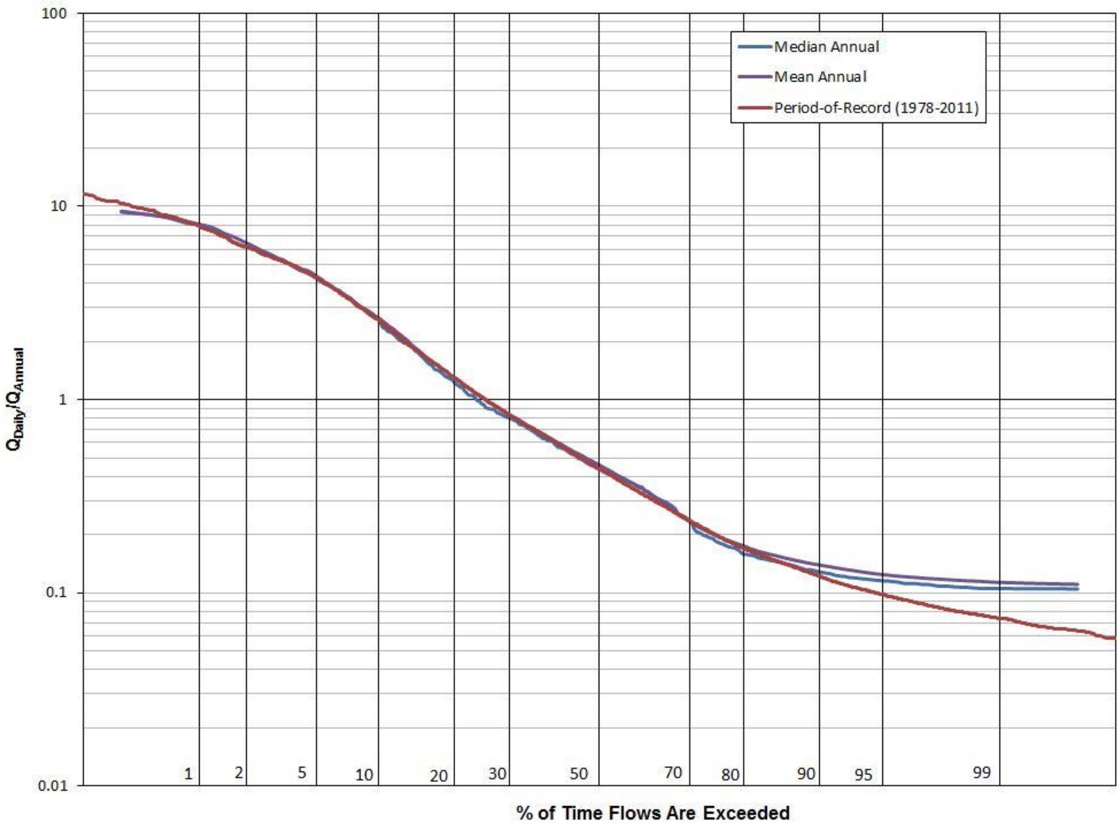

Figure 11.22 Period-of-Record Mean Annual and Median FDCs for RSA

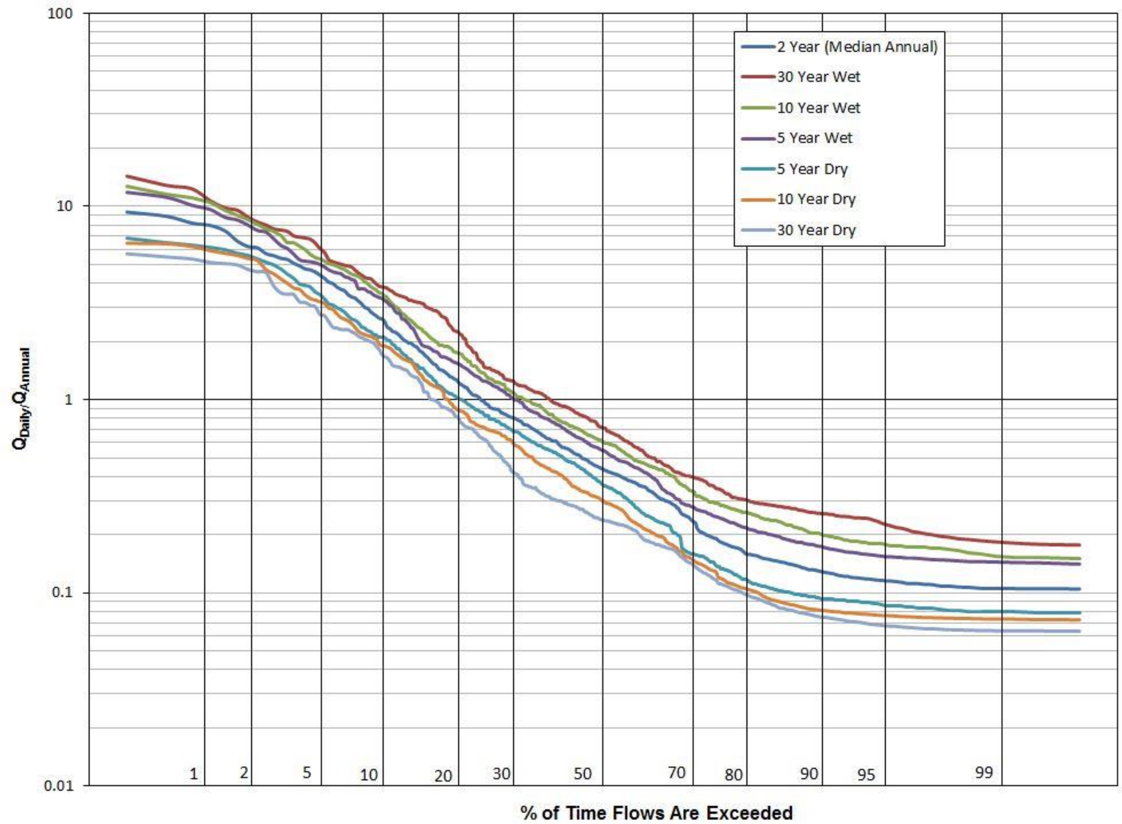

Figure 11.23 Wet and Dry Year FDCs for the RSA

Local Hydrology

The following section presents hydrometric monitoring results, such as stream flows, summarizes water levels, and compares stream flows with predicted flows using the regional relationships. Environmental water balance results for the Project area are also presented, along with hydrologic conditions in the PDA and along the proposed road. Hydrologic variables considered at each assessment node include MAFs, monthly flows, low flows, environmental maintenance flows, peak flows and FDCs.

Hydrometric Monitoring Results

The hydrometric monitoring program included four streams and four lakes in the LSA as shown in Figure 11.2. The detailed results from hydrometric monitoring program are provided in Appendix H for the period of August 2012 to July 2013. The results presented are water levels, stream flow and rating curves for stream monitoring stations and water levels for the lake monitoring stations.

Gilling River (S1)

The Gilling River hydrometric monitoring station (S1) has a drainage area of approximately 102 km². The hydrometric monitoring station is located approximately 10 km downstream of Gilling Lake and 2.5 km upstream of Astray Lake. Figure 11.24 presents the water levels and stream flows for the Gilling River (S1) for the period of August 2012 to July 2013. The highest flow of 31.8 m³/s occurred in middle of June 2013 and lowest flow of 1.62 m³/s occurred in the third week of October 2012. The flows are estimated by extrapolating from the rating curve for the station S1.

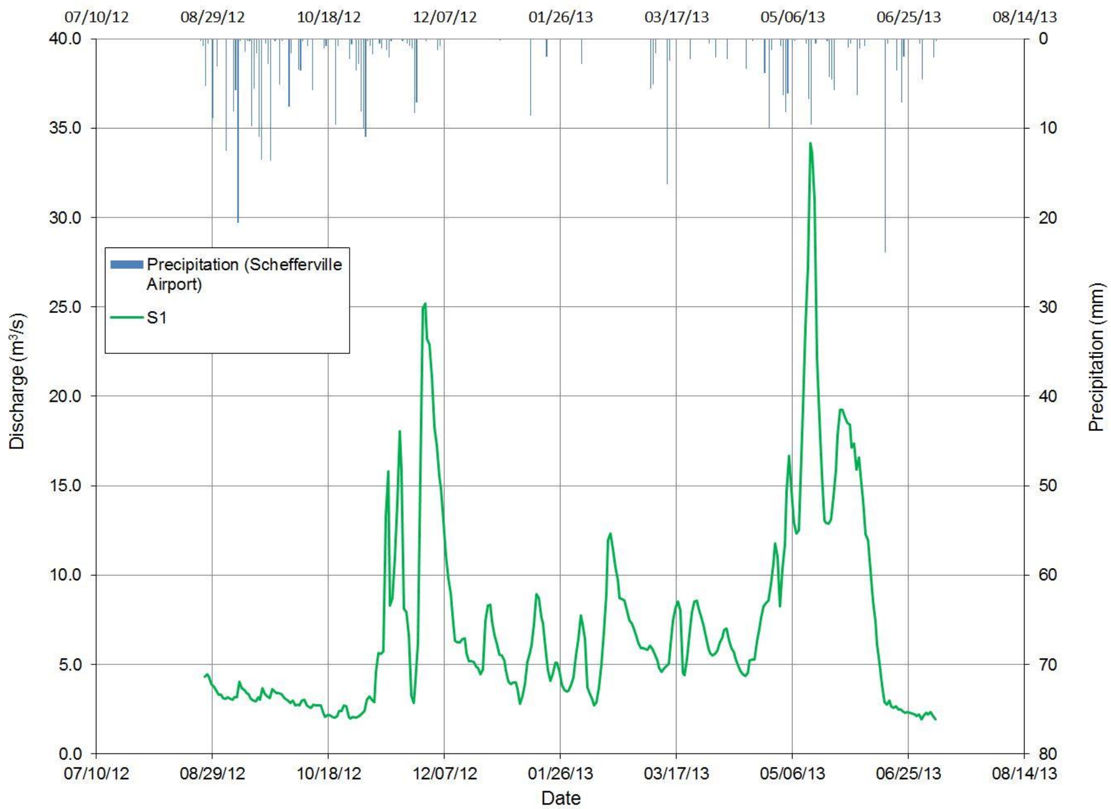

Figure 11.24 Stream Flow at Stream Monitoring Station S1

Unnamed Creek (S2)

The Unnamed Creek hydrometric monitoring station (S2) has a drainage area of 3.27 km². The hydrometric monitoring station is located between two small lakes which drain to the Petitsikapau Lake (Figure 11.2). Figure 11.25 presents the stream flows for the Unnamed Creek (S2). This hydrometric station was vandalized on August 29, 2012 and then reinstalled on October 2, 2012. However, due to an error in the logger, data following October 2012 were unable to be downloaded from this station. Only five days of water level data are available.

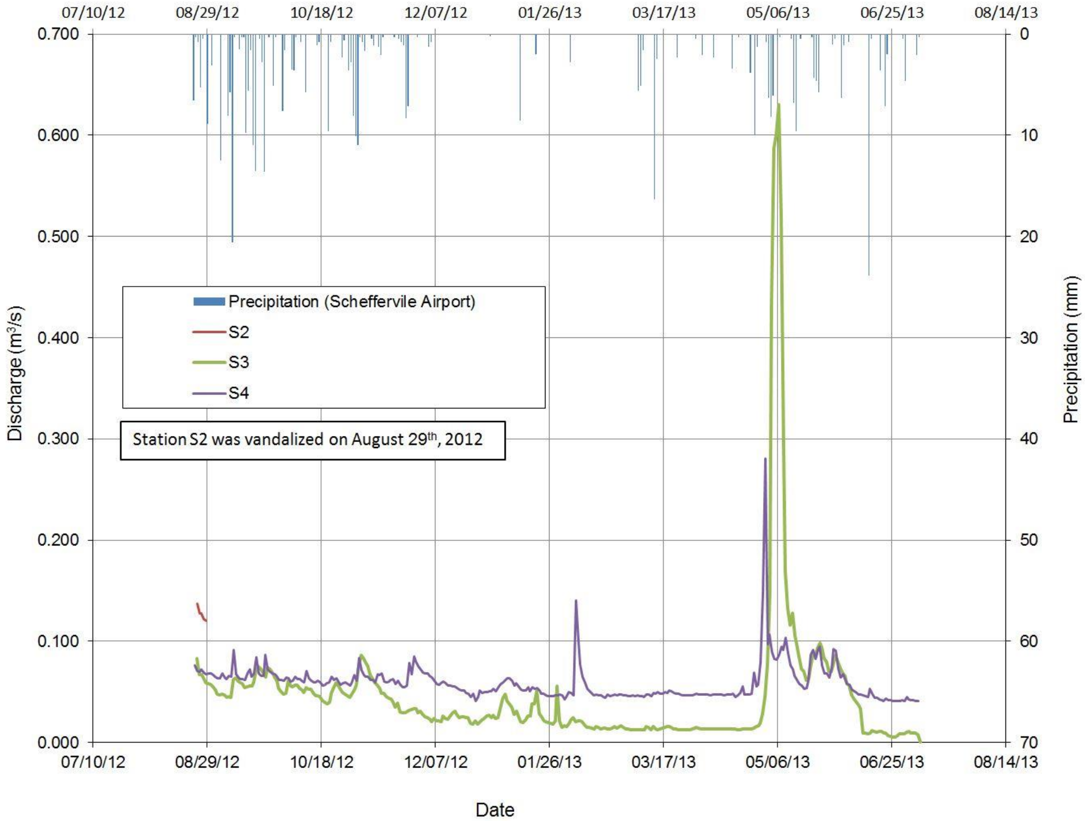

Figure 11.25 Stream Flow at Stream Monitoring Stations S2, S3 and S4

Unnamed Creek (S3)

The Unnamed Creek hydrometric monitoring station (S3) drainage area is 5.06 km^2. Figure 11.25 presents the stream flows for the Unnamed Creek (S3) for the period of August 2012 to July 2013.

Unnamed Creek (S4)

The Unnamed Creek hydrometric monitoring station (S4) drainage area is 3.03 km^2. The hydrometric monitoring station is located approximately 2 km downstream of Joyce Lake and 1.5 km upstream of Unnamed Lake which drains to Timmins Bay. Figure 11.25 presents the stream flows for the Unnamed Creek (S4) for the period of August 2012 to July 2013.

Petitsikapau Lake (L1)

The drainage area of Petitsikapau Lake is 2,678 km^2 with a water surface area of approximately 762 km^2. Twenty-eight percent of the Petitsikapau Lake watershed is covered by water surface area. The hydrometric monitoring station is located in the northwest of the lake in Bay #3 (Figure 11.2). The water level variations in Petitsikapau Lake are presented in Figure 11.26. Water level recording between November 21, 2012 and May 8, 2013 were below zero. The recording of water level below zero may have been due to Levelogger exposure due to water level drop in the lake or ice encapsulation of the Levelogger.

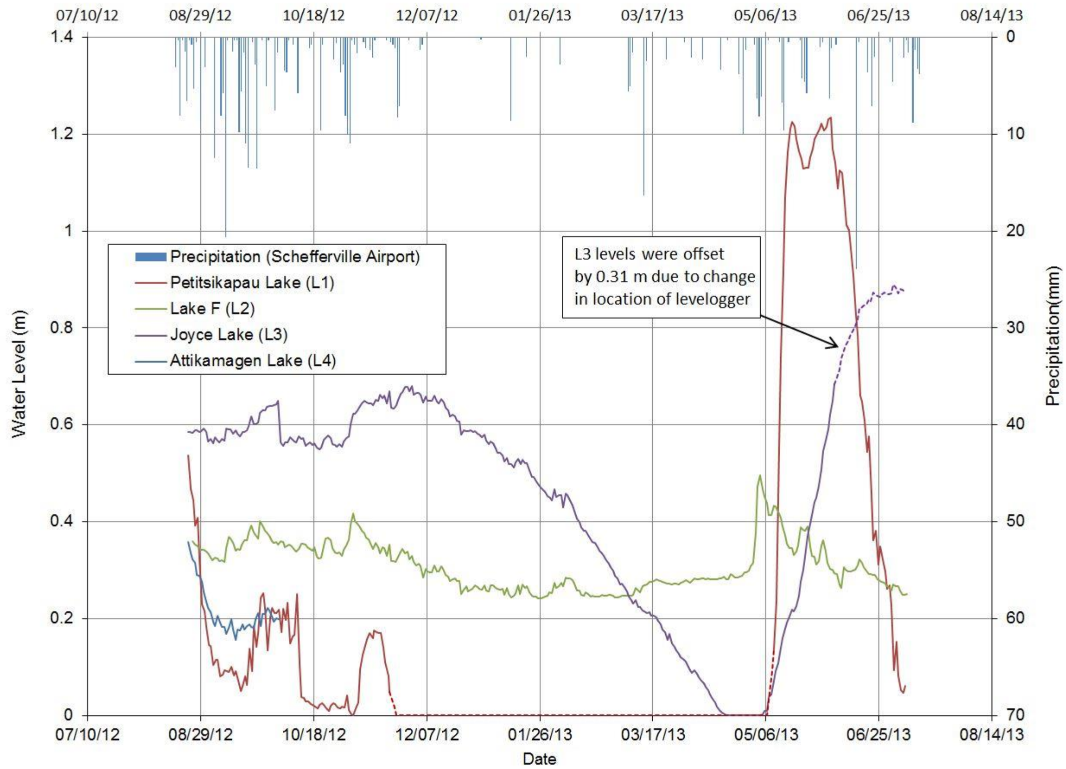

Figure 11.26 Lake Water Levels at Hydrometric Monitoring Stations

Petitsikapau Lake water levels are affected by the operation of the Churchill Falls power generating station located in Churchill River downstream of the Smallwood Reservoir and/or the operation of the Menihek power generating station located at Menihek Lake.

Lake F (L2)

Lake F (Photo 11.2) drains to Iron Arm via a small channel. The drainage area of Lake F is 2.79 km^2 with lake surface area of 0.040 km^2. The hydrometric monitoring station is located on west side of the lake (Photo 11.2). The water level variations in Lake F are presented in Figure 11.26.

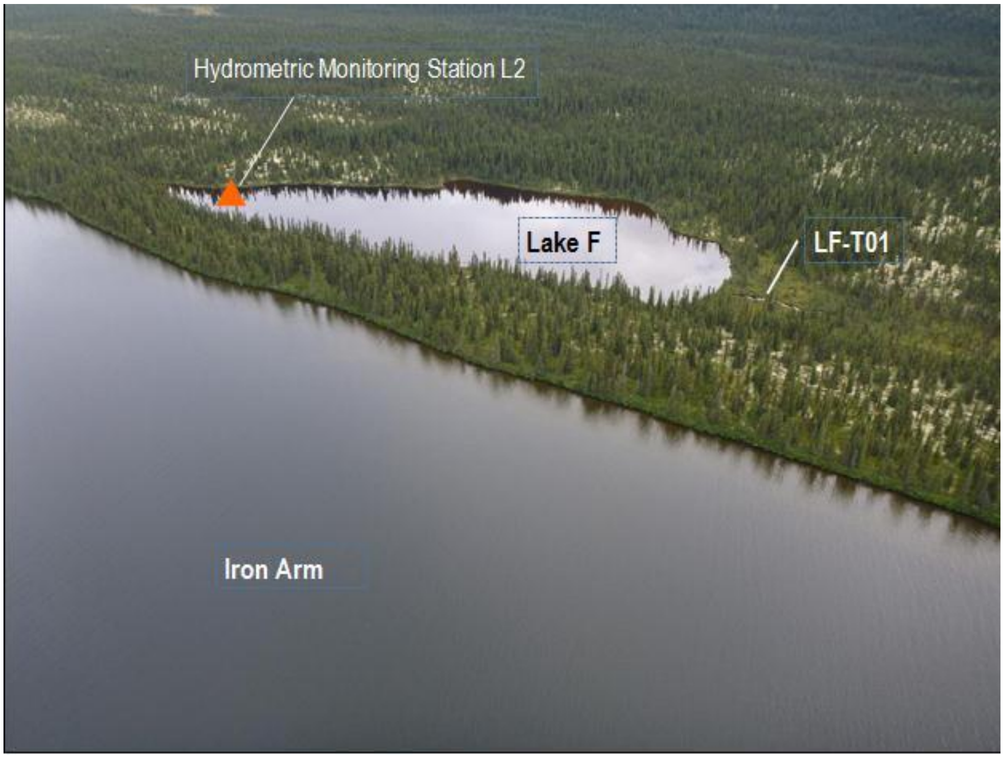

Photo 11.2 Aerial View of Lake F

Joyce Lake (L3)

Joyce Lake does not have a defined surface outlet channel (Photo 11.3); however, during large storm events, it may discharge via a wetland bog channel located at the southeast end of the lake. This channel drains to Timmins Bay via an Unnamed Lake. Stream hydrometric monitoring station S4 is located downstream of Joyce Lake outlet at a point where the watercourse became a defined permanent feature. The drainage area of Joyce Lake is 2.34 km^2 with water surface area of 0.371 km^2. The hydrometric monitoring station (L3) is located on northeast side of the lake (Photo 11.3). The water level variations in Joyce Lake are presented in Figure 11.26. It was observed that the hydrometric monitoring station S4 moved toward the shoreline from its original installation location during the data download on October 2013. And also, a review of water level data from station L3 showed a significant drop in water levels from June 6, 2013 onwards. This drop can be explained by the levelogger being pulled closer to shore perhaps by ice movement and therefore establishing a new datum from which water level data are recorded. This change in datum is corrected by the addition of 0.31 meters to water levels from June 6, 2013 onwards. The water level variations in Joyce Lake are presented in Figure 11.26, with corrected water levels as a dotted line.

Photo 11.3 Aerial View of Joyce Lake

Attikamagen Lake (L4)

Attikamagen Lake drains to Petitsikapau Lake via Iron Arm. The drainage area of Attikamagen Lake is 1,445 km^2 with a water surface area of approximately 428 km^2. Thirty percent of the Attikamagen Lake watershed is covered by water surface area. The hydrometric monitoring station is located in Bay #2 (Figure 11.2). The water level variations in Attikamagen Lake are presented in Figure 11.26. As with station S2, Levelogger data from October 2012 to October 2013 could not be downloaded due to malfunctioning of the Levelogger L4.

11.5.3.3 Environmental Water Balance

The PDA/LSA environmental water balance was modeled on a monthly basis using a spreadsheet-based monthly water balance model. The water balance model requires input of monthly precipitation, average monthly temperature, soil-moisture storage capacity and infiltration factor. The soil-moisture storage capacity for the PDA/LSA is assumed as 200 mm based on the overburden material of 'undifferentiated till' and glacial deposits.

The infiltration factor for the Joyce Lake PDA was calculated to be 0.45 based on a topographical factor of 0.10 for an average slope of 14 m/km, a soil factor of 0.20 for till (sand and clay) and a vegetation factor of 0.15 representing open pasture grassland and woodland cover types as recommended by OMOE (2003). This implies that 45% of net infiltrated precipitation will be discharged to surface water via baseflow.

It is important to note that all water recharging aquifers eventually cycles back to the surface as groundwater discharge providing baseflow to local streams and lakes. As a result, the water balance can be further simplified into precipitation, ET and streamflow.

The water balance model results for the Project area was calibrated with monitored streamflow data and streamflow data from the Environment and Climate Change Canada hydrometric stations located close to the Project area. Tables 11.22, 11.23 and 11.24 show the water balance results under the climate normal, wet year and dry year conditions, respectively. Previous studies of water balance estimates within the Labrador area (Hare 1965; Findlay 1967; Rollings 1997) indicate that streamflow is highly variable across small and large watersheds, with streamflow coefficients ranging from 55% to 85%. The estimated average streamflow coefficients for the hydrometric stations listed in Table 11.7 is 0.83 with standard deviation of 0.17. Streamflow estimates by the water balance model with a total streamflow coefficient of 73% under climate normal conditions, and this generally agreed with the observed streamflow coefficients.

Table 11.22 Water Balance Results under the Climate Normal Conditions (1971 – 2000)

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Precipitation (mm)	53.2	38.7	53.3	61.4	52.1	73.7	107.2	84.5	98.4	80.5	69.4	50.7	823
Evapotranspiration (mm)	0.00	0.00	0.00	0.00	27.3	45.5	59.0	54.5	36.7	0.00	0.00	0.00	223
Surface Runoff (mm)	0.00	0.00	0.00	0.00	238	15.5	26.5	16.5	33.9	0.00	0.00	0.00	330
Infiltration (mm)	0.00	0.00	0.00	0.00	194	12.7	21.7	13.5	27.8	0.00	0.00	0.00	270
Streamflow (mm)[1]	11.4	7.61	7.85	28.0	208	107	50.6	35.9	36.0	46.8	41.2	20.4	600

Notes:
[1] Streamflow for each month was estimated as surface runoff plus monthly infiltration contribution to streamflow. Total infiltration was distributed monthly based on long-term observed streamflow values in Labrador.

Table 11.23 Water Balance Results under Wet Year Conditions (Year 1983)

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Precipitation (mm)	51.2	37.8	110	61.3	28.3	91.5	144	98.1	152	103	82.7	77.7	1038
Evapotranspiration (mm)	0.00	0.00	0.00	0.00	28.3	52.4	56.3	51.7	41.6	0.00	0.00	0.00	230
Surface Runoff (mm)	0.00	0.00	0.00	0.00	288	21.5	48.4	25.5	60.6	0.00	0.00	0.00	444
Infiltration (mm)	0.00	0.00	0.00	0.00	236	17.6	39.6	20.9	49.6	0.00	0.00	0.00	363
Streamflow (mm)[1]	14.5	9.7	10.0	35.6	288	137	67.0	47.1	60.6	59.5	52.4	26.0	807

Notes:
[1] Streamflow for each month was estimated as surface runoff plus monthly infiltration contribution to streamflow. Total infiltration was distributed monthly based on long-term observed streamflow values in Labrador.

Table 11.24 Water Balance Results under Dry Year Conditions (Year 1997)

Parameters	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Precipitation (mm)	17.6	1.8	9.7	23.9	67	33.2	168	42.6	67.4	21.9	41.3	26.5	521
Evapotranspiration (mm)	0.00	0.00	0.00	0.00	25.9	45.1	53.4	53.1	40.7	0.00	0.00	0.00	218
Surface Runoff (mm)	0.00	0.00	0.00	0.00	101	0.00	56.4	0.00	8.90	0.00	0.00	0.00	166
Infiltration (mm)	0.00	0.00	0.00	0.00	82.7	0.00	46.2	0.00	7.29	0.00	0.00	0.00	136
Streamflow (mm)[1]	4.67	3.13	3.22	11.50	104	43.9	56.4	14.8	16.4	19.2	16.9	8.40	303

Notes:
[1] Streamflow for each month was estimated as surface runoff plus monthly infiltration contribution to streamflow. Total infiltration was distributed monthly based on long-term observed streamflow values in Labrador.

The predicted annual ET under the 30-year climate normal conditions was 223 mm based on average monthly temperatures, precipitation, soil storage and vegetation cover type. A review of annual ET estimates provided for the years 1990 – 1995 on the Natural Resource Canada website (http://map.ns.ec.gc.ca/thematic_map/?contexturl=http://map.ns.ec.gc.ca/contexts/waterbudget.xml) indicates that the Project area experienced annual ET ranging from 150 to 200 mm/yr. 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 11.9.

Furthermore, the total infiltration calculated for the Project site was 270 mm/yr or approximately 33% of incident precipitation under the 30-year climate normal condition.

11.5.3.4 Surface Water Supply

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 $30Q_{50}$ (NLDEL 1992; NLDOECC 2005). NLDOECC (2005) indicates that a surface water quantity assessment should include a review of the available yield of the water supply and should demonstrate that:

- where possible, a minimum drought return period of one in fifty years has been used for calculating the safe yield (Q_{50});
- a minimum drought duration of 30 days has been used ($30Q_{50}$);
- the yield is adequate to provide ample water for other legal users of the source including any required fish flows;
- 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
- only live storage has been used in the yield calculations.

Where site-specific stream flow data are 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 11.5.3.2 *Low and Environmental Flows*.

The Attikamagen and Petitsikapau Lakes watershed is a large lake system and is expected to have a significant controlling influence on the outflows. Therefore, outflows from Attikamagen Lake and Petitsikapau Lake were estimated using the data from Environment and Climate Change Canada Hydrometric Station 03PB001 on Naskaupi River at Fermont Lake. Table 11.25 summarizes the $30Q_{50}$ and environmental maintenance flows for two potential water supply sources, Attikamagen Lake and Petitsikapau Lake. The greater of these flows are considered the minimum environmental flow threshold, beyond which water extractions cannot impinge. Environmental maintenance flows are assumed to set the lower water taking limit during summer and winter.

Table 11.25 Minimum Environmental Flow Threshold for Water Supply Sources

Water Supply Name	Drainage Area (km^2)	$30Q_{50}$ (m^3/s)	Environmental Maintenance Flows (m^3/s)	
			Summer	Winter
Attikamagen Lake	1,598	11.0	15.6	7.8
Petitsikapau Lake	2,678	18.5	26.1	13.1

For illustration purposes, Figure 11.27 indicates the total portion of the Iron Arm outlet annual hydrograph above the maintenance flow threshold potentially available for water extraction purposes. Figure 11.28 illustrates the FDCs at the Iron Arm outlet for various wet and dry return periods. The exact water extraction rates, duration and frequency will be subject to climate conditions and further discussions with NLDOECC and DFO. However, this level of water supply potential assessment indicates that significant available surface water sustainable yield is available from Iron Arm.

Local Surface Water Supplies

Surface water is used locally by cottagers within the RSA. The closest public water supply such as for the Town of Schefferville, Matimekush and Kawawachikamach are located outside the RSA and are shown in Figure 11.29.

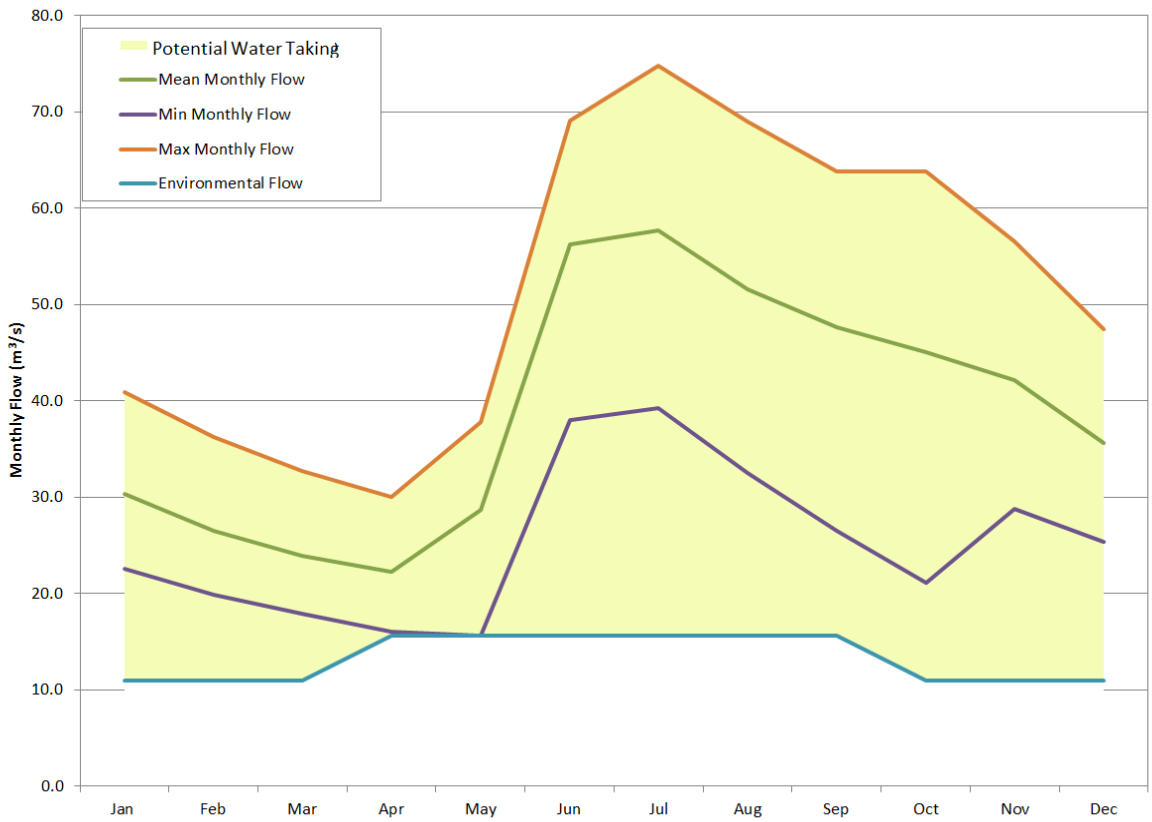

Figure 11.27 Attikamagen Lake Surface Water Supply Capacity

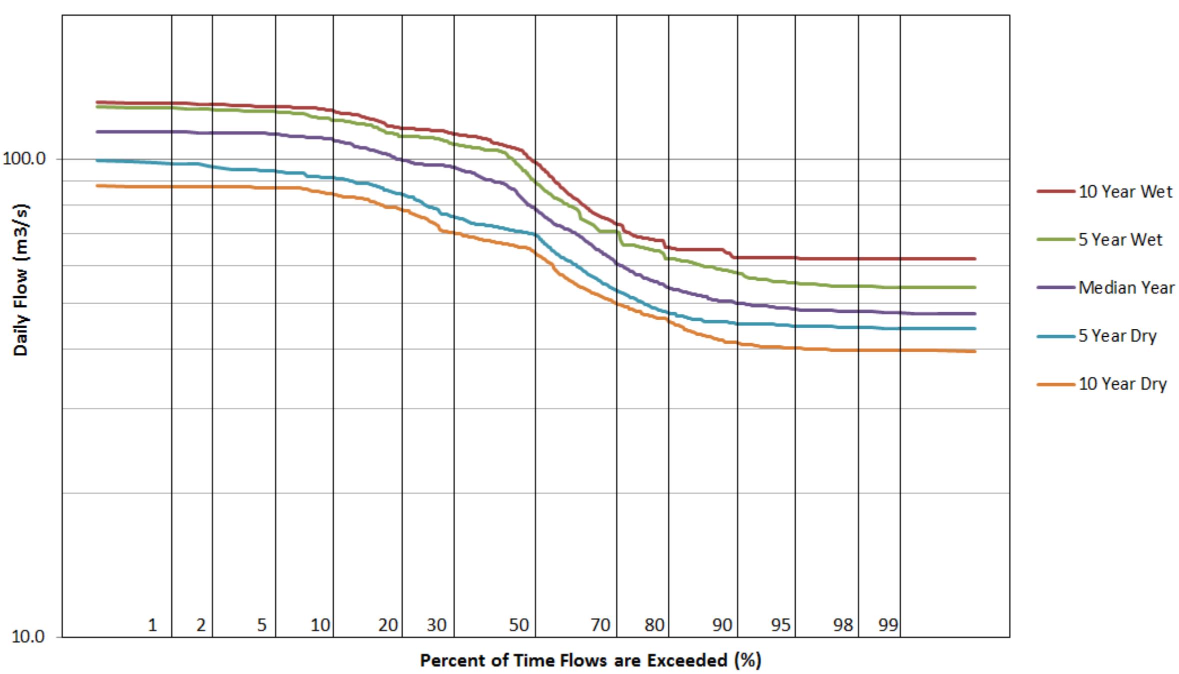

Figure 11.28 FDCs for Attikamagen Lake at the Iron Arm Outlet

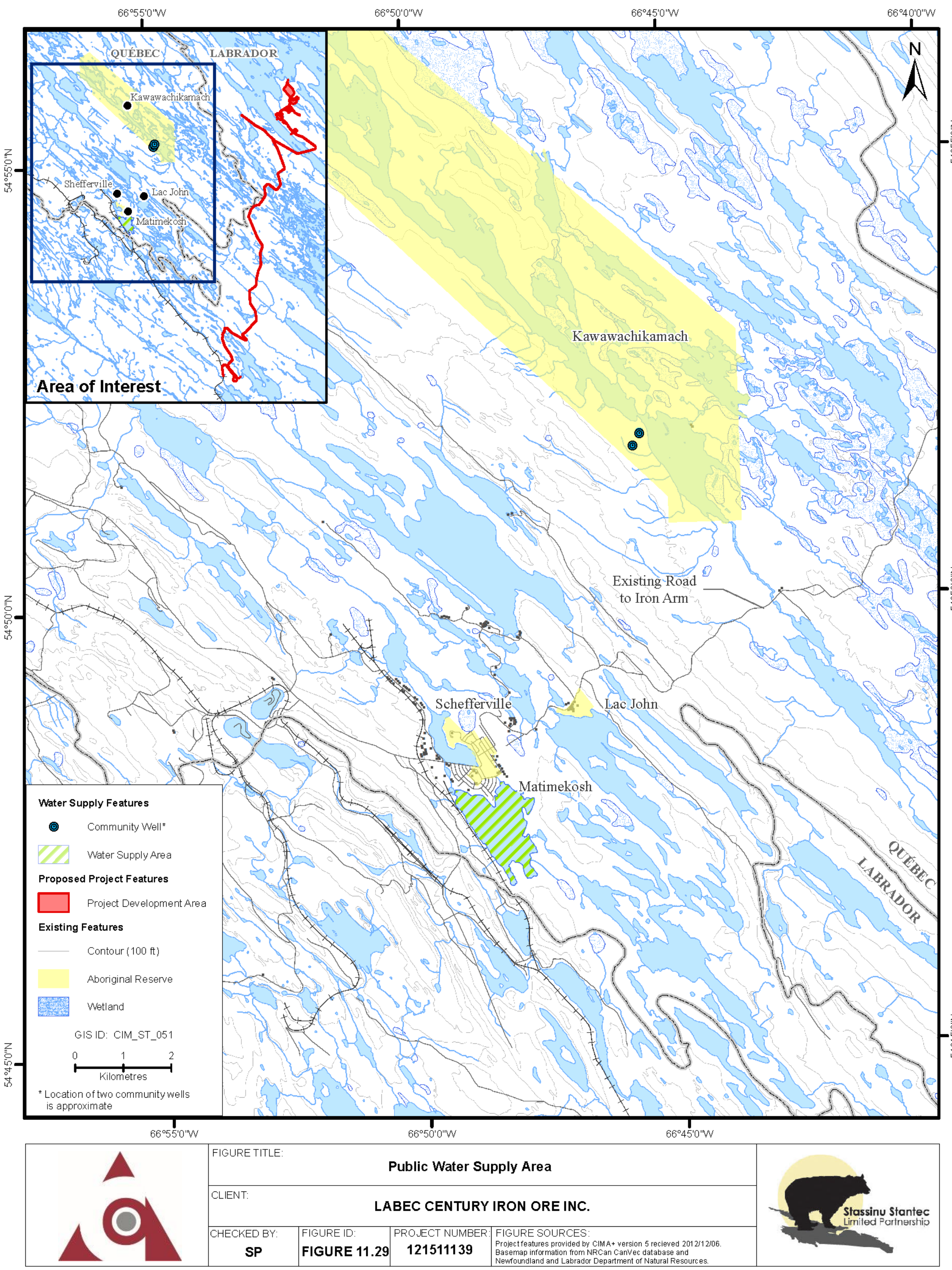

Figure 11.29 Public Water Supply Area

For the Town of Schefferville, drinking water is taken from Lac Knob which lies within the municipal boundary. The chlorination and pumping station is gravity fed, with water being distributed to the community at large via waterlines that serve both the Town of Schefferville and Matimekush. In Kawawachikamach, water is supplied to households from two community wells with a pump station. The sustainability of water supply and preservation of water quality are critical to maintain and are protected in NL and Quebec (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*.

