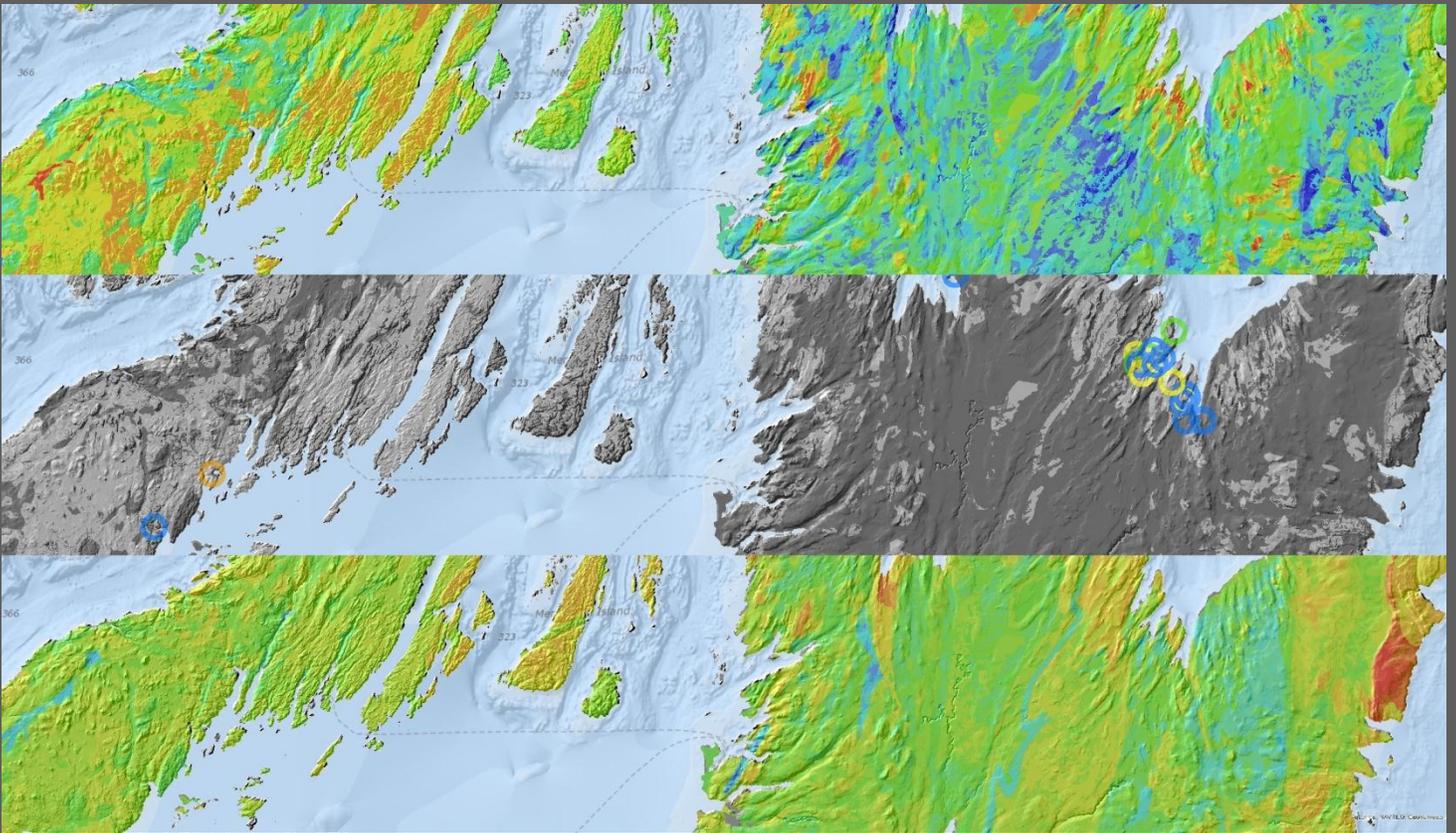


Groundwater Vulnerability Mapping Eastern Newfoundland Task 3: Results and Analysis



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Prepared for:
Water Resources Management Division
Department of Environment and Conservation
Government of Newfoundland and Labrador

Prepared by:



CBCL LIMITED
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March 18, 2014

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Dear Ms. Hanchar:

RE: Groundwater Vulnerability Mapping – Final Report # 3- Results and Analysis

On behalf of CBCL Limited, I am pleased to submit the Draft Report for Task 3 of the above noted project.

Yours very truly,

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CHAPTER 1 INTRODUCTION

1.1 Background

CBCL Limited (CBCL) was retained by the Water Resources Management Division of the Department of Environment and Conservation (ENVC) to complete a Groundwater Vulnerability Study for Eastern Newfoundland. Groundwater is an essential resource for the island portion of the province where approximately 29% of people rely on groundwater as a source of potable water. ENVC has recognized the value of Newfoundland's groundwater resources and has initiated this study to serve as a planning tool to provide a basis for protection of groundwater resources.

Groundwater vulnerability is a measure of the likelihood for contaminants to enter an aquifer, and the influence of transport and attenuation along a groundwater flow path. Groundwater vulnerability is a function of the hydrogeologic setting, and some definitions are extended to include the influence of land use on the likelihood of contaminant release. For the purposes of this report, "aquifer vulnerability" is used to describe the physical factors governing groundwater contamination by anthropogenic sources, and "land use-vulnerability" is used to describe vulnerability incorporating the potential influence of urban land uses.

Aquifer vulnerability is determined primarily by the rate of transport of contaminants through confining layers and the rate of transport through an aquifer. The thickness and grain size distribution of unconsolidated materials control the former, and the aquifer and contaminant properties control the latter. These and other factors can be further subdivided to provide a means of quantifying aquifer vulnerability. Methods to determine aquifer vulnerability have been the subject of study and application in other jurisdictions for over forty years.

1.2 Scope of Work

This report forms the final of three components of aquifer vulnerability mapping. The first task entailed collation, formatting, and trimming of data from the province and topographic survey of Canada to the Eastern Newfoundland study area. The second task provided a hydrogeological analysis of these data, including a synthesis and comparison to existing studies on the hydrogeology of Eastern Newfoundland. This report describes a methodology to adapt available data to a "DRASTIC"-style analysis of aquifer vulnerability (Aller et. al, 1987), presents a series of maps showing the results of the analysis, and a brief discussion of the results in the context of water resources management.

CHAPTER 2 **METHODOLOGY**

2.1 Study Areas

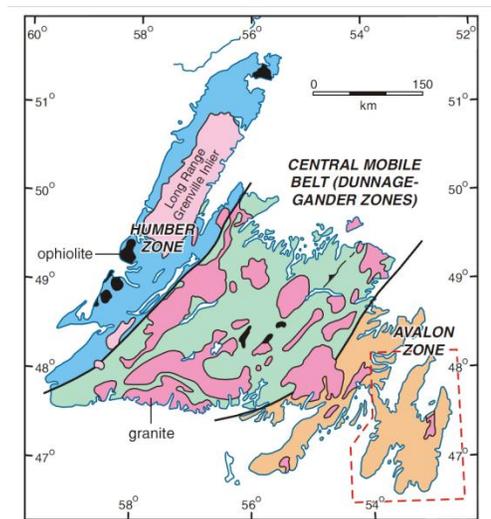
2.1.1 Eastern Newfoundland Study Area

ENVC has subdivided the Island of Newfoundland into three study areas, corresponding to principal tectonic divisions. Table 2.1 provides a summary of these study areas. This study is concerned with the Eastern Newfoundland Study Area, shown on MAP A1.

Table 2.1: Tectonic Zones of Newfoundland

Tectonic Zone	Hydrogeological Study Area
Avalon	Eastern Newfoundland
Dunnage-Gander (Central Mobile Belt)	Central Newfoundland
Humber	Western Newfoundland

Inset 'A' shows the principal tectonic divisions of Newfoundland. The study area comprises the Burin, Bonavista and Avalon Peninsulas, and has been defined for the purposes of this study using geologic contacts to define its western boundary. The western boundary extends from Fortune Bay in the south to Bonavista Bay in the north, and follows the eastern edge of the Devonian and Carboniferous granite intrusion shown on provincial mapping.



Inset A: Tectonic Zones of Newfoundland
(from: King, A.F., 1988)

2.1.2 Northern Avalon Study Areas

Watershed mapping completed as part of Task 1 was used to delineate several sub-study areas. The density of development and associated reliance on groundwater resources is greatest on the Northern part of the Avalon Peninsula. Three focus areas were identified within the Northern Avalon area, characterized by on-going development and increasing demand on groundwater resources. Land use-vulnerability mapping was completed for these areas:

- Northeast Avalon (MAP D2);
- Witless Bay-Bay Bulls (MAP D3); and
- East Conception Bay (MAP D4).

2.1.3 Public Well Heads

Water is drawn from public well heads throughout the study area. Public well heads were grouped into nine sub-study areas using watershed boundaries. Sub-study areas are indicated on MAPs C10 through C18, designated as follows:

- Bain Harbour-Red Harbour;
- Bellevue-Dildo;
- Cannings Cove;
- Conception Harbour-Holyrood;
- Frenchmans Cove-Winterland;
- Harbour Grace-Bryants Cove;
- Sandringham-Sandy Cove-Eastport;
- St. Josephs-St. Mary's; and
- Wabana.

Maps C10 through C18 show groundwater the vulnerability index overlain with local topographic, hydrologic, and public water supply features.

2.2 Qualitative Mapping

2.2.1 Quaternary Geology Rating (Intrinsic Vulnerability)

Intrinsic vulnerability scores represent the ease with which contaminants may enter the subsurface. An analysis of intrinsic vulnerability at the qualitative level was based on quaternary mapping. Quaternary map units were assigned a rating as shown in Table 2.2 and on MAP B1.

Table 2.2: Qualitative Ratings for Quaternary Map Units

Quaternary Unit	Rating
Glaciolacustrine	Low
Ablation Drift	Low
Till Blanket	Low
Till, Undifferentiated	Low
Rogen Moraine	Low
Drift Poor	Moderate
Glaciomarine and Marine	Moderate
Bog	Moderate
Alluvium	Moderate
Exposed Bedrock	High
Glaciofluvial	High

Ratings for quaternary units were based on the expected thickness and hydraulic conductivity of each unit. Eskers and glaciofluvial material are expected to consist primarily of sand and gravel, with relatively high hydraulic conductivity. Contaminants are expected to infiltrate readily through this material, resulting in a qualitative score of High. Exposed bedrock likewise exhibits a direct pathway to

the subsurface, with limited capacity to absorb/adsorb contaminants, and was assigned a qualitative score of High.

Till and glaciolacustrine material are expected to consist of finer grained, poorly sorted material, resulting in a relatively low hydraulic conductivity and greater resistance to contaminants entering the subsurface. The qualitative score for these units is Low.

Drift poor, glaciomarine and marine, bog, and alluvium material are expected to exhibit variable thicknesses, grain sizes and degrees of sorting. These units are assigned an intermediate qualitative rating of Moderate.

2.2.2 Bedrock Geology Rating (Extrinsic Vulnerability)

Reporting on the hydrogeology of the Eastern Newfoundland Study Area indicates that bedrock type is an inadequate predictor of well yields and/or transmissivity (AMEC, 2013; Golder Associates, 1985; FracFlow Consultants Inc., 1984; Nolan, Davis and Associates Limited, 1982; Nolan, Davis and Associates Limited, 1981). An alternative approach was developed for this study, described in the preceding report: “Task 2 – Analysis of Hydrogeological Data”.

Extrinsic vulnerability represents the ease with which contaminants are transported in the saturated zone. Extrinsic vulnerability at the qualitative level was based the depth-normalized yield (\bar{Q}) index of each bedrock polygon in the study area. \bar{Q} indices were assigned a qualitative rating as shown in Table 2.3 and on MAP B2.

Depth-Normalized Yield (\bar{Q})
 The airlift yield for each well record was divided by the well depth to provide a depth-normalized yield, abbreviated in this report as “ \bar{Q} ”.

Table 2.3: Qualitative Ratings for Depth-Normalized Yield

\bar{Q}	Rating
<0.2	Low
0.2 to 0.5	Moderate
>0.5	High

\bar{Q} values exceeding 0.5 m²/d represent the highest yielding zones in the study area, but may not be representative of high hydraulic conductivities and high vulnerabilities as compared to other zones in North America. Consequently, the quantitative data presented in Section 2.3 are useful for rating and comparing groundwater vulnerability on a relative scale within the study area, but are not directly comparable to the study areas presented in the original EPA study (Aller et. al., 1987).

2.2.3 Qualitative Groundwater Vulnerability Rating

A Qualitative Groundwater Vulnerability Rating was obtained by overlaying MAPS B1 and B2. The intersection of these two polygon layers resulted in a collective groundwater vulnerability rating for intrinsic and extrinsic factors. The results of the analysis are shown on MAP B3. Table 2.4 summarizes the range of potential ratings.

Table 2.4: Qualitative Groundwater Vulnerability Ratings

Intrinsic-Extrinsic Rating
Low-Low (1)
Low-Moderate (2)
Moderate-Low (2)
Moderate-Moderate (3)
Low-High (4)
High-Low (4)
Moderate-High (5)
High-Moderate (5)
High-High (6)

Community centres were overlain on MAP B3 to provide a preliminary indication of the qualitative vulnerability rating for the setting of each community. This analysis is intended to allow for prioritization of highest risk areas for more detailed study.

2.2.4 Qualitative Groundwater Potential Rating

Qualitative ratings may also be used to assess the potential for groundwater supply areas. A favourable setting would typically show a competent aquitard overlying an aquifer with a high transmissivity. A low qualitative rating for intrinsic vulnerability corresponds to favourable confining conditions, whereas a high qualitative rating for the bedrock unit would imply favourable yields. MAP B4 shows qualitative vulnerability ratings re-coloured to highlight areas that best satisfy both of these conditions. It is noted that higher yielding aquifers would typically imply greater extrinsic vulnerability, and that any analysis would require that the potential for favourable yields be balanced against the disadvantages of increased vulnerability.

2.3 Quantitative Groundwater Vulnerability Index

2.3.1 Raster Data

All input data were converted to raster format before calculation of the quantitative groundwater vulnerability index. Each polygon dataset was discretized into a raster grid with a cell size of 20 metres, based on the DEM base map created for this study (slope data were based directly on the DEM). The following index layers represent raster datasets that were created from polygon data and then overlain to calculate the quantitative groundwater vulnerability index. Lower values of the groundwater vulnerability index convey lesser groundwater vulnerability, and higher values of the groundwater vulnerability index convey greater groundwater vulnerability. Increases in each individual parameter index will likewise contribute to higher groundwater vulnerability scores.

2.3.2 Depth to Bedrock Index

Depth to bedrock data were drawn from an ANOVA of quaternary mapping and drilled well data (CBCL, 2013 (2)). Table 2.5 shows the vulnerability indices as determined by the results of the ANOVA. The indices in Table 2.5 were adjusted using the DRASTIC depth to water parameters presented in Table 4 of

the EPA methodology (Aller et al., 1987). The results of the ANOVA are shown in MAP A9, and the corresponding indices are shown on MAP C1.

Table 2.2: Depth to Bedrock Index

Depth to Bedrock (m)	Index
>24	1
24	2
21	3
18	4
15	5
12	6
9	7
6	8
3	9
<3	10

N.B. Decreases in depth to bedrock will contribute to increases in groundwater vulnerability.

2.3.3 Depth-Normalized Yield (Bedrock \bar{Q}) Index

Bedrock \bar{Q} data were drawn from an ANOVA of bedrock unit mapping and drilled well data (CBCL, 2013 (2)); the results of this analysis are shown on MAP A10. Table 2.6 shows vulnerability indices as determined by the results of the ANOVA. The indices were determined by pro-rating \bar{Q} data on a ln-normal scale. Bedrock \bar{Q} indices are used as a proxy for hydraulic conductivity and aquifer media indices, shown on MAP C2.

The DRASTIC aquifer media parameter and DRASTIC hydraulic conductivity parameters in Tables 6 and 10 of the EPA methodology (Aller et al., 1987) were not directly comparable. The hydraulic conductivities used in Table 10 of the EPA methodology ranged from 4.7×10^{-5} m/s to 9.4×10^{-4} m/s, indexed from 1 to 10. These values are likely to be one to several orders of magnitude higher than those observed in the study area. A direct comparison of vulnerability indices produced in this study to established zones in the DRASTIC methodology would therefore require adjustment and interpretation.

Table 2.6: Depth-Normalized Yield (Bedrock \bar{Q}) Index

\bar{Q} (m ² /d)	Index
0.03-0.06	1
0.06-0.10	2
0.10-0.15	3
0.15-0.30	4
0.30-0.45	5
0.45-0.75	6
0.75-1.4	7
1.4-2.4	8
2.4-4.0	9
>4.0	10

N.B. Increases in the bedrock \bar{Q} will contribute to increases in groundwater vulnerability.

2.3.4 Soil Drainage Index

Soil drainage data were drawn from provincial soils mapping (Newfoundland Department of Agriculture), shown on MAP A5. Table 2.7 shows the vulnerability indices as determined by soil drainage categories. The indices in Table 2.7 were developed from the data available for the current work and DRASTIC soil media parameters presented in Table 7 of the EPA methodology (Aller et al., 1987). Soil Drainage Indices are plotted on MAP C3.

Table 2.7: Soil Drainage Index

Soil Drainage	Index
Water	1
Very Poor	2
Poor	3
Imperfect	5
Moderate	6
Well	8
Rock	8
Rapid	10

N.B. Increases in soil drainage will contribute to increases in groundwater vulnerability.

2.3.5 Slope Index

Slope data were generated based on a DEM interpolated from national topographic data (CBCL, 2013 (1)), shown on MAP A7. Table 2.8 shows vulnerability indices, based on the DRASTIC topography parameters presented in Table 8 of the EPA methodology (Aller et al., 1987). MAP C4 provides a plot of slope indices.

Table 2.8: Slope Index

% Slope	Index
>20	1
20	2
18	3
15	4
12	5
11	6
10	7
8	8
6	9
<2	10

N.B. Decreases in slope will contribute to increases in groundwater vulnerability.

2.3.6 Quaternary Geology Index

Quaternary geology data were drawn from provincial mapping (shown on MAP A3). Table 2.9 shows vulnerability indices as determined by material type and inferred properties. The indices in Table 2.9 were based on the DRASTIC vadose zone parameters presented in Table 9 of the EPA methodology (Aller et al., 1987). MAP C5 provides a plot of the Quaternary Geology Index.

Table 2.9: Quaternary Mapping Index

Quaternary Unit	Index
Rogen Moraine	1
Glaciolacustrine	3
Ablation Drift	3
Till Blanket	3
Till, Undifferentiated	3
Bog	5
Alluvium	5
Glaciomarine and Marine	6
Drift Poor	7
Glaciofluvial	8
Exposed Bedrock	9
Esker	10

N.B. Higher permeability materials will contribute to increases in groundwater vulnerability.

2.3.7 Quantitative Groundwater Vulnerability Index

The weight of each available index was adjusted, based on the EPA methodology, to be proportional to the closest corresponding DRASTIC parameter(s) (with the exception of the Bedrock \bar{Q} Index). An analysis of available precipitation and recharge data indicated that the dataset was not complete enough to incorporate into regional mapping. As such the Recharge/Baseflow parameter was redistributed to the Soil Drainage, Slope, and Quaternary Geology Parameters as shown in Table 2.10. The “Aquifer Media” and “Hydraulic Conductivity” parameters of the DRASTIC methodology were lumped under a single “Bedrock \bar{Q} ” index.

Each parameter index (from 1 to 10) was multiplied by a weighting factor as shown in Table 2.10, and then added to provide a final score out of a maximum of 23 (whereas DRASTIC scores are commonly reported as a product total, up to a maximum of 230). This final score was the Groundwater Vulnerability Index, with increasing scores conveying increasing groundwater vulnerability. Final scores were tabulated for each raster cell in the study area. Considering the differences in the parameters used in this study and those developed for DRASTIC, a direct comparison of scores was not considered to be practical. The Groundwater Vulnerability Index is shown on MAP C6.

Table 2.3: Parameter Weightings for Study Area Screening and DRASTIC Parameters

Drastic Parameter		E. NFLD Parameter	Weighting	
D	Depth to Water	Depth to Bedrock	5	22%
R	Recharge	Redistributed	0	-
A	Aquifer Media	Bedrock \bar{Q}	3	13%
S	Soil Media	Soil Drainage	4	17%
T	Topography	Slope	2	9%
I	Impact of Vadose Zone	Quaternary Geology	6	26%
C	Hydraulic Conductivity of Aquifer	Bedrock \bar{Q}	3	13%
Total			23	100%

2.3.8 Threshold Map

A map of groundwater the vulnerability index was adapted to provide an overview of conditions at sensitive locations in the study area. An arbitrary threshold index of 15 (out of a maximum of 23; see Table 2.10) was selected as a point of comparison. Areas with a groundwater vulnerability index exceeding 15 were identified as being at highest risk in the context of the study area as a whole. The following features were overlain on the threshold map:

- Public well heads + 1500 metre buffer;
- Public water supply areas; and
- Drilled well records showing a coordinate method of “GPS” or “Map” + 500 metre buffer.

Each feature was intersected with the underlying threshold map to show the percentage of the buffer or feature area that exceeded the threshold index of 15. The resulting zones were colour coded to provide a preliminary indication of features and zones most likely exhibit the greatest groundwater vulnerability. This analysis is intended to allow for prioritization of the highest risk features for more detailed study. More detailed study area maps are provided for analysis of individual public well heads.

2.4 Land Use-Vulnerability Index

2.4.1 Land Use Index

Land uses in detailed study areas were analyzed using remote sensing data available from public domain data providers. LANDSAT7 data were obtained for the Northern Avalon study area, focussing on the Northeast Avalon, Witless Bay-Bay Bulls, and East Conception Bay study areas. Images were generated using the following RBG band combinations:

1. 3,2,1 – true colour satellite image.
2. 7,4,2 –short wavelength infrared (SWIR) image distinguishing vegetation and hard surfaces.
3. 7,3,1 –mid-infrared/red/blue-green image to distinguish between cleared spaces and high-albedo surfaces such as barren bedrock and paved surfaces.

A geospatial analysis was performed on the LANDSAT data to generate a new “Land Use” raster index layer. The index map was generated by collecting image classification samples from the “7,3,1” map

layer and processed using Arc’s “Maximum Likelihood” tool. The Land Use layer contained three types of zones corresponding to the following:

- Non-urban (Index = 1);
- Cleared areas (Index = 5); and
- Urban (Index = 10).

A comparison to true colour and SWIR imaging indicated that the Land Use index map was effective in distinguishing between non-urban, cleared and urban areas within the detailed study areas. Exposed bedrock surfaces appeared to create interference in zones outside of the detailed mapping areas. Consequently the land use index method could not be extended to a broader study area. The Land Use index for the Northeast Avalon Study Area is shown on MAP D1. It may be desirable, with higher resolution mapping, to distinguish between residential, commercial and industrial zoning in future Land-Use Vulnerability Mapping.

2.4.2 Land Use-Vulnerability Index

A Land Use-Vulnerability index was calculated in detailed study areas by adapting the method of calculation for the groundwater vulnerability index. Existing attempts to develop a method to incorporate land use information showed correlations between land use and groundwater vulnerability from 20 to 100% (Sener and Davraz, 2013; Eckhardt and Stackelberg, 1995). The results of these studies suggest that the land use parameter could carry a weighting of up to 11.5/23 (i.e. a 100% correlation would suggest that land use and other parameters should receive equal weighting). A sensitivity analysis was performed by assigning a relative weight of the land use parameter varying from 20 to 50% (4.5 to 11.5). The relative weightings of remaining parameters were maintained according to those used for groundwater vulnerability mapping.

The sensitivity analysis suggested that a lower weighting (4.5) is appropriate for the Northern Avalon study areas, as higher weightings appeared to introduced too great an influence by land use, and masked the effects of groundwater vulnerability parameters. Table 2.11 shows the preliminary weightings used to produce the maps in this study. Additional and more detailed work at local scales would be warranted to provide data on the sensitivity of groundwater vulnerability to land use in the study area. Land Use-Vulnerability is shown on MAPS D2, D3 and D4.

Table 2.11: Parameter Weightings for Land Use-Vulnerability and DRASTIC Parameters

	Drastic Parameter	E. NFLD Parameter	Weighting	
D	Depth to Water	Depth to Bedrock	4	17%
A,C	Aquifer Media/Hydraulic Conductivity of Aquifer	Bedrock \bar{Q}	5	22%
S	Soil Media	Soil Drainage	3	13%
T	Topography	Slope	1.5	7%
I	Impact of Vadose Zone	Quaternary Geology	5	22%
L	N/A	Land Use	4.5	20%
Total			23	100%

2.5 Groundwater Potential Index

2.5.1 Inverse \bar{Q} Index

The bedrock \bar{Q} index provides a measure of extrinsic vulnerability, with lower scores indicating a more favourable, lower extrinsic vulnerability. Because the index is related to the aquifer transmissivity, it may also be used as an indication of relative potential yields. When inverted, lower values of the bedrock \bar{Q} index indicate favourable yields. Map D5 shows the inverse bedrock \bar{Q} index.

2.5.2 Groundwater Potential Index

Quantitative ratings may be used to assess groundwater supply potential. A favourable setting would typically show a competent aquitard overlying an aquifer with a favourable transmissivity. A competent aquitard would correspond to a low groundwater vulnerability score in the following (intrinsic) categories:

- Depth to Bedrock;
- Soil Drainage;
- Slope; and
- Quaternary Geology.

A lower score for the inverse bedrock \bar{Q} index would imply favourable yields. A Groundwater Potential Index was calculated by combining intrinsic variables with the inverse bedrock \bar{Q} index, where lower scores show the most favourable areas. Intrinsic variables and the inverse bedrock \bar{Q} index were weighted equally, at 50% each. Table 2.12 shows the parameter weightings used in calculation of the groundwater potential index.

MAP D6 shows the groundwater potential index. It is noted that higher yielding aquifers would typically imply greater extrinsic vulnerability, and that any analysis would require that the potential for favourable yields be balanced against the disadvantages of increased vulnerability.

Table 2.12: Parameter Weightings for Groundwater Potential and DRASTIC Parameters

Parameter		E. NFLD Parameter	Weighting	
Intrinsic Parameters: Potential for Protection from Contaminant Sources at the Ground Surface				
D	Depth to Water	Depth to Bedrock	3.5	15%
S	Soil Media	Soil Drainage	2.5	11%
T	Topography	Slope	1.5	7%
I	Impact of Vadose Zone	Quaternary Geology	4	17%
Extrinsic Parameter: Potential for Favourable Yields from Bedrock Unit				
A,C	Aquifer Media, Hydraulic Conductivity	Inverse Bedrock \bar{Q}	11.5	50%
Total			23	100%

3.1 Input Data

Input data were collected and analyzed as components of Tasks 1 and 2. Mapping of this data is provided as shown in Table 3.1.

Table 3.1: Maps Showing Source Data and Layers

Map Number	Title
MAP A1	Digital Elevation Model
MAP A2	Preliminary Watershed Mapping
MAP A3	Quaternary Geology
MAP A4	Bedrock Geology
MAP A5	Soils Mapping
MAP A6	Hydrostratigraphic Units
MAP A7	Slope
MAP A8	Drilled Well Records with GPS or Map Coordinates
MAP A9	Depth to Bedrock
MAP A10	Depth-Normalized Yield (Bedrock \bar{Q})

3.2 Qualitative Mapping

Quaternary geology and bedrock \bar{Q} mapping were used to generate qualitative maps of the study area. Qualitative mapping provides a screening level analysis of vulnerability, and allows for comparison of basic geological information between sites or across the study area. Qualitative mapping can be intersected with point-data to prioritize and identify focus areas. Qualitative maps are listed in Table 3.2.

Table 3.2: Maps Showing Qualitative Layers and Results

Map Number	Title
MAP B1	Intrinsic Vulnerability Rating (Qualitative, Quaternary Geology)
MAP B2	Extrinsic Vulnerability Rating (Qualitative, Bedrock \bar{Q})
MAP B3	Qualitative Groundwater Vulnerability Index
MAP B4	Qualitative Groundwater Potential Index

3.3 Groundwater Vulnerability

Quantitative Vulnerability maps are listed in Table 3.3. Maps C1-C5 show the individual index maps that were combined to create MAP C6, the Quantitative Groundwater Vulnerability Index. Maps C7, C8 and C9 demonstrate an application of the vulnerability threshold concept, and maps C10-C21 show the groundwater vulnerability index in detailed study areas and near public well heads.

Table 3.3: Groundwater Vulnerability Maps

Map Number	Title
MAP C1	Depth to Bedrock Index
MAP C2	Depth-Normalized Yield Index
MAP C3	Soil Drainage Index
MAP C4	Slope Index
MAP C5	Quaternary Geology Index
MAP C6	Quantitative Groundwater Vulnerability Index
MAP C7	Groundwater Vulnerability Threshold and 1500 metre Buffer of Protected Well Heads
MAP C8	Groundwater Vulnerability Threshold and 500 metre Buffer of Drilled Well Records with Map or GPS Coordinates
MAP C9	Groundwater Vulnerability Threshold and Public Water Supply Areas
MAP C10	Groundwater Vulnerability and Public Water Supplies in the Bellevue-Dildo Study Area
MAP C11	Groundwater Vulnerability and Public Water Supplies in the Cannings Cove Study Area
MAP C12	Groundwater Vulnerability and Public Water Supplies in the Conception Harbour-Holyrood Study Area
MAP C13	Groundwater Vulnerability and Public Water Supplies in the Frenchmans Cove-Winterland Study Area
MAP C14	Groundwater Vulnerability and Public Water Supplies in the Harbour Grace-Bryants Cove Study Area
MAP C15	Groundwater Vulnerability and Public Water Supplies in the Sandringham-Sandy Cove-Eastport Study Area
MAP C16	Groundwater Vulnerability and Public Water Supplies in the St. Josephs-St. Mary's Study Area
MAP C17	Groundwater Vulnerability and Public Water Supplies in the Wabana Study Area
MAP C18	Groundwater Vulnerability and Public Water Supplies in the Bain Harbour-Red Harbour Study Area
MAP C19	Groundwater Vulnerability in the Northeast Avalon Study Area
MAP C20	Groundwater Vulnerability in the Witless Bay-Bay Bulls Study Area
MAP C21	Groundwater Vulnerability in the East Conception Bay Study Area

3.4 Land Use-Vulnerability and Groundwater Potential

MAP D1 provides an example of the Land Use Index as shown for the Northeast Avalon Study Area. Land Use-Vulnerability maps are provided the Northeast Avalon, Witless Bay-Bay Bulls, and East

Conception Bay study areas (Maps D2-D4). Map D5 shows the inverse index of the Depth-Normalized Yield (bedrock \bar{Q}), which was combined with intrinsic mapping parameters to generate a Quantitative Groundwater Potential Index (Map D6).

Table 3.4: Land Use-Vulnerability Maps

Map Number	Title
MAP D1	Land Use Index for the Northeast Avalon Study Area
MAP D2	Land Use-Vulnerability in the Northeast Avalon Study Area
MAP D3	Land Use-Vulnerability in the Witless Bay-Bay Bulls Study Area
MAP D4	Land Use-Vulnerability in the East Conception Bay Study Area
MAP D5	Inverse Index of Depth-Normalized Yield
MAP D6	Quantitative Groundwater Potential Index

3.5 Geodatabase

Base layers and indices have been collated into two ArcGIS file-geodatabases:

- “Vulnerability.gdb”; and
- “Vulnerability_raster.gdb”.

A map layout is provided, with drawing layers corresponding directly to the structure and file groups within the geodatabases. The geodatabases contain the map layers presented in this report, and selected other base mapping and source data layers.

CHAPTER 4 **PRELIMINARY ANALYSIS**

4.1 Qualitative Mapping

Qualitative mapping is a relatively simple and direct approach to evaluating zones of concern for the study area as a whole. The qualitative vulnerability layer is directly comparable to source data mapping (quaternary geology and bedrock \bar{Q}), allowing for identification of the factors contributing to zones of potential concern. For example, several zones around Conception Bay East show a qualitative rating of 5 (high-moderate or moderate-high). Much of this area exhibits elevated vulnerability due to the relatively high bedrock \bar{Q} of the Holyrood Intrusive Suite in this area ($0.76 \text{ m}^2/\text{d}$), and parts of the area exhibit exposed bedrock, imparting an elevated intrinsic vulnerability.

Exposed bedrock is a causal factor in higher qualitative vulnerability scores for much of the study area, including bedrock ridges to the north of Carbonear, Chance Cove, parts of the Burin Peninsula, much of the area to the north of Connaigre Bay and Fortune Bay, and the western side of Trinity Bay. Higher bedrock \bar{Q} s influenced the qualitative score for the area north of Hermitage Bay, a zone to the south of Grand Bank, and sections of the Deep Water Point Granodiorite near Great Jervais on the Burin Peninsula.

At the regional level, qualitative mapping indicates that groundwater vulnerability is moderate to low over much of the Avalon peninsula, and that high-concern areas are localized. More detailed community-scale analysis is needed to determine whether high-vulnerability zones could intersect source water areas. Higher-resolution mapping of public well heads is discussed in Section 4.2.

The qualitative vulnerability score for each community centre was determined using MAP B3. The scores for each community are shown in Table A1, Appendix A. Qualitative scores may be used to rank the relative sensitivity of the area immediately surrounding each community. This data could form the basis for addressing a more detailed analysis of groundwater vulnerability in higher priority zones. Twenty-five communities are located in zones with a qualitative vulnerability rating of high-high, and 99 communities are located in zones with a qualitative vulnerability rating of high-moderate or moderate-high. Table 4.1 shows a summary of community ratings.

Table 4.1: Frequency of Qualitative Vulnerability Rating by Community

Qualitative Vulnerability Class	Number of Communities
High-High	25
High-Moderate and Moderate-High	99
High-Low and Low-High	77
Moderate-Moderate	143
Moderate-Low and Low-Moderate	307
Low-Low	182

Qualitative vulnerability mapping can be used to obtain an overview of potentially favourable zones for well field development. Map B4 presents a modified version of Map B3, highlighting zones where intrinsic vulnerability is low, and extrinsic vulnerability is highest. In highlighted areas, quaternary geology mapping indicates that finer grained material should be present, and bedrock \bar{Q} mapping indicates that yields will be favourable within the context of the Eastern Newfoundland study area.

Mapping indicates that the “Low-High” zones shown in bright green on Map B4 should provide the best combination of conditions for well field development. Notably, qualitative mapping identifies the area south of Conception Bay as showing generally elevated vulnerability and conditions favourable to development of groundwater supply. Qualitative mapping at the regional scale is intended to direct and focus more detailed field investigations (e.g. Level I and Level II Hydrogeological Investigations).

4.2 Groundwater Vulnerability

Quantitative mapping allowed for synthesis of a greater variety of vulnerability parameters, and for discretization of the study area into 20 x 20 metre cells. In particular the intrinsic vulnerability was calculated as an aggregate of four parameters: quaternary mapping, surface soils (drainage), slope, and depth to bedrock. The results of quantitative mapping were generally consistent with the results of qualitative mapping, but quantitative mapping allowed for greater variation at local scales and a broader range of vulnerability scores. This allowed for more gradation between zones of higher and lower vulnerability.

The zones of highest vulnerability often corresponded to ridges of exposed bedrock, which led to higher indices for the quaternary geology, soil drainage and depth to bedrock parameters. Zones where the highest bedrock \bar{Q} intersected with exposed bedrock resulted in vulnerability scores approaching the maximum for the study area. Most parts of the Northeast Avalon Peninsula exhibited low to moderate groundwater vulnerability. Notable exceptions include areas north of Portugal Cove, Conception Harbour-Harbour Main, and inland parts of the East Conception Bay study area.

Existing mapping is well positioned to accommodate the introduction of more detailed data for specific areas. For example, the bedrock \bar{Q} may be revised for a specific area based on pumping test data, or transmissivity data may be used to calculate a new index for the aquifer media and hydraulic conductivity parameters. If mapping is confined to a watershed for which there is existing hydrometric data, it will be possible to incorporate the recharge parameter into the analysis. The discretization provided by quantitative mapping provides an opportunity for more detailed analysis of selected study

areas. Preliminary focus areas are presented below, including nine public well head areas and three detailed study areas where development of individual groundwater supplies is relatively concentrated.

4.2.1 Public Well Heads

Map C7 shows the 1500 metre buffer zones for public well heads overlain on the groundwater vulnerability threshold map. Table 4.2 summarizes the results of this analysis, showing wells for which the groundwater vulnerability index exceeded 15 in 25% or more of the buffer area. Table A2 (Appendix A) provides the complete results for 65 public well heads that were identified in the study area. Table A2 provides a general indication of groundwater vulnerability in the vicinity of each well. It is intended that this data be used to prioritize a more detailed analysis of each well head on a case by case basis.

