18.0 HYDROGEOLOGY OF GOOSE BAY ADA

18.1 General Description of Area

18.1.1 Location & Extent

The Goose Bay ADA is located in the Lake Melville area in southeastern Labrador. Lake Melville forms an inlet of the Labrador Sea that extends over 100 km inland. The ADA covers an area of approximately 438,257 hectares along the western extremity of the inlet encompassing the community of Goose Bay at the mouth of the Churchill River and extending approximately 125 km northeast to the Double Mer Barrens area, and encompassing the Double Mer Inlet. South of the Churchill River, the ADA extends approximately 40 km northeast along the southern shore of Lake Melville to the Kinnakak Point area. The boundary of the Goose Bay ADA is shown on Drawing No. 1034406-18-1 in Appendix 18a.

The Goose Bay ADA overlaps the communities of Happy Valley - Goose Bay, Mud Lake, Northwest River, and Sheshatsheits.

Provincial Highway Routes 500 (The Trans Labrador Highway) and 520 (Northwest River Road), along with a number of secondary roads and ATV trails provide good access in the northwest portion of the ADA around the communities of Goose Bay, Northwest River, and Sheshatsheits. The remainder of the ADA is inaccessible other than by boat or helicopter.

18.1.2 Physiography, Topography & Drainage

The Goose Bay ADA is located within a low-lying coastal plain bordering Lake Melville, referred to as the Melville Plain. This physiographic region is characterized by very low relief and elevations near sea level. Along the southern boundary of the ADA, the Melville coastal plain ends at the steep slopes of the Mealy Mountains, while in the northern portion of the ADA it borders a broad inland plateau that covers much of central Labrador. Upland areas surrounding the ADA reach elevations of greater than 300 m above sea level.

The Goose Bay ADA encompasses the lower courses of the Churchill River, Goose River, Grand Lake and Kenamu River drainage systems, all of which drain into Lake Melville along the western boundary of the ADA. In addition, numerous smaller watercourses are present within the ADA that drain to Lake Melville and Double Mer inlets. The headwaters of these drainage systems originate in the upland regions surrounding the ADA. Lake Melville, Grand Lake and Double Mer are the most significant surface water body features in the area. However, small ponds are also common throughout the drainage catchment area of the ADA. No Public Protected Surface Water Supply Areas are present within the drainage catchment area of the Goose Bay ADA.

18.1.3 Climate, Vegetation & Agricultural Land Use

The Goose Bay ADA is located within the High Boreal Forest ecoregion, which encompasses the Churchill River Valley and the coastal plain surrounding Lake Melville. This ecoregion has the most favourable climate in Labrador with warmer summers and shorter winters than surrounding regions.

Climate normal data obtained from Environment Canada's Goose Bay Airport monitoring station dating back to 1971 indicates a monthly mean temperature in the area of -0.5°C, ranging from a high of 15.4°C in July to a low of -18.1°C in January. Average annual precipitation in the area is 949 mm, of which 59% falls as rainfall and 41% as snowfall. July is typically the wettest month, and February is typically the driest month (Environment Canada, 2008). In the ADA, there are an average of 1,009 growing degree days (base temperature 5^{o}C) for the year and 983 growing degree days for the vegetative season (i.e., May to September).

The landscape in the vicinity of the Goose Bay ADA is dominated by closed-canopied and highly productive forest. The main tree species is balsam fir in association with white birch and trembling aspen. Black spruce is present in upland areas. Ribbed fens occur in uplan depressions, and plateau bogs occur on coastal plain. Based on agricultural land use information provided by the NL Department of Forest Resources and Agrifoods, no significant commercial or non-commercial farming is currently being carried out in the ADA, but rather the ADA has been designated for future planning purposes.

18.2 Geology

18.2.1 Surficial Geology

The surficial geology of the Goose Bay ADA is summarized in Drawing No. 1034406-18-2 in Appendix 18a, and is based on regional scale compilation by Klassen, R.A., *et al.* (1992), as well as descriptions of surficial geology provided in Liverman (1997). For the purposes of this study, surficial geological units on existing maps have been simplified into four (4) groups, including exposed bedrock, areas of bog, areas of till and areas of sand and gravel.

Till deposits are present throughout the ADA occurring as both thin discontinuous veneer (typically less than 2 m thick), and more extensive moraine deposits with local thicknesses up to 20 m. In addition, local areas of lineated till occur in the ADA, and contain various streamlined features including drumlins, and craig and tail structures. The composition of the veneer and moraine tills are variable and bedrock-controlled, but generally consist of a medium to fine sand to sandy loam derived from paragneiss and grantic gneiss. Within the ADA, sand and gravel material of glacial outwash and fluvial origin is also present, occurring primarily as plain and terrace deposits along major stream and river valleys. The most significant occurrences of sand and gravel are present along the Churchill and Goose rivers. Sand and gravel units shown in Drawing No. 1034406-18-2 in Appendix 18a also include un-subdivided lacustrine and marine terraces that contain various silt and clay deposits in addition to sands and gravels and occur along the shores of Lake Melville. Along with glacial units, local deposits of organic and peaty soils are scattered throughout the ADA, overlying either till or bedrock. Numerous ridges and knobs of bedrock outcrop are exposed within the till and various other surficial deposits that underlie the ADA, and typically occur as areas of high ground. Bedrock outcrops may be partially or fully concealed by a thin mat of vegetation and sparse forest. However, where exposed bedrock outcrops are commonly streamlined and display glacial striations. Streamlined glacial features in the area indicate east-southeast-directed ice flow. Available well logs indicate an average overburden thickness within the coastal plain area underlying the Goose Bay ADA of approximately 23 m.

18.2.2 Bedrock & Structural Geology

The bedrock geology of the Goose Bay ADA is summarized in Drawing No. 1034406-18-3 in Appendix 18a, and is based on the regional 1:1,000,000 scale compilation mapping by Wardle et al. (1997).

The ADA occurs almost entirely within sandstones and conglomerate of the Neoproterozoic Double Mer Formation. This unit represents graben-fill sedimentation, which occurred within a down-faulted block corresponding to the Lake Melville Lowland area in response to initial rifting associated with Appalachian orogenisis. In upland areas along the western, northern and southern boundaries of the ADA, the Double Mer Formation is in fault contact with Grenville Province Paleoproterozoic volcanic, sedimentary and igneous rocks and their metamorphic extensions.

The Paleoproterozoic rocks in the area are deformed by a series of north-directed thrust faults associated with Paleoproterozoic Labrador Orogenisis, as well as by southwest trending normal faults of Neoproterozoic age, which produced graben structures and controlled deposition of the Neoproterozoic Double Mer Formation.

18.3 Hydrogeology

18.3.1 Hydrostratigraphy

The groundwater potential of the various geological units within the Goose Bay ADA was assessed utilizing available records for water wells completed within each unit obtained from the NLDEC-Water Resources Management Division Drilled Water Well Database for wells drilled between 1950 and March, 2008. The data provided in the well records are organized by community and includes information on the well depth and yield, well casing depth and diameter, depths to water bearing zone(s), plus data on the quality and use of the water and the driller's description of the depth and lithology of the overburden and bedrock units encountered.

