10.0 HYDROGEOLOGY OF THE GANDER ADA

10.1 General Description of Area

10.1.1 Location & Extent

The Gander ADA is located in a remote area in central Newfoundland, approximately 18 km south of Glenwood, and covers an area of approximately 20,429 hectares. The boundary of the Gander ADA is shown on Drawing No. 1034406-10-1 in Appendix 10a.

No communities are present within the ADA.

Access to the Gander ADA is provided by a network of logging roads leading from the Trans-Canada Highway (Route 1) at Glenwood. In addition, numerous ATV trails are present in the area and provide access to some areas within the ADA.

10.1.2 Physiography, Topography & Drainage

The Gander ADA is located along the northern margin of a broad upland region in the interior of the province referred to as the Central Plateau. This physiographic region is characterized by gentle relief and elevations exceeding 150 m above sea level. The Gander ADA is situated at the transition zone between the Central Plateau and the adjacent lowlands of the Northeast Trough and is characterized by undulating to rolling terrain. Elevations within the ADA typically range from approximately 100 to 200 m above sea level, but decrease to less than 50 m above sea level at the base of some river valleys. Elevations increase to the south of the ADA and reach a maximum elevation of approximately 340 m above sea level in the Partridgeberry Hill area, located approximately 90 km southwest of the ADA.

The Gander ADA encompasses the lower courses of the Northwest Gander River and the Southwest Gander River drainage systems, both of which drain into Gander Lake along the northern boundary of the ADA. The headwaters of the Northwest Gander River and the Southwest Gander River drainage systems originate in the upland region south of the ADA. Gander Lake is the most significant surface water body feature in the area. However, small ponds are also common throughout the drainage catchment area of the ADA.

The boundaries of the Gander Lake Public Protected Water Supply Area overlap the Gander ADA and the lower portion of its drainage catchment area.

10.1.3 Climate, Vegetation & Agricultural Land Use

The Gander ADA is located within the Central Newfoundland Ecoregion, which is the second largest ecoregion, covering approximately one-third of the central and northeastern portion of the island. The Gander ADA is located within the Northcentral Subregion, and is characterized by higher summer maximum temperatures, lower rainfall and higher fire frequency than anywhere else in Newfoundland. Climate data obtained from Environment Canada's Gander International Airport monitoring station dating back to 1971 indicates a monthly mean temperature in the area of 3.8°C, ranging from a high of

16°C in August to a low of -7.9°C in February. Average annual precipitation in the area is 1,202 mm, of which 64% falls as rainfall and 36% as snowfall. December is typically the wettest month, and July is typically the driest month (Environment Canada, 2008). In the ADA, there are an average of 1,238 growing degree days (base temperature 5^{o}C) for the year and 1,152 growing degree days for the vegetative season (i.e., May to September).

Vegetation in the vicinity of the Gander ADA consists of pure black spruce forests and aspen stands broken by areas of domed bogs, and patches of sparsely forested heath covered barrens. Based on agricultural land use information provided by the NL Department of Natural Resources Agrifoods Division, no significant commercial or non-commercial agricultural activities are currently carried out in the ADA, but rather the ADA is designated for future planning purposes.

10.2 Geology

10.2.1 Surficial Geology

The surficial geology of the Gander ADA is summarized in Drawing No. 1034406-10-2 in Appendix 10a, and is based on regional scale compilation by Liverman and Taylor (1990), as well as descriptions of surficial geology provided in Hender (1993). 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. The veneer and moraine tills comprise a moderately stoney, sandy loam derived from black slate, shale and siltstone, and minor medium-grained granite. The veneer and moraine tills are locally eroded and dissected, particularly along stream and river channels. In addition, small areas of hummocky till occur locally. Within the ADA, sand and gravel deposits of glacial outwash and fluvial origin are limited and generally confined to stream and river valleys, with the most significant occurrences of these deposits present along Northwest Gander River and Southwest Gander River. Along with glacial units, local deposits of organic and peaty soils are common 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 thin mat vegetation and sparse forest. However, where exposed bedrock outcrops are commonly streamlined and display glacial striations that indicate eastward directed flow. No well records are available for the Gander ADA and surrounding areas, with which to evaluate overburden thickness in the ADA.

