Coastal Erosion in Newfoundland

Norm Catto

Department of Geography, Memorial University

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1. Introduction

This report classifies the coastline of the island of Newfoundland, focusing on the sensitivity of the coastline to erosion and petroleum contamination. It forms the first phase of a detailed study of the Newfoundland coastline. A subsequent report will discuss individual locations along the coast, based on field, office, and laboratory research conducted throughout the period from May 2010 through 2011, building upon research conducted since July 1989.

The report is organized in four subsequent chapters. The Shoreline Classification system, which considers coastal geomorphology and sedimentology, is discussed in Chapter 2. Chapter 3 discusses the sensitivity to short-term coastal erosion in Newfoundland coastal locations, using a newly-developed Coastal Erosion Index (CEI). Chapter 4 considers the longer-term factors involved in coastal erosion and sensitivity to sea level rise, the CSI Index. Chapter 5 introduces the Petroleum Vulnerability Index (PVI) and its application to coastal Newfoundland.

Data for 1472 locations along the coastline of Newfoundland is presented in Table 1.1, including determination of the Shoreline Class, CEI, CSI, and PVI for each. The accompanying maps indicate the shoreline classifications for the coast of Newfoundland.

2. Shoreline Classification System

The classification system used in this report is a modified version of that used by Fisheries and Oceans Canada in other regions of Newfoundland and Canada, including areas of eastern Newfoundland discussed in previous reports (Catto *et al.,* 1997, 1999a, 2003; Catto, 1997). This system was initially based on the schemes proposed by Harper and Reimer (1991) for the Pacific Coast of Canada, and by SeaConsult Ltd. for the west coast of Newfoundland (Owens, 1993, 1994). The classification system is outlined in Table 2.1. Although some issues have been observed in the application of this scheme to Newfoundland, as discussed below, it has been retained in the interests of regional consistency and to facilitate comparisons with other, similarly mapped shores.

Classification was accomplished through:

- field observations conducted from July 1989 through March 2011;
- intensive review of the coastal areas of southern, eastern, and northeastern Newfoundland from May 2010 through March 2011;
- analyses of videotaped records of surveys of the coastline, including those conducted as part of the Environmental Impact Assessment process undertaken by the Hibernia Development Corporation, and those conducted by Natural Resources Canada;
- analyses of aerial photography previously conducted by the Governments of Canada and Newfoundland and Labrador, dating from 1941;
- analyses of photographs held in the Archival Collection of Newfoundland and Labrador, in the collection of the Department of Mines and Energy, Government of Newfoundland and Labrador, and by private individuals;
- discussions with residents of the coastal communities; and
- observations and analyses reported and documented elsewhere by numerous colleagues, referenced throughout the discussion.

Multiple, repetitive observations, in all weather conditions, are vital to analysis of any coastline. Classification based on short-term observation of the shore may fail to describe fluctuations over longer terms. Analysis of a coastline based on a single observation of the coast (especially on a bright, sunny day) with the assumption that conditions will not vary substantially throughout the seasons or from year-to-year, may prove invalid. Observations of several of the beach systems throughout the study region, in addition to those observed in other parts of Newfoundland (Forbes, 1984; Forbes *et al.,* 1993; Nichols, 1994; Sherin and Edwardson, 1995; Hicks, 1995; Shaw *et al.*, 1998, and numerous others), indicate that spatial and temporal changes in sediment texture and shoreline morphology are ubiquitous. Further changes are evident for those regions where older aerial and ground-level photographs provide a record of events. In some areas, the changes are significant enough to entirely change the shoreline classifications that would be determined at different times. These shorelines are designated with compound symbols in this report and on the maps (e.g. 14/17).

The classification system divides shorelines according to the substrate, specifying ‘rock’, ‘sediment’, or ‘rock and sediment’. ‘Rock’ (Classes 1, 2, and 3) refers to consolidated bedrock *in situ* which has not been disturbed by mass movement or glacial transportation. ‘Sediment’ refers to all clastic material which has been transported, detached, or weathered from the underlying bedrock, regardless of grain size. This division would require modification in regions with easily eroded or partially consolidated bedrock or with indurated or cemented Quaternary sediments. In Newfoundland, although bedrock in different areas varies in its resistance to erosion, the only significant areas with easily eroded bedrock are the gypsum cliff shorelines of southwest Newfoundland. These areas are designated as a separate shoreline class (27).

‘Rock and sediment’ (classes 4-12) refers to sites which have areas of sediment separated by exposed rock, or which have thin (<30 cm) and transitory veneers of sediment overlying bedrock. Where such areas are subject to temporal variation in the extent and/or thickness of sediment cover, they are considered to retain their ‘rock and sediment’ substrate classification.

The second criterion is the texture of the overlying sediment. Texture is defined according to the dominant clast size present, as ‘sand’, ‘gravel’, ‘gravel and sand’, ‘mud’, ‘mixed clastics’, ‘organics and mixed clastics’, ‘organics’, or ‘none’. The textural divisions follow those of the Wentworth-Udden classification system (Udden, 1898; Wentworth, 1922; Krumbein, 1934; Pettijohn *et al.,* 1987). Gravels are subdivided into “granules” (2-4 mm diameter), “pebbles” (4-64 mm in diameter), “cobbles” (64-256 mm in diameter), and “boulders” (>256 mm in diameter). Pebbles and cobbles may be further subdivided into fine, medium, and coarse grades. Sand is subdivided into “coarse” (0.5 mm-2 mm in diameter), “medium” (0.25-0.5 mm in diameter), and “fine” (0.0625-0.25 mm in diameter) grades. Clasts between 0.0039 mm and

0.0625 mm in diameter are considered as "silt", and those less than 0.0039 mm in diameter are "clay". The term "mud" encompasses both silt and clay.

'Sand' systems (classes 10-12, 19-21) are defined as those containing a volumetric majority of clasts with diameters between 2 mm and 1/16 mm (0.0625 mm). Under this classification system, most 'sand' beaches contain more than 90% sand by volume and more than 75% by mass. The human perception of 'sand' differs from the sedimentological one, however, as most non-geologists consider a sandy beach to be dominated by medium-fine to very fine sand (0.20 mm to 0.0625 mm). Some sites classified as 'sand' beaches under this system, therefore, may not be perceived as 'sandy' by all users.

'Gravel' (classes 4-6, 13-15) is defined as all materials of granule size or coarser, ranging from 2 mm diameter to the largest boulders. This designation includes granules, pebbles, cobbles, and boulders. Gravel shorelines have a volumetric majority of gravel, and the mass fraction of gravel commonly exceeds 90%. An additional criterion is that no distinctive or temporally persistent areas dominated by sand are present. As the gravel designation encompasses all clasts larger than sand, a 'gravel' beach could theoretically be composed entirely of granules, or entirely of boulders, or have a textural assemblage of a variety of gravel classes. Differentiating among these assemblages is of importance in the assessment of beaches for several purposes, including suitability as capelin spawning areas, harlequin duck habitat (Golden Bay), sensitivity to marine pollution, assessment of dynamics and sediment flux, and ecotourism potential. Although the shoreline classification does not differentiate among gravel textures, several of the other measures of coastal erosion presented in this report incorporate these differences.

'Sand and gravel' systems (classes 7-9, 16-18) are defined as those with volumetric proportions of sand greater than 30% and less than 70%, or those with clearly segregated lateral or vertical sand and gravel assemblages. At several sites, sediments are texturally segregated, with sand dominating the intertidal and subtidal areas, and gravel dominating the exposed beach ridges. These sites are classified as 'sand and gravel' beaches if the textural segregation is preserved throughout the majority of the year (with the exception of conditions during and following storm events). Sites where sand is only dominant sporadically in the intertidal and subtidal zones, particularly those that require long periods of quiescence or specific episodes of littoral sediment transport to develop concentrations of sand, are classified as 'gravel' beaches.

At some sites, gravel and sand are mixed together in undifferentiated assemblages. These beaches are considered as ‘sand and gravel’ systems if the volumetric proportion of sand exceeds 50% (although the mass proportion will be considerably less than 50%), or where the gravel clasts are supported within a sand matrix.

Designation of particular systems as either ‘gravel’ or ‘sand and gravel’ shores is subject to change after storm events, or after prolonged periods of modification under winds originating from specific directions. For these reasons, a site classified as ‘gravel’ may display mixed textural assemblages on some occasions. Here, the textural designation refers to the modal status of the site. Sites which show repetitive alternation in textural status are designated by compound symbols (e.g. 15/18; 6/9).

Sites designated as having ‘mud’ sediment (class 22) have totals of less than 50% sand and gravel by volume. The majority of the sediment is thus silt and clay. Mud-dominated shores are very rare throughout Newfoundland, and at all sites silt is present in excess of clay. Several ‘mud’ sites contain <5% clay-sized particles. Fine organic detritus and individual lenses and thin layers of organic sediment are also commonly present.

Sites designated as having ‘organics and mixed clastics’ are located in estuaries and fringing lagoons. An estuary and fringing lagoonal (class 23) shoreline incorporates many small zones varying in texture and morphology, such as individual tidal channels, fluvial bars, areas of bank erosion and deposition, and vegetated and unvegetated zones. In these instances, subdivision of textural zones is impractical at the scale of mapping, and is also hindered by temporal changes in the configuration and position of individual small-scale features.

‘Mixed clastic’ shores are defined as those containing a range of inorganic clasts ranging from mud to cobble or boulder gravel. These shorelines represent areas where coastal processes have not completely re-worked pre-existing glacigenic sediment, but where the sediment is incorporated into the active shoreline and is influenced by shoreline processes, rather than representing an underlying substrate. These shorelines are associated with ‘bouldery tidal flats’ (class 24).

Three additional shoreline classes have been added to properly categorize specific areas in northeastern and western Newfoundland. Bouldery wash-washed rögens (class 25) occur in northeastern Newfoundland, and contain a range of inorganic clasts ranging from mud to boulders. They differ from tidal flats (class 24) in that the wave influence is dominant over tidal action, and in retaining the original linear ridges associated with rögen formation. Rögens are crescentic ridges of unsorted glacial sediment.

Salt marshes (class 26) are composed of organic sediments with admixed silt and clay. They are formed in areas of mixed tidal (high microtidal-low mesotidal) and lesser wave influence. The development of many salt-water marshes is related to slowly to moderately rising sea level (e.g. Carter *et al.,* 1989; Allen, 1990; Plater *et al.,* 1999). Regions where salt marshes have developed under conditions of moderately to rapidly rising sea level are also marked by abundant sediment supply.

Gypsum bedrock cliffs (class 27) are designated as a separate category, due to the susceptibility of gypsum to erosion.

The third element in the classification system involved designation of the width of the foreshore zone. An arbitrary division was made between 'wide' (>30 m) and 'narrow' (<30 m) conditions. Although the widths of foreshore areas will vary in response to tidal action, variation is minimal under the microtidal regimes prevalent throughout most of the study region. Mesotidal areas are frequently associated with bouldery tidal flats, salt marshes, mudflats, and estuarine shores. Foreshore widths are also subject to temporal variations resulting from storm activity, and areas with such variations are designated with compound symbols (e.g. 16/17).

The fourth element within the classification system arbitrarily separates foreshore slopes (above low neap tide line) into 'flat' and 'steep' categories, with slopes measured normal to the tide lines. The numerical distinction between flat and steep is subject to temporal variation, and also depends upon where at the site the slope is measured. No sites, with the exception of those with completely uniform exposed rock platforms, have slopes which are constant from the highest berm to the neap tide line, and lateral variations controlled by aspect and sediment flux are ubiquitous. The critical angle of repose varies with sediment texture, packing, and interstitial water content, so that a sand shore considered as 'steep' will have a lower modal angle than a steep gravel shore. In this classification system, 'steep' gravel, and sand and gravel shores are considered to have maximum angles of at least 20º measured normal to the tide line. These shores are designated as 'steep beaches', and those with lesser slopes are termed 'flats'. Sand-dominated shores are considered to be 'flats' if slope angles are generally less than 5º throughout the site, and if no conspicuous subordinate berms are present below the limit of storm wave action. Sites with temporally variable conditions are indicated by compound symbols (e.g. 13/15).

These four elements-substrate, sediment, width, and slope-are considered together to produce a classification system with 27 possible members (Table 2.1). Some potential combinations of variables are mutually exclusive.

Some difficulties were encountered in application of this classification system. Individual classes within the system encompass different ranges of variability of morphology and sediment texture, with estuarine and tidal flat systems (Classes 23 and 24) showing much spatial variability in contrast to the more homogeneous steep beaches (Classes 6, 9, 15, and 18).

Designation of a shore area as Class 23 also entails consideration of terrain inland from the mean high tide line, in contrast to the designation of a steep beach or a gravel flat, both of which will be covered with marine water during storm events. Problems are thus encountered when variations normal to the shore (cross-shore) are considered. Although the classification scheme adopted is designed primarily to reflect conditions at the shoreline edge, in many instances cross-shore variability is important when considering sediment supply, seasonal changes, and overall stability of the segment of shoreline. Throughout this report, the impacts of cross-shore successions are considered in the discussion of both individual shoreline classes and particular sites.

Cliffed shorelines are assumed to be dominated by bedrock cliffs in the classification system (Classes 3, 6, 9, 12). Along some parts of the Newfoundland shore, however, steep sediment bluffs in excess of 5 m high back gravel beaches or narrow gravel flats. Examples are found along the shoreline of Conception Bay South, in embayments between Bay Roberts and Carbonear, along the northeastern shoreline of St. Mary’s Bay, at Holyrood Pond and St. Vincents, at Big Barasway (Placentia Bay), along the southern shoreline of the Burin Peninsula, in the Highland-Robinsons and St. Teresa-Flat Bay area of St. Georges Bay, and Trout River, among other sites. These sediment bluffs supply sediment to the beach areas during storm events, and in areas where the vegetation is anthropogenically disturbed. The beaches and gravel flats developed in association with these bluffs can differ in terms of stability and morphology from those present at the bases of bedrock cliffs.

Anthropogenic modification of the shoreline is not explicitly considered as a classification unit in this system. In one sense, human activity can be regarded simply as the mechanism by which a new shoreline class is created, and the resulting shore treated as any other-i.e., a shoreline backed by a concrete wall can be compared to one backed by a resistant bedrock cliff. For other purposes, however, anthropogenic activity significantly alters the physical characteristics of the shoreline (Nakashima and Mossa, 1991; Titus *et al.,* 1991; Kelletat, 1992; Gornitz *et al.,* 1993; Pilkey *et al.,* 1993; Anthony, 1994; among many other studies), inducing changes that have not finished propagating through adjacent areas, in addition to the biological effects. In many sites throughout the study region, significant modification of the shoreline by direct human intervention is evident. The impacts of anthropogenic activity are considered in the discussions of individual sites.