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 Attikamagen Lake at Iron Arm and Petitsikapau Lake.

11.5.3.5 Water and Sediment Quality

Water Quality Regulatory Criteria

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

- CWQG-PAL;
- Schedule 4 of the MDMER (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).

As the Project is the proposed development of a metal mine, the CWQG and MDMER are the primary water quality criteria. The CWQG are those used to assess baseline water quality and assimilative capacity and MDMER are those used to set effluent limits. CWQG and MDMER criteria for parameters assessed in this study are presented in Table 11.26.

Regional Water Quality

The Canada – Newfoundland WQMA facilitates the monitoring of water quality across the province. The NLDOECC has mapped water quality concentration contours across the province. Mapping of those contours is presented in Appendix I. Average WQMA site values for the Project area are presented in Table 11.26.

Based on 2007-2009 monitoring data on freshwater quality in Newfoundland and Labrador, the freshwater quality in the western Labrador region is Good or Excellent as depicted in Figure 11.30.

Table 11.26 Summary of Regulatory Criteria and Reference Water Quality in Western Labrador

Parameter	Units	Regulatory Criteria and Reference Water Quality			
		CWQG-PAL	MDMER[1]		WQMA
			Max Monthly Mean	Max Grab	
Alkalinity	mg/L				4.0332 – 6.5461
Colour	true colour unit (TCU)	Narrative			18.5 – 27.7
Conductivity	µS/cm				8.9 – 515.9
Dissolved Oxygen (DO)	mg/L	6.5 – 9.5 (cold water –life stage)			3.61 – 5.27
pH	pH	6.5 - 9			6.77 – 6.92
Turbidity	nephelometric turbidity unit (NTU)	Narrative			0.0 – 1.98 (Jackson Turbidity Unit; JTU)
Temperature	°C	Narrative			5.2 - 6.7
TSS	mg/L	Narrative	15	30	
Calcium	mg/L				1.70 – 2.11
Chloride	mg/L	640 (short-term); 120 (long-term)			0.15 – 30.12
Fluoride	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	
Dissolved organic carbon (DOC)	mg/L				4.4 – 4.5
Nitrogen (N)	mg/L				0.122 – 0.135
Un-ionized Ammonia	µg/L	19			
Nitrite	mg/L	0.06			
Nitrate	mg/L	13			
Phosphorus	µg/L	< 4 - >100 (trophic status)			7.27 – 11.36
Silica	mg/L				3.45 - 3.59
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
Barium	µg/L				5.59 – 6.72
Boron	µg/L	29,000 (short-term); 1,500 (long-term)			
Beryllium	µg/L				0.025 – 0.027
Cadmium	µg/L	Hardness adjusted			0.103 – 0.117
Cobalt	µg/L				0.05 – 0.09
Chromium	µg/L				0.55 – 0.79

Table 11.26 Summary of Regulatory Criteria and Reference Water Quality in Western Labrador

Parameter	Units	Regulatory Criteria and Reference Water Quality			
		CWQG-PAL	MDMER[1]		WQMA
			Max Monthly Mean	Max Grab	
Copper	µg/L	Hardness adjusted, a minimum of 2 µg/l regardless of water hardness (Demayo and Taylor 1981)	300	600	3.79 – 4.34
Iron	µg/L	300			61.8 – 185.9
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
Lithium	µg/L				0.11 - 0.15
Manganese	µg/L	Variable, hardness adjusted			3.7 - 8.2
Mercury	µg/L	0.026			0.059 – 0.071
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	0.23 – 0.36
Selenium	µg/L	1			0.05 – 0.057
Strontium	µg/L				13.3 - 14
Silver	µg/L	0.25			
Thallium	µg/L	0.8			
Uranium	µg/L	33 (short-term), 15 (long-term)			
Vanadium	µg/L				0.05 – 0.19
Zinc	µg/L	Hardness adjusted	500	1000	3.4 – 3.8
$Radium_{226}$	Bq/L		0.37	1.11	

Notes:
1. The MDMER 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 MDMER effluent criteria carried forward in Project effects assessments.

CWQG-PAL – Canadian Water Quality Guidelines for the Protection of Aquatic Life

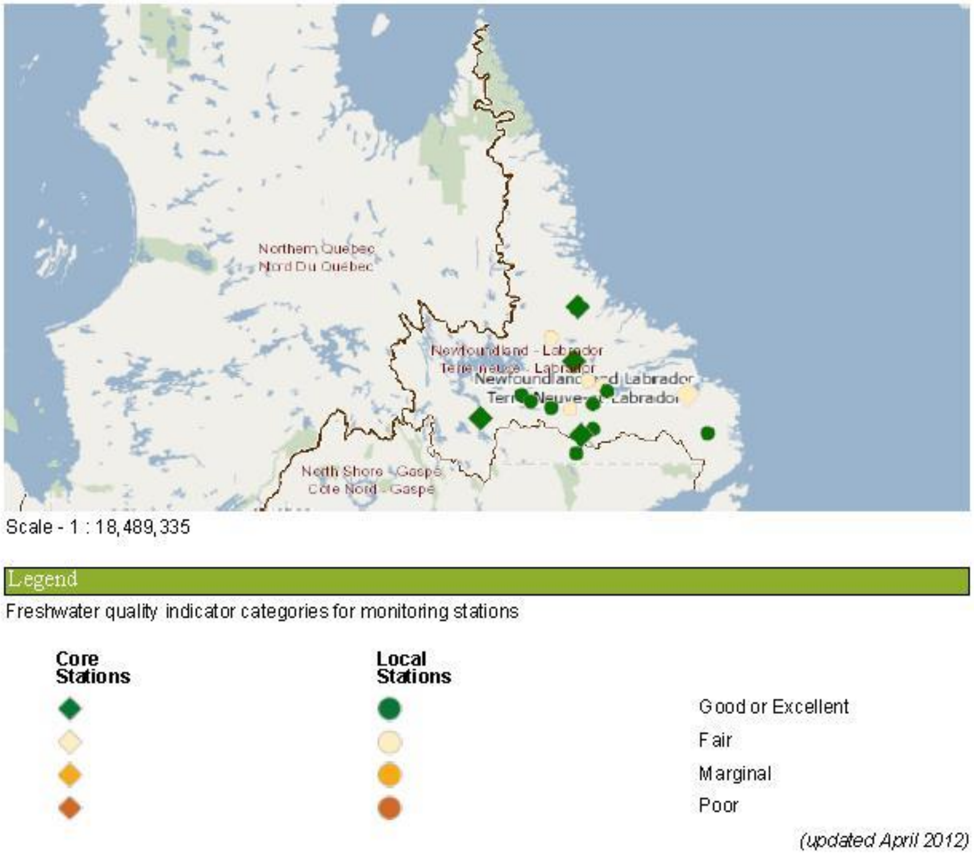

Figure 11.30 Water Quality Map for Labrador (Environment and Climate Change Canada)

LSA Water Quality

General Constituents

As discussed in previous sections, leveloggers were installed at four stream monitoring stations (S1, S2, S3 and S4) and four lake monitoring stations (L1, L2, L3 and L4). Water temperature for each station was recorded at 10 minute intervals commencing from August 2012. Figures 11.31 and 11.32 present the temperature monitoring results at the four stream monitoring stations and four lake monitoring stations along with Schefferville Airport air temperature from August 2012 to early July 2013.

The recorded temperatures were slightly above 0°C and remain relatively constant between middle of November, 2012 and the first week of May, 2013 except station L1 as can be seen from Figures 11.31 and 11.32. Station L1 may be exposed and be recording the air temperature. Water temperature information recorded at the time of water quality sampling is presented in Appendix J.

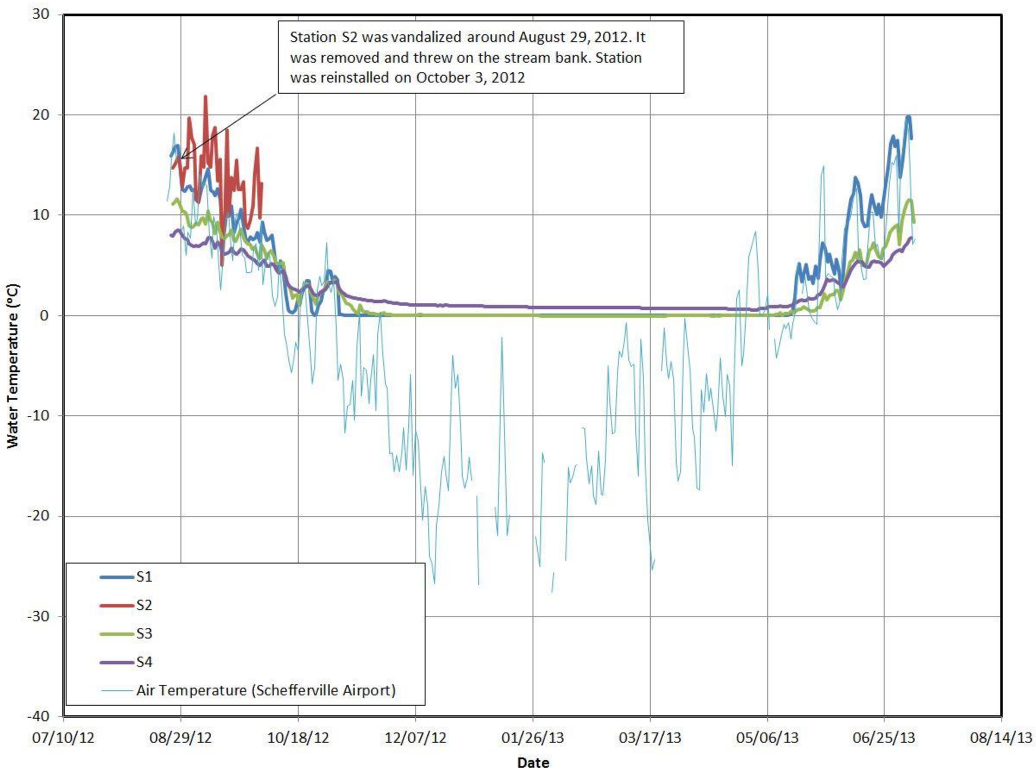

Figure 11.31 Water Temperature for Stream Monitoring Stations

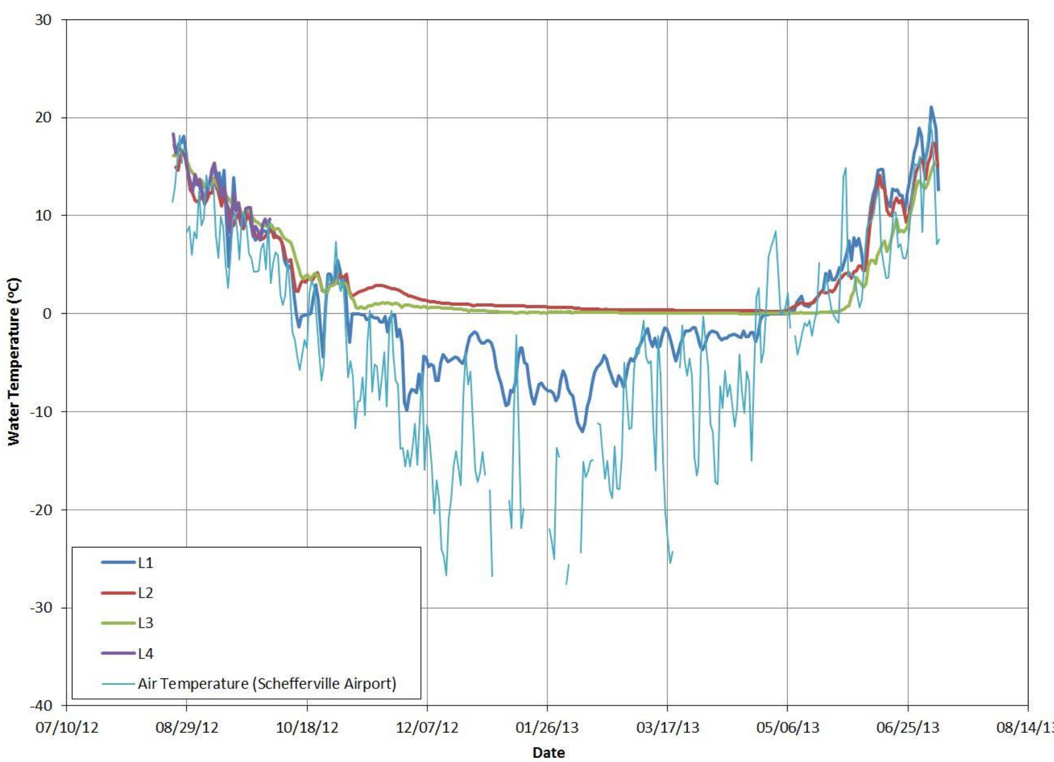

Figure 11.32 Water Temperature for Lake Hydrometric Monitoring Stations

Table 11.27 presents summary statistics for all lab analytical general constituents. All lab analytical water quality results are presented in Appendix J.

Table 11.27 Summary of General Constituents

Parameter	Units	CWQG-PAL	Min[4]	Mean[4]	Max[4]	75th Percentile[4]
Anion Sum	me/L		0	0.30	1.26	0.26
Acidity	mg/L		2.5	3.0	8.4	2.5
Bicarbonate Alkalinity (calcium as Calcium Carbonate [$CaCO_3$])	mg/L		0.5	13	57	11.75
Calculated TDS	mg/L		2	19	64	20
Carb. Alkalinity (calc. as $CaCO_3$)	mg/L		0.5	0.5	0.5	0.5
Cation Sum	me/L		0.06	0.36	1.27	0.35
Conductivity	µS/cm		5.3	32	110	28.75
Colour	TCU	Narrative[1]	2.5	28	120	46.25
Dissolved Chloride (Cl)	mg/L		0.5	0.5	0.5	0.5
Dissolved Fluoride (F-)	mg/L	0.120 (inorganic F)	0.05	0.05	0.05	0.05
Hardness ($CaCO_3$)	mg/L		2.1	16	62	13.75
Ion Balance (% Difference)	%		0.79	26	100	20.1
Langelier Index (@ 20C)	N/A		-3.87	-2.52	-0.453	-2.335
Langelier Index (@ 4C)	N/A		-4.12	-2.776	-0.705	-2.587
pH	pH	6.5-9	6.55	7.06	8.05	7.25
Reactive Silica (SiO_2)	mg/L		1.2	3.3	6	4.3
Strong Acid Dissoc. Cyanide (Cn)	mg/L	0.005 (as free CN)	0.001	0.001	0.001	0.001
Saturation pH (@ 20C)	N/A		8.50	9.72	10.50	9.94
Saturation pH (@ 4C)	N/A		8.76	9.96	10.70	10.18
Total Alkalinity (Total as $CaCO_3$)	mg/L		2.5	14	58	11.75
TDS	mg/L		5	33	69	37
TSS	mg/L	Narrative[2]	0.5	2.7	9.2	2.9
Turbidity	NTU	Narrative[3]	0.45	1.09	3.1	1.25

Notes:

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.

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).

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).

The statistical results here include monitoring location samples (from August 2012, October 2012 and October 2013).

me/L = milliequivalent per litre

CWQG-PAL – Canadian Water Quality Guidelines for the Protection of Aquatic Life

The lab results indicated that pH ranged from 6.6 to 8.1 with mean value of 7.1. Station S1 has higher pH values of 8.0, 8.1 and 7.9 from August 2012, October 2012 and October 2013 samples respectively which demonstrated slightly alkaline conditions. pH values at stations S4 and L3 are approximately 6.6 for both August 2012 and October 2012 samples, and approximately 6.3 for October 2013 samples. Generally the results were within CWQG-PAL limits which range from 6.5 to 9.0, except at stations S4 and L3 for October 2013 samples.

Total alkalinity (as Calcium Carbonate [$CaCO_3$]) ranges from below detection limit 5.0 mg/L to 58 mg/L with mean of 13.4 mg/L. For stream station S1, the total alkalinity (as $CaCO_3$) is 58 mg/L, 56 mg/L and 53 mg/L for the August 2012, October 2012 and October 2013 samples, which are higher than the rest of the samples. Station S4 and L3 have lower values of total alkalinity. However, the alkalinity values for all stations are generally low. Low alkalinity values suggest limited acid buffering potential in streams and lakes.

Hardness (as $CaCO_3$) values range from 2.1 mg/L to 62 mg/L with mean of 15.9 mg/L. Similar to the results for total alkalinity, station S1 and L3 were observed to have highest and lowest values respectively for total hardness among the eight stations. Hardness within the range of 0 to 60 mg/L is considered as soft water. Concentrations for copper, cadmium, lead and nickel are hardness-adjusted in CWQGs. The lower hardness value results in lower CWQGs thresholds for metals stated above.

Langelier Saturation Index values for all monitoring locations are negative which an indicative of under-saturation and tends to dissolve solid calcium carbonate ($CaCO_3$). Therefore, water with negative Langelier Saturation Index has limited scaling potential. The potential for scale formation is an important consideration in the selection and design of water infrastructure, as well as in the use of lime and limestone in the potential treatment of ARD.

Electrical conductivity values for all samples are generally low and range from as low as 5.3 µs/cm to 110 µs/cm with mean of 31.7 µs/cm. The higher value of 110 µs/cm was observed at stream station S1. The lowest value of 5.3 µs/cm was observed at lake station L3. 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 balances for all monitoring location were positive and range from 0.42% to 100%. This is expected in light of the soft water 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 ranged from 5 mg/L to 69 mg/L with mean of 27.1 mg/L. The highest TDS concentration was observed at station S1 at 69 mg/L. The lowest values were observed at stations L1 and L3 with a TDS concentration of 5 mg/L. Similar to the conductivity results, the highest and lowest values were observed at stations S1 and L3 where the TDS values are 69 mg/L and 5 mg/L. 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 monitoring stations were low with mean of 16.3 mg/L and ranging from <1 mg/L (below the detection limit) to a maximum of 180 mg/L.

The high total suspended solids concentration of 180 mg/L was observed at stations S3 and L2 during October 2013 samples. Turbidity levels observed are typical of very low values ranging from 0.45 nephelometric turbidity unit (NTU) to 3.1 NTU. Colour ranged from 2.5 – 150 true colour unit (TCU) with mean of 29.7 TCU. The mean colour value is slightly above the Canadian Drinking Water Quality Aesthetic Guideline of 15 TCU for colour. Colour in local surface water is expected to be derived from the decomposition of organic humic substances, such as tannins derived for soils and tree bark and lignins from woody plants and trees.

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 monitoring locations were below the detection limit of 2 µg/L.

The water quality results from the water and sediment baseline study (GENIVAR 2013) are generally in agreement with the water quality results in the present study for general constituents and are presented in Appendix J.

Nutrients

Table 11.28 presents summary for all lab analytical nutrients. All lab analytical nutrient results are also presented in Appendix J.

Table 11.28 Summary of Nutrients

Parameter	Units	CWQG-PAL	Min[3]	Mean[3]	Max[3]	75th Percentile[3]
Nitrate + Nitrite	mg/L		0.025	0.025	0.025	0.025
Nitrate (N)	mg/L	13	0.025	0.025	0.025	0.025
Nitrite (N)	mg/L	0.06	0.005	0.005	0.005	0.005
Nitrogen (Ammonia Nitrogen)	mg/L	See Table[1]	0.025	0.040	0.13	0.046
Dissolved Sulphate (SO_4)	mg/L		1	2.7	10	4.1
Orthophosphate (P)	mg/L		0.005	0.005	0.005	0.005
Total Organic Carbon (C)	mg/L		0.66	4.0	13	6.2
Total Phosphorus (TP)	mg/L	See Note[2]	0.006	0.012	0.021	0.014

Notes:
Ammonia concentration under different pH and temperatures, please see table at: http://st-ts.ccme.ca/?lang=en&factsheet=5#aql_fresh_concentration.
Ultra-oligotrophic <4, oligotrophic 4-10, mesotrophic 10-20, meso-eutrophic 20-35, eutrophic 35-100, hyper-eutrophic >100.
The statistical results here include monitoring location samples (August 2012, October 2012 and October 2013).
CWQG-PAL – Canadian Water Quality Guidelines for the Protection of Aquatic Life

Total ammonia-N ranged from below the 0.05 mg/L detection limit to 0.13 mg/L and were all consistently below the CWQG of 1.83 mg/L (Ammonia concentration at pH 7.5, temperature 15°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 19 µg/L. Nitrate concentrations are below 0.05 mg/L detection limit for all monitoring locations with the exception station S4 with a concentration of 0.091 mg/L observed from October 2013 sampling. 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 mg/L and the CWQG of 0.06 mg/L, except station S4 has a concentration of 0.09 mg/L from October 2013 sampling.

Orthophosphate levels were below the detection limit of 10 µg/L, except for station L2 where a concentration of 11 µg/L was observed during October 2013 sampling. Total Phosphorus (TP) values ranged from 0.006 mg/L to 0.027 mg/L. The CWQGs indicate that TP concentrations from 0.006 – 0.021 mg/L range from ultra-oligotrophic to meso-trophic, respectively.

Sulphate concentrations ranged from below 2 mg/L to 10 mg/L which is much lower than the 30-day average concentration of dissolved sulphate of 128 mg/L recommended in the protection of aquatic life in the BC ambient water quality guideline for sulphate (Meays and Nordin 2013). No CWQG exists for sulphate.

The water quality results from the water and sediment quality baseline study (GENIVAR 2013) are generally in agreement with the water quality results in the present study for nutrients and are presented in Appendix J.

Metals

Table 11.29 presents summary statistics for all lab analytical metals results and all lab analytical metals results are presented in Appendix J.

Table 11.29 Summary of Metals

Parameters	Units	CWQG-PAL[6]	MDMER[7]	Min[5]	Mean[5]	Max[5]	75th Perce-ntile[5]
Total Mercury (Hg)	µg/L	0.026		0.0065	0.01	0.0065	0.0065
Total Aluminum (Al)		5 µg/L if pH <6.5; 100 µg/L if pH ≥6.5		7.2	55	201	83
Total Antimony (Sb)	µg/L			0.5	0.50	0.5	0.5
Total Arsenic (As)	µg/L	5	1000	0.5	0.50	0.5	0.5
Total Barium (Ba)	µg/L			0.5	1.39	2.6	1.9
Total Beryllium (Be)	µg/L			0.5	0.50	0.5	0.5
Total Bismuth (Bi)	µg/L			1	1.00	1	1
Total Boron (B)	µg/L	1500 µg/L (Long-term) ; 29,000 µg/L (Short-term)		25	25	25	25
Total Cadmium (Cd)	µg/L	See Note[1]		0.0085	0.02	0.116	0.021
Total Calcium (Ca)	µg/L			403	3280	11900	3390
Total Chromium (Cr)	µg/L			0.5	0.50	0.5	0.5
Total Cobalt (Co)	µg/L			0.2	0.35	1.01	0.45
Total Copper (Cu)	µg/L	See Note[2]	600	1	1.8	6	2.2
Total Iron (Fe)	µg/L	300		25	324	1550	331
Total Lead (Pb)	µg/L	See Note[3]	400	0.25	0.25	0.25	0.25

Table 11.29 Summary of Metals

Parameters	Units	CWQG-PAL[6]	MDMER[7]	Min[5]	Mean[5]	Max[5]	75th Perce-ntile[5]
Total Magnesium (Mg)	µg/L			281	1872	7800	1802
Total Manganese (Mn)	µg/L			3	46	361	41
Total Molybdenum (Mo)	µg/L	73		1	1.00	1	1
Total Nickel (Ni)	µg/L	See Note[4]	1000	1	1.87	4.8	2.7
Total Potassium (K)	µg/L			50	202	410	295
Total Selenium (Se)	µg/L	1		0.5	0.50	0.5	0.5
Total Silicon (Si)				0	730	2730	1497
Total Silver (Ag)	µg/L	0.25		0.05	0.05	0.05	0.05
Total Sodium (Na)	µg/L			208	542	838	682
Total Strontium (Sr)	µg/L			1	11	28	15
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	1.2	2.6	1
Total Uranium (U)	µg/L	15 (Long-term) ; 33 (Short-term)		0.05	0.06	0.13	0.05
Total Vanadium (V)	µg/L			1	1.00	1	1
Total Zinc (Zn)	µg/L		1000	2.5	4.91	16.2	5.25

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: http://st-ts.ccme.ca/?lang=en&factsheet=139#aql_fresh_concentration.
5. The statistical results here include monitoring location samples (from August and October 2012).
6. CWQG-PAL – Canadian Water Quality Guidelines for the Protection of Aquatic Life
7. MDMER – values presented in the table are maximum authorized concentration in grab samples

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 12.29. Comparison of analytical results for these metals was conducted by calculating the individual sample hardness-adjusted CWQG limit or lower arbitrary limit. The total cadmium values ranged from below 0.017 µg/L RDL to 0.116 µg/L. The hardness adjusted CWQG limits for cadmium ranged from 0.0012 µg/L to 0.0220 µg/L. The total cadmium values exceeded the CWQG at stations S2, S3, L1, L2 and L4 however are in the range of cadmium concentrations observed in the WQMA.

Copper concentration ranged from 1 µg/L to 6 µg/L. 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). Copper concentrations exceeded the CWQG at stations S1, S2 and L3, however are in the range of copper concentrations observed in the WQMA.

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 below the CWQG limit of 300 µg/L except at stations S3, S4, L2 and L4. The total iron concentrations at station S3 is 1480 µg/L, 1550 µg/L, 1000 µg/L for August 2012, October 2012 and October 2013 samples respectively. Stations L2 and L4 only exceeded total iron concentration for October 2013 samples at 1000 µg/L and 320 µg/L respectively. Arsenic, uranium and radium226 concentrations were well below their respective CWQG and/or MDMER criteria.

Aluminum concentrations ranged from 7.2 µg/L to 560 µg/L with mean of 77.3 µg/L. The CWQG threshold for aluminum for the protection of aquatic life is 5 µg/L if pH < 6.5 and 100 µg/L if pH > 6.5. The aluminum concentration at station S3 was 182 µg/L, 201 µg/L and 170 µg/L for August 2012, October 2012 and October 2013 samples respectively and exceeded the CWQG limit. The aluminum concentration at station L2 for October 2013 samples was 560 µg/L, also exceeding the CWQG limit.

Concentrations of other metals including boron, molybdenum, selenium, silver, and zinc were well below the CWQG limits.

The water quality results from the water and sediment quality baseline study (GENIVAR 2013) are generally in agreement with the water quality results in the present study for metals and are presented in Appendix J.

Sediment Quality 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 of Project site is discussed in the following section.

In 2006, a detailed lake sediment and water survey was conducted in central and western Labrador. Samples were collected from National Topographic System (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 about 20 km southwest of the Project, and the Winokapau Lake area is located about 340 km southeast of the Project. Figure 11.33 presents the locations of survey area in Map zone 23J, I and Q as well as 13E (McConnell and Ricketts 2011).

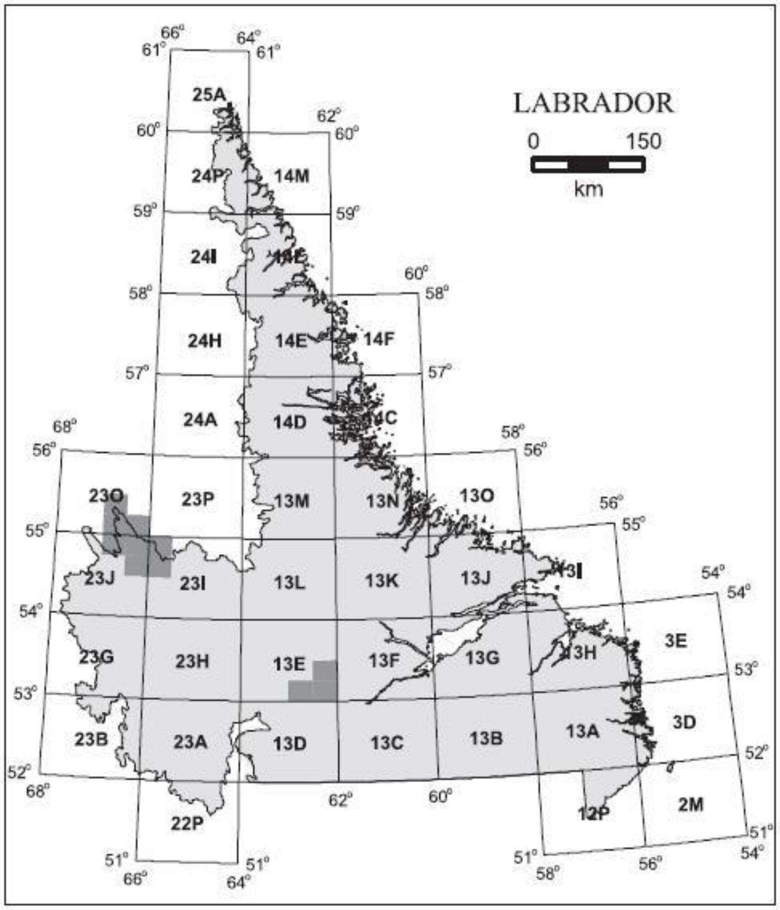

Figure 11.33 Locations for Sediment and Water Survey in Central and Western Labrador in 2006

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.

PDA/LSA Sediment Quality

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

Particle Size Distribution

Sediment sampling locations are mapped in Figure 11.2. The particle size distribution for all sediment samples is plotted in Figure 11.34. Sediment in Attikamagen Lake – Bay 3 is described as silty clay and sand with trace of gravel having grain sizes of 6% gravel, 18% sand, 55% silt, as well as 21% clay. Joyce Lake and Iron Arm sediments are also described as silty clay and sand with trace of gravel. Sediments in Gilling River are predominantly sand with traces of gravel and clay. Sediment at Petitsikapau Lake is gravel with sand and silt. Note however that cobble and boulder class materials were also observed in all of the stream sampling locations, except Lake F.

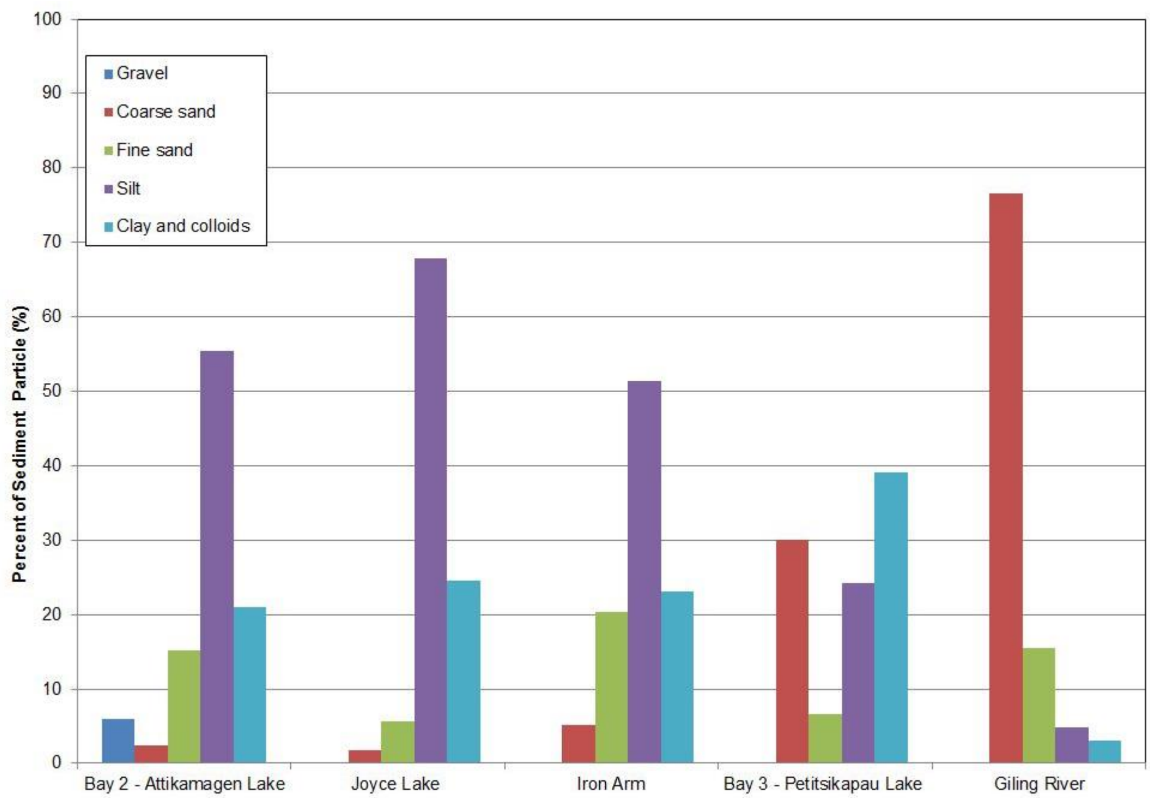

Figure 11.34 Particle Size Distribution

Metals

Most metals concentrations from sediment samples were below their respective CSQG ISQG and the PEL. The exceptions are arsenic and cadmium: arsenic concentrations exceeded the ISQG of 5.9 mg/kg for all stations except at Gilling River and cadmium concentrations exceeded the ISQG of 0.6 mg/kg at all sampling locations. The Gilling River zinc concentration exceeded the ISQG of 123 mg/kg and the Petitsikapu Lake-Bay 3 zinc concentration exceeded the PEL of 315 mg/kg. A summary of the metal concentrations for sampling locations are presented in Table 11.30 and other constituents are presented in Table 11.31.