A total of 12 drilled bedrock wells and 4 drilled surficial wells from three (3) communities in the ADA and surrounding area had adequate well data to evaluate the groundwater potential of various surficial and bedrock strata in the ADA. Since lithologic information provided in the well records was of insufficient detail to define the bedrock encountered in each individual drilled well, the wells were assigned to their respective geologic units based on the community in which the wells were located and the corresponding underlying geologic unit, as shown on the bedrock geology map provided in Drawing No. 1034406-18-3 in Appendix 18a.

The groundwater potential of each geological unit was quantified by assessing the reported well yields and depths from the records of wells completed within each unit. Reported yields for drilled wells in the Goose Bay ADA to obtain a rough estimate of well capacity, and does not necessarily represent the short or long term safe yield of the well, or the groundwater yield characteristics of the corresponding aquifer. To accurately determine such values, aquifer testing, including step drawdown and constant rate pump testing must be conducted, ideally with monitoring of groundwater levels in nearby observation wells. No aquifer testing has been carried out on any of the drilled wells in the ADA and surrounding area. Therefore, in the absence of this data, the groundwater potential of the various geological strata in the Goose Bay ADA is defined based on the estimated well yields obtained from the driller's records.

18.3.1.1 Surficial Hydrostratigraphic Units

The surficial deposits within the Goose Bay ADA have been subdivided into two broad hydrostratigraphic units, including one comprised of till deposits, and the other predominantly of sands and gravels. The yield and depth characteristics of these units are summarized on Table 18.1. No water well information was available for the till deposits present in the ADA. Therefore groundwater potential within this overburden unit was inferred based on well records for similar overburden material in the St. John's ADA.

Till Deposits

A medium to fine sand to sandy loam derived from paragneiss and grantic gneiss and forming both thin discontinuous veneer and moraine deposits blanket is present throughout the ADA. There are no documented data on their groundwater potential in the Goose Bay ADA. However, based on records of water wells within similar till material in the St. John's ADA, the range of yields from wells within the till can be expected to vary from 10 to 70 L/min at depths of 9.5 to 35 m. The average yield is estimated to be approximately 40 L/min at 21 m depth. However, median yield and depth estimates of 34 L/min at 20 m depth are more likely representative of the typical groundwater potential of this unit.

Sand and Gravel Deposits

Sand and gravel material of glacial outwash and fluvial origin is also present within the ADA, occurring primarily as plain and terrace deposits along major stream and river valleys. The most significant occurrences of sand and gravel are present along the Churchill and Goose rivers. Marine-derived sand and gravel units also occur locally, particularly along the shores of Lake Melville. These deposits are potentially significant groundwater aquifers. Four (4) wells from the communities of Goose Bay and Sheshatsheits were available to characterize the groundwater potential of this unit in the ADA. Based on well data, the sand and gravel deposits are considered capable of providing wells with high yields, having water yields ranging from 10 to 545 L/min at well depths of 29 to 48 m, and an average yield of 286 L/min at 38 m depth. However, median yield and depth estimates of 295 L/min at 38 m depth are more likely representative of the typical groundwater potential of this unit.

Table 18.1 Summary of Overburden Drilled Well Information for Goose Bay ADA

Overburden Unit	Communities	No. of Wells	Well Depth (m)		Well Yield (L/min)	
			Mean (Median)	Range	Mean (Median)	Range
Till*	St. John's ADA	6	21.3 (19.6)	9.5-35	39.5 (33.5)	10-70
Sand & Gravel	Goose Bay Sheshatsheits	4	38.4 (38.4)	28.8-48	286 (294.5)	10-545

* Groundwater yield estimates for the till deposits based on well data from the St. John's ADA

18.3.1.2 Bedrock Hydrostratigraphic Units

Well record information is available for the Neoproterozoic sandstones and conglomerate of the Double Mer Formation and the combined Grenville Province Paleoproterozoic volcanic, sedimentary and igneous rocks that underlie the ADA. The well yield and depth characteristics of this unit are summarized in Table 18.2.

Double Mer Formation

A total of four (4) well records from the community of Goose Bay were used to characterize the groundwater potential of the Double Mer Formation strata. This unit underlies the majority of the ADA. Based on well data, the Double Mer Formation rocks are considered capable of providing wells with low yields, having water yields ranging from 2 to 18 L/min at well depths of 31 to 129 m, and an average yield of 7 L/min at 56 m depth. However, median yield and depth estimates of 5 L/min at 32 m depth are more likely representative of the typical groundwater potential of this unit.

Grenville Province Paleoproterozoic Rocks

A total of eight (8) well records from the community of Rigolet were used to characterize the groundwater potential of the combined Grenville Province Paleoproterozoic volcanic, sedimentary and igneous strata. These units are present in upland areas along the western, northern and southern boundaries of the ADA. Based on well data, the combined Grenville Province Paleoproterozoic rocks are considered capable of providing wells with low yields, having water yields ranging from 3 to 27 L/min at well depths of 40 to 46 m, and an average yield of 15 L/min at 44 m depth. However, median yield and depth estimates of 14 L/min at 45 m depth are more likely representative of the typical groundwater potential of these units.

Table 18.2 Summary of Bedrock Drilled Well Information for Goose Bay ADA

Rock Group	Rock Type	Communities	No. of Wells	Well Depth (m)		Well Yield (L/min)	
				Mean (Median)	Range	Mean (Median)	Range
Double Mer Formation	Sandstone and conglomerate	Goose Bay	4	55.7 (31.5)	30.5-129.2	7.4 (4.8)	2.2-18
Grenville Province Paleoproterozoic Rocks	volcanic, sedimentary and igneous rocks and their metamorphic extensions	Rigolet	8	44.4 (45.4)	40.2-45.6	15.3 (13.5)	3-27

18.3.2 Groundwater Flow System

The Goose Bay ADA and surrounding area is underlain by an unconfined aquifer system contained within the overburden material and underlying shallow bedrock. The movement of groundwater through the overburden material is controlled by primary porosity, while groundwater flow within the underlying bedrock can be expected to mainly occur within secondary openings, such as fractures and joints, and will be variable depending on the frequency and interconnection of these structural features.

Shallow groundwater flow within the ADA is controlled by water table conditions and local variations in topography. Groundwater is thought to be recharging along areas of high ground and discharging along various wet lowland areas, ponds, lakes and rivers, as well as the coastal inlets of Lake Melville and Double Mer. It is expected that the shallow groundwater system in the ADA will be largely controlled by surface runoff and local recharge, while at moderate depths the flow system may be influenced by lateral inflow of groundwater from surrounding up-gradient areas. Based on a review of water well records for the area, groundwater levels are generally assumed to be within 11 m of the ground surface and to be a subdued reflection of the topography.

18.4 Water Quality

18.4.1 Surface Water Quality

Surface water quality data for the Goose Bay ADA was obtained from two sources, including:

1. Ambient water quality data collected as part of the Canada–Newfoundland Water Quality Monitoring Agreement, from five (5) ambient water quality monitoring sites in the ADA and surrounding area –
    - Kenamu River (NF03QA0045, 1999-2007);
    - Carter Basin (NFO3QA0044, 1999-2007);
    - Cape Caribou River (NFO3PB0028, 1999-2007);
    - Susan River (NFO3PB0032, 1999-2007); and,
    - Naskaupi River (NFO3PB0027, 1999-2004)
2. Water quality monitoring data collected by the NL Department of Environment - Water Resources Management Division from one (1) protected public surface water supplies in the ADA and surrounding area -
    - Rigolet – Rigolet Pond (WS-S-0618, 1992-2006)

A summary of chemical data obtained from these surface water sources over their respective monitoring periods is provided in Tables 18.3 and 18.4. in Appendix 18b, and is compared to the Canadian Drinking Water Quality Guidelines (CDWQG) (Health Canada, 2007), as well as the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses (CWQG-AWU) (October, 2005).

