CHALEUR REGIONAL SERVICE COMMISSION
PROJECT NO.: 191-12464-00

EROSION AND FLOODING RISK ANALYSIS

PORTION OF THE TERRITORY OF THE CHALEUR RSC

SEPTEMBER 2020

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DATE: SEPTEMBER 2020

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1 INTRODUCTION

1.1 BACKGROUND

New Brunswick includes twelve Regional Service Commissions (RSC) whose primary mandate is to provide municipal management and land development planning services at the regional level. The Chaleur RSC is located in northeastern New Brunswick and takes its name from the Bay of Chaleur, which borders its territory. The Chaleur RSC has taken the initiative to develop a regional action plan for adaptation to climate change due to the growing problems of development and public safety caused by flooding and coastal erosion. The objective of this plan is to better understand the impacts related to climate change and the adaptation strategies applicable to the region (WSP, 2019).

The initial plan involved two phases that focused on the acquisition of data on coastal and riparian hazards (Phase 1) and the development of guidelines or minimum standards for regional adaptation (Phase 2). In particular, the first report revealed that there are regional analyses of coastal erosion trends, but that local analyses on the evolution of erosion rates are very fragmented (Aubé et al., 2018). The provincial database covered only a small portion of the Chaleur RSC's territory in 2018 and many of the calculated erosion rates did not take into account the most recent aerial photos available. This shortcoming at the local level limits the scope of the regional plan, making it a priority for further adaptation.

The Chaleur RSC has mandated WSP Canada Inc. (WSP) to produce high-quality geospatial data for the municipalities of Belledune and Beresford, which will be used to identify infrastructures that are potentially at risk from coastal erosion over the next few decades.

1.2 OBJECTIVES

The goal of the project is to assess the erosion risk based on the current infrastructure position and the past and anticipated evolution of the coastline for the entire seafront and certain sections of the estuaries of the municipalities of Belledune and Beresford. This multi-temporal characterization provides a more complete picture of the geomorphological context, to better understand the past and recent evolution of the coastline. Analyzing coastal dynamics allows the potential for erosion to be assessed, to provide information on long-term evolutionary trends that will be used to predict the position of the coastline in the years to come.

More specifically, the objectives of the mandate are as follows:

- digitize, using ArcGIS software, the coastline position from historical and recent aerial photographs;
- calculate average annual movement rates from historical plotted coastlines;
- determine the coastline position in 2050 and 2100 based on the projection of historical movement rates concerning the relative sea-level rise and taking into account climate change.

The geospatial data produced determines the appropriate retreat limits or the risk that elements, such as infrastructures, will be affected by erosion and provides a decision support tool for better climate change adaptation (Chelbi et al., 2019).

2 STUDY SITE DESCRIPTION

2.1 LOCATION OF THE STUDIED MUNICIPALITIES

The two northern New Brunswick municipalities included in this study are Belledune and Beresford. The village of Belledune is located along the Chaleur Bay coastline in the northwestern part of the Chaleur RSC. It has a population of approximately 1,550 and straddles the counties of Restigouche and Gloucester.

The town of Beresford is located northwest of Bathurst in Nepisiguit Bay, which is a sub-component of Chaleur Bay. This municipality is part of Gloucester County and has a population of approximately 4,400. Part of its coastline is characterized by an extensive system of spits and lagoons, the construction of which is a legacy of the Holocene marine transgression (Long, 2006).

The coast of the two municipalities included in this study consists mainly of unconsolidated coasts and sedimentary cliffs interspersed with rocky, cliffless coast, often in the form of small points that extend toward the sea. Map 2-1 shows the two municipalities included in this mandate.

2.2 DESCRIPTION OF THE PHYSICAL ENVIRONMENT

2.2.1 GEOLOGY

The study area's bedrock is part of the Appalachian geological province. The two municipalities are located on different bedrock types. On the Belledune side, it is composed of sedimentary rocks such as the Lower Silurian La Vieille Formation (sandstone), the Upper Silurian South Charlo Formation (conglomerate), the Lower Devonian Jacquet River Formation (siltstone) and the Upper Carboniferous Bonaventure Formation (conglomerate).

Conversely, at Beresford, it is characterized by a mixture of igneous and sedimentary rocks that include the Upper Ordovician Little River Formation (basalt), the Upper Ordovician Millstream Formation (shale and siltstone) and the Upper Silurian Simpsons Field Formation (sandstone).

Sedimentary rock formations are sensitive to erosion due to the numerous stratification planes and fracture networks that make them vulnerable to congelifraction and wave attack. Igneous rock formations, although fewer in number, are less sensitive to erosion. Appendix A presents detailed geological maps.

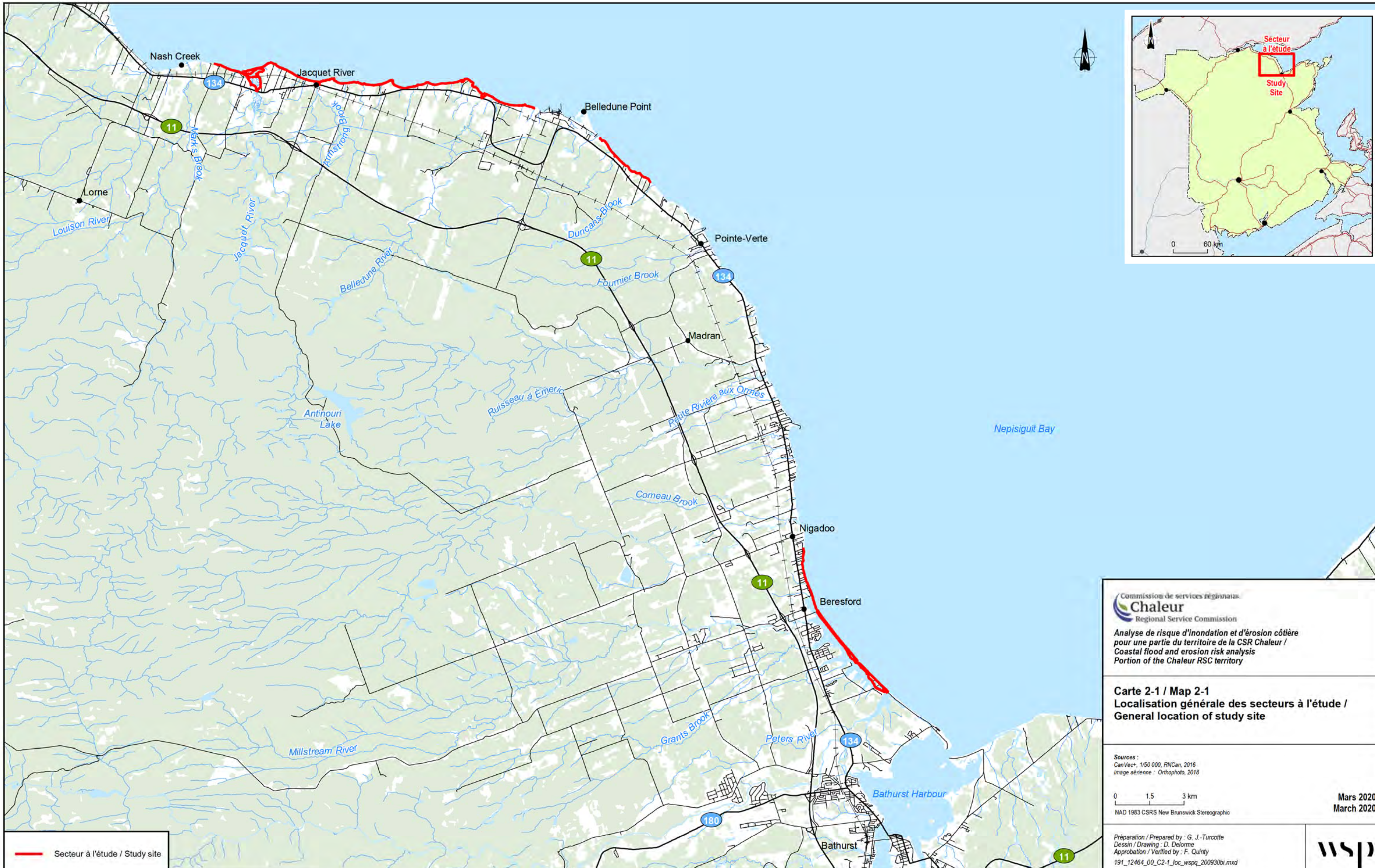
2.2.1 GEOMORPHOLOGY

Deglaciation in Chaleur Bay took place from east to west between 13,500 and 11,500 before present (Dionne, 1977; Veillette and Cloutier, 1993 in Richard *et al.*, 1997). In general, the passage of the ice left very little deposit in the region (Pronk *et al.*, 1989).

Following the ice retreat, the Goldthwait Sea that occupied the Gulf of St. Lawrence would have reached a maximum elevation of 61 m in the study area. Silt-clay deposits developed on the submerged plains, while deltaic sediments composed of sand and gravel were deposited at river mouths.

Therefore, in Chaleur Bay, Quaternary deposits reflect the evolution of relative sea-level movements during the Holocene period (Long, 2006). The sea level has experienced variations due to isostatic rebound and the water level itself. The addition of these two components results in the relative level. Currently, the relative sea level is rising, which promotes erosion.

According to the generalized geological map of surficial deposits in New Brunswick (Rampton, V.N. 1984), the deposits in the region are composed of sand, silt, some gravel and clay with a thickness of 0.5 to 3 m in some areas.



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3 METHODOLOGY

3.1 STEREOSCOPIC CHARACTERIZATION

3.1.1 ACQUISITION AND INTEGRATION OF AERIAL PHOTOGRAPHS

The historical aerial photographs were chosen to cover the longest possible period at regular intervals for the lowest possible water levels at the time the photographs were taken. Thus, two series of aerial photographs and one series of aerial images were used in this project, resulting in a 74-year coverage (Table 3-1).

The oldest aerial photographs date from 1944 and were taken by the federal government's National Air Photo Library (NAPL), while the 1985 series of aerial photographs were taken by the Nova Scotia Geomatics Centre. The other series of aerial images dates from 2018 and comes from the collection of the Service New Brunswick office.

The 1944 and 1985 aerial photographs, in paper format, were digitized using a scanner at a resolution of 600 dpi (pixel size of 0.8 m^2). They were then georeferenced from the 2018 orthophotographs by establishing control points. The average georeferencing error is less than 1 m.

Table 3-1 Photographs and aerial images used for multi-temporal stereoscopic characterization.

Source	Year	Scale or resolution	Emulsion	Roll number	Photo number
NAPL	1944	1:50,000	Black and white	A7357 A7402 A7446 A7366 A7971	54-66 34-37 1 31 1
NSGC	1985	1:15,000	Colour	DNR85504 DNR85511	90-163 44, 64, 86, 105
SNBO	2018	30 cm	Colour	N.A.	N.A.

3.1.2 COAST TYPE SEGMENTATION

The coastline was divided into segments with homogeneous geomorphological characteristics. Segmentation allows the analysis of current and past coastal dynamics for each type of coast. The segmentation was performed using the most recent aerial images (2018) to reflect current conditions. A coast type was assigned to each of the segments based on a list of predefined criteria (Table 3-2). The homogeneous segments are long enough to contain several measurement transects (30 m intervals), thus allowing a better understanding of their evolution. A total of 26 segments were thus delimited.

Table 3-2 Coast type identification criteria

Coast type	Definition
Rocky cliff	Rocky coast with escarpment (the rocky cliff can be supported by a rock abrasion platform).
Unconsolidated coast	Unconsolidated coast without escarpment and with a gradual slope.
Unconsolidated cliff	Escarpment of unconsolidated deposits (clay, silt, sand, gravel, boulders).
Spit	An accumulation of unconsolidated material that has one end connected to the mainland and one end free. Forms where there is a pronounced coastal drift in one direction.
Artificial	Any type of coast modified or protected by man-made structures (e.g. rockfill, wharf, port, etc.).

3.1.3 IDENTIFICATION OF THE COASTLINE

The coastline was first clearly defined and then drawn from aerial photographs based on morphological criteria duly identified for each type of coast (see Table 3-3). The same geomorphological criteria were applied for each year so that the interpretation would be consistent and comparable from one period to the next. Note that, based on the definitions considered, the tidal water level, although varying from one photo to the next, does not affect the accuracy of the assessments made. The scale of the coastline digitization varies from one series of aerial photographs to the next due to the scale and quality of the images. For 2018, we used an arbitrary scale of 1:300. The mapping was performed by stereoscopic (3D) photointerpretation directly on screen using the PureView software and ArcGIS.

The coastline is the maximum limit of the area modelled by extreme processes, such as waves and marine submersion during storms. The coastline was defined according to several geomorphological elements that vary according to coast type (Table 3-3).

Table 3-3 Geomorphological criteria used to determine the coastline position as a function of coast type

Coast type	Criteria
Rocky cliff	Cliff top / clear cut of the vegetation.
Unconsolidated coast	Limit of the storm crest on the landward side. Clear cut of vegetation.
Unconsolidated cliff	Cliff top / clear cut of the vegetation.
Spit	At the beach level, behind the spit: upper limit of the storm berm.
Artificial	Top of the structure.

3.1.4 CALCULATION OF THE HISTORICAL RETREAT RATE

A “geodatabase” was developed to ensure cohesion between the different data produced. This type of file makes it possible to collect and manage different data types in the same place and to ensure the accuracy of spatial relationships. The geodatabase includes shapefiles (.shp) associated with the coastline for each year.

The coastline movement was calculated using the *Digital Shoreline Analysis System* (DSAS) software (Thieler *et al.*, 2009). DSAS is an extension of the ArcGIS software. A geodatabase that contains the coastline positions at different dates (multi-temporal) manages all DSAS input data. The software can be used to create a transverse transect of the coastline every 30 m, from which movement rates can be calculated to characterize the advance and retreat of the coastline (Boucher-Brossard et al., 2013). Each transect was manually validated to ensure that they were consistent and representative.

A mean movement was calculated for each coast segment by taking the average of the segment's transects. Some segments had to be subdivided due to excessive variability in the value of the movement or in the presence of factors that could influence sediment transit (e.g. presence of a stream or groyne) (Chelbi et al., 2019).

3.1.5 CALCULATION OF THE MARGIN OF ERROR

The positioning of the coastline is influenced by three sources of error that can be calculated for each series of aerial photographs (Table 3-4). These sources of error are mainly due to resolution and image processing, which induces certain deformations proportional to the distance to nadir. For the series of photographs used in this study, these errors are of the order of:

- ±0.1 to ±0.8 m due to the resolution;
- ±0 to ±1.5 m due to orthorectification: to minimize this error, the characterization was conducted as close as possible to the nadir of the photo;
- ±0.5 to ±2 m potentially for the 2D image interpretation.

The maximum margin of error between two years of photographs is, thus, the sum of these three sources of error (Table 3-4). Therefore, the sum of its three sources of error can confer a theoretical maximum margin of error between the coverage of aerial photographs of 3 m on average, which is a value of 0.06 m/year.

Table 3-4 Parameters for the calculation of the total margin of error for each series of aerial photographs

YEAR OF PHOTOGRAPH	TYPE OF ERROR			TOTAL ERROR (m)
	RESOLUTION (m)	GEOREFERENCING (m)	INTERPRETATION (m)	
1944	0.80	1.5	2	±4.3
1985	0.5	1	1.5	±3.0
2018	0.10	N.A.	0.5	±0.80

3.2 COASTLINE PROJECTION

The coastline projection can be determined using different approaches depending on the objectives. It requires a level of effort that increases with the number of inputs available and a change in the level of analysis that moves from the regional to a more specific scale. However, there is no scientific consensus on a method for increasing erosion rates as a function of sea-level rise. Indeed, a meta-analysis shows that there is no clear indication that sea-level rise is a significant controlling factor for coastal erosion rates on a global scale. Indeed, the results differ according to the study sites, which tends to demonstrate that the regional coastal context has more influence on the rate of erosion in the medium term than relative sea-level rise (Le Cozannet et al., 2014). The same study concludes that modelling-based approaches pose significant challenges, since the lack of precision in the models does not allow estimating the evolution of the coastline with sufficient confidence. In this regard, we suggest the use of approaches based on recent observations. Indeed, along sandy coastlines, the use of models requires a deep understanding of local hydro-sedimentary processes, which can vary over a very short distance (Rosati et al., 2013). The evolution of rocky coastlines is generally slower and, therefore, less of a concern for adapting to change.

The Laboratoire de dynamique et de gestion intégrée des zones côtières (LDGIZC) of the Université du Québec à Rimouski favours the projection of coastlines based on observed rates by projecting erosion rates according to two scenarios (Fraser et al., 2017):

1 a conservative scenario where the future erosion rate corresponds to the average of all historical rates for a uniform coastal cell;
2 a pessimistic scenario corresponding to the maximum erosion rates measured during the diachronic analysis of aerial and satellite imagery. The highest historical erosion rate calculated for each type of coast was projected into the future. This scenario represents an accelerated rate compared to the historical average.

As part of this mandate, variants of these two scenarios were examined to illustrate the extent of the changes likely to occur.

On the one hand, projections of the future coastline position were based on the approach of projecting historical retreat rates (discussed above, scenario 1), combined with sea-level rise and a margin of safety. This approach is based on the one used in several similar projects along the northeast coast of New Brunswick and used by the LDGIZC.

On the other hand, projections were made using DSAS and ArcGIS based on the maximum historical rates measured for each homogeneous segment. This approach is, therefore, based on the assumption that in the context of the anticipated sea-level rise, erosion rates will be accelerated compared to the historical average.

However, although the literature considers this the preferred approach and consistent with the LDGIZC approach, residual uncertainty remains concerning the projections. To promote resilience, a margin of safety was estimated and added to the line already projected by historical rates of decline and sea-level rise. Several variables can slow or accelerate bank erosion (nature of deposits, urban infrastructure protected by development, etc.). This margin of safety was estimated according to different scenarios, which were determined by a multidisciplinary team (coastal engineering, climate change and geomorphology) and in collaboration with the client to align this study with those previously carried out for the RSC.

3.3 REPRESENTING EROSION RISK

This study uses the erosion risk index established in Chelbi et al. (2019) and is based on the methodology of the 2011 ACASA-RAC-Acadian Peninsula project (Robichaud et al., 2011). The erosion risk index makes it possible to assess the possibility that infrastructure will be affected by the retreat of the coastline in the more or less near future (Table 3-5). The index is based on margins of safety and the infrastructure position relative to the projected coastline position at different future years (2050 and 2100).

The current erosion risk (rated 3, high risk) is considered to be a risk for any infrastructure within 5 m of the 2018 coastline. Future erosion risks were assessed based on the coastline position, as projected for 2050 and 2100, with a 5 m margin of safety.

Infrastructures located more than 5 m from the projected 2100 coastline are considered risk-free (zero risk) (Chelbi et al., 2019).

All infrastructure located within an area defined by a line 5 m behind the projected 2050 coastline and a line 5 m behind the projected 2100 coastline is rated 1 (low risk).

All infrastructure located within an area defined by a line 5 m behind the projected 2018 coastline and a line 5 m behind the projected 2050 coastline is rated 2 (medium risk). This infrastructure should be monitored as a priority in addition to infrastructure with a rating of 3 (Chelbi et al., 2019).

Table 3-5 Erosion risk index for infrastructure (Chelbi et al., 2019)

Risk rating	Risk definition
3	Present erosion risk (high risk)
2	Erosion risk to 2050 (medium risk)
1	Erosion risk between 2050 and 2100 (low risk)
0	Without risk to 2100 (no risk)

4 HISTORY OF SEDIMENTARY DYNAMICS AND COASTAL EVOLUTION

4.1 COAST TYPE

The coastline characterized in the study area is 29,569 m long and is mostly dominated by unconsolidated coasts (36.8%), spits (23.3%) and unconsolidated cliffs (19.4%) (Table 4-1). All three types of coasts are sedimentary and are therefore very sensitive to either erosion (movement) or accumulation changes.