Table 4.2: Percent of 1500 metre buffer area for Public Well Heads where Groundwater Vulnerability Index exceeds 15

Community	Source Name	% Area
Baine Harbour	Dug	64
Eastport	Dug	62
Sandy Cove	Dug	61
Harbour Main-Chapel's Cove-Lakeview	Holden's Road Well	59
Holyrood	Woodford Station - Quinlan's Well	50
Colliers	#1 Mahoney's Well	48
Harbour Grace	Mercer's Road Well	47
Conception Harbour	Healey's Pond Road Well	46
Red Harbour	Drilled (Backup Well)	40
	#4 Flynn's Well	34
Canning's Cove	#1 Well - Pleman Pitts	34
Wabana	Middleton Ave. Well	34
Wabana	Scotia #1 Well	32
Bryant's Cove	#3 Backup Well & Pumphouse	30
Sandringham	Drilled (#2 Well)	29
Conception Harbour	Lower Bacon Cove Well	26
Canning's Cove	#2 Well - Eugene Ellis	25
Colliers	#2 Merrigan's Well	25

Further analysis would comprise creation of a conceptual model of groundwater flow for each well head, and examination of groundwater vulnerability within the zone of contribution. The source name “Dug” for Baine Harbour, Eastport and Sandy Cove suggests that a high vulnerability score at these locations is of particular concern. Descriptions for the Maps C10-C18 provide an opportunity to examine groundwater vulnerability scores near each of the public well heads.

4.2.2 Drilled Wells

Map C8 shows the 500 metre buffer zones for records in the drilled well database showing a coordinate method of “GPS” or “Map”, overlaid on the groundwater vulnerability threshold map. Table 4.3 provides a summary of the analysis. Of the drilled well records sampled in this analysis, most appear to

fall within areas where the groundwater vulnerability is moderate to low. Site specific information would need to be confirmed on a case by case basis.

Table 4.3: Groundwater Vulnerability in 500 Metre Buffer Area of Drilled Wells

Area*	Number	% of Records
<25%	2666	84
25-50%	262	8.3
50-75%	130	4.1
>75%	78	2.5
No Data	24	0.8

*percent of 500 metre buffer area where groundwater vulnerability index exceeds 15

4.2.3 Protected Water Supply Areas

Map C9 shows protected water supply areas overlaid on the groundwater vulnerability threshold map. The percent of each area that exhibits a groundwater vulnerability index of 15 or more is shown in Table A3, Appendix A. Forty-three protected zones were located in areas where the threshold was exceeded in 90% of the area or more. Although many of the plotted water supply areas represent surface water sources, vulnerability concerns associated with transport of groundwater contaminants could be a secondary concern.

4.3 Land Use-Vulnerability

The Land Use parameter is used to show elevated risks associated with proximity to potential contaminant sources. For the purposes of this study three land types were distinguished: non-urban, cleared, and urban. Cleared land was generally observed on the edges of urban areas or in rural developed areas. The land use parameter thus had the net effect of showing increased vulnerability in cleared and urban areas. Maps D2-D4 show Land Use-Vulnerability mapping in detailed study areas. In general urban land use elevated the vulnerability index at a given cell from low to moderate and from moderate to high. Areas of non-urban land use exhibited a slight decrease in overall vulnerability.

When evaluating the suitability of new areas for development, the Land Use-Vulnerability index may be more appropriate than the groundwater vulnerability index. The Land Use-Vulnerability index provides an indication of the effects of existing development pressure on groundwater resources. Developments draw water from an area aquifer, introduce potential contaminants in the form of on-site sewage disposal systems, reduce infiltration and groundwater recharge, increase urban run-off (bacteria loading) and flooding, and in the case of industrial and commercial zones, introduce other potential chemical contaminant sources.

The Land Use-Vulnerability index for urban parts of the Northeast Avalon, Witless Bay-Bay Bulls, and East Conception Bay study areas generally exceeded 14 to 15 (shown in yellow, orange or red). Mapping suggests the highest Land Use Vulnerabilities (range 17 to 20) are located around Flat Rock Cove, Portugal Cove, Conception Bay South, Manuels, Seal Cove, and Torbay Road near Gallows Cove Pond. Site specific evaluation of land use, individual drilled wells and on-site sewage disposal systems in these areas is warranted.

CHAPTER 5 **RECOMMENDATIONS**

5.1 Land Use Mapping

Land Use-Vulnerability mapping showed the potential effects of land use on groundwater vulnerability in urban areas. Existing work has suggested that residential, commercial and industrial zones may all be indicators of potential risks to groundwater (Eckhardt and Stackelberg, 1995). Well Head Protection strategies typically treat contaminants associated with commercial and industrial land uses as posing the greatest risks to groundwater supply. A survey of the three detailed study areas presented in this study suggests that a windshield survey would be feasible. A windshield survey and GPS mapping would help to identify major point sources and industrial areas that would carry the greatest risk to groundwater source zones.

- Conduct a windshield survey of detailed study areas to identify potential contaminant sources.

Land Use-Vulnerability mapping identified several communities located in areas of concern. Existing and future water supplies in these areas are likely to be sensitive to additional development, and may be at risk from existing land uses.

- Consider measures to protect and prioritize land uses in high priority zones.

5.2 Public Well Heads

Threshold vulnerability mapping provided a means of identifying public well heads on or near land exhibiting the highest groundwater vulnerability scores. Table 4.2 identifies the 18 wells exhibiting the highest groundwater vulnerability within a 1500 metre radius of each well. Additional mapping of the zone of contribution to these wells is warranted, followed by analysis of the groundwater vulnerability in each of those zones. Adequate sizing of well head protection zones and careful review of permitted land uses is a priority for these wells.

- Develop and/or review well head projection zones and land use controls for high priority wells.

Table 4.2 shows that dug wells serve the communities of Baine Harbour, Eastport and Sandy Cove, and that these wells are furthermore located in zones of elevated vulnerability. A windshield survey and detailed Land Use-Vulnerability mapping of these communities would help to identify the highest risk

areas. On-site inspections of these supply wells would help to identify measures to improve and secure the well heads. The sensitivity of dug wells to contaminants released at the ground surface would further suggest that back-up water supplies for these communities should be a priority.

- Conduct detailed Land Use-Vulnerability Mapping for Baine Harbour, Eastport and Sandy Cove, and investigate back-up water supplies.

5.3 Qualitative Mapping

Qualitative mapping helped to identify 25 communities located in zones with a qualitative vulnerability rating of “High-High”. Well water supplies in these communities may be at an elevated risk of contamination. Inspection of existing map data, windshield surveys, and land use mapping would help to identify any features of concern. Community planning to protect and preserve the quality of aquifers in these areas should be encouraged.

- Review and supplement groundwater vulnerability mapping for the highest priority communities identified in Table A1.

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Groundwater Vulnerability Threshold Tables

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Bishop's Falls	49.0158	-55.4772	High-High	6
Bishops Falls South	49.005	-55.4925	High-High	6
Brookside	47.4294	-54.8139	High-High	6
Clarke's Beach	47.5442	-53.2831	High-High	6
Country Road	47.5753	-53.2936	High-High	6
Cruisers	48.9794	-55.5708	High-High	6
Emerald Vale	47.5069	-53.2997	High-High	6
Grand Falls	48.9328	-55.6514	High-High	6
Grand Falls-Windsor	48.9403	-55.6658	High-High	6
Great Jervis Harbour	47.6519	-56.1819	High-High	6
Grenfell Heights	48.9478	-55.6247	High-High	6
Grole	47.5219	-56.1192	High-High	6
Juniper Stump	47.5017	-53.3031	High-High	6
Lears Cove	46.8503	-54.1853	High-High	6
Makinsons	47.4903	-53.3103	High-High	6
McCallum	47.6306	-56.2289	High-High	6
Pass Island	47.4897	-56.195	High-High	6
Pushthrough	47.6425	-56.1569	High-High	6
Rattling Brook Depot	48.9708	-55.5394	High-High	6
Seal Cove	47.4844	-56.0614	High-High	6
Stanley Cove	47.6889	-56.1614	High-High	6
Terra Nova	48.5025	-54.2142	High-High	6
Tibbos Hill	47.4997	-55.5989	High-High	6
Windsor	48.9547	-55.6736	High-High	6
Wooddale	49.0414	-55.5461	High-High	6
Ballyhack	47.4392	-53.1983	High-Moderate	5
Beau Bois	47.1392	-55.1017	High-Moderate	5
Biscayan Cove	47.8022	-52.7897	High-Moderate	5
Blow Me Down	47.5936	-53.1897	High-Moderate	5
Blundons Siding	48.3494	-53.9008	High-Moderate	5
Boat Harbour West	47.43	-54.8425	High-Moderate	5
Burns Cove	47.3919	-54.8617	High-Moderate	5
Chamberlains	47.5261	-52.9333	High-Moderate	5
Clattice Harbour	47.4878	-54.4656	High-Moderate	5
Clattice South West	47.4775	-54.4625	High-Moderate	5
Colliers	47.4594	-53.2089	High-Moderate	5
Collier's Riverhead	47.4578	-53.2072	High-Moderate	5
Conception Bay South	47.5297	-52.9414	High-Moderate	5
Corbin	47.5883	-55.4186	High-Moderate	5
Crawley Island	47.4231	-53.8575	High-Moderate	5
Cuslett	46.9606	-54.1581	High-Moderate	5
Darbys Harbour	47.4694	-54.5414	High-Moderate	5
Deep Cove	47.4139	-54.4994	High-Moderate	5
English Harbour East	47.6322	-54.8911	High-Moderate	5
Epworth	47.0283	-55.2025	High-Moderate	5
Fox Cove-Mortier	47.1044	-55.1156	High-Moderate	5
Freshwater	47.6008	-53.0083	High-Moderate	5
Glenview	47.8781	-53.9706	High-Moderate	5
Glovertown South	48.6714	-54.0042	High-Moderate	5
Great Barasway	47.1272	-54.0625	High-Moderate	5
Great Paradise	47.3511	-54.5925	High-Moderate	5
Gullies	47.6475	-53.2861	High-Moderate	5
Hibbs Cove	47.6011	-53.1844	High-Moderate	5
Jacques Fontaine	47.5228	-54.9286	High-Moderate	5
Jim Myles Garden	47.6769	-54.7125	High-Moderate	5
Lance Cove	47.605	-52.9803	High-Moderate	5
Lead Cove	48.045	-53.0919	High-Moderate	5
Little Barasway	47.1778	-54.0417	High-Moderate	5
Little Bay	47.1628	-55.1042	High-Moderate	5

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Little Bona	47.3681	-54.5664	High-Moderate	5
Little Paradise	47.3603	-54.5781	High-Moderate	5
Long Cove	47.5686	-53.6714	High-Moderate	5
Lories	46.9008	-55.9392	High-Moderate	5
Manuels	47.5231	-52.9536	High-Moderate	5
Middle Arm	47.4358	-53.2008	High-Moderate	5
Morleys Siding	48.3172	-53.9072	High-Moderate	5
Mount Arlington Heights	47.4281	-53.8547	High-Moderate	5
North River	47.5494	-53.2994	High-Moderate	5
North Valley	47.5486	-53.3028	High-Moderate	5
Old Perican	48.0803	-53.0064	High-Moderate	5
Parkers Cove	47.3942	-54.8572	High-Moderate	5
Pick Eyes	47.5997	-53.1831	High-Moderate	5
Point Lance	46.8131	-54.0853	High-Moderate	5
Port Kirwan	46.9703	-52.9108	High-Moderate	5
Presque	47.4236	-54.4881	High-Moderate	5
Rencontre East	47.6372	-55.215	High-Moderate	5
Riverdale	47.4931	-53.0214	High-Moderate	5
Riverhead	47.6689	-53.2614	High-Moderate	5
Rock Harbour	47.1744	-55.0497	High-Moderate	5
Rushoon	47.3539	-54.9156	High-Moderate	5
Sagona Island	47.3675	-55.7861	High-Moderate	5
Shalloway	47.0031	-55.1708	High-Moderate	5
Shearstown	47.5886	-53.3025	High-Moderate	5
Spanish Room	47.1992	-55.0869	High-Moderate	5
St. Annes	47.4281	-54.4586	High-Moderate	5
St. Bride's	46.9206	-54.1708	High-Moderate	5
St. Jones Without	47.9222	-53.6914	High-Moderate	5
Stepside	47.0292	-55.1511	High-Moderate	5
Swift Current	47.8811	-54.2067	High-Moderate	5
Terrenceville	47.6636	-54.7214	High-Moderate	5
Wandsworth	47.0186	-55.1989	High-Moderate	5
Wreck Cove	47.4972	-55.6047	High-Moderate	5
Badger	48.98	-56.0356	Moderate-High	5
Barchoix	47.6561	-55.6939	Moderate-High	5
Belleoram	47.5242	-55.4128	Moderate-High	5
Coomb's Cove	47.4586	-55.6219	Moderate-High	5
Dawson's Cove	47.5344	-55.9322	Moderate-High	5
Eastport	48.6519	-53.7661	Moderate-High	5
English Harbour West	47.4628	-55.4936	Moderate-High	5
Gaultois	47.6097	-55.9044	Moderate-High	5
Goblin	47.7167	-56.1158	Moderate-High	5
Goobies	47.9331	-53.9656	Moderate-High	5
Happy Adventure	48.6353	-53.7592	Moderate-High	5
Harbour Breton	47.4725	-55.8169	Moderate-High	5
Head of Bay D'Espoir	47.9292	-55.7528	Moderate-High	5
Hermitage-Sandyville	47.5497	-55.9325	Moderate-High	5
Jersey Harbour	47.4858	-55.7608	Moderate-High	5
Little Bay	47.6164	-56.0325	Moderate-High	5
Little Bay West	47.5019	-55.7189	Moderate-High	5
Milltown-Head of Bay D'Espoir	47.9175	-55.7433	Moderate-High	5
Mose Ambrose	47.4656	-55.5142	Moderate-High	5
Patricks Harbour	47.6814	-56.0133	Moderate-High	5
Piccaire	47.61	-55.9314	Moderate-High	5
Raymond Point	47.7028	-55.9403	Moderate-High	5
Red Cliff	48.9489	-55.7647	Moderate-High	5
Red Island	47.4	-54.1561	Moderate-High	5
Round Harbour	47.6156	-56.0061	Moderate-High	5
Rushy Pond	48.9444	-55.7989	Moderate-High	5
Sandringham	48.6647	-53.8219	Moderate-High	5

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
St. Jacques	47.4906	-55.4194	Moderate-High	5
St. Jacques-Coomb's Cove	47.4683	-55.5103	Moderate-High	5
St. John's Bay	47.4828	-55.5408	Moderate-High	5
Stone Valley	47.6156	-56.0319	Moderate-High	5
Tilts	46.7986	-54.0983	Moderate-High	5
Adeytown	48.0742	-53.9317	High-Low	4
Alderburn	49.1108	-55.25	High-Low	4
Arnolds Cove Station	47.7839	-53.9681	High-Low	4
Aspey Brook	48.1619	-53.8439	High-Low	4
Bareneed	47.5764	-53.2408	High-Low	4
Bay L'Argent	47.5472	-54.8856	High-Low	4
Big Pond	47.4111	-52.7675	High-Low	4
Birchy Cove	48.5961	-53.1769	High-Low	4
Blackhead	47.8472	-53.0931	High-Low	4
Bread and Cheese	47.31	-52.7917	High-Low	4
Brigus	47.5361	-53.21	High-Low	4
Brigus	47.5353	-53.2103	High-Low	4
Cahill Point	47.5636	-52.6897	High-Low	4
Centreville	49.0164	-53.8936	High-Low	4
Chance Cove	47.68	-53.8294	High-Low	4
Churchills	47.9819	-53.9569	High-Low	4
Coffin Cove	47.5139	-54.0828	High-Low	4
Come By Chance	47.8467	-53.9814	High-Low	4
Dark Cove	48.6603	-53.7083	High-Low	4
Deep Bight	48.0936	-53.945	High-Low	4
Garretts Cove	47.8539	-53.735	High-Low	4
Georges Brook	48.2383	-53.96	High-Low	4
Gooseberry Island	48.8831	-53.6156	High-Low	4
Great Brule	47.6589	-54.1342	High-Low	4
Gunridge	47.3108	-52.7803	High-Low	4
Indian Harbour	47.4875	-54.1953	High-Low	4
Keels	48.6072	-53.4044	High-Low	4
Knights Cove	48.5403	-53.3219	High-Low	4
La Manche	47.6911	-53.9389	High-Low	4
La Manche Siding	47.7025	-53.9028	High-Low	4
L'Anse-a-l'Eau	47.01	-55.2039	High-Low	4
Lead Mines	47.6878	-53.9383	High-Low	4
Little Brule	47.6675	-54.13	High-Low	4
Little Harbour East	47.6439	-53.9322	High-Low	4
Middle Gut	46.7853	-53.6244	High-Low	4
Murphys Cove	47.4447	-54.4758	High-Low	4
Norris Arm	49.0878	-55.2681	High-Low	4
Norris Arm North	49.1103	-55.2508	High-Low	4
Northeast Harbour Buffett	47.5361	-54.0711	High-Low	4
Northside	47.6058	-53.9333	High-Low	4
Petty Harbour	47.4681	-52.7086	High-Low	4
Petty Harbour-Maddox Cove	47.4717	-52.7061	High-Low	4
Port de Grave	47.5847	-53.2133	High-Low	4
Portugal Cove	47.6275	-52.8556	High-Low	4
Rantern	47.6944	-53.8581	High-Low	4
Rantern Station	47.6689	-53.8744	High-Low	4
Rattling Brook	49.0722	-55.3108	High-Low	4
Riverhead	47.5306	-53.2044	High-Low	4
Salvage	48.6856	-53.6456	High-Low	4
Ship Cove	47.5919	-53.1967	High-Low	4
Shoal Harbour	48.1831	-53.9822	High-Low	4
South River	47.5367	-53.2681	High-Low	4
Southern Harbour Station	47.7186	-53.9044	High-Low	4
Spoon Cove	47.6439	-53.2106	High-Low	4
Springfield	47.5253	-53.2775	High-Low	4

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
St. Stephens	46.7747	-53.6156	High-Low	4
St. Vincent's-St. Stephen's-Peter's River	46.7753	-53.6161	High-Low	4
Stock Cove	48.5375	-53.3403	High-Low	4
The Battery	47.5417	-53.2019	High-Low	4
The Broads	47.5197	-53.2772	High-Low	4
Tickle Harbour Station	47.5769	-53.8297	High-Low	4
Toslow	47.3936	-54.4878	High-Low	4
Trinity	48.9825	-53.9083	High-Low	4
Upper Amherst Cove	48.5561	-53.2317	High-Low	4
Upshall	47.6664	-53.8989	High-Low	4
Weybridge	48.1031	-53.8803	High-Low	4
Birch Hills	47.5617	-53.2897	Low-High	4
Boxey	47.4528	-55.5611	Low-High	4
Duffs	47.4414	-53.0978	Low-High	4
Fox Harbour	47.3197	-53.9094	Low-High	4
Furby's Cove	47.6008	-55.8361	Low-High	4
Great Jervais	47.4694	-55.1522	Low-High	4
Jumpers Brook	49.0264	-55.4003	Low-High	4
Mills Siding	48.195	-53.9661	Low-High	4
Port Blandford	48.3497	-54.1656	Low-High	4
Talcville	47.5108	-52.9614	Low-High	4
Traytown	48.6614	-53.9656	Low-High	4
Allan's Island	46.8531	-55.8025	Moderate-Moderate	3
Argentia	47.2981	-53.9853	Moderate-Moderate	3
Avondale	47.4186	-53.1911	Moderate-Moderate	3
Baine Harbour	47.3614	-54.9	Moderate-Moderate	3
Bar Haven	47.7103	-54.2206	Moderate-Moderate	3
Bauline	47.7231	-52.8306	Moderate-Moderate	3
Bay de l'Eau	47.6286	-54.9206	Moderate-Moderate	3
Bay de Verde	48.0856	-52.8964	Moderate-Moderate	3
Bay du Nord	47.7111	-55.4128	Moderate-Moderate	3
Bay View	47.0831	-55.2156	Moderate-Moderate	3
Bell Island	47.6317	-52.9614	Moderate-Moderate	3
Bellevue	47.6333	-53.73	Moderate-Moderate	3
Bloomfield	48.3767	-53.905	Moderate-Moderate	3
Bradleys Cove	47.8736	-53.0664	Moderate-Moderate	3
Brigus South	47.1144	-52.8839	Moderate-Moderate	3
Broad Cove	47.8369	-53.0931	Moderate-Moderate	3
Bryant's Cove	47.6786	-53.1875	Moderate-Moderate	3
Burgoynes Cove	48.1694	-53.7122	Moderate-Moderate	3
Burgoynes Cove	48.1675	-53.7117	Moderate-Moderate	3
Burnt Island	47.3831	-54.7008	Moderate-Moderate	3
Burnt Point	47.9583	-53.0397	Moderate-Moderate	3
Burnt Stump	47.3978	-53.1556	Moderate-Moderate	3
Butlerville	47.5739	-53.3275	Moderate-Moderate	3
Cape St. Mary's	46.8225	-54.1953	Moderate-Moderate	3
Caplin Cove	48.0133	-53.7222	Moderate-Moderate	3
Carbonear	47.7392	-53.2333	Moderate-Moderate	3
Clifton	48.1792	-53.7244	Moderate-Moderate	3
Clowns Cove	47.7581	-53.1839	Moderate-Moderate	3
Conception Harbour	47.4406	-53.2208	Moderate-Moderate	3
Conne River	47.8622	-55.7553	Moderate-Moderate	3
Crockers Cove	47.7422	-53.2	Moderate-Moderate	3
Crossroads	47.8672	-53.3631	Moderate-Moderate	3
Daniel's Cove	48.1283	-52.9733	Moderate-Moderate	3
Davis Cove	47.6358	-54.3442	Moderate-Moderate	3
Doctors Harbour	47.6619	-55.3175	Moderate-Moderate	3
Dunville	47.27	-53.8975	Moderate-Moderate	3
Eastern Corner	47.6972	-53.4781	Moderate-Moderate	3
Femme	47.6011	-54.9844	Moderate-Moderate	3

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Flatrock	47.725	-52.8339	Moderate-Moderate	3
Flatrock	47.7569	-53.1867	Moderate-Moderate	3
Fort Townshend	47.5675	-52.7111	Moderate-Moderate	3
Fox Cove	47.0942	-55.1039	Moderate-Moderate	3
Frenchman's Cove	47.2144	-55.4128	Moderate-Moderate	3
Freshwater	47.755	-53.1836	Moderate-Moderate	3
Freshwater	47.7544	-53.1825	Moderate-Moderate	3
Frog Marsh	47.5344	-53.1928	Moderate-Moderate	3
Garden Cove	47.8522	-54.1569	Moderate-Moderate	3
Garnish	47.2281	-55.3708	Moderate-Moderate	3
Georgetown	47.5689	-52.7192	Moderate-Moderate	3
Glendon Cove	47.7022	-54.2369	Moderate-Moderate	3
Grand Le Pierre	47.6783	-54.7886	Moderate-Moderate	3
Great Bona	47.3906	-54.5292	Moderate-Moderate	3
Great Harbour	47.5117	-55.8439	Moderate-Moderate	3
Great Salmonier	47.0683	-55.2167	Moderate-Moderate	3
Halls Town	47.5375	-53.3228	Moderate-Moderate	3
Hant's Harbour	48.0144	-53.2606	Moderate-Moderate	3
Hardy's Cove	47.6675	-55.6661	Moderate-Moderate	3
Hare Harbour	47.5831	-55.1431	Moderate-Moderate	3
Harricott	47.1736	-53.5406	Moderate-Moderate	3
Heart's Delight	47.7744	-53.4622	Moderate-Moderate	3
Hopewell	47.4781	-53.0519	Moderate-Moderate	3
Indian Bay	49.0367	-53.8611	Moderate-Moderate	3
Jean de Baie	47.2222	-55.0683	Moderate-Moderate	3
Kitchuses	47.4567	-53.1836	Moderate-Moderate	3
La Manche	47.1675	-52.8639	Moderate-Moderate	3
Lally Cove	47.655	-55.3689	Moderate-Moderate	3
Lance Cove	47.4664	-53.0617	Moderate-Moderate	3
Lawrence Pond	47.465	-53.0433	Moderate-Moderate	3
Lewin's Cove	47.0911	-55.2189	Moderate-Moderate	3
Little Harbour	47.3719	-54.8089	Moderate-Moderate	3
Loreburn	48.0467	-53.7142	Moderate-Moderate	3
Markland	47.3786	-53.5483	Moderate-Moderate	3
Marquise	47.2842	-53.9964	Moderate-Moderate	3
Merasheen	47.4136	-54.3456	Moderate-Moderate	3
Mercer's Cove	47.2608	-55.8694	Moderate-Moderate	3
Miller's Passage	47.5181	-55.6561	Moderate-Moderate	3
Milltown	47.9075	-55.7603	Moderate-Moderate	3
Monkstown	47.5764	-54.4325	Moderate-Moderate	3
Mortier	47.0883	-55.1242	Moderate-Moderate	3
New Burnt Cove	48.1725	-53.7194	Moderate-Moderate	3
New Chelsea	48.0242	-53.2181	Moderate-Moderate	3
New Chelsea-New Melbourne-Brownsdale-Sibley's Cove-Lead Cove	48.0275	-53.1469	Moderate-Moderate	3
New Harbour	47.5908	-53.5386	Moderate-Moderate	3
New Harbour	47.6036	-54.9681	Moderate-Moderate	3
Newport	49.0442	-53.6425	Moderate-Moderate	3
North Shore	48.6894	-54.0244	Moderate-Moderate	3
Ocean Pond	47.4233	-53.4233	Moderate-Moderate	3
Oderin	47.2928	-54.7994	Moderate-Moderate	3
Parsons Point	49.0422	-53.8736	Moderate-Moderate	3
Perry's Cove	47.7997	-53.1489	Moderate-Moderate	3
Petit Forte	47.3953	-54.6731	Moderate-Moderate	3
Placentia Junction	47.3831	-53.6656	Moderate-Moderate	3
Point Enragée	47.3892	-55.2933	Moderate-Moderate	3
Point Rosie	47.3886	-55.29	Moderate-Moderate	3
Pool's Cove	47.6797	-55.4319	Moderate-Moderate	3
Pool's Island	49.1119	-53.5839	Moderate-Moderate	3
Popes Harbour	48.2358	-53.57	Moderate-Moderate	3
Port Anne	47.3856	-54.7028	Moderate-Moderate	3

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Port Nelson	49.0822	-53.6194	Moderate-Moderate	3
Prowseton	47.6772	-54.3219	Moderate-Moderate	3
Rabbit Town	47.5636	-52.7256	Moderate-Moderate	3
Red Harbour	47.2928	-54.9969	Moderate-Moderate	3
Red Head Cove	48.1286	-52.8958	Moderate-Moderate	3
Safe Harbour	49.1039	-53.6186	Moderate-Moderate	3
Salmonier	47.0642	-55.2092	Moderate-Moderate	3
Sandy Harbour	47.675	-54.3314	Moderate-Moderate	3
Saunders Cove	48.7011	-54.0106	Moderate-Moderate	3
Seal Cove	47.4669	-53.0731	Moderate-Moderate	3
Shamblers Cove	49.075	-53.6044	Moderate-Moderate	3
Ship Cove	47.0311	-55.1808	Moderate-Moderate	3
Silver Fox Island	49.015	-53.6803	Moderate-Moderate	3
Smooth Cove	47.9225	-53.0719	Moderate-Moderate	3
Soldier's Cove	47.7939	-54.2078	Moderate-Moderate	3
South Dildo	47.5211	-53.5531	Moderate-Moderate	3
South East Bight	47.3903	-54.5797	Moderate-Moderate	3
South West Arm	49.1156	-53.6247	Moderate-Moderate	3
St. Alban's	47.8764	-55.845	Moderate-Moderate	3
St. Bernard's	47.5261	-54.9514	Moderate-Moderate	3
St. Bernard's-Jacques Fontaine	47.5228	-54.94	Moderate-Moderate	3
St. John's	47.5656	-52.7253	Moderate-Moderate	3
St. Jones Within	48.0439	-53.7528	Moderate-Moderate	3
St. Joseph's	47.3769	-54.765	Moderate-Moderate	3
St. Kyran's	47.4556	-54.4447	Moderate-Moderate	3
St. Leonards	47.4678	-54.4325	Moderate-Moderate	3
Stage Shore	46.6258	-53.5931	Moderate-Moderate	3
Stoney House	47.0506	-54.1064	Moderate-Moderate	3
Sunnyside	47.8594	-53.9239	Moderate-Moderate	3
Swanger Cove	47.8828	-55.8408	Moderate-Moderate	3
Sydney Cove	48.9864	-53.7356	Moderate-Moderate	3
The Front	47.6333	-52.94	Moderate-Moderate	3
The Motion	47.5317	-53.2958	Moderate-Moderate	3
Tickles	47.1542	-53.5717	Moderate-Moderate	3
Topsail	47.54	-52.9178	Moderate-Moderate	3
Turks Cove	47.9322	-53.3481	Moderate-Moderate	3
Turnip Cove	47.6875	-55.4372	Moderate-Moderate	3
Upper Gullies	47.4808	-53.0411	Moderate-Moderate	3
Wareham	49.0156	-53.8689	Moderate-Moderate	3
West Mines	47.6364	-52.9614	Moderate-Moderate	3
Western Cove	47.6919	-54.245	Moderate-Moderate	3
Whiteway	47.6825	-53.4842	Moderate-Moderate	3
Winterton	47.955	-53.3286	Moderate-Moderate	3
Woodford's	47.4031	-53.1558	Moderate-Moderate	3
Woody Island	47.7825	-54.185	Moderate-Moderate	3
Adams Cove	47.8619	-53.0925	Low-Moderate	2
Aspen	48.1589	-53.7531	Low-Moderate	2
Baccalieu Island	48.1503	-52.7961	Low-Moderate	2
Bally Haly	47.5897	-52.6958	Low-Moderate	2
Barasway de Plate	47.4858	-55.0694	Low-Moderate	2
Barton	48.2217	-53.8986	Low-Moderate	2
Battery	47.0331	-52.8828	Low-Moderate	2
Bell Island Front	47.6275	-52.9333	Low-Moderate	2
Biscay Bay	46.7433	-53.2919	Low-Moderate	2
Black River	47.8778	-54.1664	Low-Moderate	2
Blaketown	47.4825	-53.5503	Low-Moderate	2
Bristol's Hope	47.7211	-53.1964	Low-Moderate	2
Britannia	48.1439	-53.7217	Low-Moderate	2
Broad Cove	47.5517	-53.545	Low-Moderate	2
Brownsdale	48.0347	-53.1211	Low-Moderate	2

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Burin Bay Arm	47.0872	-55.1936	Low-Moderate	2
Butchers	47.8792	-53.3728	Low-Moderate	2
Calmer	46.8922	-55.9075	Low-Moderate	2
Camp Boggy	47.9806	-55.8006	Low-Moderate	2
Cape Dog	47.0906	-53.6975	Low-Moderate	2
Cape Race	46.6597	-53.0736	Low-Moderate	2
Caplin Cove	48.0394	-52.9842	Low-Moderate	2
Cavendish	47.7203	-53.4928	Low-Moderate	2
Churchill Park	47.5753	-52.7219	Low-Moderate	2
Codner	47.5056	-52.9936	Low-Moderate	2
Colinet	47.2189	-53.5531	Low-Moderate	2
Cross Roads	47.4478	-53.5492	Low-Moderate	2
Dildo	47.5711	-53.5506	Low-Moderate	2
Dildo	47.5669	-53.5467	Low-Moderate	2
East Landing	46.6603	-53.0731	Low-Moderate	2
Elliott's Cove	48.1403	-53.9039	Low-Moderate	2
Epworth and Great Salmonier	47.0486	-55.2197	Low-Moderate	2
Ferryland	47.0267	-52.8925	Low-Moderate	2
Flat Island	47.2717	-54.9222	Low-Moderate	2
Fortune	47.0733	-55.8131	Low-Moderate	2
Fox Marsh	47.3944	-53.4089	Low-Moderate	2
Foxtrap	47.5086	-52.9822	Low-Moderate	2
Freshwater	47.0369	-52.8858	Low-Moderate	2
Freshwater	46.8464	-52.9469	Low-Moderate	2
Glendale	47.5167	-52.8119	Low-Moderate	2
Glenridge Crescent	47.5789	-52.7108	Low-Moderate	2
Glovertown	48.6794	-54.0392	Low-Moderate	2
Goddenville	47.5992	-53.3453	Low-Moderate	2
Goobies Siding	47.9419	-53.9633	Low-Moderate	2
Goose Cove	47.8603	-54.1025	Low-Moderate	2
Gooseberry Cove	47.0694	-54.0914	Low-Moderate	2
Grand Bank	47.0978	-55.7708	Low-Moderate	2
Grand John	47.4906	-55.0561	Low-Moderate	2
Grates Cove	48.1664	-52.9394	Low-Moderate	2
Greeleytown	47.5042	-52.985	Low-Moderate	2
Greenland	47.5653	-53.1872	Low-Moderate	2
Green's Harbour	47.6331	-53.4989	Low-Moderate	2
Gull Island	47.9539	-53.0433	Low-Moderate	2
Gussetts Cove	47.8508	-53.0886	Low-Moderate	2
Halfway House	47.8039	-53.2936	Low-Moderate	2
Harbour Grace	47.6906	-53.2311	Low-Moderate	2
Harcourt	48.1975	-53.8583	Low-Moderate	2
Harnum Point	47.5667	-53.5647	Low-Moderate	2
Heart's Content	47.8753	-53.3658	Low-Moderate	2
Heart's Delight-Islington	47.7678	-53.4686	Low-Moderate	2
Heart's Desire	47.8122	-53.4408	Low-Moderate	2
High Beach	46.8886	-55.89	Low-Moderate	2
Holiday Hill	47.4622	-53.5364	Low-Moderate	2
Holyrood	47.385	-53.1425	Low-Moderate	2
Hopeall	47.6169	-53.5103	Low-Moderate	2
Indian Pond	47.4594	-53.0867	Low-Moderate	2
Islington	47.7592	-53.4783	Low-Moderate	2
Job's Cove	47.9778	-53.0133	Low-Moderate	2
John's Pond	47.1472	-53.6175	Low-Moderate	2
Kelligrews	47.5061	-53.0058	Low-Moderate	2
L'Anse-au-Loup	47.0836	-55.6731	Low-Moderate	2
Lawn	46.9419	-55.5386	Low-Moderate	2
Lethbridge	48.3694	-53.8608	Low-Moderate	2
Little Island Cove	47.4275	-53.5503	Low-Moderate	2
Little Salmonier	47.0692	-55.1761	Low-Moderate	2

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Little St. Lawrence	46.93	-55.3633	Low-Moderate	2
Logy Bay-Middle Cove-Outer Cove	47.6389	-52.6867	Low-Moderate	2
Long Beach	47.9483	-53.0542	Low-Moderate	2
Long Harbour	47.4347	-53.815	Low-Moderate	2
Long Harbour Station	47.4653	-53.7319	Low-Moderate	2
Long Harbour-Mount Arlington Heights	47.4292	-53.8322	Low-Moderate	2
Long Pond	47.5156	-52.9706	Low-Moderate	2
Low Point	48.0597	-52.9578	Low-Moderate	2
Lower Island Cove	48.0025	-52.98	Low-Moderate	2
Lower Lance Cove	48.1444	-53.7072	Low-Moderate	2
Molliers	47.1036	-55.6511	Low-Moderate	2
Morrisville	47.8728	-55.7633	Low-Moderate	2
Mount Pearl	47.5147	-52.8114	Low-Moderate	2
Musgravetown	48.4081	-53.8853	Low-Moderate	2
New Melbourne	48.0453	-53.1553	Low-Moderate	2
New Perlican	47.9097	-53.3544	Low-Moderate	2
Newtown	47.3639	-53.1794	Low-Moderate	2
North Harbour	47.8492	-54.1019	Low-Moderate	2
North Harbour	47.15	-53.6647	Low-Moderate	2
North Harbour South	47.15	-53.6508	Low-Moderate	2
North Pond Heights	47.6525	-52.7328	Low-Moderate	2
Northern Bay	47.9442	-53.0653	Low-Moderate	2
Northern Bight	48.015	-54.0828	Low-Moderate	2
Nuggetville	47.3372	-53.5572	Low-Moderate	2
Ochre Pit Cove	47.9094	-53.07	Low-Moderate	2
Old Shop	47.5339	-53.5786	Low-Moderate	2
Otterbury	47.5789	-52.8961	Low-Moderate	2
Otterbury	47.6786	-53.25	Low-Moderate	2
Path End	46.8439	-52.9475	Low-Moderate	2
Patrick's Cove	47.0358	-54.1131	Low-Moderate	2
Patrick's Cove-Angels Cove	47.0325	-54.1156	Low-Moderate	2
Peachytown	47.5014	-52.9964	Low-Moderate	2
Petley	48.1547	-53.7478	Low-Moderate	2
Point May	46.8997	-55.93	Low-Moderate	2
Portland	48.4286	-53.8189	Low-Moderate	2
Pouch Cove	47.7469	-52.7739	Low-Moderate	2
Random Heights	48.1731	-53.9322	Low-Moderate	2
Reids Room	47.5692	-53.5642	Low-Moderate	2
Renews	46.9269	-52.9325	Low-Moderate	2
Renews-Cappahayden	46.8981	-52.9475	Low-Moderate	2
Riverhead	47.8853	-53.085	Low-Moderate	2
Riverhead	46.9781	-52.9575	Low-Moderate	2
Riverhead	46.7636	-53.3511	Low-Moderate	2
Round Cove	47.6536	-55.7144	Low-Moderate	2
Salmon Cove	47.7828	-53.1656	Low-Moderate	2
Salt Pond	47.0942	-55.1928	Low-Moderate	2
Sand Pits	47.5678	-52.7294	Low-Moderate	2
Ship Cove	47.0944	-54.0706	Low-Moderate	2
Sibleys Cove	48.0408	-53.0989	Low-Moderate	2
Skibbereen	47.3911	-53.1856	Low-Moderate	2
Snooks Harbour	48.1592	-53.8775	Low-Moderate	2
Southeast Placentia	47.2172	-53.9381	Low-Moderate	2
Spread Eagle	47.3836	-53.6292	Low-Moderate	2
St. Joseph's Cove	47.9175	-55.8008	Low-Moderate	2
St. Joseph's Cove-St. Veronica's	47.9406	-55.7808	Low-Moderate	2
St. Lawrence	46.9194	-55.3975	Low-Moderate	2
St. Phillips	47.5875	-52.8778	Low-Moderate	2
St. Thomas	47.575	-52.8989	Low-Moderate	2
St. Veronica's	47.9514	-55.7847	Low-Moderate	2
Stevensons Village	47.6847	-53.2364	Low-Moderate	2