Table 2.1: Shoreline Classification System for the Coastline of Newfoundland

Class	*Substrate*	*Sediment*	*Width*	*Slope*	*Type*
1	Rock	none	wide	low	Wide Rock Platform
2	Rock	none	narrow	low	Narrow Rock Platform
3	Rock	none	narrow	steep	Rock Cliff
4	Rock and Sediments	Gravel	wide	low	Gravel Beach on Wide Rock Platform
5	Rock and Sediments	Gravel	narrow	low	Gravel Beach on Narrow Rock Platform
6	Rock and Sediments	Gravel	narrow	steep	Gravel Beach with Rock Cliff
7	Rock and Sediments	Gravel and Sand	wide	low	Gravel and Sand Beach on Wide Rock Platform
8	Rock and Sediments	Gravel and Sand	narrow	low	Gravel and Sand Beach on Narrow Rock Platform
9	Rock and Sediments	Gravel and Sand	narrow	steep	Gravel and Sand Beach with Rock Cliff
10	Rock and	Sand	wide	low	Sand Beach on

	Sediments				Wide Rock Platform
11	Rock and Sediments	Sand	narrow	low	Sand Beach on Narrow Rock Platform
12	Rock and Sediments	Sand	narrow	steep	Sand Beach with Rock Cliff
13	Sediments	Gravel	wide	low	Wide Gravel Flat
14	Sediments	Gravel	narrow	low	Narrow Gravel Flat
15	Sediments	Gravel	narrow	steep	Steep Gravel Beach
16	Sediments	Gravel and Sand	wide	low	Wide Gravel and Sand Flat
17	Sediment	Gravel and Sand	narrow	low	Narrow Gravel and Sand Flat
18	Sediment	Gravel and Sand	narrow	steep	Steep Gravel and Sand Beach
19	Sediment	Sand	wide	low	Wide Sand Flat
20	Sediment	Sand	narrow	low	Narrow Sand Flat
21	Sediment	Sand	narrow	steep	Steep Sand Beach
22	Sediment	Mud	wide	low	Mudflat
23	Sediment	Organics and Mixed Clastics	wide	flat	Estuary and Fringing Lagoonal
24	Sediment	Mixed	wide	flat	Tidal Flat
25	Sediment	Boulders with Mixed Clastics	wide	flat	Bouldery wave-washed Rögens
26	Sediment	Organics	wide to narrow	flat	Salt Marsh
27	Gypsum bedrock	none	narrow	steep	Gypsum Cliff

2.1 Class 1 - Wide Rock Platform

The wide rock platform class is defined as a bedrock platform, largely or totally devoid of sediment, which slopes seaward at a shallow angle (< 20°) and is in excess of 30 m in width. In coastal regions of Atlantic Canada, wide rock platforms are generally associated with gently dipping bedrock, of sedimentary, metamorphosed sedimentary, or extrusive volcanic lithology. They are frequently developed in areas with upper mesotidal or macrotidal regimes and limited sediment cover inland, such as the Bay of Fundy. In areas marked by mesotidal or microtidal conditions, such as coastal Newfoundland, sediment fluxes from either landward or seaward sources must remain low to keep the platforms exposed. Temporary sediment coverage or removal is typically associated with storm events, and even the barest platforms exhibit sediment coverage at times.

Sites with persistent high energy waves (especially waves of high amplitudes) and strongly reflective conditions can also develop wide rock platform shores, providing that the dip of the strata is moderate (15-30º). Structural weaknesses, including joint patterns, faults, and bedding planes, must generally be aligned parallel to the platform surface. Joints aligned normal or oblique to the surface are susceptible to widening by frost action, producing a stepped surface with areas where sediment can be trapped, and other locations where wave energy can be focused. Under these circumstances, a bare, regularly-sloping rock platform will not develop. Rock platform development is thus confined to areas with moderately dipping sedimentary bedrock, which has not been subjected to differing tectonic stresses, which would initiate the formation of multiple sets of joints of differing alignments.

The combination of steeply dipping bedrock, locally high sediment fluxes, and microtidal conditions throughout much of Newfoundland effectively precludes development of this style of coast. Areas with gently dipping bedrock, or where friable sedimentary bedrock is exposed, are commonly associated with abundant onshore sediment sources. Seasonal marine ice is most common in the area north of Cape St. Francis, although it does form or is forced ashore at more southerly locations during some years. Persistent scour by sea ice driven aground, however, would be expected only along the most northerly segments of the Conception Bay and Trinity Bay shorelines. Sea ice must be driven aground, either by waves or tides, in order to be effective as an erosional agent.

Seasonal ice activity (Forbes and Taylor, 1994; Hicks, 1995), can also act to remove sediment and expose wide rock platforms. In some locations, the influence of seasonal ice shove results in the construction of a boulder rampart, or the emplacement of individual boulders perched on the rock substrate. Seasonal ice activity, however, cannot totally denude a rock platform that is routinely subjected to sediment influx from the adjacent land area. In addition, the impact of seasonal ice activity is directly related to tidal range, with greater effects evident in macrotidal areas, such as Ungava Bay and Cumberland Sound (Gilbert and Aitken, 1981; Owens and Harper, 1983; Gilbert, 1990) than in microtidal or mesotidal regions.

2.2 Class 2 - Narrow Rock Platform

The narrow rock platform class is defined as a bedrock platform, largely or totally devoid of sediment, which slopes seaward at a shallow angle (< 20º) and is less than 30 m in width. These platforms develop in areas of moderately to steeply dipping sedimentary or volcanic bedrock, or in areas of metamorphosed sedimentary bedrock. Although rock platforms that are elevated above present sea level may indicate former marine limits (Grant, 1989), platforms can also be formed above mean high tide by terrestrial weathering processes (Bryan and Stephens, 1993). The development of narrow rock platforms is related primarily to the attitude of the bedrock, and its susceptibility to frost weathering, rather than to the duration or intensity of marine erosional processes. Storm activity since 1989 does not appear to have succeeded in forming any new narrow rock platforms, suggesting that individual storm events, or several closely-spaced storm events, are ineffective at erosion of consolidated bedrock.

The upper parts of the platforms are frequently marked by limited sediment cover. However, the narrowness of the platform facilitates removal of sediment by marine processes. A narrow rock platform can develop at a site backed by terrestrial sediment cover, if the rate of removal of sediment by shoreline processes exceeds the rate of terrestrial supply (net negative flux). In coastal Newfoundland, however, most narrow rock platforms are associated with areas characterized by low terrestrial sediment influx. Narrow rock platforms can develop in all tidal regimes, and under a variety of sea ice conditions.

The development of narrow rock platforms is primarily of result of frost weathering during intervals when the rock is exposed, rather than being the product of direct abrasion by waves, tides, or sea ice. The rate of formation is controlled by the number of freeze-thaw cycles, with each freezing event (to at least -4°C) subjecting the rock to 1.4 x 10^6 kg/m^2 stress as the ice expands its volume by 9.2% (Trenhaile and Mercan, 1984; Tharp, 1987; Trenhaile, 1987; Bloom, 1998), and is therefore dependent upon climate.

The second factor involved is the fracture pattern within the rock unit, which facilitates water percolation below the surface. The tensile strengths of all the rock units in Newfoundland, even the most resistant finely crystalline granites, gabbros, and quartzites, are significantly less than the stress induced by freezing (Catto and St. Croix, 1997). The stress induced by freezing in natural rock exposures is less than the theoretical maximum, because the ice has infiltrated along a fracture plane or other surface of weakness, and is not totally confined (Tharp, 1987). However, where fracture planes are narrow or tortuous, or where multiple micro-fractures occur, confinement is more extensive, and more pressure can be induced. The crystal margins within igneous rocks also represent weaknesses that can be exploited by frost. Thus, although the lithology of the bedrock does not serve to directly control its susceptibility to frost weathering, specific lithologies such as argillite, slate, stratified volcaniclastics, and volcanic flow units, are more susceptible to the development of fractures and joints along planes of weakness, and hence are more easily weathered.

In coastal Newfoundland, conditions are ideal for the formation of rock platforms at elevations ranging from mean low tidal position to several metres above present sea level. Platforms as much as 12 m above the present sea level are actively undergoing erosion and modification at present, notably along the Coast of Bays shore adjacent to Coomb's Cove, along Bay de Nord, and on the Cinq Islands. The presence of a rock platform at an elevation above sea level in an exposed coastal situation thus cannot be considered as evidence for a former high stand of the Atlantic Ocean. Similar phenomena responsible for active rock platform formation above mean sea level have been noted in different climate regimes (Johnson, 1933; Trenhaile, 1987; Bryan and Stephens, 1993), and complicated shorelines with alternating pocket beaches, cliffs, and platforms are common (Scott and Johnson, 1993).

The amount of frost-induced erosion increases in the higher intertidal areas, where sea water only covers the rock for short periods each day at high tide. In contrast, abrasion by tidal action is most effective in the lower parts of the intertidal zone, where the rock is only exposed at low tide. Along the dominantly microtidal Newfoundland shore, the intertidal zone is relatively narrow. Along a rock platform sloping at 15º, a tidal range of 1.5 m produces an intertidal zone only 6 m in width. Rock platforms of greater width developed under microtidal or lower mesotidal environments reflect incremental formation in a frost-dominated environment, influenced by changing sea level, as has occurred on the strandflats off Norway (Holtedahl, 1998) and the submerged limestone platforms of the northwestern shore of the Northern Peninsula. Some rock platforms currently submerged at low tide were formed during periods of lower sea level, when frost action was able to effectively weather the subaerially exposed bedrock. At Elliston Point, the abraded rock platform extends to 6 m below the present mean low tide level, substantially below the lowest tidal position.

Comparison of the relative amounts and effectiveness of abrasion in the higher and lower intertidal zones indicates that frost action is the dominant erosive process. Bedding planes exposed on the surfaces of some rock platforms are truncated in the upper intertidal zones, indicating that erosion has been more effective in those areas. The development of gently convex surfaces on rock platforms with regularly dipping bedding planes also suggests that erosion has been more effective in the upper intertidal areas, and in exposed areas above the mean high tide line. The distribution of *Ascophyllum, Fucus,* and other taxa within the rockweed communities (Catto *et al.,* 1999b) indicates that many platforms are not regularly subjected to sea ice activity or strong wave action, but continue to be eroded in the intertidal and supratidal zones by frost wedging.

2.3 Class 3 - Rock Cliff

Rock cliffs occur along virtually all segments of the coast. Cliff heights vary from less than 5 m to greater than 150 m, and range in slope from 30º to vertical. Numerous examples of overhanging cliffs, caves, and offshore arches and stacks are present, particularly in areas where sedimentary or metamorphosed sedimentary bedrock crops out along the coast. Faulting is associated with much of the cliffed shoreline development, such as along the south shore of Hermitage Bay (Hermitage Fault) and along Paradise Sound (Paradise Sound Fault). However, not all high cliffed shorelines parallel fault systems. Specific bedrock lithology and jointing patterns are major influences on cliff development, and assessment of local conditions requires detailed on-site analysis.

Most rock cliffs supply sediment to the shoreline as a result of frost wedging, although the rate of wedging and hence the quantities vary substantially. Frost wedging is the dominant weathering process along almost all of the Newfoundland coast, and jointed, fractured, and stratified bedrock facilitates wedging. Wedging by roots, and biochemical activity along the root surfaces, further accentuate weathering.

Coastal sites lacking vegetation are more susceptible to frost wedging than those with vegetation cover, as the combined result of exposure of the rock to the atmosphere and removal of any potential snow cover insulation during the winter and spring. However, areas with tuckamore (krummholz) tree vegetation developed on thinly veneered or bare rock surfaces are more susceptible to wedging and erosion by block toppling than are sites with a continuous herbaceous or grass vegetation cover. Erosion is particularly accentuated at low cliff sites, where periodic kill or damage of the tuckamore by salt spray or ice storms results in removal of the vegetation, leaving wedged fractures vulnerable to frost activity.

Mechanical erosion of cliffs by terrestrial runoff from precipitation locally contributes substantial quantities of sediment to the marine system. In most instances, however, the transported material has previously been detached from the cliff by frost wedging. Direct abrasion of the cliffs by sediment is not an important erosive process, except in instances where the bedrock is exceptionally friable. Gypsum cliffs, which are subject both to mechanical abrasion and chemical weathering, are considered as a distinctive shoreline classification category (class 27).

Marine activity, including scour by sea ice and wave action, has relatively little direct erosive impact on the cliffs. Notches up to 3 m asl present along some segments of cliffed shoreline are associated with anomalously friable bedrock units, commonly with fracture patterns oriented normal to the cliff faces, and are eroded by frost wedging of spray thrown against the cliffs by breaking waves. Notches and erosional features in the cliffs cannot be related to phases of higher sea level. In areas where sea level has exceeded 3 m asl since deglaciation, subsequent frost wedging has resulted in the removal of any coastal notches which were formerly present.

Direct weathering and erosion through crystallization of salts in fractures does not appear to be effective in most situations along the eastern Newfoundland shore. In contrast to frost wedging, erosion due to salt crystallization is inversely dependent on the number of crystallization cycles per unit time involved (Winkler and Singer, 1972; Goudie, 1989). Along a boreal coastline, frequent inputs of seaspray and the moist climate effectively dissolve the salt crystals before they are able to reach sizes capable of causing erosion. Hydration pressure generated from sea salt, which is most effective at high humidity and relatively low temperatures (Yatsu, 1988; Goudie, 1989), may be of some significance locally, although the effects have not been studied in Newfoundland. The primary influences of airborne salt on erosion are to limit or destroy coastal vegetation, and to depress the freezing point of water, thus inhibiting frost wedging.

Direct human influence is limited in coastal rock cliffed sites, in contrast to its central role in erosion of Quaternary bluffs. In several locations, grazing by sheep contributes to weathering and erosion. Sheep are responsible for denuding vegetation from many cliff edges, causing enhanced runoff and frost wedging and thus generating large quantities of sediment. This material, washed down the cliffs and streams and into the ocean, is thus available for transport along the shore and re-sedimentation along beaches, notably along the Cape Shore of Placentia Bay, northern Conception Bay, and northern Trinity Bay (Catto, 1994b).

Sea cliff morphology reflects the lithology, fracture pattern, tectonic history, and terrestrial erosional processes (ongoing frost action, previous glaciation). Marine processes play a very minor and in many instances negligible role.

2. 4 Class 4 - Gravel Beach on Wide Rock Platform

Class 4 shores are defined as those having a gravel beach, composed primarily of pebbles, cobbles, and/or boulders, superimposed on a wide, gently sloping bedrock platform. The gravel forms a patchy veneer or blanket over the bedrock surface, and outcrops of bare rock are commonly present. The beach seldom has defined ridges or crests, and those that do form are highly transitory. Frequently, the beaches accumulate over the widest areas of the platforms, which are the areas of the bedrock that have the gentlest slopes. Intervening marginally steeper-sloped areas commonly lack gravel cover. This results in areas with alternating shoreline segments classified as bare rock platforms (Class 2), gravel beaches on wide rock platforms (Class 4) and narrow rock platforms (Class 5), and mixed sand and gravel beaches on wide (Class 7) and narrow (Class 8) platforms. Variations are more common in areas of igneous and metasedimentary bedrock, and less evident in areas underlain by regularly sloping carbonate or shale bedrock. Frequent gradations and seasonal variations among these classes are to be expected, created by differential sediment fluxes generated by individual storm events.

Along the Northern Peninsula, this shoreline type is common. Variations in texture, morphology, and persistence of gravel cover are related to seasonal ice shove and the construction of boulder-cobble ramparts, as well as variations in the underlying bedrock surface. Differences in grain size can also reflect availability of sediments of differing textures, differential sediment fluxes generated from both terrestrial and marine activity (c.f. Bartholomä *et al.* 1998), friability of the bedrock (hence the tendency to disaggregate into finer particles), and chemical weathering of limestone bedrock, in addition to reflecting differences in energy level. Slope angles are generally controlled by the bedrock dip and meso-topography, rather than by the grain size of the sediment. Most Class 4 shorelines show very low slopes, typically less than 10°.

Class 7 shorelines (Gravel and Sand Beach on Wide Rock Platform) are differentiated from Class 4 shorelines on the basis of texture. Under this classification scheme, a Class 7 shoreline is defined as a beach containing between 30% and 70% sand, and is developed on a wide rock platform. The morphology of both the Class 4 and the Class 7 beaches is predominantly controlled by the lithology and attitude of the underlying bedrock. The sediments form a veneer or blanket over the bedrock, patches of which are infrequently exposed. The extent of sediment cover is generally greater for a Class 7 than for a Class 4 shoreline, but seasonal variations and topographic irregularities can produce areas of exposed bedrock platform flanked by sediment-covered segments (c.f. Semeniuk *et al.*, 1988).

2.5 Class 5 - Gravel Beach on Narrow Rock Platform

Class 5 shores differ from Class 4 in that they are developed on narrow rock platforms, generally marked by slightly greater slopes, greater wave energy, or more ice-shove activity. The two classes form in similar geomorphic environments, and commonly grade laterally into each other. Over time, individual Class 5 shores show little variation attributable to tidal status in microtidal areas, although mesotidal regions have greater differentiation between flood-tide influenced and lower zones. Seasonal variations similar to those that are characteristic of Class 2 and Class 4 shorelines were observed at some sites dominated by granules to medium pebbles. Many of the variations between class 5 and adjacent class 4 areas reflect the morphology of the underlying bedrock, rather than marine factors.