Table 4-1 Total length and proportion for each type of coast in the study area

Coast type	Total length of segments (m)	Proportion (%)
ARTIFICIAL	3,303.0	11.2
UNCONSOLIDATED CLIFF	5,739.2	19.4
ROCKY CLIFF	2,769.3	9.4
SPIT	6,877.6	23.3
UNCONSOLIDATED COAST	10,879.9	36.8
TOTAL	**29,569.1**	**100**

4.2 HISTORICAL COASTAL EVOLUTION BETWEEN 1944 AND 2018

4.2.1 EVOLUTION OF THE PORT OF BELLEDUNE BETWEEN 1944 AND 2018

This portion of the coastline (Port of Belledune) was not included in this study because it is a large port complex that is not likely to move in the coming decades (see Figure 4.1). Furthermore, the construction of the complex over the years would have biased the analysis since a large area of land has been reclaimed from the sea. This would have induced a false advance of the coastline. However, the visual analysis of the aerial photographs provides information on some aspects of the spatiotemporal dynamics of the area.

In the 1944 aerial photographs, this sector of Belledune is very poorly developed and the port facilities are not present. We can observe the presence of a triangular-shaped sedimentary point with a lagoon. This triangular salient presents an asymmetrical shape due to the meeting of a dominant longshore drift (east-west) and a secondary longshore drift (west-east). Tree vegetation is present on this point and Route 134 can be seen.

In the 1985 photograph, the Port of Belledune is visible. It was built in 1968. Terminal 1, a 155 m long infrastructure, is visible. The Port of Belledune area is highly developed, with tanks and industrial facilities present (Port of Belledune, 2020). The coastline is artificial and, therefore, protected from movement.

On the 2018 orthophotograph, there are many changes in the location of port facilities. Several expansions have been completed with the addition of several terminals. The sedimentary point is now connected to the port and appears to be more rounded. There is significant riprap covering the entire coastline of this sector.

4.2.2 CHARACTERIZATION OF COASTAL MOVEMENTS ON THE SEA FRONT BETWEEN 1944 AND 2018

Table 4-2 shows the coastline movements between 1944 and 2018 for the 26 homogeneous segments (1 to 26) of coastal change delineated along the Belledune and Beresford coastline. Map 4-1 provides an example of the mapping result (all maps are presented at Appendices 2, 3 and 4). The segments are numbered from southeast to northwest. Homogeneous areas were determined based on the type of coast, its shape and the homogeneity of the coastal evolution over time. The calculation results for the coastline movements are detailed for each segment for the different periods analyzed, i.e. 1944-1985, 1985-2018, and 1944-2018. A positive movement represents an accretionary zone, while a negative movement represents an eroding zone.

Table 4-2 Net movement (m) and retreat rate (m/year) of the coastline per homogeneous segment for the Belledune and Beresford sectors

HOMOGENEOUS SEGMENT	COAST TYPE	PERIOD					
		1944-1985		1985-2018		1944-2018	
		(m)	(m/year)	(m)	(m/year)	(m)	(m/year)
1	Spit	-6.92	-0.17	4.53	0.14	**-2.40**	**-0.03**
2	Spit	N.A.	N.A.	N.A.	N.A.	**N.A.**	**N.A.**
3	Spit	-3.78	-0.09	2.15	0.07	**-1.63**	**-0.03**
4	Artificial	-12.03	-0.29	-4.98	-0.15	**-17.01**	**-0.23**
5	Artificial	-8.37	-0.20	-2.92	-0.09	**-11.29**	**-0.15**
6	Artificial	-8.25	-0.20	-0.85	-0.03	**-9.10**	**-0.12**
7	Unconsolidated coast	-1.63	-0.04	-0.23	-0.01	**-1.85**	**-0.03**
8	Rocky cliff	-2.51	-0.06	-1.47	-0.04	**-3.98**	**-0.05**
9	Artificial	-6.39	-0.16	-3.97	-0.12	**-10.36**	**-0.14**
10	Unconsolidated coast	-2.48	-0.06	-2.05	-0.06	**-4.54**	**-0.06**
11	Rocky cliff	-5.35	-0.13	-3.99	-0.12	**-9.33**	**-0.13**
12	Unconsolidated coast	2.39	0.06	13.42	0.41	**15.81**	**0.21**
13	Unconsolidated coast	-9.47	-0.23	-9.03	-0.27	**-18.50**	**-0.25**
14	Unconsolidated coast	-1.48	-0.04	-4.18	-0.13	**-5.66**	**-0.08**
15	Rocky cliff	-1.72	-0.04	-1.23	-0.04	**-2.95**	**-0.04**
16	Unconsolidated cliff	-1.40	-0.03	-3.53	-0.11	**-4.93**	**-0.07**
17	Rocky cliff	-2.14	-0.05	-0.46	-0.01	**-2.60**	**-0.04**
18	Unconsolidated cliff	-2.60	-0.06	-0.45	-0.01	**-3.05**	**-0.04**
19	Rocky cliff	-3.54	-0.09	-0.07	0.00	**-3.61**	**-0.05**
20	Unconsolidated cliff	-6.13	-0.15	-0.93	-0.03	**-7.06**	**-0.10**
21	Rocky cliff	-3.02	-0.07	0.10	0.00	**-2.92**	**-0.04**
22	Unconsolidated coast	-26.13	-0.64	-0.11	0.00	**-26.24**	**-0.35**
23	Artificial	-47.73	-1.16	-0.73	-0.02	**-48.47**	**-0.65**
24	Spit	-23.39	-0.57	4.64	0.14	**-18.75**	**-0.25**
25	Unconsolidated coast	-2.52	-0.06	-0.05	0.00	**-2.57**	**-0.03**
26	Unconsolidated cliff	-9.05	-0.22	-9.41	-0.29	**-18.46**	**-0.25**
AVERAGE		**-6.17**	**-0.15**	**-1.05**	**-0.03**	**-7.22**	**-0.10**

For the presentation of the results, the study area was divided into three zones: Beresford, East Belledune (east of the Port of Belledune) and West Belledune (the coastline west of the Port of Belledune). Note that segment 2 was excluded from the analyses since it corresponds to the tidal gully that separates the north and south spits at Beresford.

Figure 4-1 Spatiotemporal evolution of the Port of Belledune between 1944 and 2018

BERESFORD (SEGMENTS 1 TO 5)

The Beresford sector is characterized mainly by its system of spits (segments 1 and 3) that extend over a length of 5,500 m of the municipality's coastline. Between 1944 and 1985, the two segments corresponding to this system experienced a significant retreat of 0.17 m/year (-6.92 m in 41 years) for segment 1 and 0.09 m/year (-3.78 m in 41 years) for segment 3. However, between 1985 and 2018, significant progradation was made in both segments. For segment 1, a rate of 0.14 m/year (4.53 meters in 33 years) and for segment 3, a rate of 0.07 m/year (2.15 meters in 33 years).

Segments 4 and 5 correspond to coastline segments that have been artificialized by the implementation of erosion protection infrastructures. These two segments cover 2,300 m of the municipality's coastline. Both segments suffered significant retreats between 1944 and 2018. For segment 4, a retreat rate of 0.23 m/year (-17.01 m in 74 years) is observed, while for segment 5, a retreat rate of 0.15 m/year (-11.29 m in 74 years) is observed.

EAST BELLEDUNE (SEGMENTS 6 TO 10)

The area east of the Port of Belledune is characterized primarily by an unconsolidated coastline (unconsolidated cliffs) (segments 7 and 10) that extends nearly 2,200 m in length. There is also a 540 m long rocky cliff segment (segment 8) and a 600 m long artificially created coastline (segments 6 and 9). In the unconsolidated coastline segments (7 and 10), the average rate of change is negligible. Indeed, between 1944 and 2018, both segments experienced a retreat of 0.03 m/year (-1.85 m in 74 years) for segment 7 and 0.06 m/year (-4.54 m in 74 years) for segment 10. These rates are equal to or less than the margin of error. Similarly, segment 8 (rocky cliff) has a retreat rate which is less than the margin of error, i.e. 0.05 m/year (-3.98 m over 74 years). This can be explained by the fact that some areas have undergone advances (sedimentation) while others have undergone retreat (erosion). These two phenomena, therefore, balance each other and give a low average.

Concerning the artificial segments (6 and 9), protective infrastructures were installed between 1944 and 1985 to counter erosion phenomena. Indeed, the two segments retreat at a similar rate of 0.12 m/year (-9.10 m over 74 years) for segment 6 and 0.14 m/year (-10.36 m in 74 years) for segment 9, presumably before the construction of these infrastructures.

WEST BELLEDUNE (SEGMENTS 11 TO 26)

The coast in the west Belledune sector is the most diverse as it is composed of an unconsolidated coastline including unconsolidated coast, unconsolidated cliff and spit (segments 12, 13, 14, 22 and 25) covering a length of 8,640 m, rocky cliffs (segments 8, 11, 15, 17, 19 and 21) covering 2,200 m, unconsolidated cliffs (segments 16, 18, 20 and 26) 5,740 m, a spit (segment 24) 1,315 m, and an artificial coastline (segment 23) 327 m.

The unconsolidated coastline segments are generally susceptible to erosion and sedimentation. Moreover, a significant spatiotemporal dynamic is observed in the unconsolidated segments between 1944 and 2018. To begin with, segment 12 experienced progradation between 1944 and 2018 with an accretion rate of 0.21 m/year (15.81 m over 74 years). This is the only segment that prograded. This accretion can be attributed to the movement of sediments from the adjoining segments 13 and 14 that suffered significant retreats between 1944 and 2018. Indeed, segment 13 experienced a retreat rate of 0.25 m/year between 1944 and 2018 (-18.5 m in 74 years), while segment 14 declined by 0.08 m/year (-5.66 m over 74 years). Segment 22 experienced a significant retreat of 0.35 m/year between 1944 and 2018 (-26.24 m in 74 years), while segment 25 declined by 0.03 m/year (-2.57 m over 74 years), which is below the margin of error.

The rocky cliff segments all eroded negligibly (below the margin of error), except segment 11. Segments 15, 17, 19 and 21 all have retreat rates between 0.04 and 0.05 m/year for the period 1944 to 2018. This is due to their increased resistance to erosion, as they are more cohesive. Segment 11 experienced a retreat rate of 0.13 m/year (-9.33 m over 74 years).

The unconsolidated cliff segments also suffered erosion. Overall, segment 16 retreated at a rate of 0.07 m/year (-4.93 m in over 74 years), segment 18 at a negligible rate of 0.04 m/year (-3.05 m over 74 years), segment 20 at a rate of 0.10 m/year between 1944 and 2018 (-7.06 m over 74 years) and segment 26 at a rate of 0.25 m/year (-18.46 m in 74 years). Being less cohesive material than the bedrock cliffs, it is normal that these segments have experienced more erosion.

The coastline spit at the mouth of the Jacquet River was very dynamic between 1944 and 2018. Between 1944 and 1985, it retreated by 0.57 m/year (-23.29 m in 41 years) while between 1985 and 2018, it prograded by 0.14 m/year (4.64 m over 33 years). This trend is the same as Beresford's spit, i.e. a retreat between 1944 and 1985 and an accretion between 1985 and 2018. The reasons for the progradation are different: more natural in Belledune (accumulation following certain storms), and anthropogenic in Beresford due to the installation of several protective structures between 1944 and 1985.

Segment 23 (artificial) has experienced the greatest retreat along the entire Belledune and Beresford coastline. Indeed, between 1944 and 1985, the coast experienced a retreat rate of -1.16 m/year (-47.73 m in 41 years). Protective infrastructures were subsequently implemented and between 1985 and 2018, the retreat was negligible (0.02 m/year, -0.73 m over 33 years). This gives a retreat rate of 0.65 m/year (-48.75 m in 74 years) for the entire period covered.

SYNTHESIS

Overall, the coastline in the study area was mainly in retreat throughout the entire analysis period. The highest rates of retreat were recorded in the unconsolidated segments (unconsolidated coast and unconsolidated cliffs) which are, by their nature, more dynamic. Artificialized segments experienced more erosion between 1944 and 1985 than between 1985 and 2018. This difference is explained by the relatively recent construction of the majority of the protective structures, which substantially reduced erosion. The coastline spits have experienced a dynamic process that appears to be different from the other segments, probably because they are more sensitive to coastal drift and lateral movement. Rocky cliffs were more stable than other types of coasts with the lowest rates measured.

4.2.3 CHARACTERIZATION OF THE ESTUARY COASTLINE MOVEMENTS BETWEEN 1944 AND 2018

Map 4-2 (serving as an example) and Table 4.3 show the coastline movements of estuaries in the study area between 1944 and 2018. Four homogeneous segments of coastal evolution were defined (1 to 4) along the coastline of the estuaries. The homogeneous zones were determined according to the type of coast and the homogeneity of coastal evolution over time.

The calculation results for the coastline movements are detailed for each homogeneous zone for the different periods analyzed, including 1944-1985, 1985-2018 and 1944-2018. A positive movement represents an accretionary zone, while a negative movement represents an eroding zone.

Segments 1, 2 and 3 correspond to the coastline behind the Beresford spits. Segments 1 and 2 show movement rates of -0.10 and +0.15 m per year between 1944 and 2018 (-7.28 and +10.99 m in 74 years), respectively, while segment 3 shows a movement rate below the margin of error. Segment 4 corresponds to the mouth of the Jacquet River with movements that are negligible and below the margin of error. Thus, no significant change has occurred in this segment and equilibrium prevails.

To conclude, the movements in estuaries are homogeneous over time. Indeed, the average rates are -0.04 m per year and are identical between each period analyzed. This rate is below the margin of error of 0.06 m and is negligible and corresponds to spatiotemporal stability.

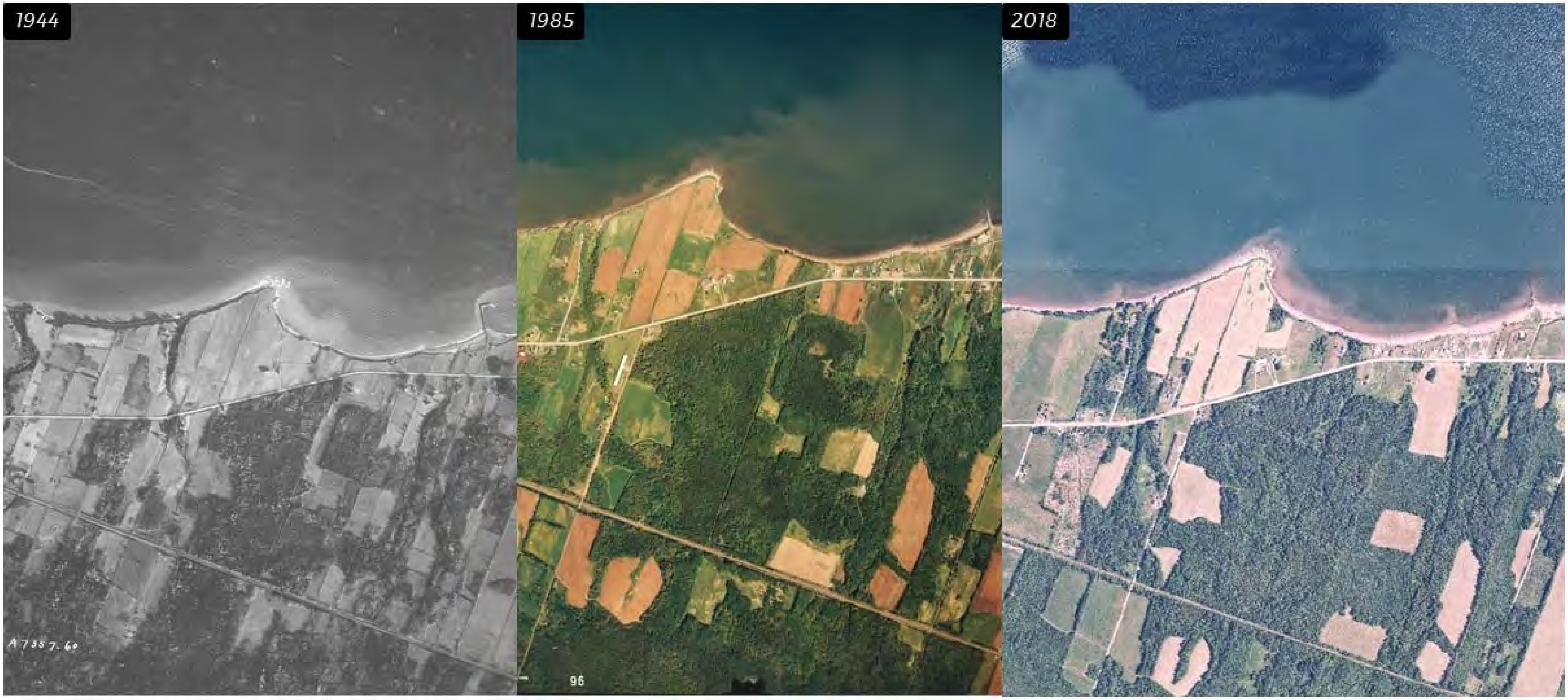

Figure 4-2 **Historical coastal evolution of segments 14, 15 and 16 in the Municipality of Belledune between 1944 and 2018**

La précision des limites et des mesures montrées sur ce document ne doivent pas servir à des fins d'ingénierie ou de délimitation foncière. Aucune analyse foncière n'a été effectuée par un arpenteur-géomètre.
Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.

Table 4-3 **Net movement (m) and retreat rate (m/year) of the estuary shores per homogeneous segment for the Belledune and Beresford sectors**

HOMOGENEOUS SEGMENT	COAST TYPE	PERIOD					
		1944-1985		1985-2018		1944-2018	
		(m)	(m/year)	(m)	(m/year)	(m)	(m/year)
1	Estuary	-6.28	-0.15	-0.99	-0.03	**-7.28**	**-0.10**
2	Estuary	25.61	0.62	-14.62	-0.44	**10.99**	**0.15**
3	Estuary	0.52	0.01	-0.97	-0.03	**-0.45**	**-0.01**
4	Estuary	-0.58	-0.01	-1.33	-0.04	**-1.91**	**-0.03**
AVERAGE		**-1.48**	**-0.04**	**-1.22**	**-0.04**	**-2.70**	**-0.04**

4.3 HISTORICAL RETREAT RATES COMPARED TO THOSE ESTIMATED FROM EXISTING DATA

The New Brunswick Department of Natural Resources and Energy Development (DNRED) is responsible for compiling coastline and shoreline movement data for the entire province. Several sets of data are therefore available for the Chaleur Bay coastline (cliffs and dunes), including the Belledune and Beresford sectors. The historical retreat rates produced in this study were compared to those found in the provincial database. However, the provincial statistics on coastal movement trends were last updated in 2015 and do not incorporate rates calculated since that date. Indeed, nearly 13,000 new movement rates were calculated over the past few years by university researchers and consultants, including several for the Chaleur Bay coastline, which could cause the statistics for the region to vary. However, any change would be minor and would not affect the historical trend.

For the cliffs (rocky and unconsolidated), 1,862 values are included in the statistics for the Chaleur region and show an average movement rate of -0.16 m/year. For the dunes, 1,084 values were considered and give an average retreat rate of -0.06 m/year. Although the margins of error associated with these statistics are larger than those of this study, due mainly to the technological limitations of older studies, there are nevertheless similarities in the calculated rates.

Table 4-4 shows the average coastline movement rates along cliffs and dunes compiled before 2015 by the DNRED and including only data sets that cover periods of more than 15 years.