Table 11.30 Summary of Metal Concentrations for Sediment Samples

Parameters	Units	CSQG-PAL[1]		Min	Mean	Max	75th Percentile
		ISQG[2]	PEL[3]				
Aluminum	mg/kg	-	-	3640	11807	13700	13575
Antimony	mg/kg	-	-	5	5	5	5
Arsenic	mg/kg	5.9	17	5.7	9.3	15.1	11.6
Barium	mg/kg	-	-	42	61	100	63
Beryllium	mg/kg	-	-	0.5	0.5	0.5	0.5
Bismuth	mg/kg	-	-	5	5	5	5
Boron	mg/kg	-	-	1	1	1	1
Cadmium	mg/kg	0.6	3.5	0.45	1.4	3.5	1.3
Calcium	mg/kg	-	-	441	1380	2420	1660
Chromium	mg/kg	37.3	90	13	36	49	42
Cobalt	mg/kg	-	-	9	14	23	17
Copper	mg/kg	35.7	197	9	43	56	53
Iron	mg/kg	-	-	29300	36417	46900	40800
Lead	mg/kg	35	91.3	5	10	18	11
Lithium	mg/kg	-	-	5	13	17	16
Magnesium	mg/kg	-	-	1530	4310	7100	4998
Manganese	mg/kg	-	-	455	1075	2310	1681
Molybdenum	mg/kg	-	-	1	3	4	4
Nickel	mg/kg	-	-	16	49	87	59
Potassium	mg/kg	-	-	247	876	1380	1089
Selenium	mg/kg	-	-	0.6	1.0	1.3	1.2
Silver	mg/kg	-	-	0.25	0.25	0.25	0.25
Sodium	mg/kg	-	-	107	140	166	158
Strontium	mg/kg	-	-	5	8	24	5
Thallium	mg/kg	-	-	5	5	5	5
Tin	mg/kg	-	-	2.5	2.5	2.5	2.5
Titanium	mg/kg	-	-	55	338	523	440
Vanadium	mg/kg	-	-	17	35	42	41
Zinc	mg/kg	123	315	42	177	326	200

Notes:
[1] Canadian Sediment Quality Guidelines for the Protection of Aquatic Life
[2] Interim Sediment Quality Guideline, below which effects to aquatic life are not expected to occur
[3] Probable Effect Level, above which effects to aquatic life are expected to occur
CSQG have not been developed

Table 11.31 Summary of Other Constituents for Sedimen Samples

Parameters	Units	CSQG-PAL[1]		Min	Mean	Max	75th Percentile
		ISQG[2]	PEL[3]				
Ammoniacal nitrogen	mg/kg	-	-	2.5	32	59	53
Chloride	mg/kg	-	-	5.0	5.3	6.0	5.4
Conductivity	µS/cm	-	-	14	24	36	29
Moisture	%	-	-	23.7	61.4	87.1	82.8
Nitrite-nitrate	mg/kg	-	-	1.0	1.6	2.6	2.1
pH		-	-	5.6	6.2	7.2	6.6
Sulphate	mg/kg	-	-	5	163	321	277
Total organic carbon	%	-	-	0.55	4.05	8.43	7.08

Notes:
[1] Canadian Sediment Quality Guidelines for the Protection of Aquatic Life
[2] Interim Sediment Quality Guideline, below which effects to aquatic life are not expected to occur
[3] Probable Effect Level, above which effects to aquatic life are expected to occur
CSQG have not been developed

11.5.3.6 Local Receiving Water Assimilative Capacity

Existing Water Uses, Impacts and Constraints

Existing water uses important to assimilative capacity assessments include extractive uses, effluent discharge uses, recreational uses, and water quality and ecological sensitivities.

No 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 should be avoided due to ice cover depth and limited vertical mixing potential;

- Avoidance of shallow zones also addresses ecological concerns for areas used by fish for redd development and juvenile rearing;

- Effluent discharge points and configuration should be in locations deep enough and at discharge orientations to avoid or reduce 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; and
  - 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 reduced to the point where the mixing zone does not extend beyond the boundary of the receiver and not beyond the boundary of the LSA; and
- Project water quality effects on local receivers should be contained within the LSA boundary, thereby minimizing the potential for water quality residual and downstream cumulative effects.

The larger lakes in the LSA and RSA likely have the greatest potential as water supply sources for the Project. Therefore, the potential sites for water extraction include the Attikamagen Lake and Petitsikapau Lake due to their size and proximity to major Project component facilities.

Existing Net Assimilative Capacity

NLDOECC (2005) provides guidance on the development of receiving water quality objectives through the conduct of a receiving water study. 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 guideline in this case is the CWQG-PAL. Dilution ratios should be based on receiver flows at the 7Q20 low flow threshold and the peak hourly effluent discharge rate.

NLDOECC (2005) indicates the following mixing zone criteria:

No conditions within the mixing zone should be permitted which:

- 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);
- Cause irreversible responses which could result in detrimental post-exposure effects;
- Result in bioconcentration of toxic materials which are harmful to the organism or its consumer; or
- 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:

- 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);
- 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;
- Eliminate rapid changes in the water quality, which could kill organisms by shock effects;
- 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;
- 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:

- Free from substances in concentrations or combinations which may be harmful to human, animal or aquatic life;
- Free from substances that will settle to form putrescent or otherwise objectionable sludge deposits, or that will adversely affect aquatic life or waterfowl;
- Free from debris, oil, grease, scum or other materials in amounts sufficient to be noticeable in the receiving water;
- Located so as not to interfere with fish spawning and nursery areas;
- Free from colour, turbidity or odour-producing materials that would:
  - Adversely affect aquatic life or waterfowl;
  - Significantly alter the natural colour of the receiving water;
  - Directly or through interaction among themselves or with chemicals used in water treatment, result in undesirable taste or odour in treated water; and
  - 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.

Table 11.32 provides the instantaneous assimilative load capacity for Attikamagen Lake and Petitsikapau Lake based on 7Q20 outlet flow and the 75th% MDMER metal baseline concentrations. Based on this preliminary assessment, Petitsikapau Lake 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. All the assessed lakes do not have assimilative capacity for copper and iron since their background levels are higher than CWQG values. More detailed assessments of local receiving water body assimilative capacity will be needed.

Table 11.32 Instantaneous Assimilative Capacity of Selected LSA Waterbodies

Parameter 7Q20 flow Instantaneous Load	Units m^3/sec	CWQG-PAL[1]	75^{th} Percentile[2]	Attikamagen Lake 12.4	Petitsikapau Lake 20.9
				kg/sec	
Arsenic	µg/L	5	0.5	5.60×10^{-5}	9.38×10^{-5}
Copper	µg/L	2	2.2	-	-
Iron	µg/L	300	357	-	-
Lead	µg/L	1	0.25	9.33×10^{-6}	1.56×10^{-5}
Nickel	µg/L	25	2.2	2.84×10^{-4}	4.75×10^{-4}
Zinc	µg/L	37 short term 7.0 long term	6.0	2.99×10^{-4}	5.01×10^{-4}

Notes:
[1] Canadian Water Quality Guidelines for the Protection of Aquatic Life.
[2] 75^{th} percentile of baseline concentrations.

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.

11.6 Assessment of Project-Related Environmental Effects

The Project will cause some disturbance to surface water hydrologic systems and water quality in the LSA during the various phases of the Project including Construction, Operation and Maintenance, and Closure and Decommissioning. Activities identified in Table 11.3 with a rating of 2 are considered to have the potential to affect local or regional water resources either temporarily or permanently, and are further discussed in detail below. Modeling assumptions were based on the Project PEA published May 8, 2013. The Project description was modified in 2014 to match the FS published April 14, 2015. Project characteristics used as inputs for this assessment may have since changed as a result of the updated description.

11.6.1 Construction

11.6.1.1 Potential Environmental Effects

Project activities and physical works rated as 2 during Construction include: site preparation; construction of roads, construction of causeway, construction of site buildings and associated infrastructure; and construction of rail loop and associated infrastructure. The primary potential adverse effects to surface water during Construction include:

- Increased runoff from disturbed ground surfaces due to increases in imperviousness and reduction of vegetative cover;
- Change in flow patterns, water levels and water quality in Iron Arm due to construction of causeway;
- Increased TSS and changes in drainage patterns from disturbed ground surfaces;
- Increased erosion scour and sediment in watercourses;
- Change in water and sediment quality;
- Flow reductions arising from water extraction for dust suppression, and construction activities; and
- Watercourse alterations/realignments to accommodate construction.

The potential effects resulting from Project Construction to surface water quantity, quality and/or drainage patterns are summarized in Table 11.33. A further detailed discussion of the potential effects of the construction of the causeway is provided below.

Table 11.33 Construction Phase Potential Project Environment Effects to Surface Water

<table>
<tr><th rowspan="2">Project Activities and Physical Works</th><th colspan="3">Potential Environmental Effects</th></tr>
<tr><th>Change in Surface Water Quantity</th><th>Change in Surface Water Quality</th><th>Change in Surface Water Drainage Patterns</th></tr>
<tr><td>Site Preparation (including clearing, excavation, material haulage, grading, removal of overburden and stockpiling)</td><td rowspan="2">These activities may increase runoff potential and reduce ET and infiltration potential through increases in surface slope and surface hardening and compaction, surface disturbance and instability and vegetation removal. This is applicable to all Project site preparation areas. Water extractions for dust suppression, and construction could affect water quantity.</td><td rowspan="2">Site preparation and construction may increase erosion and sedimentation and thereby degrade surface water quality. This is applicable to all Project site preparation areas.</td><td rowspan="2">Site preparation and construction may alter the drainage patterns locally in PDA.</td></tr>
<tr><td>Construction of Site Buildings and Associated Infrastructure</td></tr>
</table>

Table 11.33 Construction Phase Potential Project Environment Effects to Surface Water

Project Activities and Physical Works	Potential Environmental Effects		
	Change in Surface Water Quantity	**Change in Surface Water Quality**	**Change in Surface Water Drainage Patterns**
Construction of Open Pit Mine, grubbing, overburden removal	Open pit mine construction will include tree removal and overburden stripping, which may affect ET, infiltration and runoff potential, thereby affecting open pit mine area runoff as well as groundwater flow which may affect groundwater discharge (baseflow) to surface water features. Dewatering of overburden to facilitate stripping may reduce baseflows and overland flow.	Tree removal and overburden stripping may increase erosion and sedimentation and affect baseflow quality.	Construction of open pit mine and diversion of surface runoff from open pit watershed area may alter the existing drainage pattern locally in the PDA.
Construction of Causeway (refer to further detailed discussion below)	Construction of causeway may affect the flow rates, water levels and water circulation patterns in the Iron Arm.	Deposition of quarry rock in the Iron Arm may affect water quality. Increased velocities at causeway bridge openings may increase erosion and sedimentation.	Construction of causeway may affect the flow patterns in the Iron Arm in the vicinity of the causeway.
Construction of Roads and Rail Track, Yard and Loop	These activities include vegetation and overburden removal, which may increase local runoff and affect groundwater baseflow discharge.	Linear infrastructure construction may increase erosion and sedimentation.	Linear infrastructure may alter overland flow patterns, baseflow discharge locations and watercourse alignment and flooding characteristics at stream crossings.

Construction of Causeway

Construction of the causeway across the Iron Arm of Attikamagen Lake requires deposition of blasted rock. Rock fill used in causeway construction will be sourced from a quarry located south of Iron Arm on the mainland. Causeway rock fill will not be comprised of mine waste or sourced from the Project's mineralized zone. Undetonated explosives associated with the deposited rock results in release of nitrogen species, such as ammonia, nitrate and nitrite. The daily release rate of nitrogen species to Iron Arm and corresponding mixing zones were evaluated (Stassinu Stantec 2014b) and are summarized below.

Release Rates of Nitrogen Species

The estimate of the daily release of total nitrogen is generally consistent with the approach of Ferguson and Leask (1988). This approach is based on the rock deposition rate, the powder factor, and the type of explosives.

Equation (8) was used to calculate the daily mass-rate of lost nitrogen (R_N):

(Equation 8) $R_N = D_R \times PF \times P_N \times L_N$

where,

D_R = daily deposition rate (8600 metric tonnes/day; Doundarov, pers. comm. 2015);

PF = Powder Factor used (390 g/tonne; Chong pers. comm. 2013);

P_N = mass portion of nitrogen in the explosive assumed to be 1/3 or 33.3% of the lost explosive mass (Bailey et al. 2012), dimensionless;

L_N = 0.002 nitrogen loss as 0.2% of total nitrogen used, conservatively assuming using ammonium nitrate with fuel oil (ANFO) as an explosive (Ferguson and Leask (1988), dimensionless.

The resulting mass of lost nitrogen is approximately 2,230 grams of total nitrogen per day. It was conservatively assumed that all lost nitrogen will be released from deposited rock within a day, because explosives are made of soluble salts (e.g., ammonium nitrate). In reality, a portion of explosives (e.g., undetonated cartridges) may be locked in rock space (interstitial pore spaces) and will be slowly released into Iron Arm.

In order to speciate total nitrogen, the proportions (P_{sp}) of nitrate (87%), ammonia (11%), and nitrite (2%) recommended by Ferguson and Leask (1988) were used. The mass-rates of total nitrogen release were converted into the daily release of species (R_{sp}) according to their molecular mass as follows:

(Equation 9) $R_{sp} = R_N \times P_{sp} \times M_{sp} / M_N$

where,

R_N = daily mass-rate of lost/released total nitrogen (2,230 grams/day);

P_{sp} = mass portion of nitrogen species, dimensionless;

M_{sp} = molecular mass of nitrogen species, moles;

M_N = molecular mass of nitrogen (14 grams/mole).

The resulting daily mass-rates for nitrogen species are shown in Table 11.34. A portion of total ammonia becomes unionized ammonia, which has increased toxicity for aquatic life compared to other nitrogen species and, respectively, has a lower CCME guideline (Table 11.34). The percentage of total ammonia transforming into the unionized form during dissolution of the residues is the function of water pH and temperature with higher values of unionized fraction at higher pH and temperatures (CCME 2012a). Measured pH values in Iron Arm range between 6.8 and 7.35 (Stantec 2014a). The causeway will be constructed between the beginning of May and end of July with the highest measured water temperatures in July at 20^0C (Stantec, 2014a). The fraction of unionized ammonia is conservatively estimated to be 1.24% of total ammonia based on pH of 7.5 and temperature 20^0C.

Table 11.34 Daily Release Rate of Nitrogen Species

Nitrogen Species	Daily Release Rate (g/day)
Total Ammonia (NH_3)	298
Nitrate (NO_3)	1088
Nitrite (NO_2)	147
Unionized Ammonia (NH_3)	4

Estimates of Mixing Zone Extent

The extent of the zone with concentrations exceeding the respective CCME guidelines (mixing zone) was calculated in several steps. First, long-term exposure toxicity thresholds from CCME guidelines for protection of aquatic life were selected (CCME 2012a, 2012b). The long-term or chronic thresholds are more conservative because they are lower than the acute values for the same parameters and produce greater width of the mixing zone (See equations 10 and 11 below). The CCME threshold for total ammonia depends on temperature and pH of receiving water (CCME 2012a). The threshold of total ammonia calculated for pH of 7.5 and temperature 20^0C is similar to assumptions made above for estimates of unionized ammonia. The selected/ calculated toxicity thresholds are presented in Table 11.35.

Table 11.35 Estimates of the Causeway Mixing Zone

Parameter	CCME FAL (mg/L)		Daily Required Volume (Vsp) to Meet the CCME Guideline (m^3)		Mixing Zone Exceeding CCME Guidelines			
					Asp (m^2) at Depth of 1.7 m		W_{sp} (m) at Depth of 1.7 m and Daily Extension of 15.1 m	
	Long Term	Short Term	Long Term	Short Term	Long Term	Short Term	Long Term	Short Term
Total Ammonia (NH_3)	1.54	NA	194	NA	114	NA	3.8	NA
Nitrate (NO_3)	13	550	84	2	49	1.2	1.6	0.04
Nitrite (NO_2)	0.197	NA	745	NA	438	NA	14.5	NA
Unionized Ammonia (NH_3)	0.019	NA	236	NA	139	NA	4.6	NA

The second step is to estimate the volume of water required to assimilate the daily mass of nitrogen species released into Iron Arm down to the toxicity threshold. The volume of water required to assimilate each nitrogen species (V_{sp}) was calculated using the equation 10.

(Equation 10) $V_{sp} = R_{sp} / TT_{sp}$

where,

R_{sp} = daily mass-rate of lost/released total nitrogen, g/day (Table 11.34);

TT_{sp} = toxicity thresholds for protection of aquatic life, mg/L (Table 11.35).

Among all nitrogen species, nitrite (NO_2) would require the largest assimilation volume of 745 m^3 per day. The primary assumption of this calculation is that water within this volume is fully mixed.

The area of the assimilation zones (A_{sp}) can be estimated by dividing the daily assimilation volumes from Table 11.35 by the average depth of the Iron Arm along the causeway centerline (1.7 m). The largest area of 438 m^2 is predicted for nitrite (NO_2) release, as was expected from volumetric calculations.

The width of the mixing zone can also be coarsely estimated from the construction schedule and the calculated areas of the assimilation zone shown in Table 11.35. The average daily extension of the causeway into Iron Arm,15.1 m, is estimated from the total length of the water crossing (560 m) and proposed construction time span (37 days, Doundarov comm. 2015). The width of the mixing zone from the base on each side of the causeway (W_{sp}) is calculated as the following ratio:

(Equation 11) $W_{sp}=A_{sp}/L/2$

where,

A_{sp} = estimated area of the mixing zone for nitrogen species;

L = averaged daily extension of causeway into the Iron Arm (15.1 m);

2 = denominator considering an area equally split between two sides of the causeway (Figure 11.35).

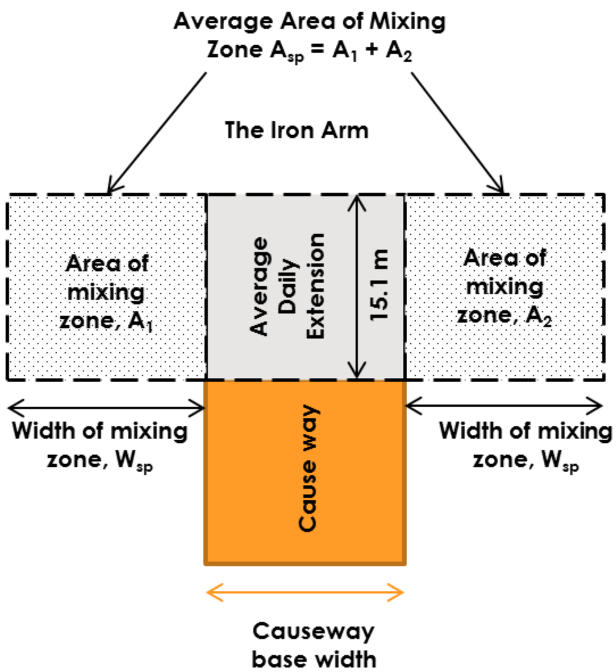

Figure 11.35 Simplified Plan View of the Mixing Zone during Causeway Construction

In this calculation, it is assumed that the mixing zone is a rectangular area, the depth within the area is the same, and calculations were completed for a one-day operation (Figure 11.35).

The results indicate that the widest mixing zone is 14.5 m for the long-term nitrite CWQG PAL threshold (Table 11.35). Therefore, on average, the concentrations of any nitrogen species should not exceed chronic toxicity thresholds for freshwater aquatic life beyond a 15 m wide zone from the base on the causeway. The west to east flow through the causeway is expected to change the shape of the mixing zone with the mixing zone on the west side of the causeway smaller than on the east side.

The short-term or acute CWQG PAL guideline is available only for nitrate (CCME 2012a). The mixing zone for the short-term nitrate CWQG PAL threshold is small and is only 0.04 m or 4 cm (Table 11.35). The deposition mixing zone is a splash zone of high turbulence generated from end-dumping material into the water. Therefore, 4-cm mixing zone for the short-term nitrate CWQG PAL threshold will not form or will dissipate quickly (within a few seconds) down to the long-term threshold levels.

Discussion

Since the mixing zone for the short-term nitrate CWQG PAL threshold will not form or is expected to dissipate quickly down to the long-term threshold levels, the mixing zone represents a transitional zone of chronic toxicity where exposures effects are based on longer-term exposures than are possible under Project conditions. Four factors support the conclusion that chronic effects are not expected:

1. The CWQG PAL long-term exposure guidelines are derived using long-term data of ≥7-day exposures for fish and invertebrates (CCME 2012a);

2. The mixing zone advances each day with the extension of the causeway on average 15.1 m, thus the mixing zone is constantly moving over itself;

3. The mixing zone is a zone of high turbulence, noise and disturbance which will displace aquatic life; and

4. The causeway will be built starting at the peak and subsequently the falling limb of the spring freshet when a very large volume of water passes through Iron Arm from the Lake and headwaters. This volume of spring flow increases the assimilative capacity decreasing the mixing zone dynamically. Further, as the causeway extends the “channel” through which water flows gets smaller and smaller, thus increasing flow rate through the mixing zone and further decreasing the mixing zone.

11.6.1.2 Mitigation of Project Environmental Effects

The following mitigation measures are proposed to reduce and mitigate Project-related effects on surface water during the site preparation and Project Construction phase:

- Reduce construction footprint (i.e., PDA) to the extent possible.

- Optimize water harvesting and re-use.

- Manage surface run-off and drainage with construction of diversion ditches, culverts and settling ponds.
- Size ditches, culverts and settling ponds appropriately. At a minimum, settling ponds will be designed for a 25-year return period storm event. A minimum culvert size of 600 mm will be installed to reduce the potential for blockage due to ice, sediment, beaver activities and vegetation, although larger may be required in many instances.
- Plan road alignments to reduce, to the extent practicable, the number of watercourse crossings, habitat disturbance of sensitive habitats (such as wetlands), and direct and indirect effects on species of conservation concern.
- Follow DFO guidance on culvert embedment and fish passage so water crossings do not constitute a barrier to fish passage.
- Construct and operate WWTP to treat sanitary effluent to regulatory criteria.
- Implement sediment control measures (e.g., sediment traps) to control sediment from entering adjacent watercourses.
- Develop a Water Management Plan for the Project. This plan will outline water management in and around the major Project component areas (i.e., ore stockpiles and overburden/waste rock disposal areas, open pit, and roads, rail yards, and water crossings).
- Train all staff authorized to handle hazardous materials in the appropriate handling, storage and disposal of these hazardous materials.

In addition, the following measures will be followed in relation to access routes (*e.g.,* roads and rail line):

- Fugitive dust suppression programs;
- Maintain existing hydrological inflow to receiving waterbodies;
- Reduce drainage interactions and alterations; and
- Construct access roads and rail line cross drainage.

11.6.1.3 Characterization of Residual Project Environmental Effects

Changes to surface water quantity during Construction arises from Project alterations to the environmental water balance, such as tree removal reduction in ET and surface hardening increases in runoff. These residual effects persist into Operation and Maintenance and are further assessed and quantified in Section 11.6.2. However, environmental water balance changes to the Attikamagen and Petitsikapau Lakes ultimate receiving water system are relatively small and within the natural range of flow and water level conditions experienced in the system. Therefore, since the effect is within the normal variability of baseline conditions, the residual effect is expected to be low, site-specific, medium term and reversible following Closure and Decommissioning.

Changes to surface water quality during construction are expected to be mitigated by the implementation of erosion and sedimentation measures. With respect to causeway construction, the mixing zone was defined as an area of water, beyond which concentrations of nitrogen species should not exceed toxicity thresholds for freshwater aquatic life. The average width of the mixing zone from the base on each side of the causeway is 15 m for all nitrogen species released from blasting residues (Table 11.35). The estimates are based on the average daily rates of construction assuming a small interaction between zones formed one day apart. In reality, the size of the mixing zone will be smaller and exposure of freshwater aquatic life to dissolved blasting residues will likely be too short to have chronic effects. Water quality effects are expected to be contained and assimilated to either baseline or CWQG threshold criteria at the edge of effluent mixing zone within the LSA. Therefore, residual effects on surface water quality are expected to be moderate, localized, continuous during causeway construction and short-term.

Site preparation and ground disturbance activities are expected to change surface water drainage patterns and alter watercourses, but this will primarily be limited to the PDA, with only minor effects extending into the LSA. While effects will be measurable and medium-term, activities will be managed such that effects remain localized. The effect will occur during the initial surface preparation, but once construction is completed, no further alterations in surface water drainage patterns are expected to occur as a result of these activities.

11.6.2 Operation and Maintenance

11.6.2.1 Potential Environmental Effects

During Operation and Maintenance, potential adverse effects to surface water include changes to flow regimes, water and sediment quality, and changes to drainage patterns. The primary Project activities that will affect surface water are presence / maintenance of the causeway, open pit mining, dewatering of Joyce Lake, ore processing, waste rock disposal on surface, and water treatment and disposal.

Water quantity effects may result from hydrological regime or water balance effects in major Project component areas arising from changes to runoff characteristics and Project water demands over a range of operating and environmental conditions. Project water demands are expected to include:

- Sanitary water uses;
- Potable water uses;
- Dust suppression water uses; and
- Fire 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. As long as non-consumptive losses do not undergo a large 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 occur as those portions of water withdrawal are not expected to be cycled back to the local surface water environment.

Water quality may be affected as a result of:

- Increased TSS loading from disturbed and unstabilized ground surfaces and active work zones and its subsequent effects on sediment quality;
- The potential for ARD/metal leaching (ML) to affect water quality; and
- The potential for ammonia contamination from incomplete combustion of explosives materials.

Mine effluent quality is regulated by the NL *Water Resources Act* and regulations which for metal mining operations use the effluent discharge criteria found in the federal MDMER promulgated under the *Fisheries Act*. Mine effluents must meet the water quality requirements of the MDMER which are presented in Table 11.26.

Changes to drainage patterns and watercourse alterations will continue beyond Construction and into Operations and Maintenance. Specifically, this is expected to occur as the open pit mine, and waste rock, low grade ore and overburden stockpile areas are expanded to their ultimate extent over the life of mine.

Causeway Presence and Maintenance

A 1.2 km long causeway with two 8 m span bridges is proposed across Iron Arm as part of the mine haul road to be constructed for the Project. Details of the proposed bridges are shown in Figure 11.36. The causeway across Iron Arm could result in the following effects on Water Resources:

- Causeway will reduce the flow area across Iron Arm and affect water levels in Iron Arm;
- Reduction in flow areas across Iron Arm will increase flow velocities at the causeway bridges;
- Circulation pattern in the vicinity of the causeway will be altered; and
- Wind-waves effects on the causeway.

A hydrotechnical assessment (Stassinu Stantec 2014c) was conducted to assess the water levels and flow velocities and the wave conditions in the vicinity of causeway crossings. Summary of the effects due to the causeway is presented below and the detailed hydrotechnical assessment is provided in Appendix K. Note that any potential effects of the causeway on fish passage are fully addressed in Chapter 15: Fish and Fish Habitat.

Changes in Water Level

The design flow return period selected for the causeway bridges is the 1:25 year flood flow. This is consistent with Environmental Guidelines for Watercourse Crossings (NL Water Resources Management Division, Water Rights, Investigations and Modelling Section, 2017) Tables 11.36 presents the predicted water levels and flow velocities at the bridge crossings for the MAF, 1:10 Year, 1:25 Year and 1:100 Year flood conditions, respectively.

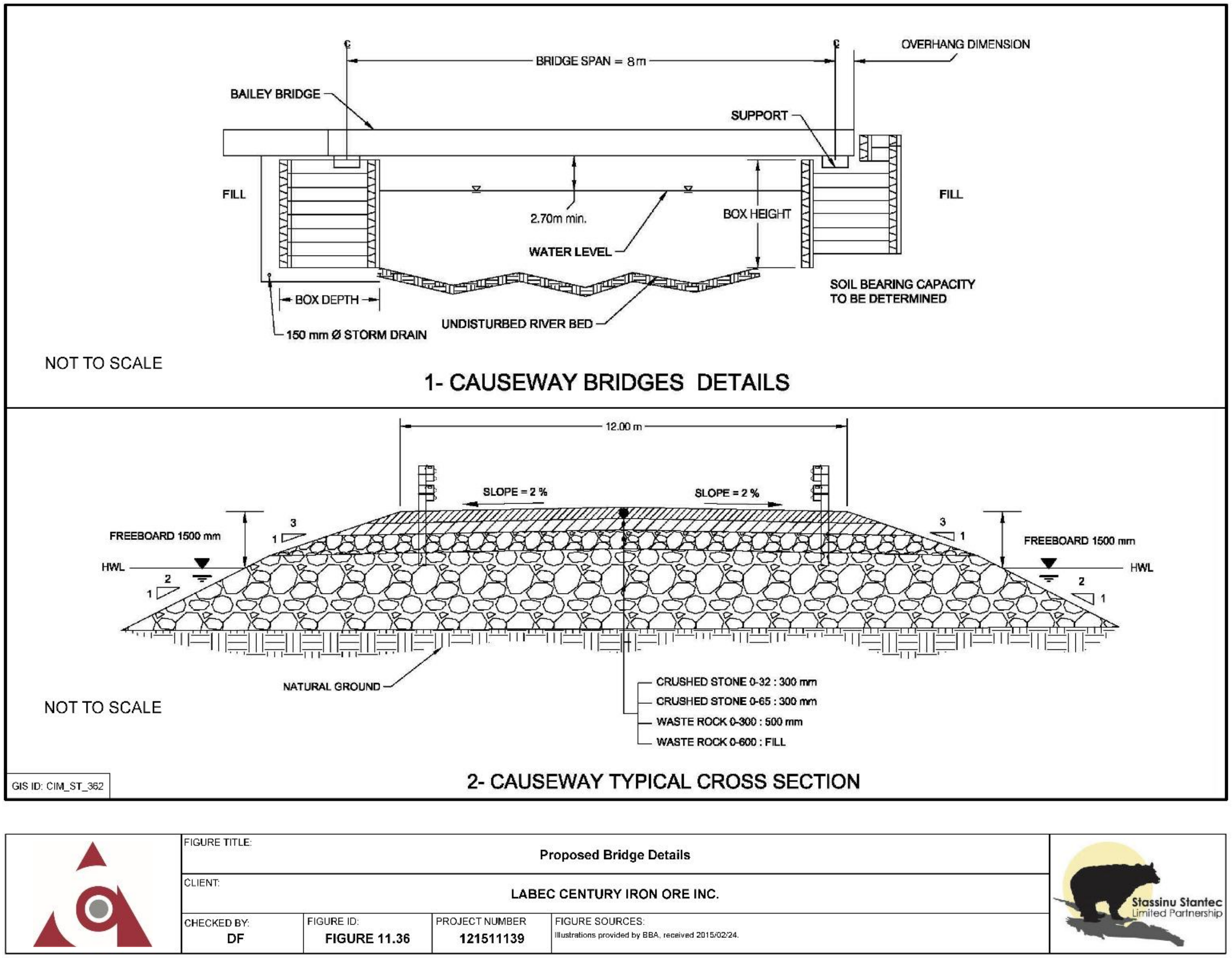

Figure 11.36 Proposed Bridge Details

Table 11.36 Predicted Water Levels and Velocities at Bridge Crossing

Return Period	Water Level[1] (m)			Average Flow Velocity at Bridge Openings (m/s)
	Upstream	Bridge Crossing	Downstream	
MAF	469.2	469.0	469.00	1.62
1:10 Year	469.7	469.4	469.25	2.62
1:25 Year	469.8	469.4	469.25	2.80
1:100 Year	470.0	469.5	469.25	3.05

Note:
[1] All elevations are based on an assumed 469 metres above mean sea level (mAMSL) normal water level (0 m depth in the bathymetry data)

The hydraulic assessment indicates that:

- The causeway will have some damming effect during flood events, raising the water level upstream. During the 1:25 Year design flood event, a maximum water level of 469.8 m was modelled upstream of the causeway crossing (Table 11.36). This is 0.55 m above the assumed flood level (469.25 metres above mean sea level [mAMSL]) and 0.8 m above the assumed normal water level. The estimated water levels are considered within the natural water level variations for the study area lakes;
- It was found that an increase or decrease of 0.25 m in the assumed downstream water level had only a minor effect on the modelled water levels at the causeway; and,
- The flow velocities at the bridge crossings range from 1.62 m/s for MAF conditions to 2.80 m/s and 3.05 m/s for 1:25 Year and 1:100 Year flood conditions.

Ice Conditions and Jamming Effects

Lakes in the study area are considered to be snow-covered lakes having a coefficient of ice growth of 19.5. Freeze-over occurs around November 1 in study area lakes and the mean maximum ice thickness is expected to range from 125 cm to 150 cm. Therefore, to allow for ice coverage, an additional clearance of 1.5 m above the normal water level is required. The ice-free condition occurs in the study area lakes around June 1.

Navigational Requirements

While Attikamagen Lake is not a “scheduled water” (defined as waterways that can receive extra oversight from Transport Canada) under the *Canadian Navigable Waters Act* (2019), it is considered a navigable water. The *Canadian Navigable Waters Act* (2019) provides a process by which the public is notified about works on navigable waters that are not on the list of scheduled waters (Transport Canada 2021). Due to the remote location of the lake, it is also not expected to have frequent users. However, passage across the causeway will be maintained through sufficient clearance at the bridges.

Wave Assessment

The design wave height at the causeway location is assumed to be the wave generated by a 1:25 year wind speed along the direction of the channel. Significant wave height, significant wave period, wave run up and wind set up were calculated based on the approach presented in the Coastal Engineering Manual (CEM) by the U.S. Army Corps of Engineers (2008) and the results are presented in Table 11.37.

Table 11.37 Wave Assessment Summary

Wind Direction	Design Wind Speed (km/h)	Fetch Length (km)	Average Depth (m)	Maximum Wind Setup (m)	Significant Wave Height (m)	Significant Wave Period (s)	Max. Wave Height (m)	Max. Wave Run Up (m)
NW	73	11.5	6	0.16	1.5	3.7	2.7	2.0
SE	55	11.3	6	0.09	1.0	3.3	1.9	1.5

As presented in Table 11.37, the 1:25 year wind is estimated to produce a significant wave height of 1.5 m and 1.0 m in the southeast and northwest directions, respectively. Based on these significant wave heights the maximum wave heights were estimated to be approximately 2.7 m and 1.9 m.

The wave run up is the vertical height above the water level to which waves will travel up an embankment. The 1:25 year significant wave height was used to determine the wave run up for the causeway. This will indicate the potential for overtopping due to run up. A maximum wave run up of 2 m was estimated based on a 2% exceedance probability.

Erosion Protection

The required rock fill size to prevent erosion from the design wave was estimated using the method outlined in the CEM (U.S. Army Corps of Engineers 2008). It was assumed that the rock fill would consist of a rough angular stone with a specific gravity of 2.65. The estimated minimum D50 for the causeway rock fill is 750 mm.