Major ion chemical data was incomplete for the ambient water quality monitoring sites. However, based on major ion chemistry for the Rigolet – Rigolet Pond protected public surface water supply indicates that surface water in the ADA and surrounding area can be classified as a calcium-sodium-chloride-sulfate-bicarbonate (Ca-Na-Cl-SO_4-HCO_3) type water. Surface water in the area is soft, neutral to slightly acidic, and of low alkalinity. Classification of surface water according to dissolved-solids and specific conductance generally indicates fresh conditions. However, slightly to moderately saline conditions were identified at the Kenamu River and Carter Basin ambient water quality monitoring sites, returning specific conductance values of up to 1,860 uS/cm and 7,590 uS/cm, over their respective monitoring periods.

With the exception of chloride, iron, manganese, pH, selenium, and turbidity at several of the ambient water quality monitoring station, and iron, pH, turbidity and color in the Rigolet – Rigolet Pond protected public surface water supply, concentrations of all other parameters tested meet CDWQG. The guidelines for chloride, iron, pH, manganese, turbidity and color are aesthetic objectives only and levels of these parameters detected at the surface water locations evaluated do not pose any health concerns, however problems may be experienced such as foul taste, deposition or staining in the case of iron, manganese, turbidity and color and corrosion in the case of chloride and pH.

In addition, concentrations of aluminum, boron, chloride, iron, and selenium were present at the Carter Basin water quality monitoring site, and concentrations of chloride, and selenium were present at the Kenamu River water quality monitoring site that exceeded CCME CWQG-AWU for irrigation and/or livestock water use.

Based on chemical data for the Rigolet – Rigolet Pond protected public surface water supply, surface water quality within the ADA is generally considered good, returning an average Canadian Water Quality Index (CWQI) value of 85. However, a negative Langelier Index indicates that water is unsaturated with calcium carbonate and it will tend to be corrosive, leading to potential leaks in the distribution system. Kenamu River, Carter Basin, Cape Caribou River, Susan River, and Naskaupi River are not considered potable water sources, and would require treatment for disinfection, as well as to improve the aesthetic quality of the water, and reduce levels of selenium in areas were elevated concentrations of this parameter that exceed CDWQG are identified. In addition, concentrations of aluminum, boron, chloride, iron, and selenium present at the Carter Basin water quality monitoring site, and concentrations of chloride, and selenium present at the Kenamu River water quality monitoring site at levels that exceed CCME CWQG-AWU for irrigation and/or livestock water use may limit usage of these surface water sources as potential agricultural water supplies without appropriate treatment. The elevated specific conductance, chloride, and trace metals levels present at the Kenamu River and Carter Basin ambient water quality monitoring sites is likely due to the coastal location of these sites at the mouths of major river systems.

18.4.2 Groundwater Quality

The groundwater quality data for the Goose Bay ADA consists of analyses from four (4) protected public supply drilled wells for the communities of Happy Valley-Goose Bay (WS-G-0322 and WS-G-0323), North West River (WS-G-0513), and Sheshatsheits (WS-G-0645) collected by the NL Department of Environment - Water Resources Management Division. A summary of chemical data obtained from these water wells is provided in Table 18.5 in Appendix 18b, and is compared to the Canadian Drinking Water Quality Guidelines (CDWQG) (Health Canada, 2007), as well as the Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses (CWQG-AWU) (October, 2005).

Based on major ion chemistry, shallow groundwater in the ADA can be classified as a combination of sodium-calcium-chloride-sulfate-bicarbonate ($Na\text{-}Ca\text{-}Cl\text{-}SO_4\text{-}HCO_3$), sodium-calcium-chloride-sulfate ($Na\text{-}Ca\text{-}Cl\text{-}SO_4$) and calcium-magnesium-bicarbonate-chloride-sulfate ($Ca\text{-}Mg\text{-}HCO_3\text{-}Cl\text{-}SO_4$) type waters. Groundwater in the area ranges from soft to very hard, slightly acidic to basic, and of low to high alkalinity. Classification of groundwater according to dissolved-solids and specific conductance generally indicates fresh conditions. However, slightly to moderately saline conditions were present in the Happy–Valley – Goose Bay (WS-G-0323) and Sheshatsheits (WS-G-0645) protected groundwater supplies over their respective monitoring periods, returning maximum specific conductance values and total dissolved solids values of 2,100 uS/cm and 1,370 mg/L, and 4,190 uS/cm and 2,720 mg/L respectively.

With the exception of chloride, copper, iron, lead, manganese, pH, sodium, total dissolved solids, true color and turbidity in several of the protected public groundwater supply wells, concentrations of all other parameters tested meet CDWQG. The guidelines for chloride, iron, manganese, pH, sodium, total dissolved solids, true color and turbidity are aesthetic objectives only and levels of these parameters detected in the wells do not pose any health concerns, however problems may be

experienced such as foul taste, deposition or staining in the case of iron, manganese, sodium, total dissolved solids, true color and turbidity, and corrosion in the case of chloride and pH.

In addition, concentrations of chloride, copper, iron, manganese, and total dissolved solids were present in several of the protected public groundwater supply wells that exceeded CCME CWQG-AWU for irrigation and/or livestock water use.

Based on chemical data, groundwater quality within the ADA is generally considered good to excellent, returning average Canadian Water Quality Index (CWQI) values ranging from 94 – 100. However, negative Langelier Index indicates in all of the protected public groundwater supply wells indicates that water is unsaturated with calcium carbonate and will tend to be corrosive, leading to potential leaks in the distribution system. Treatment would be required to improve the aesthetic quality of the groundwater in the water wells, and reduce levels of copper in wells were elevated concentrations of this parameter that exceed CDWQG are identified. In addition, concentrations of chloride, copper, iron, manganese, and total dissolved solids present in several of the protected public groundwater supply wells that exceed CCME CWQG-AWU for irrigation and/or livestock water use may limit usage of these groundwater sources as potential agricultural water supplies without appropriate treatment. The elevated specific conductance, chloride, dissolved solids and sodium levels present Happy–Valley – Goose Bay (WS-G-0323) and Sheshatsheits (WS-G-0645) protected groundwater supplies is likely due to the coastal location of these wells and suggests that saltwater intrusion may be a potential issue for water wells installed in coastal areas of the ADAs.