10.2.2 Bedrock & Structural Geology

The bedrock geology of the Gander ADA is summarized in Drawing No. 1034406-10-3 in Appendix 10a, and is based on the regional 1:250,000 scale compilation mapping by Colman-Sadd and Crisby-Whittle (2005), as well as a description of bedrock geology provided in McNicoll, *et al.* (2006).

The Gander ADA lies within the Dunnage tectonostratigraphic zone and is underlain by early Ordovician to late Silurian siliclastic and minor calcareous marine sedimentary rocks. The majority of the ADA is underlain by marine shale and thinly bedded siltstone and sandstone of the Early to Late Ordovician Davidsville Group. In the western portion of the ADA, the Davidsville Group is conformably

overlain by the Early to Late Silurian Indian Islands Group, which consists of a shoaling-upwards sequence of grey to red marine shale and calcareous sandstone and siltstone. The Mount Peyton Plutonic Suite, which comprises both gabbro and granite, is in intrusive contact with the Indian Islands Group along the western boundary of the ADA.

The most significant structural feature in the area is the Dog Bay Line, located along the western boundary of the ADA, which comprises a series of high angle faults and shear zones related to Devonian Acadian orogenesis, and separates rocks of the Davidsville and Indian Islands Groups underlying the ADA from coeval rocks of the Badger Group and Botwood Group, located to the west. Rocks of the Davidsville and Indian Islands Groups have a variable slaty cleavage associated with deformation. In addition, local high-angle, isoclinals folds are also present in the area related to Acadian deformation.

10.3 Hydrogeology

10.3.1 Hydrostratigraphy

No water well records are available for the Gander ADA and surrounding area. Therefore, in the absence of this data, the groundwater potential of the various surficial and bedrock strata in the Gander ADA is inferred based on well records for similar lithologies in other ADAs.

10.3.1.1 Surficial Hydrostratigraphic Units

The surficial deposits within the Gander 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 10.1. No water well information was available for the till and sand and gravel deposits present in the ADA. Therefore groundwater potential within these units was inferred based on well records for similar overburden material in the St. John's and Terra Nova ADAs, respectively.

Till Deposits

The till deposits form both thin veneer or more extensive moraine deposits over much of the ADA and is comprised of a moderately stoney, sandy loam. There are no documented data on their groundwater potential in the Gander 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 deposits of glacial outwash and fluvial origin occur sparingly within the ADA, and are generally confined to stream and river valleys, with the most significant occurrences of these deposits present along Northwest Gander River and Southwest Gander River. These deposits are potentially significant groundwater aquifers but there are no documented data on their groundwater potential in the Gander ADA. Based on records of water wells within similar sand and gravel deposits in the Terra Nova ADA, the range of yields from wells within the sand and gravel material can be expected to vary from 2 to 225 L/min at depths of 8 to 45 m. The average yield is estimated to be approximately 67

L/min at 21 m depth. However, median yield and depth estimates of 48 L/min at 18 m depth are more likely representative of the typical groundwater potential of this unit.

Table 10.1 Summary of Overburden Drilled Well Information for Gander 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**	Terra Nova ADA	42	20.6 (18.3)	7.6 – 45.1	67 (48)	2 - 225

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

** Groundwater yield estimates for the sand and gravel deposits based on well data from the Terra Nova ADA

10.3.1.2 Bedrock Hydrostratigraphic Units

No water well information is available for the early Ordovician to late Silurian siliclastic and minor calcareous marine sedimentary rocks of the Davidsville and Indian Islands groups that underlie the Gander ADA. Therefore groundwater potential within these units was inferred based on well records for correlative strata of the Badger and Botwood Groups in the Botwood, Lewisporte and Comfort Cove ADAs.