A typical location for a Class 5 shoreline is in a lower energy position adjacent to higher energy zones marked by narrow bare rock platforms (Class 2). This assemblage can develop where the bathymetry and/or geomorphology effectively shadows part of the shoreline from incoming strong waves, while other areas are exposed to direct attack.

Class 5 shorelines can also develop at the base of bedrock cliffs and over narrow sedimentary rock platforms sloping seaward between 5º and 20°. Locally and temporarily, beach sediment may be completely removed, exposing bare rock platforms. Replenishment from frost wedging acts to rebuild these beaches after each major marine storm event. Influx of sediment from terrestrial sources can also occur during extreme rainfall events. These beaches are dominated by limited net sediment flux, although lateral and shore-normal movement within the systems is common. Increased influx of sediment leads to greater accumulation of beach gravels, which can result in the formation of true gravel beaches if a suitable anchoring position exists. Development of many Class 5 shorelines reflects both limited sediment flux and the lack of suitable shore-parallel anchoring surfaces to retain sediment throughout the year.

2.6 Class 6 - Gravel Beach with Rock Cliff

Class 6 shorelines are defined as those with small, fringing, generally steeply-sloping gravel beaches backed by rock cliffs. In some areas, particularly along the northeast, Avalon, and south coasts, the beaches develop in confined coves, flanked by rock cliffs. These are generally referred to as “pocket beaches”. In other locations, the beaches form a discontinuous fringe of gravel at the base of bedrock cliffs. Cliff height is variable and does not influence the classification.

Pocket beaches are common along shorelines dominated by rock cliffs. Numerous examples are present along the length of the eastern Newfoundland shoreline, and pocket beaches are absent only in areas that also lack bedrock cliffs. The pockets represent the accumulation areas for sediment derived from local frost wedging and other erosive processes of the rocks surrounding the cove, as well as areas where coarse sediment transported by wave and storm activity accumulates. Although most pocket beaches receive at least some of their sediment through wave action, sediment derived from terrestrial sources is dominant at the majority of pocket beach sites in Newfoundland, as indicated by the angularity and coarse grained texture, and by the preponderance of locally-derived pebbles, cobbles, and boulders. This sediment is, however, subject to reworking by wave activity within the confines of the coves.

Pocket beaches range in length from less than 10 m (in areas where narrow, steeply-dipping fractures, faults, or thin vertically-dipping non-resistant shale beds or fissile slates reach sea level) to 10s of metres (where the beaches are developed in small coves). Steep gravel beaches in excess of 100 m in length are assigned to shore class 15 under this classification. Most pocket beaches surveyed have a gently to sharply concave sea front. Widths tend to vary along the longer pocket beaches, with the greatest widths associated either with an area of stream discharge or on the down-drift sides of the larger coves.

Cobble and boulder-dominated pocket beaches tend to have steep slope angles, locally in excess of 35º. The surface profiles are generally slightly to strongly concave. The steepest slopes tend to be aligned at sharp acute angles (60-85º) to the trend of the beach front, facing the direction of the prevalent waves. In more enclosed coves, different parts of the beach slope at different angles and trends, indicating differing wave strengths and angles of attack in consequence of the local bathymetry. Storm reworking of these beaches occurs relatively infrequently, leading to the formation of cuspate structures on the beaches. The resulting profiles are made up of several superimposed concave cusps, giving a somewhat scalloped appearance to the overall concave shape. These irregularities may persist until the next storm season. Along many of these beaches, the net effect of storm activity is accretion, as sediment from the length of the cliffed shoreline is focused in the cove area.

Pebble-dominated pocket beaches can develop from a combination of factors, including less enclosure by cliffs, a more open embayment, enhanced terrestrial sediment supply from rivers, or where erosion and weathering of the bedrock produces pebbles and sand, due to either lithology or structure. The slopes are slightly concave and gentle, and less-developed cuspate structures can be present during the spring and summer months.

Fringing Class 6 gravel shorelines occur where rock cliffs back the shore but do not confine the sediment laterally. These beaches develop where underwater obstructions serve to focus the sediment in a similar fashion to the exposed flanking cliffs of the pocket beaches. They beaches tend to be steep, narrow, and relatively unstable, although they also tend to be progressively rebuilt following disturbance by storm events. In some areas, especially where flanked by friable bedrock cliffs, the sediments may be almost exclusively terrestrial in origin.

2.7 Class 7 - Sand and Gravel Beach on Wide Rock Platform

Class 7 shorelines contain between 30% and 70% sand developed on wide rock platforms. Most of the Class 7 beaches in Newfoundland contain more gravel than sand, and the sand is predominantly coarse-grained. Yearly, seasonal, and daily variations in texture are evident on many of the beaches, and should be expected on all. In contrast to some gravel patch systems (Class 4), the angle of slope on a Class 7 beach is generally proportional to the dominant clast size.

The slope angles and lateral extent of Class 7 shorelines are predominantly controlled by the structure of the underlying bedrock. The sediments form a patchy veneer or blanket over the bedrock. The extent of sediment cover is generally greater than for Class 4 or 5 shorelines, but seasonal variations and topographic irregularities can produce areas of exposed bedrock platform flanked by sediment-covered segments, as well as producing shifts between Class 7 and Class 4. The beaches accumulate over the widest areas of the platforms, produced by shorelines marked by alternating zones of Classes 7 and 2. Aspect and wave height are critical, as the beaches can only accumulate in areas sheltered from intensive wave action. Areas where significant wave heights are less thus are more favourable to Class 7 shoreline development.

In eastern Newfoundland, where Class 7 shorelines are not common, the differences in grain size between the beaches predominantly reflect the relative availability of sand, rather than indicating differences in energy level between the sites. In western and northern Newfoundland, however, energy level appears to be a more significant factor in determining the relative grain size, as well as the distribution of coarse-gravel and mixed gravel –sand systems.

2.8 Class 8 - Sand and Gravel Beach on Narrow Rock Platform

Class 8 beaches are developed on narrow rock platforms with gentle to moderate slopes. Lateral gradations between Classes 7 and 8, and between Classes 5 and 8, are common. Temporal variations in sand content are also frequent, with many Class 8 shorelines periodically modified to form Class 5 gravel beaches. Generally, the beaches are dominated by pebbles, with lesser amounts of coarse to medium sand. However, some examples with sand present in excess of gravel occur, notably in the Coast of Bays area.

Beach slopes tend to be planar (narrower, lower energy) to concave (broader, higher energy), with maximum slopes locally exceeding 30º, following storm activity. Sand concentrations tend to increase during relatively quiescent periods, with remobilization during storms. Development of landfast ice or an ice foot also generally results in a net increase in the sand fraction.

2.9 Class 9 - Sand and Gravel Beach with Rock Cliff

Although Class 9 beaches contain modal concentrations of between 30% and 70% sand, most are sand-dominated. Seasonal and annual variations in texture are common. Lengths and widths are generally similar to those of the gravel-dominated pocket beaches of Class 6, and some Class 9 beaches are "pocket beaches". Steep mixed sediment beaches in excess of 100 m in length are assigned to shore Class 18.

Class 9 beaches can develop at the base of steep cliffs where frost-wedged clasts, generally boulders, cobbles, and coarse pebbles, are mixed with pebbles, granules, and sand derived from marine or fluvial sources. They tend to occur in areas with thicker Quaternary sediment cover, or where bedrock units weather to produce sand-sized particles. They can also form in less energetic areas. Coves that are less confined or unconfined are marked by substantial littoral movement of sand, and consequently show variations in texture with shifting wind directions. In many areas of coastal Newfoundland, the generally thin and discontinuous Quaternary sediment cover limits the formation of Class 9 shorelines.

In most cases, Class 9 shores have lesser slopes than those of Class 6. Slopes are influenced by texture, with angles as low as 5º (where sand contents are >60%) and as high as 25º (sand contents <40%). Surface profiles vary from planar to moderately concave. The steepest slopes are aligned at sharply acute angles (60- 90º) to the trend of the beach front. Divergence of slopes along the shoreline is less common than is evident on gravel pocket beaches. Cuspate features develop rarely, and when produced are generally poorly formed and ephemeral.

2.10 Class 10 - Sand Beach on Wide Rock Platform

Beaches with sand concentrations in excess of 70% are uncommon in Newfoundland. The lithology of the bedrock units, the prevalence of frost weathering, the scarcity of fine-grained Quaternary sedimentary deposits onshore, the steep slopes, and the high energy environments (either pervasive or associated with storm activity) characteristic of much of the shoreline effectively limit the opportunities for developing sandy beaches. These factors are especially evident in locations where the bedrock comprises a substantial element of the shoreline.

The only example of a Class 10 zone observed along the coast is located along the eastern side of Lance Cove, southwest of Branch. This zone grades laterally to the south into a sandy beach on a narrower rock platform (Class 11 beach). To the west, the zone grades into an open sand flat (Class 19). The relative lateral extent of the Class 10, Class 11, and Class 19 shores shifts throughout the seasons and between years.

The Class 10 zone extends for approximately 50 m along the shore, and is 30-40 m wide at low tide. The sand is moderately sorted, and medium and fine-grained. It is derived from aeolian dome dunes that back the main sand flat to the west, and is transported to the rock platform area by littoral drift, recycling from offshore areas, and rarely by northwesterly winds that rework the dunefield and move sand directly to the platform area. Minor aeolian reworking also occurs over the supratidal areas. Littoral drift is the dominant process under all but strong hurricane conditions. After a period of minimal erosion, the beach is marked by a gentle slope (2º-8º) with a planar to very gently concave profile. Slope angles reach a maximum of 12º following storms.

2.11 Class 11 - Sand Beach on Narrow Rock Platform

Class 11 beaches are developed on narrow rock platforms. The sand originates either from aeolian dunes, or from littoral drift transport from fluvial systems or erosion of Quaternary glaciofluvial deposits. Beaches derived from aeolian sediments tend to be dominated by fine sand, whereas coarse sand and granules are more common on beaches fed from other terrestrial or Quaternary sediment sources. Higher energy conditions generally result in an increase in coarse sediment, steeper, more concave slopes, and narrower profiles. However, increased sediment flux resulting from hurricane activity, especially sediment transported from terrestrial sources by rivers to the shoreline, can act to replenish the systems.

Ice foot development is a significant factor in Class 11 shorelines at Northern Bay Sands and Deadman's Bay. Winters with ice foot development halt almost all sedimentary activity, and the subsequent spring profiles reflected the conditions of late autumn. Exposure to spring waves and terrestrial runoff causes the beaches to be modified to gently sloping (<5°) planar surfaces by late spring. Winters without ice foot development at Northern Bay Sands are marked by enhanced erosion, beach coarsening (to coarse sand, granules, and fine pebbles), steeper profiles (to 12°), and offshore transport of finer sediment.

Hurricane winds are generally ineffective at modifying Northern Bay Sands. Storm rainfall increased stream flow across the beach, resulting in the addition of coarse sand and granules to the shoreline and nearshore zones, but did not affect any long-term changes to the system. The great hurricane of 12-16 September 1775, however, produced waves estimated to be in excess of 10 m high along the eastern Newfoundland coastline. Strong waves swept across the beach system and resulted in casualties among residents of Northern Bay (Stevens and Staveley, 1991, Stevens, 1995; Ruffman, 1995b, 1996). No sedimentological trace of the 1775 storm has been discovered at Northern Bay Sands. The configuration of Northern Bay renders it vulnerable to high storm waves, and ongoing sea level rise poses a continuing problem.

2.12 Class 12 - Sand Beach with Rock Cliff

Class 12 shorelines, sand beaches backed by rock cliffs, are uncommon along the Newfoundland shoreline. Genesis of a Class 12 shoreline requires bedrock that either is dominantly sandstone or weathers to sand-sized particles, along with low to moderate energy conditions. Cliff heights are generally less than 15 m. In most "pocket beach" situations, focusing of wave energy during storm events results in the removal of sand-sized material, and frost weathering produces larger clasts. Terrestrial sediment input from streams is generally minimal in steep cliff areas. The Class 12 shorelines are thus much more restricted than are those of Classes 6 and 9. These shorelines tend to be found adjacent to open sand flats and beaches (Classes 19, 20, 21), where bedrock flanks embayments.

Slopes tend to be gentle (maximum 16°) and planar or weakly concave. At most sites, the mobility of the sand and the gentle slopes preclude the development of well-formed cusps. Variations in ice foot development are a major influence.

2.13 Class 13 - Wide Gravel Flat

Wide gravel flat shores have gravel of any grade as the dominant textural component, with less than 30% sand and fine sediments. Maximum widths at mean low tide are in excess of 30 m. A relationship exists between mean low tidal width and beach texture, with the coarsest beaches generally associated with the smallest widths. Beaches that alternate between gravel flats and mixed sand-and-gravel flats (Class 16) tend to be wider than those with high proportions of boulder and cobble gravel.

Class 13 shores vary substantially in sediment texture, small- and large-scale sedimentary structures, overall morphology, and genesis. Textural assemblages range across the entire spectrum of gravel deposits, from boulder and coarse cobble-dominated assemblages, representing essentially relict sedimentary deposits formed during deglaciation; to those dominated by pebbles and cobbles; to pebble-dominated systems; to assemblages dominated by fine pebbles and granules; to assemblages where sand and gravel are co-dominant. Along Conception Bay, boulder and coarse cobble-dominated assemblages represent combinations of essentially relict sedimentary deposits formed during deglaciation with material deliberately added to the shoreline during railroad and road construction. Unaltered boulder-dominated assemblages occur in other areas (e.g. Boger, 1994; Catto *et al.*, 1997).

Sorting is also very variable, from very good to extremely poor. On some beaches, seasonal shifts in texture are ubiquitous. On others, the textural shifts are less pronounced and less predictable, and on some, little textural change with the seasons is evident. Individual segments of longer flats also show lateral variations in sorting and texture, both seasonally and in response to individual storm events. Beaches also differ in texture depending on the style of sediment transportation (shore-parallel, shore-normal, or oblique), and on the relative strength and consistency of seaward sediment movement. Similar variations have been recorded on other gravel and sand beaches subject to differing energy levels (e.g. Carr *et al.* 1982; Dubois 1989; Miller *et al.* 1989; Héquette and Ruz 1990; Jennings and Smyth 1990; Thom and Wall 1991; Medina *et al.* 1994). Textural shifts cannot be generalized between adjacent beaches, or from segment to segment of the same beach.

Many beaches undergo periodic cycles of erosion and deposition throughout the year, leading to changes in slope angle, development of temporary shore-parallel spits and bars, and collapse of oversteepened fronts. Textural variations in response to storms are most apparent on beaches which have higher proportions of pebbles and fine cobbles, and which are not directly fed by terrestrial streams.

Shifts in the quantity and texture of material supplied to the beach by streams, and seasonal fluctuations in stream volume, lead to alteration of the beach morphology. In many cases, however, variations in stream discharge are associated with high precipitation during storms. The net result on many beaches is to cancel out the effect of storm reworking, by replacing clasts moved laterally along the shore with those derived from the terrestrial hinterland.

At some locations, wide gravel flats are associated with steep gravel beaches (Class 15), and the changes in slope angle throughout the seasons (or from year-to-year) are significant enough to change the designation between these two classifications. Typically, gravel flats show modal slopes less than 5º in the late summer, especially where finer pebbles and granules are important constituents of the beach. In contrast, storm activity and seasonal fluctuations may combine to produce slopes in excess of 30º during the late autumn and early winter. The beach thus varies seasonally between broad gravel flat conditions, and a complex dominated by one or more steep gravel beaches (shore Class 15). These beaches are designated as 13/15 zones. Changes in width of the gravel flats over time (from Class 13 to Class 14) are relatively uncommon.