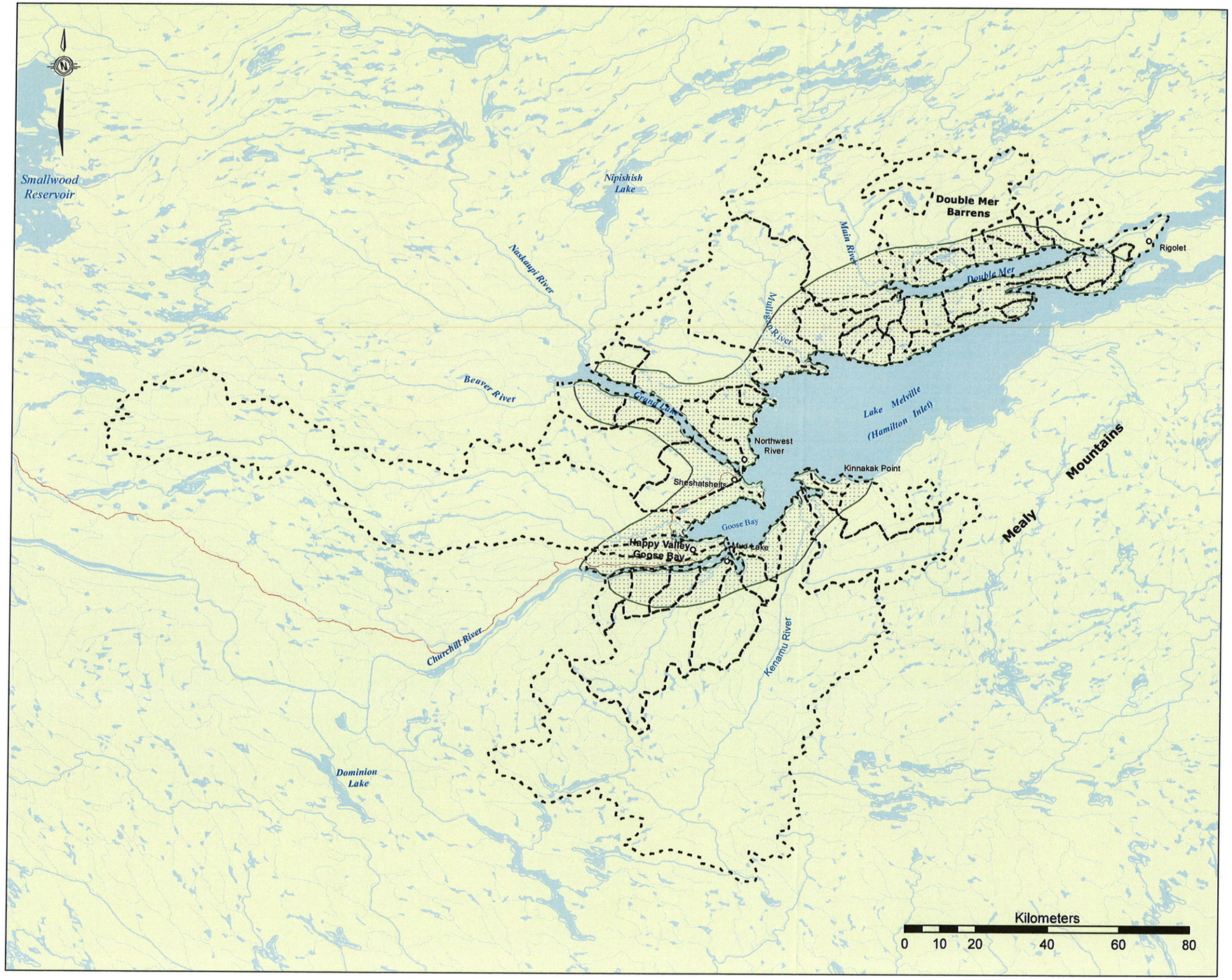
18.5 Groundwater Recharge & Availability

Recharge to the shallow groundwater system underlying the ADA is by direct infiltration of rainfall, after runoff and the requirements of evaporation and plant transpiration have been met, and is directly related to rainfall, infiltration characteristics and size of the recharge zone. A common practice in estimating the long term groundwater recharge for an area is to multiply the groundwater catchment area by the percent of precipitation estimated as able to infiltrate. The recharge to groundwater in the Goose Bay ADA is estimated on the basis of a local groundwater catchment area equivalent to the area of the ADA of approximately 438,257 hectares, and a conservative recharge coefficient of 10% of the mean annual rainfall (i.e., 10% of 949 mm, equivalent to 95 mm). Based on these values, the groundwater recharge to the Goose Bay ADA is estimated at $4.2 \times 10^8 m^3$/year or 949 m^3/hectares/yr.

Four (4) protected public groundwater supplies are present in the vicinity of the ADA, including two public groundwater supplies for the community of Happy Valley – Goose Bay (Water Supply Nos. WS-G-0322 and WS-G-0323) that serves a population of approximately 7,572, one public groundwater supply for the community of North West River (Water Supply No. WS-G-0513) that serves a population of approximately 492, and one public groundwater supply for the community of Sheshasheits (Water Supply No. WS-G-0645) that serves a population of approximately 1,048. The remainder of the water wells in the area of the ADA are limited to minor individual domestic, commercial, and public supply wells. No information is available regarding existing agricultural (i.e., irrigation and livestock) water demands in the Goose Bay ADA, thus preventing an accurate balance of groundwater supply and demand to be estimated, and making it difficult to evaluate groundwater supply potential for future agricultural development in the area. However, considering the current, overall under-utilization of groundwater in the area from other users, it is expected that an adequate supply of groundwater of sufficient quality is available to meet and/or augment water supply requirements for various existing and future agricultural needs in the ADA.

APPENDIX 18a

Drawings



LEGEND

- Transportation Route
- Drainage Catchment Area
- Waterbody
- Agricultural Development Area

PROJECT TITLE:

HYDROGEOLOGY OF AGRICULTURAL DEVELOPMENT AREAS, NEWFOUNDLAND AND LABRADOR

DRAWING TITLE:

GOOSE BAY ADA LOCATION AND DRAINAGE

Jacques Whitford

SCALE: 1:1,125,000	DATE: 13/02/2008
DRAWN BY: JLB	CHECKED BY:
EDITED BY: MCH	REV. No. 0
DRAWING No.: 1034406-18-1	
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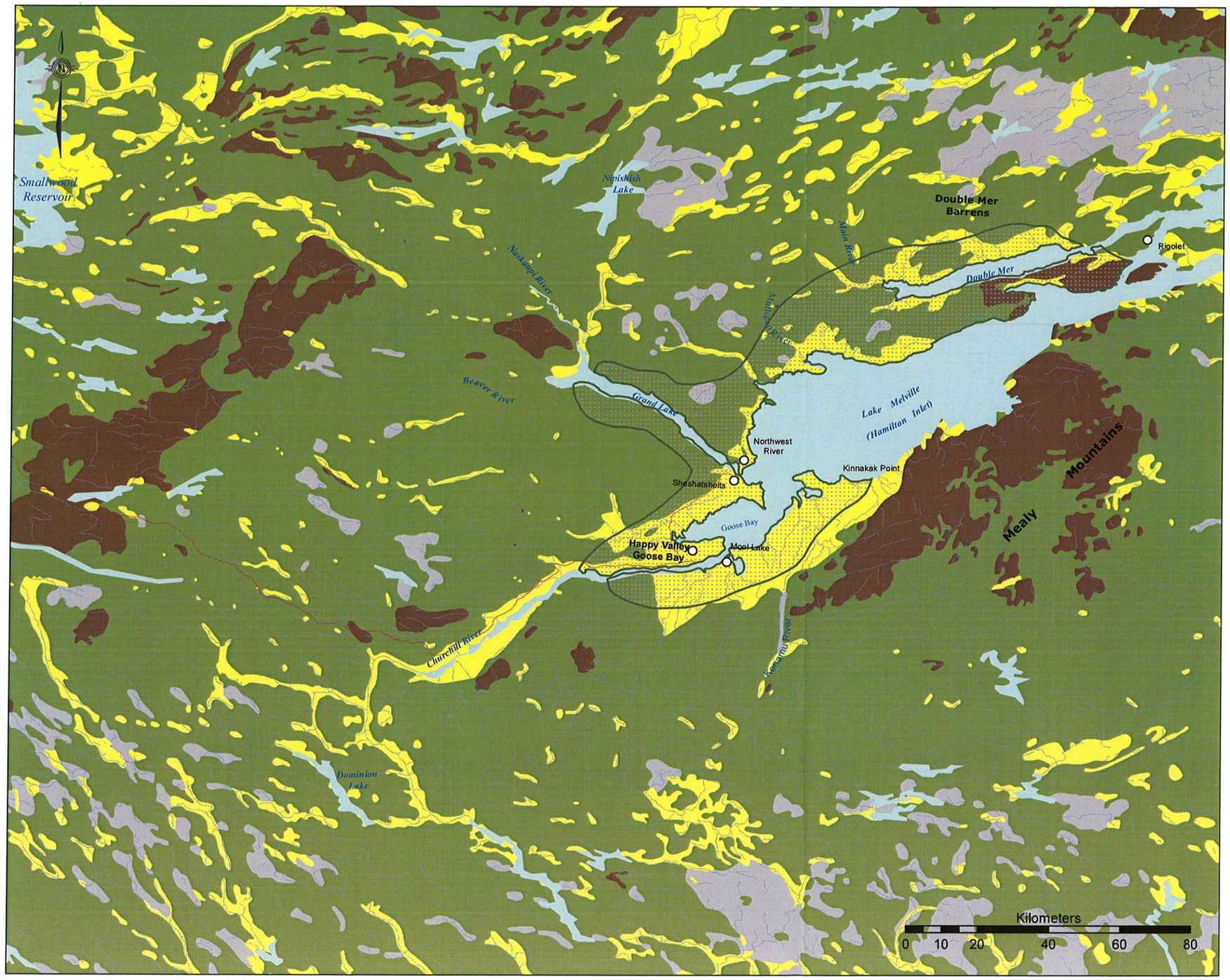
02/06/2008



Surficial Geology Legend

- Bog: Poorly drained accumulations of peat, peat moss and other organic matter; developed in areas of poor drainage
- Sand & Gravel: Sands, gravels and silts of glaciofluvial, fluvial, lacustrine or marine terrace origin
- Glacial Till: Till veneer and moraine deposits of varying thickness overlying bedrock. Composed of diamicton (poorly sorted sediment containing a mixture of grain sizes from clay to boulders)
- Rock: Exposed Bedrock, includes areas concealed by vegetation, till veneer, as well as colluvium

LEGEND

- Stream
- Transportation Route
- Waterbody
- Agricultural Development Area

PROJECT TITLE:

HYDROGEOLOGY OF AGRICULTURAL DEVELOPMENT AREAS, NEWFOUNDLAND AND LABRADOR

DRAWING TITLE:

GOOSE BAY ADA SURFICIAL GEOLOGY

Jacques Whitford

SCALE: 1:1,125,000	DATE: 05/06/2008
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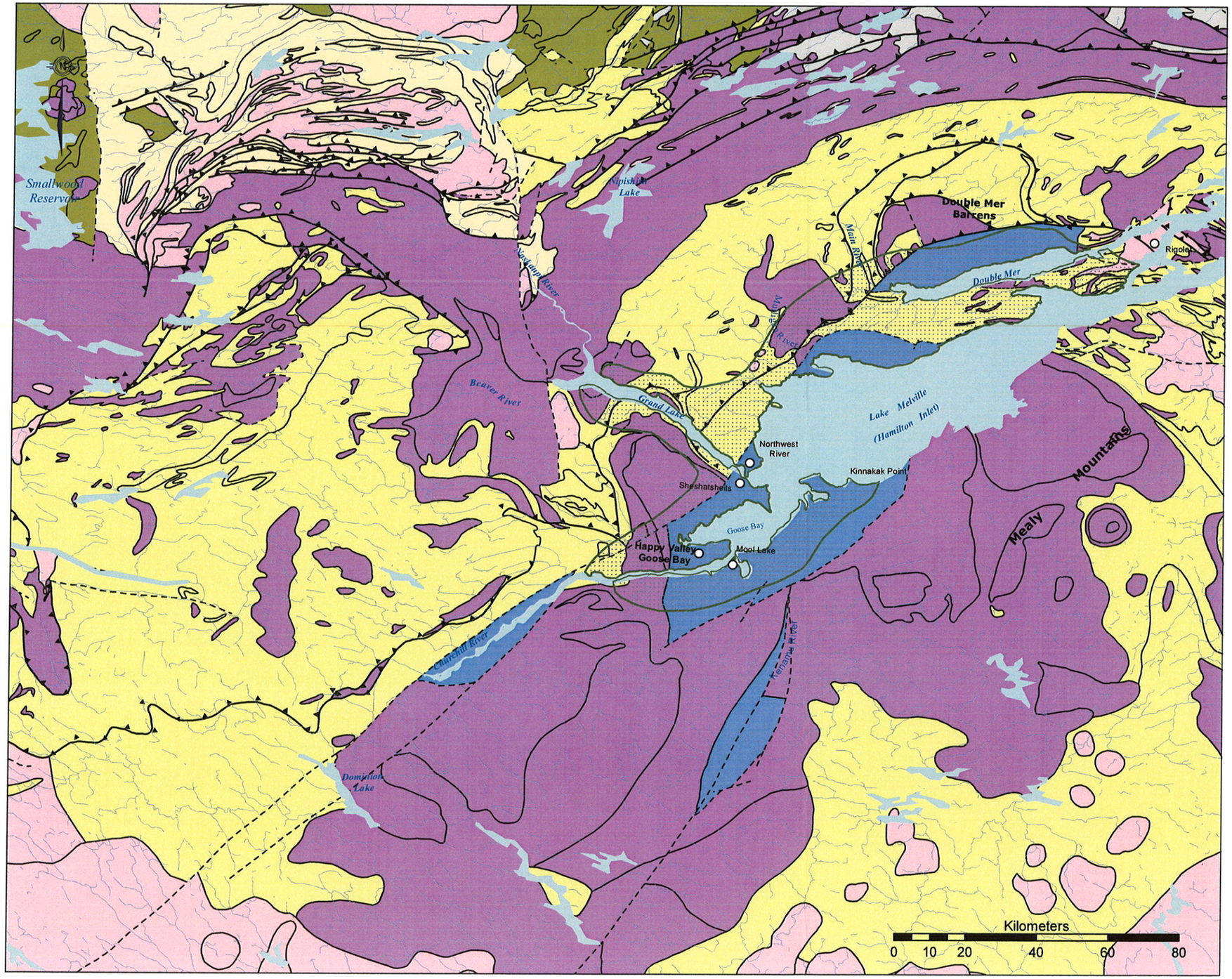