Table 4-4 **Coastline movement trends in Chaleur Bay between 1934 and 2015**

Average rate and number of transects	Coastline							
	Cliff				Dune			
	Rate (m/year)	Margin of error (m/year)	N	%	Rate (m/year)	Margin of error (m/year)	N	%
All rates	-0.16	±0.15	1862	100	-0.06	±0.14	1084	100
Negative rates	-0.23	±0.16	1433	76.96	-0.40	±0.14	593	54.70
Positive rates	+0.10	±0.12	343	18.42	+0.36	±0.14	465	42.90
Neutral rates	0.00	±0.15	86	4.62	0.00	±0.19	26	2.40
Total	**-**	**-**	**1862**	**100**	**-**	**-**	**1084**	**100**

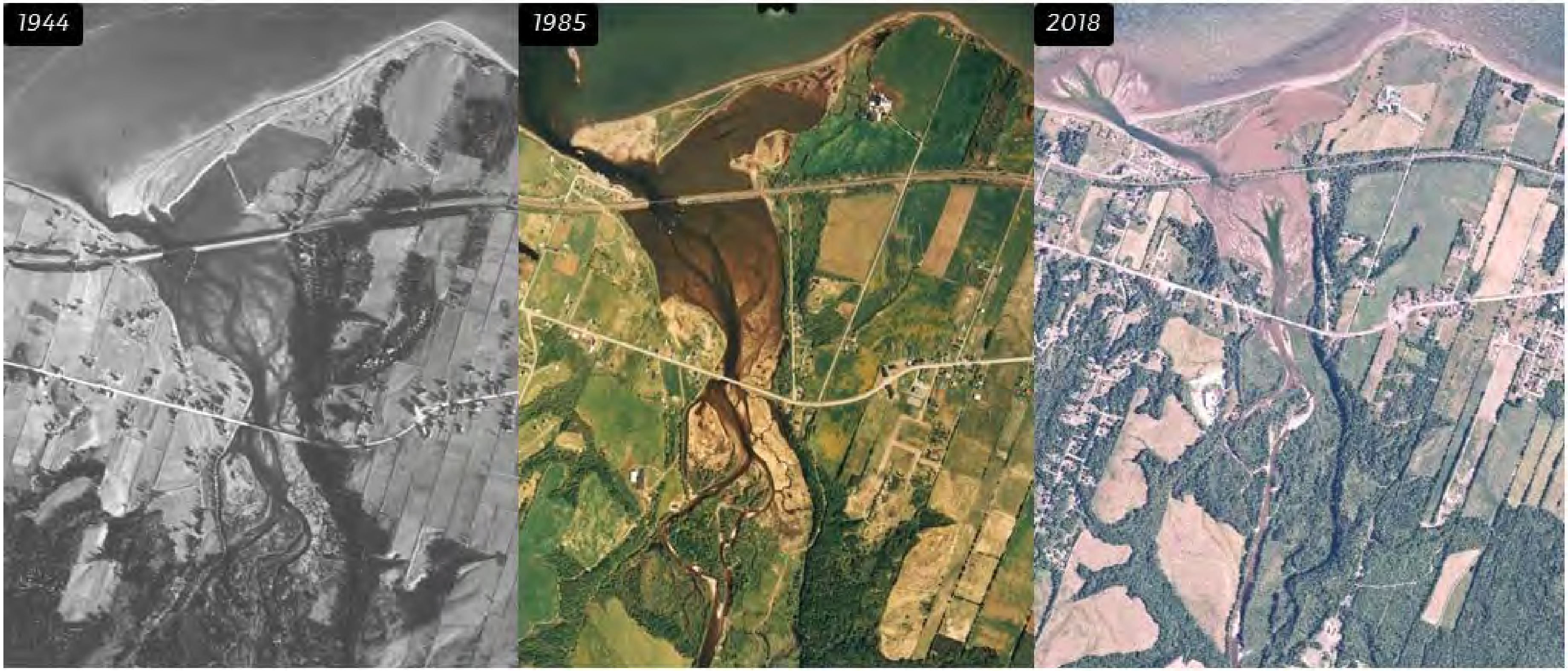

Figure 4-3 Historical morphological evolution of the Jacquet River estuary (Belledune) between 1944 and 2018

Commission de services régionaux Chaleur Regional Service Commission

Analyse de risque d'inondation et d'érosion côtière pour une partie du territoire de la CSR Chaleur / Coastal flood and erosion risk analysis Portion of the Chaleur RSC Territory

Carte 4-2 / Map 4-2
Déplacement des rives des estuaires entre 1944 et 2018 dans le secteur de Belledune et Beresford / Movement of the shoreline of the estuaries between 1944 and 2018 in Belledune and Beresford sectors

Sources :
CanVec+, 1/50 000, RNCan, 2016
Image aérienne : Orthophoto, 2018

Mars 2020
March 2020

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5 COASTLINE PROJECTION FOR 2050 AND 2100

5.1 PROJECTED COASTLINE FOR THE SEA FRONT

Map 5-1 (serving as an example) and Table 5-1 show the coastline projections for the 2018-2050 and 2050-2100 periods. As mentioned in the methodology, two scenarios were developed since it is difficult to predict how an environment will respond accurately to future climate change. The first is a projection with historical rates (continuation of trends) and the second is a pessimistic scenario where the worst retreat rates recorded in the past occur in the future. The same 26 homogeneous segments of coastal evolution were used (1 to 26).

The calculation results for the coastline projections are detailed for each segment for the periods 2018-2050 and 2050-2100. A positive movement represents an accretion projection while a negative movement represents an erosion projection.

The results show that if the trend continues, the coastline will retreat on average at a rate of 0.10 m/year. This corresponds to an average retreat of -3.17 m for the period 2018-2050 and -4.96 m for the period 2050-2100. Under a pessimistic scenario, the retreat rate will be 0.42 m/year or -13.43 m for the period 2018-2050 and -21.01 m for 2050-2100.

Belledune is projected to experience the largest retreat of the two municipalities due to a longer waterfront (12,000 m) that includes unconsolidated coast. Belledune also has more diverse coast types, making it more vulnerable to present and future climate change. Nevertheless, the density of buildings is much lower in Belledune than in Beresford. Beresford, on the other hand, has only 5,500 m of frontage and is in the coastline spit segments where the changes will be most noticeable. These segments are also densely populated, which means they will require monitoring.

Depending on the type of coastline, the retreat will be more or less significant. For example, unconsolidated coasts and unconsolidated cliffs will experience a greater retreat, while rocky cliffs, being much more cohesive than unconsolidated deposits, will be less affected.

The detailed data is included in the geodatabase and allows users a better understanding of the scope and extent attributed to future coastal erosion in the territories of the two municipalities.

5.2 PROJECTED ESTUARY COASTLINE

Table 5-2 presents projections of the estuary coastline for the periods 2018-2050 and 2050-2100, based on historical average and pessimistic rates.

The results show that if the trend continues, estuary coastlines will retreat at an average rate of -0.04 m/year. For the period 2018-2050, this corresponds to an average retreat of -1.17 m and for 2050-2100, a retreat of 1.83 m. Under a pessimistic scenario, the retreat rate will be -0.33 m/year, which corresponds to retreats of -10.59 m for the period 2018-2050 and -16.55 m for 2050-2100.

Table 5-1 Projection (m) for the periods 2018-2050 and 2050-2100 and retreat rate (m/year) of the coastline per homogeneous segment for the Belledune and Beresford sectors.

Homogeneous segment	Coast type	Period (rate)							
		2018-2050 (historical rate)		2018-2050 (pessimistic rate)		2050-2100 (historical rate)		2050-2100 (pessimistic rate)	
		(m)	(m/year)	(m)	(m/year)	(m)	(m/year)	(m)	(m/year)
1	Spit	-1.04	-0.03	-5.93	-0.19	-1.62	-0.03	-9.27	-0.19
2	Spit	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
3	Spit	-0.71	-0.02	-12.69	-0.40	-1.10	-0.02	-20.00	-0.40
4	Artificial	-7.36	-0.23	-1.74	-0.05	-11.50	-0.23	-2.71	-0.05
5	Artificial	-4.88	-0.15	-3.04	-0.10	-7.63	-0.15	-4.76	-0.10
6	Artificial	-3.94	-0.12	-1.17	-0.04	-6.15	-0.12	-1.84	-0.04
7	Unconsolidated coast	-0.80	-0.03	-3.98	-0.12	-1.25	-0.03	-6.21	-0.12
8	Rocky cliff	-1.72	-0.05	-5.57	-0.17	-2.69	-0.05	-8.70	-0.17
9	Artificial	-4.48	-0.14	-2.13	-0.07	-7.00	-0.14	-3.33	-0.07
10	Unconsolidated coast	-1.96	-0.06	-11.11	-0.35	-3.07	-0.06	-17.36	-0.35
11	Rocky cliff	-4.04	-0.13	-11.83	-0.37	-6.31	-0.13	-18.49	-0.37
12	Unconsolidated coast	6.84	0.21	-2.48	-0.08	10.68	0.21	-3.87	-0.08
13	Unconsolidated coast	-8.00	-0.25	-40.61	-1.27	-12.50	-0.25	-63.45	-1.27
14	Unconsolidated coast	-2.45	-0.08	-12.15	-0.38	-3.82	-0.08	-18.99	-0.38
15	Rocky cliff	-1.28	-0.04	-3.39	-0.11	-2.00	-0.04	-5.30	-0.11
16	Unconsolidated cliff	-2.13	-0.07	-10.77	-0.34	-3.33	-0.07	-16.82	-0.34
17	Rocky cliff	-1.13	-0.04	-3.84	-0.12	-1.76	-0.04	-6.00	-0.12
18	Unconsolidated cliff	-1.32	-0.04	-3.20	-0.10	-2.06	-0.04	-5.00	-0.10
19	Rocky cliff	-1.56	-0.05	-1.61	-0.05	-2.44	-0.05	-2.52	-0.05
20	Unconsolidated cliff	-3.05	-0.10	-4.19	-0.13	-4.77	-0.10	-6.55	-0.13
21	Rocky cliff	-1.26	-0.04	-1.26	-0.04	-1.97	-0.04	-1.97	-0.04
22	Unconsolidated coast	-11.35	-0.35	-15.27	-0.48	-17.73	-0.35	-23.86	-0.48
23	Artificial	-20.96	-0.65	-11.84	-0.37	-32.75	-0.65	-18.50	-0.37
24	Spit	-8.11	-0.25	-23.55	-0.74	-12.67	-0.25	-36.80	-0.74
25	Unconsolidated coast	-1.11	-0.03	-13.02	-0.41	-1.73	-0.03	-20.35	-0.41
26	Unconsolidated cliff	-7.98	-0.25	-15.61	-0.49	-12.47	-0.25	-24.38	-0.49
Average		**-3.17**	**-0.10**	**-13.43**	**-0.42**	**-4.96**	**-0.10**	**-21.01**	**-0.42**

Table 5-2 Projection (m) for the periods 2018-2050 and 2050-2100 and projected retreat rate (m/year) of the estuary shores per homogeneous segment for the Belledune and Beresford sectors.

Homogeneous segment	Coast type	Period							
		2018-2050 (historical rate)		2018-2050 (pessimistic rate)		2050-2100 (historical rate)		2050-2100 (pessimistic rate)	
		(m)	(m/year)	(m)	(m/year)	(m)	(m/year)	(m)	(m/year)
1	Estuary	-3.15	-0.10	-8.32	-0.26	-4.92	-0.10	-13.00	-0.26
2	Estuary	4.75	0.15	-4.15	-0.13	7.43	0.15	-6.48	-0.13
3	Estuary	-0.19	-0.01	-10.14	-0.32	-0.30	-0.01	-15.85	-0.32
4	Estuary	-0.83	-0.03	-12.39	-0.39	-1.29	-0.03	-19.36	-0.39
Average		**-1.17**	**-0.04**	**-10.59**	**-0.33**	**-1.83**	**-0.04**	**-16.55**	**-0.33**

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5.3 INFRASTRUCTURE EROSION RISK INDEX

We performed an erosion risk analysis on all available infrastructure data for the municipalities of Belledune and Beresford. It is based on infrastructure position relative to the projected coastline in 2050 and 2100 according to the index described in the methodology (see section 3-3). Table 5-3 presents the number of infrastructures at risk based on the type of infrastructure and the risk index calculated according to the historical projection (maintaining the current trend).

A total of 274 infrastructure elements were identified as potentially at risk of erosion by 2100 (index 1 to 3), of which 99 are at current risk based on their proximity to the 2018 coastline (Table 5-3).

Table 5-3 indicates that buildings represent the type of infrastructure most at immediate risk with 76, followed by utility poles with 20. Sewers and water pipes count 2 and 1 pieces of infrastructure at immediate risk respectively.

It is important to consider that these are summary results in both tabular and graphical form. The geodatabase produced for this project as well as the .mxd file generated by the data allows for a more precise geographical analysis and the precise location of the infrastructures at risk.

Table 5-3 Infrastructure count by Erosion Risk Index in Belledune and Beresford

Infrastructure	Index 0	Index 1	Index 2*	Index 3*	Total
Buildings	4915	73	71	76	**5135**
Geodetic marks	196	1	0	0	**197**
Sewers	137	0	0	2	**139**
Radio antenna	98	0	2	0	**100**
Pumping	9	0	1	0	**10**
Utility pole	2906	18	9	20	**2953**
Water pipe	128	0	0	1	**129**
Total	**8389**	**92**	**83**	**99**	**8663**

* Infrastructure to monitor

6 SUMMARY AND CONCLUSION

This study focuses on the development of erosion scenarios and the identification of infrastructures at risk by 2100 for the municipalities of Belledune and Beresford. It used the most recent data available, including the Chaleur RSC infrastructure layers as well as proven methods.

The geospatial data produced in this study can be used as a decision-support tool to determine which infrastructures are at risk of erosion, identify the most vulnerable sectors and help Chaleur RSC in its efforts to adapt and build resilience to the consequences of climate change. Furthermore, it is also possible to create educational material showing the coast's evolution and the distribution of infrastructures at risk of erosion by sector of the study area based on geospatial data, to raise public awareness of this issue.

The scientific community recognizes that the coastal sedimentary dynamics will face an increased future imbalance due to a eustatic rise, an increase in high-intensity events (storms) and a decrease in the winter ice coverage that serves as a protection for the coast. The historical coastline movement rates presented in this report reflect past and current environmental conditions, but these rates may be higher in the next century. For this reason, we developed a pessimistic scenario to take into consideration this potential acceleration in erosion rates. However, the risk of erosion varies across sectors in the study area.

The coastline projection scenarios developed in this study are considered conservative as they are based on past data and a pessimistic scenario. They raise a spectrum of possibilities that only the future can confirm. Other coastal sediment dynamic scenarios are possible.

Regardless of historical and projected erosion rates, strong focus should be placed on expected extreme future conditions (WSP, 2019). Indeed, if climate change materializes as predicted, the number of low-repeating but high-intensity events will increase. Storms cause significant destruction in a short period as they erode much coastal sedimentary material and cause significant property damage.

The segments located in the municipality of Beresford are mainly composed of coastline spits and segments protected by protective infrastructure (riprap). The installation of protective structures in the study area indicates that erosion is a problem that has already been recognized in the region. Historical erosion rates measured in these segments are lower than those measured in the north (Belledune) where the coastline is natural (less protected) and composed mainly of unconsolidated coastline and rocky cliffs. Considering that Beresford's spit system is densely inhabited, an increase in the monitoring of sedimentary dynamics is important, as the spit is very active according to the results obtained in the present study. This could include, for example, sedimentary balances of the submerged and exposed parts, longitudinal sedimentary transfer studies related to coastal drift, transverse sedimentary transfer studies related to overflowing during storms, monitoring of the impact of the presence of coastal seawalls on sedimentary transfer, etc.

In the Belledune municipality the segments of unconsolidated coast cover a long waterfront. In doing so, they are more likely to face more erosion problems in the future. Note, however, that the Belledune coastline is less densely populated than that of the Municipality of Beresford. The Municipality of Belledune segments cover a longer portion of the coastline.

As far as infrastructures are concerned, the erosion risk indices demonstrate that, although the vast majority of infrastructures on the territory of both municipalities are not at risk, several infrastructures are at risk of erosion.

Finally, the method used should be reassessed for spits because of their lateral mobility. Indeed, the present method mainly takes into account coastal advances and retreats, but not lateral movements that are specific to environments such as spits.

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APPENDIX

1

GEOLOGICAL MAPS

Department of Natural Resources
Minerals, Policy and Planning Division

New Nouveau Brunswick

Ministère des Ressources naturelles
Division des minéraux, des politiques et de la planification

P.O. Box 6000, Fredericton, N.B. E3B 5H1

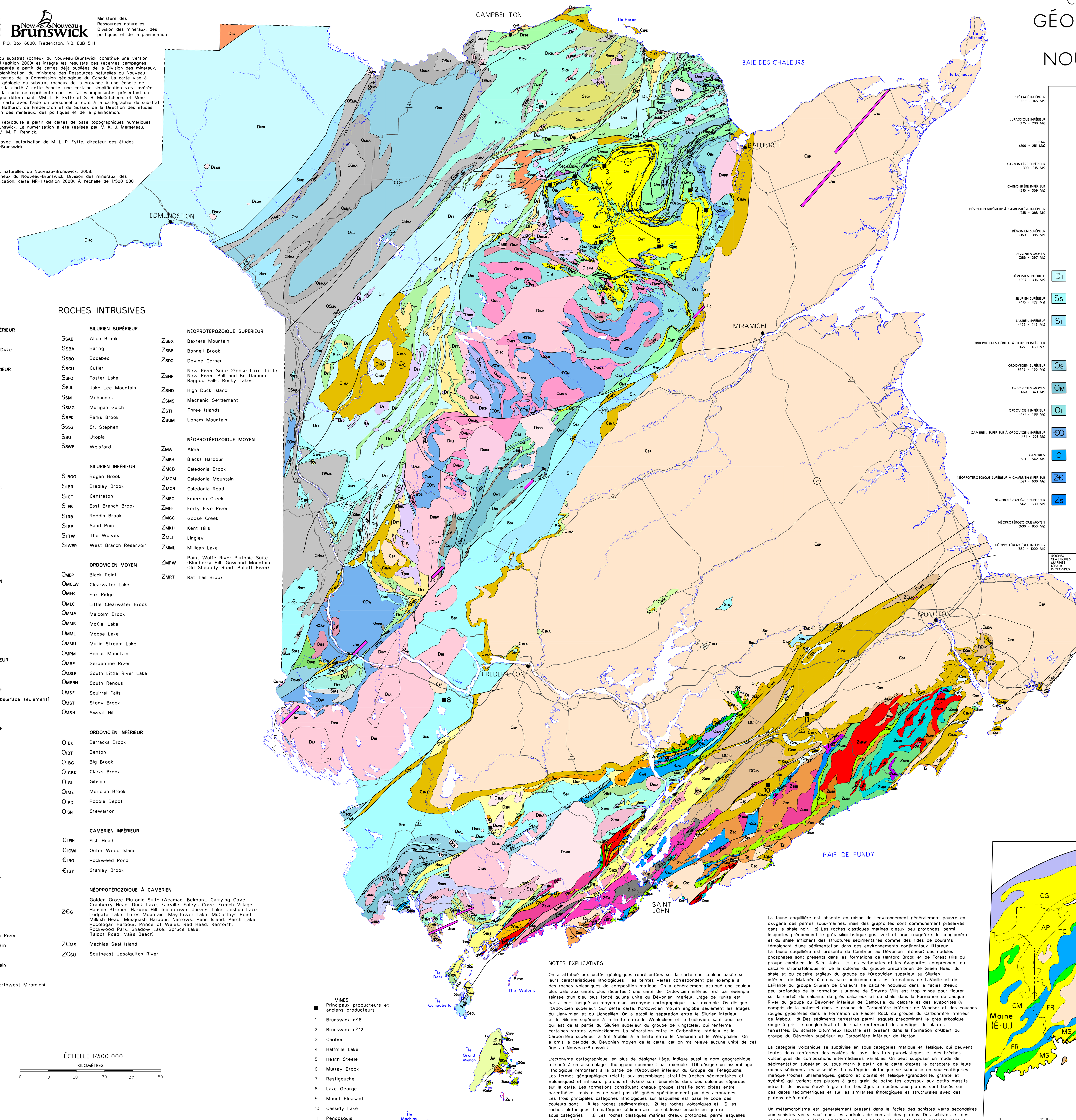
Cette carte géologique du substrat rocheux du Nouveau-Brunswick constitue une version révisée de la carte NR-1 (édition 2000) et intègre les résultats des récentes campagnes de terrain. Elle a été préparée à partir de cartes déjà publiées de la Division des minéraux, des politiques et de la planification, du ministère des Ressources naturelles du Nouveau-Brunswick, ainsi que de cartes de la Commission géologique du Canada. La carte vise à fournir un aperçu de la géologie du substrat rocheux de la province à une échelle de 1/500 000. Pour maintenir la clarté à cette échelle, une certaine simplification s'est avérée essentielle. Par exemple, la carte ne représente que les failles importantes présentant un déplacement stratigraphique déterminant. MM. L. R. Fyffe et S. R. McCutcheon, et Mme E. A. Smith ont établi la carte avec l'aide du personnel affecté à la cartographie du substrat rocheux des bureaux de Bathurst, de Fredericton et de Sussex de la Direction des études géologiques de la Division des minéraux, des politiques et de la planification.