The degrees of variation between the shorelines grouped together within Class 13, and the spatial and temporal variations within individual wide gravel flat systems, are considerable. Similar variations have been recorded in gravel systems in many other areas (e.g. Finkelstein 1982, Carter and Orford 1984, Taylor *et al.* 1986, Duffy *et al.* 1989, Forbes *et al.* 1991, Orford *et al.* 1991, Medina *et al.* 1994, Forbes *et al.* 1995, Orford *et al.* 1996).

2.14 Class 14 - Narrow Gravel Flat

Class 14 shorelines have gravel flats less than 30 m in width. These shores can develop where steep bathymetry precludes the genesis of a Class 13 shore, or where a bluff of Quaternary sediment provides an ample source of coarse material along a relatively straight, non-embayed, segment of coastline. Slopes tend to be concave (maximum >35°), and sediments are generally dominated by coarse pebbles and cobbles. Long periods of quiescence result in decreases in slope angle, formation of planar profiles, and increases in finer pebbles and granules. As with Class 13 shorelines, seasonal, spatial, and temporal variations are considerable.

2.15 Class 15 - Steep Gravel Beach

Class 15 shorelines are among the most common in Newfoundland. These steep gravel beaches commonly exhibit a wide range of texture and morphology from season to season, and among locations. Wide gravel flat/ steep gravel beach (Class 13/15) transitional assemblages are very common along the eastern Newfoundland shore. Narrow gravel flat/steep gravel beach (Class 14/15) transitional assemblages are less common. Seasonal and/or yearly variations in classification between gravel and sand-and-gravel beaches (Classes 15 and 18) occur. Textures on gravel beaches range from granules to boulders.

High energy steep gravel beaches are usually reflective in nature throughout the year, generally dominated by shore-normal transport and swash-aligned features, although shore-parallel and oblique transport also occurs locally. These systems are developed along indented or embayed coastlines marked by deep bathymetry, which are aligned facing the prevailing (or storm) winds and waves. These beaches may undergo intense modification during storm events, followed by long periods of quiescence.

High-energy beaches which directly face the prevailing storm wave direction are characterized by strongly concave profiles with stacked tiers of gravel cusps. Storm waves modify pre-existing cusps, causing temporary irregularities in the profiles and forming superimposed concave cusps, giving a somewhat scalloped appearance to the overall concave shape. These irregularities persist until the next major storm. During a severe storm event, all the cusps below storm overwash height are destroyed. Lower tiers of cusps are gradually rebuilt by lesser energy waves. Slope angles can exceed 40°, and strongly concave profiles are common.

Construction of roads across the crests of high-energy beaches results in substantial modification. Lowering the crest height leaves the shore vulnerable to overwash during the next major storm.

Moderate energy steep gravel beaches generally have lesser slopes (typically to 30°) and are dominated by medium pebbles to fine cobbles. Stacked tiers of cusps are common, reflecting both the amount of time elapsed since the last significant storm event and the absence of significant reworking by seasonal ice, where undisturbed by anthropogenic activity.

In Newfoundland, gravel beaches developed under low energy environments are influenced by glacial sedimentation. Glacial deposits exposed along the shoreline commonly have cobbles and boulders too large to be transported by wave and current activity. The large clasts accumulate to form a framework, around and over which finer pebbles, granules, and sands are deposited. During most periods, deposition occurs passively, frequently augmented by terrestrial stream flow. When these beaches are subject to storm activity, however, many of the finer particles are removed, and the sediment is remobilized to form a steeply sloping, concave coarse gravel beach. When the 'normal' low energy conditions resume, the storm deposits remain as a framework, and many stay unaltered for several years. Summer profiles are slightly to moderately concave, with maximum slope angles typically <20°, although greatly influenced by beach texture. The influx of terrestrial fluvial sediment is significant, with flux increasing with river discharge following precipitation events, and decreasing during dry summers.

The low energy gravel beaches are subject to reworking at irregular intervals, as a result of anomalous storm activity. Thus, although modal energy conditions can be defined for particular shores, high energy events can and do impact any location. High energy shorelines can be recognized and inappropriate land uses avoided, but recognition of the dangers posed along lower energy shores are equally if not more important.

2.16 Class 16 - Wide Gravel and Sand Flat

Wide gravel and sand flat shorelines are differentiated from those of Class 13 on the basis of texture. A Class 16 shoreline is defined as a wide flat that modally contains between 30% and 70% sand. Some shorelines within this class will contain less than 30% sand under certain seasonal or meteorological conditions.

Wide gravel and sand flats undergo textural modification over time scales from hours to years. Gradations to other shoreline classes of differing slopes, widths, and textures are common. Changes in wind direction, wave energy, and sediment availability are responsible for these textural and morphological variations. At some localities, anthropogenic activity and coastal land use have also resulted in textural and morphological modifications.

Slopes are generally moderate (10-20º) and gently concave to planar, although steeper concave slopes form during storm activity. Reduced snow and ice cover also results in increases in slope angle and concavity, as well as coarser textures. Cusp development is common.

2.17 Class 17 - Narrow Sand and Gravel Flat

Class 17 shores have mixed populations of sand and gravel, and are less than 30 m in width. Many Class 17 shore zones are transitional, spatially and over the short and long term, to broad sand and gravel flats (Class 16), to steep sand and gravel beaches (Class 18), to narrow gravel flats (Class 14), and to steep gravel beaches of (Class 15). These transitions reflect seasonal events, shifts or temporary truncations of sediment supply, and major storms.

Class 17 shores are gently to moderately sloping (slopes 3-20º), with planar to slightly concave profiles. Seasonal reworking results in gradually steepening slopes throughout the summer. Shorelines that are subjected to high-energy wave action commonly develop steeper profiles, with stacked tiers of cusps produced by shore-normal waves. Slopes can temporarily exceed 30º.

2.18 Class 18 - Steep Gravel and Sand Beach

Steep gravel and sand beaches develop both seasonally in association with sand and gravel flats or gravel beaches, and independently. Class 18 beaches are associated with many spits and barachoix features. They also develop in association with laterally extensive bluffs of Quaternary diamictons and glaciofluvial sediments.

Seasonal variability in morphology and texture is common. Slopes range from minima of <5º to maxima of >25º. Profiles are strongly concave on coarse cobble systems, moderately concave where fine cobbles and coarse pebbles dominate, and gently concave (locally and temporarily planar) where fine pebbles, granules, and sand comprise more than 40% of the textural assemblage together. Textural assemblages range from coarse cobble beaches with small amounts of coarse sand to seasonally granule-dominated systems. Cuspate structures are present on the coarsest beaches for at least some period in all years, but are only found on granule and fine pebble beaches for short periods following major storms. Stacked tiers of cusps are common. Textural and geomorphic features, including cusp styles, indicate that wave energy regimes and transport directions differ at each site

2.19 Class 19 - Wide Sand Flat

Sand flats contain less than 30% gravel of all grades, including granules. Wide sand flats have modal width normal to the shoreline of 30 m or more. Seasonal variations locally cause classifications to alternate between sand and gravel-dominated and sand-dominated zones (e.g. 16/19). Associations of wide and narrow sand flats and steep sand beaches (Class 21) are also present.

The generally coarse texture of the Quaternary sediment, the high energy levels of most of the Newfoundland shoreline, the shortness and steepness of the streams carrying sediment to the shore, the steep bathymetry, the low mesotidal to microtidal regime, and the prevalence of frost wedging all combine to limit the supply of sand to the coastline. Sand-dominated systems can only develop in a few isolated regions, where some of these factors are locally absent. Commonly, sand has accumulated in the coastal zone through other, terrestrial processes (such as aeolian activity), rather than having been carried to the sites by marine currents.

Sand flats have extremely gentle slopes (<1-7°). Storm activity commonly produces undercutting of exposed sand in dunes, but these features are generally quickly modified following storms. Most storm waves tend to travel over the surface of sand flats without causing significant erosion, and the energy is focused at the dune field margins. Abundant sand supply is required to develop and maintain a wide sand flat.

2.20 Class 20- Narrow Sand Flat

Narrow sand flat systems are uncommon along the Newfoundland shore. Gradation among shorelines of Classes 19, 20, and 21 is common.

Narrow sand flats resemble the broader flats of Class 19 in most respects. Sediments are generally somewhat coarser, but much of this textural differentiation can be attributed to the available sand supply.

2.21 Class 21- Steep Sand Beach

Steep sand beaches develop both associated with and independently of sand flats, grading laterally (and seasonally) into mixed sand and gravel flats. Modal grain sizes are generally in the coarse sand range. Slope angles vary from 2 to 17º, with most slopes approximating 5-8º. Profiles are linear to slightly concave.

Seasonal variability is less apparent on the steep sand beaches than on steep beaches with large concentrations of gravel (Classes 15 and 18). The beach front trends are gently concave to planar. The texture in most Class 21 systems is highly responsive to terrestrial runoff and precipitation events, particularly during the spring and summer.

2.22 Class 22 - Mudflat

Mudflat areas are defined as those shores with a slope <2º, little or no permanent vegetation cover, surface sediment composed of <50% total sand and gravel, and few or no boulders. The majority of the sediment may be either silt or clay, or a combination of both. Mudflats are generally associated with tidal activity in most regions of Atlantic Canada, but this is not a necessary component of the classification. Estuarine deposits formed predominantly by fluvial action (Class 23), those occupied in whole or large part by any form of vegetation, particularly salt marshes (Class 26), and those with boulders on the surface (Classes 24 and 25) are excluded from this classification.

The coastline of most of Newfoundland is not suited for the development of mudflats. Sediment supply is limited in many areas, and coarse materials predominate. Tidal regimes are microtidal and low mesotidal, and tides are insignificant compared to waves in shaping almost all segments of the shore. The development of many tidal flats and associated salt-water marshes is related to slowly rising sea level (e.g. Allen 1990; Plater *et al.* 1999), rather than being characteristic of the relatively rapid rise evident on parts of the coast. Regions where tidal flats have developed under conditions of rapidly rising sea level (e.g. Chezzatcook Inlet, Carter *et al.* 1989) are also marked by abundant sediment supply.

Only two examples of mudflats are present in the study region. An area of small mudflats is present at Black Duck Hole, along Bay d'Espoir. The mudflats are separated by shallow meandering channels, generally less than 1.5 m deep, with fine to medium grained sand deposited in the thalwegs. The mudflat slopes vary between 1-2º, and the surfaces are mantled with approximately equal proportions of sand and silt, with little clay. The Black Duck Hole mudflats appear to be aggrading under conditions of slow sea level rise and abundant sediment input, but the rate of aggradation is not known.

The other examples are in the vicinity of Calmer, on Point May Pond. In this area, small mudflats are associated with sandier zones (Class 19) and lagoonal margins marked by mixed sediment and organic matter (Class 23). This region is classified as a compound shore, 23/22/19, with the order reflecting the relative importance of each shoreline type. Adjacent zones are dominated by partially vegetated lagoonal margin sand flats (23/19), and by similar flats marked by spasmodic vegetation expansion and contraction (23/19 u). The small Calmer mudflats have maximum slopes of 2º. Sandy silt covers most of the area. Typically the surface sediment is

50%-60% silt, 35-45% sand, and <5% clay. Erosional scarps, less than 30 cm, in height, mark the edges of some flat surfaces.

2.23 Class 23 - Estuary and Fringing Lagoonal

Estuary and fringing lagoonal areas are defined as those where estuarine conditions prevail, together with marginal areas marked by organic sediments, aquatic or marsh vegetation, or near-stagnant lagoonal waters. Lagoons associated with the back-beach areas of barachoix, tombolos, and similar features are excluded from this classification. An 'estuary' is defined as an embayment marked by interchange of initially distinct populations of fresh terrestrial water with saline marine water. In a boreal climate, this definition raises the theoretical difficulty that some embayments may cease to qualify as 'estuaries' during the winter months, when stream inflow drops to such low levels that the fresh water mass fails to retain its identity. Most streams, however, flow with sufficient volume throughout the year to allow the estuary to maintain its status. Estuarine conditions are precluded where high-energy marine shorelines are present, and where fluvial influx is ephemeral or confined to small brooks.

In the estuarine systems of eastern Newfoundland, fresh water influx is low compared to the marine water mass. Fresh waters tend to rise to the surface, because of their lesser density (controlled by differential temperatures) and their relatively low sediment loads. Mixing on the surface is ubiquitous, due both to current and wind activity. The estuaries are not obstructed at their seaward margins by large moraines or bedrock sills, and over-deepening by glacially-induced erosion, a common feature of fjord estuaries, has not occurred or is not significant in these embayments. Consequently, the most common estuarine condition would be expected to involve mixing of surface fresh water with saline waters, and hence low salinity gradients from surface to depth, coupled with high relative velocities of basal water with respect to surface water. These estuaries are generally be categorized by well-mixed conditions during most of the year. Salt-water wedge systems would only exist during periods of anomalously high fresh water influx (e.g. for short periods following spring break-up). Partially mixed zones develop only in the lees of bathymetric obstructions that preclude rapid flow of basal water.

Along the South Coast, the larger estuarine systems are developed in fjord embayments that have been over-deepened by glacially-induced erosion. Influxes into these fjord estuaries are obstructed at the seaward margins by bedrock 'sills', glacial moraines, or underflow fan-delta deposits. Marine waters that surmount the obstructions flow with reduced velocities, creating a semi-stagnant basal layer with relatively high salinity. The upper surface of this tidally-driven slow-moving saline wedge interacts with the overlying terrestrial fresh water layer, resulting in entrainment of small amounts of saline water. Caballing flow dominates, and vertical mixing along the wedge margin is minimal. Entrainment mixing proceeds at slow rates, on the order of 10^{-3} cm/s on the horizontal plane. As a result, the saline wedge front moves slowly landward.

In addition to vertical gradients induced by salinity differences, further complications result from horizontal differentiation. Transverse gradients, across the surface of the estuaries, are induced by bathymetry and Coriolis effects. This generally results in higher salinity along the eastern sides of the estuaries than along the western sides. The prevailing southwesterly winds further accentuate this gradation. Flow in estuaries with 'dog-leg' configurations, such as Bay d'Espoir, is influenced by the bathymetry, with deflections towards the centre of the estuaries as water masses flow around protruding cliffs and bends.

The degree of mixing in an estuary depends upon the tidal range, with mesotidal conditions generally resulting in enhanced mixing. The spring freshet also encourages mixing, especially in environments where the incoming water is relatively cold (less than 5°C) and contains suspended sediment. During the summer months, fresh water input develops a stratified profile in most estuaries, with the fresh and relatively warm surface layer forming a distinct seaward-moving plume, concentrated along the western side of the estuary.

2.24 Class 24 - Bouldery Tidal Flat

Bouldery tidal flat areas are distinguished from mudflats (Class 22) by the presence of boulders scattered across the entire surface of the area inundated by high tides. The surface texture of bouldery tidal flats varies greatly throughout the system, but the overall sediment assemblages are dominated by sand, granules, and pebbles. Vegetated areas are commonly interspersed throughout the flat. Slopes of bouldery tidal flat areas are generally very gentle, approximately 1-2º, except where cut by tidal channels.

Several bouldery tidal flats have formed in mesotidal regimes at the heads of embayments. They are marked by meandering and anastomosing tidal channels, small washover fans, bank collapse sequences, and sedimentary successions resembling those of coarse-sediment oxbow lakes in abandoned channels. All display boulders on the surface that were initially transported to the sites by glaciers and which are too large to be moved by tidal action or storm waves. The tidal flats are therefore conditioned by glacial sedimentation, resulting from the surface reworking of the previously deposited glacial sediments (Catto, 1991).

2.25 Class 25 – Bouldery Wave-washed Rögen

Rögens are glacial landforms composed of diamicton (Munro, 1994). They are crescent-shaped features, up to 10 m high, with the longest axis of the crescent oriented at 90° to the direction of flow. Rögens form at the base of glaciers, but the formative processes are highly controversial, provoking acrimonious discussion at scientific meetings. Deposition or molding by active subglacial ice (lodgment), deposition by combinations of subglacial melt-out and basal thrusting or deformation, erosion by sheets of subglacial meltwater flowing at high pressures beneath the glacier, and deposition by subglacial meltwater have all been suggested as possible formative mechanisms. Many Quaternary researchers regard drumlin and rögen genesis as an unresolved problem needing more thought.