Generalized Bedrock Geology Legend

Grenville Province

Neoproterozoic

- Arkose and conglomerate (Double Mer Formation)

Mesoproterozoic

- Undifferentiated stratified igneous and sedimentary rocks, including metamorphosed equivalents
- Undifferentiated granite, anorthosite, and gabbro, including metamorphosed equivalents

Paleoproterozoic

- Undifferentiated stratified igneous and sedimentary rocks, including metamorphosed equivalents
- Undifferentiated granite, anorthosite, and gabbro, including metamorphosed equivalents

Archean

- Undivided Archean rocks, including granite, gabbro, and metamorphosed equivalent, and metabasalt, and metasediment

LEGEND

- Contact
- Fault, Strike-Slip and High Angle
- Fault, Thrust
- Transportation Route
- Stream
- Waterbody
- Agricultural Development Area

PROJECT TITLE:

HYDROGEOLOGY OF AGRICULTURAL DEVELOPMENT AREAS, NEWFOUNDLAND AND LABRADOR

DRAWING TITLE:

GOOSE BAY ADA BEDROCK GEOLOGY

Jacques Whitford

SCALE: 1:1,125,000	DATE: 05/06/2008
DRAWN BY: JLB	CHECKED BY:
EDITED BY: MCH	REV. No. 0
DRAWING No.: 1034406-18-3	
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APPENDIX 18b

Water Chemistry Data

Table 18.3 Surface Water Chemistry, NL Ambient Water Quality Monitoring Sites, Goose Bay ADA Hydrogeology of Agricultural Development Areas, Newfoundland & Labrador

Parameter	Units	CDWQG	CWQG-AWU		Kenamu River NF03QA0045 (1999-2007)[1]			Carter Basin NFO3QA0044 (1999-2007)[1]			Cape Caribou River NFO3PB0028 (1999-2007)[1]			Susan River NFO3PB0032 (1999-2007)[1]			Naskaupi River NFO3PB0027 (1999-2004)[1]		
			Irrigation Water	Livestock Water	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Alkalinity	mg/L $CaC0_3$	na	na	na	3.71	16.67	8.48	6.8	21.4	13.3	5.2	10.3	6.9	4.2	10.7	7.6	3.3	12.2	8.8
Aluminum	mg/L	na	5	5	0.13	2.42	0.51	0.09	**9.68**	1.86	0.10	0.29	0.21	0.17	1.24	0.45	-	-	-
Ammonia	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Antimony	mg/L	0.006	na	na	0.000005	0.00005	0.00001	0.000009	0.00007	0.00004	0.000005	0.00001	0.00001	0.000008	0.00001	0.00001	-	-	-
Arsenic	mg/L	0.01	0.1	0.025	0.00007	0.01	0.001	0.0001	0.003	0.0008	0.00004	0.00008	0.00006	0.00004	0.00012	0.00008	-	-	-
Barium	mg/L	1	na	na	0.01	0.04	0.02	0.01	0.13	0.03	0.01	0.01	0.01	0.005	0.01	0.007	-	-	-
Beryllium	mg/L	na	0.1	0.1	0.000005	0.00007	0.00002	0.000005	0.0003	0.0001	0.00001	0.00001	0.00001	0.000007	0.00003	0.00001	-	-	-
Bicarbonate	mg/L $CaC0_3$	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boron	mg/L	5	0.5 - 6	5	0.002	0.32	0.06	0.03	**0.61**	0.21	0.002	0.02	0.006	0.0007	0.002	0.001	-	-	-
Bromide	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cadmium	mg/L	0.005	0.005	0.08	0.000003	0.0001	0.00002	0.000004	0.00005	0.00002	0.000003	0.00003	0.000008	0.000003	0.00005	0.00001	-	-	-
Calcium	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbonate	mg/L $CaC0_3$	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chloride	mg/L	250*	100 - 700	na	0.28	**543**	108.66	82.7	**2,460**	**1,047.6**	0.22	82.1	15.93	0.17	1.89	0.57	-	-	-
Chromium	mg/L	0.05	0.005	0.05	0.0003	0.003	0.001	0.0002	0.01	0.002	-	-	-	0.0003	0.001	0.0006	-	-	-
Copper	mg/L	1*	0.2 - 1,000	0.5-5	0.0006	0.004	0.001	0.0006	0.01	0.002	0.0004	0.0008	0.0006	0.0007	0.002	0.001	-	-	-
Dissolved Organic Carbon	mg/L	na	na	na	4.70	9.10	7.36	3.50	22.40	8.15	4.30	8.40	6.91	4.50	6.60	5.36	-	-	-
Fluoride	mg/L	1.5	1	1 - 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hardness	mg/L $CaC0_3$	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iron	mg/L	0.3*	5	na	0.39	2.07	0.94	0.19	**10.1**	2.08	0.097	0.38	0.269	0.25	0.97	0.47	-	-	-
Kjeldahl Nitrogen	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Langelier Index	-	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lead	mg/L	0.01	0.2	0.1	0.0001	0.001	0.0002	0.00002	0.004	0.001	0.00002	0.0001	0.00006	0.00006	0.0003	0.0001	-	-	-
Magnesium	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese	mg/L	0.05*	0.2	na	0.01	0.05	0.02	0.01	0.16	0.04	0.01	0.01	0.01	0.01	0.04	0.02	-	-	-
Mercury	mg/L	0.001	na	0.003	-	-	-	0.000001	0.000003	0.000002	0.000002	0.000004	0.000003	0.000001	0.000003	0.000002	0.000001	0.000006	0.000003
Nickel	mg/L	na	0.2	1	0.0003	0.002	0.0009	0.0003	0.02	0.003	0.0002	0.0006	0.0004	0.0004	0.0014	0.0006	-	-	-
Nitrate	mg/L N	45	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate + Nitrite	mg/L N	na	na	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrite	mg/L	na	na	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orthophosphate	mg/L P	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
pH	Units	6.5-8.5*	na	na	6.48	7.30	6.82	6.39	7.34	6.83	6.31	7.13	6.67	6.32	7.04	6.68	6.12	7.18	6.78
Potassium	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reactive Silica	mg/L SiO2	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium	mg/L	0.01	0.02 - 0.05	0.05	0.00005	**0.07**	0.02	0.00009	**0.07**	0.02	0.00005	0.00009	0.00006	0.00005	0.00006	0.0001	-	-	-
Silver	mg/L	na	na	na	0.000001	0.000007	0.000003	0.000002	0.00003	0.00001	0.000001	0.000003	0.000002	0.000001	0.000003	0.000002	-	-	-
Sodium	mg/L	200*	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Specific Conductance	uS/cm	na	na	na	12.5	1,860	226.2	313	7,590	2,428	-	-	-	9.3	36.2	17.8	-	-	-
Sulphate	mg/L	500*	na	1,000	0.74	74.90	15.78	11.10	327.00	142.14	0.69	12.00	3.19	0.52	1.26	0.86	-	-	-
Sulphide	mg/L H2S	0.05*	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thallium	mg/L	na	na	na	0.000003	0.0001	0.00002	0.000004	0.0001	0.00004	0.000002	0.00001	0.000004	0.000003	0.00001	0.000006	-	-	-
Tin	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Dissolved Solids	mg/L	500*	500 - 3,500	3,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Organic Carbon	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Phosphorus	mg/L	na	na	na	0.01	0.04	0.02	0.01	0.09	0.02	0.00	0.04	0.01	0.003	0.02	0.01	0.003	0.03	0.01
Total Suspended Solids	mg/L	na	na	na	-	-	-	5.38	5.38	5.38				18.02	18.02	18.02	6.26	6.26	6.26
True Color	TCU	15*	na	na	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity	NTU	0.3/1.0/0.1**	na	na	0.33	78.10	13.85	1.65	130.00	25.04	0.43	4.38	2.70	1.80	26.80	7.83	-	-	-
Uranium	mg/L	0.02	0.01	0.2	0.00005	0.0002	0.0001	0.0001	0.0007	0.0003	0.00004	0.00006	0.00006	0.00004	0.00006	0.00005	-	-	-
Vanadium	mg/L	na	0.1	0.1	0.001	0.004	0.002	0.0005	0.02	0.004	0.0002	0.0009	0.0006	0.0004	0.002	0.0008	-	-	-
Canadian Water Quality Index	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zinc	mg/L	5*	1 - 5	50	0.001	0.006	0.003	0.0003	0.02	0.005	0.0005	0.0012	0.0008	0.0005	0.003	0.001	-	-	-