In addition to the potential for erosion due to waves, the estimated flow velocities at the bridge crossings may cause scour on the channel bed and erosion at the toe of the bridges. Bed and toe protection will therefore be used. As indicated in Table 11.37, the average flow velocity at the bridge openings is 2.8 m/s during the 1 in 25 year flood event. The design recommendations in the National Cooperative Highway Research Program report Countermeasures to Protect Bridge Piers from Scour (2007) were used to determine the required riprap sizing. Based on the estimated average velocity of 2.8 m/s, the minimum D50 for the bed and toe protection is 700 mm. It is recommended that the same material as the causeway is used, with a D50 of 750 mm.

Riprap placement is critical to ensure effective erosion and scour protection. It is recommended that riprap is placed in accordance with the National Cooperative Highway Research Program 2007 report and the Transport Association of Canada Guide to Bridge Hydraulics (2004).

Clearance Requirements

Based on the above assessment, the clearance requirements for the bridges and the causeway are summarized in Table 11.38. The design high water level is assumed to be the 1:25 year flood water level of 469.8 mAMSL.

Table 11.38 Minimum Clearance

	½ Maximum Wave Height (m)	Wave Run Up (m)	Freeboard (m)	Minimum Clearance Above Design High Water Level (m)
Bridge	1.4	N/A	0.5	1.9
Causeway	N/A	2.0	0.5	2.5

As noted in Table 11.38, minimum clearance of approximately 1.9 m and 2.5 m above the high water level is required for the bridges and causeway, respectively. The bridge and causeway will have a clearance of 2.7 m.

Open Pit Mine and Joyce Lake Dewatering

The open pit is located in Joyce Lake subwatershed. Joyce Lake is a headwater lake with no defined outlet channel and drains eastward to a wetland area. Hydrometric monitoring station S4 is located approximately 2 km downstream of Joyce Lake where a drainage course maintains positive flow. Open pit mine operation and Joyce Lake dewatering effects on water resources are considered together as their operations are interconnected. The dewatering of Joyce Lake is expected to start after Operations have commenced and therefore discussed in this section as opposed to the Construction phase.

The mining method selected for the Project is conventional open pit drill and blast operation with rigid frame haul trucks and hydraulic excavators. The open pit mine is approximately 1,100 m long and 575 m wide at surface with maximum pit depth of 200m. The total surface area of the open pit mine is approximately 41 ha (Table 11.39).

Table 11.39 Open Pit Mine Footprint Area over Life-of-Mine

Period	Approximate Open Pit Mine Footprint Area (ha)
End of pushback 1	11
End of pushback 2	24
End of pushback 3 (ultimate pit)	41

In pre-production (year 0), 4.615 Mt of waste will be stripped, 80,000 t of low grade ore will be mined, and 801,000 t of overburden will be removed. 104,000 t of high grade ore will also be mined and stockpiled or transported to the process plant area. In production year 1, 10.04 Mt of waste, 836,000 t of low grade ore and 1.002 Mt of overburden will be removed. In year 2 and beyond, a full production rate of approximately 2.5 Mt of high grade ore will be mined for the remaining life of the open pit. Detail on an annual basis is shown in Table 2.5 (Chapter 2).

Joyce Lake dewatering will be initiated in the summer months of Year 0, and drainage is expected to be completed in the Fall of Year 1. The Joyce Lake drainage schedule is necessary to ensure that open pit safety is not compromised by excessive water volumes in Joyce Lake being in close proximity to the pit rim.

The open pit mine operation and Joyce Lake dewatering will potentially affect surface water resources in the following ways:

- Surface water generation from the open pit mine footprint will be increased due to high runoff production, and groundwater seepage;
- Potential excess water from dewatering can be used to provide dust suppression water and offset mine water demand;
- Full development of the open pit mine will require the complete dewatering of Joyce Lake;
- Dewatering of the open pit and the Joyce Lake may affect the water levels in small lakes (Lake B, C, D and E);
- Dewatering of Joyce Lake is expected to change groundwater flow regimes in the Joyce Lake watershed;
- Diversion of non-contact surface runoff around the open pit mine and Joyce Lake via perimeter ditches may affect the local hydrological regime;
- The collection and discharge of non-contact groundwater and surface runoff within the footprint of Joyce Lake may affect the local hydrological and hydrogeological regimes;
- Similarly, the collection and pumping of open pit seepage and runoff may affect local hydrological and hydrogeological regimes;
- Open pit mine water quality concerns relate to potential ARD/ML, ammonia from uncombusted explosives and sedimentation/TSS;
- Open pit mine and Joyce Lake sediment quality concerns relate to potential deposition of suspended sediment from open pit mine and Joyce Lake dewatering, increased overall surface water discharge rates from the open pit mine and Joyce Lake footprint resulting in erosion and scour or reduction in discharge flows due to mine water use limiting receiving watercourse potential to provide self-flushing and existing condition sediment transport.

Note that a Project-wide water balance assessment was carried out for each Project feature watershed to evaluate effects of the Project on the hydrologic conditions in the LSA and RSA. This is presented at the end of Section 11.6.2 and provides more details on the effects of this activity on surface water quantity.

Changes in Surface Water Quantity

Based on climate normal conditions, the annual average streamflow generated by the open pit mine footprint is estimated at approximately 14.7 m^3/h. Under Operations and Maintenance conditions, the water balance for the open pit mine will change in that the streamflow coefficient will increase from approximately 75% in the existing condition to 95%. This increase in streamflow within the open pit mine arises from several factors, including:

- Removal of vegetation;
- Removal of overburden;
- Open pit mine requirement to collect and dewater surface runoff to the 1:100 year storm level to avoid pit and pit equipment flooding, maintain mining operations and ensure human safety;
- Minimization of time duration between runoff generation in the open pit mine and dewatering thus minimizing the potential for evaporation; and
- Snow sublimation on open pit mine slopes, however sublimation effects will be minimal in light of the annual water balance based on existing conditions and will be further reduced in the open pit mine due to shading and open pit mine cold thermal capture.

Therefore, the use of a 95% streamflow runoff coefficient for open pit mine is considered conservative and appropriate and will contribute 18.6 m^3/h under climate normal conditions.

Minor groundwater seepage is expected to seep into the open pit. In addition to surface runoff from precipitation, groundwater seepage to the open pit mine will require dewatering as indicated above. The minor groundwater seepage into the open pit is not considered in the calculations.

Open Pit Dewatering

Operation of the open pit mine will require dewatering of groundwater to ensure that the water table is maintained below the floor of the active pit and more than 25 m from the pit walls. WESA (2014) evaluated several groundwater dewatering configurations using a three-dimensional numerical groundwater flow model. Four phases of dewatering were considered:

- Phase I involves dewatering below a pit bottom elevation of 480 masl using 7 dewatering wells with a pumping rate of 2,642 m^3/d;
- Phase II involves dewatering starting from 480 masl below a pit bottom elevation of 460 masl using 7 dewatering wells with a pumping rate of 3,330m^3/d;
- Phase III involves dewatering starting from 460 masl below a pit bottom elevation of 420 masl using 7 dewatering wells with a pumping rate of 4,866m^3/d; and
- Phase IV involves dewatering starting from 420 masl below a pit bottom elevation of 380 masl using 7 dewatering wells with a pumping rate of 5,714 m^3/d.

Two cases were considered for groundwater dewatering. The base case involved complete dewatering of Joyce Lake. The optional case involved partial dewatering of Joyce Lake with construction of a dam situated approximately 100 to 200 m from the limits of the open pit. Two scenarios of Joyce Lake bottom sediments were considered for the optional case as the permeability of the Joyce Lake bottom sediments has not been assessed in the field. Table 11.40 presents the simulated number of wells and the total pumping rates for each of the four mine dewatering phases associated with the base case and two optional cases.

Table 11.40 Pumping Rates for Mine Dewatering – Groundwater (WESA, 2014)

Case	Scenario	Description	Phase	Pit Bottom Elevation (masl)	Simulated No.of Dewatering Wells	Total Pumping Rate (m^3/d)
Base	n/a	Joyce Lake completely dewatered	I	480	7	2,642
			II	460	7	3,330
			III	420	7	4,866
			IV	380	7	5,714
Optional	1	Joyce Lake partially dewatered (silty sediments at bottom of lake)	I	480	7	2,868
			II	460	7	3,721
			III	420	7	5,552
			IV	380	8	6,764
Optional	2	Joyce Lake partially dewatered (sandy sediments at bottom of lake)	I	480	8	3,524
			II	460	8	4,623
			III	420	9	7,131
			IV	380	10	7,821

Construction of a dam across Joyce Lake will likely involve underwater construction and require specialized equipment (e.g., barge) and skilled personnel (e.g., divers). Failure of the dam would flood the open pit mine, compromise the safety of the workers in the open pit mine and would also interrupt the mine operation until the pit is completely dewatered. As discussed in Chapter 2 Section 2.8, these factors were considered in the alternatives analysis and as a result, the construction of a dam has been determined to be not technically feasible due to safety concerns.

The annual open pit dewatering rate for the operational case is estimated to be 257 m^3/h including a surface water dewatering rate of 18.6 m^3/h and groundwater seepage dewatering rate of 238 m^3/h under climate normal conditions. The open pit dewatering rate is estimated for ultimate mine pit development and the dewatering rate is less than 257 m^3/h prior to the ultimate mine pit development. Surface water runoff and seepage into the open pit will be pumped into a perimeter ditch around the overburden and waste rock stockpiles. The overburden and waste rock perimeter ditch will convey the open pit dewater into sediment pond SP1 prior to release to Attikamagen Lake. Groundwater intercepted from the open pit perimeter dewatering wells will be pumped into perimeter ditches around the open pit and the shoreline of Joyce Lake. The monthly open pit dewatering rate is shown in Figure 11.37 under climate normal conditions over the life-of-mine.

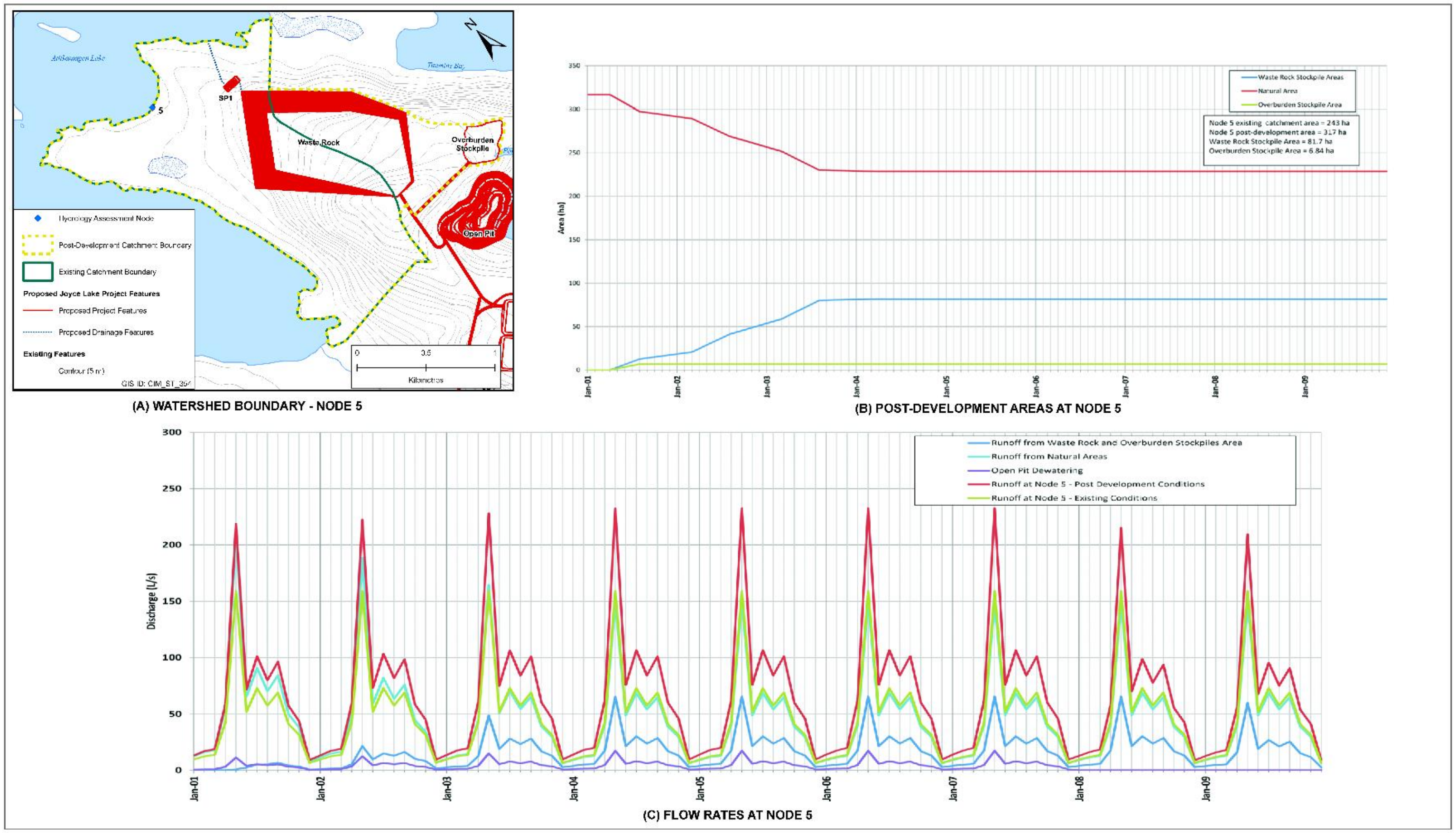

FIGURE TITLE:	**Existing and Project Conditions Monthly Flow Rates at Node # 5 under Climate Normal Conditions over LOM**
CLIENT:	**LABEC CENTURY IRON ORE INC.**

CHECKED BY:	FIGURE ID:	PROJECT NUMBER	FIGURE SOURCES:
SP		**121511139**	Project features provided by BBA version 2 received 2014/11/07. Basemap information from NRCan CanVec database and Newfoundland and Labrador Department of Natural Resources.

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Figure 11.37 Existing and Project Conditions Monthly Flow Rates at Node # 5 under Climate Normal Conditions over LOM

Table 11.41 presents the open pit surface runoff and groundwater dewatering rates for the ultimate pit development under climate normal conditions.

Table 11.41 Monthly Runoff and Dewatering Pumping Rate Estimation from Open Pit During Climate Normal Conditions – Ultimate Open Pit Development

Month	Existing Condition	Operational Condition				
	Runoff Volume (m^3)	Runoff Volume (m^3)	Seepage Volume (m^3)	Total Volume (m^3)	Open Pit Pumping Rate (m^3/hr)	Perimeter Dewatering Well Pumping Rate (m^3/hr)
January	2,181	2,762	177,010	179,772	3.71	238
February	2,569	3,254	159,880	163,134	4.84	238
March	3,148	3,987	177,010	180,997	5.36	238
April	9,489	12,019	171,300	183,319	16.7	238
May	36,633	46,401	177,010	223,411	62.4	238
June	11,553	14,663	171,300	185,963	20.4	238
July	16,804	21,285	177,010	198,295	28.6	238
August	13,246	16,777	177,010	193,787	22.5	238
September	15,424	19,537	171,300	190,837	27.1	238
October	9,464	11,987	177,010	188,997	16.1	238
November	7,017	8,888	171,300	180,188	12.3	238
December	1,496	1,895	177,010	178,905	2.54	238
Annual	129,022	163,427	2,084,150	2,247,577	18.6	238

Comparing the existing condition climate normal annual streamflow of 14.7 m^3/h to the operational case climate normal total open pit mine dewatering rate of 257 m^3/h represents an increase in streamflow of 243 m^3/h to Stream T3 downstream of Joyce Lake. Stream T3 drains to Timmins Bay via an Unnamed Lake.

Joyce Lake Dewatering

A bathymetric survey of Joyce Lake indicated that it has an approximate volume of 2.8 Mm^3 with the deepest part of the Lake at its western end where the open pit will be located. Therefore, a start of dewatering and initial drawdown of Joyce Lake must occur before the open pit rim advances into Joyce Lake. The mining plan indicates that pump installation in Joyce Lake must start 173 days following the start of the project construction and first water discharge 182 days following the start of project construction, with dewatering discharge continuing until freeze up and then continuing for the majority of the following summer, with completion of drainage expected 592 days after the start of project construction. The estimated maximum initial dewatering rate is approximately 260 l/s. After initial dewatering, operational dewatering is required for runoff and seepage from the Joyce Lake footprint area. It is assumed that most of the groundwater would flow towards the open pit mine because the open pit is deeper than Joyce Lake and seepage into the Joyce Lake is assumed to be negligible. Tables 11.42 and 11.43 provide initial and operational dewatering from Joyce Lake, respectively. Monthly dewatering rates from Joyce Lake are illustrated in Figure 11.37. Joyce Lake dewater will be discharged to Stream T3 downstream of the Joyce Lake outlet.

Table 11.42 Joyce Lake Initial Dewatering Rate – Year 1

Month	Dewatering Rate (L/s)
July	251
August	257
September	247
October	260
November	114

Table 11.43 Joyce Lake Operational Dewatering Rates

Month	Dewatering Rate (L/s)
January	1.68
February	2.18
March	2.42
April	7.53
May	25.6
June	0
July	0.233
August	0.035
September	6.35
October	6.00
November	5.57
December	1.15

Diversion of Joyce Lake Catchment Runoff

Two perimeter ditches, Joyce Lake North Perimeter Ditch (JLNPD) and Joyce Lake South Perimeter Ditch (JLSPD), will be used for the following:

- Collection and diversion of Joyce Lake catchment area runoff around the open pit and the shoreline of Joyce Lake;
- Collection and diversion of Joyce Lake initial dewatering;
- Collection and diversion of groundwater intercepted from the open pit perimeter dewatering wells; and
- Collection and diversion of Joyce Lake footprint operational dewatering.

Collected water in the perimeter ditches will be discharged to Stream T3 downstream of the Joyce Lake outlet. The JPNPD will collect surface runoff from 49.3 ha of the Joyce Lake catchment area and JPSPD will collect surface runoff from 89.3 ha of the Joyce Lake catchment area. Surface runoff diversion from the Joyce Lake watershed area away from open pit and Joyce Lake is presented in Table 11.44.

Table 11.44 Monthly Runoff Diversion Rate

Month	Diversion Rate (L/s)
January	5.40
February	7.04
March	7.79
April	24.3
May	90.6
June	29.5
July	41.6
August	32.8
September	39.4
October	23.4
November	17.9
December	3.70

Changes in Surface Water Quality

There are four potential effects from the open pit that may adversely affect surface water quality and aesthetic conditions in the LSA. These include:

- Sedimentation;
- ARD/ML;
- Ammonia contamination; and
- Red water.

The water quality will, in part, depend on the residence time in the pit. Other potential water contamination vectors exist, such as hydrocarbon contamination from oil spills, and are considered in Section 11.8 under Accidents and Malfunctions. The open pit and Joyce Lake water management plan was developed to maximize the diversion of non-mine contact runoff and groundwater away from mine contact areas. Integral to this plan to divert non-mine contact water are the open pit perimeter interception wells, the open pit and Joyce Lake perimeter ditches and the Joyce Lake footprint area dewatering and runoff collection plan.

Sedimentation

Within the open pit mine, sedimentation is caused primarily from runoff over exposed overburden and freshly exposed rock and ore. Small rock particles are also generated from the open pit mine blasting and excavation processes, as well as the rock pulverization arising from equipment movement along the floor of the open pit mine. Other factors such as freeze-thaw action will mechanically degrade bedrock to finer rock particles. Sedimentation arises from the entrainment of mostly inorganic rock and overburden soil particles in the dewatering process. High sediment or TSS load in mine effluent is considered a deleterious substance and when suspended in the water column can inhibit the ability of fish to forage, decrease water column light penetration and inhibit the growth of submerged aquatic plants. When high sediment loads settle out they can affect sediment quality, inhibit fish egg incubation and degrade benthic habitat.

The mine effluent TSS concentration limit is 15 mg/L derived from MDMER. The open pit mine will generate TSS from mine dewatering in excess of 15 mg/L. Long term average annual erosion rates from the open pit mine was predicted using the Revised Universal Soil Loss Equation for Application in Canada (RUSLEFAC; Wall et al. 2002). The Modified Universal Soil Loss Equation (MUSLE; Williams 1975) was used to predict the TSS concentrations during storm events. The long-term average erosion rates from open pit mine slopes and bottom is estimated at 55,031 kg/year. This equates to an average TSS concentration in open pit runoff of 336 mg/L. The estimated average TSS concentration during the 10 year storm event is 1, 660 mg/L.

Joyce Lake sediments are described as silty clay and sand with trace gravel. Due to the Joyce Lake sediment distribution, the potential for high TSS concentrations in Joyce Lake footprint runoff is considered to be high. As mitigation, Joyce Lake footprint runoff will be collected in three sumps and will be released after removal of sediments.

Acid Rock Drainage / Metal Leaching (ARD/ML)

ARD/ML can occur within the open pit when sulphide bearing minerals are exposed to air and water. The resulting low pH water can readily dissolve heavy metals that are contained in the ore body, waste rock and overburden. Acidic water within the open pit is a problem if the water within the pit migrates to groundwater via rock pores or fissures or if the water from the pit is pumped to a storage area which may leach or overflow to receiving waters. It may also be an operational problem; for example corroding pipes and pumps. However, ARD will not occur if host geologic materials contain enough carbonate minerals to neutralize the acid as it is generated. Thus, both acid generating and acid neutralizing components must be considered in determining the ARD potential.

The Open Pit lithology is comprised of three upper units of the meta-sedimentary Sokoman Formation: Lower Massive Hematite (LMH), Red Chert, Upper Massive Hematite (UMH). As indicated in Chapter 13: Terrain and ARD/ML, the Sokoman formation composed of bands of magnetite and hematite with chert-rich rock with variable amount of silicates, carbonates and sulfides. The rock from the three units all have low ARD/ML potential based on static tests (refer to Chapter 13) and historical data from other mines in the Schefferville area. Therefore, it is unlikely that the mine water will be acid generating or metal leaching or contain trace elements in concentrations exceeding the MDMER limits.

Stantec previously assessed two mine sites in the Schefferville area (western Labrador), where mining activities have occurred since the 1950s. Acid Base Accounting indicated that the waste rock could be classified as non-acid generating based on neutralization potential ratio (NPR) criteria. Surface drainage, including flooded open pits, did not show any evidence for ARD/ML. Observed iron exceedances of the CWQG-PAL were related to the suspended forms of the metal and to annual redox stratification of water bodies.

As pit lakes in closed iron ore mines in the Schefferville area did not show evidence of ARD/ML, nor did historical monitoring records from two local iron ore mines, the open pit mine component of the Project is not expected to generate adverse environmental effects associated with ARD/ML. From the historical review, the same conclusion can be made about waste rock disposal areas, and overburden stockpile. These findings will be supported by ongoing tests of the drill cores and overburden from the Project. Chapter 13 provides a complete overview of the ARD/ML assessment undertaken for the Project and mitigation measures and monitoring which will be in place to verify results and conclusions of the assessment.

Ammonia Contamination

Open pit dewater along with waste rock and overburden stockpile area surface runoff will be collected in a common sediment pond prior to release in Attikamagen Lake. Therefore, ammonia contamination in open pit dewater is discussed under *Waste Rock and Overburden Stockpile*

Red Water

Red water is a tailings effluent condition associated with iron ore mining and processing. When iron ore tailings come in contact with water, the iron precipitation and staining processes occur and results in the red discoloration of water due to very fine particulate suspension. At other iron ore mining operations in the Labrador City, Wabush, NL and Fermont, Québec area, the red water condition is associated with tailings effluent and is not an issue associated with waste rock or open pit runoff. The red water condition is not associated with ARD and is associated with very fine colloidal reddish iron mineral or iron stained quartz / silica particles in suspension. As a result, red water is not considered to be a potential concern at the open pit mine.

Change in Surface Water Drainage Patterns

Development of the open pit mine over the life-of-mine will alter local drainage patterns, require Joyce Lake dewatering, and will require mitigation. Drainage patterns in the open pit mine catchment area will be altered through the lateral development of the open pit mine. This will include two components including the collection and dewatering of all incident precipitation – runoff within the open pit mine footprint and Joyce Lake and the construction and maintenance of open pit mine and Joyce Lake perimeter ditching to divert overland flow into the open pit mine and Joyce Lake. The hydrological effects will be related to the change in water balance described previously due to the increase in runoff coefficient and reduction in ET associated with open pit mine development.

Watercourse alteration will take several forms, including lake dewatering, watercourse diversion, as well as potential change in baseflow and water level characteristics. Development of the open pit mine will require dewatering of Joyce Lake and open pit encroachment into part of Joyce Lake. Also associated with the dewatering of Joyce Lake will be infiltration trenches proposed within Joyce Lake to collect surface water runoff and seepage to be dewatered to the perimeter ditches. Dewatering of the open pit mine and Joyce Lake will alter the hydrologic and geomorphologic conditions (flow rate, flow depth and velocity, and erosion and sediment rates) of stream T3 downstream of Joyce Lake outlet. Open pit mine and Joyce Lake groundwater seepage collection and dewatering may alter upstream headwater watercourse baseflows within the open pit mine's and Joyce Lake's hydrogeologic zone of influence. The existing condition assessment indicated that baseflow was an important contributor to the annual hydrograph for watercourses in the LSA. Similarly, there is potential for open pit mine and Joyce Lake surface and groundwater dewatering to affect the water levels in the small lakes referred to as Pond A, Pond B, Pond C, Pond D and Lake E. Pond A will be completely dewatered during the Phase I of the dewatering operation. Groundwater recharge from Ponds A and B will slightly increase from the existing conditions and the corresponding water level changes are expected to be negligible. Groundwater recharge to Pond D and E will decrease from the existing conditions and the corresponding water level changes are expected to be low (WESA 2014).

Waste Rock and Overburden Stockpiles (Stockpile Area)

Waste rock and overburden stockpiles will be placed on discrete pad areas above ground on the northeast and north sides of the open pit beyond the limits of mineralized zone as shown in Figure 11.38 and referred to as “stockpile areas” hereafter. The total tonnage of overburden and waste rock estimated to be generated during operation of the mine is approximately 70.08 million tonnes with overburden totaling 2.33 million tonnes and ore totaling 17.72 million tonnes as per Table 2.5 (Chapter 2). The stockpile areas is designed with overall slopes of 22^{o} to account for revegetation required as a part of the closure plan. An ascending construction sequence will be used to allow for rock placement and progressive rehabilitation to be completed in sections, with clearing and grubbing out only on the next section when waste is being placed. Runoff from the waste rock and overburden stockpiles will be collected in a sediment pond via perimeter ditches and will be released to Attikamagen Lake. The total footprint area of the waste rock and overburden stockpiles including the natural areas located within the perimeter ditches is approximately 115 ha. Both stockpile areas drain to Attikamagen Lake via a sediment pond.

The main potential effects of the stockpile areas associated with surface water are the following:

- Changes to existing surface water runoff quantity arising from water balance alteration due to vegetation removal and waste rock, low grade ore and overburden filling;
- Changes to existing surface water quality due to increased sediment loading from stockpile area runoff and the potential for ARD/ML, ammonia contamination and red water; and
- Changes to drainage patterns within the stockpile area affecting the hydrological regime of adjacent waterbodies, including Attikamagen and Joyce Lakes.

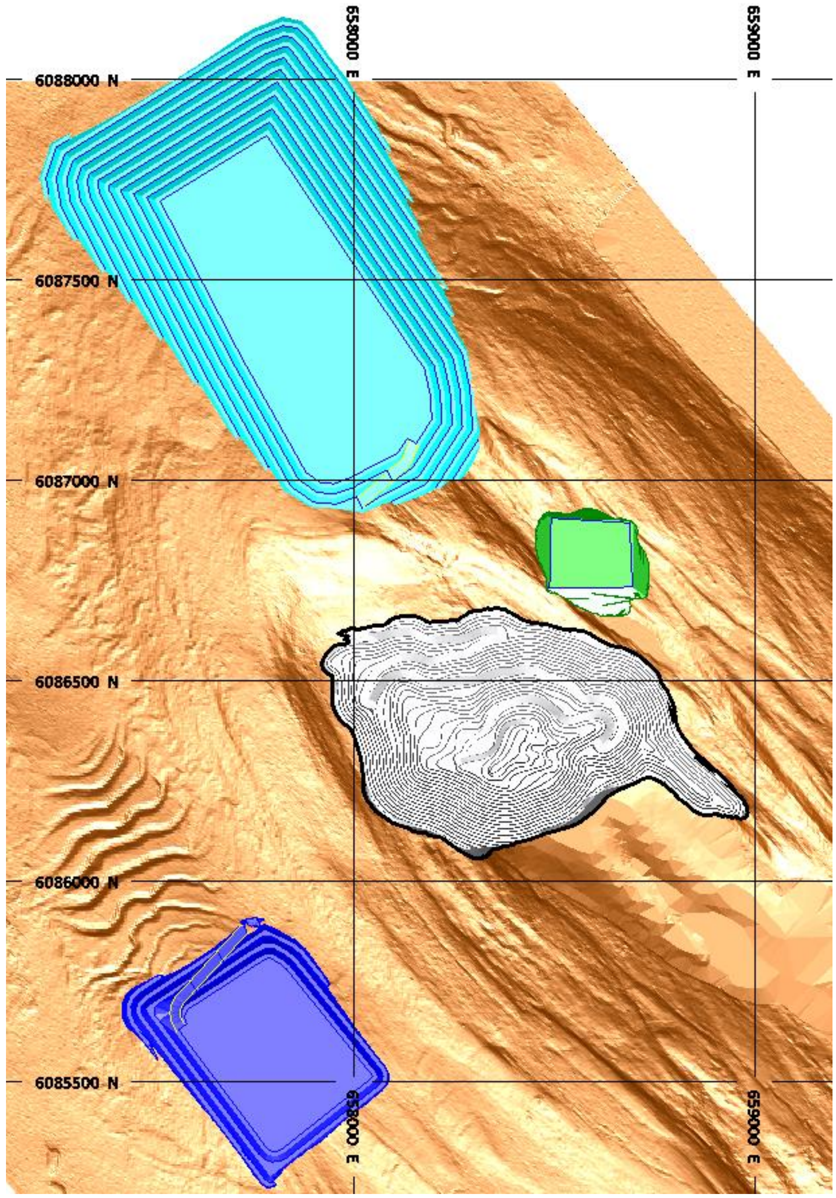

Figure 11.38 Waste Rock and Overburden Stockpile Area Plan

Change in Surface Water Quantity

Based on climate normal conditions, the annual average streamflow generated by waste rock and overburden stockpile areas is estimated at approximately 81.0 m^3/h. Under operations and maintenance conditions, the water balance for stockpile areas will change in that the streamflow coefficient will increase from approximately 75% in the existing condition to 85%. This increase in streamflow within the stockpile area arises from several factors, including:

- Removal of vegetation resulting in less ET;
- Increase in soil compaction from the waste rock, and overburden stockpiles dumping process;

- Surficial grading reducing surface depression storage; and
- Increase in slope angle at the waste rock and overburden stockpiles surfaces.

Therefore, the use of an 85% streamflow coefficient for the stockpile area is considered appropriate and will contribute 89.4 m^3/hr under climate normal conditions accounting for an approximate increase in total streamflow of 10.4% from existing conditions.

Table 11.45 presents the monthly existing and Operations and Maintenance phase runoff conditions under climate normal conditions. Operation and Maintenance phase runoff listed in Table 11.45 corresponds to ultimate development of waste rock and overburden stockpile areas. Note that further discussion of the effects of this change is contained in the Project-wide water balance assessment carried out for each Project feature watershed and found at the end of Section 11.6.2.

Table 11.45 Monthly Runoff Estimation from the Waste Rock and Overburden Stockpile Area under Climate Normal Conditions – Ultimate Development

Month	Runoff Volume (m^3)	
	Existing Conditions	Operational Condition
January	11,999	13,230
February	14,137	15,588
March	17,320	19,098
April	52,210	57,569
May	201,566	222,257
June	63,566	70,092
July	92,460	101,951
August	72,881	80,363
September	84,870	93,582
October	52,073	57,419
November	38,608	42,571
December	8,234	9,079
Annual	709,924	782,800

Change in Surface Water Quality

Potential water quality effects associated with the waste rock and overburden stockpile area during the operation and maintenance phase include sedimentation and ammonia contamination and are discussed in the following sections. As described above for the open pit, ARD/ML is not expected to be a concern for this Project. This is further discussed in Chapter 13: Terrain and ARD/ML. In addition, as described above for the open pit, red water is a tailings effluent condition associated with iron ore mining and processing and as such is not expected to be a concern for this Project.

Sedimentation

The long-term average erosion rates from stockpile area is estimated at 366,492 kg/year. This equates to an average TSS concentration in stockpile area runoff of 468 mg/L. The estimated average TSS concentration during the 10 year storm event is 1,893 mg/L. Runoff from the stockpile area will be collected in a sediment pond for control of suspended solids prior to release in natural environment.

The predicted sediment concentrations for average and storm events are presented during the Construction and Operations and Maintenance phases. Progressive rehabilitation of the waste rock disposal areas will be undertaken over the course of the Operations and Maintenance phases. Therefore, the predicted TSS concentrations take into account progressive rehabilitation effects.

Ammonia Contamination

Ammonia contamination in open pit mine and waste rock and overburden stockpile area runoff was assessed (Stassinu Stantec 2014d) and is summarized below.

Incomplete combustion of explosives used in open pit mining may result in contamination of open pit mine and waste rock and overburden stockpile area surface runoff and groundwater. The following describes the methodology and assumptions used to estimate average monthly concentrations of nitrogen species in the discharge from the open pit mine and waste rock and overburden stockpile area during the Operations and Maintenance phase.

Ore, low grade ore and waste rock production rates are shown in Table 11.46. The mining plan in the PEA study report (CIMA 2013) states a powder factor of 0.39 kg/tonne with the assumption that only 50% of the rock will require drill and blast. The explosives are assumed to be 60% packaged emulsion and 40% ANFO (Chong pers. comm. 2013).

Table 11.46 Annual Production of Ore, Waste Rock and Overburden

Year	Ore (tonnes)	Low Grade Ore (tonnes)	Waste Rock (tonnes)	Overburden (tonnes)
0 (pre-production)	104,219	80,175	4,615,000	801,000
1	2,167,444	836,054	10,104,000	1,002,000
2	2,487,985	1,339,860	14,498,000	531,000
3	2,508,986	596,070	16,370,000	0
4	2,448,645	584,262	15,286,000	0
5	2,944,297	186,442	8,912,000	0
6	1,420,749	19,742	299,000	0

The potential for contamination of open pit mine water and waste rock and overburden stockpile area surface runoff with residual nitrogen species was evaluated using the empirical method of Ferguson and Leask (1988). The method is based on the ratio of ANFO /slurry in explosives. In the Project, no slurry will be used according to Labec Century (Chong pers. comm. 2013). Therefore, the nitrogen loss from the explosive was conservatively assumed to be 0.2%, which was set by Ferguson and Leask (1988) for use of 100% ANFO. Emulsion use in the Diavik mine did not reduce the concentration of nitrogen significantly (Matts et al. 2007). Therefore, the 0.2% value was conservatively used in the calculations of nitrogen loss from the mass of the explosives.

The nitrogen release rate from the open pit mine site was shown to be dependent on the annual hydrological cycle. Ferguson and Leask (1988) recommended distribution of monthly nitrogen release rates proportional to the ratio of monthly flow to annual flow. Nitrogen release rates in the open pit mine were calculated proportional to average of monthly dry, normal and wet runoff from the open pit area.