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Swansea	47.7556	-53.2592	Low-Moderate	2
The Droke	47.0625	-55.1728	Low-Moderate	2
The Green	47.6472	-52.9528	Low-Moderate	2
The Mines	47.5872	-53.6956	Low-Moderate	2
Thorburn Lake	48.2675	-54.1575	Low-Moderate	2
Tilton	47.6286	-53.3031	Low-Moderate	2
Victoria	47.7669	-53.2361	Low-Moderate	2
Villa Marie	47.2997	-53.8606	Low-Moderate	2
Vitters Cove	47.9089	-53.3725	Low-Moderate	2
Wabana	47.6419	-52.9592	Low-Moderate	2
Watering Chute	47.8489	-53.3794	Low-Moderate	2
West Lake	49.0164	-56.1989	Low-Moderate	2
West Landing	46.6586	-53.0794	Low-Moderate	2
Western Bay	47.8833	-53.0844	Low-Moderate	2
Whitbourne	47.4192	-53.5303	Low-Moderate	2
White Rock	48.1917	-53.8339	Low-Moderate	2
Winterland	47.1614	-55.3069	Low-Moderate	2
Woodfords Cut	47.8383	-53.3906	Low-Moderate	2
Woodstock	47.5319	-52.9069	Low-Moderate	2
Anderson's Cove	47.605	-55.1128	Moderate-Low	2
Appleton	48.9847	-54.8533	Moderate-Low	2
Aquaforte	47.0081	-52.9561	Moderate-Low	2
Back Shore	46.6175	-53.5869	Moderate-Low	2
Bacon Cove	47.4803	-53.1711	Moderate-Low	2
Baker Cove	47.5717	-54.2089	Moderate-Low	2
Bauline East	47.1797	-52.8458	Moderate-Low	2
Beckfords	46.8953	-53.9117	Moderate-Low	2
Benton	48.9011	-54.4128	Moderate-Low	2
Best's Harbour	47.5747	-54.2097	Moderate-Low	2
Bishops Beach	47.6108	-53.2242	Moderate-Low	2
Bishop's Cove	47.6381	-53.2222	Moderate-Low	2
Bishop's Harbour	48.6886	-53.6536	Moderate-Low	2
Black Duck Cove	48.2197	-53.5033	Moderate-Low	2
Black Duck Cove	47.0528	-55.1803	Moderate-Low	2
Black Duck Pond	47.5725	-53.2642	Moderate-Low	2
Blackhead	47.525	-52.6567	Moderate-Low	2
British Harbour	48.2619	-53.5042	Moderate-Low	2
Broad Cove	47.5758	-54.2208	Moderate-Low	2
Bulls Cove	47.0497	-55.1603	Moderate-Low	2
Burin	47.0372	-55.1742	Moderate-Low	2
Burin Bay	47.0217	-55.1758	Moderate-Low	2
Burnside	48.7164	-53.7989	Moderate-Low	2
Burnside-St. Chads	48.7036	-53.7853	Moderate-Low	2
Burnt Cove	47.1992	-52.8525	Moderate-Low	2
Burnt Cove-St. Michael's-Bauline East	47.1931	-52.845	Moderate-Low	2
Butter Cove	48.0264	-53.6489	Moderate-Low	2
Centreville-Wareham-Trinity	48.9831	-53.9822	Moderate-Low	2
Champney's Arm	48.3914	-53.3072	Moderate-Low	2
Champney's West	48.3844	-53.3008	Moderate-Low	2
Chapel Cove	47.4347	-53.1467	Moderate-Low	2
Collins Cove	47.0303	-55.1753	Moderate-Low	2
Cooperage	47.6692	-53.2478	Moderate-Low	2
Cooper's Cove	47.5833	-54.2025	Moderate-Low	2
Corbin	46.9603	-55.24	Moderate-Low	2
Cornfield	47.04	-52.8908	Moderate-Low	2
Deer Harbour	48.1372	-53.5689	Moderate-Low	2
Deer Island	48.9331	-53.7156	Moderate-Low	2
Delbys Cove	48.2353	-53.5369	Moderate-Low	2
Devils Kitchen	47.06	-52.9367	Moderate-Low	2
Dover	48.8719	-53.97	Moderate-Low	2

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Drook	46.6731	-53.2469	Moderate-Low	2
Dunfield	48.3497	-53.3761	Moderate-Low	2
Duricle	47.1122	-55.0931	Moderate-Low	2
Eastport North	48.6692	-53.7581	Moderate-Low	2
Elliston	48.6325	-53.0389	Moderate-Low	2
Fair Haven	47.5344	-53.8989	Moderate-Low	2
Fort William	47.5711	-52.6967	Moderate-Low	2
Frenchs Cove	47.6133	-53.2197	Moderate-Low	2
Gallows Cove	47.4436	-53.1569	Moderate-Low	2
Gambo South	48.7672	-54.2244	Moderate-Low	2
Gasters	47.43	-53.1461	Moderate-Low	2
Georgetown	47.5028	-53.2164	Moderate-Low	2
Glenwood	48.9922	-54.87	Moderate-Low	2
Goose Cove	48.3639	-53.3842	Moderate-Low	2
Gooseberry Cove	48.0325	-53.6419	Moderate-Low	2
Grand Beach	47.1342	-55.5078	Moderate-Low	2
Grants	48.7303	-54.1767	Moderate-Low	2
Greenspond	49.0678	-53.5694	Moderate-Low	2
Harbour Buffett	47.5275	-54.0867	Moderate-Low	2
Harbour Grace South	47.6786	-53.2158	Moderate-Low	2
Harbour Island	47.5517	-54.2603	Moderate-Low	2
Harbour Main	47.4339	-53.1611	Moderate-Low	2
Harbour Main-Chapel Cove-Lakeview	47.4269	-53.1467	Moderate-Low	2
Harbour Mille	47.5814	-54.8794	Moderate-Low	2
Harbour Mille-Little Harbour East	47.5858	-54.8706	Moderate-Low	2
Hare Bay	48.8556	-54.0117	Moderate-Low	2
Haystack	47.6375	-54.0778	Moderate-Low	2
Hodge's Cove	48.0092	-53.7381	Moderate-Low	2
Hoop Cove	47.6253	-55.1061	Moderate-Low	2
Hoylestown	47.5758	-52.6889	Moderate-Low	2
Ireland's Eye	48.2169	-53.4956	Moderate-Low	2
Island Cove	48.0028	-53.7761	Moderate-Low	2
Isle Valen	47.4775	-54.3875	Moderate-Low	2
Ivanhoe	48.2019	-53.5147	Moderate-Low	2
Jean de Gaunt Island	47.5258	-54.2722	Moderate-Low	2
Kerleys Harbour	48.2808	-53.4697	Moderate-Low	2
Kingman's	46.965	-52.9408	Moderate-Low	2
Kingston	47.825	-53.1153	Moderate-Low	2
Kingwell	47.5492	-54.1053	Moderate-Low	2
Kirby's Cove	47.025	-55.1694	Moderate-Low	2
Lakeview	47.42	-53.1394	Moderate-Low	2
Lancaster	48.6597	-53.0667	Moderate-Low	2
Little Harbour East	47.5961	-54.86	Moderate-Low	2
Little Heart's Ease	48.0083	-53.6994	Moderate-Low	2
Long Beach	46.6422	-53.135	Moderate-Low	2
Long Beach	47.9964	-53.8164	Moderate-Low	2
Long Cove	47.0592	-55.1719	Moderate-Low	2
Lower Coast	46.7233	-53.38	Moderate-Low	2
Maddox Cove	47.4736	-52.7011	Moderate-Low	2
Marystown	47.1697	-55.1678	Moderate-Low	2
Marysvale	47.4889	-53.2172	Moderate-Low	2
McAndrew	47.2844	-53.9789	Moderate-Low	2
Melrose	48.4806	-53.0728	Moderate-Low	2
Mercer's Cove	47.6033	-53.2342	Moderate-Low	2
Milton	48.2158	-53.9631	Moderate-Low	2
Mobile	47.2497	-52.8489	Moderate-Low	2
Mooring Cove	47.1886	-55.14	Moderate-Low	2
Mosquito	46.9858	-53.6878	Moderate-Low	2
New Bonaventure	48.2842	-53.4428	Moderate-Low	2
North West Brook - Ivany's Cove	48.03	-53.9572	Moderate-Low	2

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Old Bonaventure	48.2875	-53.4292	Moderate-Low	2
Open Hall-Red Cliffe	48.5536	-53.4914	Moderate-Low	2
Pardy Island	47.0403	-55.1444	Moderate-Low	2
Path End	47.0472	-55.1706	Moderate-Low	2
Peaches Cove	47.6756	-54.0808	Moderate-Low	2
Plate Cove West	48.4961	-53.5092	Moderate-Low	2
Pleasantville	47.5878	-52.6806	Moderate-Low	2
Port au Bras	47.0581	-55.1336	Moderate-Low	2
Port Royal	47.5272	-54.0975	Moderate-Low	2
Port Union	48.4975	-53.0822	Moderate-Low	2
Pouch Cove	47.7617	-52.7706	Moderate-Low	2
Queen's Cove	48.0092	-53.9269	Moderate-Low	2
Quidi Vidi	47.5806	-52.6778	Moderate-Low	2
Red Cliff	48.5592	-53.49	Moderate-Low	2
Red Cove	47.5339	-55.6178	Moderate-Low	2
Rioux	48.2064	-54.0431	Moderate-Low	2
Riverhead	46.9742	-53.5139	Moderate-Low	2
Rosedale	48.6922	-53.9561	Moderate-Low	2
Sandy Cove	48.6419	-53.7347	Moderate-Low	2
Sandy Point	47.0578	-55.1808	Moderate-Low	2
Scrape Shore	46.6133	-53.5567	Moderate-Low	2
Seal Cove	47.1872	-52.8444	Moderate-Low	2
Shalloway Cove	48.8439	-53.6844	Moderate-Low	2
Shea Heights	47.5436	-52.7117	Moderate-Low	2
Ship Harbour	47.3656	-53.89	Moderate-Low	2
Small Point	47.8317	-53.1056	Moderate-Low	2
Small Point-Broad Cove-Blackhead-Adams Cove	47.8325	-53.0989	Moderate-Low	2
Southern Harbour	47.7142	-53.9686	Moderate-Low	2
Southport	48.0425	-53.6394	Moderate-Low	2
Spaniard's Bay	47.6153	-53.2778	Moderate-Low	2
Spaniard's Bay	47.6167	-53.2747	Moderate-Low	2
Spencers Cove	47.6672	-54.0764	Moderate-Low	2
Spout Cove	47.8153	-53.1283	Moderate-Low	2
St. Chads	48.6919	-53.7761	Moderate-Low	2
St. Michaels	47.1922	-52.8453	Moderate-Low	2
Stone's Cove	47.5858	-55.1214	Moderate-Low	2
Stopperside	47.4942	-52.65	Moderate-Low	2
Summerville	48.45	-53.5592	Moderate-Low	2
Tacks Beach	47.5775	-54.2122	Moderate-Low	2
The Battery	47.5683	-52.6911	Moderate-Low	2
The Dock	47.5728	-53.2528	Moderate-Low	2
The Groves	47.0353	-52.8939	Moderate-Low	2
The Houser	47.2603	-52.7764	Moderate-Low	2
The Thicket	47.6506	-53.2589	Moderate-Low	2
The Tickles	47.5181	-54.0775	Moderate-Low	2
Thornlea	47.6094	-53.7186	Moderate-Low	2
Thoroughfare	48.1983	-53.5483	Moderate-Low	2
Tickle Cove	48.5822	-53.4814	Moderate-Low	2
Trouty	48.3289	-53.4044	Moderate-Low	2
Upper Island Cove	47.6467	-53.2242	Moderate-Low	2
Waterville	48.1992	-53.7892	Moderate-Low	2
Whale Cove	47.0169	-55.1839	Moderate-Low	2
Admiral's Beach	47.0042	-53.6433	Low-Low	1
Admiral's Cove	47.0967	-52.9072	Low-Low	1
Alexander Bay	48.6792	-54.1161	Low-Low	1
Amherst Cove	48.5753	-53.2072	Low-Low	1
Angels Cove	47.0028	-54.1361	Low-Low	1
Arnold's Cove	47.7653	-53.9889	Low-Low	1
Barchois	46.8617	-53.5833	Low-Low	1
Bay Bulls	47.315	-52.8172	Low-Low	1

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Bay Roberts	47.5964	-53.2656	Low-Low	1
Beachy Cove	47.5967	-53.2525	Low-Low	1
Bellevue Beach	47.6303	-53.7769	Low-Low	1
Birchy Nap	47.6536	-52.7467	Low-Low	1
Bonavista	48.6536	-53.1125	Low-Low	1
Branch	46.8819	-53.9642	Low-Low	1
Briens	47.4014	-53.1211	Low-Low	1
Brigus Gullies	47.5267	-53.2392	Low-Low	1
Brigus Junction	47.3864	-53.2997	Low-Low	1
Brooklyn	48.3842	-53.8692	Low-Low	1
Bunyan's Cove	48.3961	-54.0203	Low-Low	1
Butts	48.8219	-54.2844	Low-Low	1
Calvert	47.0561	-52.9131	Low-Low	1
Cannings Cove	48.4422	-53.8489	Low-Low	1
Cape Broyle	47.0967	-52.9506	Low-Low	1
Cappahayden	46.8614	-52.9467	Low-Low	1
Catalina	48.5167	-53.0781	Low-Low	1
Champney's	48.3906	-53.2869	Low-Low	1
Chapel Arm	47.5256	-53.6722	Low-Low	1
Charleston	48.3922	-53.6536	Low-Low	1
Charlottetown	48.4339	-54.0067	Low-Low	1
Clarenville	48.1636	-53.9778	Low-Low	1
Clarenville South	48.1561	-53.9719	Low-Low	1
Clarenville-Shoal Harbour	48.1758	-53.9681	Low-Low	1
Cobb	47.8389	-53.9742	Low-Low	1
Coley's Point	47.5806	-53.2656	Low-Low	1
Coley's Point South	47.5792	-53.2669	Low-Low	1
Cootes Pond	46.9539	-53.5203	Low-Low	1
Creston	47.1444	-55.1919	Low-Low	1
Creston North	47.1531	-55.1986	Low-Low	1
Culls Harbour	48.6797	-53.9489	Low-Low	1
Cupids	47.5503	-53.2181	Low-Low	1
Cupids Crossing	47.5283	-53.2508	Low-Low	1
Daniel's Point	46.7522	-53.3775	Low-Low	1
Davis Island	47.2611	-54.9358	Low-Low	1
Dock Cove	48.8592	-53.645	Low-Low	1
Donovans	47.5258	-52.835	Low-Low	1
Doyles	47.4594	-52.7614	Low-Low	1
Duntara	48.5964	-53.3692	Low-Low	1
East Meadows	47.5981	-52.7097	Low-Low	1
English Harbour	48.3719	-53.2614	Low-Low	1
Evergreen Village	47.5394	-52.8417	Low-Low	1
Fermeuse	46.9803	-52.9514	Low-Low	1
Fermeuse	46.9778	-52.9525	Low-Low	1
Ferndale	47.2633	-53.9467	Low-Low	1
Flat Rock	47.0139	-52.9836	Low-Low	1
Flatrock	47.7106	-52.7267	Low-Low	1
Forest Field	47.1603	-53.4519	Low-Low	1
Forest Field-New Bridge	47.1494	-53.4656	Low-Low	1
Freshwater	47.2592	-53.9839	Low-Low	1
Gallardin Point	47.26	-53.9733	Low-Low	1
Gambo	48.7758	-54.2164	Low-Low	1
Gambo Pond	48.7361	-54.225	Low-Low	1
Gander	48.9539	-54.6047	Low-Low	1
Gaskiers	46.8744	-53.6108	Low-Low	1
Gaskiers-Point La Haye	46.8842	-53.605	Low-Low	1
Gin Cove	48.1969	-53.8156	Low-Low	1
Glennville Court	47.6097	-52.7133	Low-Low	1
Goobies Station	47.92	-53.9486	Low-Low	1
Goulds	47.4786	-52.7664	Low-Low	1

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Graven Bank	46.9603	-53.5317	Low-Low	1
Gripes Nest	46.9033	-52.9189	Low-Low	1
Gulch	46.9075	-53.5975	Low-Low	1
Halfway Tucks	46.7036	-53.5981	Low-Low	1
Harcourt-Monroe-Waterville	48.2003	-53.8019	Low-Low	1
Hatchet Cove	48.0283	-53.7994	Low-Low	1
Haywards Cove	48.8683	-53.6475	Low-Low	1
Hickman's Harbour	48.1083	-53.7422	Low-Low	1
Hillview	48.0336	-53.9172	Low-Low	1
Hodderville	48.5278	-53.3011	Low-Low	1
Hogan's Pond	47.5844	-52.8636	Low-Low	1
Iona	47.435	-53.9814	Low-Low	1
Irishtown	47.3214	-52.8156	Low-Low	1
Irvine	47.53	-52.8794	Low-Low	1
Jamestown	48.4425	-53.7989	Low-Low	1
Jerseyside	47.2544	-53.9614	Low-Low	1
Kilbride	47.5278	-52.7411	Low-Low	1
King's Cove	48.5669	-53.3364	Low-Low	1
Lady Cove	48.0936	-53.8439	Low-Low	1
Lamaline	46.8614	-55.8097	Low-Low	1
Lance Cove	48.6639	-53.0861	Low-Low	1
Little Bay East	47.5556	-54.8636	Low-Low	1
Little Catalina	48.5464	-53.0417	Low-Low	1
Lockston	48.3961	-53.3753	Low-Low	1
Lodges	47.5575	-53.6286	Low-Low	1
Logy Bay	47.6297	-52.6783	Low-Low	1
Long Beach	48.4375	-53.5764	Low-Low	1
Lord's Cove	46.8808	-55.6717	Low-Low	1
Maberly	48.6197	-53.015	Low-Low	1
Maccles	48.6331	-54.1322	Low-Low	1
Mahers	47.3969	-53.3617	Low-Low	1
Mall Bay	46.9767	-53.5872	Low-Low	1
Marystown South	47.1564	-55.1617	Low-Low	1
Middle Amherst Cove	48.5642	-53.2206	Low-Low	1
Middle Brook	48.8022	-54.2083	Low-Low	1
Middle Cove	47.6478	-52.6958	Low-Low	1
Mitchells Brook	47.1297	-53.5111	Low-Low	1
Monchy	48.9708	-54.7914	Low-Low	1
Monroe	48.2	-53.7989	Low-Low	1
Mount Carmel	47.1528	-53.475	Low-Low	1
Mount Carmel-Mitchells Brook-St. Catherines	47.1489	-53.4833	Low-Low	1
Mount Cashel	47.5889	-52.7108	Low-Low	1
Muddy Brook	48.3767	-54.1842	Low-Low	1
New Bridge	47.1358	-53.4764	Low-Low	1
New Country Siding	48.3469	-53.7369	Low-Low	1
Newmans Cove	48.5875	-53.1908	Low-Low	1
Newton	47.6597	-52.7169	Low-Low	1
Norman's Cove	47.56	-53.6656	Low-Low	1
Norman's Cove-Long Cove	47.5639	-53.6714	Low-Low	1
North Side	46.9611	-52.9317	Low-Low	1
North West Arm	47.5853	-53.2822	Low-Low	1
O'Brien	49.0494	-54.9933	Low-Low	1
O'Donnells	47.0692	-53.5656	Low-Low	1
Open Hall	48.5483	-53.4817	Low-Low	1
Otterbury	47.5556	-53.2728	Low-Low	1
Outer Cove	47.6464	-52.6806	Low-Low	1
Paradise	47.5367	-52.8706	Low-Low	1
Path End	46.8956	-53.5503	Low-Low	1
Path End	47.8561	-53.9419	Low-Low	1
Penetanguishene	47.6042	-52.7614	Low-Low	1

Table A1. Qualitative Vulnerability Class for Communities in the Eastern Newfoundland Study Area

COMMUNITY NAME	DD_LAT	DD_LONG	QUALITATIVE VULNERABILITY CLASS	RATING
Peter's River	46.7622	-53.6067	Low-Low	1
Placentia	47.2431	-53.9672	Low-Low	1
Plate Cove East	48.5164	-53.4872	Low-Low	1
Point au Gaul	46.86	-55.7494	Low-Low	1
Point La Haye	46.8917	-53.5986	Low-Low	1
Point Verde	47.2294	-54.0025	Low-Low	1
Port Rexton	48.3928	-53.3319	Low-Low	1
Portugal Cove South	46.7044	-53.2561	Low-Low	1
Portugal Cove-St. Philip's	47.6019	-52.8636	Low-Low	1
Princeton	48.4175	-53.59	Low-Low	1
Pritchetts	48.8242	-54.2831	Low-Low	1
Random Island West	48.1336	-53.8517	Low-Low	1
Reids Fishing Room	47.5242	-53.6719	Low-Low	1
Ricketts Bridge	47.5997	-52.7322	Low-Low	1
Robinson Bight	48.0997	-53.7997	Low-Low	1
Roundabout	46.9164	-55.5822	Low-Low	1
Salmon Cove	47.5417	-53.2633	Low-Low	1
Sandy Beach	47.5353	-53.2372	Low-Low	1
Sharks Cove	47.5578	-53.2114	Low-Low	1
Shoal Point	46.7608	-53.365	Low-Low	1
Shoe Cove	47.745	-52.7411	Low-Low	1
Shore's Cove	47.0972	-52.9292	Low-Low	1
Southern Bay	48.4003	-53.6236	Low-Low	1
Southside	47.5633	-53.2069	Low-Low	1
Spillars Cove	48.6603	-53.0764	Low-Low	1
Spread Eagle	47.5381	-53.6161	Low-Low	1
St. Brendan's	48.8678	-53.6628	Low-Low	1
St. Catherine's	47.1758	-53.4142	Low-Low	1
St. Joseph's	47.1169	-53.5206	Low-Low	1
St. Mary's	46.9114	-53.5797	Low-Low	1
St. Shores	46.6608	-53.6239	Low-Low	1
St. Shotts	46.6319	-53.5864	Low-Low	1
St. Vincent's	46.8	-53.6378	Low-Low	1
Sweet Bay	48.4461	-53.6497	Low-Low	1
Tartan Lane	46.6847	-53.4372	Low-Low	1
Taylor's Bay	46.8761	-55.7261	Low-Low	1
The Flats	46.7969	-53.6433	Low-Low	1
The Keys	47.3042	-52.8125	Low-Low	1
Thorburn Road	47.5817	-52.8397	Low-Low	1
Torbay	47.6586	-52.7408	Low-Low	1
Tors Cove	47.2203	-52.8464	Low-Low	1
Trepassey	46.7333	-53.3675	Low-Low	1
Trinity	48.3664	-53.3586	Low-Low	1
Trinity East	48.3789	-53.3447	Low-Low	1
Trinny Cove	47.4903	-53.9094	Low-Low	1
Valna Fad	46.7144	-53.3858	Low-Low	1
Virginia Park	47.5969	-52.6908	Low-Low	1
Walsh	48.5831	-54.1989	Low-Low	1
Wedgewood Park	47.605	-52.7114	Low-Low	1
Williams	47.4383	-52.7669	Low-Low	1
Windsor Heights	47.6114	-52.8094	Low-Low	1
Winter Brook	48.4236	-53.7447	Low-Low	1
Wishingwell Park	47.56	-52.7358	Low-Low	1
Witless Bay	47.2797	-52.8336	Low-Low	1

Table A2. Percent of 1500 metre buffer area around public well heads with groundwater vulnerability index exceeding 15

COMMUNITY	SOURCE NAME	% AREA
Baine Harbour	Dug	64
Eastport	Dug	62
Sandy Cove	Dug	61
Harbour Main-Chapel's Cove-Lakeview	Holden's Road Well	59
Holyrood	Woodford Station - Quinlan's Well	50
Colliers	#1 Mahoney's Well	48
Harbour Grace	Mercer's Road Well	47
Conception Harbour	Healey's Pond Road Well	46
Red Harbour	Drilled (Backup Well)	40
	#4 Flynn's Well	34
Canning's Cove	#1 Well - Pleman Pitts	34
Wabana	Middleton Ave. Well	34
Wabana	Scotia #1 Well	32
Bryant's Cove	#3 Backup Well & Pumphouse	30
Sandringham	Drilled (#2 Well)	29
Conception Harbour	Lower Bacon Cove Well	26
Canning's Cove	#2 Well - Eugene Ellis	25
Colliers	#2 Merrigan's Well	25
Colliers	#5 Whalen's Well	19
Holyrood	Woodford Station - Healey's Well	18
Wabana	Quigley's Line Well	15
Conception Harbour	Upper Bacon Cove Well	13
Holyrood	Main Line (well #5)	13
Harbour Main-Chapel's Cove-Lakeview	Flynn's Hill Well	12
Wabana	Main Street Well	11
Wabana	Davidson Ave. Well	9
Holyrood	Main Line (well #3)	8
Sandringham	Drilled (#1 Well)	6
Wabana	Kelloway's The Front Well	6
Conception Harbour	Cemetery Road Well	5
Bellevue	#5 Dave Paul Well	5
Colliers	#3 Griffin's Well	5

Table A2. Percent of 1500 metre buffer area around public well heads with groundwater vulnerability index exceeding 15

COMMUNITY	SOURCE NAME	% AREA
Holyrood	O'Connell's Well	5
Harbour Grace	#2 Thicket Well	5
Winterland	#1 Well	4
Bellevue	#1 & #2 James Hefferan Wells	3
Harbour Grace	Southside Well	3
Wabana	Fancy Hill Well	3
Wabana	#4 West Mines Well	2
Winterland	#2 Well	2
Dildo	#2 Well	2
Harbour Grace	#1 Thicket Susie Galway Well	2
Red Harbour	Drilled	2
St. Mary's	#3 Well	1
Canning's Cove	#3 Well - Glenda Penney	1
Bryant's Cove	#2 Baxter Bowering Well	1
St. Mary's	Wellhead	1
Wabana	St. Edwards Well	0
Bryant's Cove	#1 Bert James Well	0
Frenchman's Cove	Dug Well	0
St. Mary's	Wellhead	0
St. Mary's	#5 Well	0
St. Mary's		0
Holyrood	Main Line (well #1)	0
St. Joseph's	Backup Well #1	0
St. Joseph's	Backup Well #2	0
St. Joseph's	Supply Well #1	0
St. Mary's	#2 Well	0
St. Mary's	#4 Well	0
St. Mary's	Wellhead	0
St. Mary's	Wellhead	0
Wabana	#3 Yard Well	0
Wabana	East #1 Well	0
Wabana	Kavanagh's Lane Well	0

Table A3. Percent of water supply area with groundwater vulnerability index exceeding 15

COMMUNITY	SOURCE NAME	% AREA
	Salters Pond - Rock Harbour	100
	Seal Cove - F.B. (MAPA - 1985)	100
	Unnamed Pond - Recontre East	100
Belleoram	Rabbit's Pond	100
Chance Cove	Edgar Crann Well	100
Conception Harbour	Cemetery Road Well	100
Conception Harbour	Healey's Pond Road Well	100
Conception Harbour	Upper Bacon Cove Well	100
Eastport	Dug	100
Eastport	Dug	100
Harbour Main-Chapel's Cove-Lakeview	Holden's Road Well	100
Holyrood	O'Connell's Well	100
Holyrood	Woodford Station - Quinlan's Well	100
Jean de Baie	Colleen's Pond	100
Makinsons	Taylor's Wells (Back Well)	100
Makinsons	Taylor's Wells (Front Well)	100
North Harbour	Bugdens Pond	100
Old Perlican	Bell Pond	100
Pool's Cove	Widgeon Pond	100
Sandringham	Sandringham Wellhead	100
Sandringham	Sandringham Wellhead	100
Sandy Cove	Dug	100
Sandy Cove	Dug	100
Seal Cove (FB)	Big Black Duck Pond	100
Swift Current	Drilled	100
Wabana	#4 West Mines Well - Wabana	100
Wabana	Middleton Ave. Well - Wabana	100
New Chelsea-New Melbourne- Brownsdale-Sibley's Cove-Lead Cove	Sibley's Cove Pond	100
Marysvale	Drilled	100
Swift Current	Black Duck Pond	100
Petty Harbour-Maddox Cove	Western Barrens Pond	99
Green's Harbour	Barrett's Well	99
	Bona Pond - South East Bight	98
Little Harbour East	Unnamed Pond	98
Colliers	#5 Whalens Well	95
Marysvale	Drilled	95
Bryant's Cove	Well Field	93
Colliers	#1 Mahoney's Well	92
	Unnamed Stream - Beau Bois	92
Wabana	Scotia #1 Well - Wabana	92
Hermitage	Granfer's Pond	92
Baine Harbour	Baine Harbour Pond	91
Victoria	Rocky Pond	91
Salmon Cove	Rocky Pond	91
Spaniard's Bay	Kelly's Pond (Spider's Pond)	89
Upper Island Cove	Kelly's Pond (Spider's Pond)	89
St. Jacques-Coomb's Cove	St. Jacques Pond (Proposed)	86
	Unnamed Pond - Pool's Cove	85
Old Perlican	Cooks Cove Pond	83
Harbour Grace	Mercer's Road Well	83
Parkers Cove	Unnamed Pond	83
	Beer Pond	83
Bay de Verde	Island Pond	82
Southern Harbour	Brigades Pond	80
Portugal Cove-St. Phillips	Blast Hole Ponds	79
Rushoon	Big Pond Brook	78
Britannia	Big Long Pond	78
Lower Lance Cove	Big Long Pond	78

Table A3. Percent of water supply area with groundwater vulnerability index exceeding 15

COMMUNITY	SOURCE NAME	% AREA
Harbour Mille-Little Harbour East	Head Pond	76
Lewin's Cove	Big Pond	76
Fox Cove-Mortier	Deep Pond (Proposed)	76
Burin	Big Pond	76
Port Kirwan	Chance Pond	75
	Trout Pond - Chance Cove	75
Long Harbour-Mount Arlington Heights	Shingle Pond and/or Trout Pond	74
Garden Cove	Arch Cove Pond	74
Fortune	Horsebrook	73
Grand Bank	Horsebrook	73
Upper Amherst Cove	Drilled	69
Marystown	Fox Hill Reservoir/Linton Lake	69
Keels	Boland's Pond	68
Newman's Cove	Heale Pond Brook	67
Grand Le Pierre	Nip Nose Pond	66
Makinsons	Country Path Wells (Dean Efford Well)	64
Petty Harbour-Maddox Cove	Western Barrens Pond	63
Petit Forte	Reddy's Pond	61
Burgoyne's Cove	Lower Rocky Pond	60
Bay Roberts	Rocky Pond	59
Blaketown	#4 Well	59
Wabana	Kavanagh's Lane Well - Wabana	58
Norman's Cove-Long Cove	John Newhooks Pond	58
Holyrood	Woodford Station - Healey's Well	57
Terrenceville	Big Brook	57
Trinity	Indian Pond	57
Clarke's Beach	Clarke's Pond	56
Harbour Breton	Connaigra Pond, Hutchings Pond	55
Thornlea	Big Bakeapple Pond	53
Fermeuse	Merrymeeting Pond, Bear Cove Pond	52
	Indian Pond - Trinity	52
St. John's	Petty Harbour Long Pond	52
Wabana	#3 Yard Well - Wabana	52
Avondale	Lee's Pond	51
Jean de Baie	#1 Well	51
South Dildo	Broad Cove Pond	50
Dildo	Broad Cove Pond	49
Burin	Long Pond	48
Burin	Gripe Cove Pond	45
	Upper & Western Ponds - Birchy Cove	45
Pouch Cove	North Three Island Pond	44
Red Harbour	Wellfield	43
Grand Bank	Grand Bank Brook	43
Wabana	East #1 Well - Wabana	42
St. Bernard's-Jacques Fontaine	Rattle Brook	40
Southport		40
Salvage	Wild Cove Pond	40
	Mare Brook - Little Bay East	39
New Perlican	New Perlican River	38
Wabana	Davidson Ave. Well - Wabana	38
Harbour Main-Chapel's Cove-Lakeview	Flynn's Hill Well	38
Placentia	Wyses Pond	37
Chance Cove	Olive Smith Well	36
Hickman's Harbour-Robinson Bight	Big Loss Pound Pond	36
	Duck Pond - Community of Renewes / Cappahayden	35
	Miller's Cove & Briton's Ponds - Musgravetown	34
Little St. Lawrence	Butler's Brook	34
Placentia	Southeast River	33
Riverhead	Well Field	33

Table A3. Percent of water supply area with groundwater vulnerability index exceeding 15

COMMUNITY	SOURCE NAME	% AREA
	Clancey's Pond - Grand Beach	32
Ferryland	Deep Cove Pond	32
Harbour Main-Chapel's Cove-Lakeview	Maloney's River	32
Trepassey	Miller's Pond	32
Bay L'Argent	Sugarloaf Hill Pond	32
Plate Cove East	Eastern Pond (Inactive)	32
Carbonear	Island Pond/Flings Long Pond	31
	Rattling Brook Big Pond	30
Wabana	Main Street Well - Wabana	30
George's Brook-Milton	George's Brook	30
George's Brook-Milton	Lilly Pond	28
Sunnyside (T.B.)	Center Cove River	27
Wabana	Fancy Hill Well - Wabana	26
Placentia	Clarke's Pond	26
Placentia	Larkin's Pond	25
Dildo	Broad Cove Pond	25
South Dildo	Broad Cove Pond	25
	#1 Well - Parkside Wells (Outside Well)	25
Plate Cove East	Eastern Pond (Inactive)	23
South Dildo	Broad Cove Pond	23
	Bay Bulls River - St. John's	23
Dildo	Broad Cove Pond	23
Port Rexton	Champney's Arm Well	22
Harbour Grace	Bannerman Lake	22
Canning's Cove	#1 Well - Pleman Pitts	21
South Dildo	#5 Well - Calvin Reid Well	21
	Fox Harbour Pond - Fox Harbour	20
Heart's Content	Southern Cove Pond	19
Deep Bight	Deep Bight Well Field (well #2)	19
St. Bride's	South Side Brook	17
	Bruce's Pond - Chapel Arm	16
Heart's Desire	Terrence Pond	16
Deep Bight	Deep Bight Well Field	15
	Thomas Pond - St. John's	15
St. Lawrence	St. Lawrence River	15
St. Lawrence	St. Lawrence River	15
Whitbourne	Hodges River	15
Little Catalina	Whirl Pond	15
Trinity Bay North	Whirl Pond	15
Trinity Bay North	Whirl Pond	15
Heart's Delight-Islington	Long Pond	13
	Middle Brook - Town of Port Blandford	13
Cupids	Brigus Long Pond (to Brigus)	13
Brigus	Brigus Long Pond (to Brigus)	13
Colliers	#3 Griffin's Well	13
South River	Brigus Long Pond (to Brigus)	13
	#1 Well - Parkside Wells (Inside Well)	12
Hant's Harbour	Eastern Pond (Halfway Brook)	11
Portugal Cove-St. Phillips	Bay Bulls Big Pond	11
Conception Bay South	Bay Bulls Big Pond	11
Mount Pearl	Bay Bulls Big Pond	11
Paradise	Bay Bulls Big Pond	11
St. John's	Bay Bulls Big Pond	11
	Pierre's Brook - St. John's	10
Carbonear	Island Pond/Flings Long Pond	10
Cavendish	Long Pond	10
Clareville	Shoal Harbour River	10
	Rogers Tilt Pond - St. John's	10
Whiteway	Long Pond	10