Davidsville Group

No documented data is available for the groundwater potential of the Davidsville Group rocks that underlie the majority of the ADA. However, based on well data for correlative strata of the Badger Group from the Botwood, Lewisporte and Comfort Cove ADAs, wells within the Davidsville Group are considered capable of providing wells with low yields, having water yields ranging from 1 to 230 L/min at well depths of 12 to 113 m, and an average yield of 24 L/min at 54 m depth. However, median yield and depth estimates of 14 L/min at 46 m depth are more likely representative of the typical groundwater potential of this unit.

Indian Island Group

No documented data is available for the groundwater potential of the Indian Island Group rocks that are present in the western portion of the ADA. However, based on well data for correlative strata of the Botwood Group from the Botwood, Lewisporte and Comfort Cove ADAs, wells within the Indian Island Group are considered capable of providing wells with low yields, having water yields ranging from 1 to 273 L/min at well depths of 12 to 98 m, and an average yield of 31 L/min at 47 m depth. However, median yield and depth estimates of 10 L/min at 45 m depth are more likely representative of the typical groundwater potential of this unit.

Table 10.2 Summary of Bedrock Drilled Well Information for Gander ADA

Rock Group	Rock Type	Communities	No. of Wells	Well Depth (m)		Well Yield (L/min)	
				Mean (Median)	Range	Mean (Median)	Range
Davidsville*	Marine siliciclastic sedimentary rocks and minor carbonate, volcanic, intrusive, and metamorphic rocks	Botwood, Lewisporte and Comfort Cove ADAs (Badger Group)	21	54.4 (46.2)	12-112.8	24.3 (13.5)	1-230
Indian Island*	Siliciclastic sedimentary rocks, and minor bimodal volcanic rocks	Botwood, Lewisporte and Comfort Cove ADAs (Botwood Group)	58	47.4 (45.3)	12.2-97.6	30.9 (9.6)	1-272.8

* Groundwater yield estimates for the Davidsville and Indian Islands groups based on well data for correlative strata in the Botwood, Lewisporte and Comfort Cove ADAs

10.3.2 Groundwater Flow System

No well records are available for the Gander ADA and surrounding areas. However, it is assumed that the 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 expected to be controlled by water table conditions and local variations in topography. Groundwater is thought to be recharging along the topographic highs and discharging in various wet lowland areas, ponds, lakes and rivers. 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 up-gradient areas to the southwest. Based on proximity to Gander Lake and low lying topography within the ADA, groundwater levels are generally assumed to be within 5 m of the ground surface and to be a subdued reflection of the topography.

10.4 Water Quality

10.4.1 Surface Water Quality

Surface water quality data for the Gander ADA is limited to water quality monitoring data collected by the NL Department of Environment - Water Resources Management Division from the Gander – Gander Lake (WS-S-0268) protected public surface water over a monitoring period from 1993 to 2007. A summary of chemical data obtained from this surface water source over the monitoring period is provided in Table 10.3 in Appendix 10b, 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, surface water in the ADA and surrounding area can be classified as a calcium-sodium-bicarbonate-chloride-sulfate (Ca-Na-HCO_3-Cl-SO_4) type water. Surface water in the

area is soft to slightly hard, slightly acidic, and of low alkalinity. Classification of surface water according to dissolved-solids and specific conductance indicates fresh conditions.

With the exception of pH, turbidity and color, concentrations of all other parameters tested meet CDWQG over the monitoring period. The guidelines for pH, 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 turbidity and color, and corrosion in the case of pH.

Concentrations of all parameters tested in the Gander – Gander Lake protected public surface water supply meet CCME CWQG-AWU for irrigation and/or livestock water use.

Based on chemical data, surface water quality within the ADA is considered good, returning an average Canadian Water Quality Index (CWQI) value of 93. 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. Treatment would be required to improve the aesthetic quality of the water.