In the Middle Arm-Eastern Arm area, east of Carmanville, submerged rögens are subject to reworking by waves, producing a coast with ribbons of boulders on the rögen crests, separated by areas of accumulation of fine gravel, sand, and silt. These areas are differentiated from boulder tidal flats (Class 24), as tidal processes are not significant in modifying the coastline.

2.26 Class 26 – Salt Marsh

Salt marshes develop along tidally-influenced coastlines. In this report, small fringing saltmarshes, such as those along the coastline of Placentia Bay (Catto and Hooper, 1999), are classified together with estuarine and fringing lagoonal areas within Class 23.

The only extensive areas of saltmarsh development are associated with mesotidal estuaries on the west coast of Newfoundland. These organic-sediment dominated areas are designated as Class 26. Salt marsh development represents a balance among changing sea level (generally slowly rising), sediment supply, and tidal flux (Allen 1990, Plater *et al.* 1999).

2.27 Class 27 – Gypsum Cliff

Cliffs with steeply dipping or vertical beds of gypsum of the Codroy Group, ranging from 0.8 to 30 m in thickness (Knight, 1983, 2004; House and Catto) are present in the Woodville-

Codroy area of southwestern Newfoundland. The combination of gypsum's softness and bedding structure, which makes the material susceptible to frost wedging and mechanical abrasion, and its susceptibility to geochemical weathering, makes these cliffs unique.

Gypsum is deposited as a chemical precipitate, $CaSO_4 \cdot 2H_2O$, in shallow saline lakes and coastal lagoons. Deposition requires a tropical climate, high rates of evaporation from the water surface, and minimal or no current activity. Both calcium and sulphate ions are soluble in water at normal surface temperatures, and precipitation thus requires that the water remain over saturated in both ions, and that currents not disturb the accumulation of precipitated crystals on the bottom. The gypsum of the Codroy Group was formed during the Mississippian period ca. 330-340 million years ago (Knight, 1983, 2004).

Gypsum is consolidated to form geologic beds, but it is easily deformed during folding and faulting. Consequently, beds of gypsum tend to be deformed, varying in thickness and orientation. The units generally consist of white, finely crystalline gypsum enclosing various amounts of black shale, shaly carbonate, and carbonate.

When gypsum is exposed to water that is not saturated with respect to either calcium or sulphate, dissolution occurs. The rate of dissolution depends upon the concentration of SO_4^{2-} ions in the water (low concentrations promoting dissolution), the concentration of hydrogen ions (high concentrations or acidic water favoring dissolution), and the presence of humic acids and organic compounds in the water. In addition to these chemical factors, the volume of water flowing through or across the gypsum surface (discharge), the duration of contact between individual water molecules and gypsum crystals, and the turbulence of the water also influence the rate of dissolution. Temperature is also a factor, but the relatively low temperatures common in western Newfoundland limit its importance for gypsum dissolution, as optimal conditions for dissolving the rock require relative warmth.

Under normal circumstances, the rate of surface dissolution over a flat expanse of gypsum would be on the order of millimeters/100 years. However, accelerated rates of dissolution occur when the gypsum beds are confined laterally by other rock units that are not susceptible to dissolution, or where dissolution is concentrated locally by wave action. Both conditions exist in the Woodville-Codroy area, as the coastal gypsum beds are laterally confined by shale and are exposed to wave action, as well as by dissolution by surface water running down the beds, and groundwater emanating from eroded cavities. Increases in the amount of precipitation through climate change, or in the rate at which precipitation enters the groundwater system, resulting from clearing of forest cover, will also result in increased dissolution.

3. Sensitivity to Coastal Erosion: CEI Index

3.1 Introduction

Coastal erosion involves both long-term processes, including sea level change and changes in storm surge frequency and intensity, and shorter term processes and events. Individual events, such as the January 2000 storm impacting southwestern and southern Newfoundland (Forbes et al., 2000; Catto et al., 2006), Tropical Storm Chantal impacting Placentia Bay and Conception Bay in 2007 (Cameron Consulting et al., 2009), and Hurricane Igor in 2010 (Catto, 2011), can result in extensive and significant coastal erosion, outside of the context of a gradual rise in sea level or changes in long-term storm activity. Consequently, a comprehensive assessment of sensitivity to coastal erosion requires that both long-term and short-term processes be considered: particular sites may be more susceptible to one form of erosion than another.

This chapter addresses the sensitivity to short-term coastal erosion in Newfoundland coastal locations, using a newly-developed Coastal Erosion Index. Long-term coastal erosion resulting from sea-level rise, discussed for Canada as a whole by Shaw et al. (1998) and for eastern Newfoundland by Catto et al. (2003), is considered in detail in the following chapter.

The Coastal Erosion Index (CEI) involves consideration of five factors: sediment type (parameter values 1-4), shoreline classification (1-5), sediment flux (1-5), aspect (1-5), and extent of seasonal ice and snow cover (1-2). After each parameter was determined, the CEI was calculated as:

CEI = (product of five parameter values / 10)

A higher CEI value indicates greater sensitivity to coastal erosion. The maximum possible CEI value is (4 x 5 x 5 x 5 x 2 / 10), equalling 100. The minimum possible value is 0.1.

In microtidal and low mesotidal situations, such as those which prevail throughout coastal Newfoundland, wave action is the dominant form of erosion, and is partially or totally responsible for shaping the majority of the coastal landforms. Although bedrock features are largely the products of pre-existing geology and climatically-induced frost weathering, wave action accounts for the majority of sedimentary landforms and contributes substantially to coastal erosion of unconsolidated cliffs.

Wave energy is controlled by the fetch, the expanse of open water unobstructed by land (or islands) across which winds blow (Komen, 1994). Prolonged periods of wind activity are necessary to overcome the frictional losses of energy between atmosphere and ocean, and to overcome the inertia of the water, in order to set the waves in motion. A wind blowing at 5.1 m/s (10 nautical miles per hr, or 10 knots) can theoretically produce waves 2.2 m high with a velocity of 8.6 m/s, but the wind velocity must be maintained for at least 11 h and the fetch must be at least 129 km (Duxbury and Duxbury, 1991; Massel, 1996). For gale-force winds at 40 knots to produce waves of 25.8 m height and 28 m/s velocity, they must operate constantly for 69 h over a minimum fetch of 2590 km. As waves of this height have been recorded by ship's captains off the coast of Newfoundland (WASA, 1995; Resio *et al.,* 1995; Swail, 1996; Catto and Tomblin, in press), these theoretical conditions can be met, but they are relatively rare. In most cases, the heights and wave velocities actually produced are far less than the theoretical maxima.

In deep water, the wave velocity is a function of the period of the wave. The velocity of one of these clapotis waves (m/s) is equal to the period(s) multiplied by 1.56. This relationship holds as long as the wave does not interact with the bottom. In most circumstances, if the wavelength (distance between successive wave crests) is less than 50% of the water depth, the wave will not frictionally interact with the bottom. The orbital motion of water within the wave will continue unhindered by friction or compression, and the wave will exhibit clapotis behaviour.

As the wave enters shallower water, it "feels the bottom" when the depth shallows to 50% of the wavelength. The orbital motion within the wave is disrupted, and frictional interaction with the substrate slows the base of the wave. The crest continues to move forward, resulting in the development of a curl of water as the surface moves faster than the base. When fully developed, the 'tube' of semi-compressed air beneath the forming breaker produces the 'tubular' conditions beloved by surfers. Eventually, the wave crest and the centre of mass of the wave move so far ahead of the base that the breaker is unable to sustain its position, and it collapses ('breaks') under the influence of gravity. The breakpoint occurs where the water depth is between 5% and 10% of the initial clapotis wavelength. Once the wave is broken, it may dissipate all of its energy, or smaller wavelets may reform and head shoreward, only to break in shallower waves.

The release of the energy of the compressed air ‘tube’ is the major factor in wave-induced erosion, much more so than the impact of the water itself. The air pressure beneath the breaker may exceed 4 times the value of atmospheric pressure (3000 mm Hg or 400 kiloPascals). In contrast, the water itself exerts a pressure only slightly greater than atmospheric. The amount of coastal erosion is thus conditioned by the shape and volume of the air pocket, in addition to the properties of the material.

Coastlines affected by waves are classified in three ways. The angle of attack of the waves, and the resultant direction of sediment movement, can be specified as either shore-parallel, shore-normal (at approximately 90º to the shore), or shore-oblique.

Wave action can generate a net current parallel to the shore (littoral drift or longshore current), or can result in sediment motion normal or oblique to the shore in the form of incoming swash or outgoing backwash. Landforms that are created by littoral drift are described as drift-aligned. Barrier islands, such as those formed along the Gulf of St. Lawrence coastlines of New Brunswick and Prince Edward Island, are classic examples of drift-aligned features. Littoral drift coastlines are less common in coastal Newfoundland, although examples are present along the southwestern coast, such as Sandbanks Provincial Park (Burgeo), Grand Bay West- JT Cheeseman Provincial Park, and Flat Island (St. George’s Bay).

Most coastlines in Newfoundland are dominated by swash-backwash motion, producing features which extend seaward (cuspate spits, tombolos) or indicate that waves move sediment normal to the shore (cusps and overwash fans). These coastlines are referred to as swash-aligned. Individual segments of shoreline may have both swash- and drift-aligned parts, or may evolve from swash- to drift-aligned systems (or vice versa) over time (e.g. Forbes *et al.* 1995).

Beaches which are subject to shore-normal transport can be modified by overtopping, overwashing, or both processes. Overtopping occurs where waves surmount a beach crest, but do not erode it. The net result is that sediment is gradually added to the crest, causing it to increase in height and become steeper over time. The growing crest remains in the same position, and its increasing height provides an effective gravitational obstacle to wave penetration across the sediment ridge. Under conditions of constant sea level, a beach crest subject to overtopping will not migrate, and will serve as a stable barrier to wave activity further inland. If sea level rise does occur, stability will depend upon the relative rate of sediment input to the beach system (sediment flux) compared to the rate of sea level rise, within time frames of years to decades. Unless sea level rises extremely rapidly (m/a), the system will remain stable as long as sediment flux is maintained and the crest is not artificially lowered or flattened.

Overwashing occurs where waves simultaneously surmount and erode a beach. The height of the beach crest is not sufficient to completely obstruct the waves. Consequently, sediment is removed from the beach crest and deposited in the lagoon behind the barrier, forming overwash fans. A beach crest subject to overwashing will become lower, as sediment is transported landward, and thus will serve as a less effective obstacle to the next wave event. The beach will also migrate landward. Eventually, a steep beach subject to overwashing will be converted to a low-slope flat, and will provide a less effective obstruction to wave activity.

Overwashing is facilitated by rising relative sea level and increased storm activity. It can also be triggered by reducing the sediment flux, which results in less sediment availability to replenish the beach between storm events. Overwashing can also be accentuated by artificial lowering and flattening of the beach crest by road construction or all-terrain vehicle traffic.

The third classification scheme involves assessment of the fate of the incoming wave energy (Kemp, 1960; Wright *et al.,* 1979; Bryant, 1982). If the offshore bathymetry is very shallow, or gently sloping, the incoming waves will 'feel bottom' and break far from the shore. This will result in their energy being dissipated across the surf zone, away from the shoreline. These coasts are termed 'dissipative' (Wright *et al.,* 1979). Although many dissipative coasts are characterized by relatively low energy levels, others are marked by higher energy conditions (e.g. Portland Creek).

Alternatively, if the offshore bathymetry slopes steeply, waves will be able to reach the vicinity of the shore before breaking. If the shoreline is a vertical cliff, the waves will strike it in an unbroken state. Under these circumstances, the waves will retain most of their energy until the instant of breaking, and substantial amounts of wave energy will be available to be returned to the sea as backwash (unless the wave completely surmounts the beach to create an overwash fan in the lagoon behind it). As well, the incoming wave will rise above mean sea level, creating a potential energy gradient and gravitational effect that will add impetus to the outgoing backwash. As a result, a substantial proportion of the incoming energy will be reflected seaward (Baquerizo *et al.,* 1998). These coastlines are termed 'reflective' (Wright *et al.,* 1979).

Reflective coastlines are generally (though not always) associated with deep embayments and high-energy situations. The shorelines of Conception Bay north of Holyrood, Fortune Bay west of Terrenceville, Bonavista Bay, Notre Dame Bay, and White Bay are good examples of areas with predominantly reflective systems.

The strength of the incoming waves, and hence their velocities, wavelengths, and locations where they break, depend upon the direction of wind and the fetch. Consequently, coastlines which are periodically influenced by waves of differing characteristics (e.g. by different wind strengths and directions) may alternate between reflective and dissipative behaviour. These coastlines are referred to as 'transitional'. Under some circumstances, a shoreline may alternate between dissipative and reflective behaviour over the course of a single tidal cycle, with the transition being driven by changes in the slope (e.g. Forbes *et al.,* 1995). Several Newfoundland beaches exhibit reflective, transitional, and dissipative conditions at different times in response to differing wave regimes.

All wave parameters undergo substantial changes as the waves 'feel bottom' and approach the shoreline. Consequently, wave heights and periods measured adjacent to the shorelines, and those which are responsible for modifying and eroding shoreline geomorphology, may differ substantially from these offshore values.

3.2 Sediment Type

Erosion of sediments by wave action requires that the sediment clast to be either rolled across the substrate, moved by a series of jumps (saltation), or transported in suspension (not in contact with the substrate). The susceptibility of an individual clast to erosion depends upon its density, shape, and diameter.

Most clasts in coastal deposits throughout Newfoundland have densities approximately equal to that of quartz (2650 kg/m^3), including clasts of feldspar, granite, and limestone. Iron-bearing minerals (commonly called "heavy minerals") have higher densities, and are commonly concentrated in distinctive bands or layers as a result of density-induced sorting. However, they seldom occur in proportions sufficient to change the overall dynamics of sediment erosion and transport in beach systems. Similarly, minerals and rocks which have densities significantly lower than that of quartz (e.g. crushed gypsum, which also tends to dissolve on beaches) do not form a large percentage of beach clasts.

Clast shape influences both erodability and transport. Angular clasts tend to interlock with adjacent particles, restricting movement. Clasts which are elongated tend to roll across beaches more readily than those which are disc-shaped, but disc-shaped clasts are more influenced by buoyancy (due to the larger surface area) and are more readily transported by waves. Disc-shaped clasts can also be packed more closely, reducing the surface roughness and the opportunities for erosion through saltation and rolling. Clast characteristics can also indicate energy levels and beach processes (Masselink and Hughes, 2003). Well-rounded, disc-shaped clasts can indicate a high energy environment where there is constant mechanical abrasion as a result of wave activity. On an individual beach, elongated clasts may be concentrated near the waterline, while disc-shaped clasts may be transported higher up the beach in suspension by wave action (e.g. McNeil, 2009).

Typically, beach clasts are described using three components: roundness, equantancy, and overall shape. Roundness observations and measurements used in investigations of Newfoundland beaches followed the Powers (1953) system. The level of roundness is generally determined through visual inspection of the clasts. Clasts are also examined for equantancy (also termed sphericity), the measure of the ratio of the three mutually perpendicular axial lengths of clasts. Clasts with axes of approximately equal length are classified as having high sphericity, whereas clasts with a low shortest axis: longest axis ratios are described as having low sphericity.

Classification of the overall shape of the clasts used a modification of the Zingg (1935) system. This system divides clasts into four categories: Bladed, for which both axial ratios are less than 0.667; Disc, for which the intermediate:long axial ratio is greater than 0.667; Elongate or Roller-shaped, for which the short:intermediate axial ratio is greater than 0.667; and Equantic, for which both ratios are greater than 0.667. The majority of tabular, disc, and elongate clasts would have low sphericity using Powers' classification. A transitional sub-equantic category, comprising clasts of moderate sphericity, was also designated.