Table A3. Percent of water supply area with groundwater vulnerability index exceeding 15

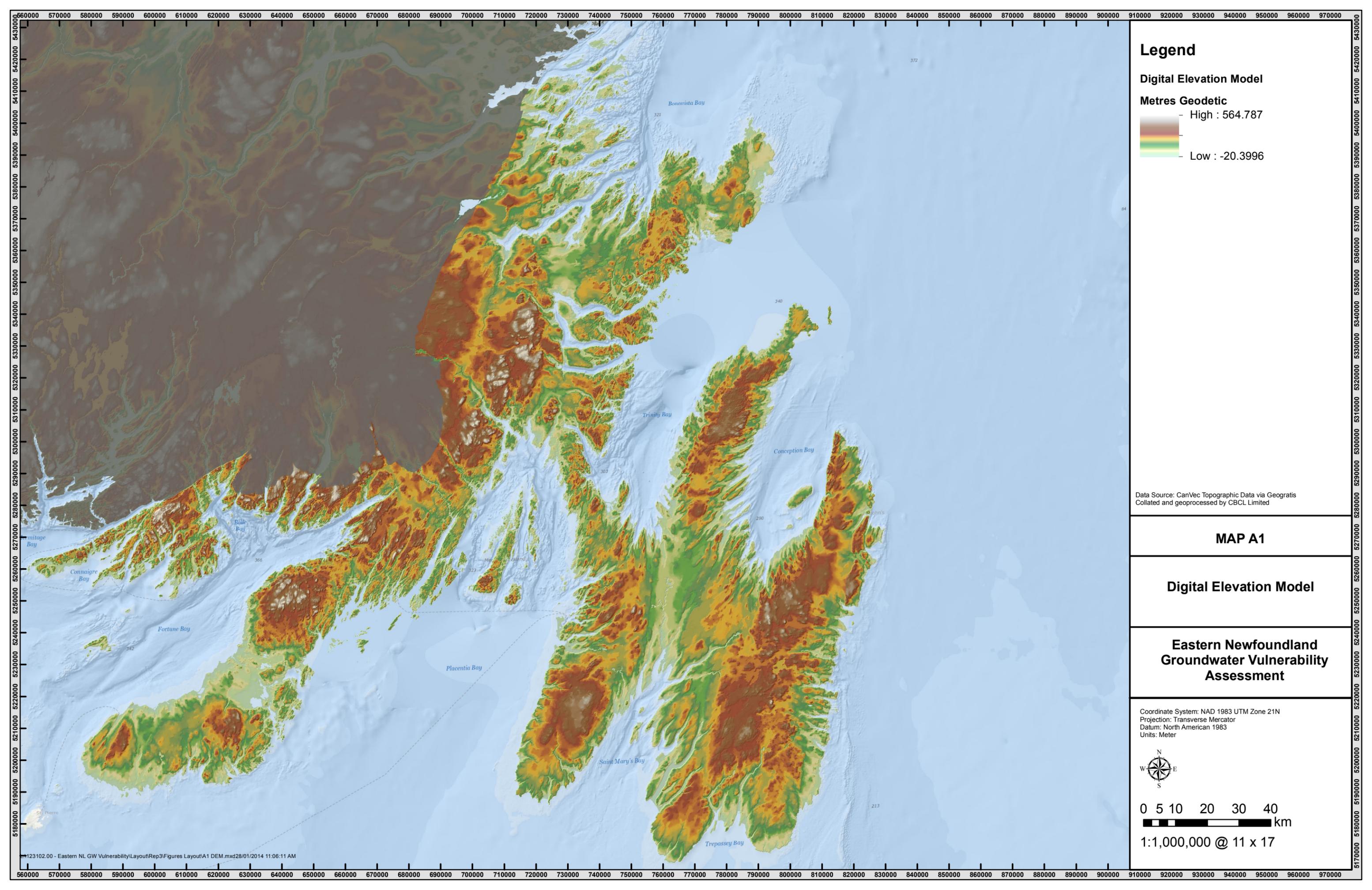
COMMUNITY	SOURCE NAME	% AREA
Bellevue Beach	Unnamed Brook	10
	Middle Pond - Town of Flatrock - (CNLR 651/96)	10
Glovertown	Northwest Pond	9
Deep Bight	Deep Bight Well Field (well #1)	8
Georgetown	Drilled	8
Bellevue	Big Pond (Inactive)	7
St. John's	Windsor Lake	6
Lamaline	Upper Hodges Pond	5
	North Arm Brook - St. John's	5
Makinsons	Country Path Wells (Dale Efford Well)	5
Holyrood	Main Line (well #1 and well#3)	5
Point Lance	Unnamed Pond	5
Grates Cove	#4 Stoyles Hill Well	4
Bellevue	Bellevue Wellheads	4
Chance Cove	New Housing Area Well	4
New Perlican	New Perlican River	4
Winterton	Western Pond	3
Placentia	Southeast River	3
Freshwater	#3 Well - Wallace Snow Well	3
Baine Harbour	Dug	3
Chance Cove	Eugene Smith Well	2
Hodge's Cove	Drilled	1
Arnold's Cove	Steve's Pond	1
Holyrood	Main Line (well #5)	1
Lawn	Brazil Pond	1
Happy Adventure	Goose Neck Pond	0
Bonavista	Long Pond	0
Trepassey	Broom Cove Pond	0
	Great Pond - Torbay	0
	Snows Pond - North River	0
Little St. Lawrence	Butler's Brook	0
	#1 Well	0
	#10 Well - Les Gover Well	0
	#2 Well	0
	#2 Well - Clem Temple Well	0
	#3 Well	0
	#3 Well - Fred Osborne Well	0
	#3 Well - Randy Whitten Well	0
	#4 Well - Cleo White Well	0
	#4 Well - Community Centre Well	0
	#5 Well - Albert White Well	0
	#5 Well - Hayward Newhook Well	0
	#6 Well - Gerald Newhook Well	0
	#7 Well - Garden Hill Well	0
	#8 Well - Bob Hellings Well	0
	#9 Well - Ambrose Piercey Well	0
	King's Hill Pond - Port Rexton	0
	Peddle's Pond	0
	St. Joseph's Pond - St. Joseph's	0
	Unnamed Brook - Charlottetown	0
Admirals Beach	2 Well Fields	0
Aquaforte	Davies Pond	0
Bellevue	Bellevue Wellheads	0
Biscay Bay	Unnamed Pond	0
Blaketown	#1 Well	0
Blaketown	#2 Well - Mercer's Well	0
Branch	Valley Pond	0
Brigus South	#1 Well Forge Hill	0
Brigus South	#2 Well Dunphey's Hill	0

Table A3. Percent of water supply area with groundwater vulnerability index exceeding 15

COMMUNITY	SOURCE NAME	% AREA
Brigus South	#3 Well Main Road	0
Bunyan's Cove	#1 Well	0
Bunyan's Cove	#2 Well	0
Calvert	Juniper Knot Brook	0
Canning's Cove	#2 Well - Eugene Ellis	0
Canning's Cove	#3 Well - Glenda Penney	0
Cavendish	#1 Well - Max Bishop	0
Cavendish	#2 Well - Tom Critch	0
Chance Cove	Albert Rowe Well	0
Chance Cove	Angus Brace Well	0
Clarke's Beach	#1 Well - Quinlon Well	0
Clarke's Beach	#2 Well - Delaney Well	0
Colliers	#2 Merrigan's Well	0
Come By Chance	Butcher's Brook	0
Conception Harbour	Lower Bacon Cove Well	0
Dildo	#2 Well	0
Dildo	#2 Well	0
Elliston	Big Pond	0
Fermeuse	Port Kirwan Road Well	0
Frenchman's Cove	Dug Well	0
Freshwater	#2 Well - Covage's Lane Well	0
Garnish	Witchazel Pond	0
Gaskiers	Big Hare Hill Pond	0
Goobies	Water Pond	0
Grates Cove	#1 Cyril Meadus Well	0
Grates Cove	#2 Frank Janes Well	0
Harbour Grace	#1 Thicket Susie Galway Well	0
Harbour Grace	#2 Thicket Well	0
Harbour Grace	Southside Well	0
Harcourt-Monroe-Waterville	Developed Spring	0
Hopeall	Charles Cumby Well	0
Hopeall	Charles Cumby Well	0
Hopeall	Gilberts Hill Well	0
Hopeall	Gilberts Hill Well	0
Lance Cove	Local Service District Well	0
Mount Carmel-Mitchells Brook-St. Catherine's	Dug	0
North Harbour	Communal Well	0
North Harbour	Grandfathers Pond	0
North West Brook-Ivany's Cove	#1 Well - Cabot Road South Well	0
North West Brook-Ivany's Cove	#2 Well	0
North West Brook-Ivany's Cove	#3 Well - Harbour Well	0
North West Brook-Ivany's Cove	#4 Well (Inactive, not hooked up)	0
O'Donnells	Well Field (well #1)	0
O'Donnells	Well Field (well #2)	0
O'Donnells	Well Field (well #3)	0
Petley	Drilled	0
Point May	Short's Pond	0
Port Blandford	Noseworthy's Pond	0
Port Kirwan	Dug Well / Drilled Well (Drilled Well)	0
Port Rexton	#1 Well - Lois Long Well	0
Port Rexton	#2 Well - Edmund Brown's Well	0
Port Rexton	#3 Well - Harold Vivian's Well	0
Port Rexton	#5 Well - Mabel Clarke's Well	0
Port Rexton	#6 Well - Banister's Well	0
Portugal Cove South	Wrights Brook	0
Queen's Cove	Reservoir	0
Renews-Cappahayden	#1 Dinn's Well	0

Table A3. Percent of water supply area with groundwater vulnerability index exceeding 15

COMMUNITY	SOURCE NAME	% AREA
Small Point-Adam's Cove-Blackhead-Broad Cove	#1 Well - Reg Bursey Well	0
Small Point-Adam's Cove-Blackhead-Broad Cove	#4 Well - Leonard King Well	0
Small Point-Adam's Cove-Blackhead-Broad Cove	#6 Well - Herb Trickett Well	0
Small Point-Adam's Cove-Blackhead-Broad Cove	#7 Well - Gin Badcock Well	0
Small Point-Adam's Cove-Blackhead-Broad Cove	#8 Well - Effie Flight Wells (Inside Well)	0
Small Point-Adam's Cove-Blackhead-Broad Cove	#8 Well - Effie Flight Wells (Outside Well)	0
Small Point-Adam's Cove-Blackhead-Broad Cove	#9 Well - Walter Reynolds Well (Inside Well)	0
Small Point-Adam's Cove-Blackhead-Broad Cove	#9 Well - Walter Reynolds Well (Outside Well)	0
St. Bride's	North Side Brook	0
St. Joseph's	Well Field	0
St. Mary's	Drilled	0
St. Shott's	Unnamed Pond	0
Torbay	North Pond	0
Torbay	South Pond (Proposed)	0
Traytown		0
Wabana	Kelloway's The Front Well - Wabana	0
Wabana	Quigley's Line Well - Wabana	0
Wabana	St. Edwards Well - Wabana	0
Winterland	Well Field	0
Winterton	Winterton Spring Protection Area	0



Legend

Digital Elevation Model

Metres Geodetic

- High : 564.787
- Low : -20.3996

Data Source: CanVec Topographic Data via Geogratis
 Collated and geoprocessed by CBCL Limited

MAP A1

Digital Elevation Model

**Eastern Newfoundland
 Groundwater Vulnerability
 Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

1:1,000,000 @ 11 x 17



Legend

-  Watercourse
-  Inland Water
-  Watershed Group
-  Watershed (>10 km2)

Digital Elevation Model

Metres Geodetic

-  High : 564.787
- Low : -20.3996

Data Source: CanVec Topographic Data via Geogratis
Watersheds geoprocesed by CBCL Limited

MAP A2

Watershed Mapping

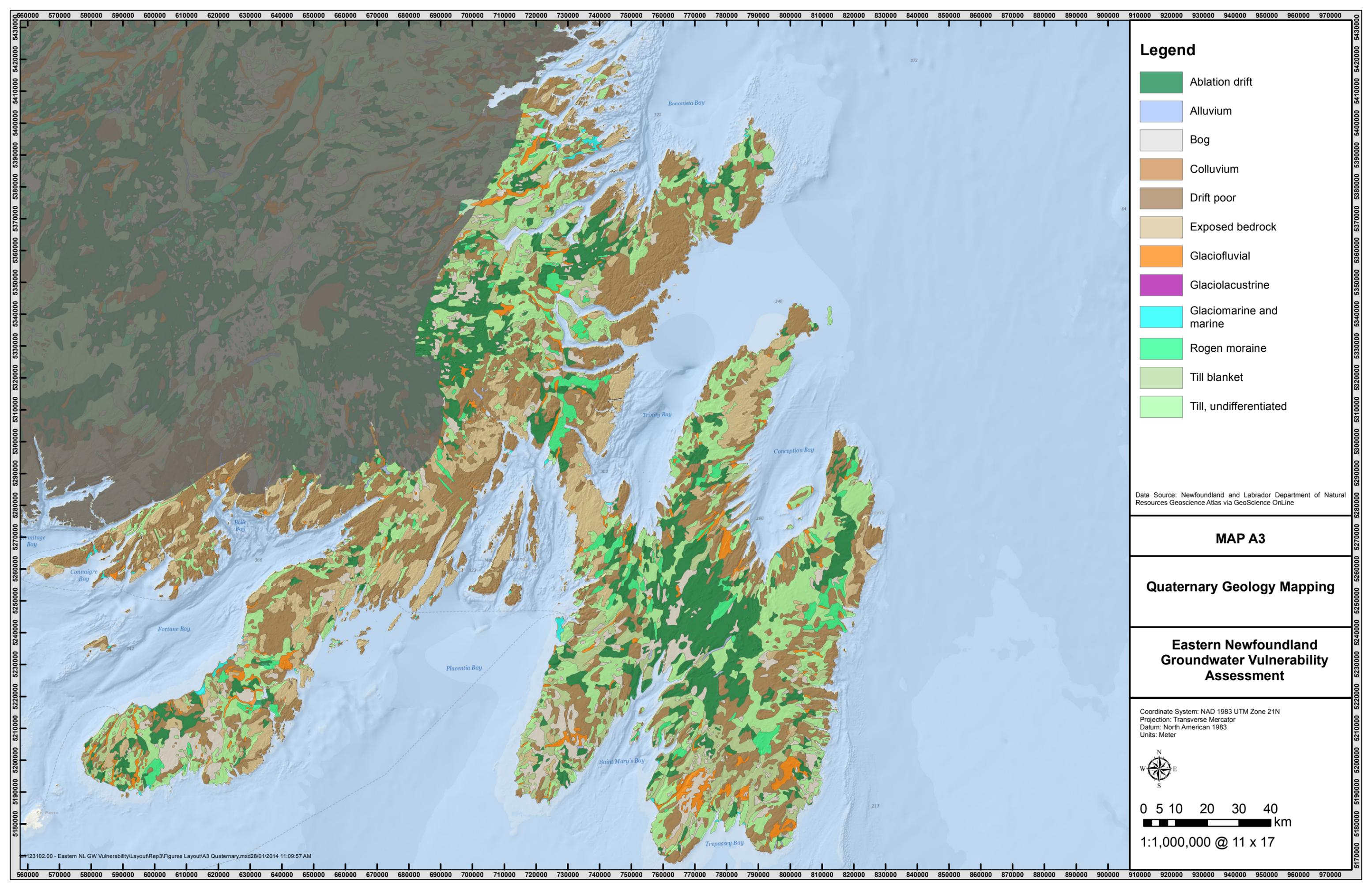
**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter



0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17



- ### Legend
- Ablation drift
 - Alluvium
 - Bog
 - Colluvium
 - Drift poor
 - Exposed bedrock
 - Glaciofluvial
 - Glaciolacustrine
 - Glaciomarine and marine
 - Rogen moraine
 - Till blanket
 - Till, undifferentiated

Data Source: Newfoundland and Labrador Department of Natural Resources Geoscience Atlas via GeoScience OnLine

MAP A3

Quaternary Geology Mapping

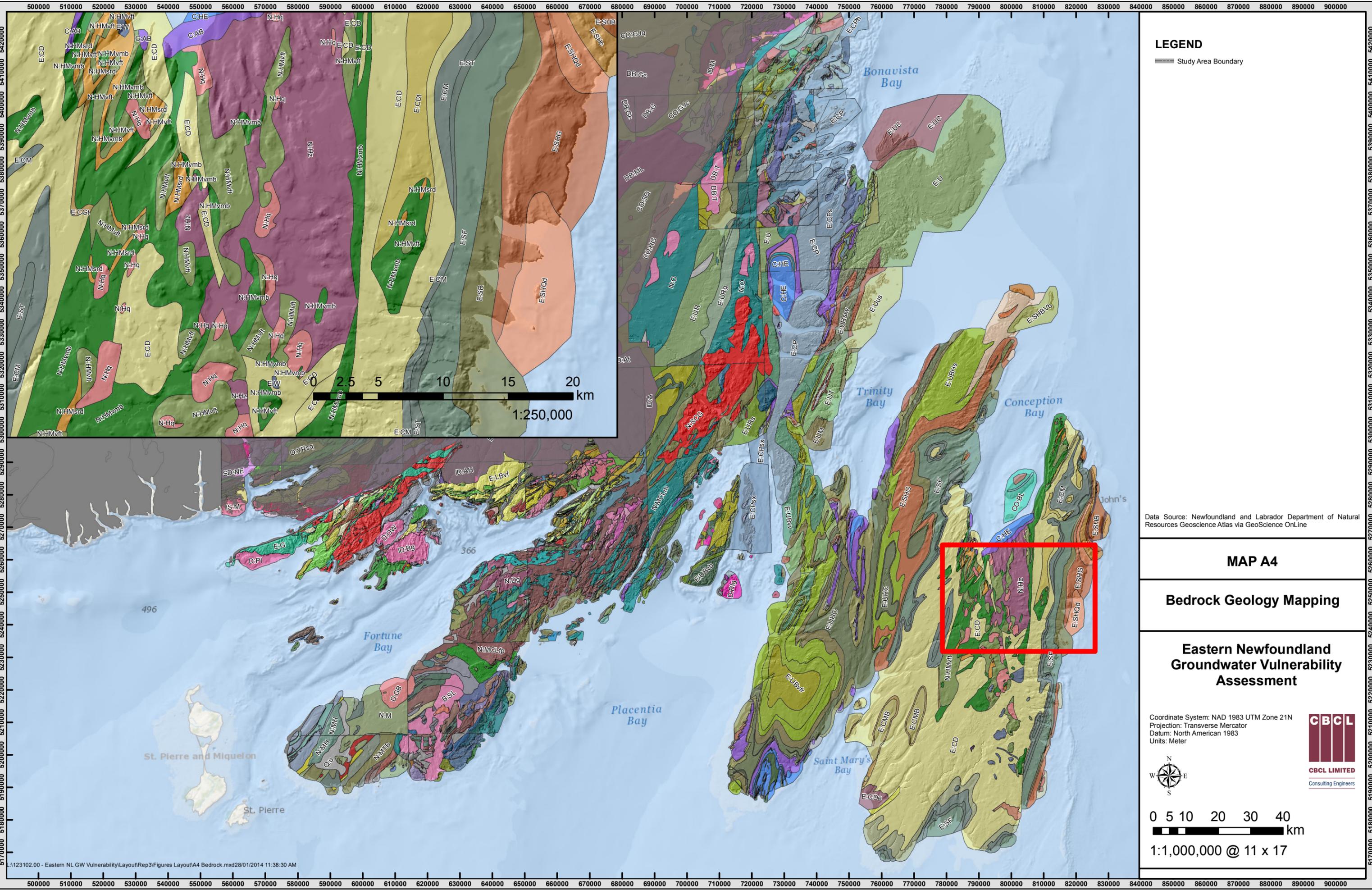
Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



0 5 10 20 30 40
 km

1:1,000,000 @ 11 x 17



LEGEND

Study Area Boundary

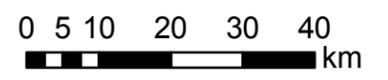
Data Source: Newfoundland and Labrador Department of Natural Resources Geoscience Atlas via GeoScience OnLine

MAP A4

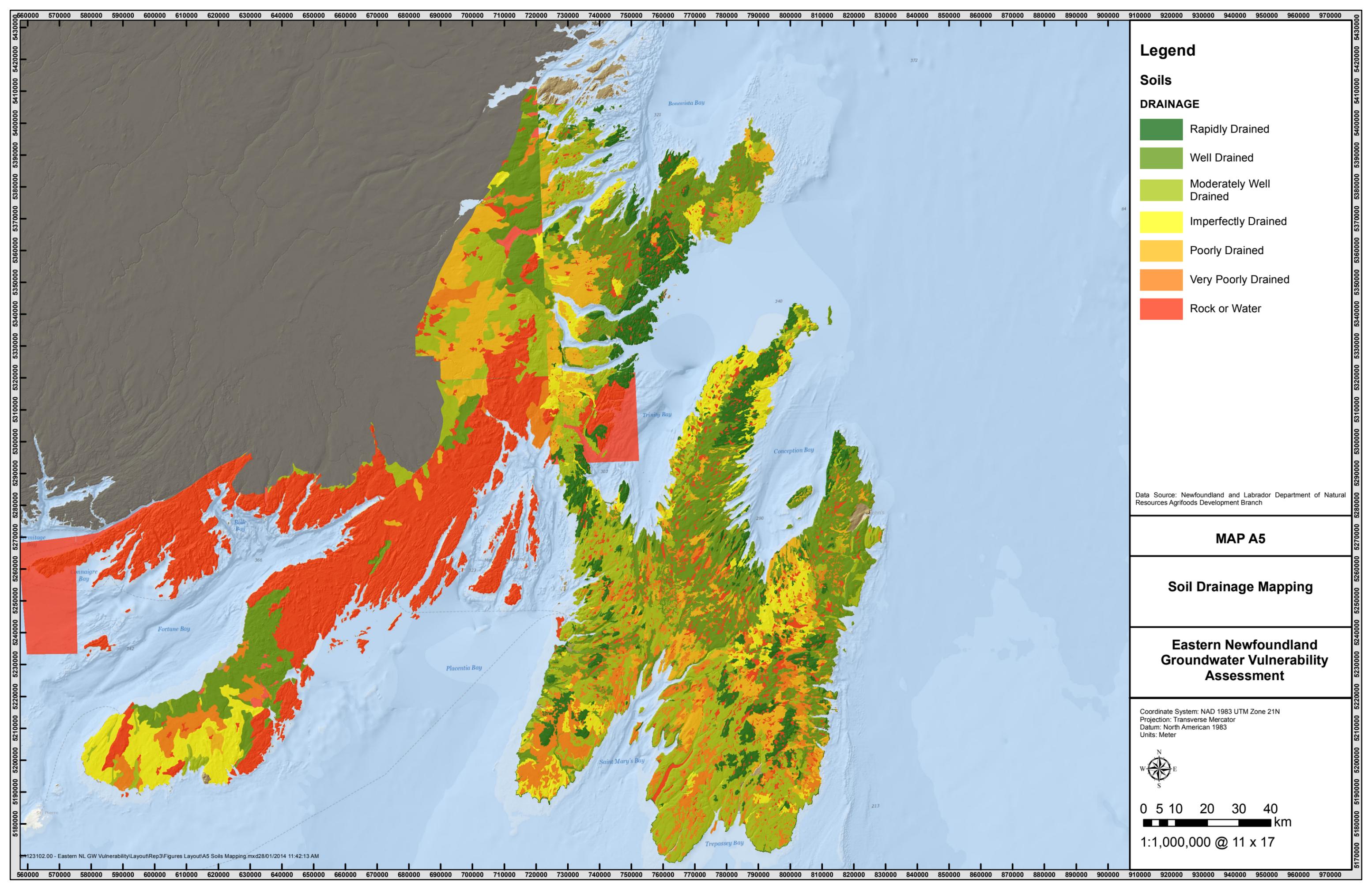
Bedrock Geology Mapping

**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter



1:1,000,000 @ 11 x 17



Legend

Soils

DRAINAGE

- Rapidly Drained
- Well Drained
- Moderately Well Drained
- Imperfectly Drained
- Poorly Drained
- Very Poorly Drained
- Rock or Water

Data Source: Newfoundland and Labrador Department of Natural Resources Agrifoods Development Branch

MAP A5

Soil Drainage Mapping

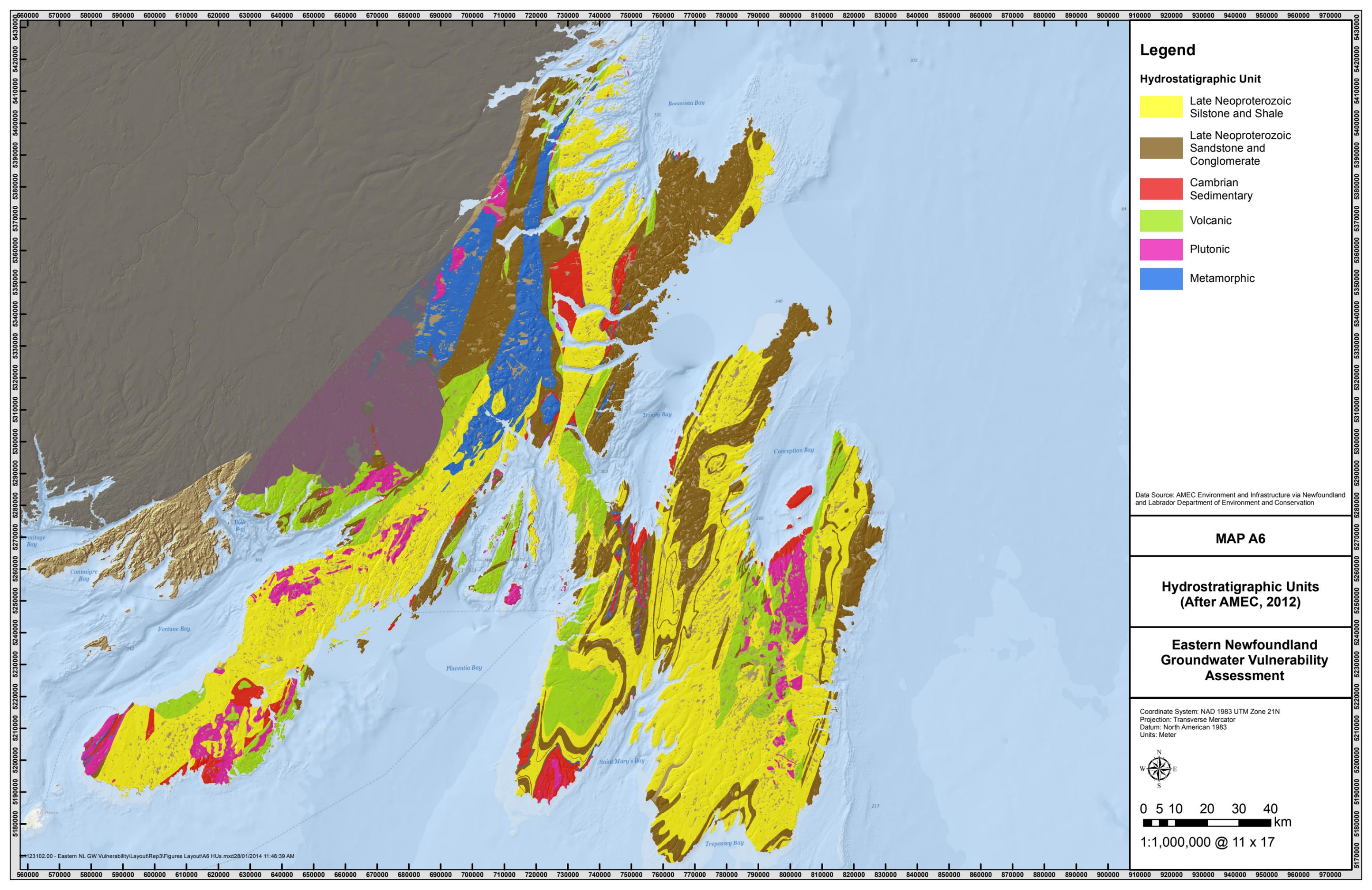
**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17



Legend

Hydrostratigraphic Unit

- Late Neoproterozoic Silstone and Shale
- Late Neoproterozoic Sandstone and Conglomerate
- Cambrian Sedimentary
- Volcanic
- Plutonic
- Metamorphic

Data Source: AMEC Environment and Infrastructure via Newfoundland and Labrador Department of Environment and Conservation

MAP A6

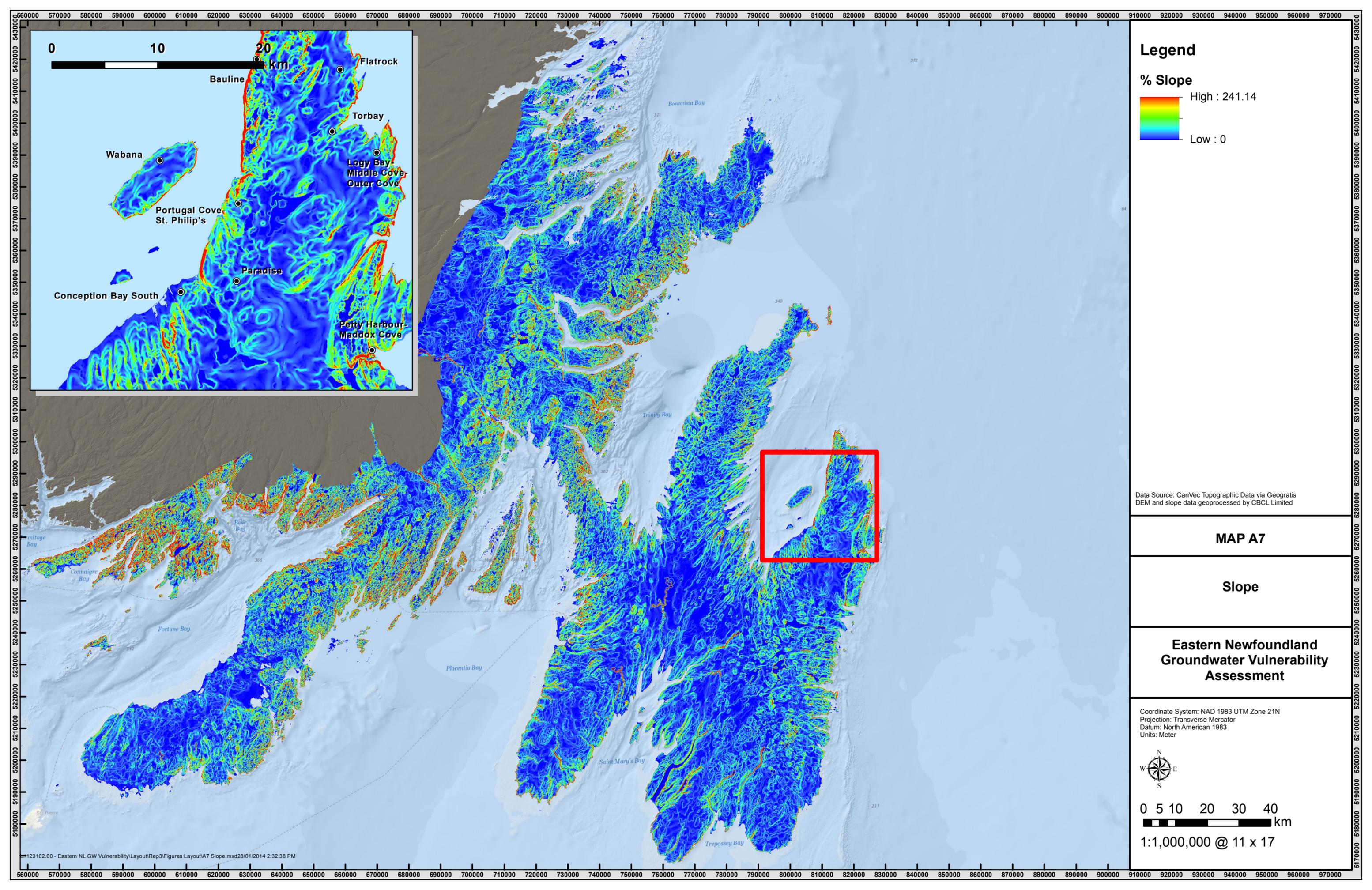
Hydrostratigraphic Units (After AMEC, 2012)

Eastern Newfoundland Groundwater Vulnerability Assessment

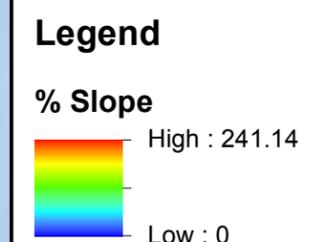
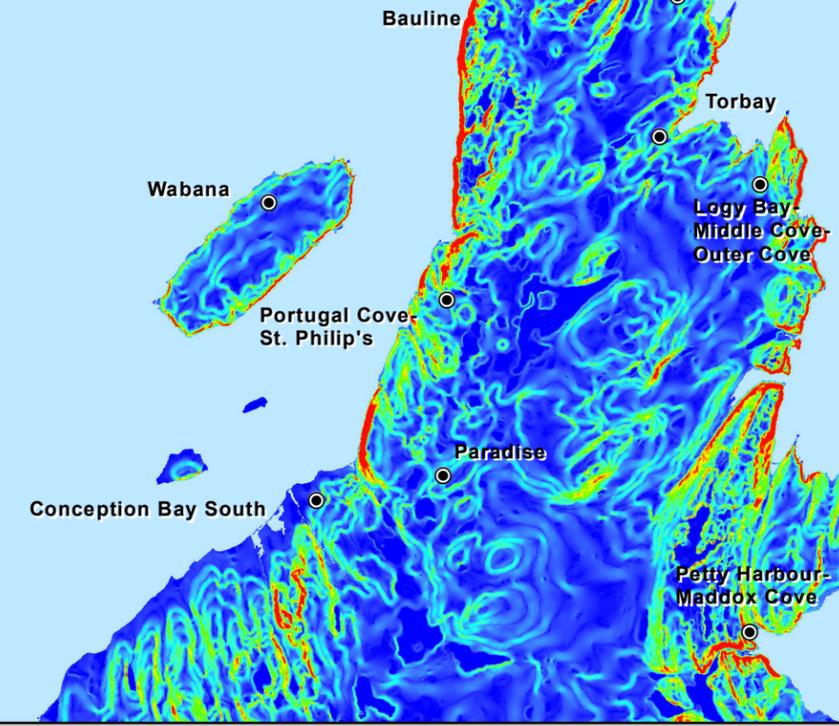
Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17



0 10 20 km



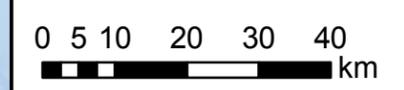
Data Source: CanVec Topographic Data via Geogistics
DEM and slope data geoprocesed by CBCL Limited

MAP A7

Slope

**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter



1:1,000,000 @ 11 x 17



Legend

- Town
- Drilled Well Database: Records with GPS or map coordinates
- Arterial Highway
- Regional Road
- Road
- Street

Data Source: Newfoundland and Labrador Department of Environment and Conservation Drilled Well Database