Notes:

CDWQG = Health Canada Canadian Drinking Water Quality Guidelines (March, 2007)

CWQG-AWU = CCME Canadian Water Quaility Guidelines for the Protection of Agricultural Water Uses (Irrigation and Livestock Water) (October, 2005)

1 = Summary statisitics calculated using chemicial data obtained from the NL Ambient Water Quaility Database available through the Canada and Newfoundland/Labrador Aqua Link

na = No applicable criteria

* = Aesthetic objective

** = Operational guideline value based on conventional treatment/slow sand or diatomaceous earth filtration/membrane filtration.

"-" = Not analyzed

Shaded = Value does not meet applicable criteria

Bolded = Value does not meet CWQG-AWU for irrigation and/or livestock water

Table 18.4 Surface Water Chemistry, Public Water Supply, Goose Bay ADA
Hydrogeology of Agricultural Development Areas, Newfoundland & Labrador

Parameter	Units	CDWQG	CWQG-AWU		Rigolet - Rigolet Pond WS-S-0618 (1992-2006)[1]		
			Irrigation Water	Livestock Water	Min	Max	Mean
Alkalinity	mg/L $CaC0_3$	na	na	na	2.5	10	6.1
Aluminum	mg/L	na	5	5	0.18	0.35	0.27
Ammonia	mg/L	na	na	na	0	0.07	0.03
Antimony	mg/L	0.006	na	na	0	0.0005	0.0002
Arsenic	mg/L	0.01	0.1	0.025	0	0.003	0.0009
Barium	mg/L	1	na	na	0.02	0.04	0.03
Beryllium	mg/L	na	0.1	0.1	-	-	-
Bicarbonate	mg/L $CaC0_3$	na	na	na	-	-	-
Boron	mg/L	5	0.5 - 6	5	0	0.03	0.01
Bromide	mg/L	na	na	na	0	0.03	0.01
Cadmium	mg/L	0.005	0.005	0.08	0	0.0003	0.0001
Calcium	mg/L	na	na	na	1.13	5	2.43
Carbonate	mg/L $CaC0_3$	na	na	na	-	-	-
Chloride	mg/L	250*	100 - 700	na	1	4	3
Chromium	mg/L	0.05	na	na	0	0.003	0.001
Copper	mg/L	1*	0.2 - 1	0.5-5	0	0.03	0.01
Dissolved Organic Carbon	mg/L	na	na	na	7.4	13.5	10.7
Fluoride	mg/L	1.5	1	1 - 2	0	0.27	0.10
Hardness	mg/L $CaC0_3$	na	na	na	5	13	6.78
Iron	mg/L	0.3*	5	na	0.15	0.5	0.35
Kjeldahl Nitrogen	mg/L	na	na	na	0.1	0.46	0.30
Langelier Index	-	na	na	na	-4.19	-3.52	-3.81
Lead	mg/L	0.01	0.2	0.1	0	0.001	0.001
Magnesium	mg/L	na	na	na	0	0.5	0.24
Manganese	mg/L	0.05*	0.2	na	0	0.02	0.01
Mercury	mg/L	0.001	na	0.003	0	0.00005	0.00002
Nickel	mg/L	na	0.2	1	0	0.003	0.002
Nitrate	mg/L N	45	na	na	-	-	-
Nitrate + Nitrite	mg/L N	na	na	100	0	0.74	0.16
Nitrite	mg/L	na	na	10	-	-	-
Orthophosphate	mg/L P	na	na	na	-	-	-
pH	Units	6.5-8.5*	na	na	5.9	6.6	6.27
Potassium	mg/L	na	na	na	0	0.5	0.21
Reactive Silica	mg/L SiO2	na	na	na	-	-	-
Selenium	mg/L	0.01	0.02 - 0.05	0.05	0	0.001	0.0004
Silver	mg/L	na	na	na	-	-	-
Sodium	mg/L	200*	na	na	0	2	0.9
Specific Conductance	uS/cm	na	na	na	15	31	22
Sulphate	mg/L	500*	na	1,000	2	10	4
Sulphide	mg/L H2S	0.05*	na	na	-	-	-
Thallium	mg/L	na	na	na	-	-	-
Tin	mg/L	na	na	na	10	20	15
Total Dissolved Solids	mg/L	500*	500 - 3,500	3,000	-	-	-
Total Organic Carbon	mg/L	na	na	na	-	-	-
Total Phosphorus	mg/L	na	na	na	0	0.03	0.02
Total Suspended Solids	mg/L	na	na	na	2	2	2
True Color	TCU	15*	na	na	60	105	87
Turbidity	NTU	0.3/1.0/0.1**	na	na	0.8	1.9	1.28
Uranium	mg/L	0.02	0.01	0.2	0	0	0
Vanadium	mg/L	na	0.1	0.1	-	-	-
Canadian Water	-	-	-	-	84	86	85
Zinc	mg/L	5*	1 - 5	50	0	0.03	0.01

Notes:

CDWQG = Health Canada Canadian Drinking Water Quality Guidelines (March, 2007)

CWQG-AWU = CCME Canadian Water Quaility Guidelines for the Protection of Agricultural Water Uses (Irrigation and Livestock Water) (October, 2005)

1 = Summary statisitics calculated using chemicial data obtained from the NL Department of Environment - Water Resources Management Division Drinking Water Quality Database. Note in the data base, prior to March 31, 2004 analytical results less than the detection limit were reported as half of the detection limit, while after March 31, 2004 analytical results less than the detection limit were reported as zero.

na = No applicable criteria

* = Aesthetic objective

** = Operational guideline value based on conventional treatment/slow sand or

"-" = Not analyzed

Shaded = Value does not meet applicable criteria

Bolded = Value does not meet CWQG-AWU for irrigation and/or livestock water

Table 18.5 Groundwater Chemistry, Protected Public Drilled Wells, Goose Bay ADA
Hydrogeology of Agricultural Development Areas, Newfoundland & Labrador