La carte de base a été reproduite à partir de cartes de base topographiques numériques de Services Nouveau-Brunswick. La numérisation a été réalisée par M. K. J. Mersereau, Mme D. M. Richard, et M. M. P. Rennick.

Cette carte est publiée avec l'autorisation de M. L. R. Fyffe, directeur des études géologiques du Nouveau-Brunswick.

CITATION RECOMMANDÉE

Ministère des Ressources naturelles du Nouveau-Brunswick, 2008.
Géologie du substrat rocheux du Nouveau-Brunswick. Division des minéraux, des politiques et de la planification, carte NR-1 (édition 2008). À l'échelle de 1/500 000 (Révisé, décembre 2008)



ROCHES INTRUSIVES

JURASSIQUE INFÉRIEUR

JIC	Caraquet Dyke
JIMI	Ministers Island Dyke

DÉVONIEN SUPÉRIEUR

DSAL	Antinouri Lake
DSBH	Beech Hill
DSBU	Buttermilk Brook
DSDG	Dungarvon
DSEL	Eagle Lake
DSK	Kedron Stream
DSMB	McDougall Brook
DSMD	Mount Douglas
DSMP	Mount Pleasant
DSPA	Patapedia River
DSPR	Pleasant Ridge
DSQM	Quisibis Mountain
DSRA	Ramsay Brook
DSRD	Red Brook
DSRV	Rivière Verte
DSSB	Sisters Brook
DSSR	Sorrel Ridge
DSTR	True Hill
DSWB	Watson Brook

DÉVONIEN MOYEN

DMBU	Burnthill
DMCN	Canaan River
DMGA	Gaytons
DMN	Nigadoo
DMND	Nicholas Denys
DMPF	Pabineau Falls

DÉVONIEN INFÉRIEUR

DIA	Allandale
DIBE	Beadle Mountain
DIBL	Becaguimec Lake
	Bois-Gagnon [subsurface seulement]
DICH	Charlo
DICM	Clark Mountain
DICB	Clearwater Brook
DIDB	Dickie Brook
DIED	Evandale
DIGL	Goodwin Lake
DIHT	Hartfield
DIH	Hawkshaw
DIHP	Howard Peak
DIJF	Jerry Ferguson
DIJL	John Lee Brook
DIJB	Juniper Barren
DILB	Landry Brook
DILL	Lost Lake
DIMA	Magaguadavic
DIMK	McKenzie Gulch
DIMBA	Mount Bailey
DIMDB	Mount DesBarres
DIMED	Mount Edward
DIME	Mount Elizabeth
DIML	Mount Latour
DIMM	Mount Manny
DINW	Nashwaak
DINDR	North Dungarvon River
DINP	North Pole Stream
DIPB	Portage Brook
DIRM	Redstone Mountain
DISL	Skiff Lake
DISNM	South Branch Northwest Miramichi
DISC	Squaw Cap
DISQ	Squaw Lake
DISG	Sugarloaf
DITH	Tower Hill

SILURIEN SUPÉRIEUR

SSAB	Allen Brook
SSBA	Baring
SSBO	Bocabec
SSCU	Cutler
SSFO	Foster Lake
SSJL	Jake Lee Mountain
SSM	Mohannes
SSMG	Mulligan Gulch
SSPK	Parks Brook
SSSS	St. Stephen
SSU	Utopia
SSWF	Welsford

SILURIEN INFÉRIEUR

SIBOG	Bogan Brook
SIBR	Bradley Brook
SICT	Centreton
SIEB	East Branch Brook
SIRB	Reddin Brook
SISP	Sand Point
SITW	The Wolves
SIWBR	West Branch Reservoir

ORDOVICIEN MOYEN

OMBP	Black Point
OMCLW	Clearwater Lake
OMFR	Fox Ridge
OMLC	Little Clearwater Brook
OMMA	Malcolm Brook
OMMK	McKiel Lake
OMML	Moose Lake
OMMU	Mullin Stream Lake
OMPM	Poplar Mountain
OMSE	Serpentine River
OMSLR	South Little River Lake
OMSRN	South Renous
OMSF	Squirrel Falls
OMST	Stony Brook
OMSH	Sweat Hill

ORDOVICIEN INFÉRIEUR

OIBK	Barracks Brook
OIBT	Benton
OIBG	Big Brook
OICBK	Clarks Brook
OIGI	Gibson
OIME	Meridian Brook
OIPD	Popple Depot
OISN	Stewarton

CAMBRIEN INFÉRIEUR

€IFIH	Fish Head
€IOWI	Outer Wood Island
€IRO	Rockweed Pond
€ISY	Stanley Brook

NÉOPROTÉROZOIQUE À CAMBRIEN

Z€G	Golden Grove Plutonic Suite (Acamac, Belmont, Carrying Cove, Cranberry Head, Duck Lake, Fairville, Foleys Cove, French Village, Hanson Stream, Harvey Hill, Indiantown, Jarvies Lake, Joshua Lake, Ludgate Lake, Lutes Mountain, Mayflower Lake, McCarthys Point, Milkish Head, Musquash Harbour, Narrows, Penn Island, Perch Lake, Pocologan Harbour, Prince of Wales, Red Head, Renforth, Rockwood Park, Shadow Lake, Spruce Lake, Talbot Road, Vairs Beach)
Z€MSI	Machias Seal Island
Z€SU	Southeast Upsalquitch River

NÉOPROTÉROZOIQUE SUPÉRIEUR

ZSBX	Baxters Mountain
ZSBB	Bonnell Brook
ZSDC	Devine Corner
ZSNR	New River Suite (Goose Lake, Little New River, Pull and Be Damned, Ragged Falls, Rocky Lakes)
ZSHD	High Duck Island
ZSMS	Mechanic Settlement
ZSTI	Three Islands
ZSUM	Upham Mountain

NÉOPROTÉROZOIQUE MOYEN

ZMA	Alma
ZMBH	Blacks Harbour
ZMCB	Caledonia Brook
ZMCM	Caledonia Mountain
ZMCR	Caledonia Road
ZMEC	Emerson Creek
ZMFF	Forty Five River
ZMGC	Goose Creek
ZMKH	Kent Hills
ZMLI	Lingley
ZMML	Millican Lake
ZMPW	Point Wolfe River Plutonic Suite (Blueberry Hill, Gowland Mountain, Old Shepody Road, Pollett River)
ZMRT	Rat Tail Brook

MINES

■ Principaux producteurs et anciens producteurs

1 Brunswick n° 6
2 Brunswick n° 12
3 Caribou
4 Halfmile Lake
5 Heath Steele
6 Murray Brook
7 Restigouche
8 Lake George
9 Mount Pleasant
10 Cassidy Lake
11 Penobsquis

ÉCHELLE 1/500 000

KILOMÈTRES

0 10 20 30 40 50

NOTES EXPLICATIVES

On a attribué aux unités géologiques représentées sur la carte une couleur basée sur leurs caractéristiques lithologiques : les teintes vertes correspondent par exemple à des roches volcaniques de composition mafique. On a généralement attribué une couleur plus pâle aux unités plus récentes : une unité de l'Ordovicien inférieur est par exemple teintée d'un bleu plus foncé qu'une unité du Dévonien inférieur. L'âge de l'unité est par ailleurs indiqué au moyen d'un acronyme cartographique : par exemple, Os désigne l'Ordovicien supérieur. Sur cette carte, l'Ordovicien moyen englobe seulement les étages du Llanvirnien et du Llandeilien. On a établi la séparation entre le Silurien inférieur et le Silurien supérieur à la limite entre le Wenlockien et le Ludlovien, sauf pour ce qui est de la partie du Silurien supérieur du groupe de Kingsclear, qui renferme certaines strates wenlockiennes. La séparation entre le Carbonifère inférieur et le Carbonifère supérieur a été établie à la limite entre le Namurien et le Westphalien. On a omis la période du Dévonien moyen de la carte, car on n'a relevé aucune unité de cet âge au Nouveau-Brunswick.

L'acronyme cartographique, en plus de désigner l'âge, indique aussi le nom géographique attribué à un assemblage lithologique connexe : par exemple, TOI désigne un assemblage lithologique remontant à la partie de l'Ordovicien inférieur du Groupe de Tetagouche. Les termes géographiques relatifs aux assemblages stratifiés (roches sédimentaires et volcaniques) et intrusifs (plutons et dykes) sont énumérés dans des colonnes séparées sur la carte. Les formations constituant chaque groupe stratifié sont citées entre parenthèses, mais elles ne sont pas désignées spécifiquement par des acronymes. Les trois principales catégories lithologiques sur lesquelles est basé le code des couleurs sont : 1) les roches sédimentaires, 2) les roches volcaniques et 3) les roches plutoniques. La catégorie sédimentaire se subdivise ensuite en quatre sous-catégories : a) Les roches clastiques marines d'eaux profondes, parmi lesquelles prédominent le shale gris, vert et noir, et le grès silicoclastique granoclassé allant du gris au vert. Le shale et le chert ferromanganésifère sont courants dans de nombreuses formations du Cambrien à l'Ordovicien supérieur et ils sont présents par endroits dans la formation du Silurien inférieur de Smyrna Mills du Groupe de Perham. La faune coquillière est absente en raison de l'environnement généralement pauvre en oxygène des pentes sous-marines, mais des graptolites sont communément préservés dans le shale noir. b) Les roches clastiques marines d'eaux peu profondes, parmi lesquelles prédominent le grès siliciclastique gris, vert et brun rougeâtre, le conglomérat et du shale affichant des structures sédimentaires comme des rides de courants témoignant d'une sédimentation dans des environnements continentaux littoraux. La faune coquillière est présente du Cambrien au Dévonien inférieur; des nodules phosphatés sont présents dans les formations de Hanford Brook et de Forest Hills du groupe cambrien de Saint John. c) Les carbonates et les évaporites comprennent du calcaire stromatolitique et de la dolomie du groupe précambrien de Green Head, du shale et du calcaire argileux du groupe de l'Ordovicien supérieur au Silurien inférieur de Matapédia; du calcaire noduleux dans les formations de LaVieille et de LaPlante du groupe Silurien de Chaleurs; (le calcaire noduleux dans le faciès d'eaux peu profondes de la formation silurienne de Smyrna Mills est trop mince pour figurer sur la carte); du calcaire, du grès calcareux et du shale dans la Formation de Jacquet River du groupe du Dévonien inférieur de Dalhousie; du calcaire et des évaporites (y compris de la potasse) dans le groupe du Carbonifère inférieur de Windsor et des couches rouges gypsifères dans la Formation de Plaster Rock du groupe du Carbonifère inférieur de Mabou. d) Des sédiments terrestres parmi lesquels prédominent le grès arkosique rouge à gris, le conglomérat et du shale renfermant des vestiges de plantes terrestres. Du schiste bitumineux lacustre est présent dans la Formation d'Albert du groupe du Dévonien supérieur au Carbonifère inférieur de Horton.

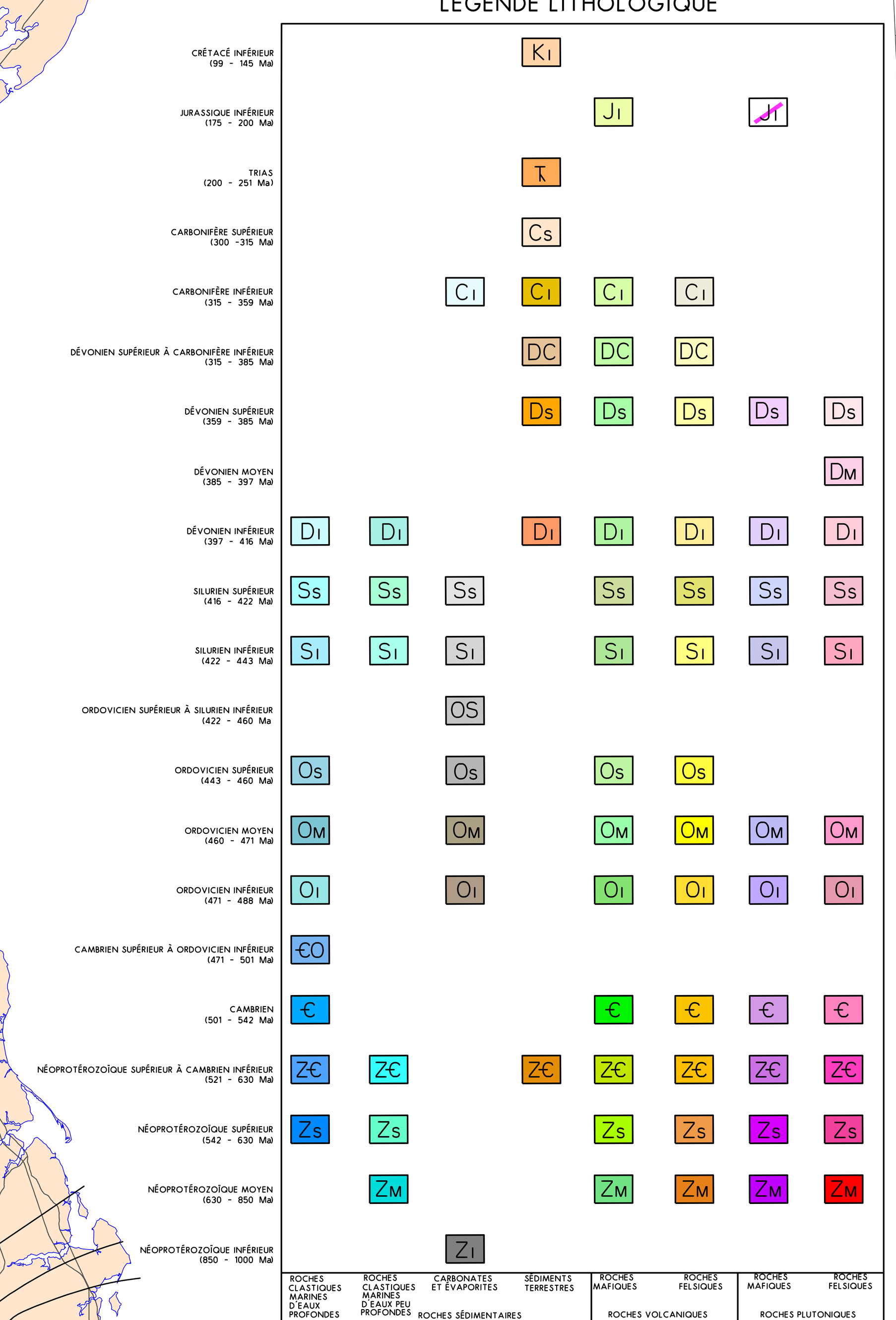
La catégorie volcanique se subdivise en sous-catégories mafique et felsique, qui peuvent toutes deux renfermer des coulées de lave, des tufs pyroclastiques et des brèches volcaniques de compositions intermédiaires variables. On peut supposer un mode de sédimentation subaérien ou sous-marin à partir de la carte d'après le caractère de leurs roches sédimentaires associées. La catégorie plutonique se subdivise en sous-catégories mafique (roches ultramafiques, gabbro et diorite) et felsique (granodiorite, granite et syénite) qui varient des plutons à gros grain de batholites abyssaux aux petits massifs intrusifs de niveau élevé à grain fin. Les âges attribuées aux plutons sont basés sur des dates radiométriques et sur les similarités lithologiques et structurales avec des plutons déjà datés.

Un métamorphisme est généralement présent dans le faciès des schistes verts secondaires aux schistes verts, sauf dans les auréoles de contact des plutons. Des schistes et des gneiss régionaux à faciès amphiboliques à granulitiques sont toutefois présents dans le cortège métamorphique du Précambrien de Brookville dans le sud du Nouveau-Brunswick de même que dans le cortège métamorphique du Cambrien à l'Ordovicien inférieur du lac Trousers dans le centre du Nouveau-Brunswick.

CARTE NR-1 (ÉDITION 2008)

GÉOLOGIE DU SUBSTRAT ROCHEUX DU NOUVEAU-BRUNSWICK

LÉGENDE LITHOLOGIQUE



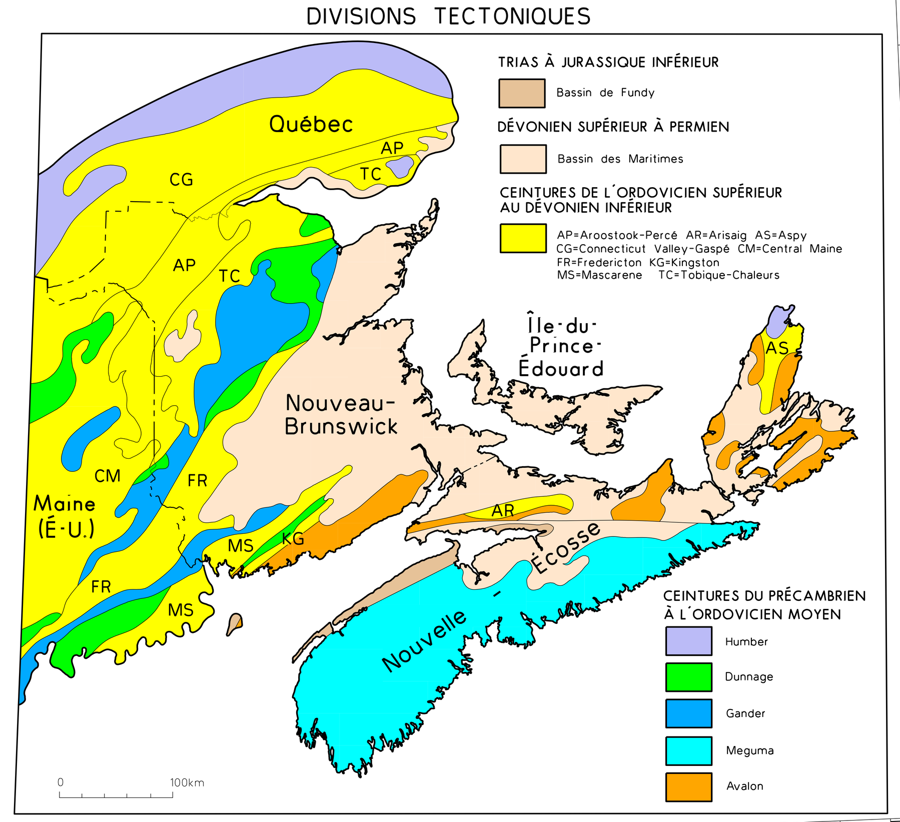
OROGÈNE DES APPALACHES DE LA RÉGION DES MARITIMES

Les divisions tectoniques des provinces Maritimes et des régions adjacentes, illustrées en médaillon ci-dessous, proviennent à quelques modifications près de l'ouvrage « Geology of the Appalachian-Caledonian Orogen in Canada and Greenland, 1985 ». Les roches du Paléozoïque inférieur et les roches plus anciennes sont subdivisées en cinq zones correspondant aux divers cadres paléogéographiques en bordure et à l'intérieur de l'océan du Paléozoïque inférieur Iapetus. La zone de Humber repose sur des roches sédimentaires qui se sont déposées le long de la marge continentale laurentienne de l'Amérique du Nord ancienne; la zone de Dunnage renferme des arcs insulaires et des bassins arrière-arcs de l'ocean Iapetus; les zones de Gander et de Meguma s'appuient sur des séquences sédimentaires s'étant détachées de la marge continentale du Gondwana; et la zone d'Avalon est caractérisée par des roches volcaniques précambriennes recouvertes par des roches cambriennes renfermant une faune trilobite présentant une affinité avec le Gondwana. Les roches des zones de Dunnage, de Gander et d'Avalon ont été déformées et se sont successivement ajoutées à la marge continentale laurentienne pendant la période de fermeture de l'océan Iapetus.