10.4.2 Groundwater Quality

No groundwater quality data was available with which to evaluate groundwater quality in the Gander ADA.

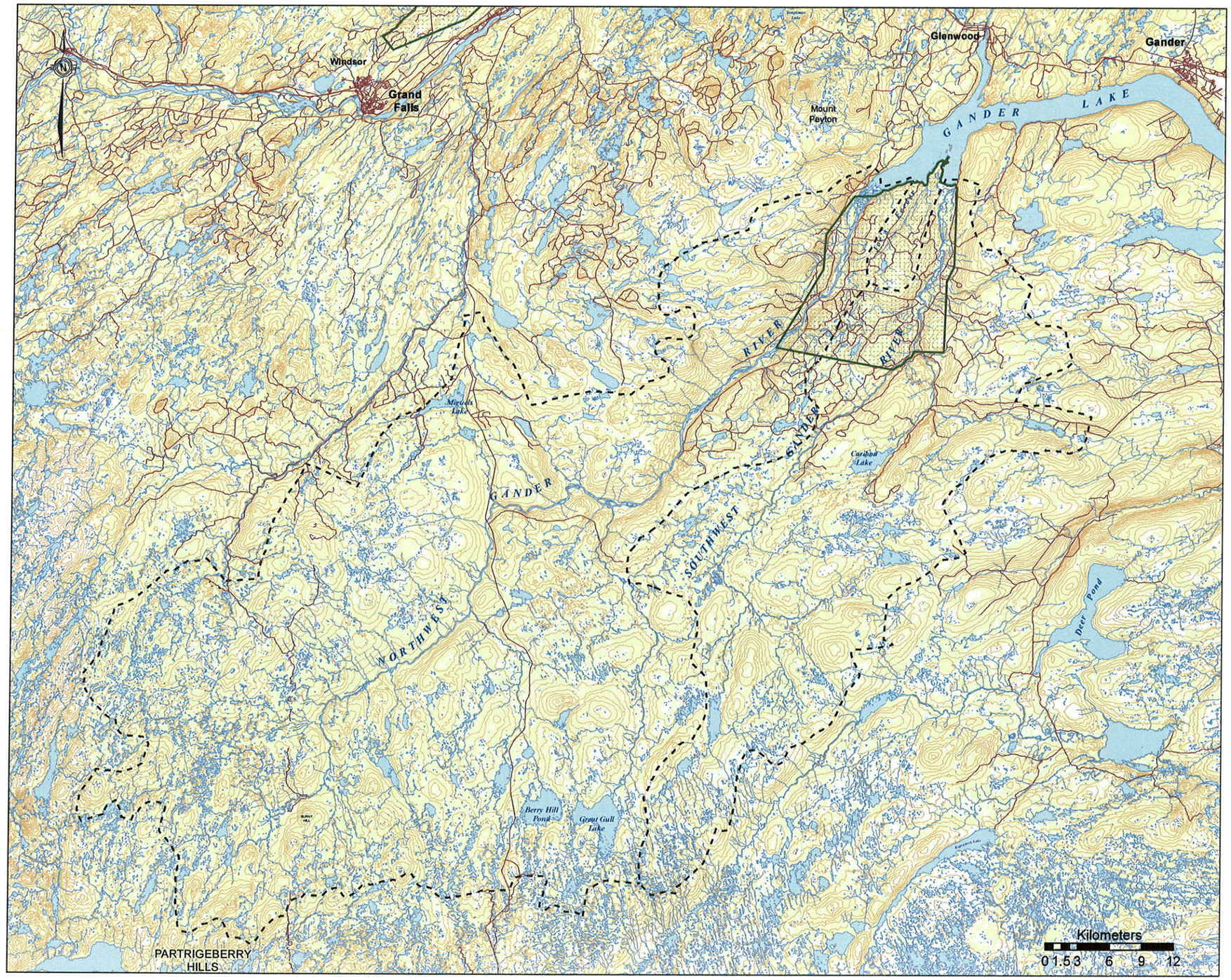
10.5 Groundwater Recharge & Availability

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 Gander ADA is estimated on the basis of a local groundwater catchment area equivalent to the area of the ADA of approximately 20,429 hectares, and a conservative recharge coefficient of 10% of the mean annual rainfall (i.e., 10% of 1,202 mm, equivalent to 120 mm). Based on these values, the groundwater recharge to the Gander ADA is estimated at $2.5x10^7 m^3$/year or 1,202 m^3/hectares/yr.