Equation 12 was used to calculate monthly nitrogen losses associated with ore and waste rock blasting residual nitrogen for the open pit mine and waste rock stockpile areas:

(Equation 12) $C_{NP} = R \times (M_{WR} + M_O) \times L_N \times P_E \times F \times r \times 1000/V_i$

Where C_{NP} - monthly nitrogen concentration in open pit dewater (mg/L)

M_{WR} and M_O – monthly production of waste rock and ore (tonnes)

R – explosive application rate used for waste rock (0.36/2 = 0.18 kg/tonne, Chong, pers.comm. 2013)) and ore (0.23 kg/tonne)

L_N = 0.002 nitrogen loss as 0.2% of total N used (dimensionless)

P_E – mass portion of nitrogen assumed to be 1/3 of the explosive (emulsion) mass (Baily et al. 2012) (dimensionless)

F – fraction of nitrogen leached either in pit or in disposal area assumed to be, 2/3 and 1/3, respectively. Usually, higher nitrogen loadings are associated with mine water than with runoff from waste rock due to fast dissolution of blasting residues (Matts et al. 2007). Therefore, it was arbitrary assumed that 2/3 of lost nitrogen would leach into mine water, while a third of nitrogen lost in waste rock (no contribution from ore) would be released from the disposal areas. dimensionless

r – monthly nitrogen release rate coefficient (Table 12.43), dimensionless

1000 – conversion factor from kg/m^3 to mg/L

V_i - average monthly volume of runoff from stockpile area or mine water from pit

In order to speciate nitrogen, the proportions nitrate (87%), ammonia (11%), and nitrite (2%) recommended for effluents by Ferguson and Leask (1988) were used. The speciated nitrogen concentrations were converted into the final concentrations of species according to their molecular mass.

Regulatory criteria for nitrogen species effluent is indicated in Table 11.47. There are no MDMER criteria for nitrogen species release, therefore the CWQG is used as a mixing zone boundary condition and the NL *Environmental Control Water and Sewerage Regulation 65/03 Schedule A* is used as the effluent criteria. Monthly concentrations of nitrogen species in discharges from the open pit mine and waste rock and overburden stockpile area was calculated for years 1 to 7 and the results are presented in Figure 11.39 for climate normal and dry/wet year conditions.

Table 11.47 Regulatory Criteria for Nitrogen Species in Mine Effluent

Nitrogen Species	Regulatory Criteria (mg/L)	
	CWQG	NL Reg. 65/03, Schedule A
Ammonia	1.916 – 0.855 (Temp. 0 – 10ºC)	2
Nitrate	13	10
Nitrite	0.197	Not indicated

The nitrogen assessment indicates that nitrogen species release to mine dewater and waste rock and overburden stockpile area surface runoff peaks during spring freshet and higher concentration occurs for dry year climatic conditions. Ammonia and nitrite concentrations are below regulatory effluent criteria in all years. Nitrate concentrations may slightly exceed NL Reg. 65/03 Schedule A effluent criteria in years 2 and 3 for dry year conditions. This will be mitigated through an ammonia management program.

Change in Surface Water Drainage Patterns

The development of waste rock and overburden stockpile areas will affect drainage patterns within their footprint areas; however due to their headwater locations in their catchment areas, they will have minimal effect on external drainage. Stockpiles areas will continue to drain to Attikamagen Lake. Perimeter ditches are proposed to convey side slope runoff to a sediment pond which will discharge to Attikamagen Lake via an outlet channel. Sediment pond design is further discussed in Section 11.6.2.2.

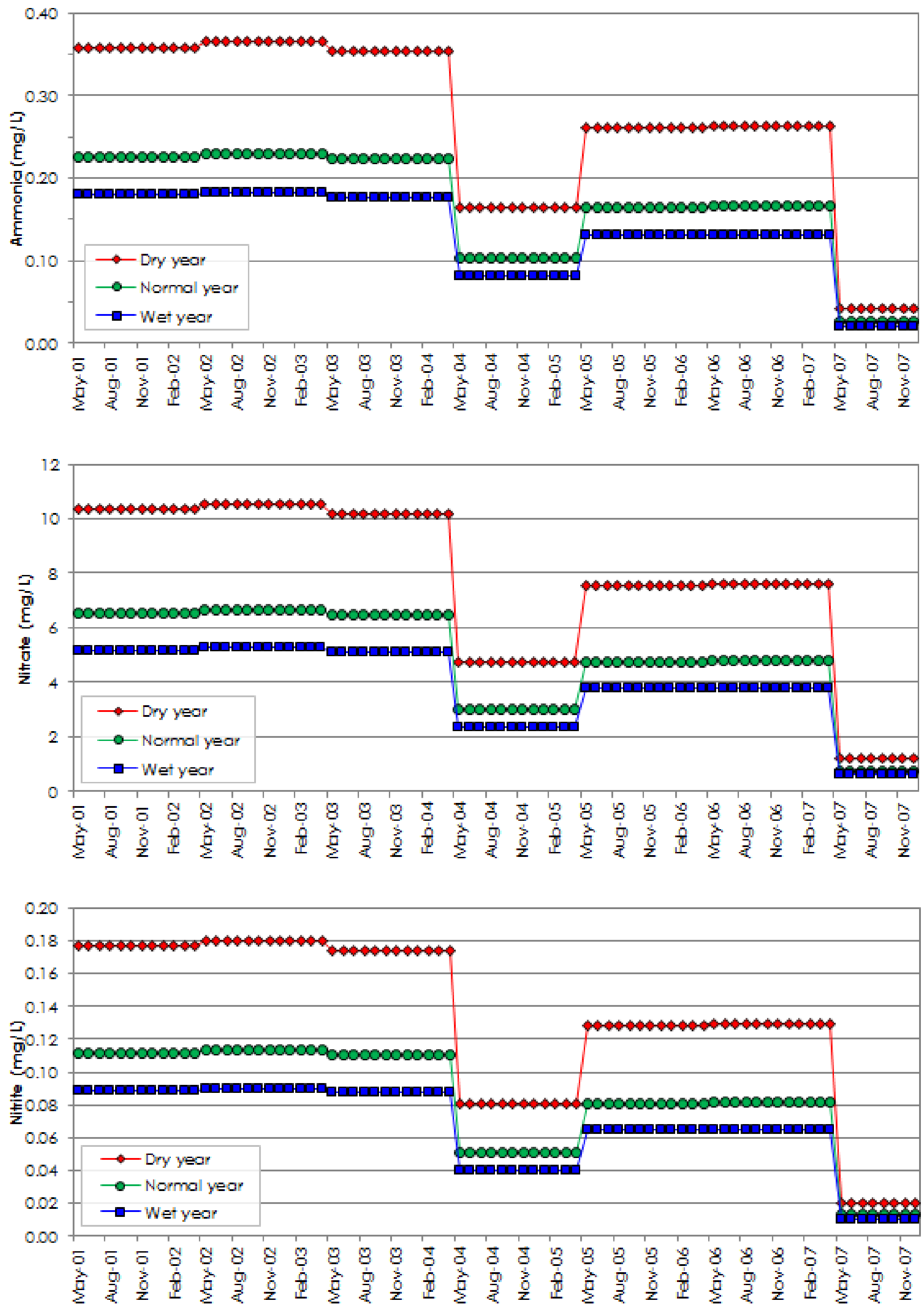

Figure 11.39 Estimated Average Monthly Concentration of Nitrogen Species in Open Pit and Waste Rock and Overburden Stockpile Area Runoff

Low Grade Ore Stockpile

The low grade ore stockpile is a stockpile with a maximum tonnage of approximately 3.64 million tonnes, an approximate area of physical disturbance of 18.1 ha (Figure 11.40). The Low Grade Ore stockpile area drains to Attikamagen Lake via a sediment pond and Stream T1.

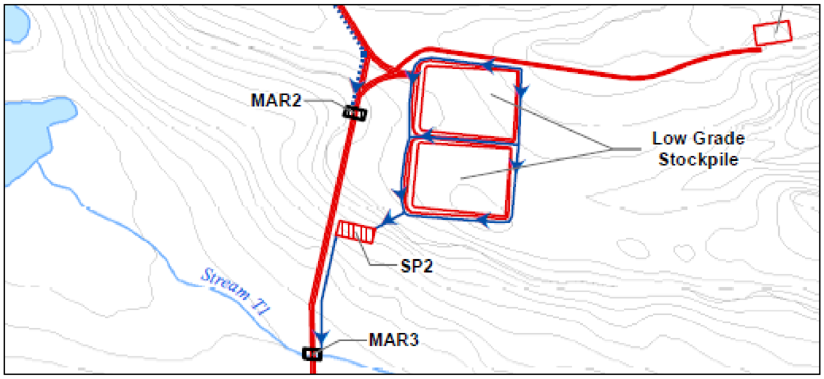

Figure 11.40 Low Grade Ore Stockpile Area Plan

The main potential effects of the low grade ore stockpile associated with surface water are the following:

- Changes to existing surface water runoff quantity arising from water balance alteration due to vegetation removal and ROM filling;
- Changes to existing surface water quality due to increased sediment loading from stockpiles runoff and the potential for ARD/ML, ammonia contamination and red water; and
- Changes to drainage patterns within the stockpiles area affecting the hydrological regime of adjacent waterbodies, including Attikamagen Lake.

Change in Surface Water Quantity

Based on climate normal conditions, the annual streamflow generated by the low grade ore stockpile is estimated at approximately 12.7 m^3/h. Under Operations and Maintenance conditions, the water balance for low grade stock pile stockpiles will change in that the streamflow coefficient will increase from approximately 75% in the existing condition to 85%. This increase in streamflow within the low grade ore stockpile area arises from several factors, including:

- Removal of vegetation resulting in less evaporation; and
- Increase in slope angle at the low grade ore stockpile surfaces.

Therefore, the use of a 85% streamflow coefficient for the low grade ore stockpile is considered appropriate and will contribute 14.4 m^3/hr under climate normal conditions accounting for an approximate increase in total streamflow of 13.4% from existing conditions.

Table 11.48 presents the monthly existing and Operations and Maintenance phase runoff conditions under climate normal conditions. Note that further discussion of the effects of this change is contained in the Project-wide water balance assessment carried out for each Project feature watershed and found at the end of Section 11.6.2.

Table 11.48 Monthly Runoff Estimation from Low Grade Ore Stockpile Under Climate Normal Conditions

Month	Runoff Volume (m^3)	
	Existing Conditions	Operational Condition
September	13,358	15,139
October	8,196	9,289
November	6,077	6,887
December	1,296	1,469
January	1,899	2,140
February	2,225	2,522
March	2,726	3,090
April	8,217	9,313
May	31,725	35,955
June	10,005	11,339
July	14,552	16,493
August	11,471	13,001
Annual	111,736	126,634

Change in Surface Water Quality

Potential water quality effects associated with the ROM stockpile during the Operations and Maintenance phase include sedimentation and ammonia contamination. As described above for the open pit, ARD/ML is not expected to be a concern for this Project. This is further discussed in Chapter 13: Terrain and ARD/ML. In addition, as described above for the open pit, red water is a tailings effluent condition associated with iron ore mining and processing and as such is not expected to be a concern for this Project.

Sedimentation

The long-term average erosion rates from low grade ore stockpile area is estimated at 39,404 kg/year. This equates to an average TSS concentration in open pit runoff of 311 mg/L. The estimated average TSS concentration during the 10 year storm event is 1,429 mg/L. Runoff from the low grade ore stockpile area will be collected in a sediment pond for control of suspended solids prior to release in natural environment.

Ammonia Contamination

The approach and methodology used to assess nitrogen species contamination in the low grade ore stockpile area is described under *Waste Rock and Overburden Stockpile*. Figure 11.41 presents the nitrogen species concentrations in runoff from low grade ore stockpile areas for climate normal and dry/wet year conditions. The nitrogen assessment indicates that nitrogen species higher concentration occurs for dry year climatic conditions. Ammonia, nitrate and nitrite concentrations are below regulatory effluent criteria in all years.

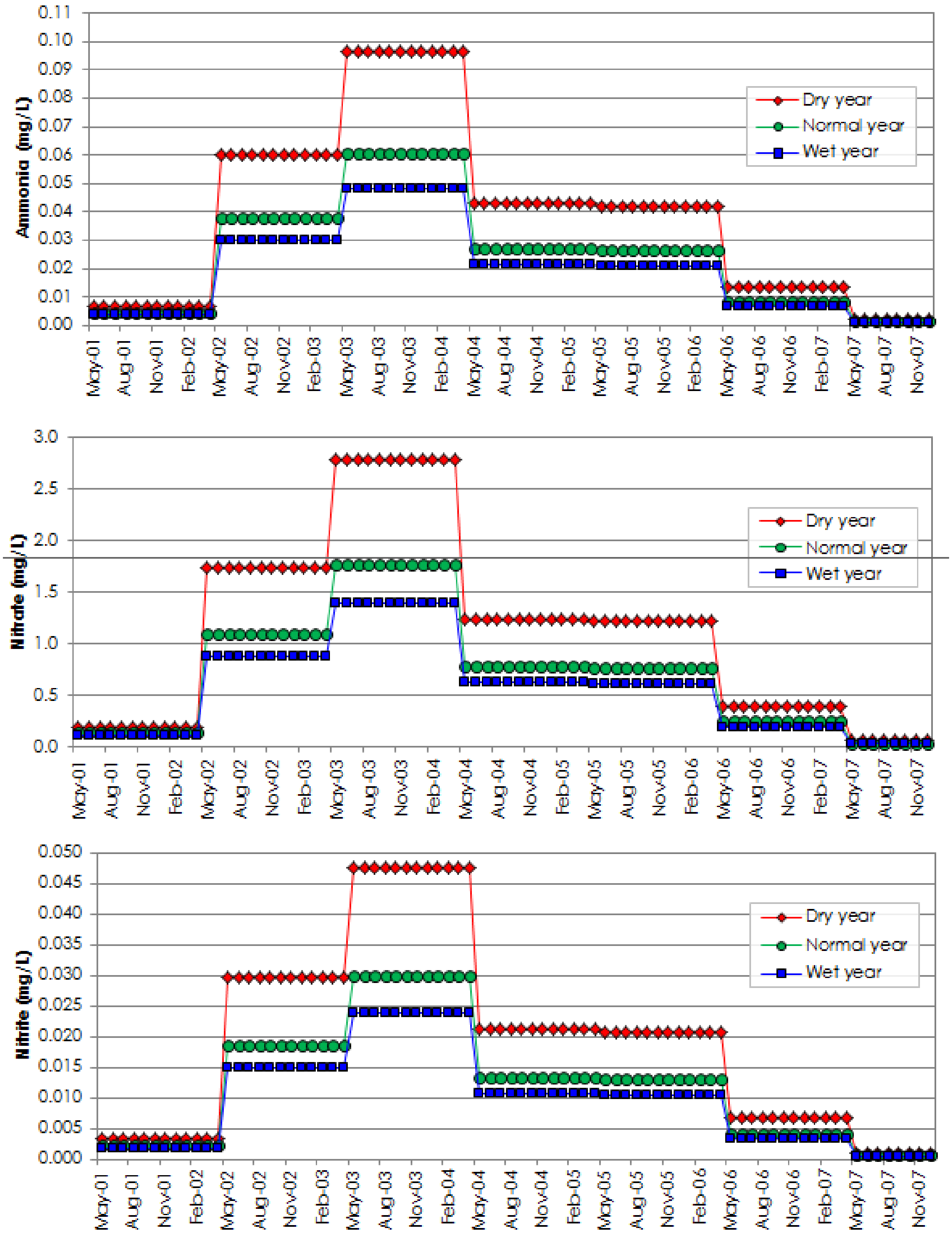

Figure 11.41 Estimated Average Monthly Concentration of Nitrogen Species in Low Grade Ore Stockpile Area Runoff

Change in Surface Water Drainage Patterns

The development of low grade ore stockpile area will affect drainage patterns within their footprint areas; however due to their headwater locations in their catchment areas, they will have minimal effect on external drainage. Stockpiles areas will continue to drain to Attikamagen Lake. Perimeter ditches are proposed to convey side slope runoff to a sediment pond which will discharge to Attikamagen Lake via Stream T1. Sediment pond design is further discussed in Section 11.6.2.2.

Other Mine and Processing Infrastructure

The following section assesses the effects of the processing plant, accommodation facility, power plant, and rail yard on change in surface water quantity, quality and drainage patterns.

Ore processing will consist of a dry circuit with two crushing and two screening steps necessitating no water addition. No tailings will be produced. The processing plant area is comprised of the following:

- Processing plant area including fine ore and lump ore stockpiles – approximately 13.6 ha;
- ROM blending area – approximately 4.31 ha;
- Mining office, truck shop and wash bay – approximately 0.33 ha; and
- Fuel island – approximately 0.13 ha.

Gravel pads will be constructed for buildings including the modular plant. All structures will be temporary in nature, constructed from materials brought in by rail and truck, and assembled on-site. The drainage area of the processing plant area is 36.5 ha and it drains to Iron Arm via a sediment pond.

The accommodation facility will be built in a location along the access road several kilometres from the processing plant in order to reduce the noise disturbance that may be associated with the ore processing. The footprint area of the accommodation facility is 5.48 ha. The accommodation facility area drains to Iron Arm via a sediment pond.

The power plant area includes power plant, main fuel depot and fuel island. The footprint area of the power plant area is 2.5 ha. Power plant area drains to Iron Arm via a sediment pond.

The iron ore produced will be trucked from the processing plant to a new rail yard approximately 27 km south of the plant and north of Astray Lake. The footprint area of the rail yard is 7.4 ha. Rail yard is located in the Gilling River watershed.

The main potential effects to surface water from these facilities are expected to include:

- Increased runoff from disturbed/compacted ground surfaces due to increases in imperviousness, reduction of vegetative cover and grading;
- Spillage of crushed ore from wheeled loaders may affect receiving water quality;

- Facility runoff and dust suppression activities may increase TSS runoff concentrations;
- Sanitary sewage effluent from worker facilities may affect receiving water quality; and
- Facility grading and stormwater management may alter drainage patterns.

These potential effects are assessed in further detail in the following sections.

Change in Surface Water Quantity

Based on climate normal conditions, the annual streamflow generated by the processing plant areas is estimated at approximately 25.7 m^3/h, approximately 3.86 m^3/h for the accommodation facility areas, approximately 1.76 m^3/h for the power plant areas and approximately 5.2 m^3/h for the rail yard.

The compacted and paved surfaces of the above areas will be less permeable than natural surfaces, and result in reductions in ET, higher volume of surface runoff and lesser potential of infiltration than under existing conditions. The primary change in surface water quantity will arise from water balance alteration from facility development and the increase in total streamflow coefficient from approximately 75% in the existing case to 85% in the operational and maintenance case.

Therefore, the use of an 85% streamflow coefficient for the processing area will contribute 29.1 m^3/hr under climate normal conditions, 4.38 m^3/hr under climate normal conditions for the accommodation facility area, 2.00 m^3/hr under climate normal conditions for the power plant area, and 5.91 m^3/hr under climate normal conditions for the rail yard area. For all cases, this accounts for an approximate increase in total streamflow of 13.4% from existing conditions. Estimated monthly runoff is presented in Table 11.49 for the each of the individual areas for existing and operational conditions. Note that further discussion of the effects of this change is contained in the Project-wide water balance assessment carried out for each Project feature watershed and found at the end of Section 11.6.2.

Table 11.49 Estimated Existing and Operational Monthly Runoff Volumes for Processing Area, Accommodation Facility, Power Plant and Rail Yard

Month	Runoff Volume (m^3)							
	Processing Area		Accommodation Facility		Power Plant		Rail Yard	
	Existing Condition	Operational Condition	Existing Condition	Operational Condition	Existing Condition	Operational Condition	Existing Condition	Operational Condition
Jan	3,808	4,316	572	648	261	296	772	875
Feb	4,487	5,085	674	763	307	348	910	1,031
Mar	5,497	6,230	825	935	377	427	1,115	1,263
Apr	16,571	18,780	2,488	2,820	1,135	1,286	3,360	3,808
May	63,975	72,505	9,605	10,886	4,382	4,966	12,970	14,700
Jun	20,175	22,865	3,029	3,433	1,382	1,566	4,090	4,636
Jul	29,346	33,259	4,406	4,993	2,010	2,278	5,950	6,743

Table 11.49 Estimated Existing and Operational Monthly Runoff Volumes for Processing Area, Accommodation Facility, Power Plant and Rail Yard

Month	Runoff Volume (m^3)							
	Processing Area		Accommodation Facility		Power Plant		Rail Yard	
	Existing Condition	Operational Condition	Existing Condition	Operational Condition	Existing Condition	Operational Condition	Existing Condition	Operational Condition
Aug	23,132	26,216	3,473	3,936	1,584	1,796	4,690	5,315
Sept	26,937	30,529	4,044	4,583	1,845	2,091	5,461	6,189
Oct	16,528	18,731	2,481	2,812	1,132	1,283	3,351	3,798
Nov	12,254	13,888	1,840	2,085	839	951	2,484	2,816
Dec	2,613	2,962	392	445	179	203	530	600
Annual	225,324	255,367	33,829	38,340	15,433	17,491	45,682	51,773

Change in Surface Water Quality

At the processing plant area, accommodation facility, and power plant, the potential for ARD/ML, ammonia contamination and red water are considered to be low. At the rail yard area the potential for ARD/ML, ammonia contamination are also considered to be low. Crushed ore has increased potential to generate red water. Crushed ore spillage from wheeled loaders will be cleaned and placed in crushed ore stockpile. Runoff from crushed ore stockpiles is not considered to pose a red water production hazard due to the limited storage and potential oxidation period, as well as the relatively coarse grain size of product ore. However it is recommended that the rail yard runoff be monitored for the production of red water.

Potential changes to surface water quality arise from the following: sedimentation and sanitary effluent. These are assessed in further detail in the following sections.

Sedimentation

Long term average annual erosion rates from the facility areas was predicted using the RUSLEFAC (Wall et al. 2002). MUSLE (Williams 1975) was used to predict the TSS concentrations during storm events. Predicted erosion rates and the TSS concentrations are presented in Table 11.50 for processing plant, accommodation facility, power plant and rail yard areas.

Table 11.50 Predicted Erosion Rates and TSS Concentrations

	Long-term Sediment Rates		1:10 Year Storm
	Load (Kg/Yr)	TSS (mg/L)	TSS (mg/L)
Processing Plant	8,631	34	103
Accommodation Facility	528	14	77
Power Plant	246	14	58
Rail Yard	587	12	41

Stormwater management will be implemented for the facility areas and internal roads in the form of grading controls, and appropriately sized sedimentation ponds. Further details on the Water Management Plan is found in Section 11.6.2.2.

Ammonia Contamination

Processing plant area includes fine ore and lump ore stockpiles area. Runoff from the fine ore and lump ore stockpiles area has potential for nitrogen species contamination. The approach and methodology used to assess nitrogen species contamination in the low grade ore stockpile area is described under *Waste Rock and Overburden Stockpile*. Figure 11.42 presents the nitrogen species concentrations in runoff from processing plant areas for climate normal and dry/wet year conditions. The nitrogen assessment indicates that nitrogen species higher concentration occurs for dry year climatic conditions. Ammonia, nitrate and nitrite concentrations are below regulatory effluent criteria in all years.

Sanitary Effluent

The accommodation facility will provide the workspace for most workers. A membrane bioreactor WWTP is proposed for the accommodation facility and for the sewage from the other Project facilities. The details of the WWTP is provided in Appendix L. The membrane bioreactor WWTP is sized using the parameters listed in Table 11.51. Influent and effluent water quality characteristics are presented in Table 11.52. The sewage from other Project areas will be collected and transported for treatment. Sanitary effluent criteria is not covered under MDMER, however it is covered under Schedule A of NL Regulation 65/03. Sanitary effluent will be treated to regulatory effluent criteria before discharge to the receiving environment.

Table 11.51 Design Parameters

	Design Value	Unit
Per capita design flow	250	L/p/d
Number of persons on site	150	persons
Average daily flow	38	m3/d
Peak hourly flow (assumed)	400	L/p/d
Overall time for peak to occur	5 hours	
Maximum number of peak events per day	2 times	
Mixed liquor suspended solids	1%	
Minimum inlet temperature	8	oC
Site power	Three-phase, 480V, 60Hz	
System area classification	According to NFPA 820, 2012 Edition	
Ambient temperature	Max: 37oC, min: -40oC	
Elevation	< 500 m	

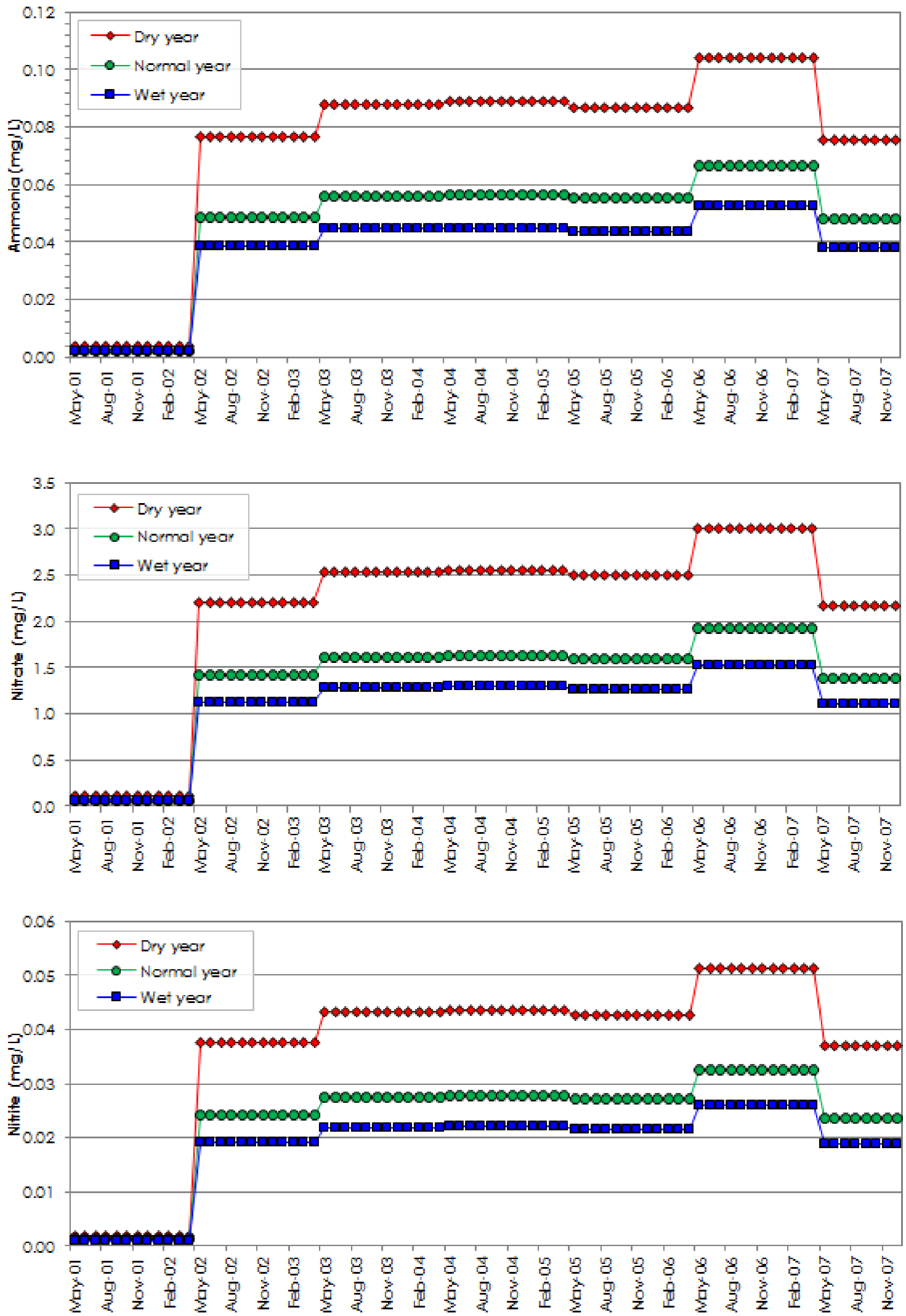

Figure 11.42 Estimated Average Monthly Concentration of Nitrogen Species in Processing Plant Area Runoff

Table 11.52 Influent and Effluent Wastewater Characteristics

Parameter	Unit	Influent	Effluent
pH	s.u	6-9	7-9
FOG	mg/L	< 30	-
BOD_5	mg/L	400	<5
TSS	mg/L	350	<1
TDS	mg/L	<1,200	-
TKN	mg/L	70	-
TAN	mg/L	65	-
TP	mg/L	10	-
Fecal Coliform	colony-forming unit/100ml	-	<200[1]
Alkalinity	mg/L	>200	-

Note:
[1] After Ultraviolet (UV) disinfection

Change in Surface Water Drainage Patterns

Vegetation removal, surface grading, soil compaction and the institution of stormwater runoff controls will affect drainage patterns within the processing plant area, accommodation facility, power plant and rail yard. These effects will be localized and would not extend beyond the LSA.

Water Crossing Locations

Approximately 15 water crossings are proposed for the Project including a causeway across Iron Arm associated with the haulage road from processing plant to train loading and four crossing associated with haulage from mine area to the processing plant area (Figure 11.43). No water crossings are associated with the rail track and loop.

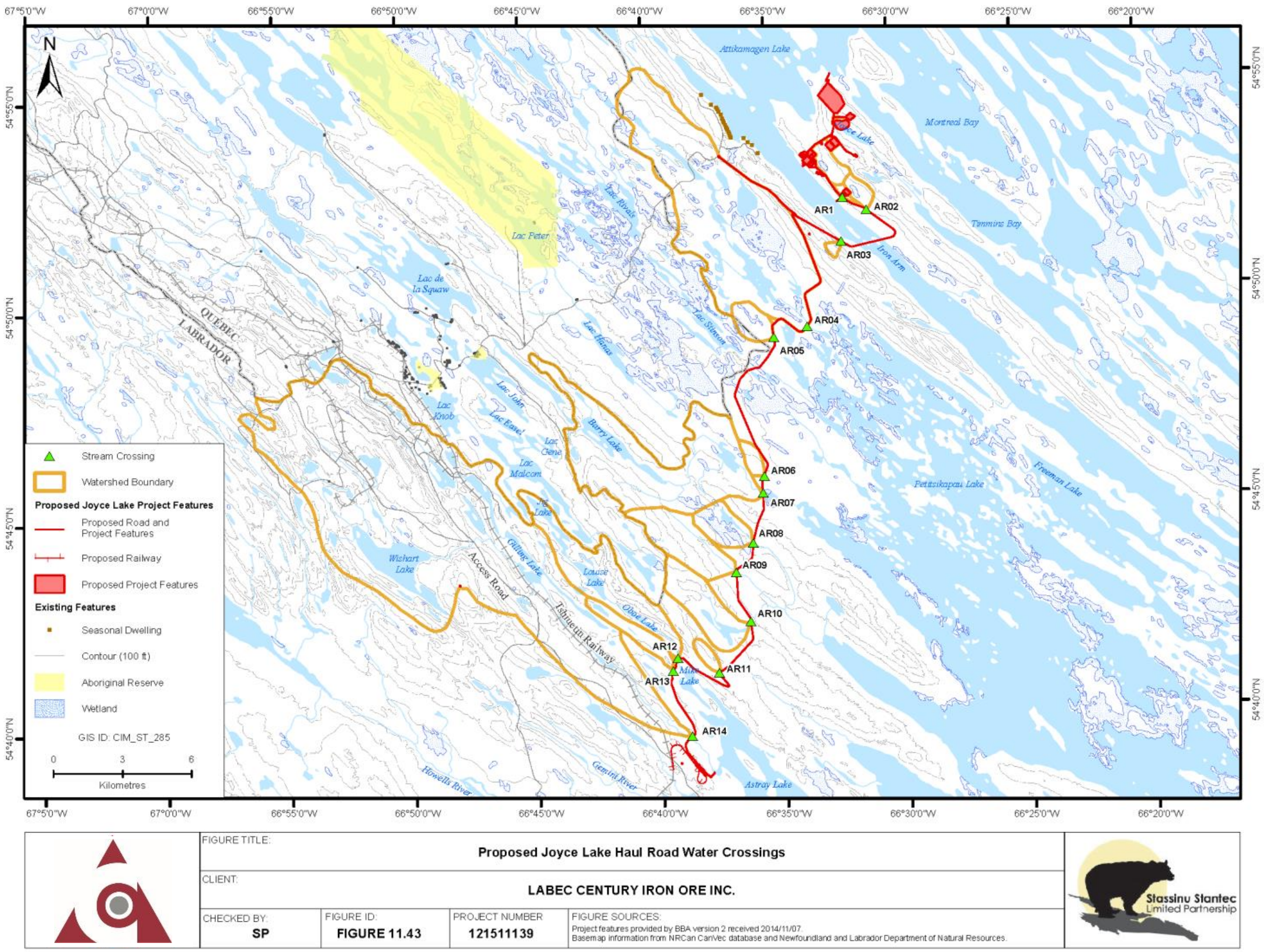

Figure 11.43 Proposed Joyce Lake Haul Road Water Crossings

Bridge Crossing

A bridge is proposed across Gilling River as part of the mine haul road to be constructed for the Joyce Lake Direct Shipping Iron Ore Project. Details of the proposed bridge crossing are shown in Figure 11.44 (BBA 2015). A hydraulic assessment (Stassinu Stantec 2014e) was conducted to assess the water levels and flow velocities at the bridge crossing. Summary of the effects due to the bridge crossing at Gilling River is presented below and detailed hydraulic assessment is provided in Appendix M.

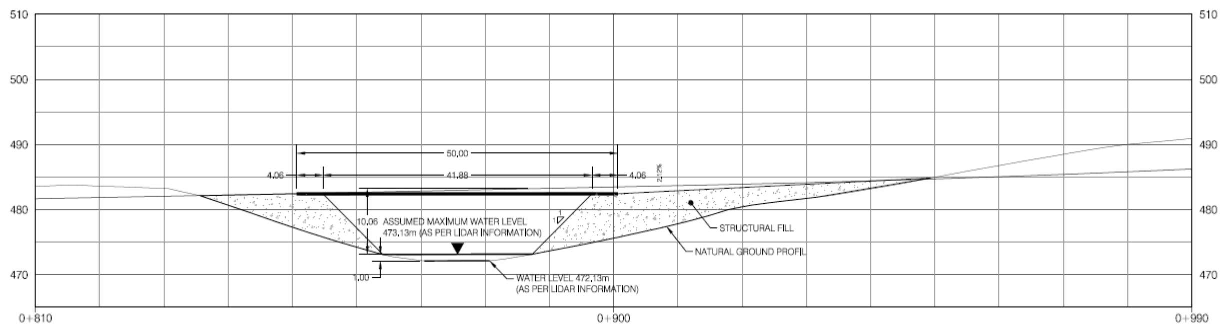

Figure 11.44 Proposed Bridge Crossing Details

Hydraulic Assessment

The design flow frequency selected for the bridge crossing is the 1:25 year flood flows. This is consistent with Environmental Guidelines for Watercourse Crossings (NL Water Resources Management Division, Water Rights, Investigations and Modelling Section, 2017). The proposed bridge crossing is located on the Gilling River. Table 11.53 presents the predicted water levels and flow velocity at the bridge crossing for a range of flood events. Hydraulic assessment indicates that:

- the bridge can pass the design flood without adverse upstream flooding impacts;
- the available freeboard/clearance is 9.29 m for 1:100 Year flood event and can pass floating debris and ice without any adverse impacts;
- the bridge abutments are located more than 0.5 m away from the normal water's edge;
- the 1:10 Year water level is contained within the natural channel at the bridge crossing; and
- the flow velocities at the bridge crossing range from 0.81 m/s for MAF conditions to 1.75 m/s for 1:100 Year flood conditions.

Table 11.53 Predicted Water Levels and Velocities at Bridge Crossing

Return Period (year)	Water Level (m)			Soffitt Elevation (m)	Average Flow Velocity (m/s)
	Upstream	Bridge Crossing	Downstream		
MAF	472.38	472.35	472.25	482.40	0.81
1:10 Year	473.05	473.01	472.91		1.64
1:25 Year	473.09	473.05	472.96		1.69
1:100 Year	473.15	473.11	473.02		1.75

Approximately 9 m of clearance is available between the 1:100 Year water level and the soffit of the bridge. Hydraulic conditions (flow depth and velocity) at the bridge crossing have not been altered up to the 1:10 year flood events by the proposed construction of bridge at Gilling River. Therefore, the proposed bridge crossing meets the fish passage requirements (refer to Chapter 15: Fish and Fish Habitat).