MAP A8

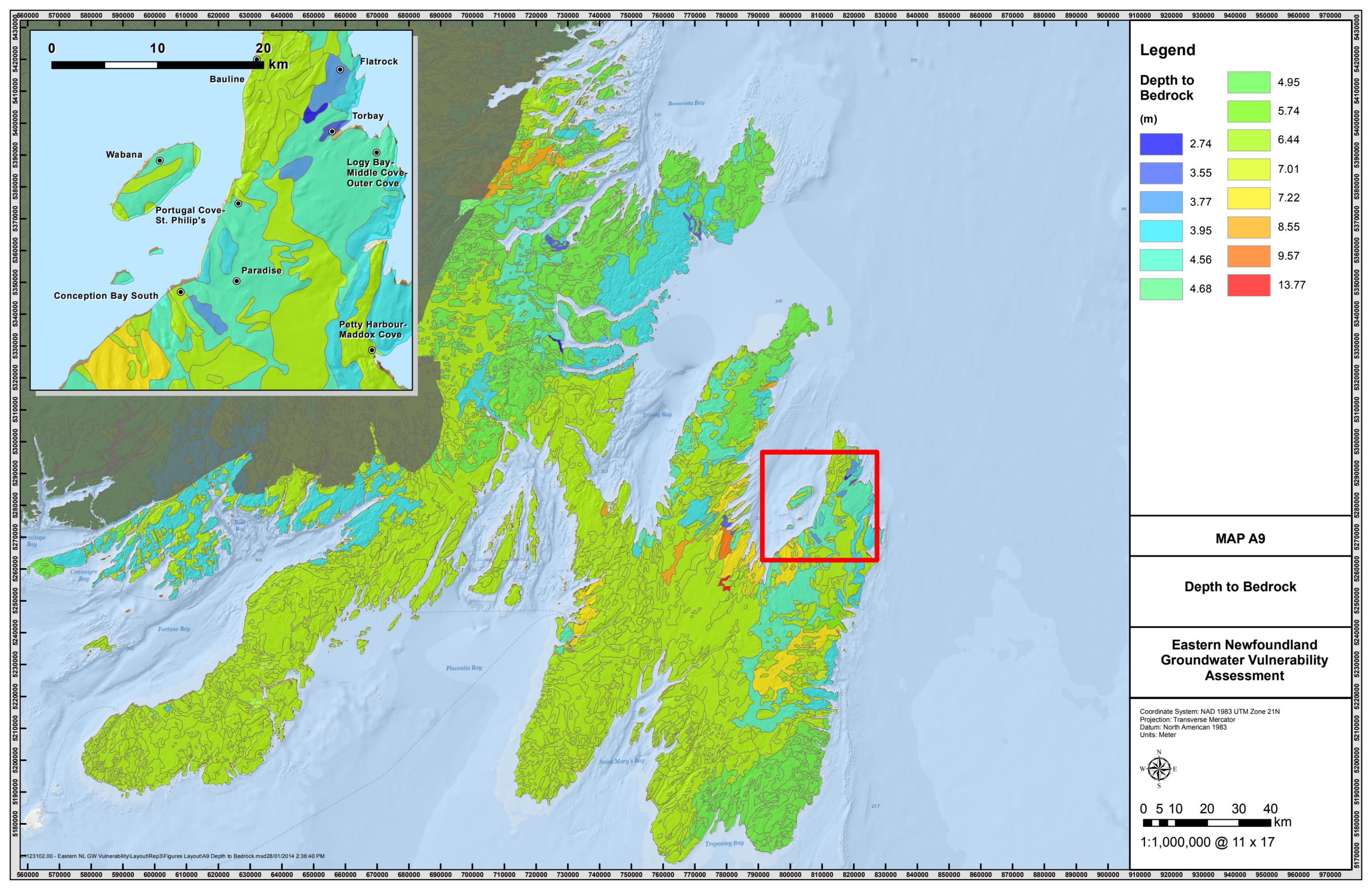
Drilled Well Records with GPS or Map Coordinates

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



1:1,000,000 @ 11 x 17



Legend

Depth to Bedrock (m)

	4.95
	5.74
	6.44
	7.01
	7.22
	8.55
	9.57
	13.77
	3.95
	3.77
	3.55
	2.74
	4.56
	4.68

MAP A9

Depth to Bedrock

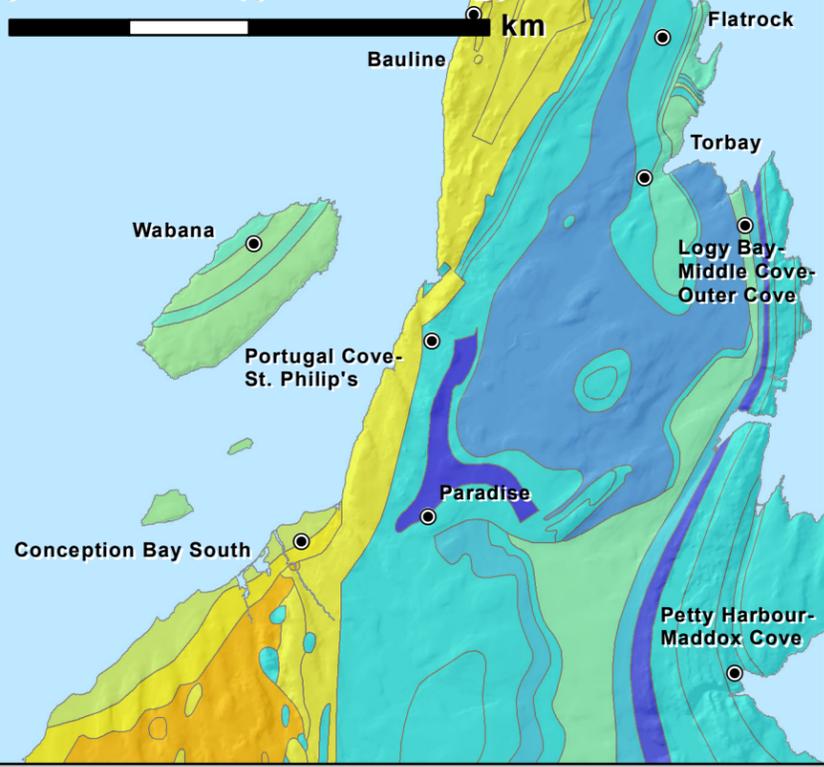
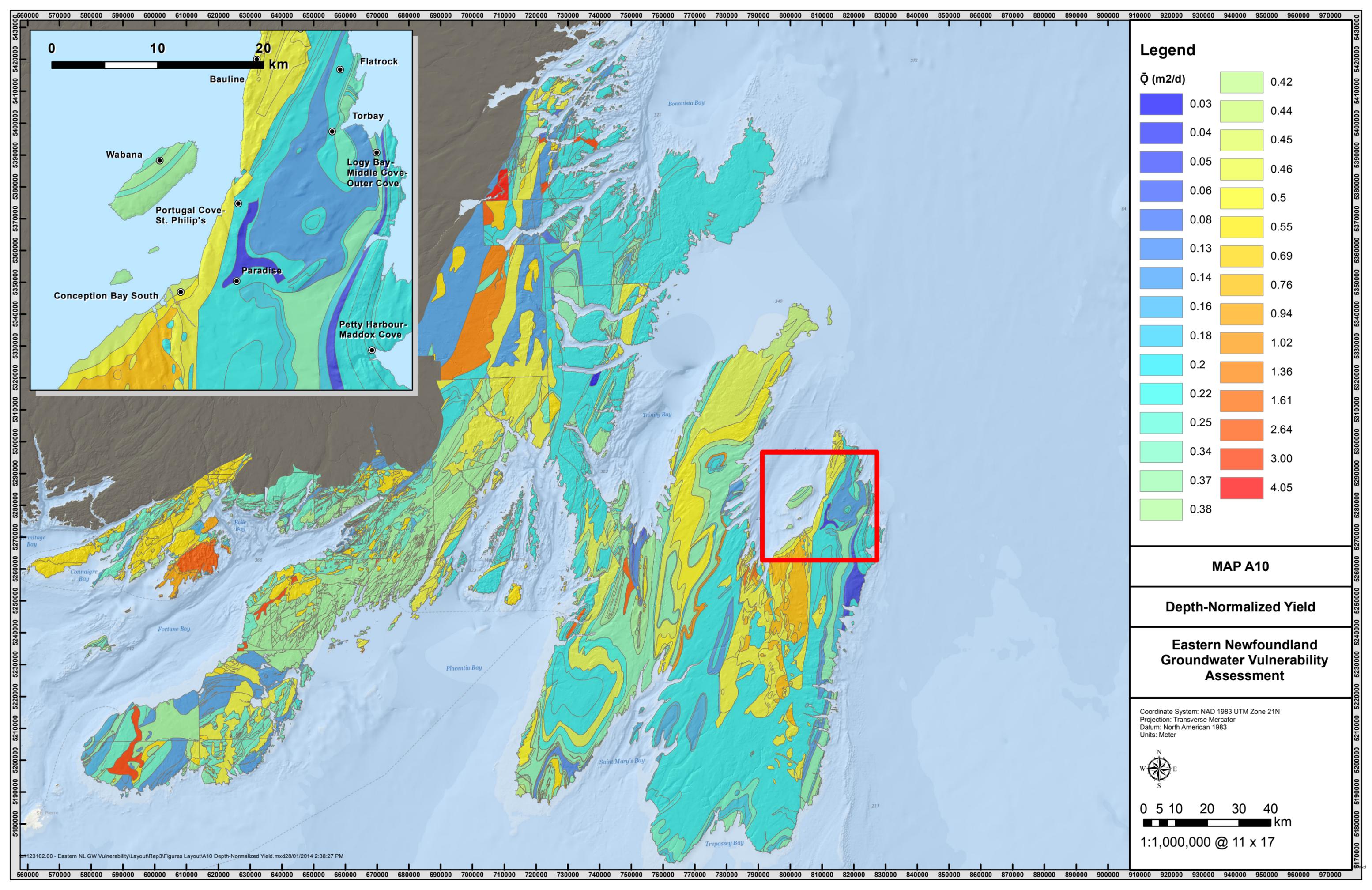
**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

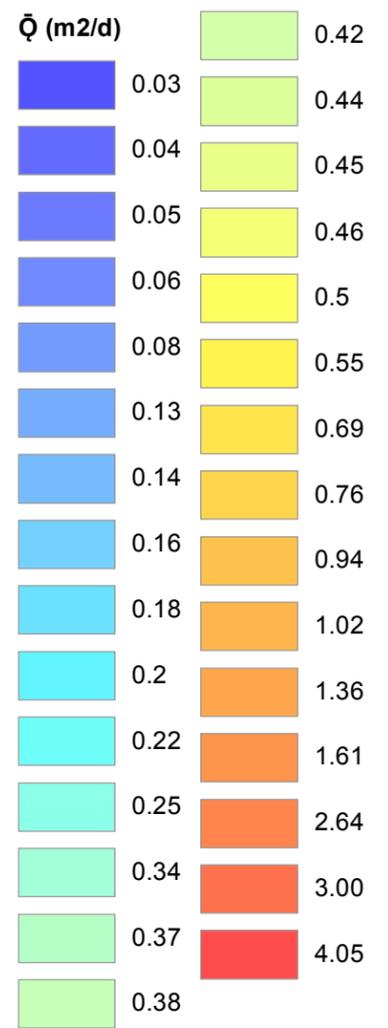


0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17



Legend

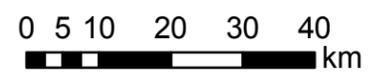


MAP A10

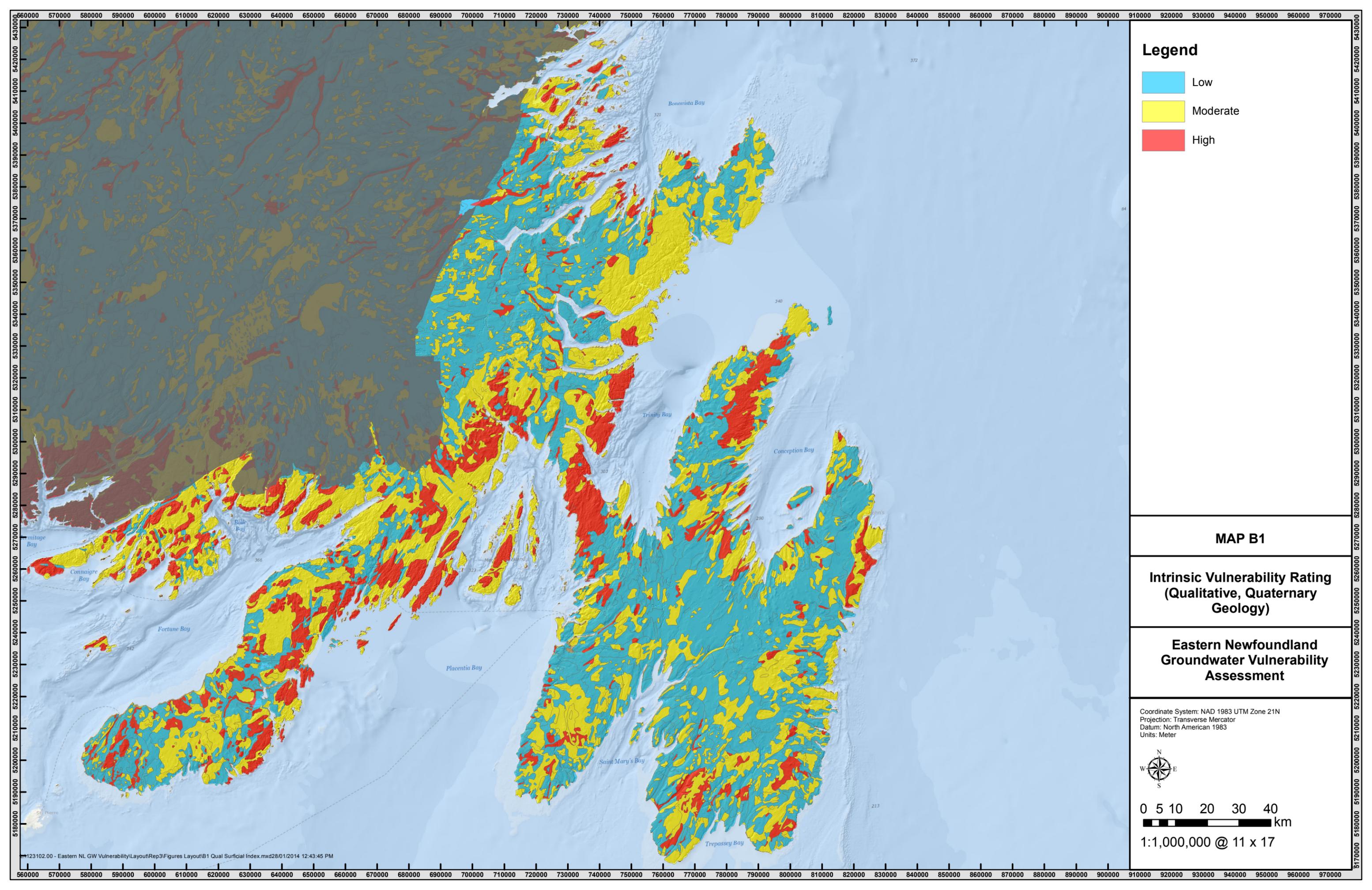
Depth-Normalized Yield

**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



1:1,000,000 @ 11 x 17



Legend

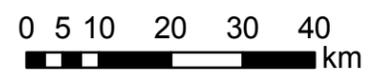
- Low
- Moderate
- High

MAP B1

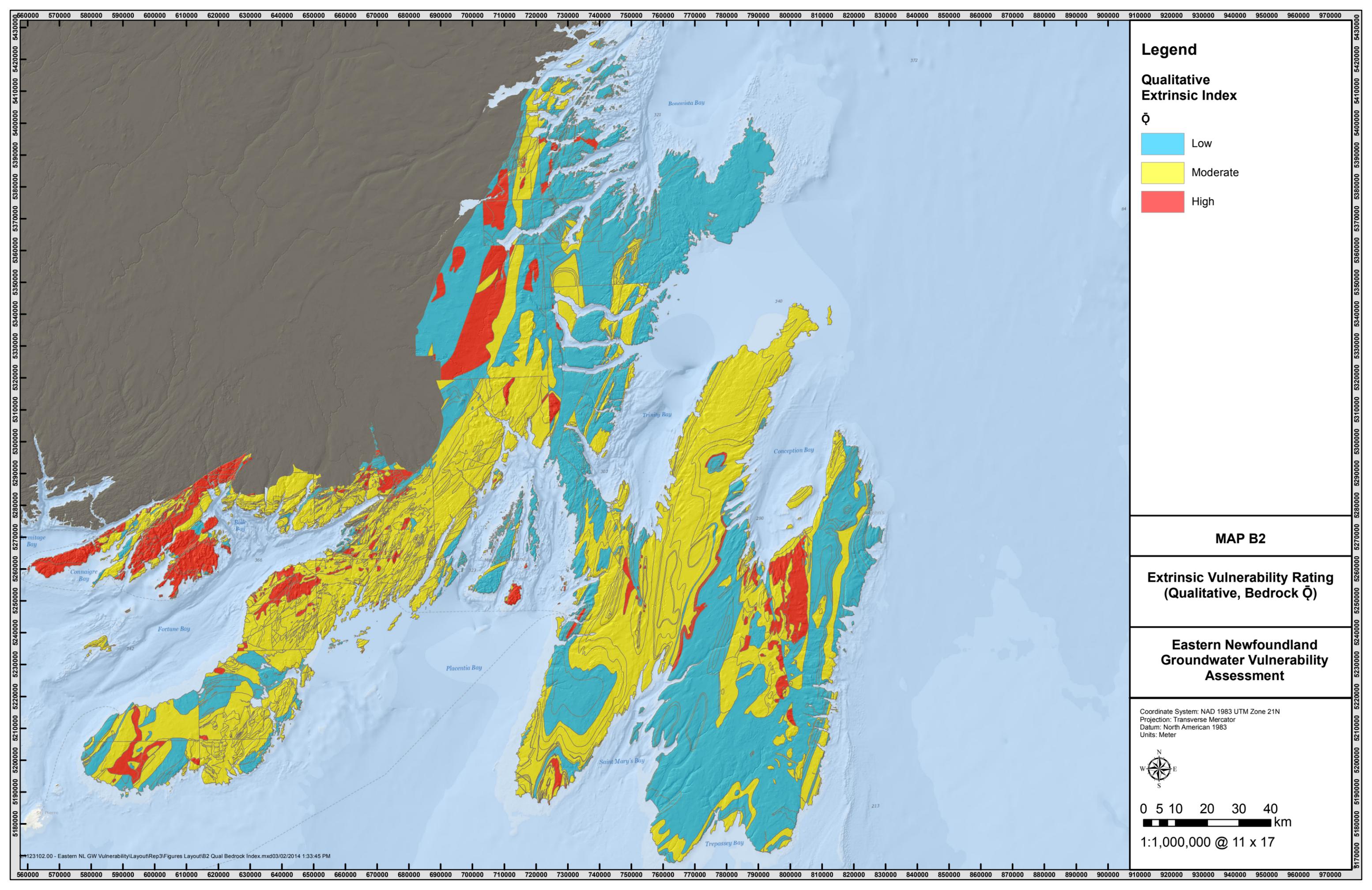
**Intrinsic Vulnerability Rating
(Qualitative, Quaternary
Geology)**

**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



1:1,000,000 @ 11 x 17



Legend

Qualitative Extrinsic Index

\bar{Q}

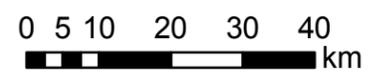
- Low
- Moderate
- High

MAP B2

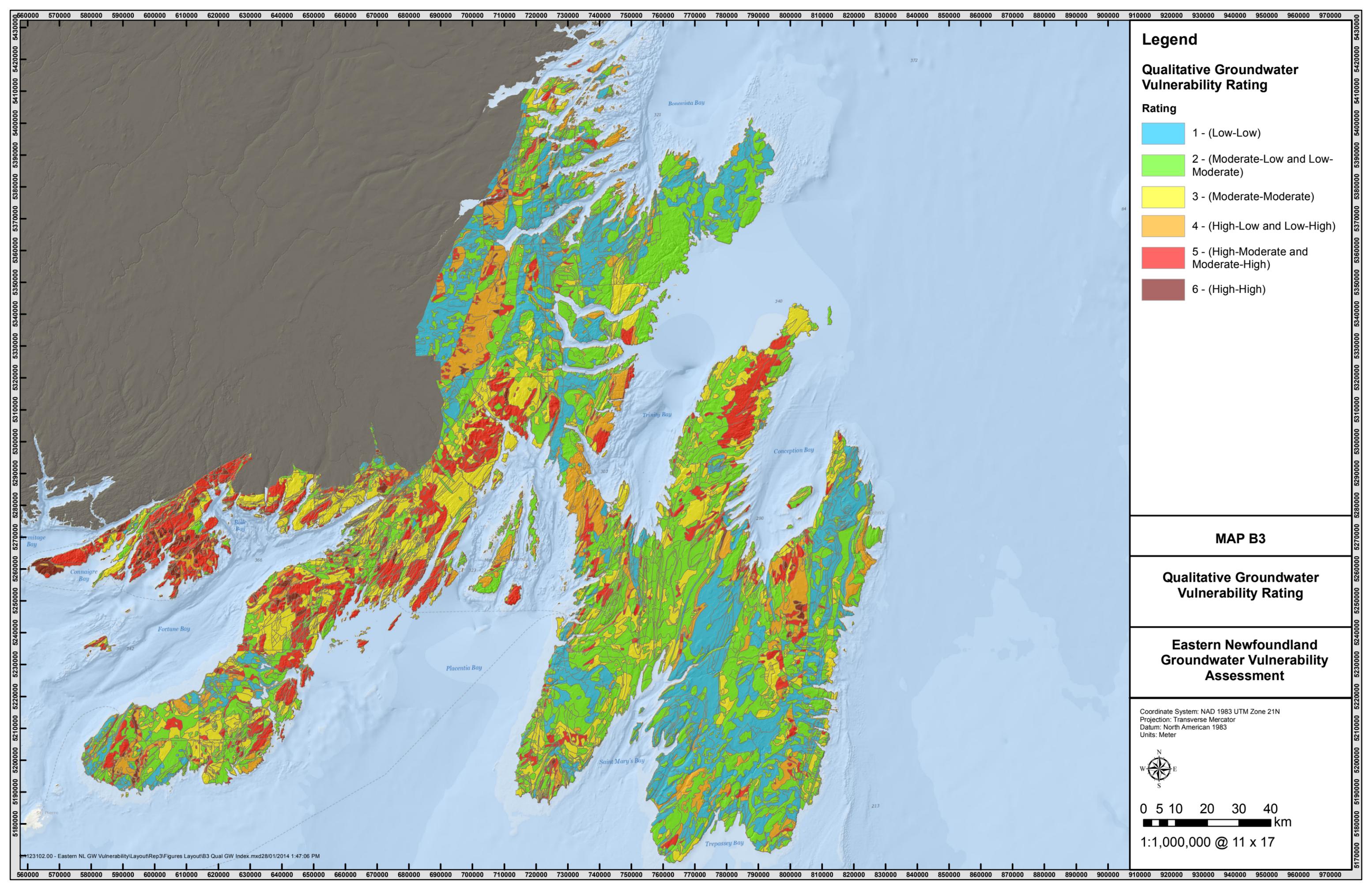
**Extrinsic Vulnerability Rating
(Qualitative, Bedrock \bar{Q})**

**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



1:1,000,000 @ 11 x 17



Legend

Qualitative Groundwater Vulnerability Rating

Rating

- 1 - (Low-Low)
- 2 - (Moderate-Low and Low-Moderate)
- 3 - (Moderate-Moderate)
- 4 - (High-Low and Low-High)
- 5 - (High-Moderate and Moderate-High)
- 6 - (High-High)

MAP B3

Qualitative Groundwater Vulnerability Rating

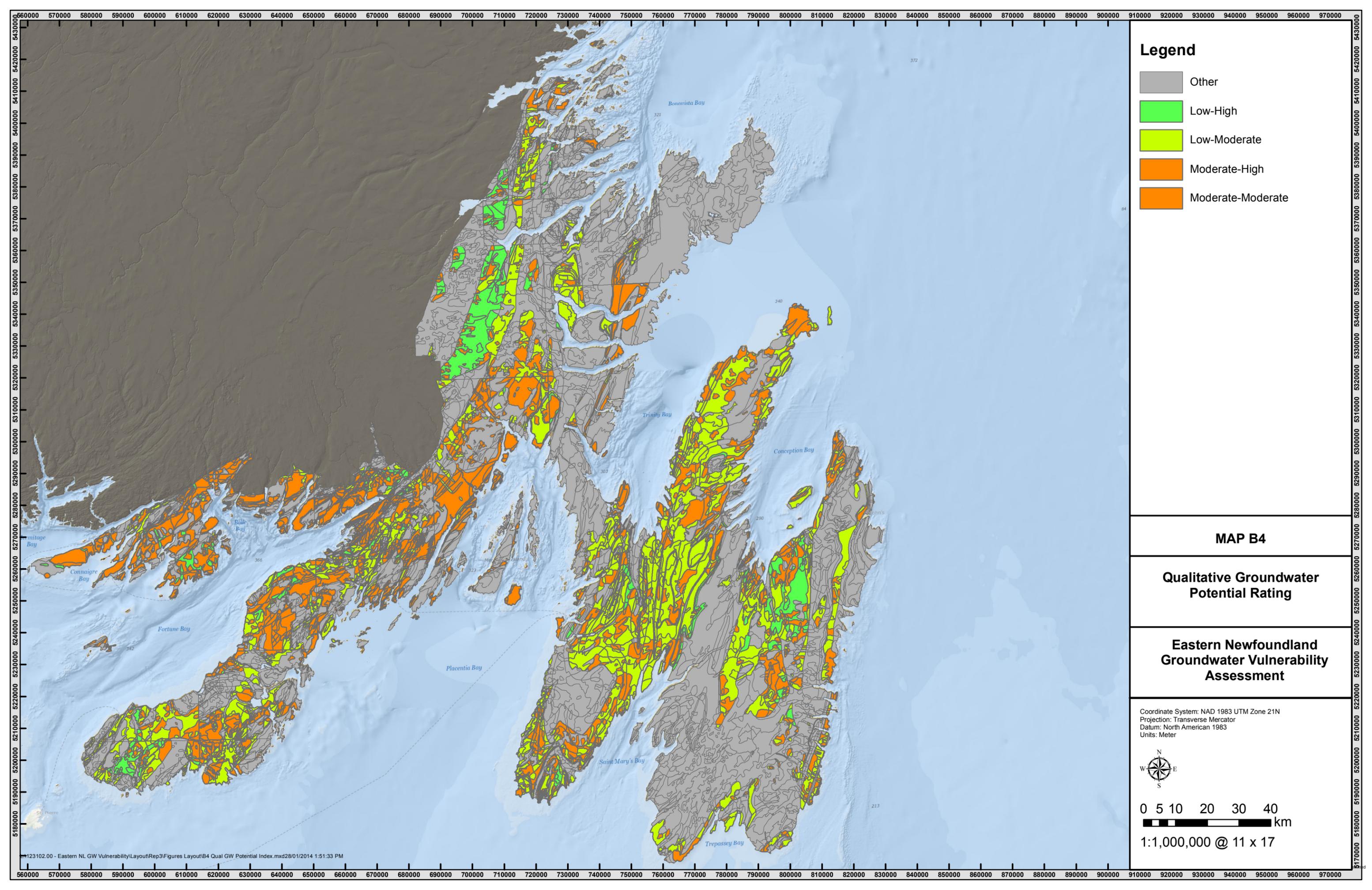
Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17



Legend

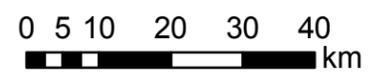
- Other
- Low-High
- Low-Moderate
- Moderate-High
- Moderate-Moderate

MAP B4

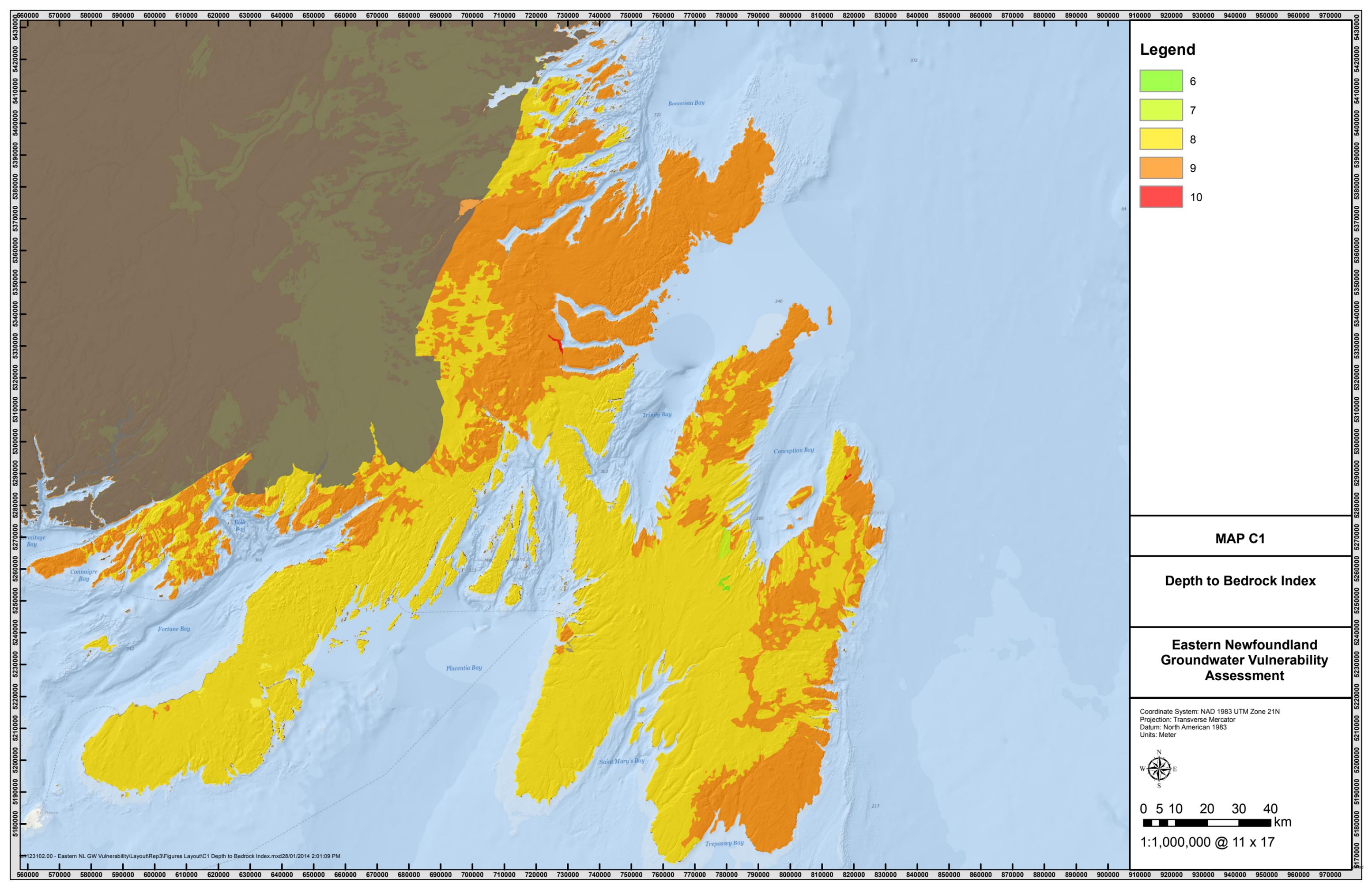
Qualitative Groundwater Potential Rating

Eastern Newfoundland Groundwater Vulnerability Assessment

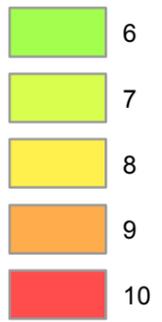
Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



1:1,000,000 @ 11 x 17



Legend

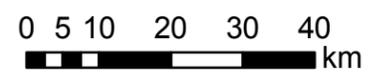


MAP C1

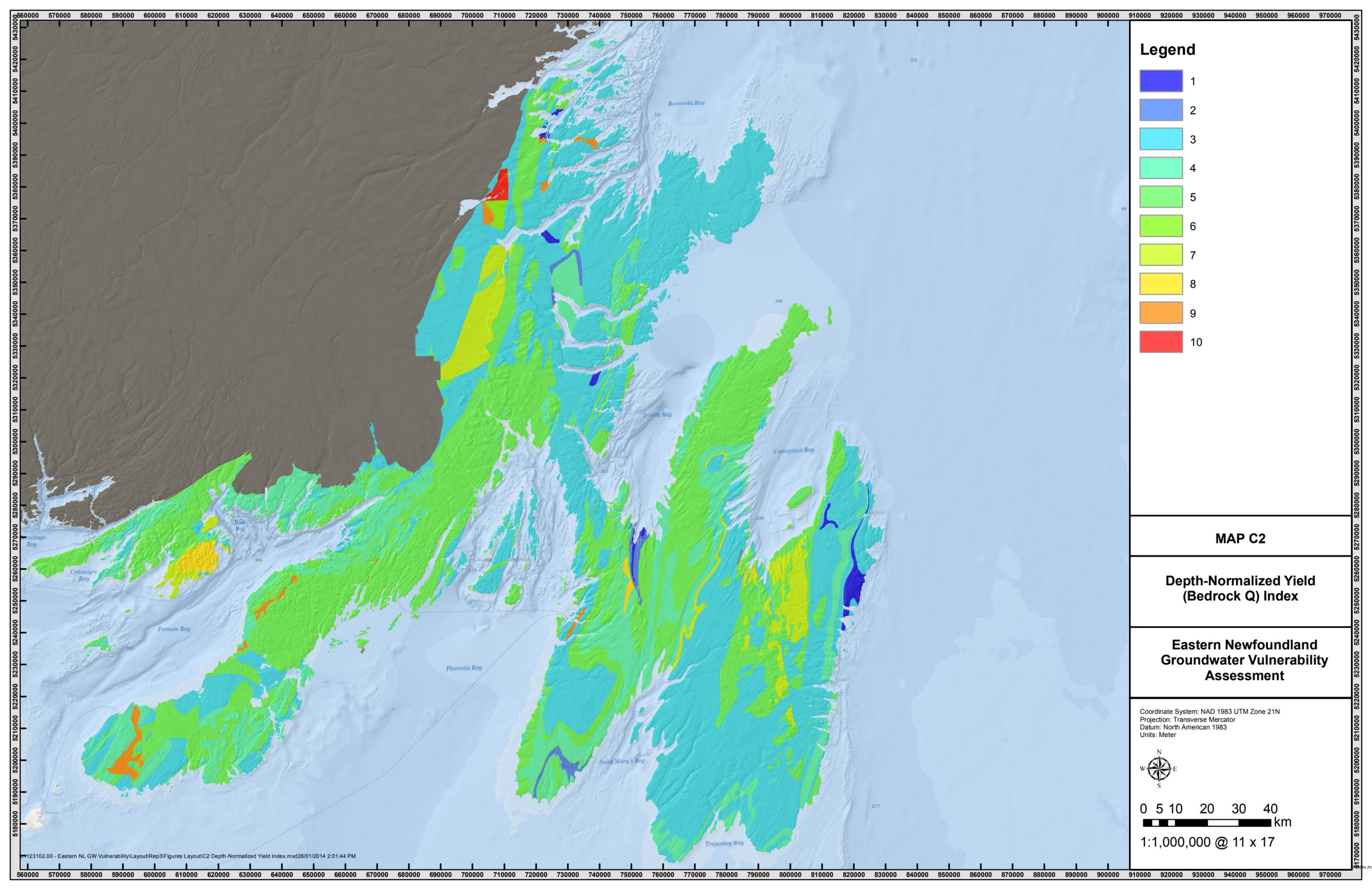
Depth to Bedrock Index

**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

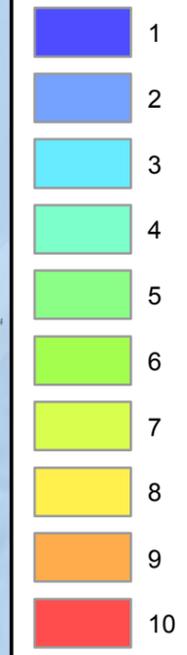
Coordinate System: NAD 1983 UTM Zone 21N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter



1:1,000,000 @ 11 x 17



Legend

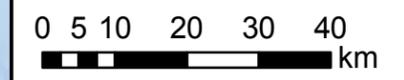


MAP C2

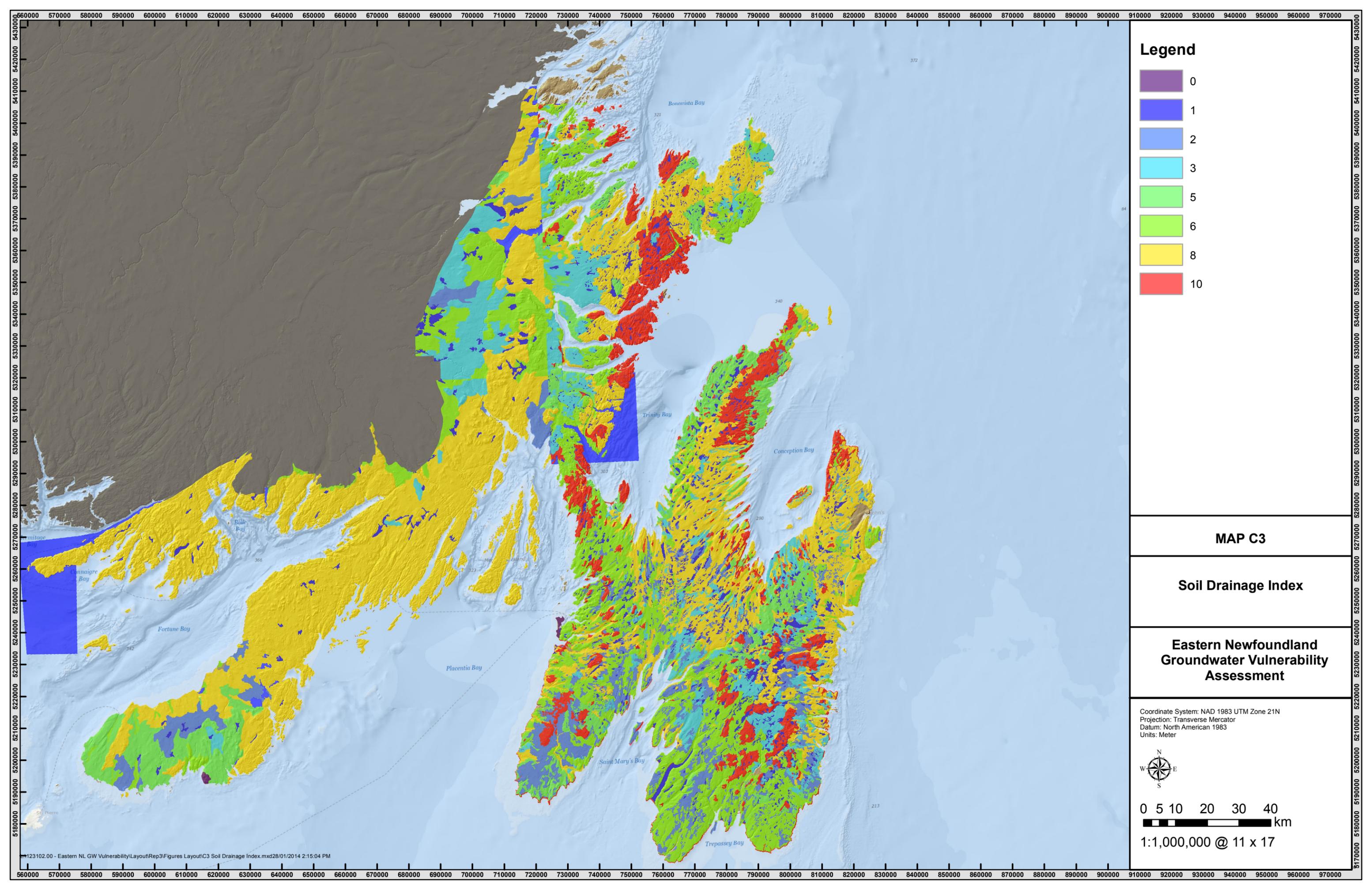
Depth-Normalized Yield (Bedrock Q) Index