Les ceintures du Paléozoïque moyen au nord-ouest de la zone d'Avalon renferment des roches sédimentaires et volcaniques s'étant déposées principalement dans les bassins résiduels demeurés en place après la destruction d'une vaste partie de l'océan Iapetus. Les ceintures du Paléozoïque moyen à l'intérieur de la zone d'Avalon renferment des roches volcaniques présentant une affinité avec les arcs insulaires probablement apparentés à l'accrétion de la zone de Meguma sur le continent laurentien.

Le bassin du Paléozoïque supérieur des Maritimes renferme des roches sédimentaires terrestres généralement plates contenant des détritus érodés de l'Orogène appalachien soulevé. Le bassin mésozoïque de Fundy renferme des couches rouges et des roches volcanobasaltiques qui se sont déposées dans une vallée d'effondrement formée pendant l'ouverture de l'océan Atlantique moderne.

DIVISIONS TECTONIQUES



ROCHES STRATIFIÉES

CRÉTACÉ INFÉRIEUR

KIVH	Formation de Vinegar Hill

JURASSIQUE INFÉRIEUR

JIF	Groupe de Fundy (formations de North Mountain et de Scots Bay [au large seulement]

TRIAS

TrF	Groupe de Fundy (formations de Blomidon, d'Echo Cove, de Honeycomb Point, de Lepreau, de Quaco et de Wolfville [subsurface seulement])

CARBONIFÈRE SUPÉRIEUR

CSP	Groupe de Pictou (formations de Clifton, de Hurley Creek, de Minto, de Mountain View, de Richibucto, de Salisbury, de Sunbury Creek et de Tormentine)
CSC	Groupe de Cumberland (formations de Balls Lake, de Boss Point, de Grande Anse, de Lancaster et de Tynemouth Creek)

CARBONIFÈRE INFÉRIEUR

CIMA	Groupe de Mabou (formations d'Arthurette, de Beaver Harbour, de Carlisle, de Cumberland Hill, d'Enragé, de Gladwyn, de Hardwood Ridge, de Hopewell Cape, de Maringouin, de Newcastle Creek, de Plaster Rock, de Poodiac, de Queenstown, de Red Pine Brook, de Royal Road, de Scoodic, de Shepody, de Shin et de Wanamaker)
CIPE	Groupe de Percé (Formation de Bonaventure)
CIW	Groupe de Windsor (formations de Cassidy Lake [subsurface seulement], de Clover Hill [subsurface seulement], de Gays River, de Hillsborough, de Lime-Kiln Brook, de Macumber, de Parleeville, de Pugwash Mine [subsurface seulement] et d'Upperton)
CISX	Groupe de Sussex (formations de Briggs Cross, de Dutch Valley, de Gautreau, de Mill Brook, de Ridge Brook, de Round Hill, de Stilesville, et de Weldon)

DÉVONIEN SUPÉRIEUR / CARBONIFÈRE INFÉRIEUR

DCHO	Groupe de Horton (formations d'Albert, de Bloomfield, de Fairfield, d'Indian Mountain, de Kennebecasis, de McQuade Brook, de Memramcook, de Perry et de Sagwa)

DÉVONIEN SUPÉRIEUR

DSHV	Groupe de Harvey (formations de Cherry Mountain, de Harvey Mountain et de York Mills)
DSPI	Groupe de Piskahegan (formations de Bailey Rock, de Big Scott Mountain, de Carrow, de Hoyt Station, de Kleef, de Little Mount Pleasant, de Rothea, de Scoullar Mountain, de Seelys et de South Oromocto)

DÉVONIEN INFÉRIEUR

DIG	Groupe de Gaspé Sandstone (formations de Campbellton et de York Lake)
DID	Groupe de Dalhousie (formations d'Archibald Settlement, de Big Hole Brook, de Jacquet River, de Mitchell Settlement, de Sunnyside et de Val d'Amour)
DIFO	Groupe de Fortin (formations de Temiscouata et de Tracy Brook)
DIT	Groupe de Tobique (formations de Cameron Mountain, de Costigan Mountain, de Dorrington Hill, de Dow, de Hartin et de Wapske)

SILURIEN SUPÉRIEUR

SSCH	Groupe de Chaleurs (formations de Bailey's Chasm, de Benjamin, de Bryant Point, de Free Grant, d'Indian Point, de LaPlante, de New Mills, de Simpsons Field, de South Charlo et de West Point)
SSK	Groupe de Kingsclear (formations de Burtts Corner, de Flume Ridge, de Gordon Meadow Brook, de Sand Brook et de Taxis River)
SSMS	Groupe de Mascarene (formations de Cripps Stream, de Cunningham Creek et d'Eastport)
SSPE	Groupe de Perham (formations de Canterbury, de Chambord Brook, de Pocowagamis, de Scott Siding et de Smyrna Mills)

SILURIEN INFÉRIEUR

SICH	Groupe de Chaleurs (formations de Clemville, de La Vieille, de Limestone Point, d'Upsalquitch et de Weir)
SIK	Groupe de Kingsclear (formations de Cross Creek, de Digdeguash et de Hayes Brook)
SIKG	Groupe de Kingston (formations de Bayswater, de Nancy Head, de Quoddy, de Raymond Mountain, de Walton Lake, de Westfield et de Williams Lake)
SIMS	Groupe de Mascarene (formations de Back Bay, de de Fowle Lake, de Grant Brook, de Henderson Brook, de Jones Creek, de Letete, de Lighthouse Cove, de Long Reach, d'Oak Bay, de Waweig et de Wilsons Beach)
SIPE	Groupe de Perham (formations de Gounamitz Lake, de Hazeldean, de Jemtland, de New Sweden, de Siegas et de Smyrna Mills)

ORDOVICIEN SUPÉRIEUR / SILURIEN INFÉRIEUR

OSMS	Groupe de Mascarene (Formation de Goss Point)
OSMA	Groupe de Matapédia (Formation de White Head)

ORDOVICIEN SUPÉRIEUR

OSCAL	Groupe de California Lake (Formation de Boucher Brook)
OSCK	Groupe de Cookson (formations de Halls Brook et de Kendall Mountain)
OSFO	Groupe de Fournier (formations de Belledune River Mélange, d'Elmtree et de Millstream)
OSG	Groupe de Grog Brook (formations de Boland Brook et se Whites Brook)
OSMA	Groupe de Matapédia (Formation de Pabos)
OSMD	Groupe de Meductic (Formation de Belle Lake)
OST	Groupe de Tetagouche (formations de Hayden Lake, de Little River, de Push and Be Damned et de Tomogonops)

ORDOVICIEN MOYEN

OMB	Groupe de Balmoral (formations de Goulette Brook et de Popelogan)
OMCAL	Groupe de California Lake (formations de Canoe Landing Lake, de Mount Brittain et de Spruce Lake)
OMCK	Groupe de Cookson (Formation de Woodland)
OMFO	Groupe de Fournier (formations de Devereaux, de Pointe Verte et de Sormany)
OMMD	Groupe de Meductic (Formation de Craig Brook)
OMSB	Groupe de Sheephouse Brook (formations de Sevogle River et de Slacks Lake)
OMT	Groupe de Tetagouche (formations de Flat Landing Brook, de Hayden Lake, de Little River, de Nepisiguit Falls et de Push and be Damned)

ORDOVICIEN INFÉRIEUR

OICK	Groupe de Cookson (Formation de Calais)
OIMD	Groupe de Meductic (formations de Eel River, d'Oak Mountain et de Porten Road)
OIM	Groupe de Miramichi (formations de Knights Brook et de Patrick Brook)
OISB	Groupe de Sheephouse Brook (Formation de Clearwater Stream)
OIT	Groupe de Tetagouche (Formation de Turnbull Mountain)
OIW	Groupe de Woodstock (Formation de Bright Eye Brook)

CAMBRIEN SUPÉRIEUR / ORDOVICIEN INFÉRIEUR

€OM	Groupe de Miramichi (Formation de Chain of Rocks)
€OTL	Ensemble métamorphique de Trousers Lake (paragneiss et amphibolites)
€OW	Groupe de Woodstock (Formation de Baskahegan Lake)

CAMBRIEN

€AN	Groupe d'Annidale (formations de Carpenter Brook, d'East Scotch Settlement, de Grant Brook, de Lawson Brook et de Queen Brook)
€CK	Groupe de Cookson (Formation de Crocker Hill)
€EL	Groupe d'Ellsworth (formations de Matthews Lake et de Mosquito Lake Road)
€SJ	Groupe de Saint John (formations de Buckmans Creek, de Forest Hills, de Glen Falls, de Hanford Brook, de King Square, de Ratcliffe Brook, de Rose Brook et de Silver Falls; incluant les formations ordovicienne inférieure de Grassy Lake et de Reversing Falls)

NÉOPROTÉROZOIQUE SUPÉRIEUR/CAMBRIEN INFÉRIEUR

Z€BI	Groupe de Belleisle Bay (formations de Beulah Camp, de Browns Flat, de Leavitts Head, de Lobster Brook et de Simpsons Island)
Z€CS	Groupe de Castalia (formations de Flagg Cove, de Great Duck Island, de Long Pond Bay, de North Head, de Priest Cove et de Ross Island)

NÉOPROTÉROZOIQUE SUPÉRIEUR

ZSLO	Groupe de Lorneville (formations de Taylors Island et de West Beach)
ZSDH	Groupe de Dipper Harbour (formations de Clear Lake et de Round Meadow Cove)
ZSC	Groupe de Coldbrook (formations de Ben Lomond, de Bloomsbury Mountain, de Browns Lake, de Burley Lake, de Cedar Camp, de Dolan Brook, de Fletcher Brook, de Hosford Brook, de McBrien Lake, de Saddleback Brook, de Seely Beach, de Silver Hill, de Walton Dam et de Willow Grove)

NÉOPROTÉROZOIQUE MOYEN

ZMBR	Groupe de Broad River (formations de Bennett Brook, de Black River Road, de Cape Spencer, de Crooked Creek, d'East Branch Black River, de Goose Creek, de Gordon Falls, de Hastie Hill, de Hayward Brook, de Hubley Hill, de Little Salmon River, de Pine Brook, de Teahans Corner et de Toms Brook)
ZMBK	Gneiss de Brookville
ZMGM	Groupe de Grand Manan (formations d'Ingalls Head, Kent Island et de Thoroughfare)

NÉOPROTÉROZOIQUE INFÉRIEUR

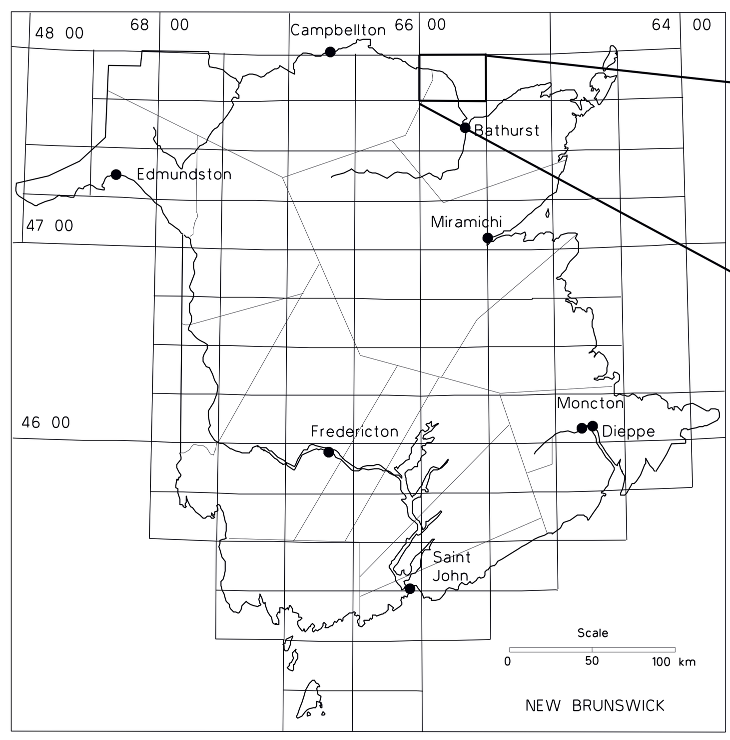
ZIGH	Groupe de Green Head (formations d'Ashburn et de Martinon)

GEOLOGY OF THE BELLEDUNE AREA (NTS 21 P/13e and f), GLOUCESTER AND RESTIGOUCHE COUNTIES, NEW BRUNSWICK

NTS 21 P/13e, f

PLATE 2012-52

LOCATION MAP



REFERENCE

- Municipal Roads
- National, Arterial, Collector and Local Paved Roads
- Gravel and Other Local Roads (DOT)
- Non-DOT Resource Access Roads
- Lake, River, Stream
- Railway Track
- Power Line
- Marsh or Swamp Outline
- Gravel Pit or Quarry Outline
- County Boundary
- Microwave Tower
- Pipeline
- Contour

Base map derived from Service New Brunswick 1:10 000 base map
Reference System: North American Datum 1983 (CSRS)
Map Projection: New Brunswick Stereographic Double Projection

SYMBOLS

- Outcrop, area of outcrop, probable outcrop (subcrop)
- Bedding, inclined (tops known, tops unknown)
- Bedding (overturned, vertical)
- Cleavage or schistosity, inclined (first generation); may represent a composite schistosity in Ordovician rocks
- Cleavage or schistosity (first generation, vertical)
- Geological contact
- Angular unconformity, disconformity
- Normal or reverse fault
- Strike-slip fault
- Thrust fault
- F1 (Salinic) syncline
- F2 (Acadian) anticline, syncline
- Mafic dyke or sill
- RW_P13E237 Lithogeochemical sample site
- 0-105150 Fossil occurrence with GSC identification number
- Turgeon SM 0016 Mineral deposit or occurrence (Unique Reference Number): BM = Stratiform bimodal volcanic and sediment-hosted massive sulphide deposits; includes stringer and disseminated sulphides; SM = Stratiform mafic volcanic and sediment-hosted massive sulphide deposits; includes stringer and disseminated sulphides.

Geology by John Langton, Jim Walker, and Sue Gower; revised by R.A. Wilson, 2011
Digitizing by Ken Mersereau (2002) and Diane Richard, 2002 and 2012

This map should be referenced as follows:

WILSON, R.A. (compiler). 2012. Geology of the Turgeon area (NTS 21 P/13e and f), Gloucester and Restigouche counties, New Brunswick. New Brunswick Department of Natural Resources; Lands, Minerals, and Petroleum Division, Plate 2012-52 (revised April 2016).

LATE CARBONIFEROUS

PERCÉ GROUP

CBV_{cc} BONAVENTURE FORMATION: Brick red pebble conglomerate and sandstone

EARLY DEVONIAN

DALHOUSIE GROUP

DJR_{s} JACQUET RIVER FORMATION: Green to grey, locally fossiliferous siltstone and fine-grained sandstone; minor limestone and basalt.

DMS_{mv} MITCHELL SETTLEMENT FORMATION: Dark grey to dark green, fine-grained, typically massive, locally amygdaloidal mafic to intermediate flows interbedded with olive to greenish grey, micaceous, locally fossiliferous siltstone and sandstone; very minor red siltstone.

LATE SILURIAN

DICKIE COVE GROUP

SBP_{mv} BRYANT POINT FORMATION: Dark green to dark grey, massive to amygdaloidal, locally coarsely porphyritic basalt; minor interbedded sedimentary rocks.

SSC_{cc} SOUTH CHARLO FORMATION: Mainly reddish brown to dark grey polymictic pebble-cobble conglomerate locally containing clasts of Early Silurian limestone; minor sandstone and siltstone.

EARLY SILURIAN

QUINN POINT GROUP

SLA_{ls} LA VIEILLE FORMATION: Light grey nodular micritic limestone, light grey calcarenite, and minor calcareous sandstone.

SLI_{s} LIMESTONE POINT FORMATION: Light greenish grey, thin- to medium-bedded, fine-grained calcareous sandstone, and thin interbeds of white fossiliferous limestone.

SWE_{s} WEIR FORMATION: Reddish maroon, thin-bedded, feldspathic or lithic fine- to medium-grained sandstone, and reddish maroon to greenish grey, polymictic pebble to cobble conglomerate.

LATE ORDOVICIAN to EARLY SILURIAN

$OSBRM_{s}$ BELLEDUNE RIVER MÉLANGE: (Tectonic mélange formed in a Late Ordovician to Early Silurian subduction complex and derived from Fournier Group lithotypes): Mainly deformed clasts of sedimentary, and lesser (local) mafic volcanic or ultramafic igneous rocks, in a dark grey to black shale matrix.

MIDDLE TO LATE ORDOVICIAN

SORMANY GROUP

OE_{s} ELMTREE FORMATION: Dark grey shale, locally interbedded with dark grey, fine- to medium-grained quartz wacke and finely laminated siltstone.

POINTE VERTE GROUP

OMN_{mv} MADRAN FORMATION: Light to dark green, massive to pillowed alkalic basalt and related hyaloclastites; minor sheeted mafic dykes, and interbedded dark grey shale.

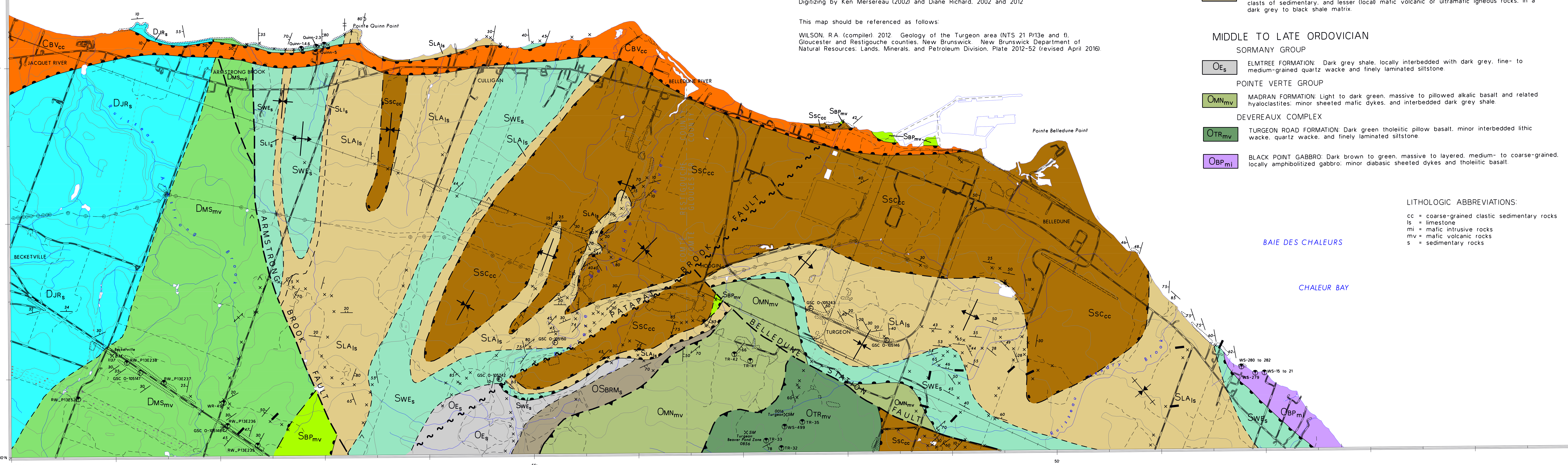
DEVEREAUX COMPLEX

OTR_{mv} TURGEON ROAD FORMATION: Dark green tholeiitic pillow basalt, minor interbedded lithic wacke, quartz wacke, and finely laminated siltstone.