In field investigations, the axial lengths are seldom precisely measured, and the assignment of Zingg shapes is usually done visually. Standard practice is to report the proportion of clasts which fall into each shape category.

Clast diameter (texture) has a significant effect on erosion and transport. As in the discussion of shoreline classification classes, texture is defined according to the Wentworth-Udden classification system (Udden 1898; Wentworth 1922; Krumbein 1934; Pettijohn *et al.*

1987). Gravels are subdivided into "granules" (2-4 mm diameter), "pebbles" (4-64 mm in diameter), "cobbles" (64-256 mm in diameter), and "boulders" (>256 mm in diameter). Pebbles and cobbles may be further subdivided into fine, medium, and coarse grades. Sand is subdivided into "coarse" (0.5 mm-2 mm in diameter), "medium" (0.25-0.5 mm in diameter), and "fine" (0.0625-0.25 mm in diameter) grades. Clasts between 0.0039 mm and 0.0625 mm in diameter are considered as "silt", and those less than 0.0039 mm in diameter are "clay".

Studies of clast movement in rivers, laboratory settings, and coastlines have demonstrated that erosion is not a simple function of decreasing clast size. Finer particles, including fine silt and clay, are generally more difficult to erode than are fine- and medium-grained sands, due to combinations of their cohesion, greater water contents, geochemical bonding, and platy shape, which renders them less susceptible to be 'levered' away from the substrate. Once eroded, however, finer particles are transported more readily. One implication of this is that storm action that results in the initial disturbance of fine silt and clay successions may trigger substantial erosion, whereas erosion during non-storm periods may be almost minimal for these clasts, in contrast to the ongoing erosion of fine sands under relatively low-energy conditions. Considering clasts of identical shape and lithology (density), fine sand is most readily eroded by wave action. Clay particles may require as much energy input as fine gravels (granules and fine pebbles) to be eroded.

The presence of multiple clast sizes on a shoreline adds a further complication. Along the surface, larger clasts may act to shadow or shield smaller clasts from erosion and wave action. Deposition of larger clasts on top of smaller clasts during storm activity also reduces erosion, by forming a discontinuous armour. Large glacially-transported boulders, which are not subject to movement by even the strongest waves, effectively form a framework which retains many otherwise susceptible smaller clasts.

In formulating a erosion parameter governed by sediment type, clast density, shape, and diameter should be considered. As well, differences exist between the susceptibility to erosion of different segments of the same shoreline, because these parameters are not identical along the shore or at right angles to the shore throughout any system. This necessitates detailed analysis of each particular beach system in order to thoroughly understand erosion and transport processes. For a general study of the coastlines of Newfoundland, however, some simplification is necessary and possible. All clastic sediment-dominated shorelines investigated here were dominated by moderate-density clasts (approximating the density of quartz). Clast assemblages on higher-energy wave-dominated systems (pebbles and cobbles) also tended to have greater proportions of disc-shaped, rounded, low equantancy forms. Gravel-dominated assemblages on lower-energy systems tended to have higher proportions of angular and sub-angular clasts, with variable equantancy, and also had higher proportions of elongate and prolate clasts and laower concentrations of discs. Granite clasts tended to be larger (cobbles and boulders), with higher equantancy, moderate to high roundness, and equantic Zingg shapes. Sand particles in general showed high equantancy, high roundness, and equantic to sub-equantic shapes.

The erosion parameter based on sediment type was assessed on a scale of 1 to 4 as follows:

1 (low erodability): resistant bedrock; boulders

1.5: moderately resistant bedrock; cobbles

2: mixed pebble-cobble beaches

2.25: mixed sand-pebble-cobble beaches

2.5 (moderate erodability): mixed sand-coarse pebble beaches

3: mixed sand-fine pebble-granule beaches; silt; weakly resistant bedrock (gypsum, weakly consolidated sedimentary rock); coarse-medium sand beaches

3.5: organic deposits

4: (highest erodability): fine sand beaches

3.3. Shoreline Classification

The type of shoreline has a significant influence on the sensitivity to coastal erosion. Shorelines which have gentle slopes and low relief are susceptible to erosion during wave run-up. Overwashing, involving removal of sediment from a beach system into the flanking lagoon, also is more prevalent on shorelines with gentle slopes and low beach crests. The energy level of the system is also important, as high-energy coastlines are more susceptible to erosion. The ranking of CEI sensitivity indices for shoreline classification types is illustrated in Table 3.1.

Table 3.1 Ranking of sensitivity indices for landform types

Rank	Landform types
Very Low (1):	High Rock Cliff (Shoreline Class 3)
Low (2):	Low to Moderate Rock Cliffs (Shoreline Class 3)
Low-Moderate (2.5):	Rock Platforms (Shoreline Classes 1 and 2)
	Exposed gypsum cliffs (Shoreline Class 27)
Moderate (3):	Gravel over Rock Platform (Shoreline Classes 4 and 5)
	High Energy Gravel Pocket Beach (Shoreline Class 6)
	Mixed Sand and Gravel over Rock Platform (Shoreline Classes 7 and 8)
	Wide Gravel Flat (Shoreline Class 13)
	Bouldery Tidal Flat (Shoreline Class 24)
	Bouldery Wave-washed Rögens (Shoreline Class 25)
Moderate-High (3.5):	Moderate Energy Gravel Pocket Beach (Shoreline Class 6)
	Mixed Sand and Gravel Pocket Beach (Shoreline Class 9)
	Sand over Rock Platform (Shoreline Classes 10 and 11)
	Narrow Gravel Flat (Shoreline Class 14)
	High Energy Steep Gravel Beaches not associated with lagoons (Class 15)
	Mixed Sand and Gravel Flats (Shoreline Classes 16 and 17)
High (4):	Sand beaches at Base of Rock Cliffs (Shoreline Class 12)
	High Energy Steep Gravel Beaches associated with lagoons (Class 15)
	Low and Moderate Energy Steep Gravel Beaches (Shoreline Class 15)
	Steep Sand and Gravel Beaches (Shoreline Class 18)
	Mudflat (Shoreline Class 22)
	All gravel spits and tombolos

Very High (4.5): Sand Beaches and Flats (Shoreline Classes 19, 20, 21)
Estuarine and Fringing Lagoonal (Shoreline Class 23)
Salt Marshes (Shoreline Class 26)

Extremely High (5): Sand spits and Tombolos

3.4 Sediment Flux

Although storm action may result in the removal of sediment from a system on a temporary basis, net erosion depends upon a decrease in the total amount of sediment input from all sources. In many reflective beach systems, such as Middle Cove (NE Avalon), Northern Bay Sands (Conception Bay), Sandy Cove (Eastport Peninsula), and qqq, sediment that is eroded from the beach face during storm action is transported offshore, but remains within the embayment. Subsequently, the sediment is gradually returned to the shoreline during more quiescent periods, and the net amount of erosion is considerably less than the immediate aftermath of the storm would suggest. Along shorelines dominated by littoral drift or shore-oblique transport, an equilibrium regime will result if the amount of sediment transported downdrift is balanced by an influx of new sediment from the head of the littoral conveyor belt. Erosion in these systems will result if the updrift sediment supply is interrupted (e.g. by reducing the amount of sediment fed into the shoreline from the land), or if sediment is extracted from the beach at a rate exceeding the littoral influx. Erection of docks and breakwaters, which interrupt the course of littoral drift, can also result in erosion (e.g. Psuty, 1988; Illenberger and Kerley, 1993; Nordstrom, 1994; Ingram, 2004; van Vuren et al, 2004; Catto and Catto, 2009).

Sediment influx can also come from terrestrial sources, including transport by river systems and wind. Rainstorm-induced erosion on land, as commonly accompanies tropical cyclones and nor'easters in Newfoundland, results in influxes of sediment to the coastline. Thus, a hurricane event such as Igor may actually produce reduced erosion or net deposition along shorelines, as extra sediment arrives from the river systems. Higher river flows also tend to transport coarser sediment, which is subsequently less susceptible to wave erosion.

Transport by wind is important in the maintenance of sand-dominated beaches backed by aeolian dunes. Much of the sand necessary to maintain the beaches is stored temporarily in the dune systems, both the larger backing dunes and the low coastal foredunes (Short and Hesp, 1982; Psuty, 1988; Arens and Wiersma, 1994; Sherman and Lyons, 1994). Thus, any loss of sand from the dunes has a negative impact on the health of the beaches.

Beaches exist as a result of sediment supplied by erosion from somewhere – terrestrial sources (rivers, wind, slope failures), coastal sources (from littoral drift), or offshore sources (moved landward by waves and tides). Cessation of all erosion of beaches is not possible: armouring or protecting one segment of a coastline will starve another beach somewhere else. Although protection of local areas from erosion may be necessary or desirable, care must be taken to ensure that sediment flux to the coastline as a whole is maintained.

The erosion parameter based on sediment flux was assessed on a scale of 1 to 5 as follows:

1: high sediment flux (input from large river, active sand dune development, persistent supply from littoral drift

2: moderate sediment flux

3: low sediment flux (limited input to system, although confined systems may retain sediment, e.g. coves dominated by shore-normal reflective conditions)

4: very low sediment flux

5: negligible flux (bedrock shorelines with little terrestrial erosion; shorelines affected by artificial modification or interruption of sediment transport).

Quantitative measurements of sediment flux are possible only where repeated measurements of a beach have been undertaken. Ideally, this should be done over several years in order to minimize the impact of individual events (e.g. Catto, 2006b). For this study, sediment flux was assessed qualitatively, based on site visits and aerial photograph analysis.

Consideration of sediment flux together with sediment type and shoreline classification for particular shorelines highlights the different effect of these parameters. For example, a resistant bedrock cliff has low scores for the sediment type parameter (1) and the shoreline class (1), but also has minimal or negligible flux (4-5). Conversely, an estuarine delta (shoreline class 23) scores high in potential erodability based on the landform type, but also may have high sediment flux, and therefore may not suffer much net erosion over time.

3.5 Aspect

Aspect with respect to prevailing winds and storm directions also governs the susceptibility of a particular segment of the coastline to erosion. In coastal Newfoundland, wind patterns vary seasonally, and local topographical effects are extremely significant in many embayments. Statistically in all areas, westerly and southwesterly winds are more prevalent throughout the year (Banfield, 1981, 1993; Environment Canada 1982, 1993, 2005), although winds may originate from any point of the compass at any time of the year.

Along open coastlines which face south or southwest, such as St. Marys Bay, Placentia Bay, Fortune Bay, South Coast, and southwestern Gulf of St. Lawrence, the extensive fetch allows southwesterly winds to be effective agents driving the evolution of coastal geomorphology. Strong southwesterly winds are associated with many of the major storms and hurricanes during the summer and autumn, which generally pass over the region from southwest to northeast (Banfield, 1993). Northeasterly winds, which are responsible for much of the storm modification of beaches along Conception, Trinity, Bonavista, Notre Dame, and White Bay, and the open Atlantic Southern Shore, are generally ineffective agents of shoreline modification in these areas. Northwest winds are significant along the Conception Bay South, southern Bonavista Bay, and Northern Peninsula gulf shorelines. As a result, the impact of 'extreme' storm events varies greatly with aspect and location. Diurnal onshore and offshore winds are common in most embayments, but seldom result in high waves or extensive erosion.

The erosion parameter based on aspect was assessed on a scale of 1 to 5 as follows:

1: sheltered from the open ocean

2: partially sheltered

3: open to the ocean, but not facing the prevalent wind or effective storm direction

4: partially exposed to the prevalent wind or effective storm direction

5: completely exposed to the prevalent wind or effective storm direction, coupled with evidence of repeated, significant past damage and/or erosion from wave activity

3.6 Extent of Seasonal Ice and Snow Cover

Although onshore ice shove can locally result in erosion, the net effect of persistent ice cover, both offshore and on beaches, is generally protective (Forbes and Taylor, 1994). Typically, the development of ice offshore, whether continuous pack ice or more sporadic brash ice or 'swish', dampens storm wave energy during the winter months (February-April). In contrast to Nova Scotia, where winter storms have significant effects on coastal erosion (Taylor et al., 1997), the impacts on the northeast coast of Newfoundland are largely muted once offshore ice cover develops. Exposed coastlines of southern Newfoundland, however, are vulnerable to winter storm erosion (Forbes et al., 2000; Ingram, 2004).

Conditions along the shoreline, such as ice foot development and to a lesser extent snow and adhering ice cover, can also inhibit winter erosion (Boger, 1994; Pittman, 2004; Catto, 2006b). Enhanced ice foot activity is associated with colder temperatures and hence reduced frost action, as the temperature remains below 0°C for longer periods. Formation of the ice foot begins in late December during most winters, and several beaches commonly retain an ice foot until late March. In a typical winter, ice foot development characterizes most shorelines north of Spaniards Bay (Conception Bay) and St. Paul's (Gulf of St. Lawrence). The southerly extent of persistent ice foot development coincides with the position of the -0.5°C February SST isotherm (US Naval Oceanographic Office, 1967; Markham, 1980; Cote, 1989; McManus and Wood, 1991). Shorelines in southern Newfoundland do not commonly develop an ice foot, although anomalously cold winters will permit development even in northern Placentia Bay and at Burgeo (Boger, 1994; Ingram, 2004).

The erosion parameter based on ice cover was assessed on a scale of 1 to 2 as follows:

1: offshore ice cover throughout most winters, coupled with ice foot development (most areas north of Cape Bonavista and St. Paul's)

1.5: partial offshore ice cover, variable annually, with annual variations in ice foot development (most areas of central Gulf of St. Lawrence coastline, Trinity Bay, northern Conception Bay)

2: limited or no offshore ice influence, with rare or no ice foot development (most areas of South Coast, Placentia Bay, St. Mary's Bay, Southern Shore, southern Conception Bay).

Ice cover in specific locations was assumed as the regional standard, unless detailed local investigations were available.

3.7 Summary

Calculated CEI values for selected locations along the coastline of the island of Newfoundland are presented in Table 1.1. The mean CEI value for all Newfoundland coastal sites determined in this study is approximately 10.3 (median 9.5), with values locally reaching 40 (compared to a theoretical minimum of 0.1 and a theoretical maximum of 100).

Qualitative assessment of the CEI scores involves dividing the numerical values into 5 categories:

Very Low Sensitivity: CEI <4.9
Low Sensitivity: CEI 5.0-9.9
Moderate Sensitivity: CEI 10.0- 14.9
High Sensitivity: CEI 15.0-19.9
Extreme Sensitivity: CEI >20.0

Thus, sites with CEI values approximating the mean of 10.3 for the island of Newfoundland are considered to have moderate to low sensitivity to coastal erosion resulting from shorter-term processes and events. This conclusion reflects the resistant nature of much of Newfoundland's coast (bedrock, coarse gravel beaches), locally high sediment fluxes, and the prevalence of offshore seasonal ice cover. Changes in the latter two factors would impact the CEI values calculated here.

The CEI values do not directly indicate the severity of erosion (i.e. how much sediment is removed), or the amount removed temporarily by a single event (perhaps eventually to be replaced by sediment flux). Importantly, from a coastal management perspective, they do not indicate the likelihood of damage to infrastructure or dwellings, or impacts on the residents of coastal communities.

4. Coastal Erosion and Sensitivity to Sea Level Rise: CSI Index

4.1 Introduction

In order to assess the sensitivity of a shoreline to erosion, several variables must be considered. Study of shorelines in the eastern United States by Gornitz (1990, 1991, 1993), Gornitz and Kanciruk (1989), and Gornitz *et al.* (1991, 1993), and of Canada by Shaw *et al.* (1998), led to the identification of parameters which can be used to assess the sensitivity of a shoreline to erosion. Shaw *et al.* (1998) list seven critical parameters:

- sea-level change (amount of rise or fall per year);
- relief;
- mean annual maximum significant wave height;
- rock and/or sediment type exposed along the shore;
- landform type (e.g. cliff, beach, salt marsh);
- shoreline displacement (laterally, expressed in m/a); and
- tidal range

Shaw *et al.* (1998) assigned each parameter an equal weight, and ranked variations within each from 1 (very low sensitivity) to 5 (very high sensitivity). By combining the scores for each parameter, coastal sensitivity indices (CSI) can be calculated as:

CSI = $\sqrt{}$ (product of scores of all 7 parameters/7)

Thus, a shore with the least sensitivity to coastal erosion would have a CSI of $\sqrt{(1/7)}$, or ~ 0.38, whereas the greatest value possible is $\sqrt{(5 \times 5 \times 5 \times 5 \times 5 \times 5 \times 5/7)}$, or ~105.6.