Parameter	Units	CDWQG	CWQG-AWU		Happy Valley-Goose Bay Spring Gulch WS-G-0322 (2001-2007)[1]			Happy Valley-Goose Bay WS-G-0323 (2001-2007)[1]			North West River WS-G-0513 (2001-2007)[1]			Sheshasheits - Indian Band Council WS-G-0645 (2001-2007)[1]		
			Irrigation Water	Livestock Water	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Alkalinity	mg/L $CaC0_3$	na	na	na	16	24	19	15	71	46	35	78	55	36	721	170
Aluminum	mg/L	na	5	5	0	0.16	0.06	0	0.46	0.06	0	0.82	0.04	0	0.025	0.005
Ammonia	mg/L	na	na	na	0	0.19	0.06	0	0.27	0.11	0	0.09	0.01	0	0.3	0.09
Antimony	mg/L	0.006	na	na	0	0.0005	0.0002	0	0.0005	0.0001	0	0.0005	0.0001	0	0.0005	0.0001
Arsenic	mg/L	0.01	0.1	0.025	0	0.001	0.0004	0	0.002	0.0004	0	0.001	0.0002	0	0.001	0.0003
Barium	mg/L	1	na	na	0	0.03	0.01	0	0.06	0.01	0.03	0.11	0.06	0	0.08	0.05
Beryllium	mg/L	na	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Bicarbonate	mg/L $CaC0_3$	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-
Boron	mg/L	5	0.5 - 6	5	0	0.03	0.01	0	0.04	0.02	0	0.04	0.02	0	0.25	0.10
Bromide	mg/L	na	na	na	0	1.09	0.25	0	2.78	0.27	0	0.03	0.01	0	1.19	0.29
Cadmium	mg/L	0.005	0.005	0.08	0	0.0002	0.0001	0	0.0003	0.00003	0	0.0004	0.00003	0	0.00005	0.00001
Calcium	mg/L	na	na	na	1	17	6	2	32	9	13	29	21	5	30	18
Carbonate	mg/L $CaC0_3$	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-
Chloride	mg/L	250*	100 - 700	na	0	**169**	38	0	**610**	66	0	8	2	2	**1,030**	**171**
Chromium	mg/L	0.05	na	na	0	0.001	0.0004	0	0.004	0.001	0	0.001	0.0002	0	0.009	0.002
Copper	mg/L	1*	0.2 - 1	0.5-5	0	0.001	0.0004	0	**3.85**	0.09	0	0.039	0.003	0	0.013	0.004
Dissolved Organic Carbon	mg/L	na	na	na	0	4.3	1.7	0	6.4	1.4	0	1.3	0.4	0	5.2	1.6
Fluoride	mg/L	1.5	1	1 - 2	0	0.13	0.07	0	0.31	0.12	0	0.7	0.30	0	1.2	0.46
Hardness	mg/L $CaC0_3$	na	na	na	3	108	32	9	311	64	41	94	68	25	140	82
Iron	mg/L	0.3*	5	na	0.06	**17.8**	4.01	0.05	**30.9**	**5.01**	0	2.23	0.11	0	1.29	0.20
Kjeldahl Nitrogen	mg/L	na	na	na	0	0.26	0.10	0	0.48	0.14	0	0.31	0.06	0	0.44	0.12
Langelier Index	-	na	na	na	-3.91	-2.75	-3.31	-3.44	-1.21	-1.82	-1.62	-0.48	-1.04	-1.14	-0.31	-0.66
Lead	mg/L	0.01	0.2	0.1	0	0.001	0.0004	0	0.183	0.005	0	0.01	0.001	0	0.001	0.0003
Magnesium	mg/L	na	na	na	0.5	16	4.5	1	56	10	2	6	4	2	17	9
Manganese	mg/L	0.05*	0.2	na	0	**1.34**	**0.30**	0.005	**1.77**	**0.43**	0	**0.26**	0.02	0	0.15	0.06
Mercury	mg/L	0.001	na	0.003	0	0.00005	0.00002	0	0.00005	0.00002	0	0.00005	0.00001	0	0.00005	0.00001
Nickel	mg/L	na	0.2	1	0	0.005	0.002	0	0.04	0.002	0	0.005	0.001	0	0.005	0.001
Nitrate	mg/L N	45	na	na	-	-	-	-	-	-	-	-	-	-	-	-
Nitrate + Nitrite	mg/L N	na	na	100	0	0.05	0.02	0	0.05	0.02	0	1.28	0.16	0	0.5	0.09
Nitrite	mg/L	na	na	10	-	-	-	-	-	-	-	-	-	-	-	-
Orthophosphate	mg/L P	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-
pH	Units	6.5-8.5*	na	na	6.3	7.3	6.76	6.4	7.7	7.02	6.6	8	7.49	6.4	10	7.80
Potassium	mg/L	na	na	na	0.5	4	1.6	1	9	4	2	3.4	2.4	1	9	5
Reactive Silica	mg/L SiO2	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-
Selenium	mg/L	0.01	0.02 - 0.05	0.05	0	0.003	0.001	0	0.007	0.001	0	0.002	0.0003	0	0.003	0.001
Silver	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-
Sodium	mg/L	200*	na	na	0	63	15	0	292	35	0	3	2	4	969	156
Specific Conductance	uS/cm	na	na	na	32	675	177	34	2,100	322	108	200	158	84	4,190	893
Sulphate	mg/L	500*	na	1,000	0	17	5	2	74	10	5	24	20	6	60	22
Sulphide	mg/L H2S	0.05*	na	na	-	-	-	-	-	-	-	-	-	-	-	-
Thallium	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-
Tin	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-
Total Dissolved Solids	mg/L	500*	500 - 3,500	3,000	21	439	115	22	**1,370**	205	70	130	102	55	**2,720**	**561**
Total Organic Carbon	mg/L	na	na	na	-	-	-	-	-	-	-	-	-	-	-	-
Total Phosphorus	mg/L	na	na	na	0	0.1	0.03	0	0.31	0.05	0	0.26	0.04	0	0.5	0.15
Total Suspended Solids	mg/L	na	na	na	0	0	0	-	-	-	-	-	-	-	-	-
True Color	TCU	15*	na	na	5	11	8	0	187	30	0	1	0.23	0	12	4
Turbidity	NTU	0.3/1.0/0.1**	na	na	0.3	20.3	4.8	0.2	120	11.3	0	42.7	2.1	0	18.4	2.09
Uranium	mg/L	0.02	0.01	0.2	0	0	0	0	0	0	0	0	0	0	0	0
Vanadium	mg/L	na	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
Canadian Water Quality Index (CWQI)	-	-	-	-	95	100	97.2	97	100	98	100	100	100	94	96	94.6
Zinc	mg/L	5*	1 - 5	50	0	0.008	0.003	0	0.3	0.01	0	0.58	0.03	0	0.16	0.01

Notes:
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1 = Chemicial data obtained from the NL Department of Environment - Water Resources Management Division Drinking Water Quality Database. Note in the database, prior to March 31, 2004 analytical results less than detection limit were reported as half of the detection limit, while after March 31, 2004 analytical results less than the detection limit were reported as zero.
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