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter



1:1,000,000 @ 11 x 17



Legend

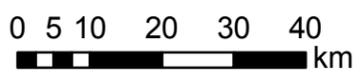


MAP C3

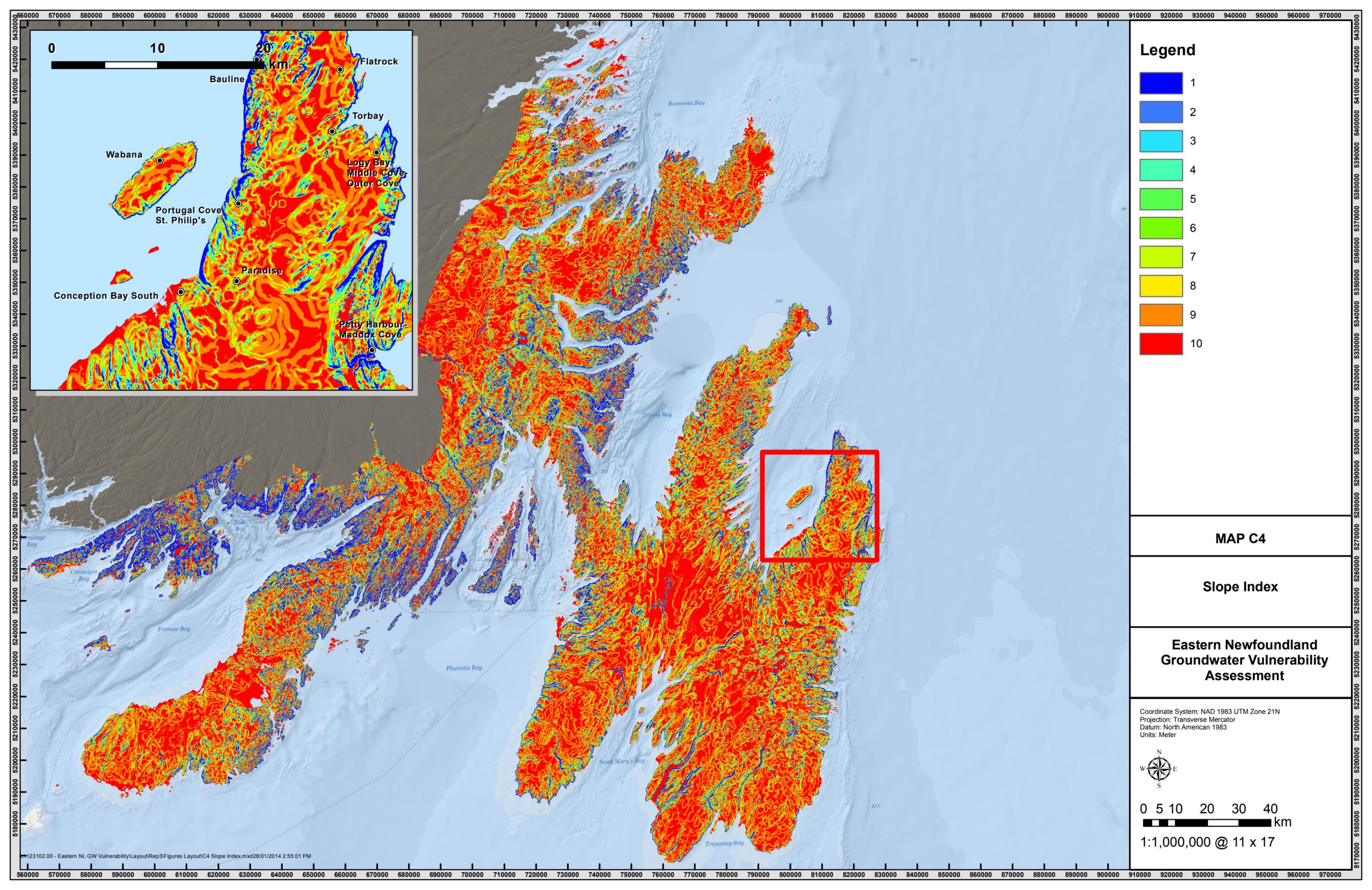
Soil Drainage Index

**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

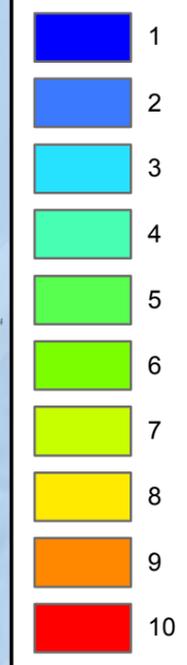
Coordinate System: NAD 1983 UTM Zone 21N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter



1:1,000,000 @ 11 x 17



Legend

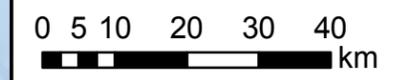


MAP C4

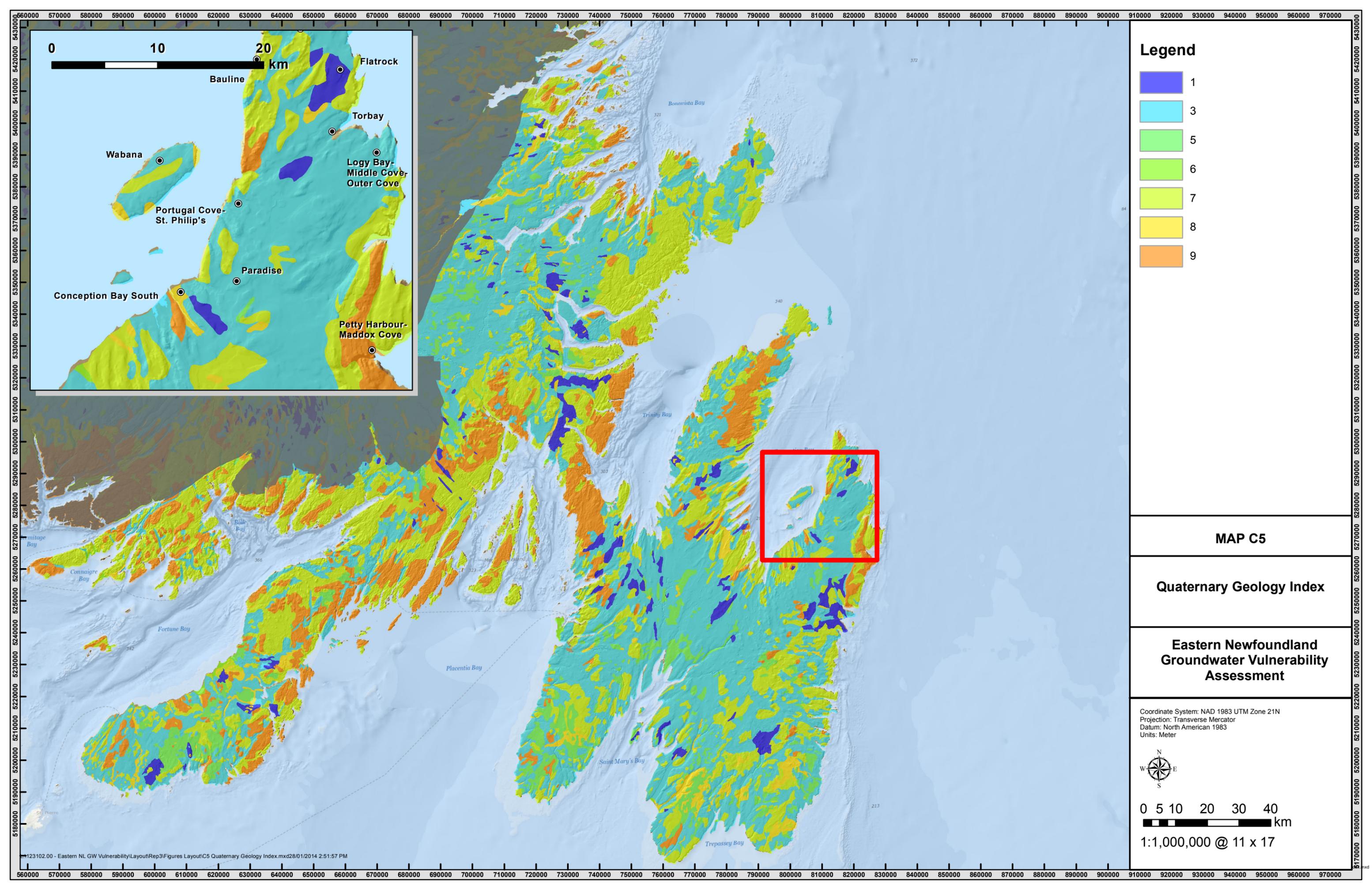
Slope Index

**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

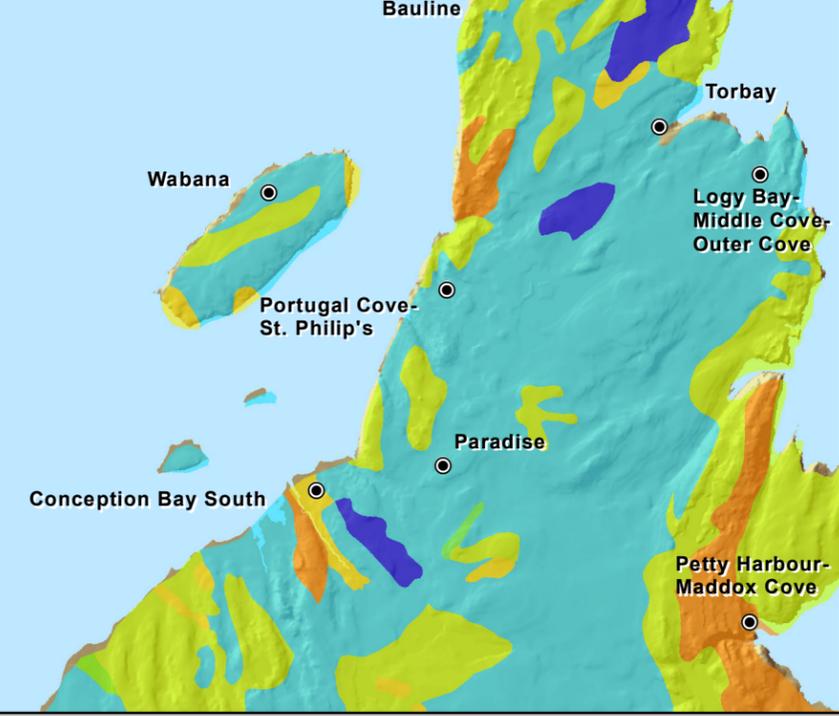
Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



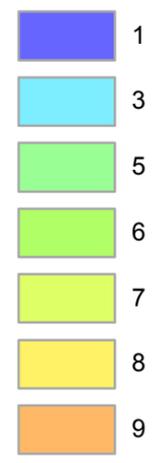
1:1,000,000 @ 11 x 17



0 10 20 km



Legend



MAP C5

Quaternary Geology Index

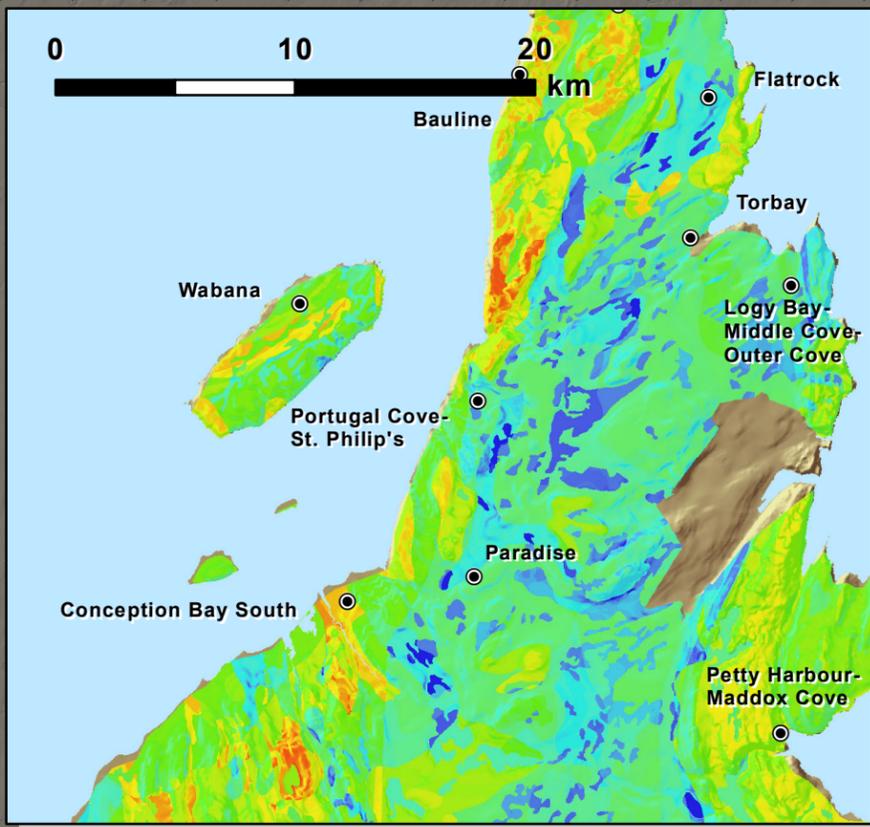
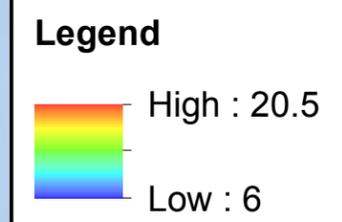
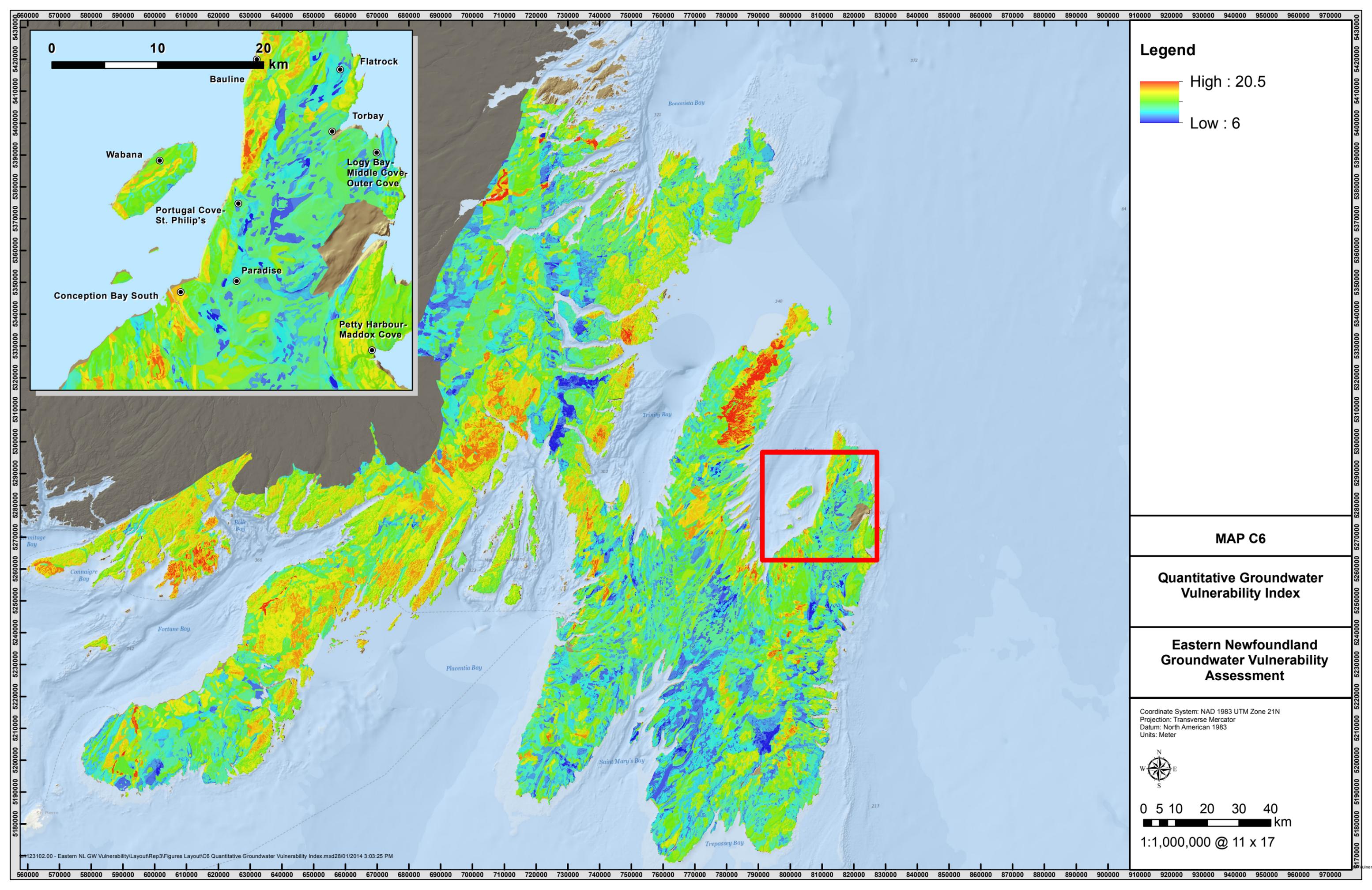
**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17



MAP C6

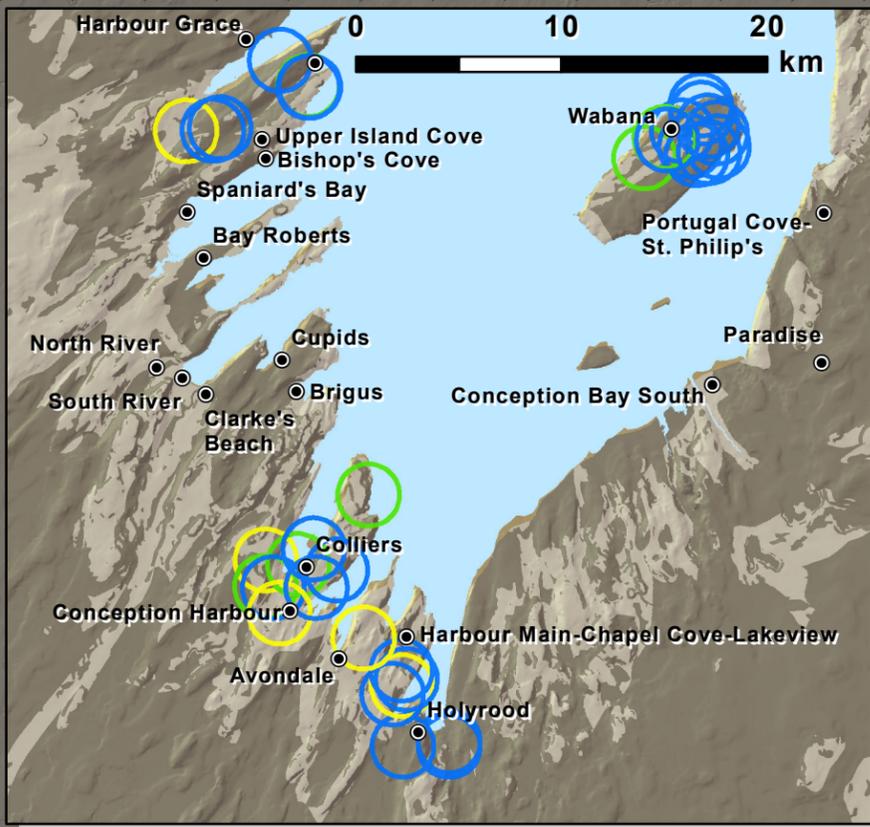
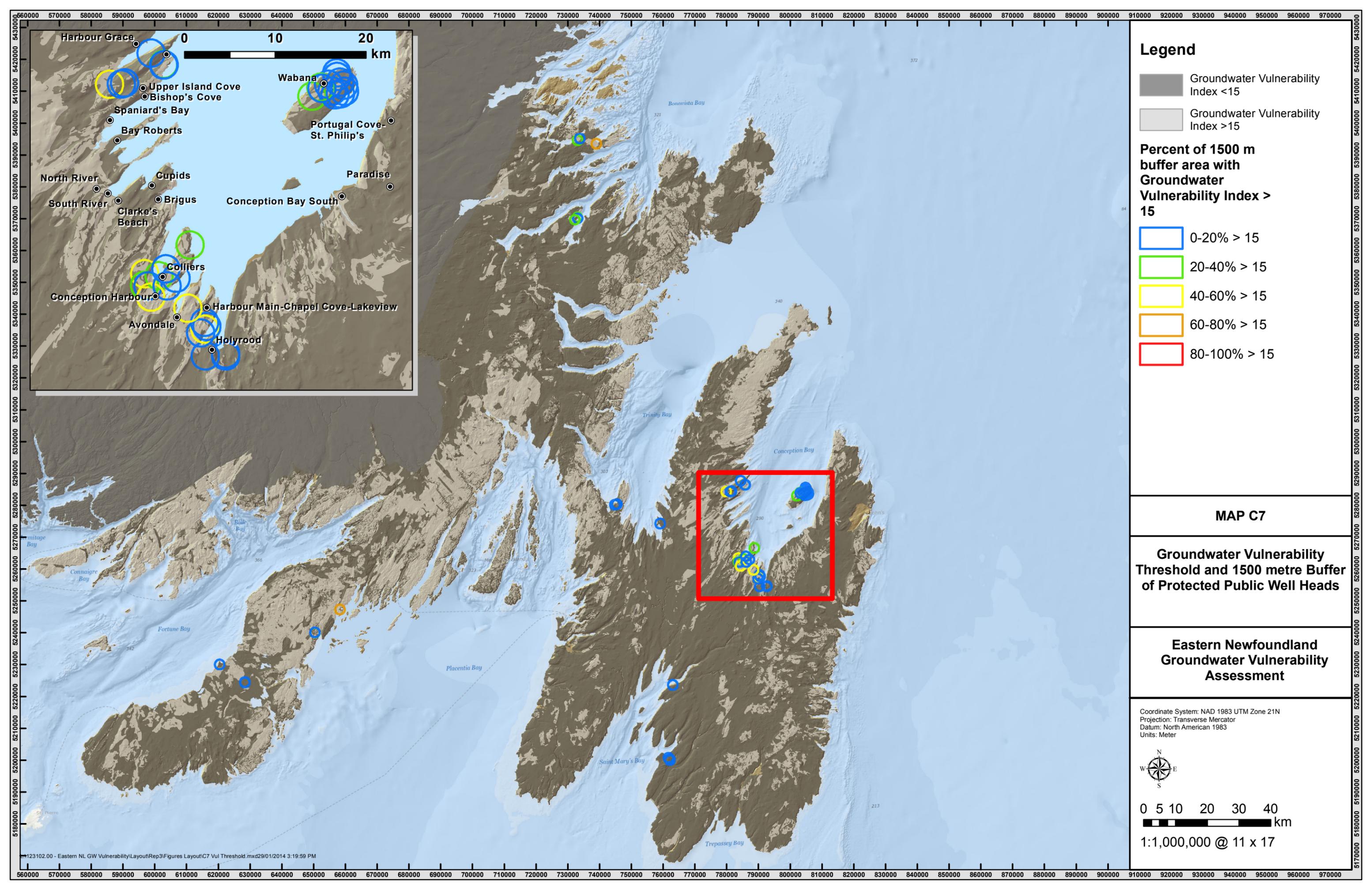
Quantitative Groundwater Vulnerability Index

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17



Legend

- Groundwater Vulnerability Index < 15
- Groundwater Vulnerability Index > 15

Percent of 1500 m buffer area with Groundwater Vulnerability Index > 15

- 0-20% > 15
- 20-40% > 15
- 40-60% > 15
- 60-80% > 15
- 80-100% > 15

MAP C7

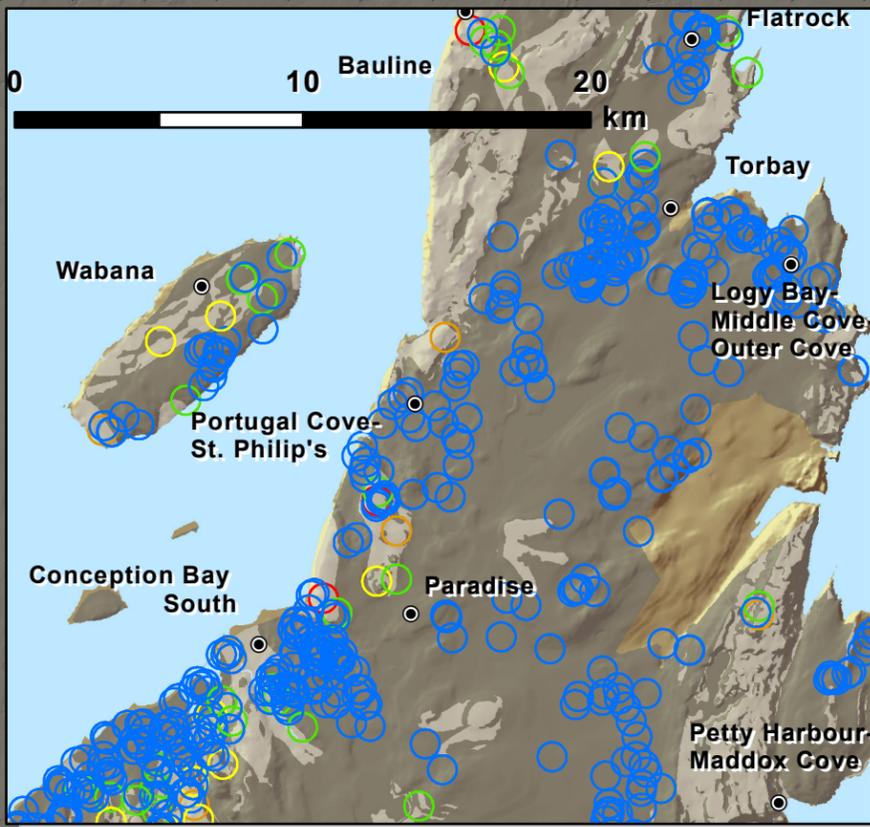
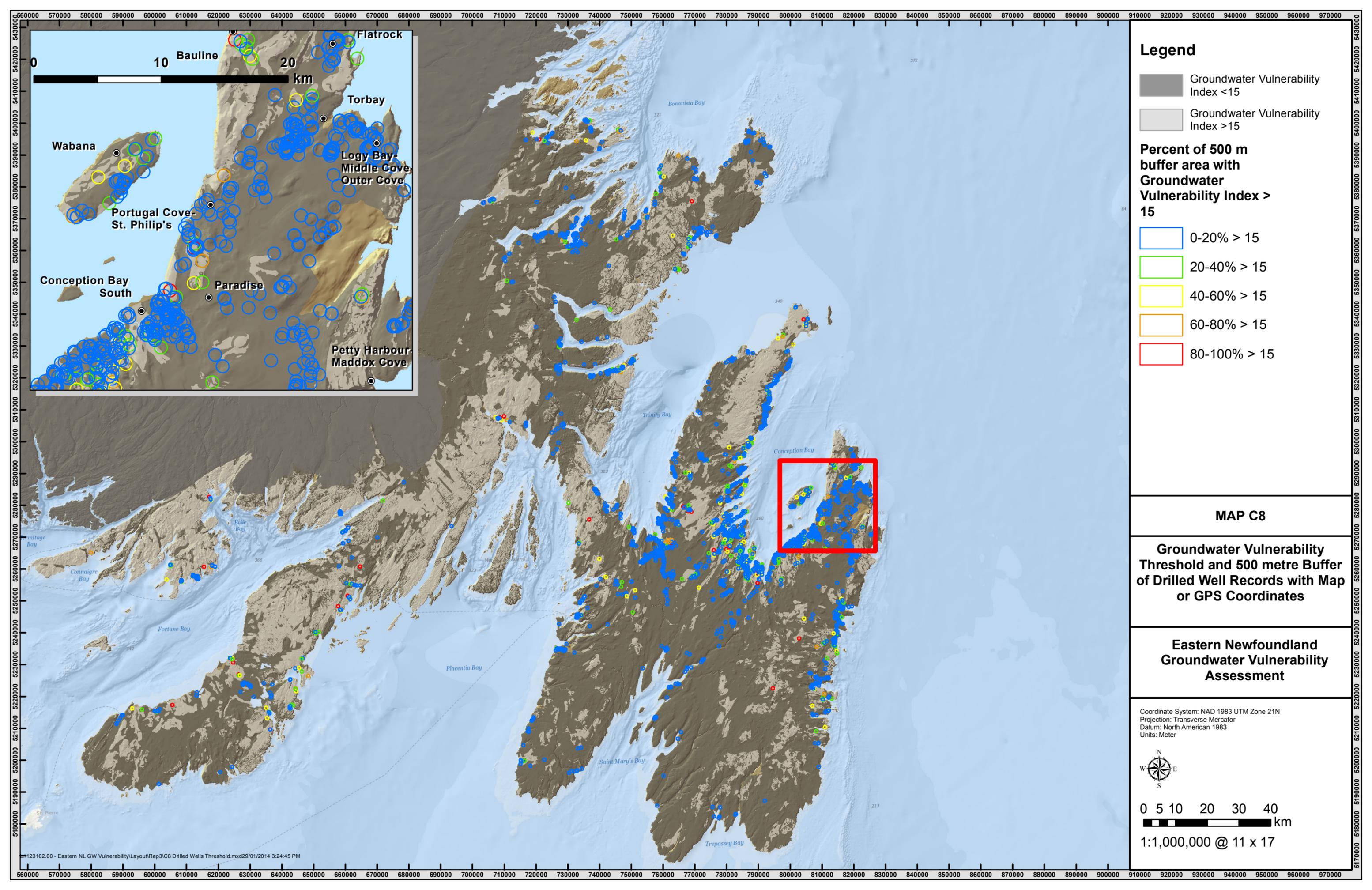
Groundwater Vulnerability Threshold and 1500 metre Buffer of Protected Public Well Heads

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17



Legend

- Groundwater Vulnerability Index < 15
- Groundwater Vulnerability Index > 15

Percent of 500 m buffer area with Groundwater Vulnerability Index > 15

- 0-20% > 15
- 20-40% > 15
- 40-60% > 15
- 60-80% > 15
- 80-100% > 15

MAP C8

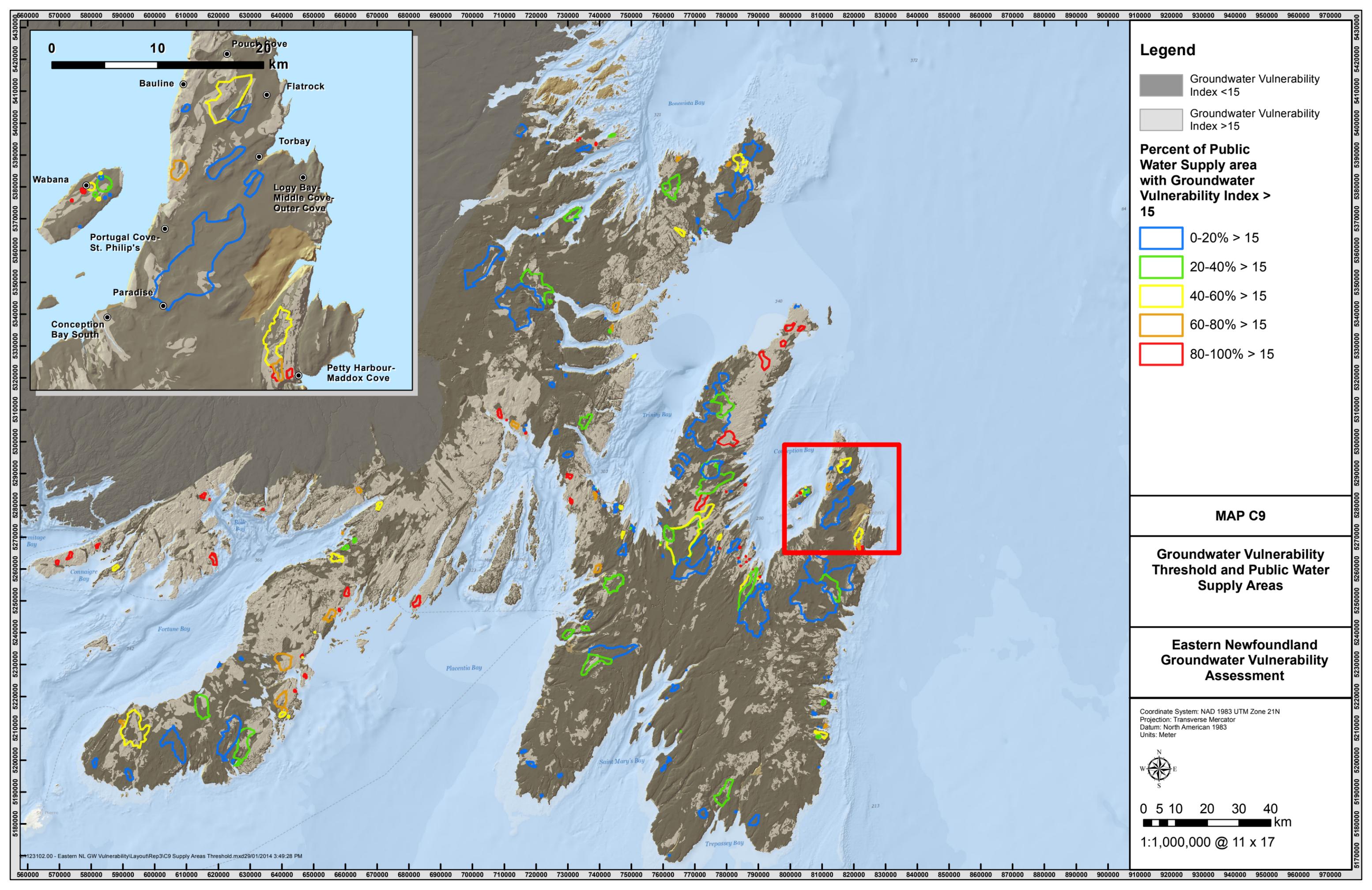
Groundwater Vulnerability Threshold and 500 metre Buffer of Drilled Well Records with Map or GPS Coordinates