Shaw *et al.* (1998) divided the coastline of Canada into three categories of CSI. Coastlines with low sensitivity had SI values of < 4.9; moderately sensitive coastlines had values between 5.0 and 14.9; and highly sensitive coastlines had values in excess of 15.0. A single sensitivity index was calculated for each of the 1:50,000 map areas (2899 in total) along the Canadian coastline. Locally, separate CSI indices were calculated for map areas with two distinctly different coasts. Two examples are the Placentia map area, where values were calculated separately for the

Placentia Bay and St. Mary's Bay shorelines; and the Marystown map area, with separate values for the Placentia Bay and Fortune Bay shores.

Throughout the analysis, Shaw *et al.* (1998) cautioned that the regional nature of their investigation may serve to partially conceal local problem areas. The serious nature of erosion problems documented at Point Verde, Placentia town, and Holyrood Pond Barrier-St. Stephens is not diminished by the overall score for the entire 1:50,000 map area. In the Placentia area, for example, Placentia town is vulnerable to sea level rise and erosion (Forbes, 1985; Shawmont Martec, 1985; Shaw and Forbes, 1987; Forbes *et al.,* 1989; Liverman *et al.,* 1994a, 1994b; Catto *et al.,* 2003; Cameron Consulting *et al.,* 2009), but because it is flanked by high resistant bedrock cliffs at Jerseyside and along Placentia Roads, and is subject only to microtidal conditions, the CSI score for the map area as a whole calculated by Shaw et al. (1998) is low. A similar situation prevails at The Beaches, White Bay, among many other locations. In contrast, areas with overall moderate sensitivity (such as St. Brides and Ferryland) will contain shoreline segments of low sensitivity (such as Cape St. Marys and Brigus Head). The St. John's map area, ranked overall as a low sensitivity region, includes the highly sensitive shoreline of Conception Bay South and the non-sensitive shoreline of Cape Spear. Even within high sensitivity areas, extremely sensitive locations may not be sufficiently highlighted.

The requirements for a rapid preliminary assessment at a national level limited the depth of regional and local investigation in the study of Shaw *et al.* (1998). Investigation at regional or local scales can provide more detailed information, further subdivision of parameters, assessment of their relative importance locally, and designation of more specific areas for categorization. Although all seven variables identified nationally by Shaw *et al.* (1998) are of significance, the local environments of coastal areas in Newfoundland provides a framework in which these can be considered further. Catto *et al.* (2003) provided a CSI analysis for points in eastern Newfoundland, based on a modification of the original models of Gornitz and Shaw *et al*. and using data collected prior to April 2000. This chapter updates the 2003 study with more recent data, and extends the investigations to encompass the coastline of Newfoundland.

4.2 Sea Level Change

Changes in sea level are driven by a combination of local, regional, hemispheric, and global factors. Each coastal area responds differently to a different combination of factors, and the change in sea level is not identical, throughout the world, along Canada's Atlantic marine coastlines, or around the island of Newfoundland. Archaeological sites at Ferryland and Fort Frederick (Placentia) NL (Catto *et al.*, 2000, 2003), among others, indicate that sea level has risen since *ca.* 1600. Longer-term sea level rise is indicated by archaeological sites at The Beaches, Bonavista Bay (Catto *et al.,* 2000), Burgeo (Rast, 1999), and Port-au-Choix (Renouf and Bell, 2000, 2006; Bell and Renouf, 2003; Bell *et al.,* 2005). Evidence of enhanced erosion along many Newfoundland and Labrador beaches, and inundation of terrestrial peat deposits and trees, indicates that transgression is currently occurring.

Sea level can be measured as an absolute quantity. Using satellites stationed above Earth, the water levels can be measured and compared to the configuration of the planet's surface as influenced by gravity and Earth's rotation, referred to as the geoid. Because Earth is not a perfect sphere (with a greater diameter at the Equator than through the Poles), the geoid is not spherical. The "absolute" mean sea level as measured from outside Earth conforms to differences in the gravitational field, and therefore varies with location. These differences also mean that the difference between the mean sea level and the geoid can be significant, locally by several metres. To compensate for these differences, each country defines its own "zero datum", which represents an approximation of mean sea level in that area. Equatorial and tropical areas, near the area of Earth with maximum diameter (and hence maximum gravitational effect on the geoid) have higher sea levels than do polar areas. Mean sea level as measured from a satellite is thus slightly higher (by ± 0.5 m) in the Caribbean than it is in the Barents Sea. These differences in sea level have an effect on current flow as well: although the modal difference in sea level between Nain and St. John's is less than 5 cm, and therefore cannot be seen or felt by mariners, this gradient is sufficient to reduce the volume and velocity of the Labrador Current. Thus, travelers moving northward against the Labrador Current are moving down the sea level gradient to northern Labrador.

When considering coastal hazards, it is the relative sea level with respect to the terrain (or a harbor) that is important, rather than the absolute volume of marine water in the ocean. Changes in sea level are measured relative to a point, such as a wharf. A rise in relative sea level results in flooding and inconvenience, regardless of the total amount of water in the basin. From a relative sea level perspective, it does not matter if the change involves an increase in the amount of water, or subsidence of the land, or a combination of both: the net result is a rise in relative sea level. A combination of a slowing declining ocean coupled with rapid subsidence of the land will result in a relative sea level rise. In contrast, rapidly rising land coupled with a slower increase in ocean water volume, as is currently occurring at Happy Valley-Goose Bay, will result in a fall in relative sea level. In Lake Melville, the current rate of fall in sea level is approximately 1 mm/a, the only area of Newfoundland & Labrador where relative sea level is currently declining.

The largest factor in the observed sea level change in NL, and the projected changes in the future, is the interaction between the changing volume of the oceans and glacioisostatic activity. The weight of glacial ice which covered the province during the most recent glaciation (beginning ca. 120,000 years ago) resulted in depression of Earth's crust beneath the glacial load, termed glacio-isostatic depression. Simultaneously, the volume of sea water globally was lower during glaciation, due to the incorporation of large volumes of water in the terrestrial glacial ice. This combination resulted in lower relative sea levels around Newfoundland, exposing the Grand Banks above the waters of the Atlantic Ocean, and allowing terrestrial glaciers to advance across dry land in the Gulf of St. Lawrence, along the northeast coast, and through all the major bays towards the receded shorelines. In eastern Newfoundland south of St. Mary's Bay, relative sea level during the Last Glacial Maximum approximately 18,000 years ago was at least 110 m lower than at present (Fader, 1989; Piper *et al.,* 1990; Miller, 1999).

When the glaciers began to melt, the combination of the addition of meltwater to the ocean with the removal of the ice from the land allowed the sea to flood the glacio-isostatically depressed coastal terrain. Relative sea level substantially increased in many areas. All areas of the South Coast were subjected to marine inundation. Glacio-isostatic depression of the land surface allowed marine waters to reach up to 55 m asl at St. Veronicas, 35 m asl at the head of Hermitage Bay, 25 m asl at McCallum and Rencontre East, and 15 m asl at English Harbour West and Pass Island (Leckie, 1979; Leckie and McCann, 1983; Shaw and Forbes, 1995; Catto *et al.*, 2003). Lower levels of inundation are present along the Fortune Bay and Burin Peninsula Placentia Bay coastlines.

Elevated relative sea levels are also present along the east shore of Placentia Bay north of St. Brides (Catto, 1992), and along the western shore north of Marystown (Catto, 1998b). After the initial deglaciation, sea level varied from slightly above present elevation near St. Brides and Marystown to 20 m asl at Swift Current. Similar elevated sea levels are recorded along

Bonavista, Trinity, and Conception Bays (Liverman, 1994; Catto, 1994b; Catto *et al.,* 2000, 2003; Shaw *et al.,* 2002). Sea levels up to 35 m above the present shoreline are recorded by terraces at Eastport, Traytown, and Sandy Cove, Bonavista Bay (e.g. Dyke, 1972), and by erosional benches at Charlottetown (Sommerville, 1997). At St. Chad's, north of Eastport, shells of the marine mollusc *Hiatella arctica* indicate that the sea stood about 40 m above its present elevation *ca.* 12,400 BP. Near Port Blandford, marine clays preserved in coastal bluffs also indicate higher sea levels. Around the shoreline of Conception and Trinity Bays, higher sea levels carved erosional benches and deposited gravel terraces at elevations between 5 m and 20 m above sea level, with the northwestern shore suffering the greatest inundation and the southern tips the least (Brückner, 1969; Henderson, 1972; Catto, 1993, 1995, 2001; Catto and Thistle, 1993).

The earliest Holocene phase of sea level history appears to be substantially different on the southernmost part of the Burin Peninsula, and along the open Atlantic coastline south of Cape St. Francis, where raised marine features have not been recognized. Cores taken from St. John's Harbour indicate that a freshwater lake existed shortly after deglaciation, *ca.* 11,000 BP (Lewis *et al.,* 1987). This suggests that sea level at this time was at least 14 m below present, the elevation of the controlling sill in The Narrows (prior to blasting to improve access for cruise ships). Marine transgression is recognized by a transition from a brackish thecamoebian (*Centropyxis aculeata*) to a marine foraminiferal assemblage, *ca.* 9,900 B.P.

Relative sea level in St. John's Harbour appears to have remained below present throughout the Holocene. No raised marine deposits have been encountered in excavations in downtown St. John's, although marine deposits at elevations to 8 m above sea level are present along the southern shore of Conception Bay at Portugal Cove, St. Philips, and Conception Bay South (Brückner, 1969; Catto and Thistle, 1993; Catto and St. Croix, 1998).

In northeastern Newfoundland, marine beaches, sediments, and surfaces scoured by marine erosion are found at several locations along the shorelines of Notre Dame Bay and Hamilton Sound. Along the Bay of Exploits, the oldest and highest delta and terraces are located in the Brown's Arm area, at 65-68 m asl, and are estimated to have formed about 13,000 years ago (Mackenzie and Catto, 1993a, 1993b). A slightly younger high-level marine beach is represented by the flat-topped delta exposed at Laurenceton at 58 m asl. Raised marine features with similar elevations are found at Carmanville and along Gander Bay (Munro and Catto, 1993a, 1993b; Munro-Stasiuk and Catto, 1999). Further west, marine features are present at 75 m asl at Springdale (Scott *et al.,* 1991; Scott, 1996), 75-80 m asl in southern White Bay (McCuaig, 2003), and more than 100 m asl near Roddickton. Along the west coast, the maximum level of marine inundation declines from 150 m asl at Burnt Cape, along the Strait of Belle Isle (Grant, 1989, 1992), to 140 m at Watts Point, 135 m at St. Barbe (Grant, 1989), 110-120 m between Port-au-Choix and The Arches (*see* Bell *et al*., 2005), 100 m above sea level at Cow Head (Brookes and Stevens, 1985; Grant, 1989), 75 m asl at Bonne Bay (Proudfoot *et al.,* 1988; Grant, 1989), 50 m asl at Deer Lake and Corner Brook (Batterson, 1998; Batterson and Catto, 2001, 2003), and 27 m asl in St. Georges Bay (Bell *et al.,* 2001, 2003a). At Cape Ray, an eroded rock platform indicates that maximum postglacial sea level was less than 10 m asl (Grant, 1991).

Subsequently, Newfoundland began to recover from the glacio-isostatic depression. The resulting glacio-isostatic rebound elevated the land, causing the relative sea level to regress, even as ongoing glacial melting continued to add more water to the ocean. In the Lake Melville area, glacio-isostatic regression is still occurring, resulting in progressively declining relative sea level.

In Newfoundland, the decline in relative sea level in the remainder of the province continued until the coastal areas had rebounded in excess of their original pre-glacial elevation, resulting in glacio-isostatic overcompensation. This resulted in relative sea levels lower than the present positions around western, southwestern, southern, and eastern Newfoundland (Shaw and Forbes, 1995), in accordance with the "Type B" model of sea level change proposed by Quinlan and Beaumont (1981, 1982) and modified by Liverman (1994). Approximately 7,000 years ago, relative sea level along the Straight Shore of northeastern Newfoundland (Deadman's Bay – Cape Freels) was approximately 10 m below its present position (Shaw and Forbes, 1990). Offshore of Eastport and Port Blandford, relative sea level was 17 m below its present position 8,600 years ago, as indicated by the discovery of submerged terrestrial sediments offshore (Shaw and Forbes, 1990, 1995; Cumming *et al*., 1992; Liverman, 1994).

In Trinity Bay and Conception Bay, sea level fell to between 10 m and 25 m below present during the early Holocene (Grant, 1989; Shaw and Forbes, 1990, 1995; Liverman, 1994; Shaw *et al.,* 1994). Submerged deltas and wave-cut terraces in Placentia Bay indicate lower sea levels offshore of Swift Current (-8 m asl), Paradise Sound (-13.9 m asl), Long Harbour (-18.9

m), and Argentia (-19.6 m). In addition, ^{14}C dated terrestrial peat deposits at exposed locations along the Cape Shore and St. Mary's Bay, that are subject to coastal erosion, high winds, and salt spray, and where trees are currently unable to grow, indicate that sea levels were at or below the present level throughout the mid-Holocene (Catto 1993b, 1994b).

Along the South Coast and Burin Peninsula, the postglacial lowstand varies from -12.4 m asl at Long Harbour (Fortune Bay), -15 m to -16 m asl at the Head of Bay d'Espoir, to -17.8 m in North Bay and East Bay (Bay d'Espoir), -19.5 m asl at Marystown Harbour, and -19.4 m asl at Facheux Bay (Shaw and Forbes, 1995). Similar lowstands have been recorded at Port-au-Choix (ca. 3 m below present 3,000 years ago, c.f. Bell *et al.,* 2005; Smith *et al.,* 2005), Trout River (ca. 10 m below present 5000 years ago, c.f. Proudfoot *et al.,* 1988; Grant, 1989), Stephenville and St. Georges Bay (Brookes et al., 1985; Bell et al., 2003a), and Burgeo (Rast, 1999).

Between 3,000 and 8,000 years ago, depending on location, the land then began to subside from the over-compensated positions, resulting in renewed sea-level rise. Evidence of transgression due to relative sea level rise is reflected by enhanced erosion along many Newfoundland beaches, and inundation of terrestrial peat deposits and trees. Relative sea level change across Newfoundland over the past 2,000 years has been discussed recently by Carrera and Vanicek (1988), Forbes and Liverman (1996), Forbes *et al*. (1998), Liverman (1998), Shaw *et al*. (1998, 2001), Hilmi *et al* (2002), and Vasseur and Catto (2008). Shaw *et al*. (2002), Liverman *et al*. (2004) and Daly *et al*. (2007) discussed sea level changes across several regions of Newfoundland.

In northern Newfoundland, relative rising sea level is evident on the Great Northern Peninsula at L'Anse-Aux-Meadows (Catto, 2006b; Vasseur and Catto, 2008); Port-aux-Choix (Bell *et al*., 2005; Smith *et al*., 2005); and along the Gulf of St. Lawrence coastline (Proudfoot *et al*, 1988; Grant, 1989; Liverman *et al*, 2004; Catto, 2006b; Daly *et al*, 2007). Sea level at these localities is currently rising slowly, approximately 1 mm/a. Sea level rise of 3.3 mm/a over the past 50 years has been documented at Port-aux-Basques (Catto et al., 2006), and the sandy, gently sloping coastlines at Grand Bay West and JT Cheeseman Provincial Park are vulnerable to marine transgression and erosion (Shaw *et al.,* 1998; Catto, 2002a, 2002c, 2006). In southwestern Newfoundland, coastal dune development and associated sandy beach evolution is related to destabilization of littoral areas initiated by marine transgression (Catto, 1994b; Catto, 2002a). Rising relative sea level is also evident at Burgeo (Rast, 1999; Ingram, 2004; Ingram and Catto, 2005; Catto et al., 2006). Additional recent research on sea level changes in southwestern Newfoundland has been conducted by Batterson (1998, 2001), Bell *et al*. (2001, 2003), Catto (2006b, 2006d), and Catto *et al*., (2006).