OBP_{mi} BLACK POINT GABBRO: Dark brown to green, massive to layered, medium- to coarse-grained, locally amphibolitized gabbro; minor diabasic sheeted dykes and tholeiitic basalt.

LITHOLOGIC ABBREVIATIONS:

- cc = coarse-grained clastic sedimentary rocks
- ls = limestone
- mi = mafic intrusive rocks
- mv = mafic volcanic rocks
- s = sedimentary rocks



Scale 1:20 000

Feet

Metres

Department of Natural Resources
Lands, Minerals and Petroleum Division
New Nouveau Brunswick
Ministère des Ressources naturelles
Division des terres, des minéraux et du pétrole

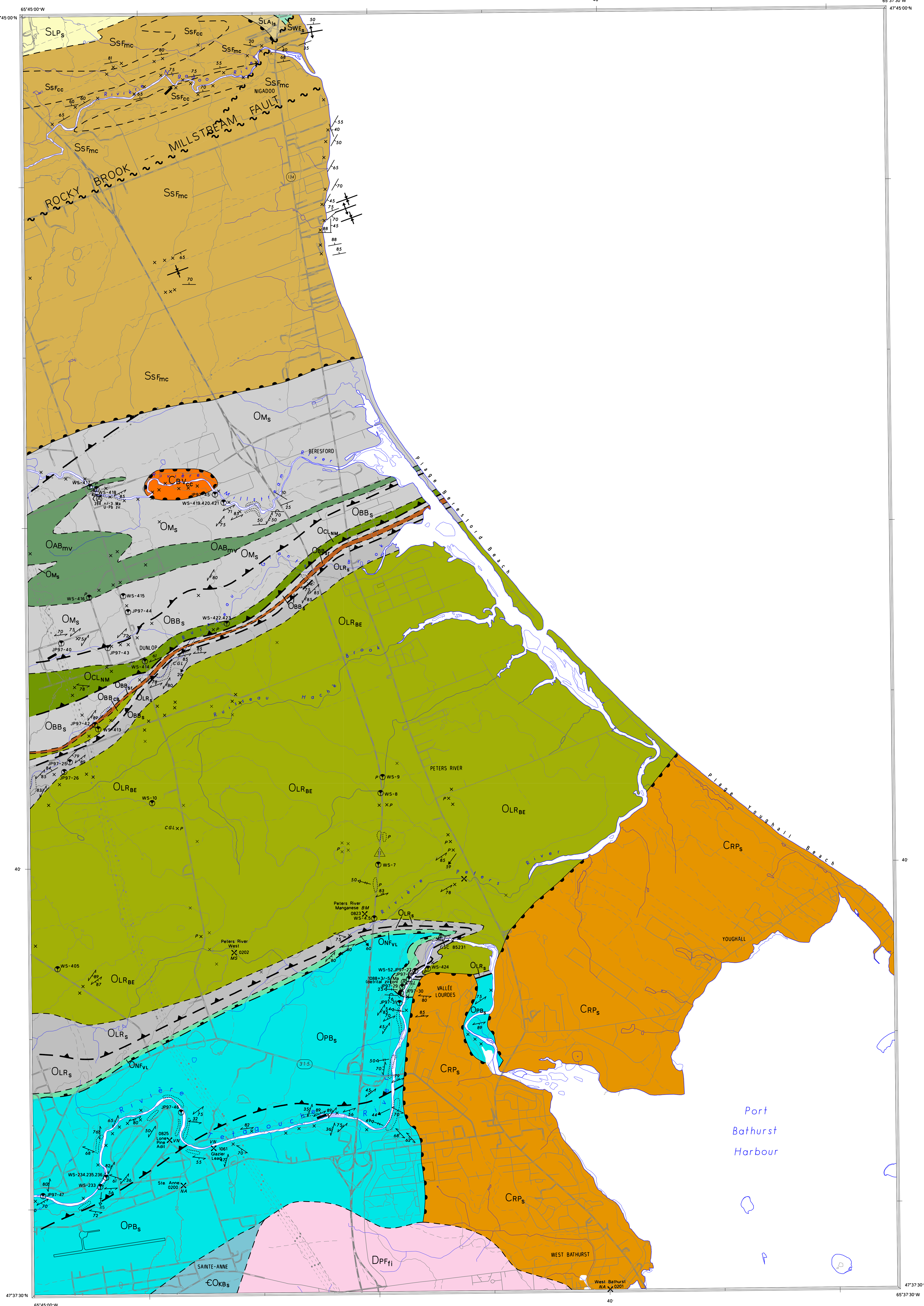
NTS 21 P/12g

Department of Energy and Mines
Geological Surveys Branch

New Brunswick / Nouveau Brunswick

Ministère de l'Énergie et des Mines
Direction des études géologiques

PLATE 2013-10 (revised 2014)



Scale 1:20 000

Feet

Metres

GEOLOGY OF THE BERESFORD AREA (NTS 21 P/12g), GLOUCESTER COUNTY, NEW BRUNSWICK

EARLY CARBONIFEROUS

MABOU GROUP

CRPs — RED PINE BROOK FORMATION: Red sandstone, granule to pebble conglomerate, and red and grey mudstone.

PERCÉ GROUP

CBVcc — BONAVENTURE FORMATION: Brick red to grey pebble-cobble conglomerate, sandstone and minor shale.

EARLY DEVONIAN

DPFfi — PABINEAU FALLS GRANITE: Pink, coarse-grained, equigranular to subporphyritic, biotite granite.

LATE SILURIAN

PETIT ROCHER GROUP

SLPs — LAPLANTE FORMATION: Medium to dark grey, locally laminated calcareous shale and calcisiltite.

SSFcc / SSFmc — SIMPSONS FIELD FORMATION: SSFcc - Reddish maroon to greenish grey, pebble-cobble polymictic conglomerate; SSFmc - Greyish green, variably calcareous, thin- to thick-bedded, fine-to medium-grained, commonly micaceous, locally feldspathic or lithic sandstone; minor siltstone and coarse-grained lithic sandstone.

EARLY SILURIAN

QUINN POINT GROUP

SLAls — LA VIEILLE FORMATION: Light to dark grey, thin-bedded, nodular micritic limestone; minor light grey calcarenite and calcareous sandstone.

SWEs — WEIR FORMATION: Reddish maroon, locally greyish green or grey, thin-bedded, feldspathic or lithic, fine- to medium-grained sandstone and siltstone.

MIDDLE to LATE ORDOVICIAN

SORMANY GROUP

OMs — MILLSTREAM FORMATION: Dark grey shale and siltstone, and light to dark grey or greenish grey, fine- to coarse-grained, thick-bedded feldspathic or lithic wacke.

OABmv — ARMSTRONG BROOK FORMATION: Dark green, high-chromium, massive to pillowed (P) tholeiitic basalt.

CALIFORNIA LAKE GROUP

OBBs / OBBCB / OBBsr — BOUCHER BROOK FORMATION: OBBs - Dark grey, thin-bedded to laminated shale, siltstone and fine-grained feldspathic sandstone; OBBCB (Camel Back Member) - Dark green, massive to pillowed alkalic basalt and hyaloclastite; local intercalated chert and limestone; OBBsr - Red shale and chert.

OCLNM — CANOE LANDING LAKE FORMATION: OCLNM (Nine Mile Brook Member) - Dark green, massive to pillowed (P) tholeiitic basalt.

TETAGOUCHE GROUP

OLRs / OLRBE — LITTLE RIVER FORMATION: OLRs - Dark grey, very thin-bedded shale, siltstone, and local feldspathic wacke; rare conglomerate (CGL); OLRBE (Beresford Member) - Dark green, massive to pillowed (P), strongly alkalic basalt and hyaloclastite; minor intercalated chert, conglomerate (CGL) and peralkaline felsic volcanic rocks.

ONFVL — NEPISIGUIT FALLS FORMATION (Vallée Lourdes Member): Light grey calcarenite and calcisiltite, and cobble to boulder conglomerate (CGL).

LATE CAMBRIAN to EARLY ORDOVICIAN

MIRAMICHI GROUP

OPBs — PATRICK BROOK FORMATION: Dark grey, thin-bedded shale and siltstone, typically interbedded with medium grey, medium-bedded quartzose or feldspathic wacke.

€OKBs — KNIGHTS BROOK FORMATION: Light to medium greenish grey, thin- to medium-bedded, quartzose sandstone, siltstone, quartz wacke, and dark grey shale.

LITHOLOGIC ABBREVIATIONS:

cc = coarse-grained clastic sedimentary rocks
fi = felsic volcanic rocks
ls = limestone
mc = medium-grained clastic sedimentary rocks
s = sediments
sr = red manganiferous shale

SYMBOLS

- Outcrop, area of outcrop, compiled outcrop
- Bedding (tops known, overturned)
- Schistosity or cleavage (first, second, third and fourth generations)
- Geological contact
- Disconformity
- Angular unconformity
- Strike-slip fault
- Thrust fault
- L1 stretching and mineral lineation
- F1 fold hinge; F2 fold hinge or intersection lineation
- Anticline, syncline
- Felsic dyke, mafic dyke
- GSC 85231 — Fossil locality
- 394+/-3 Ma. U-Pb zir — Geochronological sample site, with age and dating method
- JP97-31 — Lithogeochemical sample site
- Lone Pine Adit 0825 VN — Mineral occurrence (with Unique Reference Number): BM = Stratiform bimodal volcanic and sediment-hosted massive sulphide deposits; includes stringer and disseminated sulphides. MS = Marine sediment-hosted stratagound deposits; includes Mississippi Valley-type deposits. NA = Not enough available data. VN = Quartz-carbonate veins and stockworks associated with fracture/shear zones in a wide variety of settings.

Geology modified from van Staal and Rogers 2000 (GSC Open File 3839), Walker et al. 1993 (Plate 93-6) and Skinner 1974 (GSC Map 1331A). For added detail on the structural geology of the area, see GSC Open File 3839, Sheet 2.

This map should be referenced in the following manner:

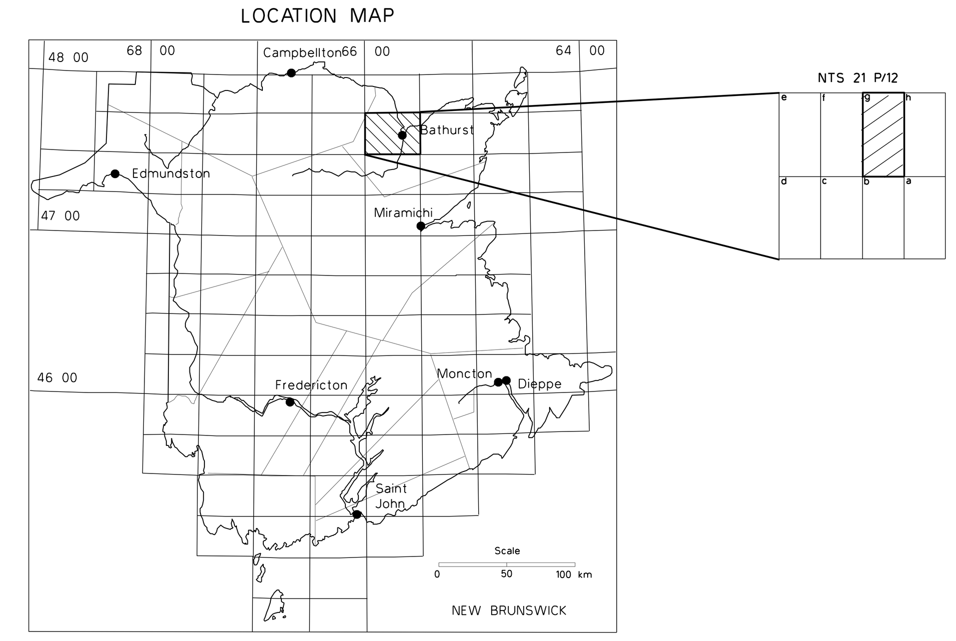
Wilson, R.A. 2013 (Compiler). Geology of the Beresford area (NTS 21 P/12g), Gloucester County, New Brunswick. New Brunswick Department of Energy and Mines, Geological Surveys Branch, Plate 2013-10 (revised 2014).

REFERENCE

- Municipal Roads
- National, Arterial, Collector and Local Paved Roads
- Gravel and Other Local Roads (DOT)
- Non-DOT Resource Access Roads
- Lake, River, Stream
- Topographic contour (10 m interval)
- Railway Track
- Power Line
- Marsh or Swamp Outline
- Gravel Pit or Quarry Outline
- County Boundary
- Microwave Tower

Base map derived from Service New Brunswick 1:10 000 base map.
Reference System: North American Datum 1983 (CSRS)
Map Projection: New Brunswick Stereographic Double Projection

LOCATION MAP



NR-8

QUATERNARY

Cb — COLLUVIAL SEDIMENTS: blanket deposits of silt, sand, rubble (angular pebble- through boulder-sized clasts), including minor till and gravel; generally 0.5 to 1.5 m thick, mainly materials derived from subaerial weathering processes but includes minor deposits relating to glaciation(s) of unknown age

HOLOCENE

MARINE SEDIMENTS: sand, gravel, silt, clay, minor peat and organic sediment; deposited in beach and intertidal environments at or near present sea level

Wr — Beaches, bars and spits: gravel, sand, minor silt; generally more than 1 m thick

Wp — Intertidal plains and salt marshes: clay, silt, some fine sand, minor peat and organic sediment; generally more than 2 m thick

Ap — ALLUVIAL SEDIMENTS: terraces and floodplains: sand, gravel, some silt, minor clay and organic sediment; generally more than 2 m thick; deposited as channel, overbank, and floodbasin deposits at or near present base level

Op — ORGANIC SEDIMENTS: bogs, fens, swamps: peat, muck, minor silt and fine sand; generally 1 to 5 m thick; deposited in shallow basins and on poorly drained surfaces

LATE WISCONSINAN AND/OR EARLY HOLOCENE

LACUSTRINE SEDIMENTS: sand, silt, gravel, and clay deposited in shallow lake basins which were in part formed by retreating Late Wisconsinan ice

Lb — Blankets and plains: sand, silt, minor clay and gravel, patchy thin veneer of organic sediment; generally 0.5 to 3 m thick

MARINE SEDIMENTS: sand, silt, gravel, and clay; deposited in shallow marine water, locally deep, which submerged coastal areas and sections of many valleys during and following Late Wisconsinan deglaciation

Wb — Blankets and plains: sand, silt, some gravel and clay; generally 0.5 to 3 m thick

LACUSTRINE AND MARINE SEDIMENTS: **undifferentiated**

L.Wb — Blankets and plains: sand, silt, minor clay and gravel, patchy thin veneer of organic sediment; generally 1 to 10 m thick

LATE WISCONSINAN

GLACIOFLUVIAL SEDIMENTS: sand, gravel, minor silt and till; deposited in front of, at the margin of, within or under retreating Late Wisconsinan ice

Gp3 **Gd3** — Outwash: sand, gravel, minor till
Gp - plains and valley trains, generally thicker than 1.5 m
Gd - deltas, generally thicker than 5 m

Gx3 — Ice-contact deposits: eskers, kames, kame and kettle complexes; sand, gravel, minor silt and till, generally more than 2 m thick

MORAINAL SEDIMENTS: lodgment till, ablation till, and associated sand and gravel deposited directly by Late Wisconsinan ice or with minor reworking by water

Mm3 — Hummocky, ribbed, and rolling ablation moraines: loamy ablation till, some lodgment till, minor silt, sand, gravel, and boulders; generally greater than 1.5 m thick
aMm - mainly stony till (more than 35% of clasts pebble-sized and larger);
bMm - mainly bouldery till (more than 25% of clasts boulder-sized)

Mb3 **Mv3** — Blanket and veneer: loamy lodgment till, minor ablation till, silt, sand, gravel, rubble
Mb - blanket, generally 0.5 to 3m thick
Mv - discontinuous veneer over rock, less than 0.5m thick
sMb, sMv - mainly sandy till (sand content greater than 50%)
aMb, aMv - mainly stony till (more than 35% of clasts pebble-sized and larger)
bMb, bMv - mainly bouldery till (more than 25% of clasts boulder-sized)

WISCONSINAN

GLACIOFLUVIAL SEDIMENTS: sand, gravel, minor silt and till; deposited in front of, at the margin of, within and under ice of Wisconsinan age

Gp2 **Gd2** — Outwash: sand, gravel, minor silt
Gp - plains and valley trains, generally more than 1.5 m thick;
Gd - deltas, generally more than 5 m thick

Gx2 — Ice-contact deposits: eskers, kames, kame and kettle complexes; sand, gravel, minor silt; generally more than 2 m thick

MORAINAL SEDIMENTS: lodgment till, ablation till, and associated gravel and sand deposited directly by Wisconsinan ice or with minor reworking by water

Mm2 — Rolling and ribbed ablation moraines: loamy ablation till, some lodgment till, minor silt, sand, gravel, and boulders; generally greater than 1.5 m thick
aMb - mainly stony till (more than 35% of clasts pebble-sized and larger)

Mb2 **Mv2** — Blanket and veneer: loamy lodgment till, minor ablation till, silt, sand, gravel, rubble
Mb - blanket, generally 0.5 to 3 m thick
Mv - discontinuous veneer over rock, less than 0.5 m thick
aMb, aMv - mainly stony till (more than 35% of clasts pebble-sized and larger)

WISCONSINAN AND/OR PRE-WISCONSINAN

Gx1 — GLACIOFLUVIAL SEDIMENTS, ice-contact: eskers, kames, kame and kettle complexes: sand, gravel, minor silt, and till; generally more than 2 m thick; deposited at the margin of, within and under ice of unknown age

Mm1 — MORAINAL SEDIMENTS: rolling and ribbed ablation moraines: stony ablation till, some lodgment till, minor silt, sand, and gravel, more than 35% of clasts pebble-sized and larger; generally greater than 1.5 m thick; deposited directly by ice of unknown age or with minor reworking by water

M.Cb — MORAINAL AND COLLUVIAL SEDIMENTS: loamy till and colluvium, regolith and weathered bedrock, and isolated boulder fields, undifferentiated; mixture of deposits formed directly from ice of unknown age and materials produced by weathering processes; generally greater than 1 m thick
aM.Cb - mainly stony deposits (more than 35% of clasts pebble-sized and larger)
sM.Cb - mainly sandy deposits (sand content greater than 5%)

PRE-QUATERNARY

R — Rock: various lithologies and ages; generally weathered and partially disintegrated, glacially moulded surface; few localities show glacially scoured and polished surfaces

Recommended citation:

Rampton, V.N. 1984. Generalized surficial geology map of New Brunswick Department of Natural Resources and Energy, Minerals, Policy and Planning Division, NR-8 (scale: 1: 500 000).