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17



Legend

Groundwater Vulnerability Index <15

Groundwater Vulnerability Index >15

Percent of Public Water Supply area with Groundwater Vulnerability Index > 15

0-20% > 15

20-40% > 15

40-60% > 15

60-80% > 15

80-100% > 15

MAP C9

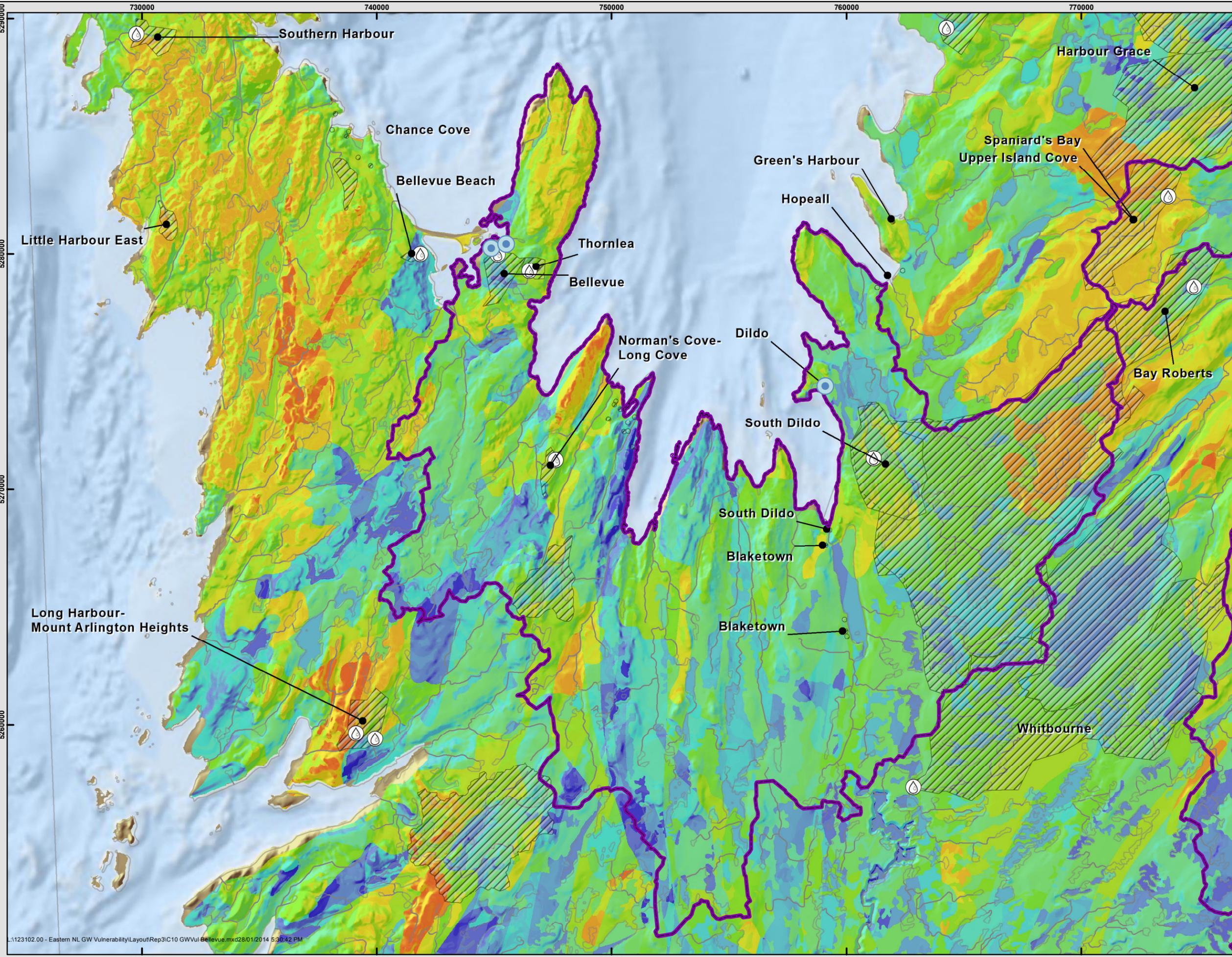
Groundwater Vulnerability Threshold and Public Water Supply Areas

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17



Legend

- Bellevue-Dildo
- Protected Well Head
- Public Water Intake
- Public Water Supply Area
- Watercourse
- Inland Water

Groundwater Vulnerability Index

High : 20.5

Low : 6

MAP C10

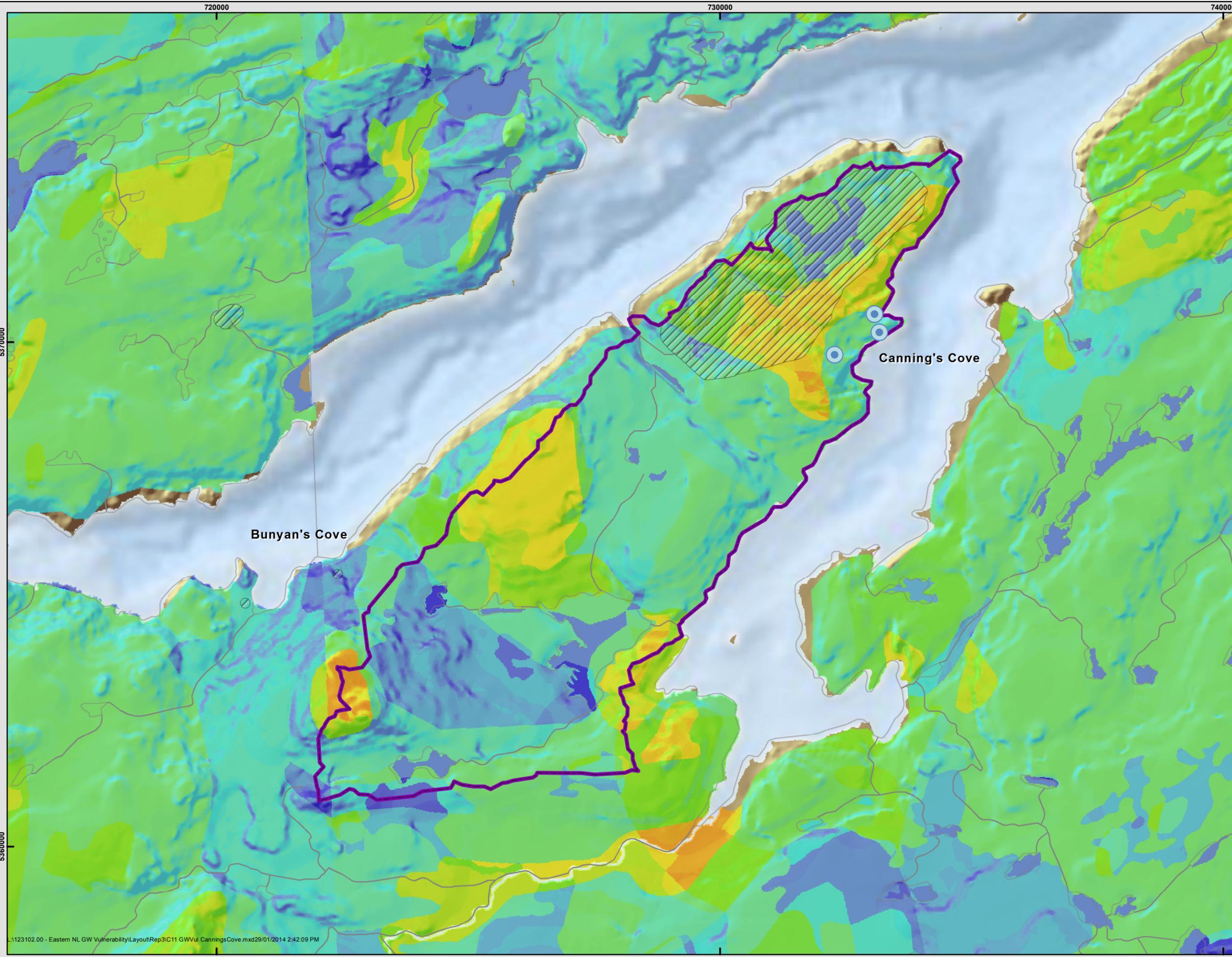
Groundwater Vulnerability and Public Water Supplies in the Bellevue-Dildo Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 1 2 4 6 8 km

1:150,000 @ 11 x 17

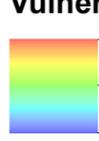


Legend

-  Canning's Cove
-  Protected Well Head
-  Public Water Intake
-  Public Water Supply Area
-  Watercourse
-  Inland Water

Groundwater Vulnerability Index

High : 20.5



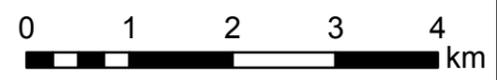
Low : 6

MAP C11

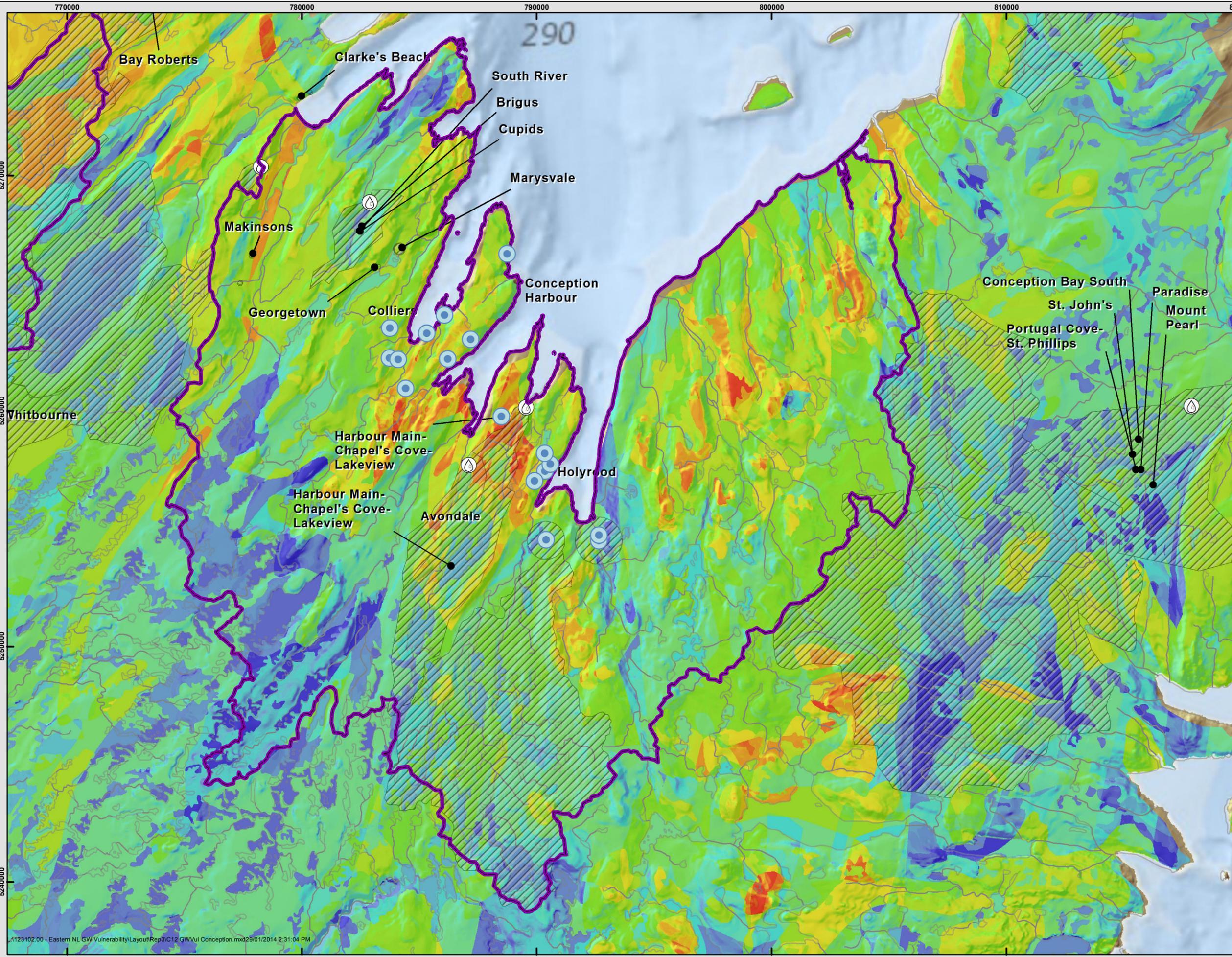
Groundwater Vulnerability and Public Water Supplies in the Canning's Cove Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



1:70,000 @ 11 x 17



Legend

- Conception Harbour-Holyrood
- Protected Well Head
- Public Water Intake
- Public Water Supply Area
- Watercourse
- Inland Water

Groundwater Vulnerability Index

High : 20.5

Low : 6

MAP C12

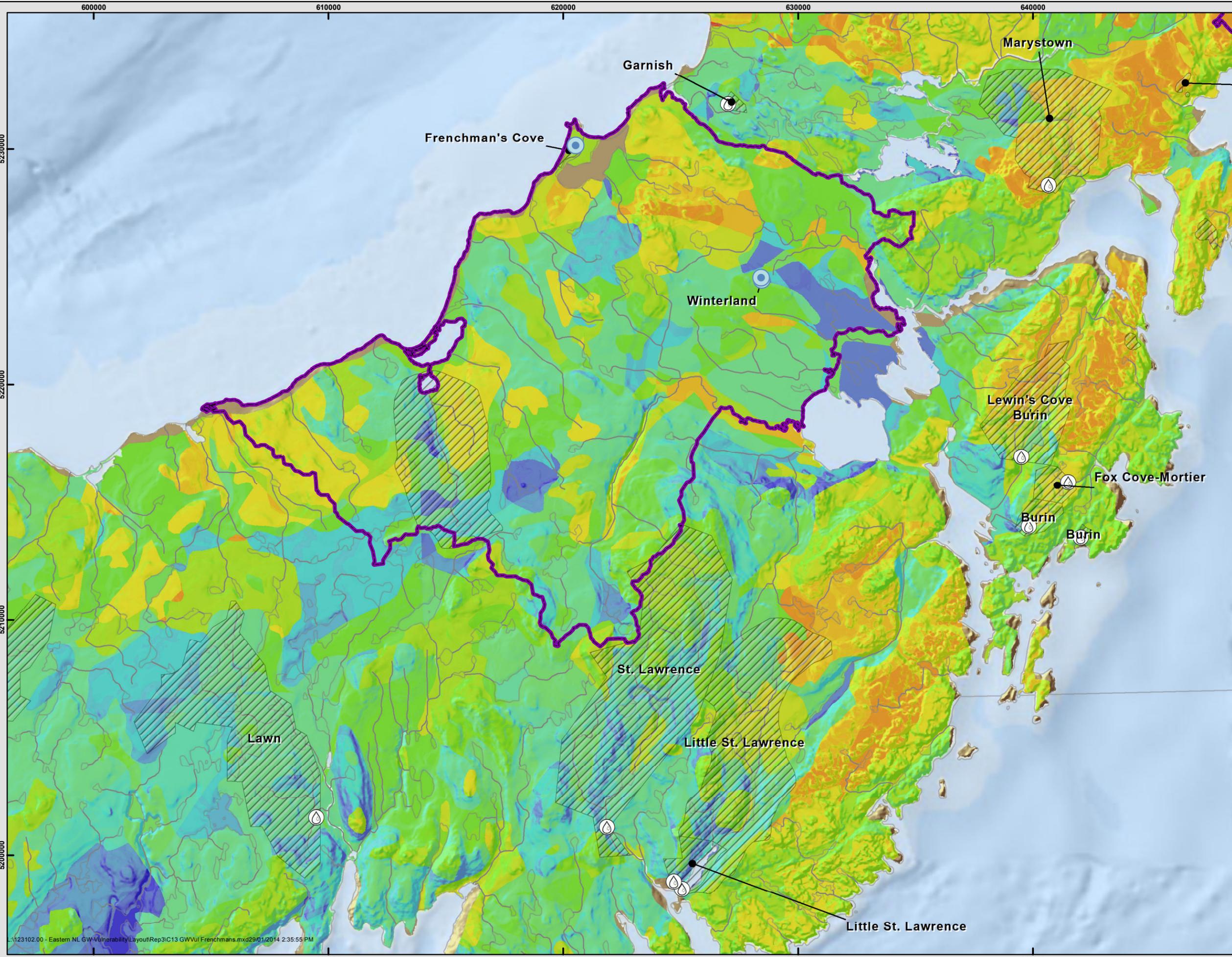
Groundwater Vulnerability and Public Water Supplies in the Conception Harbour-Holyrood Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 1 2 4 6 8 km

1:150,000 @ 11 x 17



Legend

- Frenchman's Cove-Winterland
- Protected Well Head
- Public Water Intake
- Public Water Supply Area
- Watercourse
- Inland Water

Groundwater Vulnerability Index

High : 20.5

Low : 6

MAP C13

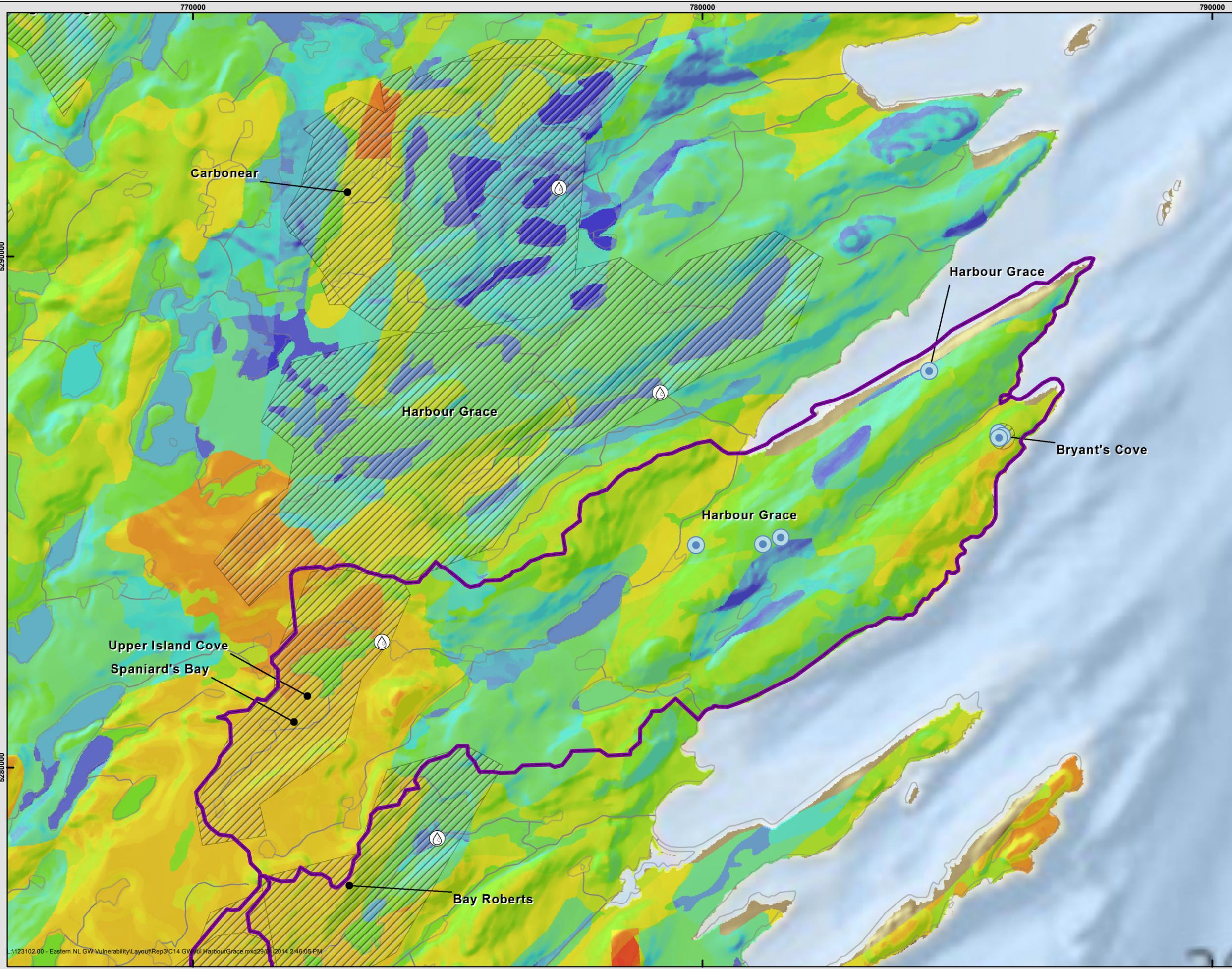
Groundwater Vulnerability and Public Water Supplies in the Frenchman's Cove-Winterland Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 1 2 4 6 8 km

1:150,000 @ 11 x 17



Legend

- Harbour Grace-Bryant's Cove
- Protected Well Head
- Public Water Intake
- Public Water Supply Area
- Watercourse
- Inland Water

Groundwater Vulnerability Index

High : 20.5

Low : 6

MAP C14

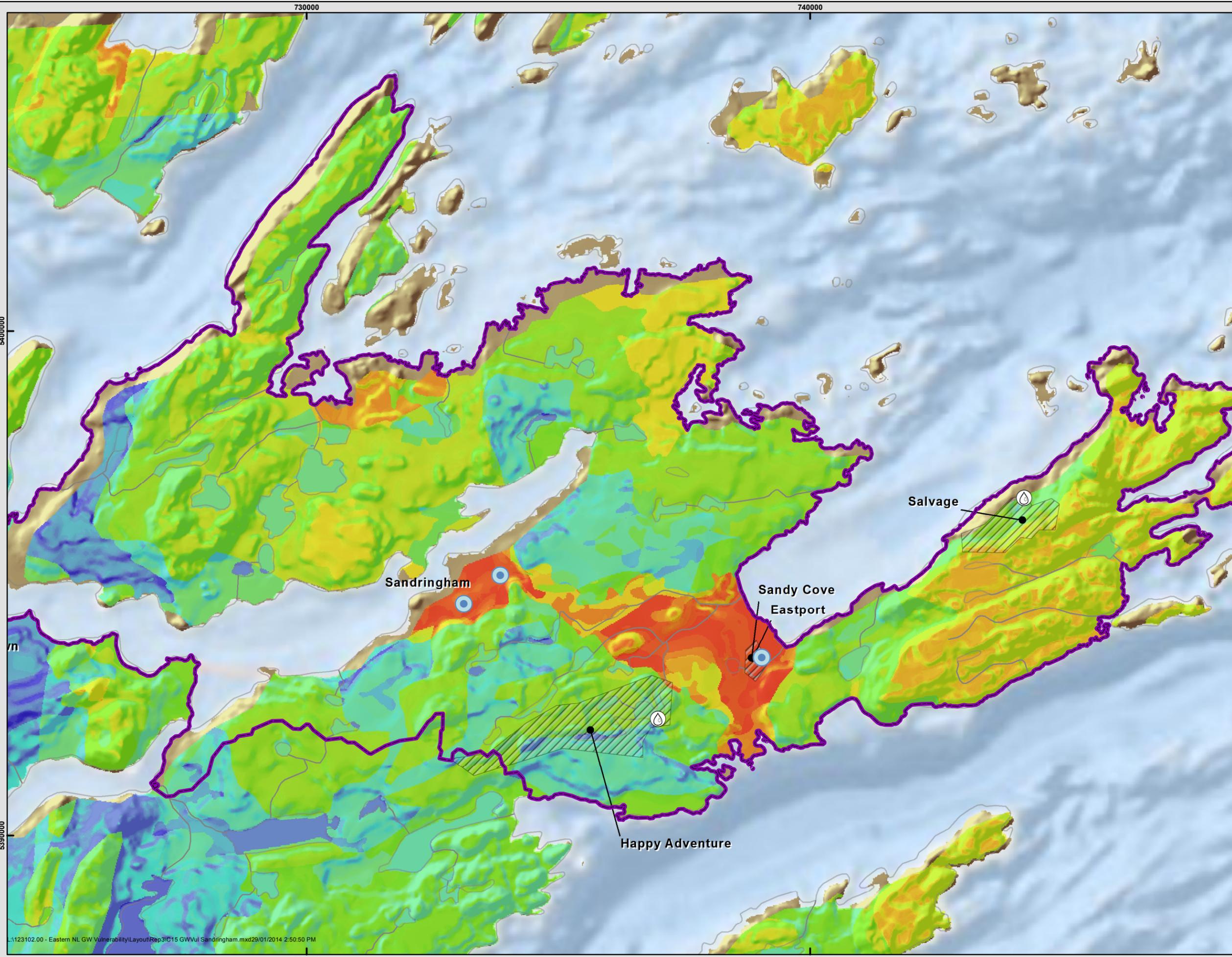
Groundwater Vulnerability and Public Water Supplies in the Harbour Grace-Bryant's Cove Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 1 2 3 4 km

1:70,000 @ 11 x 17



Legend

- Sandringham-Sandy Cove-Eastport
- Protected Well Head
- Public Water Intake
- Public Water Supply Area
- Watercourse
- Inland Water

Groundwater Vulnerability Index

High : 20.5

Low : 6

MAP C15

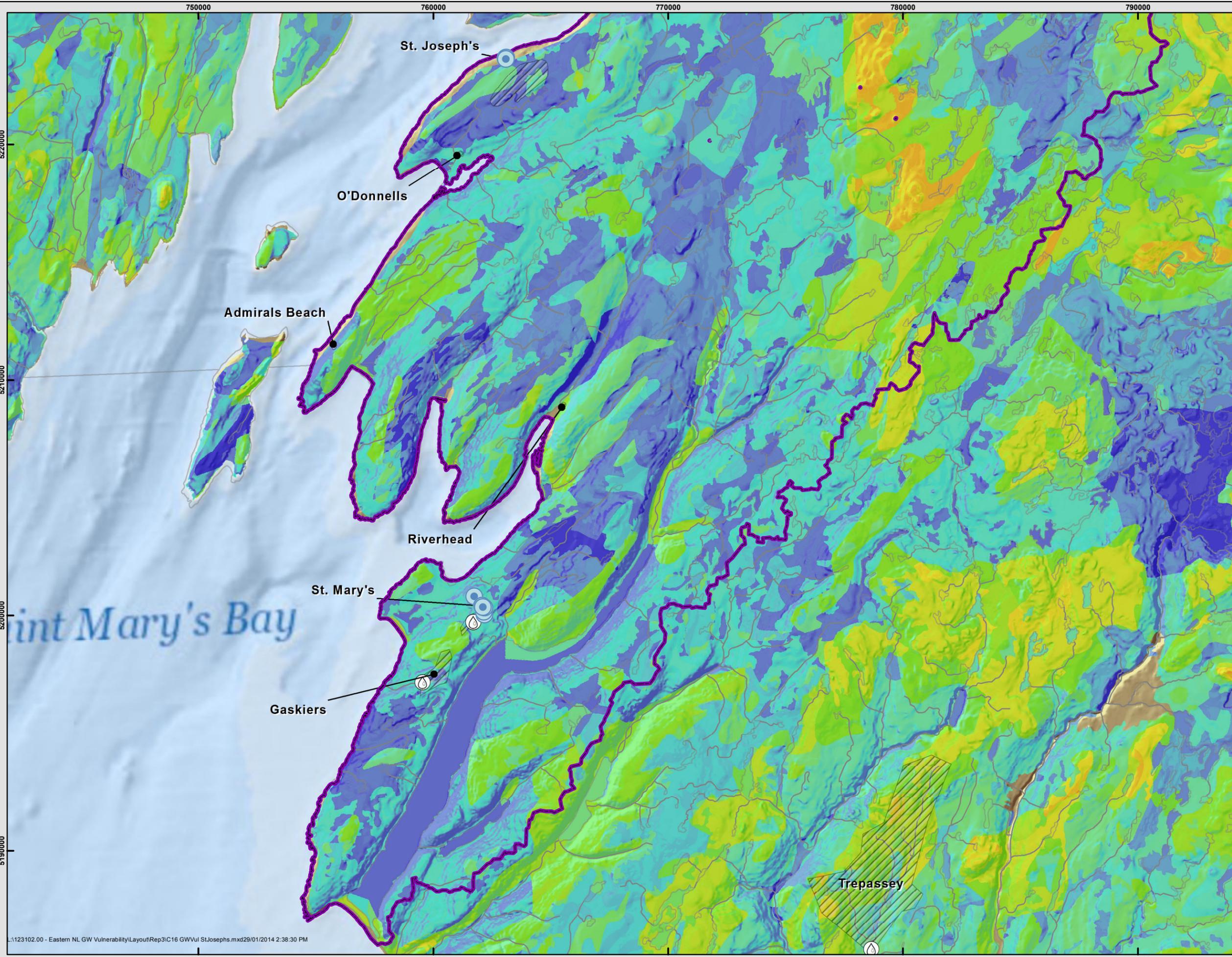
Groundwater Vulnerability and Public Water Supplies in the Sandringham-Sandy Cove-Eastport Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 1 2 3 4 km

1:70,000 @ 11 x 17



Legend

-  St. Josephs-St. Marys
-  Protected Well Head
-  Public Water Intake
-  Public Water Supply Area
-  Watercourse
-  Inland Water

Groundwater Vulnerability Index

High : 20.5



Low : 6

MAP C16

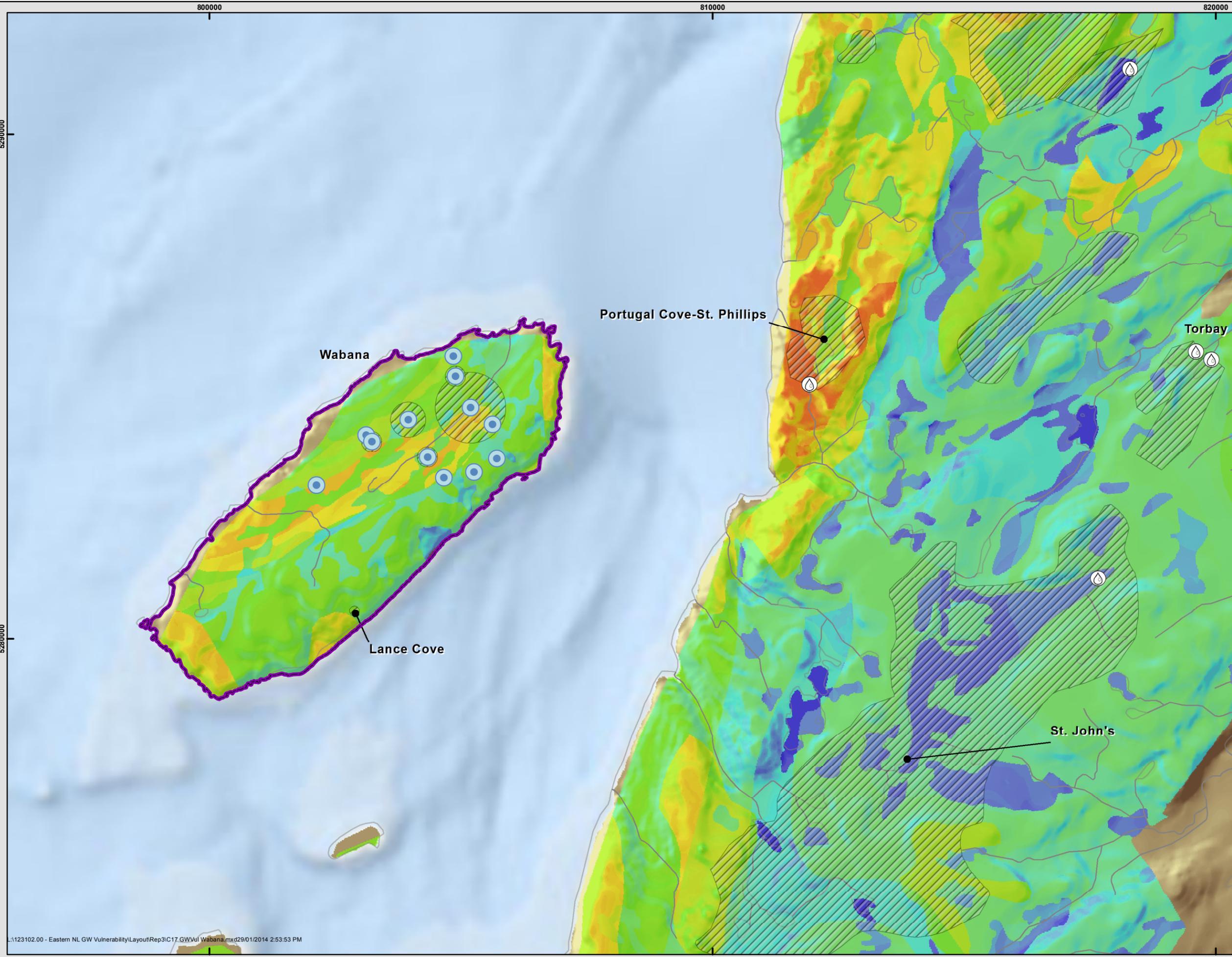
Groundwater Vulnerability and Public Water Supplies in the St. Joseph's-St. Mary's Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



1:150,000 @ 11 x 17

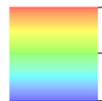


Legend

-  Wabana
-  Protected Well Head
-  Public Water Intake
-  Public Water Supply Area
-  Watercourse
-  Inland Water

Groundwater Vulnerability Index

High : 20.5



Low : 6

MAP C17

Groundwater Vulnerability and Public Water Supplies in the Wabana Study Area

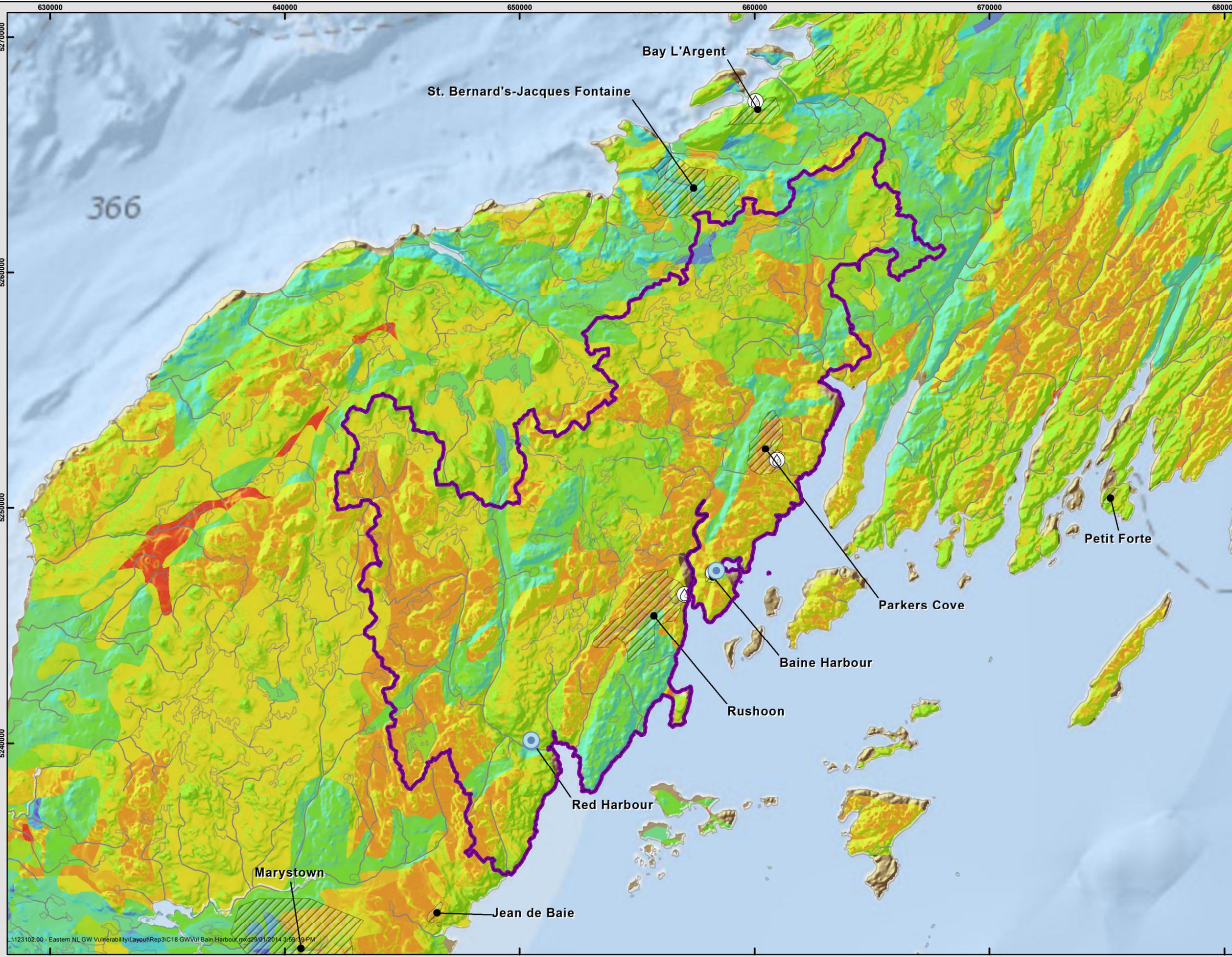
Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



0 1 2 3 4 km

1:70,000 @ 11 x 17



Legend

- Bain Harbour-Red Harbour
- Protected Well Head
- Public Water Intake
- Public Water Supply Area
- Watercourse
- Inland Water