Culvert Crossing Design

Approximately 13 culvert crossings are proposed for the haulage road from the processing plant to train loading and four crossings associated with haulage from mine area to the processing plant area (Figure 11.43). Stantec (2014f) completed a preliminary culvert crossing design. The summary of the culvert crossing design are provided below and culvert crossing design details are provided in Appendix N.

The following general approach was adopted for culvert crossing design (refer to Chapter 15: Fish and Fish Habitat for further assessment of fish passage):

- Design flow frequency selected for the culvert crossings is the 1:25 year flood flows (NL Water Resources Management Division, Water Rights, Investigations and Modelling Section, 2017);
- The following hydraulic consideration will be assessed during the design:
  - Potential for damage to the culvert and/or roadway during the floods;
  - Potential for upstream flooding due to headwater ponding; and
  - Potential for downstream scour/erosion due to excessive outlet velocities.
- A single culvert will be used whenever flow is mainly confined to a single well defined channel under normal flow conditions;
- Multiple culverts will be considered at sites where poorly-defined channel exist in fens or wetland areas that are being crossed by the proposed access road to ensure that the natural drainage through these areas is adequately maintained;
- For sites with no fish habitat, culverts will be sized based on entirely hydraulic criteria;

- For sites with confirmed or potential fish habitat, culvert crossing will be designed to meet requirements for fish passage;
- If fish passage requirements cannot be met with a culvert crossing, an alternative design involving a “clearspan” structure will be considered; and
- A minimum culvert size of 600 mm will be used to reduce the potential blockage due to ice, sediment, beaver activities and vegetation.

Ice Jamming Consideration

Stream freeze-up produces a mass of ice on a river. Break-up of river ice may result in ice jams and ice forces on water crossings. The resulting ice jam may cause the following type of problems:

- Increased scour at waterway constrictions;
- Flooding upstream of an ice jam and aggravated channel scour downstream resulting in damage to land and properties;
- Damage to stream crossings due to ice abrasion;
- Impact of ice forces on bridges, abutments and piers which could result in structural damage or destruction;
- Channel icing which may reduce the conveyance capacity of a water crossing, resulting in upstream flooding; and
- Surges of flow from sudden release of jams may aggravate these problems.

The following will be considered during the design of each water course crossings:

- Each stream crossing site will be assessed to determine whether a site under consideration is prone to significant ice problems and its suitability for a stream crossing;
- For sites potentially subjected to ice runs, the following locations will be avoided for a stream crossing:
  - the outside of a meander bend; and
  - near a location historically known for ice jams.
- Design high ice conditions at water crossing sites will be considered in the design of water crossings.

Table 11.54 provides preliminary design information for haul road water crossings. Figures 11.45 and 11.46 provide conceptual design of water crossings for non-fish bearing streams and fish bearing streams, respectively.

Table 11.54 Culvert Crossing Design Summary

Crossing ID	Fish Passage Required	Culvert Details					Min. Cover (mm)	Inlet and Outlet Protection Required
		TYPE	Shape	Size (mm)	Length (m)	Embedment Depth (mm)		
AR2	No	CSP	Circular	900	22	0	600	Yes
AR3	No	CSP	Circular	600	21	0	600	Yes
AR4	Yes	CSP	Open Bottom Arch	6400 x 2100	31	-	1,000	Yes
AR5	No	CSP	Circular	1,200	24	0	600	Yes
AR6	No	CSP	Circular	900	22	0	600	Yes
AR7	Yes	CSP	Open Bottom Arch	4500 x 2000	29	-	700	Yes
AR8	Yes	CSP	Circular	1,400	24	210	600	Yes
AR9	Yes	CSP	Circular	2,000	27	300	600	Yes
AR10	Yes	CSP	Circular	2,000	27	300	600	Yes
AR11	Yes	CSP	Circular	1,000	24	150	600	Yes
AR12	Yes	CSP	Circular	2,400	28	360	600	Yes
AR13	Yes	CSP	Circular	1,400	24	210	600	Yes
AR14	Yes	Bridge	-	-	-	-	-	-

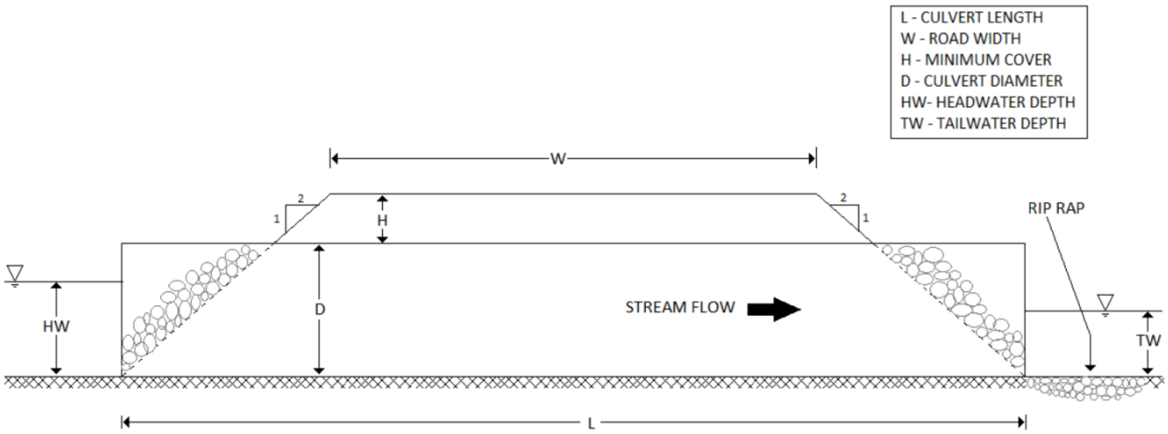

Figure 11.45 Conceptual Design of Water Crossing – Non-Fish Bearing Stream

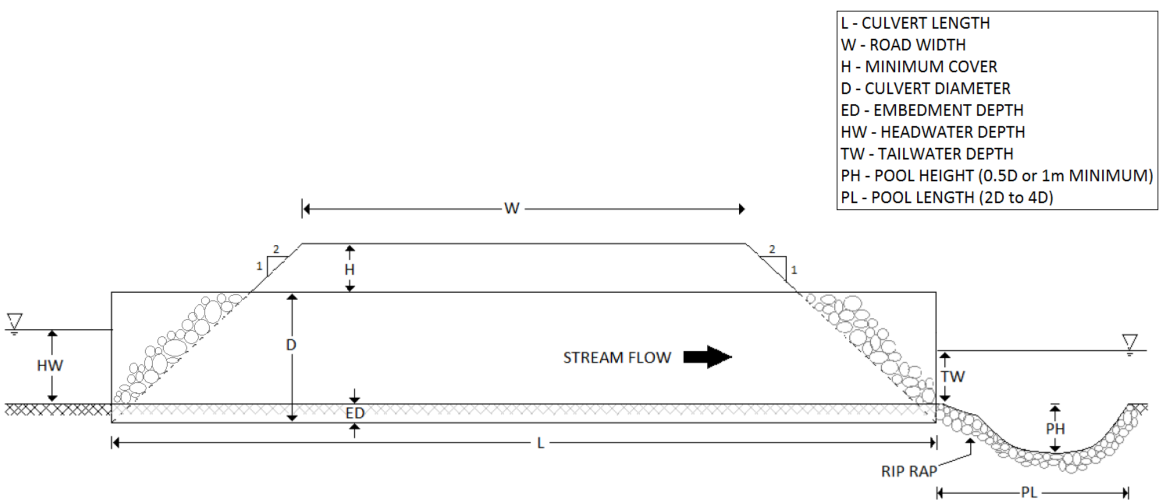

Figure 11.46 Conceptual Design of Water Crossing – Fish Bearing Stream

Project-Wide Water Balance

The Project will cause some disturbance to the surface water hydrologic systems in the LSA during the various phases of the Project. A Project-wide water balance assessment was carried out for each Project feature watershed as shown in Figure 11.47 over the LOM. This assessment evaluated effects of the Project on the hydrologic conditions in the LSA and RSA. Details of the footprint size and location of the facilities are described in Chapter 2: Project Description. The Project footprint areas, watershed areas of each Project component located are presented in Table 11.55.

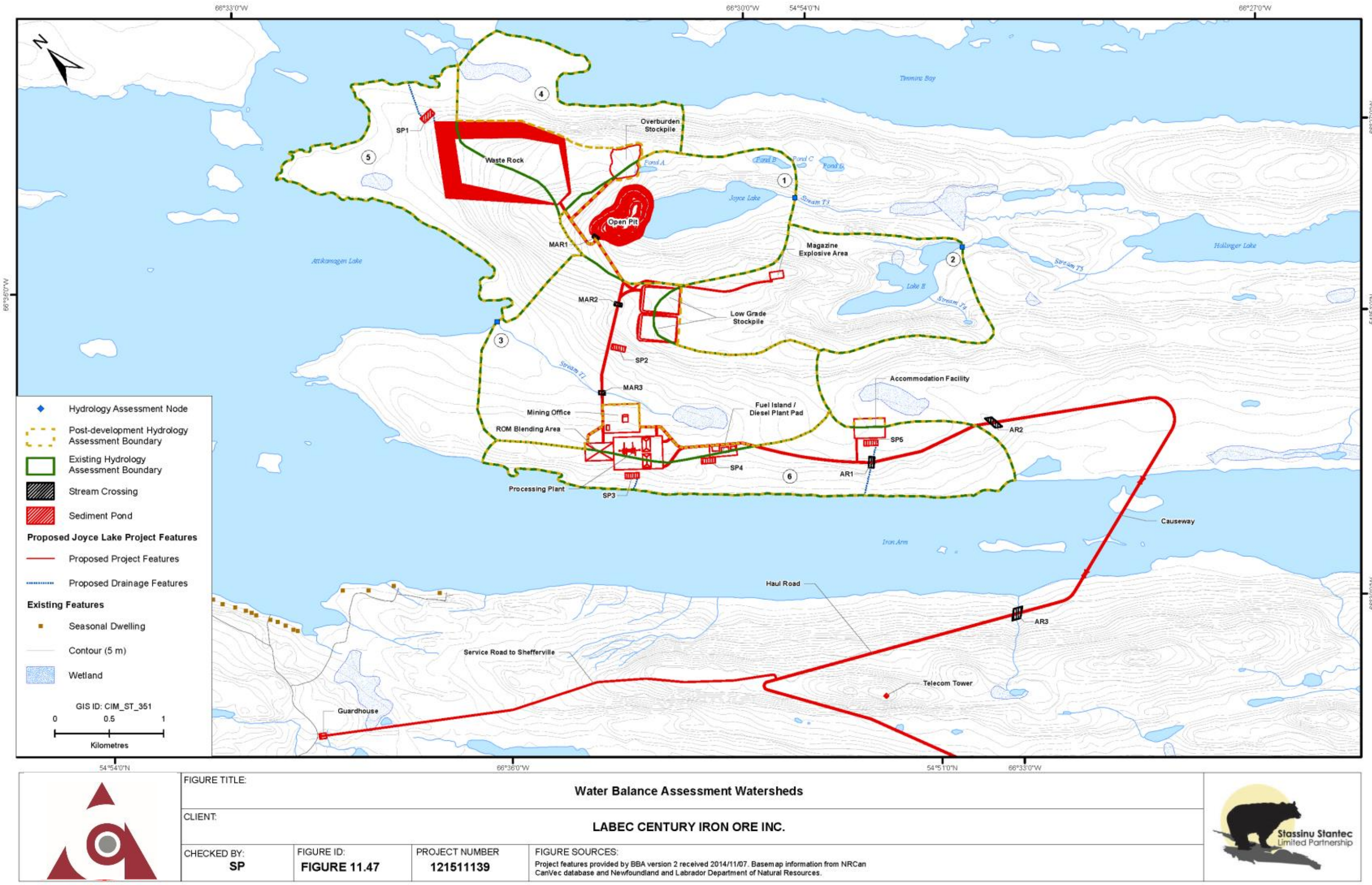

Figure 11.47 Water Balance Assessment Watersheds

Table 11.55 Project Footprint Areas and Watershed Areas

Watershed Name	Watershed Area (ha)	Sub-Watershed ID	Receiving Waterbody	Existing Drainage Area (ha)	Drainage Area under Operation and Maintenance Conditions (ha)	Project Components				
						Name	**Area (ha)**	**Total Area (ha)**	**% of Disturbed Area in Each Sub-Watershed[4]**	**% of Disturbed Area in Watershed**
Attikamagen Lake	159,800	1	Unnamed Stream, T3[1]	210	196	Open Pit	20.9	23.6	12.0	0.130
						Access Road	2.7			
		2	Unnamed Stream, T5[2]	252	243	Magazine Explosive Area	0.90	2.10	0.864	
						Access Road	1.20			
		3	Attikamagen Lake	380	364	Low Grade Stockpile	18.1	27.0	7.42	
						Access Road	6.66			
						Sediment Pond	2.2			
		4	Timmins Bay[3]	187	120					
		5	Attikamagen Lake[3]	243	317	Waste Rock Stockpile	81.7	97.6	30.8	
						Overburden Stockpile	6.84			
						Access Road	1.08			
						Sediment Pond	8.0			
		6	Iron Arm[3]	220	256	Processing Plant Area	36.5	57.6	22.5	
						Main Fuel Depot and Power Plant	2.50			
						Accommodation Facility	5.48			
						Sediment Ponds (3 Nos.)	4.1			
						Access Road	9.0			
Gilling River	10,200	7	Gilling River	77	77	Rail Yard	7.4	15.9	20.6	0.152
						Access Road	7.9			
						Sediment Pond	0.6			

Note:
[1] outlet to Joyce Lake and ultimately drains to Timmins Bay; [2] outlet to Lake E and ultimately drains to Timmins Bay; [3] distributed flows, based on post-development watershed areas.

The relatively small and localized effects due to surface disturbance do not warrant the use of hydrologic models for impact assessment. Physically-based hydrologic models require a considerable amount of input data for calibration and verification. Since long-term site specific data are not available, the calibration of such models would have to be based on regional data. Regionally calibrated hydrologic models, however, cannot be expected to be accurate enough to identify hydrologic impacts due to disturbance of less than 5% of the drainage area.

Climate in the Project area is continental with lengthy, very cold winters and deep snow. During the cold months, there is very little surface runoff and precipitation (snow) accumulates on the ground. The accumulated snow will be released largely as surface runoff during the freshet. This process is modeled by applying a monthly precipitation-runoff factor to precipitation that will account for how much precipitation becomes surface runoff for a particular month. The remainder of the precipitation will be added to the next month. The monthly precipitation–runoff factors were selected based on the Project area environmental water balance and recorded stream flow data for Labrador and are provided in Table 11.56.

Table 11.56 Precipitation-Runoff Factor

Month	Precipitation-Runoff Factor
September	1.0
October	0.75
November	0.50
December	0.10
January	0.10
February	0.10
March	0.10
April	0.25
May	1.0
June	1.0
July	1.0
August	1.0

The starting month in the water balance model was selected as a month that generates 100% of runoff to model snowmelt and accumulation process during cold months.

The following section describes water balance results for each Project feature watershed.

Watershed # 1 (Open Pit-Joyce Lake Watershed)

The open pit mine is located within watershed # 1 (Figure 11.47). Footprint areas of the Project features located within the watershed # 1 are provided in Table 11.55. The drainage area of watershed # 1 is 234 ha under existing conditions and 196 ha under Project conditions due to Project Water Management Plan as described in Section 11.6.2.2. Currently, watershed # 1 drains to Joyce Lake and then discharges to a wetland bog located southeast of the Lake. Joyce Lake may also regularly discharge to the wetland bog channel via groundwater flow.

During Project conditions, the Joyce Lake outlet will receive discharge from the following:

- Joyce Lake catchment area runoff around the open pit mine and the shoreline of Joyce Lake;
- Initial and operational dewatering of Joyce Lake; and
- Groundwater intercepted from the open pit perimeter dewatering wells.

Table 11.57 summarizes annual flow rates at Node #1 over LOM. Monthly flow rates at Node # 1 for existing and Project conditions are shown in Figure 11.48 under climate normal conditions. Flow changes at Node # 1 ranged from 6% to 253% during Operation and Maintenance conditions. Flow at Node # 1 is expected to return to existing conditions after Closure and Decommissioning.

Table 11.57 Climate Normal Flow Rates at Node # 1 under Existing and Project Conditions over LOM

Year	Average Annual Flows (L/s)		Change %	Comments
	Existing Case	Project Case		
1	44.7	158	253	Joyce Lake initial dewatering
2	65.1	68.8	5.68	Open pit partial development
3	65.1	76.7	17.8	Open pit partial development
4	65.1	92.0	41.3	Open pit partial development
5	65.1	98.2	50.8	Open pit partial development
6	65.1	98.2	50.8	Open pit partial development
7	65.1	98.2	50.8	Open pit ultimate development
8	65.1	30.0	-53.9	Closure and decommissioning

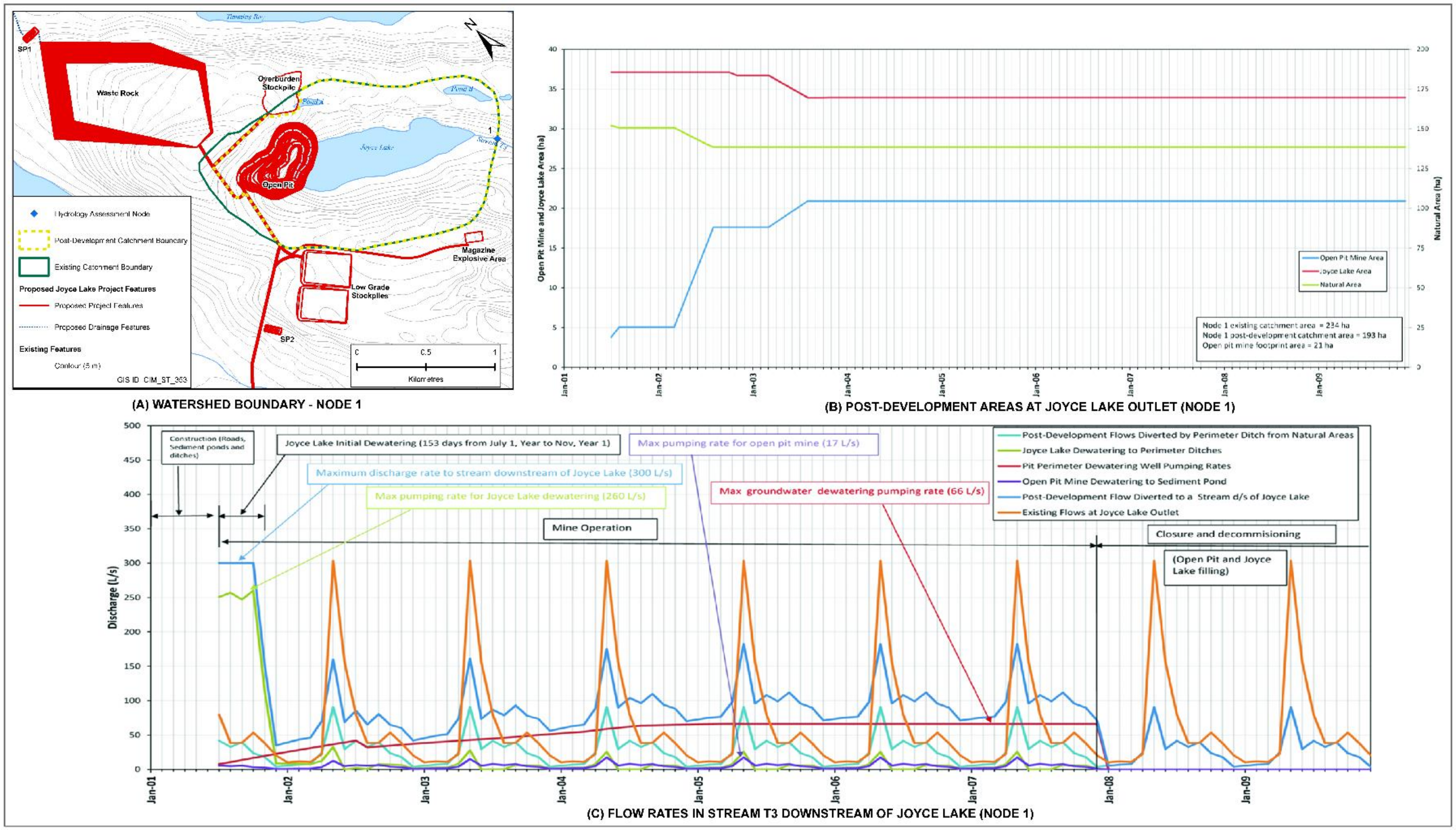

FIGURE TITLE:			
Existing and Project Conditions Monthly Flow Rates at Node # 1 under Climate Normal Conditions over LOM			
CLIENT: LABEC CENTURY IRON ORE INC.			
CHECKED BY: SP	FIGURE ID: FIGURE 11.48	PROJECT NUMBER 121511139	FIGURE SOURCES: Project features provided by BBA version 2 received 2014/11/07. Basemap information from NRCan CanVec database and Newfoundland and Labrador Department of Natural Resources.

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Figure 11.48 Existing and Project Conditions Monthly Flow Rates at Node # 1 under Climate Normal Conditions over LOM

Existing monthly flow rates in Node # 1 ranges from 1.0 L/s in January to 303 L/s in May during the spring freshet. Maximum monthly flow rates at Node # 1 is 300 L/s during the Joyce Lake initial dewatering operation and will occur from July 1, Year 1 to November 30, Year 1 as illustrated in Figure 11.47. Therefore, the expected maximum monthly flow rate in Node 1 during the Joyce Lake initial dewatering operation is within the natural flow variation in Node # 1.

Environmental maintenance flows in Stream T3 outlet of Joyce Lake are 26.2 L/s and 12.9 L/s for summer and winter conditions, respectively. The minimum monthly flow of 35.0 L/s occurs in December, Year 1 of operation and higher than the environmental maintenance flows.

Pond A and Pond B within the Watershed #1 will be affected by the groundwater dewatering during the open pit mine operation. Pond A recharges to the groundwater at a rate of 499 m^3/d during the existing conditions and become completely dewatered during the Phase 1 of the groundwater dewatering (WESA 2014). Pond B recharges to groundwater increases to 325 m^3/d, 344 m^3/d, 379 m^3/d and 394 m^3/d during the Phase I, II, III and IV, as presented in 11.6.2.1 of groundwater dewatering operations, respectively from 301 m^3/d during the existing conditions.

Stream T3 (outlet of Joyce Lake) recharges to groundwater increases to 244 m^3/d, 261m^3/d, 292 m^3/d and 306 m^3/d during the Phase I, II, III and IV of groundwater dewatering operations, respectively from 189 m^3/d during the existing conditions. Maximum groundwater recharge increment in Stream T3 will be approximately 1.35 L/s corresponding to Phase IV of groundwater dewatering operations and is not expected to alter the Stream T3 flow rates significantly.

Losses to groundwater in Pond B and Stream T3 increase between 18 and 62%. Although water levels may decrease, these water features are not expected to be completely dewatered (WESA 2014).

Watershed # 2 (Magazine Explosive Area)

Magazine explosive area and access roads are proposed to be constructed within watershed # 2 (Figure 11.47) and corresponding footprint areas of each feature are presented in Table 11.55. Watershed # 2 drains to Lake E which ultimately drains to Timmins Bay via series of lakes and streams. The drainage area of watershed # 2 is 252 ha under existing conditions and 243 ha under Project conditions due to Project Water Management Plan for the low grade ore stockpile as described in Section 11.6.2.2. The existing and Project conditions monthly flow at node # 2 under climate conditions over the LOM are presented in Table 11.58. The flows at Node # 2 are expected to return to existing conditions after Closure and Decommissioning. Flow change at Node # 2 is expected to be -3.4% during Operation and Maintenance under ultimate pit development conditions.

Table 11.58 Existing and Project Conditions Flow Rates at Node # 2 under Climate Normal Conditions over LOM

Month	Monthly Flow at Node # 2 (L/s)		Change (%)
	Existing Conditions	Project Conditions	
January	9.81	9.48	-3.40
February	12.8	12.4	-3.40
March	14.2	13.7	-3.40
April	44.1	42.6	-3.40
May	165	159	-3.40
June	53.7	51.9	-3.40
July	75.6	73.0	-3.40
August	59.6	57.6	-3.40
September	71.7	69.3	-3.40
October	42.6	41.1	-3.40
November	32.6	31.5	-3.40
December	6.74	6.51	-3.40
Annual	**49.0**	**47.4**	**-3.40**

Node # 2 environmental maintenance flows are 19.6 L/s and 9.80 L/s for summer and winter conditions, respectively. The minimum monthly flow of 6.52 L/s occurs in December during the operation and maintenance conditions and less than the winter environmental maintenance flow as in the case of existing conditions.

Lake E is located with watershed # 2. Groundwater recharge to Lake E changes to 905 m^3/d, 876 m^3/d, 820 m^3/d and 795 m^3/d during the Phase I, II, III and IV of groundwater dewatering operations, respectively from 870 m^3/d during the existing conditions (WESA 2014).

Losses to groundwater in Lake E increases to 6% and 9% during the Phase III and IV of the dewatering operations, respectively. Although water levels may decrease, these water features are not expected to be completely dewatered. Maximum groundwater recharge decline in Lake E will be approximately 0.868 L/s corresponding to Phase IV of groundwater dewatering operations and is not expected to alter the Node # 2 flow rates substantially.

Watershed # 3 (Low Grade Ore Stockpile Area)

The low grade ore stockpile, sediment pond and access roads are proposed to be constructed in watershed # 3 (Figure 11.47). The corresponding footprint areas of each feature are presented in Table 11.55. Watershed # 3 drains to Attikamagen Lake via Stream T1. The existing drainage area of watershed # 3 is approximately 380 ha and will decrease to 364 ha under the Project conditions as a result of Project Water Management Plan as described in Section 11.6.2.2. The existing and Project conditions monthly flow at node # 3 under climate conditions over the LOM are presented in Table 11.59. The flows at Node # 3 will be returned to the existing conditions after Closure and Decommissioning. Monthly flow change at Node # 3 is -2.91% during Operation and Maintenance conditions.

Table 11.59 Existing and Project Conditions Flow Rates at Node # 3 under Climate Normal Conditions over LOM

Month	Monthly Flow at Node # 3 (L/s)		Change (%)
	Existing Conditions	Project Conditions	
January	14.8	14.4	-2.91
February	19.3	18.7	-2.91
March	21.4	20.7	-2.91
April	66.6	64.6	-2.91
May	249	241	-2.91
June	81.0	78.7	-2.91
July	114	111	-2.91
August	89.9	87.3	-2.91
September	108	105	-2.91
October	64.2	62.4	-2.91
November	49.2	47.8	-2.91
December	10.2	9.86	-2.91
Annual	**74.0**	**71.8**	**-2.91**

Stream T1 is located with watershed # 3. Groundwater recharge to Stream T1 changes to 1,058 m^3/d, 972 m^3/d, 769 m^3/d and 648 m^3/d during the Phase I, II, III and IV of groundwater dewatering operations, respectively from 1,270 m^3/d during the existing conditions (WESA 2014).

Watershed # 4

No Project features are located within watershed # 4 (Figure 11.47). The drainage area will change from 187 ha to 120 ha due to the waste rock and overburden stockpiles water management plan as described in Section 11.6.2.2 during Operational and Maintenance conditions. The existing and Project conditions monthly flow at node # 4 under climate conditions over the LOM are presented in Table 11.60. Monthly flows at Node # 4 are expected to be decreased by approximately 36% and expected to remain during Closure and Decommissioning.

Table 11.60 Existing and Project Conditions Flow Rates at Node # 4 under Climate Normal Conditions over LOM

Month	Monthly Flow at Node # 4 (L/s)		Change (%)
	Existing Conditions	Project Conditions	
January	7.30	4.66	-36.1
February	9.52	6.08	-36.1
March	10.5	6.73	-36.1
April	32.8	21.0	-36.1
May	123	78.3	-36.1
June	40.0	25.5	-36.1
July	56.2	35.9	-36.1
August	44.3	28.3	-36.1
September	53.3	34.1	-36.1
October	31.7	20.2	-36.1
November	24.3	15.5	-36.1
December	5.01	3.20	-36.1
Annual	**36.5**	**23.3**	**-36.1**

Watershed # 5 (Waste Rock and Overburden Stockpile Area)

Waste rock and overburden stockpiles are located within watershed # 5 (Figure 11.47). Footprint areas of the Project features located within the watershed #5 are provided in Table 11.55. The drainage area of watershed # 5 is 243 ha under existing condition and 317 ha under Project conditions due to the Project Water Management Plan as described in Section 11.6.2.2. Watershed # 5 drains to Attikamagen Lake via overland flow. It is assumed that the waste rock and overburden stockpiles will be progressively reclaimed. Figure 11.37 compares monthly flow rates at Node # 5 for existing and Project conditions under climate normal conditions. Annual flow rates are summarized in Table 11.61 over LOM. Flow changes at Node # 5 are expected to range from 32.8% to 38.1% during operation and maintenance conditions and 38.1% after closure and decommissioning due to watershed area increase.

Table 11.61 Climate Normal Flow Rates at Node # 5 under Existing and Project Conditions over LOM

Year	Average Monthly Flows (L/s)		Change %
	Existing Case	Project Case	
1	61.2	81.3	32.8
2	47.3	64.0	35.3
3	47.3	65.0	37.4
4	47.3	65.3	38.1
5	47.3	65.3	38.1
6	47.3	65.3	38.1
7	47.3	65.3	38.1
8	47.3	65.3	38.1

Note:
[1] from May, Year 1 to December; Year 1

Watershed # 6 (Processing Plant, Main Fuel Depot and Power Plant and Accommodation Facility Areas)

In the processing plant and associated infrastructure, main fuel depot, power plant, and accommodation facility, three sediment ponds are proposed to be constructed in the watershed # 6 (Figure 11.47). Footprint areas of each feature are presented in Table 11.55. Watershed # 6 drains to Iron arm via overland flow. The existing drainage area of watershed #6 is 220 ha under existing conditions and 256 ha under Project conditions. Watershed # 6 watershed boundary will be altered in the Project conditions due to the Project Water Management Plan as described in Section 11.6.2.2. The existing and Project conditions monthly flow at node # 6 under climate conditions over the life of mine (LOM) are presented in Table 11.62. The flows at Node # 6 are expected to return to existing conditions after Closure and Decommissioning. Flow at Node # 6 increases by 20% during Operation and Maintenance conditions.

Table 11.62 Existing and Project Conditions Flow Rates at Node #6 under Climate Normal Conditions over LOM

Month	Monthly Flow at Node # 6 (L/s)		Change (%)
	Existing Conditions	Project Conditions	
January	8.57	10.3	19.9
February	11.2	13.4	19.9
March	12.4	14.8	19.9
April	38.5	46.2	19.9
May	144	173	19.9
June	46.9	56.3	19.9
July	66.0	79.2	19.9
August	52.0	62.4	19.9
September	62.6	75.1	19.9
October	37.2	44.6	19.9
November	28.5	34.2	19.9
December	5.88	7.05	19.9
Annual	**42.8**	**51.4**	**19.9**

Watershed #7 (Rail Yard Area)

The rail yard and a sediment pond are proposed to be constructed in watershed # 7. The footprint areas of each feature are presented in Table 11.55. Watershed # 7 drains to the Gilling River via overland flow. The drainage area of watershed # 15 is approximately 77 ha. The existing and project conditions monthly flow at node # 7 under climate conditions over the LOM are presented in Table 11.63. The flows at Node # 7 are expected to be returned to existing conditions after Closure and Decommissioning conditions. Flow at Node # 7 are expected to increase by approximately 1.28% during Operations and Maintenance conditions.

Table 11.63 Existing and Project Conditions Flow Rates at Node # 7 under Climate Normal Conditions over LOM

Month	Monthly Flow at Node # 15 (L/s)		Change (%)
	Existing Conditions	Project Conditions	
January	3.00	3.04	1.28
February	3.91	3.96	1.28
March	4.33	4.38	1.28
April	13.5	13.7	1.28
May	50.4	51.0	1.28
June	16.4	16.6	1.28
July	23.1	23.4	1.28
August	18.2	18.4	1.28
September	21.9	22.2	1.28
October	13.0	13.2	1.28
November	9.97	10.1	1.28
December	2.05	2.08	1.28
Annual	**15.0**	**15.2**	**1.28**

Assessment of Mine Water and Sanitary Effluent Discharge Mixing Zone

This section presents a summary of methodology and results of effluent mixing analyses conducted for the mine water and sanitary effluents. Open pit dewater and waste rock and overburden stockpile area runoff discharges to Attikamagen Lake via sediment Pond SP1. Low grade ore stockpile area runoff discharges to Attikamagen Lake via Sediment Pond SP2 and Stream T1. Processing area including ore stockpiles area runoff discharges to Iron Arm via Sediment Pond SP3. WWTP effluent (located within the accommodation facility) will discharge to Iron Arm via a pipe. Therefore, effluent mixing zone analyses were conducted for the mine water discharges from sediment ponds SP1,SP2, SP3 and sanitary effluent from the WWTP.

The Cornell Mixing (CORMIX™) model was used to simulate the mixing zone of mine and sanitary effluent discharges into Attikamagen Lake. This model is extensively used for predicting mixing behaviour in surface waterbodies. The CORMIX™ model assumes steady-state ambient conditions and effluent discharges, and predicts the plume geometry and dilution characteristics required for assessment of regulatory mixing zone compliance.

Effluent Conditions

Mine water discharge and sanitary effluent information are summarized in Table 11.64 for sediment ponds SP1, SP2 and SP3, and WWTP.

Table 11.64 Mine Water and Sanitary Effluent Conditions

Parameter	Sediment Pond SP1		Sediment Pond SP2		Sediment Pond SP3		WWTP	
	Open-Water	Ice-Cover	Open-Water	Ice-Cover	Open-Water	Ice-Cover	Open-Water	Ice-Cover
Discharge Rate (m^3/d)	2,592-8,640	432-2,592	432-1,296	43-259	864-2,592	86-864	35-60	35-60
Temperature (ºC)	10	1	10	1	10	1	10	1
Density (kg/m^3)	999.7	999.9	999.7	999.9	999.7	999.9	999.7	999.9

Ambient receiving water conditions at proposed discharge locations are provided in Table 11.65. Maximum ammonia, nitrate and nitrite concentrations were predicted for sediment ponds SP1, SP2 and SP3 outflows to Attikamagen Lake during the dry year weather conditions as dry year conditions produce the highest effluent concentrations. The maximum predicted mine effluent concentrations (Table 11.66) were used for the effluent mixing zone analysis. Mine water will be treated to meet the MDMER water quality criteria at the end of the pipe. The project mine water quality at the end of the pipe is provided in Table 11.66.