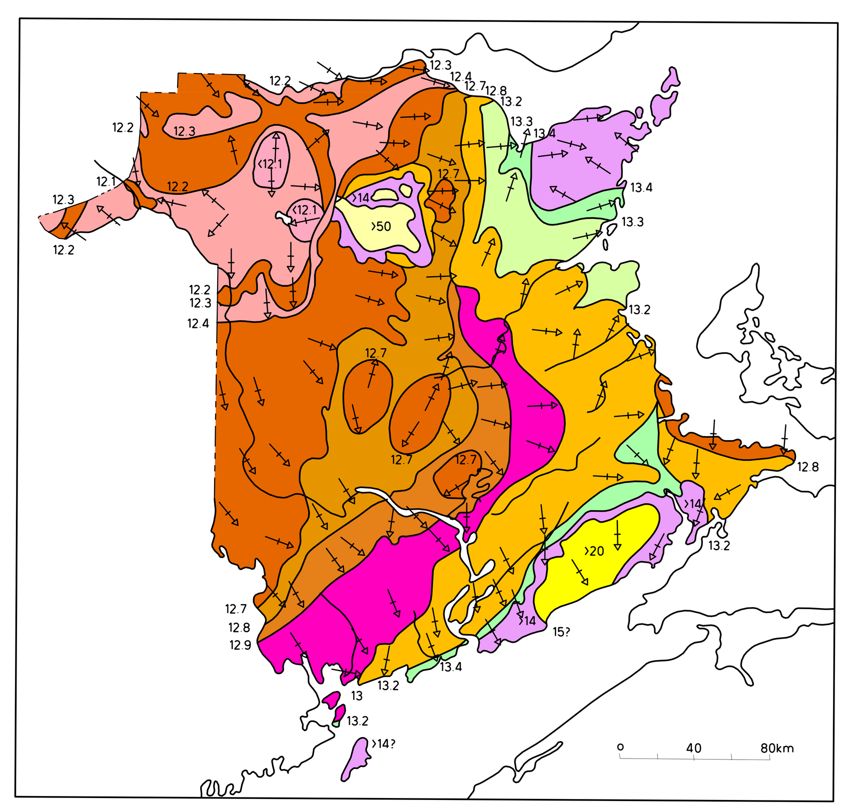
Modified from:

Rampton, V.N. 1984. Surficial geology, New Brunswick. Geological Survey of Canada, Map 1594A (scale 1:500 000).

Edited by AA. Seaman, 2002.

Digitzed by K.J. Mersereau, 2002.

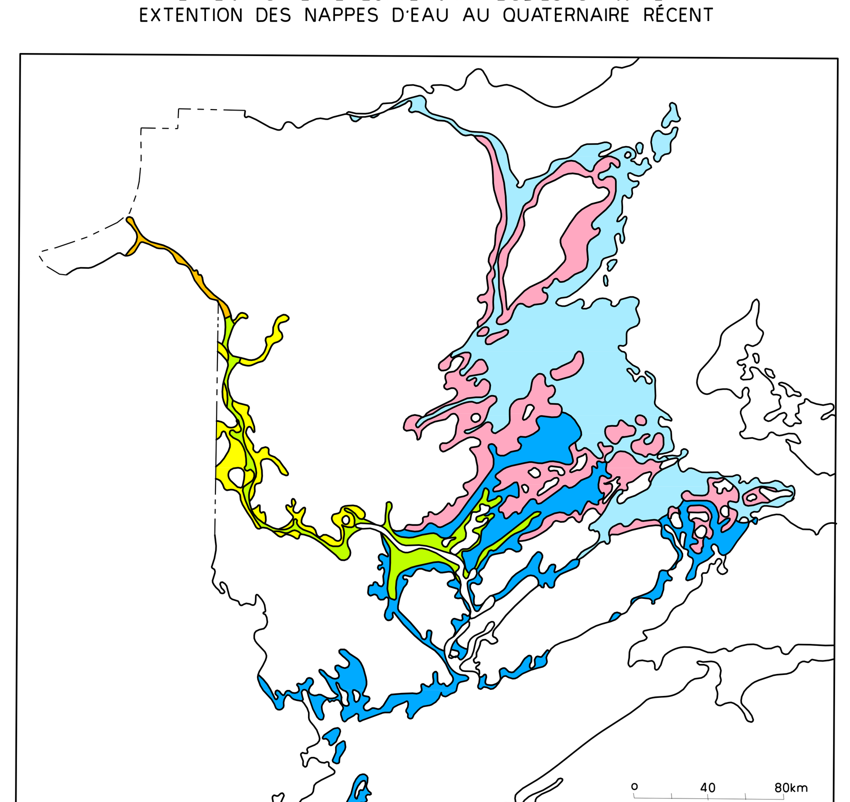
SPECULATIVE ICE MARGINAL POSITIONS DURING RETREAT OF WISCONSINAN ICE
POSITIONS THÉORIQUES DE LA MARGE GLACIAIRE AU COURS DE LA PHASE RÉGRESSIVE WISCONSINIENNE



13.2 ICE MARGINAL ISOCHRONES IN THOUSANDS OF YEARS B.P.
ISOCHRONES DE LA MARGE GLACIAIRE (EN MILLIERS D'ANNÉES B.P.)

ICE FLOW OR SLOPE
ÉCOULEMENT GLACIAIRE OU PENTE

EXTENT OF LATE QUATERNARY BODIES OF WATER
EXTENTION DES NAPPES D'EAU AU QUATERNAIRE RÉCENT



LAKE MADAWASKA / LAC MADAWASKA

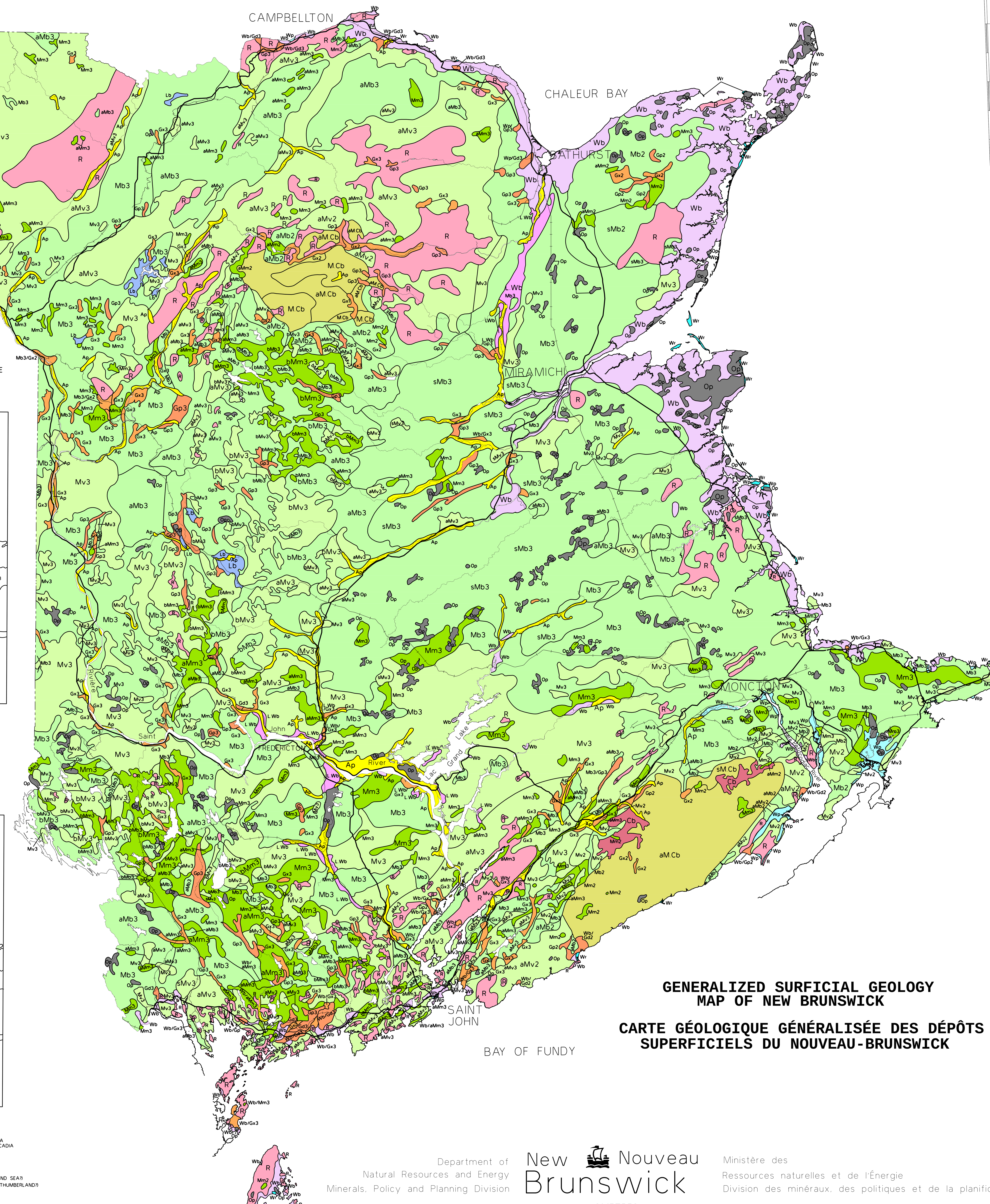
INLAND SEA ACADIA / MER INTÉRIEURE D'ACADIA

DeGEER SEA AND INLAND SEA ACADIA / MER DE DeGEER ET MER INTÉRIEURE D'ACADIA

MAXIMUM POSSIBLE-GOLDTHWAIT AND DeGEER SEA / EXTENSION MAXIMUM POSSIBLE - LES MERS DE GOLDTHWAIT ET DE DeGEER RÉUNIES

DeGEER SEA / MER DE DeGEER

GOLDTHWAIT SEA (NORTHUMBERLAND INLAND SEA?) / MER DE GOLDTHWAIT (MER INTÉRIEURE DE NORTHUMBERLAND?)



GENERALIZED SURFICIAL GEOLOGY MAP OF NEW BRUNSWICK

CARTE GÉOLOGIQUE GÉNÉRALISÉE DES DÉPÔTS SUPERFICIELS DU NOUVEAU-BRUNSWICK

Department of Natural Resources and Energy
Minerals, Policy and Planning Division

New Brunswick / Nouveau Brunswick

Ministère des Ressources naturelles et de l'Énergie
Division des minéraux, des politiques et de la planification

KILOMETRES
0 10 20 30 40 50

QUATERNAIRE

Cb — COLLUVIONS : dépôts de silt en couverture, sable et pierraille (fragments anguleux de roche détritique de taille allant de celle de cailloux à celle de blocs), y compris un peu de till et de gravier; il s'agit principalement de matériaux de 0,5 à 1,5 m d'épaisseur, en général, issus de processus météoriques subaériens, mais aussi de petits dépôts issus d'une ou de plusieurs glaciations d'époque inconnue

HOLOCÈNE

SÉDIMENTS MARINS : sable, gravier, silt, argile, un peu de tourbe ainsi que des sédiments organiques; dépôts de plage et d'environnements intertidaux, au niveau actuel de la mer ou près de ce niveau

Wr — Plages, remblais et flèches : gravier, sable et un peu de silt; épaisseur de plus de 1m, en général

Wp — Plaines et marais salants de formation intertidale : argile, silt, un peu de sable fin et de tourbe, ainsi que des sédiments organiques; épaisseur de plus de 2 m, en général

Ap — ALLUVIONS : terrasses et lits de hautes eaux : sable, gravier, un peu de tourbe ainsi que des sédiments organiques; de plus de 2 m d'épaisseur, en général; dépôts de chenaux, d'inondations et de bassin d'inondations au niveau de base actuel ou près de ce niveau

Op — SÈDIMENTS ORGANIQUES : marais, tourbières et marécages : tourbe, sol organique, un peu de silt ainsi que du sable fin; épaisseur de 1 à 5m, en général; mis en place dans des bassins peu profonds et sur des surfaces mal égouttées

WISCONSINIEN SUPÉRIEUR ET/OU HOLCÈNE INFÉRIEUR

SÉDIMENTS LACUSTRES : sable, silt, gravier et argile déposés dans des bassins lacustres peu profonds, formés en partie par le retrait des glaces du Wisconsinien récent

Lb — Couvertures et plaines : sable, silt, un peu d'argile ainsi que du gravier et de minces placages de sédiments organiques en taches; épaisseur de 0,5 à 3 m, en général

SÉDIMENTS MARINS : sable, silt, gravier et argile; déposés sur des fonds marins peu profonds ainsi que dans des bassins locaux de grande profondeur, sous des eaux qui ont recouvert des régions côtières et des sections de nombreuses vallées au cours et après la déglaciation du Wisconsinien récent

Wb — Couvertures et plaines : sable, silt, un peu de gravier et d'argile; de 0,5 à 3 m d'épaisseur, en général

SÉDIMENTS LACUSTRES ET MARINS : non différenciés

L.Wb — Couvertures et plaines : sable, silt, et argile et un peu de gravier; placage mince de sédiments organiques en taches; de 1 à 10 m d'épaisseur, en général

WISCONSINIEN SUPÉRIEUR

SÉDIMENTS FLUVIO-GLACIAIRES : sable, gravier, un peu de silt, ainsi que till, déposés au devant, en bordure, à l'intérieur et en dessous de la glace en retrait du Wisconsinien récent

Gp3 **Gd3** — Épandage fluvio-glaciaire : sable, gravier et un peu de silt
Gp – plaines et moraines glaciaires, de plus de 1,5 m d'épaisseur, en général
Gd – deltas, de plus de 5 m d'épaisseur, en général

Gx3 — Dépôts de contact glaciaires : eskers, kames et complexe de kames et kettles, sable, gravier et un peu de silt, et de till de plus de 2 m d'épaisseur, en général

SÉDIMENTS MORAINIQUES : till de fond et till d'ablation ainsi que le sable et le gravier qui leur sont associés, déposés directement par la glace du Wisconsinien récent ou avec un léger remaniement par l'eau

Mm3 — Moraines d'ablation mamelonnées, striées et ondulées; till d'ablation loameux, un peu de till de fond et de silt, sable, gravier et blocs; de plus de 1,5 m d'épaisseur, en général
aMm – surtout du till pierreux (dont plus de 35% consistent en fragments détritiques de dimensions égales ou supérieures à celles de galets)
bMm - surtout du till formé de blocs (dont plus de 25% consistent en fragments détritiques de la dimension de blocs)

Mb3 **Mv3** — Couverture et placage: till de fond loameux, un peu de till d'ablation, silt, sable, gravier et pierraille
Mb – placage de 0,5 à 3 m d'épaisseur, en général
Mv – placage discontinu recouvrant la roche; de moins de 0,5 m d'épaisseur,
sMb, sMv – surtout du till sablonneux (teneur en sable supérieure à 50%)
aMb, aMv – surtout du till pierreux (dont plus de 35% consistent en fragments détritiques de dimensions égales ou supérieures à celles de galets)
bMb, bMv - surtout du till formé de blocs (dont plus de 25% consistent en fragments détritiques de la taille de blocs)

WISCONSINIEN

SÉDIMENTS FLUVIO-GLACIAIRES : sable, gravier, un peu de silt et till, déposés au devant, en bordure, à l'intérieur et au-dessous de la glace du Wisconsinien

Gp2 **Gd2** — Épandage fluvio-glaciaire : sable, gravier et un peu de silt
Gp – plaines et moraines glaciaires, de plus de 1,5 m d'épaisseur, en général
Gd – deltas, de plus de 5 m d'épaisseur, en général

Gx2 — Dépôts de contact glaciares : eskers, kames et complexes de kames et kettles; sable, gravier et un peu de silt; de plus de 2 m d'épaisseur, en général

SÉDIMENTS MORAINIQUES : till de fond et d'ablation ainsi que les graviers et sables qui leur sont associés, déposés tels quels par la glace du Wisconsinien ou avec un léger remaniement par l'eau

Mm2 — Moraines d'ablation ondulées et striées; till d'ablation loameux, un peu de till de fond et de silt, sable, gravier et blocs; de plus de 1,5 m d'épaisseur, en général
aMm – surtout du till pierreux (dont plus de 35% consistent en fragments détritiques de dimensions égales ou supérieures à celles de galets)

Mb2 **Mv2** — Couverture et placage: till de fond loameux, un peu de till d'ablation, silt, sable, gravier et pierraille
Mb – de 0,5 à 3 m d'épaisseur, en général
Mv – placage discontinu recouvrant la roche; de moins de 0,5 m d'épaisseur,
aMb, aMv – surtout du till pierreux (don't plus de 35% consistent en fragments détritiques de dimensions égales ou supérieures à celles de galets)

WISCONSINIEN ET/OU PRE-WISCONSINIEN

Gx1 — SÉDIMENTS FLUVIO-GLACIAIRES, de contact : eskers, kames et complexes de kames et kettles: sable, gravier, un peu de silt, et till; de plus de 2 m d'épaisseur, en général; déposés au-dessous ou en bordure de la glace d'âge inconnu

Mm1 — SÉDIMENTS MORAINIQUES : Moraines d'ablation ondulées et striées : till d'ablation pierreux, un peu de till de fond et de silt, sable, et gravier, dont plus de 35% consistent en fragments détritiques de dimensions égales ou supérieures à celles des cailloux; de plus de 1,5 m d'épaisseur, en général; déposés directement ou avec un léger remaniement par la glace d'âge inconnu

M.Cb — SÉDIMENTS MORAINIQUES ET COLLUVIONS : till et colluvions loameux, rigolites, socle désagrégé, et champs de blocs isolés, indifférenciés; mélange de dépôts formés directement par des glaces d'âge inconnu et de matériaux issu de processus météoriques; de plus de 1 m d'épaisseur, en général
aM.Cb - surtout des dépôts pierreux (dont plus de 35% consistent en fragments détritiques de dimensions égales ou supérieures à celles des galets)
sM.Cb - surtout des dépôts sablonneux (dont la teneur en sable est supérieure à 5%)

PRÉ-QUATERNAIRE

R — Roche : lithologies et âges divers; généralement désagrégée et partiellement désintégrée, à surface façonnée par les glaces; roche à surface décapée et polie par les glaces à quelques endroits

Notation bibliographique consellllée:

Rampton, V.N. 1984. Ministère des Ressources naturelles et de l'Énergie du Nouveau-Brunswick, Division des minéraux, des politiques et de la planification, NR-8 (échelle : 500 000)

Modifiée de :

Rampton, V.N. 1984. Géologie des formations en surface, Nouveau-Brunswick. Commission géologique du Cnada, Cate 1594A (échelle: 1:500 000).

Numérisés par K.J. Mersereau, 2002.

Édités par A.A. Seaman, 2002.

APPENDIX

2

SHORELINE MOVEMENT BETWEEN 1944, 1985 AND 2018 IN BELLEDUNE AND BERESFORD SECTORS

Limites côtières / Coastal limits

- Estuaire / Estuary
- Trait de côte de 1944 / Shoreline 1944
- Trait de côte de 1985 / Shoreline 1985
- Trait de côte de 2018 / Shoreline 2018

Taux de déplacement (m/an) / Movement rate (m/year)

Recul / Retreat

- (-) > 0,50
- (-) 0,25 - 0,49
- (-) 0,00 - 0,24

Stabilité (inchangé) / Stability (unchanged)

- 0,00

Avancée / Advanced

- (+) 0,00 - 0,24
- (+) 0,25 - 0,49
- (+) > 0,50

Commission de services régionaux Chaleur Regional Service Commission

Analyse de risque d'inondation et d'érosion côtière pour une partie du territoire de la CSR Chaleur / Coastal flood and erosion risk analysis Portion of the Chaleur RSC territory

Annexe 2 – Carte 1 / Annex 2 - Map 1
Déplacement du trait de côte entre les années 1944, 1985 et 2018 dans les secteurs de Belledune et Beresford /
Shoreline Movement between 1944, 1985 and 2018 in Belledune and Beresford sectors

Source :
Fond image : Google Earth, 2019

0 100 200 m

NAD 1983 CSRS New Brunswick Stereographic

Août 2020
August 2020

Préparation / Prepared by : G. J.-Turcotte
Dessin / Drawing : J.-M. Tremblay
Approbation / Verified by : F. Quinty
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wsp

La précision des limites et des mesures montrées sur ce document ne doivent pas servir à des fins d'ingénierie ou de délimitation foncière. Aucune analyse foncière n'a été effectuée par un arpenteur-géomètre.
Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.