Groundwater is currently not in use in the ADA, and it is expected that an adequate supply of groundwater of sufficient quality is available to meet and/or augment water supply requirements for any future agricultural needs in the ADA.

APPENDIX 10a

Drawings



- Transportation Route
- Drainage Catchment Area
- Stream
- Contour Line
- Waterbody
- Agricultural Development Area
- Wetland/String Bog
- Vegetated Area

PROJECT TITLE:

HYDROGEOLOGY OF AGRICULTURAL DEVELOPMENT AREAS, NEWFOUNDLAND AND LABRADOR

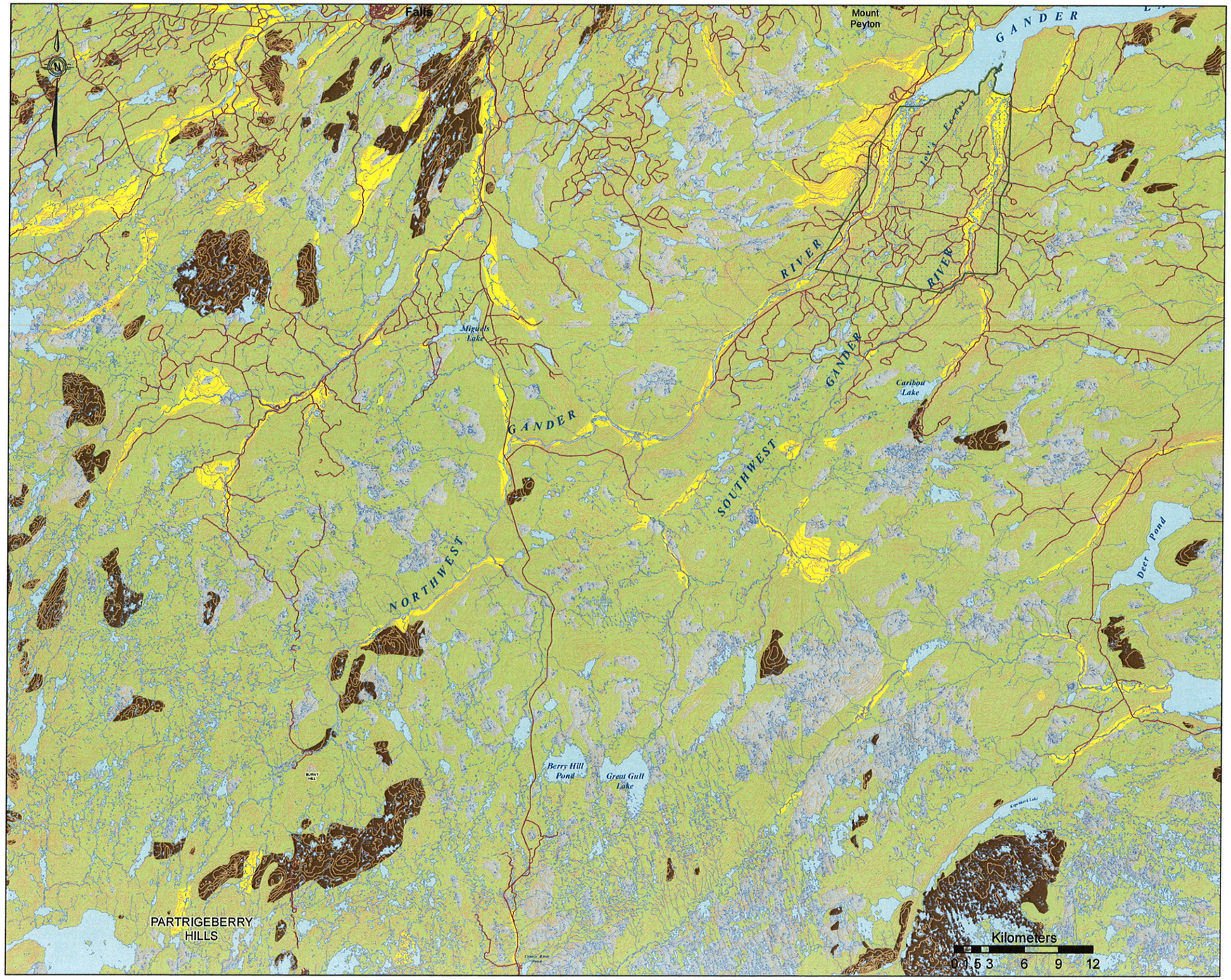
DRAWING TITLE:

GANDER ADA LOCATION AND DRAINAGE

Jacques Whitford

Jacques Whitford

SCALE: 1:375,000	DATE: 11/03/2008
DRAWN BY: JLB	CHECKED BY:
EDITED BY: JLB	REV. No. 0
DRAWING No.: 1034406-10-1	
MAP FILE: 1034406-XX.MXD	



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

- Stream
- Transportation Route
- Contour Line
- Waterbody
- Agricultural Development Area

PROJECT TITLE:

HYDROGEOLOGY OF AGRICULTURAL DEVELOPMENT AREAS, NEWFOUNDLAND AND LABRADOR

DRAWING TITLE:

GANDER ADA SURFICIAL GEOLOGY

Jacques Whitford

SCALE:	1:350,000	DATE:	03/06/2008
DRAWN BY:	JLB	CHECKED BY:	
EDITED BY:	MCH	REV. No.	0
DRAWING No.:	1034406-10-2		
MAP FILE:	1034406-XX.MXD		

Generalized Bedrock Geology Legend

POST-ORDOVICIAN OVERLAP SEQUENCES

Silurian

Siliciclastic sedimentary rocks, including sandstone, shale and conglomerate and minor bimodal to mainly felsic volcanic rocks (Indian Island and Botwood Group)

DUNNAGE ZONE

Stratified Rocks

Middle Ordovician and Early Silurian

Black shale, slate and argillite, including subordinate chert and greywacke and turbidites consisting of sandstone, shale and conglomerate; other marine sedimentary rocks (Caradoc Shale)

Cambrian to Middle Ordovician

Marine siliciclastic sedimentary rocks, including slate, shale, argillite, siltstone, sandstone, conglomerate, and minor unseparated carbonate, volcanic and intrusive rocks, and schist, gneiss and migmatite (Davidsville and Budger Groups)

Intrusive Rocks

Cambrian and Ordovician

Granitoid intrusions, including trondhjemite of ophiolite complexes

Mafic intrusions, including unseparated granitoid rocks, and ultramafic rocks of ophiolite complexes

POST-ORDOVICIAN INTRUSIVE SEQUENCES

Devonian and Carboniferous

Granite and high silica granite (sensu stricto), and other granitoid intrusions that are posttectonic relative to mid-Paleozoic orogenies

Silurian and Devonian

Gabbro and diorite intrusions, including minor ultramafic phases

Granitoid suites, varying from pretectonic to syntectonic, relative to mid-Paleozoic orogenies

GANDER ZONE

Undifferentiated

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

PROJECT TITLE:

HYDROGEOLOGY OF AGRICULTURAL DEVELOPMENT AREAS, NEWFOUNDLAND AND LABRADOR

DRAWING TITLE:

GANDER ADA BEDROCK GEOLOGY

Jacques Whitford

SCALE: 1:350,000	DATE: 11/03/2008
DRAWN BY: JLB	CHECKED BY:
EDITED BY: JLB	REV. No. 0
DRAWING No.:	
MAP FILE: 1034406-XX.MXD	

APPENDIX 10b

Water Chemistry Data

Table 10.3 Surface Water Chemistry, Public Water Supply, Gander ADA
Hydrogeology of Agricultural Development Areas, Newfoundland & Labrador

Parameter	Units	CDWQG	CWQG-AWU		Gander - Gander Lake WS-S-0268 (1993-2007)[1]		
			Irrigation Water	Livestock Water	Min	Max	Mean
Alkalinity	mg/L $CaC0_3$	na	na	na	0	13	5
Aluminum	mg/L	na	5	5	0.025	0.73	0.13
Ammonia	mg/L	na	na	na	0	0.12	0.02
Antimony	mg/L	0.006	na	na	0	0.0005	0.00002
Arsenic	mg/L	0.01	0.1	0.025	0	0.005	0.001
Barium	mg/L	1	na	na	0	0.025	0.004
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	12	0.03
Cadmium	mg/L	0.005	0.005	0.08	0	0.001	0.0002
Calcium	mg/L	na	na	na	0	10	2
Carbonate	mg/L $CaC0_3$	na	na	na	-	-	-
Chloride	mg/L	250*	100 - 700	na	2	10	4
Chromium	mg/L	0.05	na	na	0	0.005	0.001
Copper	mg/L	1*	0.2 - 1	0.5-5	0	0.09	0.01
Dissolved Organic Carbon	mg/L	na	na	na	1.1	7.5	5.2
Fluoride	mg/L	1.5	1	1 - 2	0	0.12	0.04
Hardness	mg/L $CaC0_3$	na	na	na	0	25	6
Iron	mg/L	0.3*	5	na	0.01	0.1	0.05
Kjeldahl Nitrogen	mg/L	na	na	na	0.07	0.46	0.197
Langelier Index	-	na	na	na	-5.48	-3.05	-4.02
Lead	mg/L	0.01	0.2	0.1	0	0.004	0.001
Magnesium	mg/L	na	na	na	0	0.73	0.42
Manganese	mg/L	0.05*	0.2	na	0	0.023	0.005
Mercury	mg/L	0.001	na	0.003	0	0.0005	0.0001
Nickel	mg/L	na	0.2	1	0	0.005	0.003
Nitrate	mg/L N	45	na	na	-	-	-
Nitrate + Nitrite	mg/L N	na	na	100	0	0.34	0.1
Nitrite	mg/L	na	na	10	-	-	-
Orthophosphate	mg/L P	na	na	na	-	-	-
pH	Units	6.5-8.5*	na	na	5.9	6.9	6.4
Potassium	mg/L	na	na	na	0	0.8	0.3
Reactive Silica	mg/L SiO2	na	na	na	-	-	-
Selenium	mg/L	0.01	0.02 - 0.05	0.05	0	0.005	0.001
Silver	mg/L	na	na	na	-	-	-
Sodium	mg/L	200*	na	na	0	6	2
Specific Conductance	uS/cm	na	na	na	16.9	58	26.6
Sulphate	mg/L	500*	na	1,000	0	4	2
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	1	2	1
Total Organic Carbon	mg/L	na	na	na	-	-	-
Total Phosphorus	mg/L	na	na	na	0	0.05	0.01
Total Suspended Solids	mg/L	na	na	na	-	-	-
True Color	TCU	15*	na	na	29	55	43
Turbidity	NTU	0.3/1.0/0.1**	na	na	0	1.78	0.46
Uranium	mg/L	0.02	0.01	0.2	0	0	0
Vanadium	mg/L	na	0.1	0.1	-	-	-
Canadian Water Quality Index (CWQI)	-	-	-	-	93	94	93
Zinc	mg/L	5*	1 - 5	50	0	0.02	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 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