Table 11.65 Ambient Conditions at Mine Water and Sanitary Effluent Discharge Locations

Parameter	Sediment Pond SP1 Discharge Location – Attikamagen Lake		Sediment Pond SP2 Discharge Location – Attikamagen Lake		Sediment Pond SP3 Discharge Location – Iron Arm		WWTP Discharge Location – Iron Arm	
	Open-Water	Ice-Cover	Open-Water	Ice-Cover	Open-Water	Ice-Cover	Open-Water	Ice-Cover
Water Depth (m)	3.0	2.0	3.0	2.0	5.0	4.0	4.0	3.0
Mean Lake Currents (cm/s)	0.06	0.0006	0.06	0.0006	0.06	0.0006	0.06	0.0006
Temperature (°C)	10	1	10	1	10	1	10	1
Manning's Coefficient	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Wind Speed (m/s)	4.5	-	4.5	-	4.5	-	4.5	-

Table 11.66 Mine Water Effluent Concentrations and Attikamagen Lake Water Quality Criteria

Constituents	Unit	Effluent Water Quality at End of the Pipe			Water Quality Criteria at Mixing Zone Boundary	Required Dilution at Mixing Zone Boundary		
		Sediment Pond SP1	Sediment Pond SP2	Sediment Pond SP3		Sediment Pond SP1	Sediment Pond SP3	Sediment Pond SP3
Total Suspended Solids	mg/L	15			7.62[a]	2		
Arsenic	µg/L	500			5	100		
Copper	mg/L	0.3			0.002	150		
Cyanide	mg/L	0.025			0.005	5		
Iron	mg/L	10			0.3	33		
Lead	µg/L	200			1	200		
Nickel	mg/L	0.5			0.025	20		
Radium $_{225}$	Bq/L	0.37			Not detected [b]			
Zinc	µg/L	500			30	17		
Ammonia	mg/L	0.370	0.097	0.104	1.04	N/A	N/A	N/A
Nitrate	mg/L	10.5	2.79	3.00	13	N/A	N/A	N/A
Nitrite	Mg/L	0.180	0.048	0.051	0.197	N/A	N/A	N/A
Note: [a] Background water quality values (75 percentiles), [b] No CWQG								

Sanitary effluent will be treated to meet the Newfoundland and Labrador ECWSR water quality criteria at the end of the pipe. The project sanitary effluent water quality at the end of the pipe is provided in Table 11.67. Water temperature of the mine water and sanitary effluent is assumed to be approximately 10.0^{o}C during open-water conditions and 1.0^{o}C during ice-cover conditions. Outlet channel widths were assumed to be 1.0 m, 0.5 m and 0.5 m for the sediment pond SP1, SP2 and SP3, respectively. The sanitary effluent pipe was assumed as 100 mm high-density polyethylene pipe.

Table 11.67 Sanitary Effluent Concentrations and Iron Arm Water Quality Criteria

Constituents	Unit	Effluent Water Quality at End of the Pipe	Water Quality Criteria at Mixing Zone Boundary	Required Dilution at Mixing Zone Boundary
Solids (Dissolved)	mg/L	1000	28.3[b]	35
Solids (Suspended)	mg/L	30	7.62[b]	2
Arsenic	µg/L	500	5	100
Barium	µg/L	546[a]	2.73[b]	200
Boron	mg/L	5	1.5	3
Cadmium	µg/L	28[a]	0.09	200
Chlorine	mg/L	1.0	-	-
Chromium (hexavalent)	mg/L	0.05	0.001	50
Chromium (trivalent)	mg/L	1	0.0089	112
Copper	mg/L	0.3	0.002	150
Cyanide	mg/L	0.025	0.005	5
Iron	mg/L	10	0.3	33
Lead	µg/L	200	1	200
Mercury	µg/L	5	0.026	192
Nickel	mg/L	0.5	0.025	20
Nitrates	mg/L	10	13	-
Nitrogen (ammoniacal)	mg/L	2	0.86	2
Phenol	µg/L	100	4	25
Phosphates (total as P_2O_5)	mg/L	1	0.025[b]	40
Phosphorus (elemental)	mg/L	0.0005	0.0085[b]	-
Selenium	µg/L	10	1	10
Sulfide	mg/L	0.5	0.01[b]	50
Silver	µg/L	20[a]	0.1	200
Zinc	µg/L	500	30	17

Notes:
[a] WWTP will be designed to provide the end of the pipe Barium, Cadmium and Silver concentrations as indicated which is much lower than ECWSR criteria
[b] Background water quality values (75 percentiles)

Receiving Water Ambient Conditions

The proposed discharge locations for mine water from sediment ponds SP1, SP2, SP3 and sanitary effluent from the WWTP are shown in Figure 11.37. Water temperature data in Attikamagen Lake and Iron Arm indicate that a uniform vertical temperature distribution can be assumed. The ambient water temperature at the discharge locations are estimated to be approximately 1.0^{o}C during the ice-cover period and 10.0^{o}C during the open-water season. There are no lake current measurements within Attikamagen Lake and Iron Arm. It is assumed that wind-generated currents will be much greater than the lake inflow-outflow generated currents.

Wind-generated surface current velocities are estimated to be 6 cm/s during the open-water period, based on wind speed recorded at the Schefferville Environment and Climate Change Canada Climate Station. The lake current is assumed to be minimal during ice-cover conditions. Table 11.65 summarizes ambient receiving water conditions at the discharge locations. No bathymetry information is available for sediment ponds SP1 and SP2 discharge locations and therefore, water depth at these discharge location were assumed for mixing zone analyses.

Stream and lake water quality samples were collected at the Project site from October 2011 to October 2013 and the results are summarized in Appendix J for constituents listed in MDMER and ECWSR guidelines.

Mixing Zones

The water quality criteria to be satisfied at the mixing zone boundary is selected as the higher of background water quality of Attikamagen Lake (Table 11.29) or water quality criteria recommended by CWQG-PAL presented in Table 11.26. The selected water quality criteria for mine water discharge in Attikamagen Lake are presented in Table 11.66 based on background water quality and CWQGs. Table 11.67 presents the selected water quality criteria for sanitary effluent discharge in Iron Arm based on background water quality and CWQGs. Tables 11.66 and 11.67 show the mine water and sanitary effluent concentration at the end of pipe and the required dilution of effluent to achieve water quality criteria. The required dilution factor varies between 2 and 200 depending on constituents. Therefore, the mixing zone boundary also varies with constituents. Hence, the mixing zone boundary was defined as a boundary where the dilution factor is 200. At the mixing zone boundary, effluent water quality will meet either the CWQGs or background water quality of Attikamagen Lake.

Results

The predicted mixing zone boundary corresponding to various average dilution factors are presented in Tables 11.68, 11.69, and 11.70 for sediment ponds SP1, SP2 and SP3 discharges, rtespectively. Table 11.71 presents the predicted mixing zone boundary corresponding to various average dilution factors for the sanitary effluent discharges. The predicted mixing zone boundary for the open-water condition is smaller than that of the ice-cover season. During open-water conditions, the dilution factors are expected to be greater than those predicted for the ice-cover period. The better dilution expected during the open-water period is due to generally stronger currents produced by winds, which induce more mixing than what would occur during ice-cover conditions.

Table 11.68 Predicted Mixing Zone Boundary at Various Dilutions – Sediment Pond SP1

Discharge (m3/d)	Mixing Zone Boundary (m)			
	S = 10	S = 50	S = 100	S = 200
Open – Water Season				
8,640	55	277	483	809
4,320	34	154	284	491
2,592	30	95	187	333
Ice –Cover Season				
2,592	4	5,598	5614	5,640
1,728	3	4,308	4,320	4,340
864	3	2,636	2,644	2,656
43	2	703	1,706	1,713

Table 11.69 Predicted Mixing Zone Boundary at Various Dilutions – Sediment Pond SP2

Discharge (m3/d)	Mixing Zone Boundary (m)			
	S = 10	S = 50	S = 100	S = 200
Open – Water Season				
1,296	7	50	95	187
864	7	47	72	140
432	10	36	49	71
Ice –Cover Season				
259	1	51	1,237	1,895
86	1	22	192	963
43	1	15	105	622

Table 11.70 Predicted Mixing Zone at Various Dilutions – Sediment Pond SP3

Discharge (m3/d)	Mixing Zone Boundary (m)			
	S = 10	S = 50	S = 100	S = 200
Open – Water Season				
2,592	10	76	120	221
1,296	12	61	80	119
864	16	49	65	91
Ice –Cover Season				
864	1	53	647	3,558
432	1	35	301	2,313
259	1	30	229	1,614
86	1	21	125	745

Table 11.71 Predicted Mixing Zone at Various Dilutions - WWTP

Discharge (m3/d)	Mixing Zone Boundary (m)			
	S = 100	S = 200	S = 500	S = 1000
Open – Water Season				
35	1	4	8	14
60	1	7	12	20
Ice –Cover Season				
35	3	4	5	6
60	3	4	6	8

The mixing zone analyses of proposed mine water and sanitary effluent discharges into Attikamagen Lake and Iron Arm indicates that:

- The mixing zone extents for sediment pond SP1 discharges are approximately 800 m for open-water conditions and 5,600 m for ice-cover conditions;
- The mixing zone extents for sediment pond SP2 discharge are approximately 190 m for open-water conditions and 1,900 m for ice-cover conditions;
- The mixing zone extents for sediment pond SP3 discharges are approximately 220 m for open-water conditions and 3,600 m for ice-cover conditions;
- The mixing zone extents for WWTP discharges are approximately 20 m for open-water conditions and 8 m for ice-cover conditions; and
- Under worse-case ice cover conditions, the mixing zone boundary, meaning the point at which boundary conditions return to baseline or CWQG background conditions, is completely enclosed within Attikamagen Lake and therefore within the boundary of the LSA.

These results are preliminary and detailed studies such as Attikamagen Lake circulation patterns, bathymetry data for sediment ponds SP1 and SP2 discharge locations, temperature profiles are needed to improve the mixing zone predictions.

11.6.2.2 Mitigation of Project Environmental Effects

A Project Water Management Plan is developed to manage the surface water in the PDA and mitigate potential Project effects on surface water. This includes a Water Management Plan.

Water Management Plan

The Water Management Plan being developed for the Project will describe how water on site will be diverted, collected, treated, and/or stored so as to avoid adverse environmental effects and maximize Project efficiencies through water conservation. This plan outlines water management in and around the major Project component areas (i.e., waste rock, low grade ore and overburden stockpile areas, open pit, processing plant areas, and roads, rail yards, and water crossings). A schematic of the site-wide Water Management Plan showing various mine water components is shown in Figures 11.49 and 11.50 for the mine area and rail yard area, respectively. An overview of key features of the site-wide Water Management Plan is as follows:

- Diversion of Joyce Lake catchment area runoff around the open pit and the shoreline of Joyce Lake via runoff interception in perimeter ditches;
- Initial and operational dewatering of Joyce Lake;
- Collection and pumping of groundwater intercepted via open pit perimeter dewatering wells;
- Collection and pumping of incident precipitation, direct mine contact runoff and groundwater seepage into the open pit;
- Collection of runoff from areas disturbed by mining activities (waste rock, low grade ore and overburden stockpiles, open pit, processing plant, rail yard, and accommodation camp) in sediment ponds primarily for control of suspended solids prior to discharge from the site;
- Discharge of excess mine water to receiving environments in accordance with MDMER effluent criteria as well as other mine effluent criteria which may be applicable (i.e., Red Water and nitrogen species effluent criteria); and,
- Diversion of clean non-mine contact runoff away from areas disturbed by mine activities.

Stormwater management facilities (e.g., local retention ponds, berms, drainage ditches, pumps) will be used to collect and contain surface water runoff from open pit mine, waste rock, low grade ore and overburden stockpile areas, processing plant, main fuel depot and power plant, accommodation camp, and rail yard. These will be designed to provide on-site storage of local runoff with controlled releases permitted after appropriate settling and water quality sampling indicates the water is suitable for release.

Newfoundland and Labrador uses a “two zone” approach to flood design (NLDEL 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.

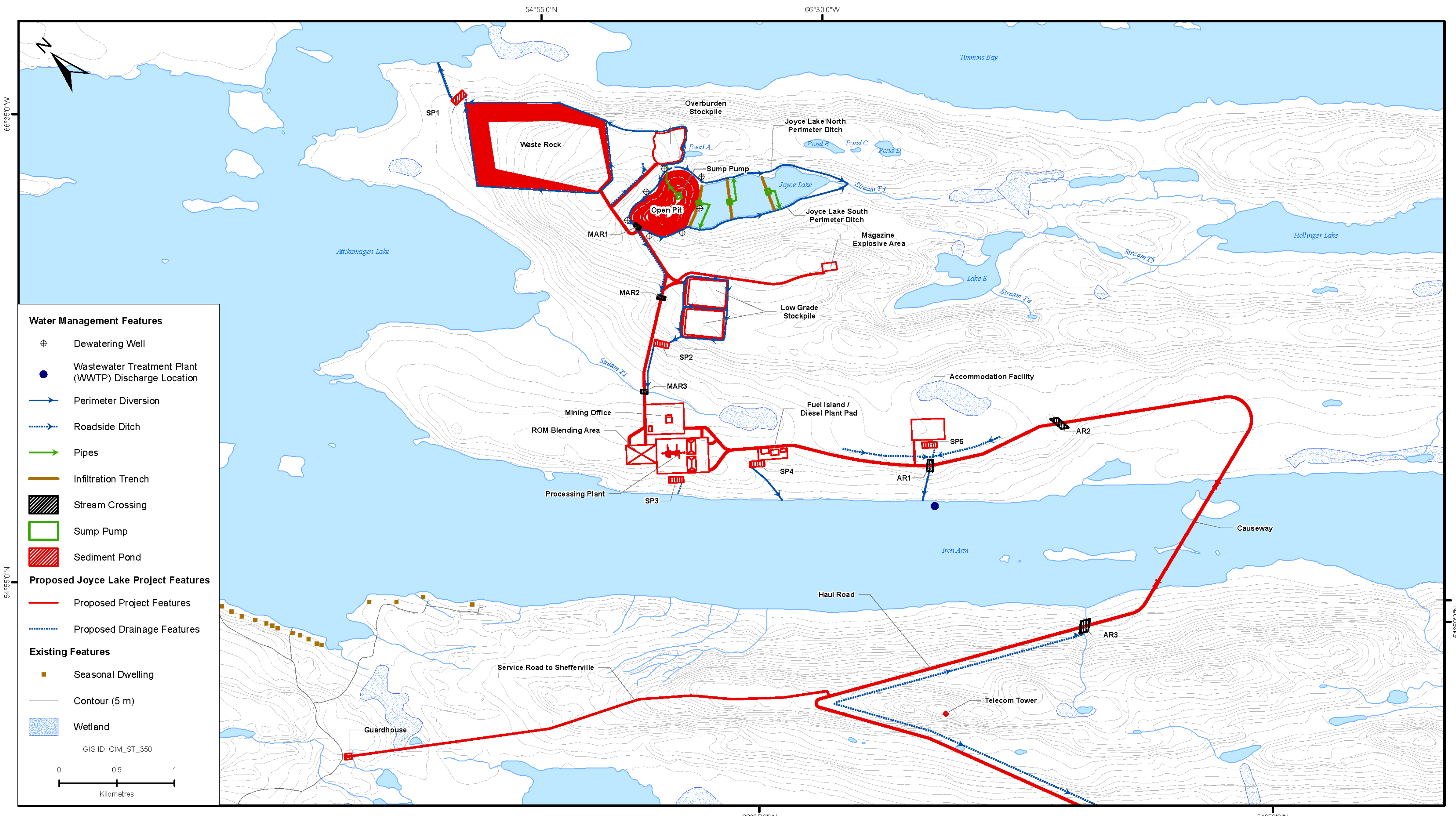

FIGURE TITLE:			
Proposed Water Management Plan - Mine Area			
CLIENT: **LABEC CENTURY IRON ORE INC.**			
CHECKED BY: **SP**	FIGURE ID:	PROJECT NUMBER **121511139**	FIGURE SOURCES: Project features provided by BBA version 2 received 2014/11/07. Basemap information from NRCan CanVec database and Newfoundland and Labrador Department of Natural Resources.

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Figure 11.49 Mine Area Water Management Plan

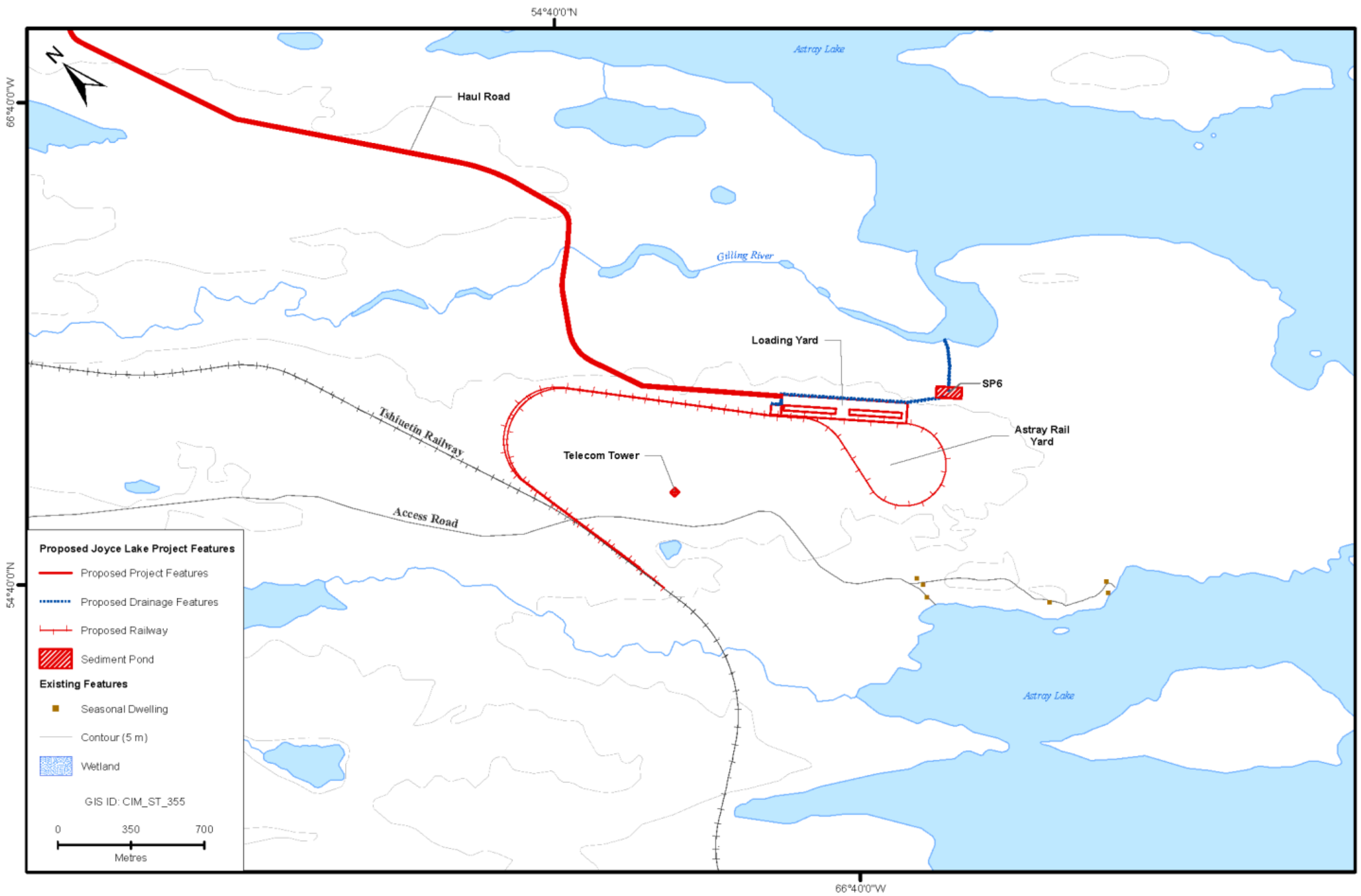

FIGURE TITLE:			
Water Management Plan - Astray Rail Yard			
CLIENT: LABEC CENTURY IRON ORE INC.			
CHECKED BY: SP	FIGURE ID:	PROJECT NUMBER: 121511139	FIGURE SOURCES: Project features provided by BBA version 2 received 2014/11/07. Basemap information from NRCan Canvec database and Newfoundland and Labrador Department of Natural Resources.

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Figure 11.50 Rail Yard Area Water Management Plan

Stormwater control and sedimentation facilities associated with the Project will use the 1:100 year storm as the primary quantity control design criteria. Runoff from the Project component areas for storm events up to 1:10 year return period are to provide water quality controls to meet the MDMER effluent limits.

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 containment of the attenuated 1:100 year discharge peak from the respective facility. This criterion will avoid potential flooding of downstream mine infrastructure.

Sediment pond sizing was conducted for the project sediment ponds (Stassinu Stantec 2014g) and are summarized below.

The design criteria for the sediment ponds for the Project area are described below:

- Water quality control: Settle particles greater than 5 microns size during 1:10 year storm event;
- Water quantity control: Contain and attenuate flows up to 1:100 year storm event;
- Provide at least 1.5 m depth of permanent pool storage to reduce inlet velocities, reduce scour, facilitate quiescent settling of sediment and potential biological treatment between rainfall events, and provide sediment storage;
- Pond length to width ratio should be at least 2:1 to reduce short circuiting;
- Pond area at permanent pool depth shall be sufficient to settle particles greater than 5 microns based on the following relationship:

  (Equation 13) $A = FSC\ Q_o/V_s$

  Where :

  A = pond surface area at normal water level (m^2)

  Q_o = peak outflow rate from pond during design event (m^3/s);

  V_s = settling velocity of 5 µm particle (m/s); and

  FSC = short-circuiting factor (usually 1.2).

- Pond freeboard shall be 0.5 m during the 1:100 year storm event;
- Inlet section of the pond should incorporate energy dissipation to spread out the flow and reduce the velocity of incoming water;

- The low flow outlet should intake from below the permanent pool so that sedimentation ponds can also act as hydrocarbon and Light Non-Aqueous Phase Liquids (LNAPL) containment features and mitigate discharge thermal effects; and
- An emergency spillway may be required to convey storm event larger than the 1:100 year event.

A conceptual design of a typical sediment pond is shown in Figure 11.51. Figures 11.49 and 11.50 show the proposed sediment pond locations for the Project.

Two perimeter ditches, JLNPD and JLSPD, will be used for the following:

- Collection and diversion of Joyce Lake catchment area runoff around open pit and the shoreline of Joyce Lake;
- Collection and diversion of Joyce Lake initial dewatering;
- Collection and diversion of groundwater intercepted from the open pit perimeter dewatering wells; and
- Collection and diversion of Joyce Lake operational dewatering.

Collected water in the perimeter ditches, JPNPD and JPSPD, will be discharged to Stream T3 downstream of the Joyce Lake outlet. The JPNPD will collect surface runoff from 49.3 ha of the Joyce Lake catchment area and JPSPD will collect surface runoff from 89.3 ha of the Joyce Lake catchment area.

Operation of the open pit mine will require dewatering of groundwater to ensure that the water table is maintained below the floor pit and more than 25 m from the pit walls. Seven (7) open pit perimeter dewatering wells are currently proposed to pump the seepage into the two perimeter ditches, JLNPD and JLSPD, and eventually will be discharged to Stream T3 downstream of the Joyce Lake outlet.

Phase 1 of the pit development will occur on land southwest of Joyce Lake. Phase 2 pit development advances into the footprint of Joyce Lake. Joyce Lake initial dewatering will occur during the Phase 1 of pit operations. Operational dewatering of Joyce Lake will start after the initial dewatering is completed and will continue throughout the life of the Project. Three infiltration trenches will be used to collect runoff from the Joyce lake footprint as shown in Figure 11.49. The infiltration trenches also prevent non-mine contact groundwater seepage and runoff water from the Joyce Lake footprint entering into the open pit and becoming mine contact water. Collected runoff in the infiltration trenches will be pumped into the perimeter ditches, JLNPD and JLSPD, to discharge downstream of the Joyce Lake outlet, Stream T3.

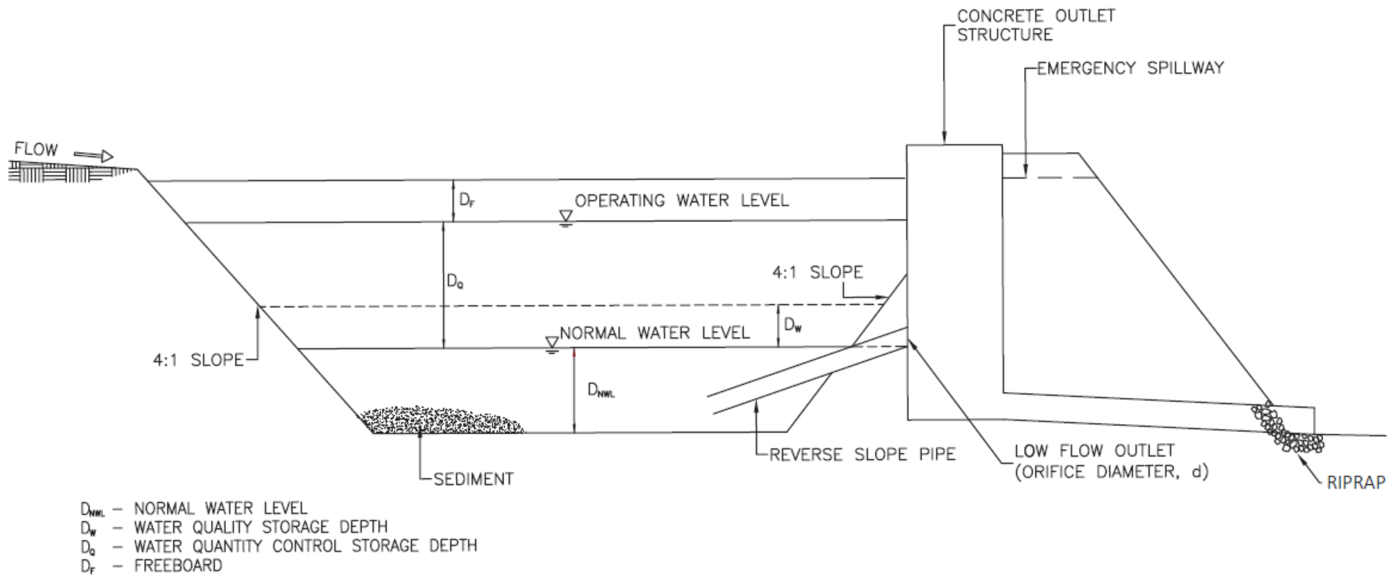

Figure 11.51 Schematic of Sediment Pond

Dewatering of the open pit will begin with the start of pit construction and will continue throughout the Project. The total area of the open pit mine is 20.9 ha. Surface runoff from pit surfaces and groundwater seepage inflows will be collected in sump(s) inside the open pit and will be pumped into a perimeter ditch around the overburden and waste rock stockpiles as shown in Figure 11.49. The overburden and waste rock perimeter ditch will convey the open pit dewater into sediment pond SP1 prior to release to Attikamagen Lake.

The runoff from waste rock and overburden stockpiles area will be collected in sediment pond SP1 via perimeter collection channels, as shown in Figure 11.49. Sediment pond SP1 will collect runoff from 115 ha stockpiles area including the natural areas between stockpiles and perimeter ditch and open pit dewater. Sediment pond SP1 will discharge to Attikamagen Lake via a newly constructed outlet ditch.

Low grade ore stockpile area runoff will be collected in sediment pond SP2 via perimeter collection channels as shown in Figure 11.49. Sediment pond SP2 will collect runoff from a 20.4 ha area and will discharge to Attikamagen Lake via Stream T1.

Runoff from the processing area, main fuel depot and power plant and accommodation facility will be collected in sediment ponds SP3, SP4 and SP5, respectively and will be discharge to Iron Arm as shown in Figure 11.49.

The runoff from the rail yard will be collected by a perimeter ditch and directed to settling pond SP6 for subsequent release to Gilling River as shown in Figure 11.50.

Table 11.72 lists the location of sediment ponds and estimated sizes of various sediment ponds proposed for the Project. Each sediment pond was sized to capture 5 micron size settleable particles during the 10-year design storm event. The sizes of sediment ponds indicated in Table 11.72 are preliminary and require optimization of pond sizing during detailed design.

Table 11.72 Sediment Pond Design Values

Sediment Pond ID	Project Area	Pond Bottom Dimensions Length (m) x Width (m)	Pond Side Slope (H:V)	Permanent Pool Depth (m)	Total Pond Depth (m)	Pond Block Area (ha)	Low Flow Orifice Diameter (m)	Receiving Stream
SP1	Waste Rock and Overburden Stockpile	475 x 120	4:1	1.5	3.0	8.0	600	Attikamagen Lake
SP2	Low Grade Ore Stockpile	175 x 45	4:1	1.5	3.0	2.2	240	Attikamagen Lake
SP3	Processing Plant	275 x 70	4:1	1.5	2.9	3.1	350	Iron Arm
SP4	Main Fuel Depot	75 x 20	4:1	1.5	2.5	0.4	110	Iron Arm
SP5	Accommodation Facility	100 x 25	4:1	1.5	2.7	0.6	150	Iron Arm
SP6	Rail Yard	100 x 25	4:1	1.5	2.8	0.6	125	Gilling River

The following guidelines will be followed for the open pit mine sump sizing and configuration:

- Locate sump away from trafficked areas for safety and convenience;
- Select sump location to ensure floor slopes and seam slopes are accounted for;
- Locate the sump to give a suitable route for the pipeline to the required discharge point;
- Locate the sump to give maximum life before pit development dictates a new location; and
- Provide at least two cells for the sump due to typically high sediment loads in in-pit runoff. The first cell will allow suspended solids to settle water migrates to the second cell and should be routinely cleaned by in-pit equipment.

Guidelines for design and operation of fuel storage areas include the following:

- Bunding to the appropriate Canadian Standards to contain spillage;
- Frequent inspection of storage tanks and piping for corrosion and leaks;
- Construction of facilities to collect and contain minor spillages outside the bunded area during refueling operations; and
- Diversion of oil containment bund water collected during rain events through oil interception or separation facilities.

Guidelines for the design and operation of workshop and washdown areas include the following:

- Better control of hydrocarbon using central bulk storage and reticulation through the workshop;
- Design of dispensing facilities to prevent drips and spillage;
- Covering of the workshop area to prevent storm water picking up contaminants;
- Installing a drainage system to separate clean and contaminated water stream from within and surrounding all workshop areas;
- Diversion of oil contaminated water to a separation system, which can range from simple concrete sumps through to more sophisticated mechanical systems such as coalescing plate separators, and skimmers;
- Use of dry cleaning methods such as industrial vacuum cleaners and absorbents rather than water to clean floors and other surfaces; and
- Use water-based detergents for the cleaning of hydrocarbons soiled equipment.

Appropriately sized drainage culverts will be installed at all defined watercourses and at low points along all access roads to maintain natural flow patterns and to eliminate potential flow impediment. This will reduce potential water logging or ponding upstream side of roads and prevent “drying out” of wetlands area on the downstream side. Details of culvert crossing design and mitigation measures are discussed in *Culvert Crossing Design* in Section 11.6.2.

In bog areas, where the water table is close to the ground surface, granular road fill material will be used for access road construction where practical.

Ammonia Management Plan

Predicted nitrate concentrations for the sediment pond SP1 discharging into Attikamagen Lake exceed the regulatory limits of 10 mg/l by 0.5 mg/L during dry year weather conditions. The dry year weather condition is expected to occur 1 in 63 years and the expected mine life is 7 years. Therefore, the chances of nitrate concentration exceeding the regulatory limit is low. However, to account for the potential that dry year conditions may result in ammonia effluent criteria exceedances, an ammonia management plan will be implemented and will include the following:

- Monitoring the nitrate concentrations at the sediment pond SP1 outlet channel bi-weekly throughout the LOM;
- The following design and loading practices will be considered to reduce ammonia losses to the environment:
    - Blasts will be designed to maximize efficiency of blasting agents;
    - Blast hole liners will be used even when minimal amounts of water are present. If there is excessive water, blasters will use emulsion instead; and
    - Disposal of blasting reagent packaging and related waste will be done according to BMP;
- If the monitored nitrate concentration increases continuously and exceeds 8 mg/L, the explosive used in mining will be replaced by an explosive with less ammonia content.

11.6.2.3 Characterization of Residual Project Environmental Effects

Changes to Surface Water Quantity

Changes to surface water quantity can occur in association with the open pit mine as a result of increase in streamflow discharge from existing conditions and Joyce Lake dewatering, waste rock, low grade ore and overburden stockpile areas as a result of increase in streamflow discharge from existing conditions; and from the access roads and rail lines as water used to control dust from access roads will be withdrawn from on-site sedimentation ponds. Dust suppression water reuse has the potential to balance Project water consumptive losses with Project water discharge increases.

Table 11.73 provides MAF increases/decreases at each assessment nodes (Figure 11.47) and corresponding MAF increases to Attikamagen Lake. It is assumed that no reuse of excess water from the open pit mine and Joyce Lake dewatering, waste rock, low grade ore, overburden stockpile area, and from other facilities sediment ponds with the exception of dust suppression will be undertaken.

Table 11.73 MAF Changes to Attikamagen Lake

Node #	Max Change in MAF at Assessment Nodes		Change in MAFs in Attikamagen Lake (%)
	L/s	%	
1	113	253	0.143
2	-1.60	-3.40	-0.002
3	-2.20	-2.91	-0.003
4	-13.2	-36.1	-0.017
5	18.0	38.1	0.023
6	8.6	19.9	0.011
Total	**123**		**0.156**

MAFs at Node #1 outlet of Joyce Lake would increase by 111 L/s (253%) during the Joyce Lake initial dewatering operations in Year 1 and then subsequent years would increase between 3.7 L/s (6%) and 33.1 L/s (50.8%) over existing conditions. Increased flows at this location may result in deeper inundation of wetlands downstream of Joyce Lake outlet, later in the growing season. Wetlands with stable water levels are particularly vulnerable to changes in seasonal water levels because the plants have a narrow range of inundation tolerance. Vegetation mortality as a result of change in the depth and timing of inundation is expected to be temporary in nature and the herbaceous plant community is expected to recover in 1 to 2 years, whereas populations of trees may take 5 to 10 years to recover. This wetland area will be assessed, mitigated and monitored as part of the Wetland Mitigation and Monitoring Plan. Therefore surface water quantity effect at Node #1 is considered to be a moderate effect, local and medium-term.

MAFs at Nodes # 2 and # 3 would decrease by 1.60 L/s (3.40%) and 2.20 L/s (2.91%), respectively and therefore a negligible effect.

MAFs at Node # 4 would decrease by 13.2 L/s (36.1%) and the water level changes in the Timmins Bay will not be detectable, and therefore the effect is considered negligible. MAFs at Nodes #5 and #6 would increase by 18.0 L/s (38.1%) and8.6 L/s (19.9%), respectively, and the water level changes at Attikamagen Lake and Iron Arm will not be detectable and therefore are also considered negligible.

MAFs to Attikamagen Lake is 79.0 m^3/s. MAFs would increase by 0.156% in Attikamagen Lake system due to the Project. These increases are not detectable and therefore would be negligible in magnitude. Likely effects on water levels and flow velocities in receiving lakes will not be detectable due to increase in runoff volumes in Operation and Maintenance conditions.

Nodes #3, #4, #5 and #6 directly drain to Attikamagen Lake and flow in Attikamagen Lake will increase by 0.2% during Operation and Maintenance conditions. Flow at Stream T5 downstream of Node #2 will increase by 3.4%. A high level of ecological protection will be provided when flow alterations are within 10% of the natural flow (Ritcher et al. 2011). Therefore, change in surface water quantity will have a negligible effect on the receiving ecosystem with the exception of Node # 1, which is rated as moderate. Downstream of Joyce Lake outlet (Node #1), however, is not considered fish habitat. Changes in surface water quantity associated with the access roads and rail line are considered to be negligible, local and long-term.

Water levels in Iron Arm upstream of causeway are expected to increase to 0.20 m during the MAF conditions and to 1.0 m during the 1:100 year flood conditions. These water level changes are expected to be within the natural water level variation of the Attikamagen Lake and therefore a low effect. Significant wave heights up to 1.5 m is expected to be generated due to the 1:25 year winds and this conditions are expected to be similar to the existing wave conditions. Therefore, the effect is considered negligible, local and long term. The causeway is not expected to be flooded by wave overtopping and run up over the causeway during the 1:25 Year wind event. Mitigation for this possible but unlikely event during life of the mine will be considered during final causeway design and operational planning. For example, crossings could be suspended during periods of high winds and waves.