Limites côtières / Coastal limits

- Estuaire / Estuary
- Trait de côte de 1944 / Shoreline 1944
- Trait de côte de 1985 / Shoreline 1985
- Trait de côte de 2018 / Shoreline 2018

Taux de déplacement (m/an) / Movement rate (m/year)

Recul / Retreat

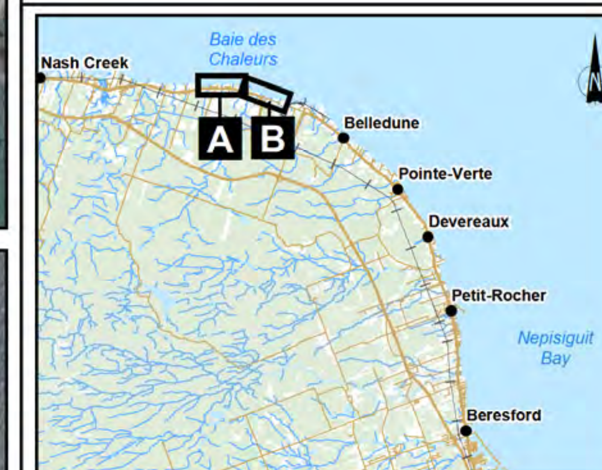
- (-) > 0,50
- (-) 0,25 - 0,49
- (-) 0,00 - 0,24

Stabilité (inchangé) / Stability (unchanged)

- 0,00

Avancée / Advanced

- (+) 0,00 - 0,24
- (+) 0,25 - 0,49
- (+) > 0,50



Commission de services régionaux Chaleur Regional Service Commission

Analyse de risque d'inondation et d'érosion côtière pour une partie du territoire de la CSR Chaleur / Costal flood and erosion risk for a portion of the Chaleur RSC territory

Annexe 2 – Carte 2 / Annex 2 - Map 2
Déplacement du trait de côte entre les années 1944, 1985 et 2018 dans les secteurs de Belledune et Beresford /
Shoreline movement between 1944, 1985 and 2018 in Belledune and Beresford

Source :
Fond image : Google Earth, 2019

0 100 200 m

NAD 1983 CSRS New Brunswick Stereographic

Août 2020
August 2020

Préparation / Prepared by : G. J.-Turcotte
Dessin / Drawing : J.-M. Tremblay
Approbation / Verified by : F. Quinty
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Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.

Limites côtières / Coastal limits

- Estuaire / Estuary
- Trait de côte de 1944 / Shoreline 1944
- Trait de côte de 1985 / Shoreline 1985
- Trait de côte de 2018 / Shoreline 2018

Taux de déplacement (m/an) / Movement rate (m/year)

Recul / Retreat

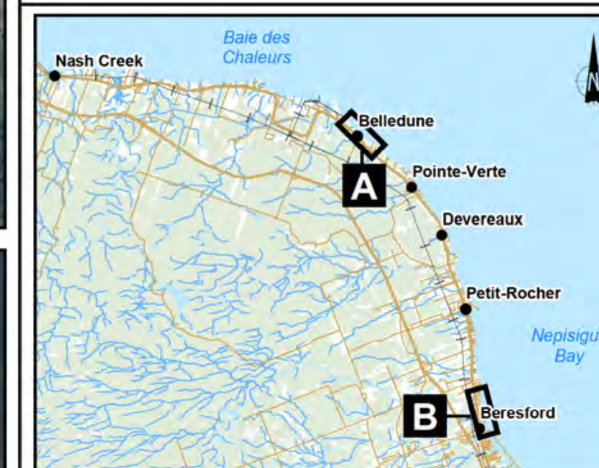
- (-) > 0,50
- (-) 0,25 - 0,49
- (-) 0,00 - 0,24

Stabilité (inchangé)

- 0,00

Avancée / Advanced

- (+) 0,00 - 0,24
- (+) 0,25 - 0,49
- (+) > 0,50



Commission de services régionaux Chaleur Regional Service Commission

Analyse de risque d'inondation et d'érosion côtière pour une partie du territoire de la CSR Chaleur / Coastal flood and erosion risk analysis Portion of the Chaleur RSC territory

Annexe 2 – Carte 3 / Annexe 2 - Map 3
Déplacement du trait de côte entre les années 1944, 1985 et 2018 dans les secteurs de Belledune et Beresford /
Shoreline movement between 1944, 1985 and 2018 in Belledune and Beresford sectors

Source :
Fond image : Google Earth, 2019

0 100 200 m
NAD 1983 CSRS New Brunswick Stereographic

Août 2020
August 2020

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Dessin / Drawing : J.-M. Tremblay
Approbation / Verified by : F. Quinty
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La précision des limites et les mesures montrées sur ce document ne doivent pas servir à des fins d'ingénierie ou de délimitation foncière. Aucune analyse foncière n'a été effectuée par un arpenteur-géomètre.
Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.

Limites côtières / Coastal limits

- Estuaire / Estuary
- Trait de côte de 1944 / Shoreline 1944
- Trait de côte de 1985 / Shoreline 1985
- Trait de côte de 2018 / Shoreline 2018

Taux de déplacement (m/an) / Movement rate (m/year)

Recul / Retreat

- (-) > 0,50
- (-) 0,25 - 0,49
- (-) 0,00 - 0,24

Stabilité (inchangé) / Stability (unchanged)

- 0,00

Avancée / Advanced

- (+) 0,00 - 0,24
- (+) 0,25 - 0,49
- (+) > 0,50

Commission de services régionaux Chaleur Regional Service Commission

Analyse de risque d'inondation et d'érosion côtière pour une partie du territoire de la CSR Chaleur / Coastal flood and erosion risk analysis Portion of the Chaleur RSC territory

Annexe 2 – Carte 4 / Annex 2 - Map 4
Déplacement du trait de côte entre les années 1944, 1985 et 2018 dans les secteurs de Belledune et Beresford /
Shoreline movement between 1944, 1985 and 2018 in Belledune and Beresford sectors

Source :
Fond image : Google Earth, 2019

0 100 200 m

NAD 1983 CSRS New Brunswick Stereographic

Août 2020
August 2020

Préparation / Prepared by : G. J.-Turcotte
Dessin / Drawing : D. Delorme
Approbation / Verified by : F. Quinty
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Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.

APPENDIX

3

MOVEMENT OF THE SHORELINE OF THE ESTUARIES BETWEEN 1944 AN D 2018 IN BELLEDUNE AND BERESFORD SECTORS

Limites côtières / Coastal limits

- Trait de côte / Shoreline
- Estuaire de 1944 / Estuary 1944
- Estuaire de 1985 / Estuary 1985
- Estuaire de 2018 / Estuary 2018

Taux de déplacement (m/an) / Movement rate (m/year)

Recul / Retreat

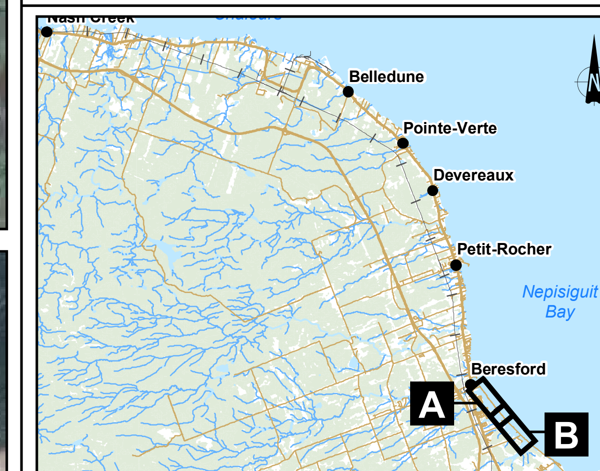
- (-) > 0,50
- (-) 0,25 - 0,49
- (-) 0,00 - 0,24

Stabilité (inchangé) / Stability (unchanged)

- 0,00

Avancée / Advanced

- (+) 0,00 - 0,24
- (+) 0,25 - 0,49
- (+) > 0,50



Commission de services régionaux Chaleur Regional Service Commission

Analyse de risque d'inondation et d'érosion côtière pour une partie du territoire de la CSR Chaleur / Coastal flood and erosion risk analysis Portion of the Chaleur RSC Territory

Annexe 3 – Carte 1 / Annex 3 - Map 1
Déplacement des rives des estuaires entre 1944 et 2018 dans le secteur de Belledune et Beresford / Movement of the shoreline of the estuaries between 1944 and 2018 in Belledune and Beresford sectors

Source :
Fond image : Google Earth, 2019

0 100 200 m

NAD 1983 CSRS New Brunswick Stereographic

Août 2020
August 2020

Préparation / Prepared by : G. J.-Turcotte
Dessin / Drawing : J.-M. Tremblay
Approbation / Verified by : F. Quinty
191_12464_00_a3_c1_Estuaire_wspq_200930bi.mxd

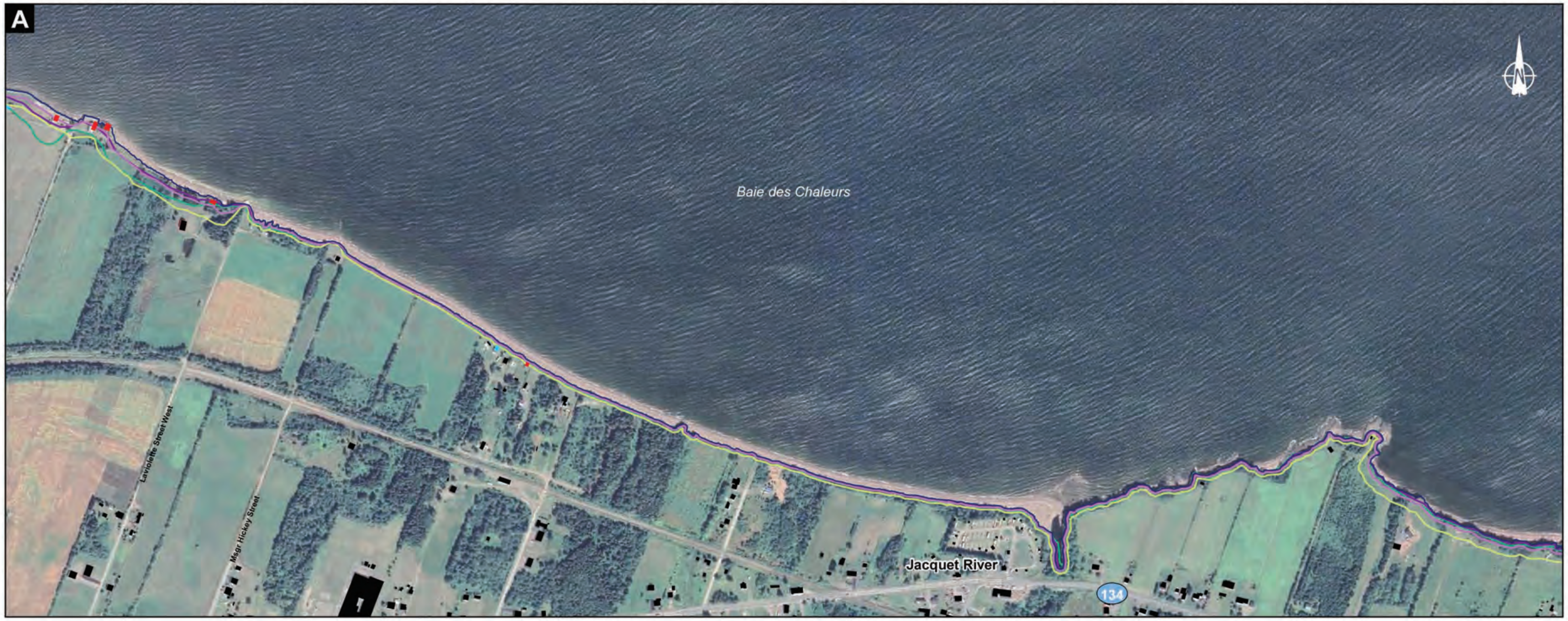
wsp

La précision des limites et les mesures montrées sur ce document ne doivent pas servir à des fins d'ingénierie ou de délimitation foncière. Aucune analyse foncière n'a été effectuée par un arpenteur-géomètre.
Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.

APPENDIX

4

PROJECTED SHORELIN INE 2050 AND 2100 IN THE BELLEDUNE AND BERESFORD SECTORS



Bâtiments à risques / Building at risk

- Risque d'érosion actuel / Actual erosion risk
- Risque d'érosion d'ici 2050 / Erosion risk by 2050
- Risque d'érosion entre 2050 et 2100 / Erosion risk between 2050 and 2100
- Potentiellement sans risque avant 2100 / Potentially risk-free before 2100

Traits de côte / Shoreline

- 2018
- 2050 (Historique) / (Historic)
- 2050 (Pessimiste) / (Pessimistic)
- 2100 (Historique) / (Historic)
- 2100 (Pessimiste) / (Pessimistic)

Commission de services régionaux Chaleur Regional Service Commission

Analyse de risque d'inondation et d'érosion côtière pour une partie du territoire de la CSR Chaleur / Coastal flood and erosion risk analysis Portion of the Chaleur RSC Territory

Annexe 4 - Carte 1 / Annex 4 - Map 1
Projection du trait de côte en 2050 et 2100 dans le secteur de Belledune et Beresford / Projected shoreline in 2050 and 2100 in the Belledune and Beresford sectors

Source :
Fond image : Google Earth, 2019

0 100 200 m

NAD 1983 CSRS New Brunswick Stereographic

Janvier 2021

Préparation : G. J.-Turcotte
Dessin : J.-M. Tremblay
Approbation : F. Quinty
191_12464_00_a4_c1_Projection_wspq_210122.mxd

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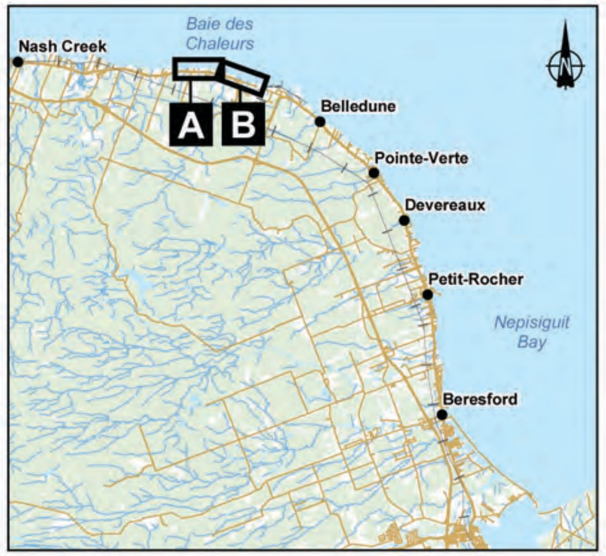
La précision des limites et les mesures montrées sur ce document ne doivent pas servir à des fins d'ingénierie ou de délimitation foncière. Aucune analyse foncière n'a été effectuée par un arpenteur-géomètre.
Boundaries and measurements shown on this document must not be used for engineering or land survey delineation. A land register analysis conducted by a land surveyor was not undertaken.

Bâtiments à risques / Building at risk

- Risque d'érosion actuel / Actual erosion risk
- Risque d'érosion d'ici 2050 / Erosion risk by 2050
- Risque d'érosion entre 2050 et 2100 / Erosion risk between 2050 and 2100
- Potentiellement sans risque avant 2100 / Potentially risk-free before 2100

Traits de côte / Shoreline

- 2018
- 2050 (Historique) / (Historic)
- 2050 (Pessimiste) / (Pessimistic)
- 2100 (Historique) / (Historic)
- 2100 (Pessimiste) / (Pessimistic)



Commission de services régionaux
Chaleur
Regional Service Commission

Analyse de risque d'inondation et d'érosion côtière pour une partie du territoire de la CSR Chaleur / Coastal flood and erosion risk analysis Portion of the Chaleur RSC Territory

Annexe 4 - Carte 2 / Annex 4 - Map 2
Projection du trait de côte en 2050 et 2100 dans le secteur de Belledune et Beresford / Projected shoreline in 2050 and 2100 in the Belledune and Beresford sectors

Source :
Fond image : Google Earth, 2019

0 100 200 m

NAD 1983 CSRS New Brunswick Stereographic

Janvier 2021

Préparation : G. J.-Turcotte
Dessin : D. Delorme
Approbation : F. Quinty
191_12464_00_a4_c2_Projection_wspq_210122.mxd

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Bâtiments à risques / Building at risk

- Risque d'érosion actuel / Actual erosion risk
- Risque d'érosion d'ici 2050 / Erosion risk by 2050
- Risque d'érosion entre 2050 et 2100 / Erosion risk between 2050 and 2100
- Potentiellement sans risque avant 2100 / Potentially risk-free before 2100

Traits de côte / Shoreline

- 2018
- 2050 (Historique) / (Historic)
- 2050 (Pessimiste) / (Pessimistic)
- 2100 (Historique) / (Historic)
- 2100 (Pessimiste) / (Pessimistic)

Commission de services régionaux Chaleur Regional Service Commission

Analyse de risque d'inondation et d'érosion côtière pour une partie du territoire de la CSR Chaleur / Coastal flood and erosion risk analysis Portion of the Chaleur RSC Territory

Annexe 4 - Carte 3 / Annex 4 - Map 3
Projection du trait de côte en 2050 et 2100 dans le secteur de Belledune et Beresford / Projected shoreline in 2050 and 2100 in the Belledune and Beresford sectors

Source :
Fond image : Google Earth, 2019

0 100 200 m

NAD 1983 CSRS New Brunswick Stereographic

Janvier 2021

Préparation : G. J.-Turcotte
Dessin : J.-M. Tremblay
Approbation : F. Quinty
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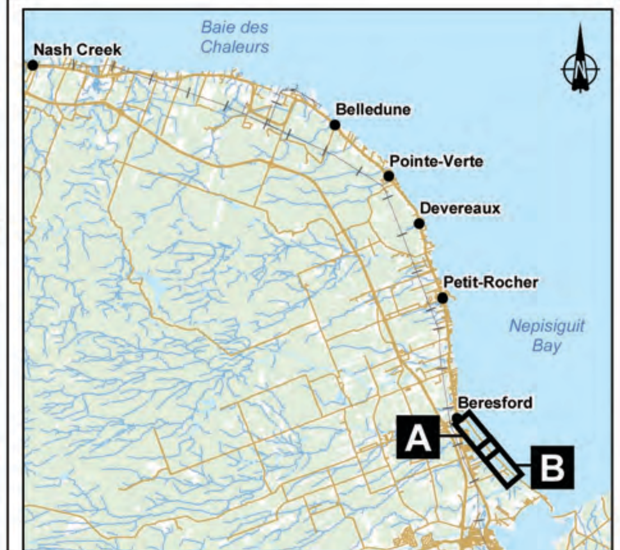
Bâtiments à risques / Building at risk

- Risque d'érosion actuel / Actual erosion risk
- Risque d'érosion d'ici 2050 / Erosion risk by 2050
- Risque d'érosion entre 2050 et 2100 / Erosion risk between 2050 and 2100
- Potentiellement sans risque avant 2100 / Potentially risk-free before 2100

Traits de côte / Shoreline

- 2018
- 2050 (Historique) / (Historic)
- 2050 (Pessimiste) / (Pessimistic)
- 2100 (Historique) / (Historic)
- 2100 (Pessimiste) / (Pessimistic)



Commission de services régionaux Chaleur Regional Service Commission

Analyse de risque d'inondation et d'érosion côtière pour une partie du territoire de la CSR Chaleur / Coastal flood and erosion risk analysis Portion of the Chaleur RSC Territory

Annexe 4 - Carte 4 / Annex 4 - Map 4
Projection du trait de côte en 2050 et 2100 dans le secteur de Belledune et Beresford / Projected shoreline in 2050 and 2100 in the Belledune and Beresford sectors

Source :
Fond image : Google Earth, 2019

0 100 200 m

NAD 1983 CSRS New Brunswick Stereographic

Janvier 2021

Préparation : G. J.-Turcotte
Dessin : J.-M. Tremblay
Approbation : F. Quinty
191_12464_00_a4_c4_Projection_wspq_210122.mxd

wsp

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