Groundwater Vulnerability Index

High : 20.5

Low : 6

MAP C18

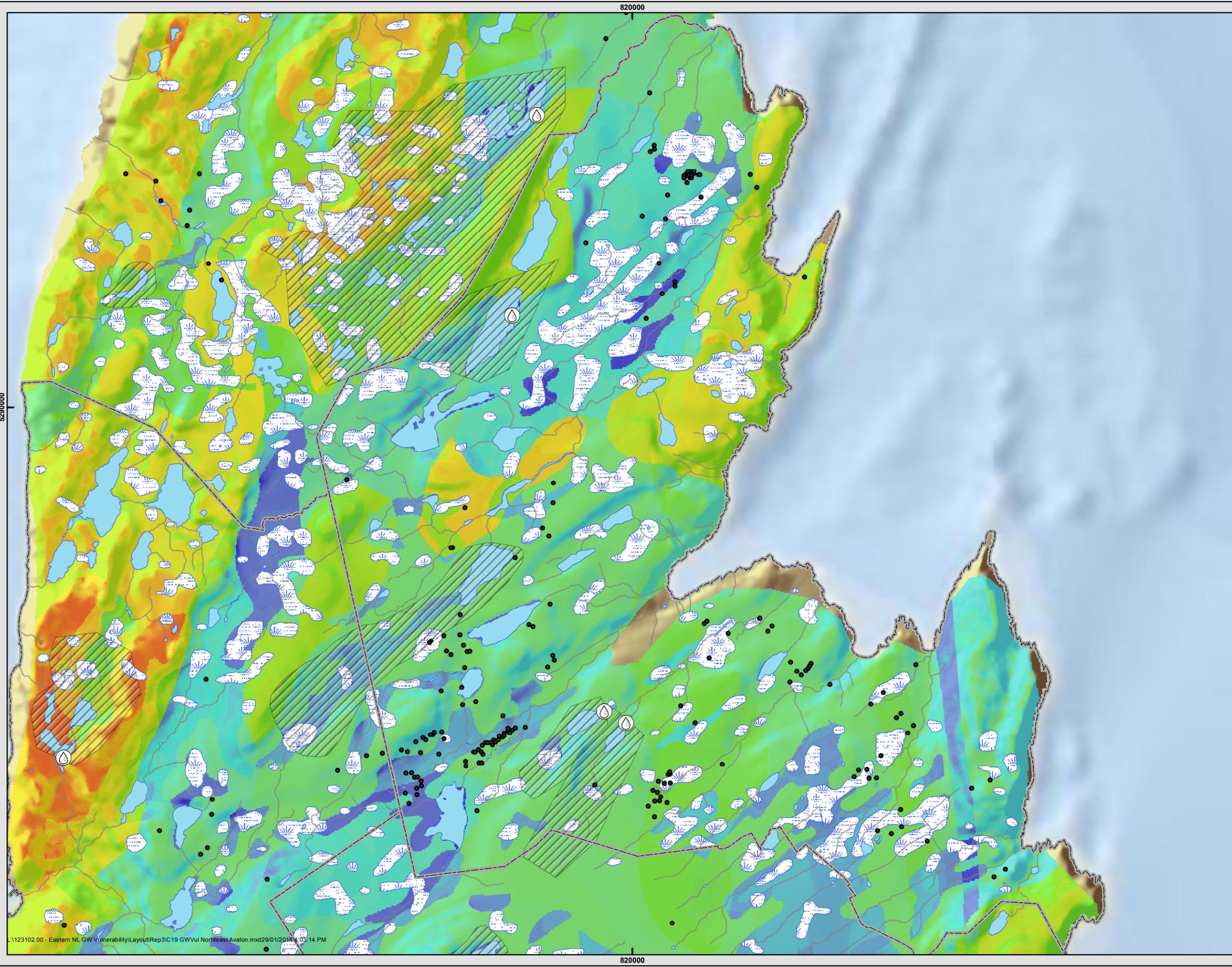
Groundwater Vulnerability and Public Water Supplies in the Bain Harbour-Red Harbour Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 1 2 4 6 8 km

1:150,000 @ 11 x 17



Legend

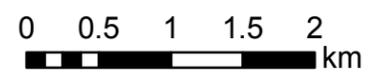
-  Northeast Avalon
-  Drilled Well Database:
Records with GPS or
map coordinates
-  Public Water Intake
-  Public Water Supply
Area
-  Lake
-  Watercourse
-  String Bog
-  Wetland
- Groundwater
Vulnerability Index**
-  High : 20.5
Low : 6

MAP C19

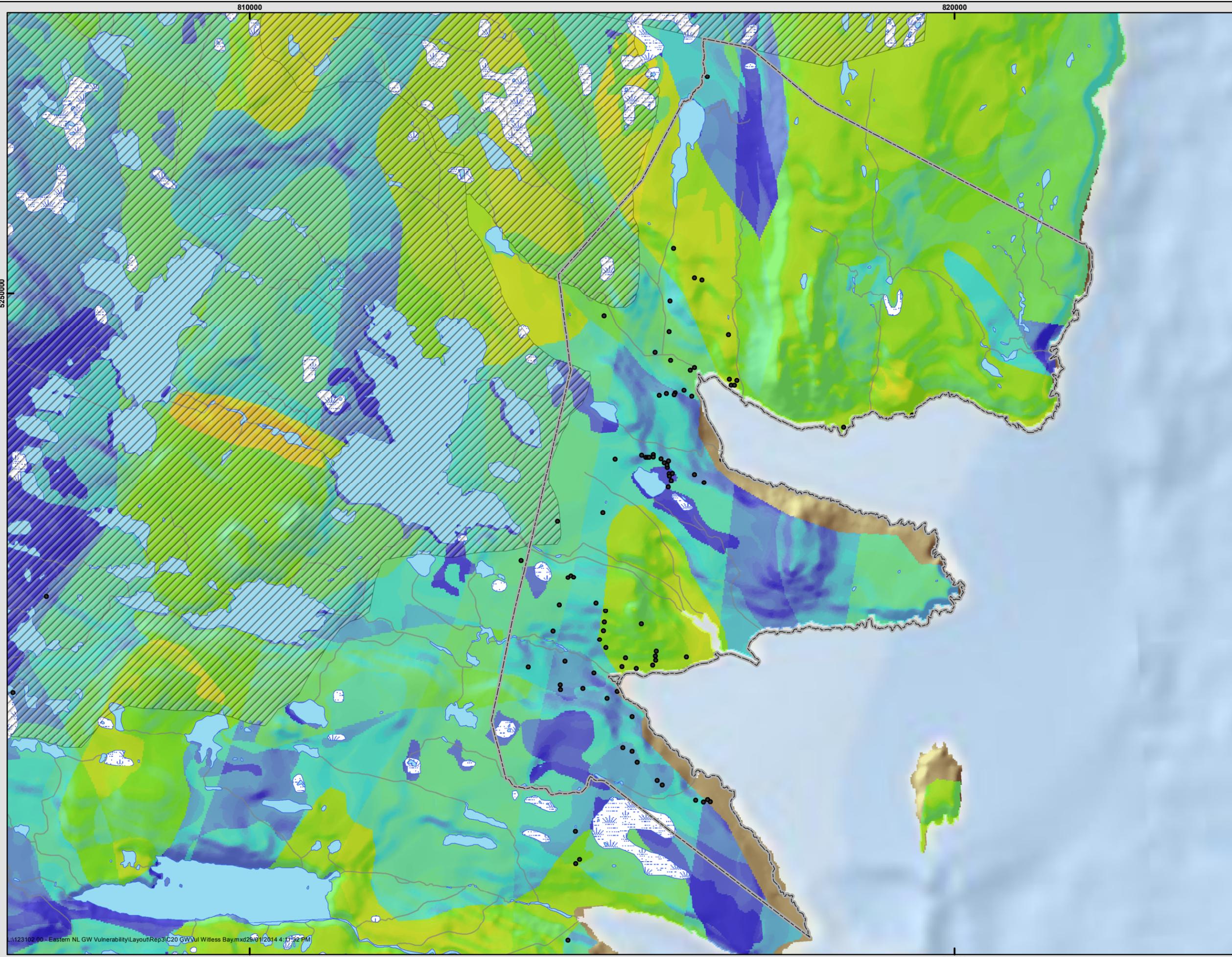
**Groundwater Vulnerability in the
Northeast Avalon Study Area**

**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

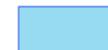
Coordinate System: NAD 1983 UTM Zone 21N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter

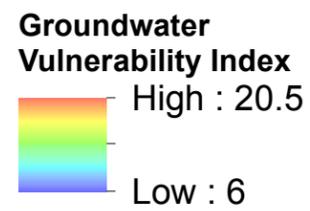


1:50,000 @ 11 x 17



Legend

-  Witless Bay-Bay Bulls
-  Drilled Well Database:
Records with GPS or map coordinates
-  Public Water Intake
-  Public Water Supply Area
-  Lake
-  Watercourse
-  String Bog
-  Wetland

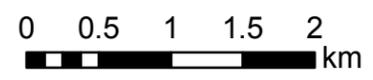


MAP C20

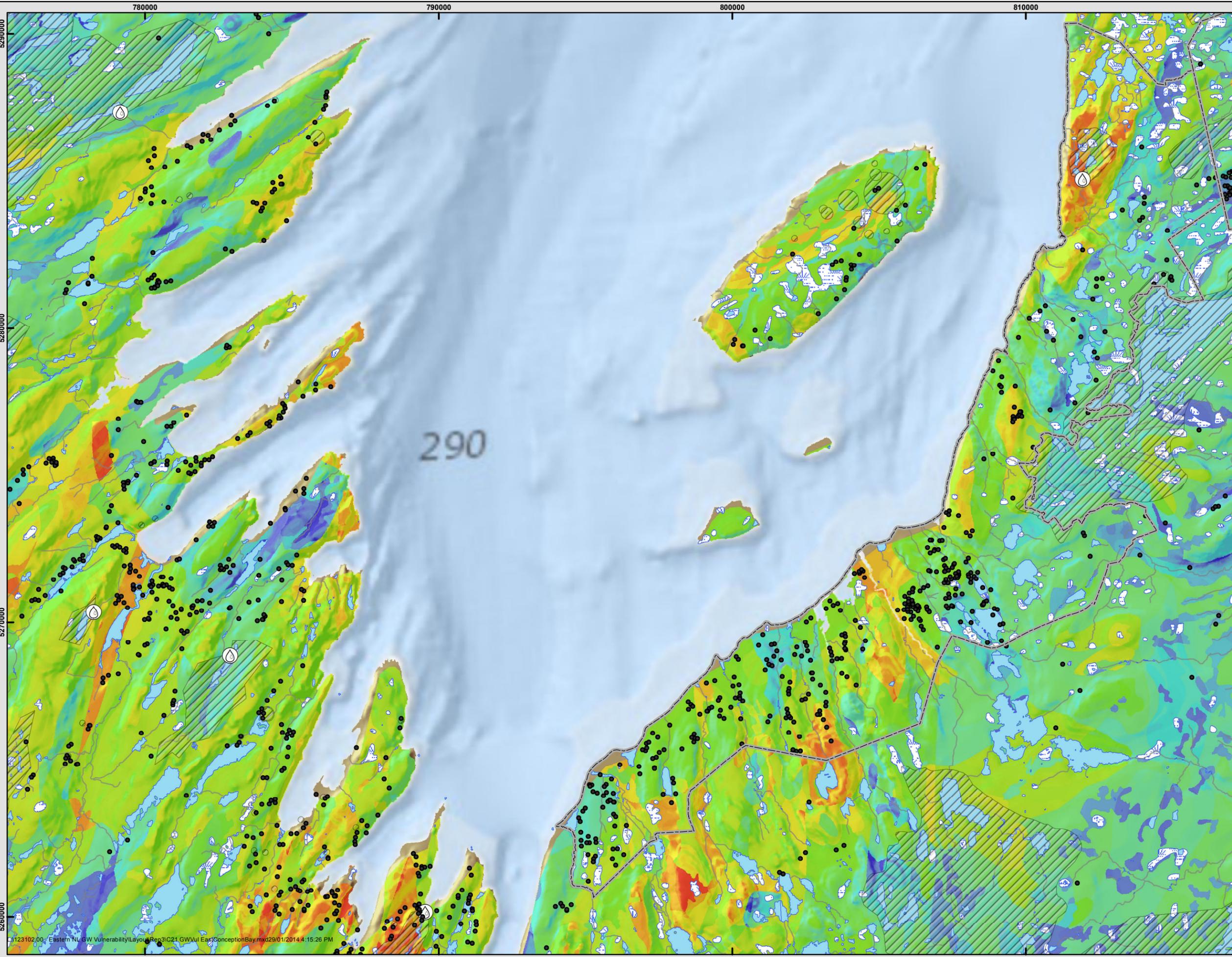
Groundwater Vulnerability in the Witless Bay-Bay Bulls Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter



1:50,000 @ 11 x 17



Legend

- East Conception Bay
- Drilled Well Database: Records with GPS or map coordinates
- Public Water Intake
- Public Water Supply Area
- Lake
- Watercourse
- String Bog
- Wetland

Groundwater Vulnerability Index

High : 20.5

Low : 6

MAP C21

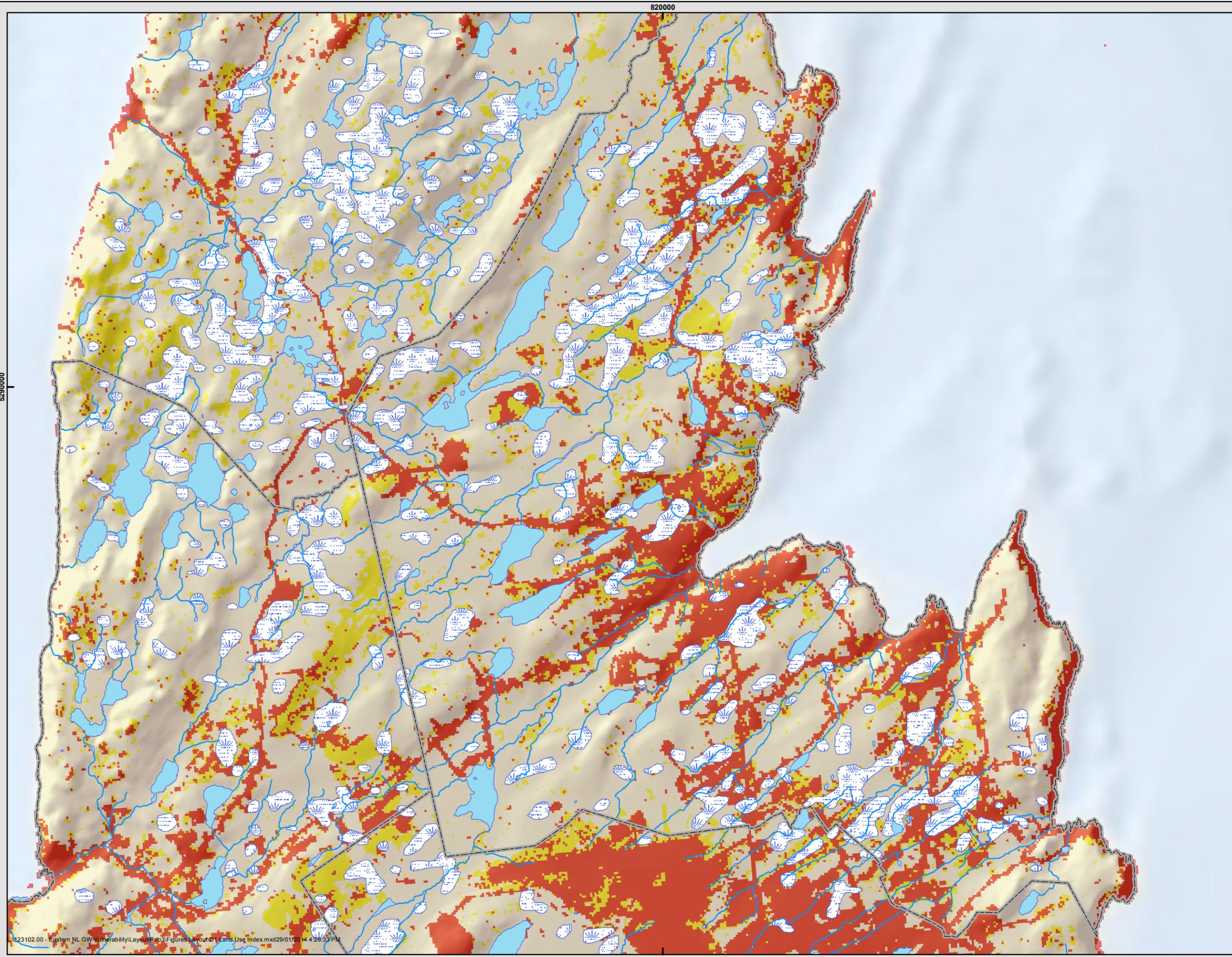
Groundwater Vulnerability in the East Conception Bay Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 1 2 3 4 km

1:120,000 @ 11 x 17



Legend

-  Northeast Avalon
- Land Use Index**
-  Non-Urban (1)
-  Cleared (5)
-  Urban (10)
-  Watercourse
-  Lake
-  String Bog
-  Wetland

MAP D1

**Land Use Index for the
Northeast Avalon Study Area**

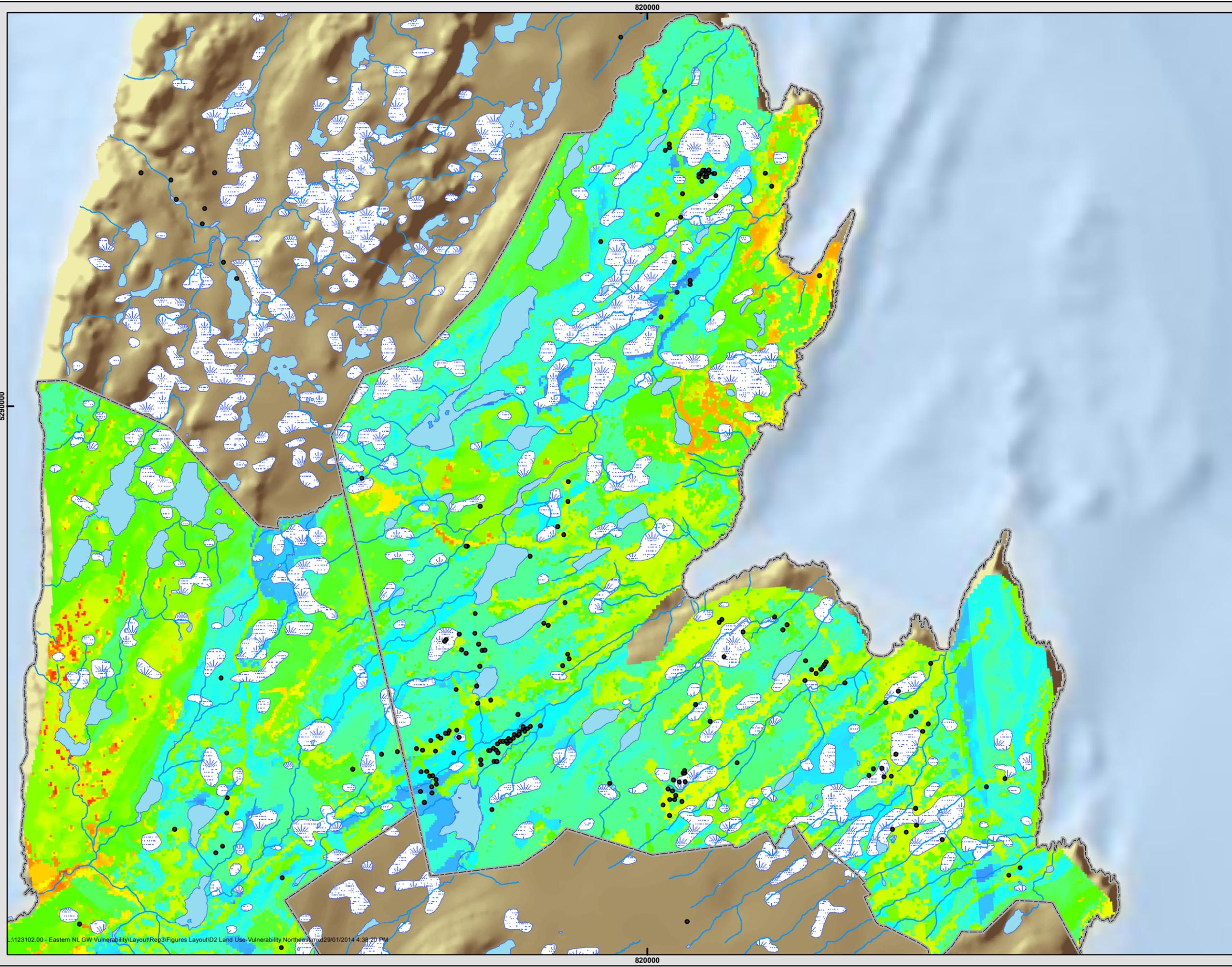
**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



0 0.5 1 1.5 2 km

1:50,000 @ 11 x 17



Legend

Northeast Avalon

Land Use-Vulnerability

Value

High : 19.45

Low : 6

Drilled Well Database: Records with GPS or map coordinates

Watercourse

Lake

String Bog

Wetland

MAP D2

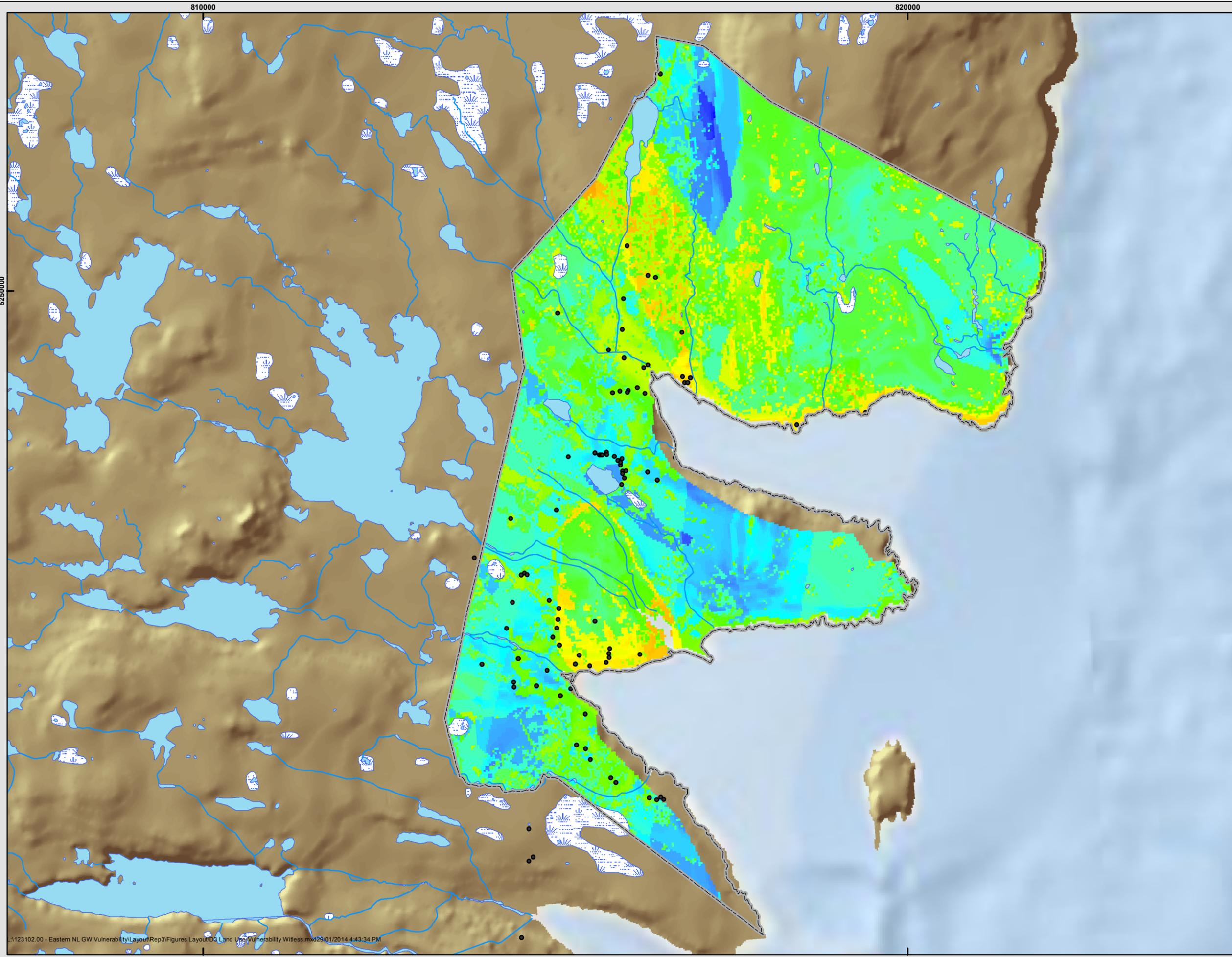
Land Use-Vulnerability in the Northeast Avalon Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 0.5 1 1.5 2 km

1:50,000 @ 11 x 17



Legend

-  Witless Bay-Bay Bulls

Land Use-Vulnerability

Value

-  High : 19.45
-  Low : 6

-  Drilled Well Database: Records with GPS or map coordinates
-  Watercourse
-  Lake
-  String Bog
-  Wetland

MAP D3

**Land Use-Vulnerability in the
Witless Bay-Bay Bulls Study
Area**

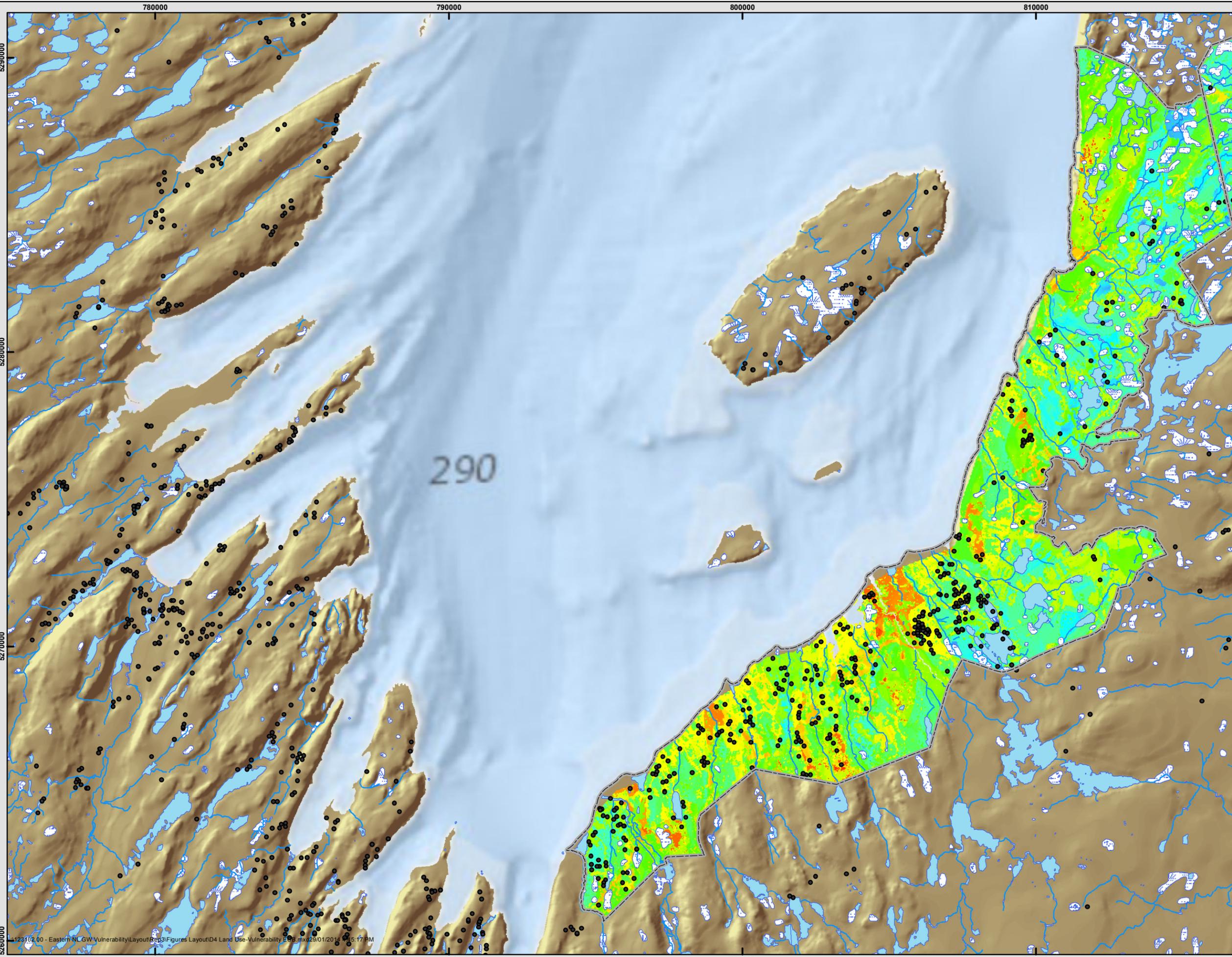
**Eastern Newfoundland
Groundwater Vulnerability
Assessment**

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



0 0.5 1 1.5 2 km

1:50,000 @ 11 x 17



Legend

East Conception Bay

Land Use-Vulnerability

Value

High : 19.45

Low : 6

Drilled Well Database:
Records with GPS or map coordinates

Watercourse

Lake

String Bog

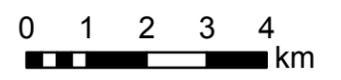
Wetland

MAP D4

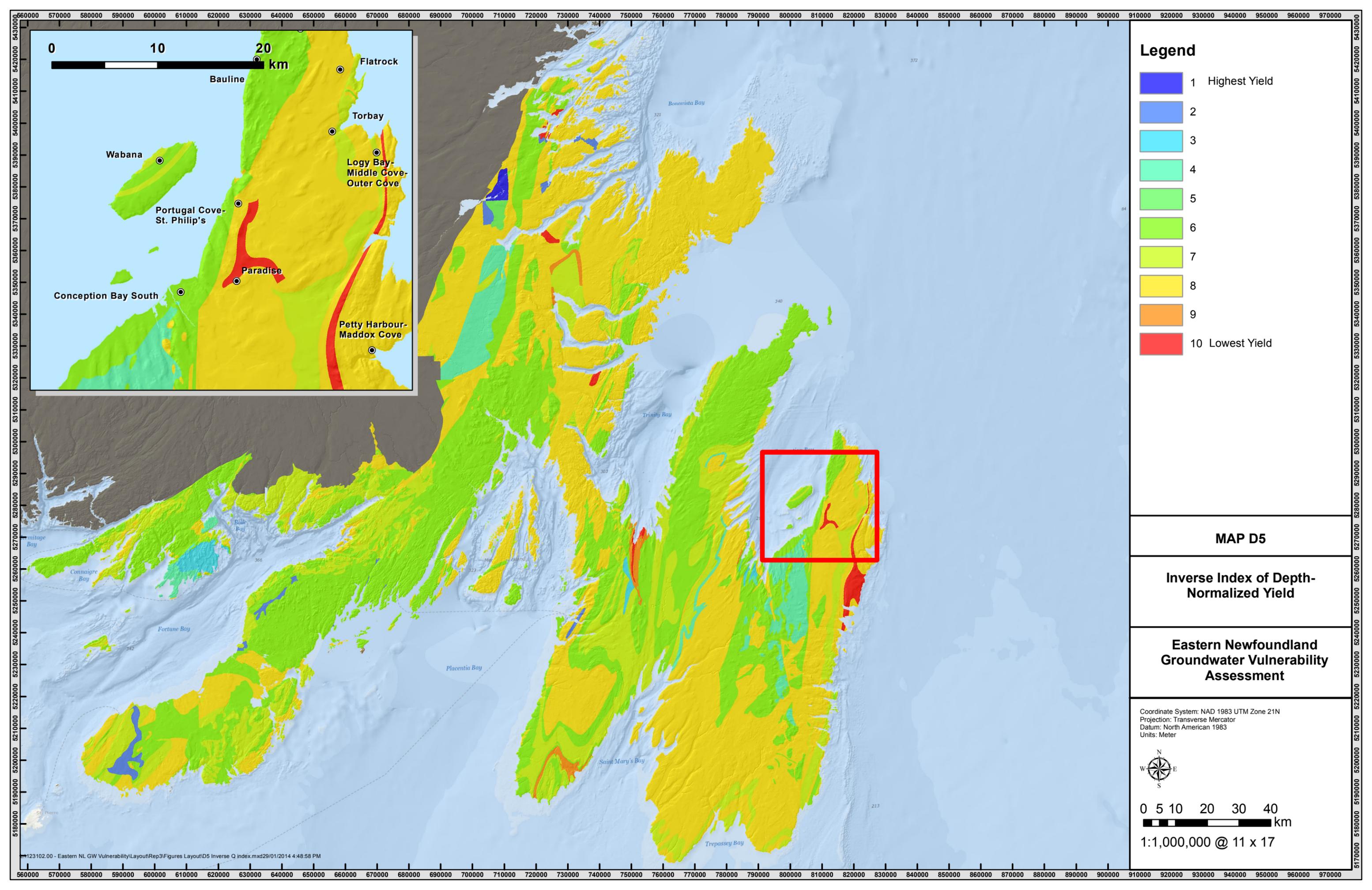
Land Use-Vulnerability in the East Conception Bay Study Area

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter



1:120,000 @ 11 x 17



Legend

1	Highest Yield
2	
3	
4	
5	
6	
7	
8	
9	
10	Lowest Yield

MAP D5

Inverse Index of Depth-Normalized Yield

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17

0 10 20 km

Flatrock

Bauline

Torbay

Wabana

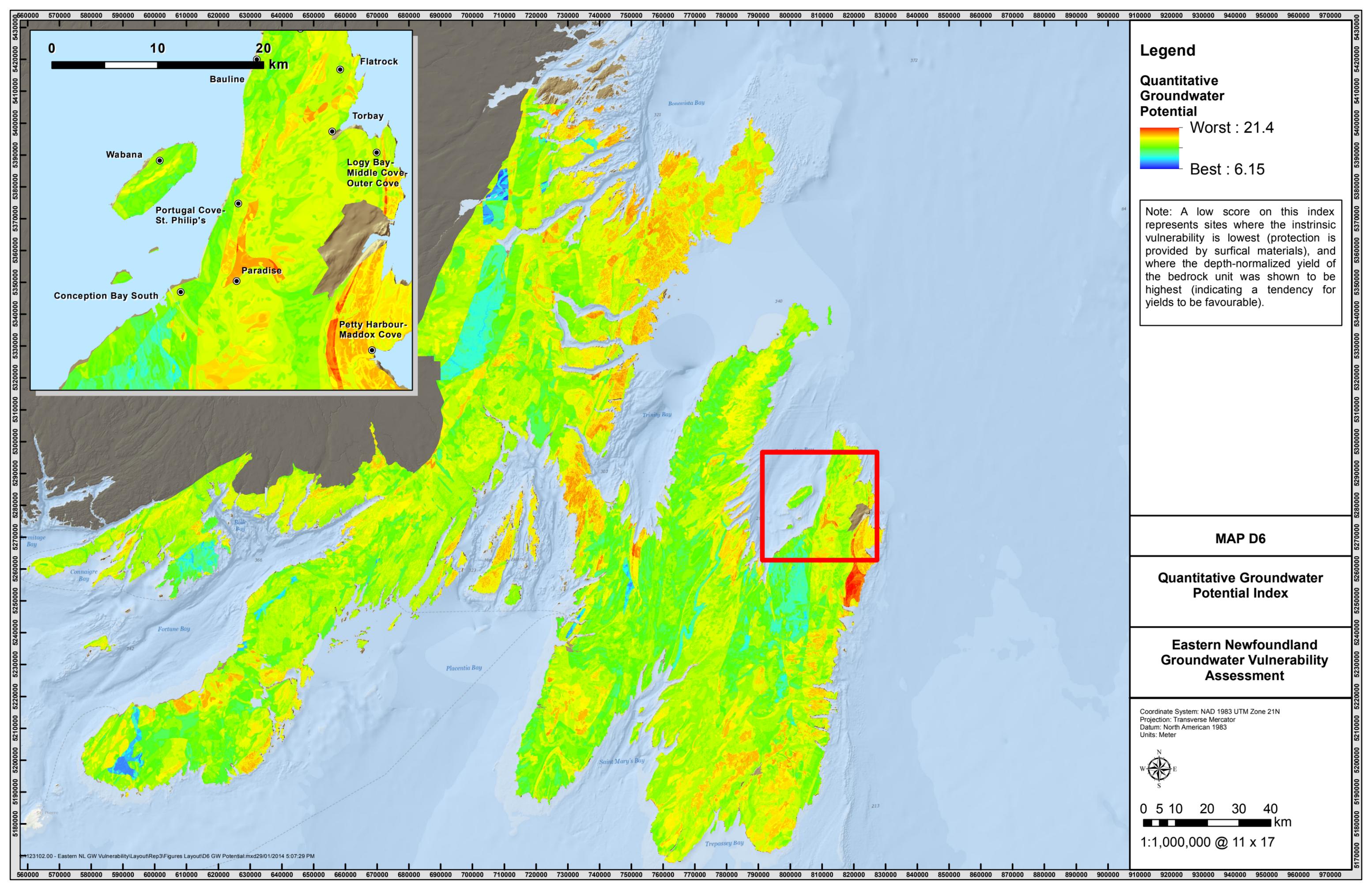
Logy Bay-Middle Cove-Outer Cove

Portugal Cove-St. Philip's

Paradise

Conception Bay South

Petty Harbour-Maddox Cove



Note: A low score on this index represents sites where the intrinsic vulnerability is lowest (protection is provided by surficial materials), and where the depth-normalized yield of the bedrock unit was shown to be highest (indicating a tendency for yields to be favourable).

MAP D6

Quantitative Groundwater Potential Index

Eastern Newfoundland Groundwater Vulnerability Assessment

Coordinate System: NAD 1983 UTM Zone 21N
 Projection: Transverse Mercator
 Datum: North American 1983
 Units: Meter

0 5 10 20 30 40 km

1:1,000,000 @ 11 x 17