Changes to Surface Water Quality

Changes to surface water quality can result from increase in TSS loading and sedimentation in open pit mine dewater discharge, Joyce Lake dewater discharge, waste rock and overburden stockpiles area runoff, low grade ore stockpile area runoff and processing plant, accommodation facility, power plant and rail yard areas runoff. Dust suppression water reuse may reduce effluent discharges, however will not eliminate them. Therefore, open pit mine, waste rock and overburden stockpiles area, low grade ore stockpile area and processing plant, accommodation facility, power plant and rail yard areas discharges will be routed to sedimentation ponds, where TSS concentrations will be reduced to below regulatory criteria, as detailed in the Project Water Management Plan. The proposed sedimentation pond approach and conceptual design will also ensure stormwater discharge meets regulatory effluent criteria and residual effects will be low and restricted to the LSA. An effluent mixing analysis of the mine water effluent discharges from the open pit, waste rock and overburden stockpile area, low grade ore stockpile area, as well as sanitary discharge, was conducted to assess mixing zone extent within the LSA under a variety of effluent discharge and climate conditions. The mixing zone analysis indicates that mine water and sanitary effluent water quality return to baseline or CWQG background conditions within the LSA

With respect to the access road and rail line, use of appropriately sized and vegetated roadside and railside ditches and sediment ponds will prevent TSS loading to local receiving waterbodies and will result in negligible, localized residual effects.

Surface water quality can also be affected by nitrogen species contamination of open pit mine dewater discharge and stockpile area runoff particularly for nitrate and nitrite. Ammonia contamination will be managed, and effluent will be treated for nitrates, if required, to meet regulatory effluent criteria where there would be a negligible effect. Options for management include changes to the emulsification or ammonia content of explosives and treatment (e.g. constructed or engineered wetland, mechanical / biological treatment facility, managing effluent discharge to coincide with the spring freshet) will be considered, as and if required.

Changes to Drainage Patterns and Watercourse Alterations

Development of the open pit mine, waste rock and overburden stockpiles area, low grade ore stockpile area, processing plant, power plant, accommodation facility, rail yard and access road and rail line all have the potential to affect local drainage patterns; however in all cases, effects will be localized in nature, low in magnitude and medium-term.

Fish passage effects are addressed in Chapter 15: Fish and Fish Habitat. With respect to the access roads and rail lines, watercourse alterations are expected to be minimal and related to minor channel realignment to reduce culvert/bridge length. Watercourse alteration effects will be localized in extent, medium-term and negligible.

11.6.3 Closure and Decommissioning

11.6.3.1 Potential Environmental Effects

Closure rehabilitation involves measures undertaken after mining operations, in order to restore or reclaim the property as close as reasonably possible to its pre-mining condition. This could include demolition and removal of site infrastructure, re-grading, re-vegetation, and any other activities required to achieve the requirements and goals detailed in the Rehabilitation and Closure Plan.

Decommissioning would involve the removal of site structures, infilling and/or flooding of the open pit mine and Joyce Lake and stabilization of the waste rock, low grade ore and overburden stockpiles (residual not used in pit decommissioning). Details of the open pit mine decommissioning are presented below.

The environmental effects of the decommissioning and reclamation phase will bear many similarities to the construction phase. Buildings will be demolished and removed, developed areas will be regraded, the waste rock, low grade ore and overburden stockpile areas rehabilitation with soil cover and vegetation planting will be completed.

11.6.3.2 Mitigation of Project Environmental Effects

The following general environmental protection measures will be implemented, including:

- Erosion and sedimentation controls similar to the site preparation and construction phase;
- If required, maintenance of sedimentation ponds / facilities during the decommissioning and reclamation phases until disturbed ground surfaces are re-stabilized; and
- Restore existing water balance conditions, to the extent feasible;

These measure will serve to reduce any potential for further adverse environmental effects on surface water as physical activities associated with Closure and Decommissioning activities are carried out.

11.6.3.3 Characterization of Project Residual Effects

Open Pit Mine and Joyce Lake

After Operation and Maintenance works cease in the open pit mine and Joyce Lake, groundwater seepage and surface water runoff collection in open pit and dewatering of Joyce Lake will cease to allow refilling of the open pit mine and Joyce Lake. Based on surface runoff and seepage estimates, it may take as much as 25 years for the open pit mine and Joyce Lake to fill. Ponds A, B, C, and D and Lake E water levels will return to normal water levels once the refilling of open pit and Joyce Lake is completed. After open pit mine and Joyce Lake refilling is completed, annual flows at Node #1 will also return to normal conditions. The effect will be positive as conditions will be returning to pre-construction conditions.

The details for decommissioning will be provided in the Rehabilitation and Closure Plan that will be prepared under the Newfoundland and Labrador *Mining Act*. The post-closure monitoring program will continue for an anticipated period of five years after final closure activities are completed, or earlier should Labec Century and the appropriate regulatory bodies be satisfied that all physical and chemical characteristics are stable.

Waste Rock, Low Grade Ore and Overburden Stockpiles

Waste rock, low grade ore and overburden stockpile areas will be progressively rehabilitated over the Operations and Maintenance phase and rehabilitation completed during Closure and Decommissioning. The details for decommissioning will be provided in the Closure and Rehabilitation Plan. Annual flow rate at Node # 5 is expected to increase by 38.1% due to the Node #5 watershed area increase and the water level changes in the Attikamagen Lake will not be detectable, therefore effects are considered negligible.

Causeway

After closure and decommissioning of the open pit and other facilities in the mine area, two causeway bridges will be removed and the two bridge openings will be enlarged by displacing the rocks to allow the upstream water levels to return normal water level conditions. Residual effects are therefore considered to be positive.

Processing Plant, Accommodation Facility, Power Plant and Rail Yard

Site rehabilitation will grade the ground surface with soil and revegetate to restore existing drainage patterns to the extent feasible. Stormwater ponds will be dewatered, sediment will be removed if required, pond dams breached and permitted to naturalize into small open water ponds or wetland features. Surface water conditions are expected to return normal conditions and therefore residual effects are predicted to be positive.

Access Roads and Rail Tracks

The main site access road will remain intact for post-decommissioning activities and emergency situations. Other roads will be scarified to loosen the surface structure and promote re-vegetation, and the existing drainage ditches will be infilled by grading, and the cross section contour will be shaped to match the adjacent ground. All cross contour ditching will be filled, any culverts and bridges will be removed and disposed of off-site, and the roads will be assessed for re-vegetation opportunities where practical.

11.6.4 Summary of Project Residual Effects

The residual environmental effects of the Project on Surface Water are summarized in Table 11.74 The residual environmental effects on surface water for Construction and Operation and Maintenance of the Project are characterized by the following descriptors: direction; magnitude; geographic extent; duration and frequency; reversibility; ecological/socio-economic context; significance; and confidence. In each case, a conservative approach has been taken by describing the worst-case effect associated with a given phase of the Project.

Several residual effects are predicted related to surface water quantity, quality and drainage patterns. Surface water quantity effects related to the Project at assessment nodes range from -3.4% to 253% during Operation and Maintenance and are limited to the LSA. These water quantity effects related to the Project are negligible on Attikamagen and Petitisikapau Lakes system. The changes in flows are within the natural range of flows experienced in the Attikamagen and Petitsikapau Lakes system..

Water levels in Iron Arm upstream of causeway are expected to increase to 0.20 m during the MAF conditions and to 1.0 m during the 1:100 year flood conditions. These water level changes are expected to be within the natural water level variation of the Attikamagen Lake.

Surface water quality effects relate to the mixing zones required in Attikamagen Lake to attenuate effluent quality back to baseline or CWQG thresholds. The assessment has demonstrated that mixing zones would be contained within the LSA and that baseline or CWQG background conditions would be achieved at the boundary of the LSA. Therefore, no significant residual effect for surface water quality is predicted.

Changes in drainage patterns are PDA in scale and result in no significant residual effects after Closure and Decommissioning.

Table 11.74 Summary of Residual Environmental Effects – Water Resources

Project Phase	Mitigation/Compensation Measures	Direction	Residual Environmental Characteristics						Significance	Prediction Confidence	Recommended Follow-up and Monitoring
			Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental or Socio-economic Context			
Change in Surface Water Quantity											
Construction	• Optimize water harvesting and re-use • Manage surface run-off and drainage with construction of diversion ditches culverts and settling ponds • Size ditches, culverts and settling ponds appropriately. At a minimum, settling ponds will be designed for a 25-year return period storm event	A	L	S	MT	R	R	U	N	H	Surface water quantity (water level) monitoring during construction, operations and closure.
Operation and Maintenance	• Prepare and implement Water Management Plan • Optimize water harvesting and re-use • Restore natural drainage patterns and maintain or restore existing water balance condition, to the extent feasible	A	M	L	MT	R	R	U	N	H	
Closure and Decommissioning	• Implement progressive rehabilitation • Restore natural drainage patterns and maintain or restore existing water balance condition, to the extent feasible • Refine and implement Water Management Plan	P	L	S	ST	O	R	U	N	H	

Table 11.74 Summary of Residual Environmental Effects – Water Resources

Project Phase	Mitigation/Compensation Measures	Direction	Residual Environmental Characteristics						Significance	Prediction Confidence	Recommended Follow-up and Monitoring
			Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental or Socio-economic Context			
Change in Surface Water Quality											
Construction	• Implement erosion and sediment controls • Use of appropriately sized sedimentation ditches and ponds • Construction and operation of WWTP(s) to treat sanitary wastewater to regulatory effluent criteria	A	M	L	ST	C	R	U	N	H	Surface water quality monitoring during construction, operation and closure.
Operation and Maintenance	• Manage effluent treatment to meet MDMER and NL ECWSR discharge limits	A	L	L	MT	R	R	U	N	H	
Closure and Decommissioning	• Refine and implement Water Management Plan	A-P	L	S	ST	O	R	U	N	H	
Change in Surface Water Patterns											
Construction	• Reduce drainage interactions and alterations • Manage surface run-off and drainage with construction of diversion ditches, culverts and settling ponds • Size ditches, culverts and settling ponds appropriately. At a minimum, settling ponds will be designed for a 25-year return period storm event	A	L	S	MT	R	R	U	N	H	

Table 11.74 Summary of Residual Environmental Effects – Water Resources

Project Phase	Mitigation/Compensation Measures	Direction	Residual Environmental Characteristics						Significance	Prediction Confidence	Recommended Follow-up and Monitoring
			Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental or Socio-economic Context			
Operation and Maintenance	• Restore natural drainage patterns and maintain or restore existing water balance conditions, to the extent feasible	A	L	S	MT	R	R	U	N	H	
Closure and Decommissioning	• Refine and implement Water Management Plan • Implement progressive rehabilitation • Restore natural drainage patterns and maintain or restore existing water balance condition, to the extent feasible	P	L	S	ST	S	R	U	N	H	

Table 11.74 Summary of Residual Environmental Effects – Water Resources

Project Phase	Mitigation/Compensation Measures	Direction	Residual Environmental Characteristics						Significance	Prediction Confidence	Recommended Follow-up and Monitoring
			Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental or Socio-economic Context			

Key:

Direction:
P Positive
A Adverse
N Neutral

Magnitude:
N Negligible: no measurable adverse effect anticipated;
L Low: effect occurs that is detectable, but is within normal variability of baseline conditions;
M Moderate: effect occurs that would cause an increase (or decrease) with regard to baseline, but is within regulatory limits and objectives; or
H High: effect occurs that would singly or as a substantial contribution in combination with other sources cause exceedances of objectives or standards.

Geographic Extent
S Site-specific: effect is restricted to the PDA;
L Local: effect restricted to the LSA; or
R Regional: effect restricted to the RSA.

Duration:
ST Short-term:Effect does not extend beyond one year
MT Medium-term:Effect does not extend beyond seven years
LT Long-term: Effects are measurable and extend beyond seven years
P Permanent :Effects persistent and measurable parameter unlikely to recover to baseline conditions

Frequency
O Once per month or less.
S Occurs sporadically at irregular intervals.
R Occurs on a regular basis and at regular intervals.
C Continuous.
U Unlikely to occur

Reversibility:
R Reversible
I Irreversible

Ecological or Socio-economic Context:
U Undisturbed: effect takes place within an area that is relatively or not adversely affected by human activity; or
D Disturbed: effect takes place within an area with human activity. Area has been substantially previously disturbed by human development or human development is still present.

Significance:
S Significant
N Not Significant

Prediction Confidence
Based on scientific information and statistical analysis, and effectiveness of mitigation or effects management measure
L Low level of confidence.
M Moderate level of confidence.
H High level of confidence.

11.7 Assessment of Cumulative Environmental Effects

Potential cumulative effects to Water Resources relate to changes in surface water quantity and quality, as well as changes in surface water drainage patterns, as a result of Project activities in combination with those of other past, present, and future projects and activities in the RSA. In association with the Project environmental effects discussed above, an assessment of the potential cumulative effects was conducted for other projects and activities that have potential to interact with the Project. A summary of interactions resulting from other projects and activities with Water Resources is presented in Table 11.75.

Table 11.75 Potential Cumulative Environmental Effects

Other Projects and Activities with the Potential for Cumulative Environmental Effects	Potential Cumulative Environmental Effects		
	Change in Surface Water Quantity	Change in Surface Water Quality	Change in Surface Water Drainage Patterns
Schefferville Iron Ore Mine and Houston 1&2	1	1	1
DSO Iron Ore Project	1	1	1
Kami Iron Ore Project	0	0	0
First Lake North Iron Ore Project	0	0	0
IOC Labrador Operation	0	0	0
Mont Wright Mine	0	0	0
Wabush (Scully) Mines	0	0	0
Bloom Lake Mine and Rail Spur	0	0	0
Lower Churchill Hydroelectric Generation Project	0	0	0
Maritime Transmission Link Project	0	0	0

Key:
0 Project environmental effects do not act cumulatively with those of other projects and activities.
1 Project environmental effects act cumulatively with those of other projects and activities, but the resulting cumulative effects are unlikely to exceed acceptable levels with the application of best management or codified practices.
2 Project environmental effects act cumulatively with those of other projects and activities and the resulting cumulative effects may exceed acceptable levels without implementation of project-specific or regional mitigation.

11.7.1 Interactions Rated as 0

No interactions are expected between the following projects or activities identified on Table 11.71 and the Project:

- Kami Iron Ore Project;
- First Lake North Iron Ore Project;
- IOC Labrador Operation;
- Mont Wright Mine;
- Wabush Mine;

- Bloom Lake Mine and Rail Spur;
- Lower Churchill Hydroelectric Generation Project; and
- Maritime Transmission Link Project.

These projects are either located in a different watershed or outside the RSA; beyond which Project residual effects are not measurable for Water Resources.

11.7.2 Interactions Rated as 1

Schefferville Iron Ore Mine and Houston 1&2, and DSO Iron Ore Project have the potential for cumulative effects with those of the Project, although project activities themselves do not overlap spatially with the Project. Baseline conditions reflect the effects of these mines within the RSA.

11.7.3 Summary of Cumulative Environmental Effects

As discussed previously, surface water quantity and quality residual effects are determined to be not significant. Because the Project will result in localized, low magnitude effects that are not significant, the Project is not likely to contribute to the cumulative effects of other projects and activities within the RSA. Future projects and activities will be required to comply with planning and regulatory processes, and therefore cumulative effects will be managed.

Other projects and activities will not overlap the physical footprint of the Project or interfere with water supply and discharge potential. Therefore, there will be no cumulative effects to surface water resulting from other projects and activities in combination with the Project.

11.8 Accidents and Malfunctions

The accidents and malfunctions scenarios that could affect Water Resources include:

- Train derailment;
- Forest fire;
- Hydrocarbon Spill; and
- Settling/Sedimentation Pond Overflow.

In the unlikely event of any of these scenarios, local surface water in the immediate and down-gradient areas could be affected. The following sections discuss each accidental/malfunction event scenario and the mitigation and contingency measures that will be implemented during these events to reduce the effects to surface water.

11.8.1 Train Derailment

Iron ore product will be transported by truck from the Project site to the Astray rail loop which connects directly to the Tshiuetin/QNS&L railway for transport to Sept-Îles. Diesel fuel will be transported by rail to Schefferville and then by contracted trucker to site. On average, iron ore will be transported on approximately four trains each week during summer months between the Astray rail loop and the Sept-Îles port. Each train set will carry approximately 24,000 tonnes of ore in 240 gondola cars. Based on the speed the train will be travelling in the rail loop (5 miles per hour or 8 km/h), the reasonable worst case is the derailment of a maximum of four to five cars. This could result in the iron ore being spilled onto the ground or at stream crossings. Such an event is highly unlikely.

It is estimated that diesel fuel transport frequency will be a maximum of six 96,000 L tank cars per week for all site purposes.

Fuel tank car numbers are based on shipment in standard 96,000 L tank cars similar to those already in fuel haulage service between Sept-Îles and Labrador City. In a reasonable worst case scenario (i.e., where six tanks of diesel fuel are de-railed), approximately 576,000 L (127,000 Imperial gallons) of diesel fuel could be released.

A major fuel spill could result in the movement of free phase petroleum hydrocarbons across the surface towards receiving waters and drainage features. Spill within the LSA will flow to Gilling River and Astray Lake via overland. Spill within the rail yard area will drain into the sediment pond via surface drainage conveyance channels. Effects would depend on a variety of factors including the quantity and location spilled, time of year and efficiency of response.

Diesel fuel is a light, refined petroleum product with a relatively narrow boiling range, meaning that, when spilled on water, most of the oil will evaporate or naturally disperse within a few days or less (National Oceanic and Atmospheric Administration [NOAA] 2006). Due to low viscosity, it is readily dispersed into the water column. Diesel oil is much lighter than water, so while it is not possible for this oil to sink and accumulate as pooled or free oil, it can be physically mixed into the water column and can adhere to fine-grained suspended sediments. Diesel oil is not very sticky or viscous, compared to black oils. The oil tends to penetrate porous sediments quickly, but will also be flushed downstream by watercourses, such that cleanup of river banks is usually not needed. Diesel oil is readily and completely degraded by naturally occurring microbes, under time frames of one to two months (NOAA 2006).

A spill of ore could also affect surface water should the spill occur in or immediately adjacent to a watercourse or during a heavy precipitation event that allowed solids to be dissolved or washed into watercourses. It could also result in localized effects on drainage patterns if the iron ore product were to spill into a stream, blocking or altering flow.

Should any spill occur with the potential of contaminating surface water resources used by the public for drinking water or recreational purposes such as swimming, public notifications would be issued in conjunction with Provincial authorities. If required, alternate drinking water (*i.e.,* bottled water) would be supplied to affected users and monitoring of water quality would be conducted until such time as water quality returns to pre-spill conditions.

11.8.1.1 Emergency Response/Mitigation of Environmental Effects

The operation of the train will be under current QNS&L environmental and safety procedures. Mitigation measures to prevent derailments include the following:

- Manual inspection of rolling stock to confirm there are no problems with the wheels, couplers, carbody or brakes;
- Track inspections in accordance with Transport Canada regulations;
- Properly maintained equipment;
- Fuel transport amounts will be limited to the amounts required by the Project; and
- During the spill event within the rail yard, sediment pond outlet will be closed until the spill is recovered and cleaned from the rail yard area and sediment pond.

A detailed Emergency Response and Spill Response Plan will be developed by Labec Century and submitted to appropriate regulatory agencies for review prior to the initiation of Project activities. It will contain specific measures related to train derailment and hydrocarbon spill response. Response measures to recover lost fuel include:

- Immediate response through use of absorbent booms and pads;
- Liquids cleanup can be used to capture both fuels and groundwater near the site for removal and disposal; and
- Physical reclamation of contaminated soils; removal of contaminated soil and replacement with clean soil.

To reduce the likelihood of such an event, emphasis will be placed on safety and accident prevention.

11.8.1.2 Characterization of Residual Environmental Effects

Even with the proposed mitigation in place, a worst-case accidental event could results in short-term contamination of surface water, resulting in a high magnitude effects as concentrations of TSS or hydrocarbons could exceed objectives. Based on behavior of spilled diesel fuel, effects are likely to be short-term and reversible, but could extend downstream, such that effect could extend beyond the LSA. In this worst-case scenario, the residual effect would be significant, but this event is also considered unlikely given the mitigation and response procedures that would be in place.

11.8.2 Forest Fire

Although unlikely, Project activities involving the use of heat or flame could result in a fire. Fires can alter habitat, consume riparian vegetation, destabilize shore area soils, and lead to erosion and sedimentation events. The extent and duration of a fire would be dependent on response efforts and meteorological conditions. Fire suppression water systems will be maintained on site. The fire suppression water supply at the mine site will be extracted from well water and stored in a 200,000 L fire water tank prior to use. Staff will be trained to prevent and control fires. A plan for preventing and combating forest fires will be incorporated into the Emergency Response and Spill Response Plan.

The nearest district forest management unit office in Labrador is in Wabush, which has staff and equipment to provide initial suppression activities. The Town of Schefferville also provides fire control services. Labec Century is discussing a reciprocal response arrangement with the Town of Schefferville, approximately 20 km away from the site. In the event of a fire, the on-site response and proximity of fire suppression services in Schefferville will limit the size of any burn.

Fires can alter habitat, consume riparian vegetation, destabilize shore area soils, and lead to increased erosion and sedimentation. The extent and duration of a fire would be dependent on response efforts and meteorological conditions.

11.8.2.1 Emergency Response/Mitigation of Environmental Effects

The potential for Project-related fires will be mitigated through proper planning, Project design, and the use of standard BMPs, including employee training, proper vigilance working with power equipment in forested areas (e.g., power saw mufflers), and equipment maintenance (e.g., vehicle exhaust systems). All Project activities will be completed in compliance with all appropriate regulation (e.g., *Forest Fire Regulations* under the provincial *Forestry Act*).

Fire suppression water systems will be maintained on site. The fire suppression water supply at the mine and processing site will be extracted from Attikamagen Lake or wells and stored in a 200,000 L water tank prior to use. The fire suppression water at the rail loop will be sourced from Astray Lake. Staff will be trained to prevent and control fires. A plan for preventing and combating forest fires will be incorporated into the Emergency Response and Spill Response Plan.

In the unlikely event of a large fire, local emergency response and fire-fighting capability will be called to respond to reduce the severity and extent of damage and to protect the safety of workers. The nearest district forest management unit office in Labrador is in Wabush, which has staff and equipment to provide initial suppression activities.

11.8.2.2 Characterization of Residual Environmental Effects

Forest fires can change surface water quantity and quality and affect surface water drainage patterns if debris were to block or alter watercourses. Fire fighting efforts could also result in effects on surface water. For a larger spill, large volumes of water could be extracted for fire suppression purposes. The burning of the forest cover and scorching of the forest floor will remove the interception capacity of the forest surface and temporarily eliminate the potential for transpiration. Therefore forest fire will affect the forest water balance by increasing overland flows and reducing ET. The deposition of volatile organic compounds, ash and other burning residuals may affect local water quality, resulting in a high magnitude effect which could extend into the RSA depending on the extent of the fire. Continued runoff from a burn would continue to carry burn residual material to receiving waters and may continue to degrade surface water quality.

Natural regrowth or planned reforestation will reverse the water quantity and quality effects, although recovery of vegetation from a burn could take a number of years, resulting in potential medium to long term effects. In a worst-case scenario, residual effects on surface water quality could be significant, although these effects would be reversible in the long-term. With fire prevention and response in place, a fire resulting from Project activities is considered unlikely as is spread to nearby forested areas.

11.8.3 Hydrocarbon Spill

Hydrocarbon spills associated with rail transport are addressed under Section 11.8.1: Train Derailment.

Fuel storage on the site will include diesel and fuel oil tanks located at the rail unloading area, near the diesel generators at the mine site, and the process plant area. The maximum total storage capacity for diesel fuel will be 250,000 L. The fuel storage tanks will be located in secondary containment to control spills and will comply with requirements of the applicable provincial and federal acts and regulations, as well as the conditions of the permit and authorizations. The control measures will be able to contain the maximum capacity of all tanks in a storage area.

11.8.3.1 Emergency Response/Mitigation of Environmental Effects

Diesel fuel storage tanks will be designed to mitigate and reduce the probability of accidents and malfunctions. The fuel storage tanks will be located in secondary containment to control spills and will comply with requirements of the applicable provincial and federal acts and regulations, and the conditions of the permit and authorizations.

As part of the Emergency Response and Spill Response Plan, spill prevention and response protocols will include the daily inspection of vehicles and hydraulics for leaks or damage that could cause minor spills and rapid spill response. Vehicles and equipment will be stored in controlled areas where containment of spills can be provided. Staff will be trained in the handling of emergency response and spill scenarios.

Spill response equipment stored on site will include containment and absorbent booms, pads, barriers, sand bags, and skimmers, as well as natural and synthetic sorbent materials. The Emergency Response and Spill Response Plan will include the identification of persons responsible for managing spill response efforts, including their authority, role, and contact details, and a description of steps to take to immediately contain and recover spills. In the event of a spill, hydrocarbon-saturated soil will be removed for temporary storage and eventual treatment / disposal.

11.8.4 Characterization of Residual Environmental Effects

While the source is different, the nature of the effects from a spill on site are considered similar to the effects of a spill from a train derailment. Because of mitigation measures like secondary containment on-site, personnel training and proximity of spill response equipment, a spill onsite is less likely to reach surface waters. However, in the extremely unlikely event that a large uncontained release did affect surface water quality, the residual effect could be significant in a worse-case scenario. Again, effects would be short-term, reversible and likely limited to the LSA.

11.8.5 Sedimentation Pond Overflow

Settling/sedimentation ponds will be established at waste rock, overburden, ROM stockpile areas, at the crushing and screening plant area, at the accommodation camp area, and at the rail loop. Run-off from the stockpiles and site run-off will be directed to the settling/sedimentation ponds prior to discharge to the receiving environment. The likelihood of an overflow is low because the ponds will be designed to contain run-off associated with a 1:100 year precipitation event and the entire project is scheduled to occur over a period of <10 years.

11.8.5.1 Emergency Response/Mitigation of Environmental Effects

In the unlikely event of an overflow, contingency plans will be in place as part of the Emergency Response and Spill Response Plan to mitigate environmental effects to the receiving environment. Water sampling of TSS and other MDMER parameters will be conducted in downstream water bodies. Applicable stakeholders, including regulatory agencies, First Nations and communities, will be consulted to discuss such events and mitigation measures to be implemented.

11.8.6 Characterization of Residual Environmental Effects

If a runoff event >1:100 year were to occur, and design freeboard were to be exceeded, settling/sedimentation ponds could overflow, releasing untreated water. Untreated water could have elevated TSS levels and elevated ammonia species concentrations, depending on the location of the pond. No other contaminants are anticipated. Elevated TSS concentrations would result in increased turbidity in receiving waters and the potential for increased though moderate sedimentation in receiver mixing zones. An extreme runoff event would be expected to have a large diluting/assimilating effect on potentially elevated ammonia concentrations, reducing release concentrations during an overflow event to below regulatory criteria.

A sedimentation pond overflow could increase discharge flows above the design erosion thresholds of discharge channels resulting in erosion. Erosion damage will be repaired and the increase in sediment loading will be temporary.

11.8.7 Summary of Residual Effects Resulting from Accidents and Malfunctions

A summary of residual environmental effects resulting from accidents and malfunctions is summarized in Table 11.76.

Table 11.76 Summary of Residual Environmental Effects – Accidents and Malfunctions

Project Phase	Emergency Response/Contingency Measures	Direction	Residual Environmental Characteristics: Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental or Socio-economic Context	Significance	Prediction Confidence	Recommended Follow-up and Monitoring
Change in Surface Water Quantity											
Forest Fire	• EPP • ERP	A	L	S	ST	U	R	U	N	H	None recommended
Settling/Sedimentation Pond Overflow	• EPP • ERP	A	M	L	ST	U	R	D	N	H	None recommended
Change in Surface Water Quality											
Train Derailment	• EPP • ERP	A	H	L	MT	U	R	U/D	S	H	Standard surface water monitoring to confirm effectiveness of clean-up.
Forest Fire	• EPP • ERP	A	H	L	MT	U	R	U	S	H	Standard surface water monitoring to confirm effectiveness of clean-up.
Hydrocarbon Spill	• EPP • ERP	A	H	L	MT	U	R	U/D	S	H	Standard surface water monitoring to confirm effectiveness of clean-up.
Settling/Sedimentation Pond Overflow	• EPP • ERP	A	M	L	ST	U	R	D	N	H	Standard surface water monitoring to confirm effectiveness of clean-up.
Change in Surface Water Drainage Patterns											
Hydrocarbon Spill	• EPP • ERP	N	N	S	ST	UO	R	N/A	N	H	None recommended

Table 11.76 Summary of Residual Environmental Effects – Accidents and Malfunctions

Project Phase	Emergency Response/Contingency Measures	Direction	Residual Environmental Characteristics						Significance	Prediction Confidence	Recommended Follow-up and Monitoring
			Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental or Socio-economic Context			

Key:

Direction:
P Positive
A Adverse
N Neutral

Magnitude:
N Negligible: no measurable adverse effect anticipated;
L Low: effect occurs that is detectable, but is within normal variability of baseline conditions;
M Moderate: effect occurs that would cause an increase (or decrease) with regard to baseline , but is within regulatory limits and objectives; or
H High: effect occurs that would singly or as a substantial contribution in combination with other sources cause exceedances of objectives or standards.

Geographic Extent
S Site-specific: effect is restricted to the PDA;
L Local: effect restricted to the LSA; or
R Regional: effect restricted to the RSA.

Duration:
ST Short-term: Effect does not extend beyond one year
MT Medium-term: Effect does not extend beyond seven years
LT Long-term: Effects are measurable and extend beyond seven years
P Permanent :Effects persistent and measurable parameter unlikely to recover to baseline conditions

Frequency
Quantitative measure; or
O Once per month or less.
S Occurs sporadically at irregular intervals.
R Occurs on a regular basis and at regular intervals.
C Continuous.
U Unlikely to occur

Reversibility
R Reversible - Will likely recover to baseline conditions after the end of Project decommissioning;
I Irreversible - Unlikely to recover to baseline conditions after the end of Project decommissioning (i.e., Permanent).

Ecological or Socio-economic Context:
U Undisturbed: Area relatively or not adversely affected by human activity.
D Developed: Area has been substantially previously disturbed by human development (e.g., urban setting) or human development is still present.

Significance:
S Significant
N Not Significant

Prediction Confidence
Based on scientific information and statistical analysis, and effectiveness of mitigation or effects management measure
L Low level of confidence.
M Moderate level of confidence.
H High level of confidence.

11.9 Determination of Significance of Residual Adverse Environmental Effect

11.9.1 Project Residual Environmental Effects

Changes to surface water quantity during Construction arises from Project alterations to the environmental water balance, such as tree removal reduction in ET and surface hardening increases in runoff. These residual effects persist into the Operation and Maintenance and have been assessed as part of the Project-wide water balance. During Operation and Maintenance, residual surface water quantity effects will occur at Nodes #1, 4, 5 and 6 within the LSA. The Attikamagen Lake system and Petitsikapau Lake system will see an increase in outflows due to the increase in open pit mine surface and groundwater collection, Joyce Lake dewatering, and increase in waste rock, low grade ore and overburden stockpile area runoff. The increase in flows are within the natural range of flows experienced in the Attikamagen Lake system and Petitsikapau Lake system. Subsequently, during Closure and Decommissioning, flows to the Attikamagen Lake system and Petitsikapau Lake system will return to pre-construction conditions. During Operation and Maintenance, water levels upstream of causeway are expected to increase to 0.20 m during the mean annual conditions and to 1.0 m during the 1:100 year flood conditions. These water level changes are expected to be within the natural water level variation of the Attikamagen Lake. Therefore, the residual effect on surface water quantity during all Project phases is predicted to be not significant with a high level of confidence.

Changes to surface water quality during Construction are expected to be mitigated by the implementation of erosion and sedimentation measures. With respect to causeway construction, water quality effects are expected to be contained and assimilated to either baseline or CWQG threshold criteria at the edge of effluent mixing zone within the LSA. During Operation and Maintenance, the proposed sedimentation pond approach and conceptual design will ensure stormwater discharge meets regulatory effluent criteria. TSS concentrations will be below regulatory effluent criteria. An effluent mixing analysis of the mine water effluent discharges from the open pit, waste rock and overburden stockpile area, low grade ore stockpile area, processing plant area as well as sanitary discharge, was conducted to assess mixing zone extent within the LSA under a variety of effluent discharge and climate conditions. The mine water and effluent water quality return to baseline or CWQG background conditions within the LSA. Ammonia contamination will be also managed, and effluent will be treated for nitrates, if required, to meet regulatory effluent criteria. With these mitigation measure in place, surface water quality effects during all Project phases are predicted to be not significant with a high level of confidence.

During Construction, site preparation and ground disturbance activities are expected to change surface water drainage patterns and alter watercourses, but this will primarily be limited to the PDA, with only minor effects extending into the LSA. While effects will be measurable and likely permanent, activities will be managed such that effects remain localized. During Operation and Maintenance, development of the open pit mine, waste rock and overburden stockpiles area, low grade ore stockpile area, processing plant, power plant, accommodation facility, rail yard and access road and rail line all have the potential to affect local drainage patterns; however in all cases, effects will be localized in nature, low in magnitude and long-term. Decommissioning and Closure activities will serve to return surface drainage patterns to pre-construction conditions where possible. The residual effects on surface water drainage and watercourse alterations are predicted to be not significant with a high degree of confidence.

11.9.2 Cumulative Environmental Effects

The potential environmental effects of the Project on Water Resources will not overlap nor affect the water supply or discharge potential of other known projects within the RSA, such as Schefferville Iron Ore Mine and Houston 1&2, and DSO Iron Ore Project or activities that have been or will be carried out in any substantive way. Therefore, the residual cumulative effect on Water Resources as a result of past, present, and reasonably foreseeable projects and activities, in combination with the environmental effects of the Project during all phases, is likely to be not significant. Potential changes to surface water quality, quantity, and drainage patterns have been assessed and residual effects are anticipated to be not significant. This determination has been made with a high level of confidence because of the limited extent of the Project and the lack of substantive overlapping or interfering environmental effects with other projects or activities that have been or will be carried out.

11.9.3 Accidents and Malfunctions

The potential environmental effects of accidents and malfunctions on Surface Water are, for the most part, likely to be not significant. An exception is the accidental release of petroleum hydrocarbons from a major tank rupture or a train derailment. Depending on location, effects on groundwater and indirectly on surface water could be significant but as the site fuel storage is distributed in double wall steel tanks, additionally with impoundment and a maximum of 576,000 L of diesel fuel in six tanker cars would be transported by rail at any time the likelihood of an occurrence and potential overall impact is considered low.

11.10 Follow-up and Monitoring

A monitoring program will be conducted at the following locations:

- Stream T3 downstream of Joyce Lake Outlet;
- Stream T1 which will receive runoff from Low Grade Ore Sediment Pond (SP2);
- Outlet of Waste Rock and Overburden Stockpile Sediment Pond (SP1); and
- Upstream of Joyce Lake.

The following aspects will be monitored at discharge and receiving environment locations for compliance with MDMER, NL ECWSR, and the Project-specific Certificate of Approval:

- Water level recording;
- Channel velocity, depth and flow profiling during the ice-free period; and
- Water quality.

Only water level will be monitored upstream of Iron Arm continuously using a levelogger. The monitoring frequency will be once a month until Project Closure and Decommissioning.

The results for surface water levels, flows, and water quality as well as weather records will be reported on an annual basis.

11.11 Summary

The Project is located in an area where mining and rail activities currently occur. The proposed Project Construction, Operation and Maintenance and Closure and Decommissioning activities will result in localized changes to surface water quantity, quality and drainage patterns. All residual effects associated with these phases of the Project are predicted to be low in magnitude, i.e., effect occurs that is detectable but is within normal variability of baseline conditions, and contained within the LSA. Mitigation will be in place to ensure effluent and runoff from the Project are treated and meet applicable provincial and federal (MDMER) discharge requirements. Monitoring for surface water quality will also be implemented. In conclusion, residual effects from these stages of the Project on Water Resources are not likely to be significant.

Significant residual effects have been predicted for several worst-case accidental/malfunction event scenarios, including a train derailment, which could result in significant, but localized effects on surface water quality. These effects will be mitigated through implementation of appropriate and timely operational safety and emergency response procedures.

Likely cumulative effects on Surface Water as a result of the Project are not significant.

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