In eastern and northeastern Newfoundland, regional and local studies include the work of Catto (1999, 2006a 2008b), Catto *et al*. (2000, 2002a, 2002b, 2003, 2006b), Jones (1995), Paone (2003), Paone *et al*. (2003), Shaw *et al*. (1998, 2001), and Smith *et al*. (2004a). New ^{14}C dates obtained from Lumsden indicate that inundation of terrestrial vegetation is ongoing (Philbrick, in preparation). Along the Avalon Peninsula, rising relative sea level since the mid-Holocene resulted in the inundation of terrestrial peat deposits and tree stumps at several locations (Catto and Thistle, 1993; CANQUA, 1995; Jones, 1995; Catto *et al.*, 2000; Catto, 2001, 2006b). At present, the rate of sea level rise, based on tide gauge data (St. John's), ^{14}C dates from several Avalon Peninsula locations, and archaeological data (Ferryland and Placentia), is estimated at 3 mm/a (Catto *et al.,* 2003; Catto, 2006b). Along the Bonavista Peninsula, relative sea level is rising at an approximate rate of 2 mm/a (Catto *et al.,* 2003). In northeastern Newfoundland, the estimated rates of sea level rise (*c.f.* Scott, 1991; Mackenzie and Catto, 1993a, 1993b; Munro and Catto, 1993a, 1993b; Liverman, 1994, 1998; Munro, 1994; Shaw and Forbes, 1995; Munro-Stasiuk and Catto, 1999; Scott *et al.,* 1991; Catto *et al.,* 2000; McCuaig, 2003; Catto, 2006) vary from 1-2 mm/a, with the rate decreasing from southeast (Bonavista) to northwest (White Bay). Currently, the rate of rise along Pistolet Bay and at L'Anse-aux-Meadows appears to be on the order of 1 mm/a.

Future changes in sea level will be determined by combinations of ongoing glacioisostatic adjustment, as discussed above, and increases in volume of the oceans due to glacial melting (e.g. James et al., 2010). Thermal expansion, the increase in the volume occupied by water molecules without an increase in mass, due to temperature alone, will also increase sea level. The amount of melting and the consequent rise in sea level attributed to climate change alone, as estimated from GCMs (climate models; e.g. http://www.cics.uvic.ca/scenarios), varies widely. The Intergovernmental Panel on Climate Change (IPCC, 2007) presented a range of projections varying from 0.18 to 0.59 m globally averaged sea-level rise at the end of the 21st century (mean for 2090-2099 relative to mean for 1980-1999), with a median value of 40 cm. This estimated rise of 4 mm/a is greater than the currently observed rates of relative sea level rise of 3.0-3.5 mm/a observed for locations in southern Newfoundland (Catto et al., 2006; Catto, 2006). There is substantial evidence that accelerated melting of ice sheets, ice caps and mountain glaciers will occur (Alley et al., 2005, 2008; Velicogna and Wahr, 2006; Rignot et al., 2008; Dahl-Jensen et al., 2009; Pritchard et al., 2009; Radić and Hock, 2011). Several papers published since the release of the IPCC (2007) report project considerably higher rates of global mean sea-level rise (Rahmstorf, 2007; Horton et al., 2008; Pfeffer et al., 2008; Grinsted et al., 2009; Vermeer and Rahmstorf, 2009), up to 1.90 m by 2100. These values, however, are global averages, and do not predict what could happen in individual areas of Newfoundland and Labrador. They are also values for change in global absolute sea level, not relative sea level at any particular locality. The observed relative sea level rise, and the projected rise for the future, depends upon the interaction between the changing volume of the oceans and glacio-isostatic activity.

As a factor in coastal erosion, the trend of relative sea level change was assessed on a scale of 1 to 5 as:

1: falling at more than 5 mm/a (no examples in Newfoundland & Labrador)

2: falling between 2 and 5 mm/a (no examples in Newfoundland & Labrador)

3: changing between -1.9 mm/a and +1.0 mm/a (northern part of Northern Peninsula, and Labrador)

3.5: rising between +1.1 and +2.0 mm/a (northeast Newfoundland, and southern part of Northern Peninsula)

4: rising between 2.1 and 4.0 mm/a (southern Newfoundland); and

5: rising in excess of 4.0 mm/a (no examples in Newfoundland & Labrador)

The scale differs from that used by Shaw et al. (1998) and Catto et al. (2003) in subdividing rates of sea level change between -1.9 mm/a and +2.0 mm/a (considered as a single category with an assessed value of 3 in previous works) into two categories. This was considered necessary because the former combined category overlapped substantially different areas of relative sea level change, extending from Cape Bonavista to Cape Bauld, and Labrador. The change does not affect the calculation of CSI for all of the sites investigated by Catto et al. (2003), as all of those areas have rates of relative sea level rise estimated at between 2.1 and 4.0 mm/a.

4.3 Relief

Relief is a critical variable, with shorelines showing high relief above sea level being relatively insensitive to erosion resulting from changes in sea level or storm wave activity. Shorelines with relief less than the mean annual maximum significant wave height are clearly liable to periodic inundation and erosion in consequence. Offshore of eastern and northeastern Newfoundland, the mean annual significant wave height is estimated at 7 m-8 m (Neu, 1982; see also Lewis and Moran, 1984; TDC, 1991), with the 10-year and 100-year values estimated at 11 m and 15 m respectively. In addition, estimates of significant wave heights based on models tend to under-predict extreme storm wave heights (Bacon and Carter, 1991; Cardone and Swail, 1995; Cardone *et al.,* 1995). These data suggest that shorelines with relief of less than 11 m along the eastern and northeastern coasts are likely to be periodically inundated by storm waves, suffering erosion in consequence. Estimates of mean annual significant wave heights are considerably lower in the Gulf of St. Lawrence (TDC, 1991), requiring appropriate adjustment of the relief risk variable of the CSI.

Historical storm surge disasters in Newfoundland include the 'Great Independence Hurricane' of 12-16 September 1775, which killed a large but undetermined number of fish harvesters and people in Avalon and Burin coastal communities and St-Pierre-et-Miquelon (possibly as many as 4,000; *see* Stevens and Staveley, 1991; Ruffman 1995, 1996; Stevens, 1995), and the destruction of La Manche and damage to other Southern Shore communities in 1966 (Catto *et al*, 2003; Catto, 2006a, 2008b). If the extreme offshore wave heights in excess of 30 m recorded during some storms (Swail, 1996), the heights of storm-driven and rogue waves noted at Newfoundland localities since 1990 (e.g. Forbes et al., 1998, 2000; Catto, 1999, in press; Catto et al., 2003; Smith *et al.*, 2004a, 2004b; Wright, 2004; Hickman, 2006; Catto and Tomblin, 2009a, 2009b, in press; Cameron Consulting *et al*., 2009), and those associated with tsunami activity (Ruffman, 1991, 1993, 1995; Anderson *et al.*, 1995; Liverman *et al.,* 2001; McCuaig and Bell, 2005; Hickman, 2006; Brake, 2008) are considered, 11 m may be a conservative figure for relief not exposed to risk of erosion.

A shoreline with laterally variable relief, frequently reflective of the offshore bathymetry, tends to funnel waves into low-lying areas between the cliffs. This is evident during storms at locations around Newfoundland, including Middle Cove (Northeast Avalon), Ship Cove (Placentia Bay), Mobile (Southern Shore), Bristols Hope (Conception Bay), The Beaches (White

Bay), Plate Cove (Bonavista Bay), Sandy Cove (Eastport Peninsula), and many others. Funneling of tsunami waves into low-lying areas has been documented elsewhere (e.g. Tinti, 1993; Bondevik *et al.*, 1998; Dawson, 1999), as well as on the Burin Peninsula during the 1929 event (Ruffman, 1995). An overall 'high relief' shoreline may actually increase the sensitivity of intervening coves and embayments to coastal erosion during storm, tsunami, and rogue wave events, as is apparent at The Beaches and Middle Cove. Assessment of the influence of relief must therefore include allowance for lateral variability, inducing energy focusing.

The ranking of sensitivity for relief is depicted in Table 4.1. Relief is considered over an area within 100 m of the point assessed. Shorelines with relief less than the mean annual significant wave height offshore are considered to have a very high risk relief factor. Shorelines with relief less than the mean 10-year significant wave height are considered to have a high risk relief factor. Along shorelines with variable relief, an additional risk factor has been assigned to locations where concentration of wave energy due to offshore bathymetric conditions is anticipated, or has been observed during previous events. Many sites along embayed coastlines are affected in this manner.

Table 4.1 Risk relief variable

Category	*E, NE, S Newfoundland*	*Western Newfoundland*
1: (Very low)	Relief in excess of 30 m	Relief in excess of 30 m
2: (Low)	Relief 21 - 30 m	Relief 15 - 30 m
3: (Moderate)	Relief 15 - 20 m; Relief 11 - 15 m on non-embayed shorelines	Relief 11-15 m
4: (High)	Relief 11 - 15 m on embayed shorelines exposed to prevailing storm direction; Shorelines with Relief 7-11 m	Shorelines with relief 4-11 m
5: (Very High)	Relief < 7 m	Relief < 4 m

4.4 Mean annual Maximum Significant Wave Height

The criteria for the mean annual maximum significant wave height variable follow those of Shaw et al. (1998) and Catto et al. (2003). Based on a scale of 1 to 5:

1: 0 – 2.9 m

2: 3.0 - 4.9 m

3: 5.0 – 5.9 m

4: 6.0 – 6.9 m

5: > 6.9 m

4.5 Rock or Sediment type

The rock or sediment type is also critical in determining the sensitivity to coastal erosion. Rock and sediment-dominated coastlines are assessed separately. Coastlines with both rock and sediment are assessed based on the more dominant type.

For exposed bedrock along the Newfoundland shoreline, the dominant process responsible for weathering is frost action. The susceptibility to erosion depends in large measure on the cliff aspect; on the orientation and number of jointing, fracture, bedding, and other planes of weakness; and on the crystal size (metamorphic and igneous) or clast size (sedimentary), as water can percolate and freeze along clast or crystal margins. Frost action is effective in the Newfoundland coastal environment because the rocks are virtually always saturated during the winter months, which effectively forces freezing in laterally confined areas. The effectiveness of salt hydration pressure (Yatsu, 1988; Goudie, 1989) is uncertain in Newfoundland, as no detailed research has been conducted. Thus, with the exception of limestone and gypsum outcrops, which are also subject to coastal karst activity, the prevalence and effectiveness of frost action is an effective measure of the susceptibility of bedrock to coastal erosion.

Cliffs with southerly aspects (on the north side of embayments) receive less snow and freezing rain, and are less subject to frost action than north-facing slopes. This is one reason why many communities along Conception Bay, such as Bay Roberts, Harbour Grace, and Carbonear, developed on the north sides of the embayments (Catto, 1999). Southwesterly facing cliffs are also more subject to frost wedging than are those facing northward.

Jointing, fracture, and bedding plane orientation and density, and crystal and clast sizes, vary greatly within individual lithological units throughout Newfoundland. Thus, the susceptibility of any particular cliff to erosion must be determined through on-site investigation (e.g. White, 2002; Thompson, in preparation). Lithology, however, exerts a substantial control on weathering and consequent erosion. Due to the relatively cold climate, physical weathering completely dominates over chemical weathering for all rock types except carbonates (limestone, dolostone) and gypsum.

Weathering of carbonates involves chemical dissolution in addition to physical weathering, forming karst features. Dissolution results from running or standing water on the carbonate surface. The rate of dissolution is dependent upon the amount and velocity of water flow, the concentration of acids and carbon dioxide, and the temperature of the water (White, 1988; Ford and Williams, 1989). Unlike most other substances, carbonates dissolve more readily in cold water than in warm water. However, dissolution rates for karst activity in Newfoundland are low, ca. 40 mm/1000 a (Catto, 2006). Physical weathering dominates over chemical weathering in most carbonate outcrops in Newfoundland.

Gypsum also is subject to chemical dissolution. In the Woodville area of the Codroy valley, gypsum dissolution and karst formation have been examined, including the impact of climate factors (Batterson and Liverman, 1995; House and Catto, 2004, 2008; GeoScott *et al.,* 2004; Catto, 2006a). Accelerated rates of dissolution occur where the gypsum beds are confined laterally by other rock units that are not susceptible to dissolution, where dissolution is concentrated locally by wave action on coastal cliffs, and where dissolution occurs beneath the surface. In coastal outcrops, both physical and chemical processes contribute to the rapid weathering of this friable rock.

The most resistant cliffs to erosion are those composed of unjointed, unfractured, metamorphosed quartzite. Finely crystalline granitic rocks, quartz sandstones, and orthogneisses are also resistant to erosion. Moderately resistant rock types under the climates of Newfoundland include unstratified rhyolite, finely crystalline diabase dykes, fine to medium-grained arkosic sandstone, paragneiss, fine to medium crystalline gabbro, and basalt. Igneous rocks with internal stratification, such as flow-banded rhyolites and trachytes, sheeted diabase (with porphyritic zones), and ignimbrite assemblages are less resistant to erosion, but generally form cliffs where planes of weakness are approximately vertically oriented. Rocks with coarse crystals, such as coarse granite and porphyries; those with diagenetically created weaker and more resistant zones, such as dolomitized and cherty limestones; and sandstones and conglomerates with coarse clasts, are more subject to erosion. However, if these rocks are unjointed and unfractured, and if they are oriented vertically or with steep dips, they can locally resist erosion. Limestones in coastal environments are generally susceptible to erosion.

In Newfoundland, the rock units which are least resistant to erosion include argillite (particularly prone to extensive fracturing), slate, shale, pelite, phyllite, weakly consolidated sedimentary rocks, and peridotite (ophiolite). Gypsum is the least resistant rock type.

The factors used to determine the sensitivity variable for bedrock-dominated coastlines are depicted in Table 4.2. The factors were considered in two groups: those related to susceptibility to frost action (jointing, frost activity, and aspect), and lithology. Shorelines with a combination of factors from both categories indicating increased sensitivity were assigned high and very high rankings (4 and 5), whereas those with low sensitivity factors in both categories were assigned very low or low rankings (1 and 2). Intermediate cases were assessed by considering the factors in combination, and fractional ratings were possible. For example, a fine granite (2), which had few joints (2), faced the prevailing wind (5), and was subject to moderate frost activity (4) was assessed a combined sensitivity of 3. The overall ranking for any segment of bedrock shoreline thus depends on the combination of the parameters.

Table 4.2. Lithological and Related Factors Influencing Coastal Sensitivity to Erosion

	Sensitivity				
Factors	1	2	3	4	5
Jointing	none	Gradational to			pervasive
Frost Activity	none	Gradational to			prominent
Aspect	Away from prevalent wind/spray direction	Gradational to			Directly facing prevalent wind/spray direction
Lithology	quartzite	Fine granite Quartz sandstone Orthogneiss Fine gabbro	Diabase Unstratified rhyolite Arkosic sandstone Paragneiss Basalt Ignimbrite (3.5) Medium gabbro Coarse granite Feldsp. Sandstone Conglomerate Dolostone Cherty Limestone (3.5)	Trachyte Argillite Slate Shale Pelite Limestone Weak Sed. Rks. Peridotite	Gypsum

Unconsolidated sediments are more susceptible to coastal erosion than is bedrock. Along the Newfoundland shorelines, these deposits include glacial, glaciofluvial, glaciomarine, aeolian, fluvial, colluvial, and organic sediments, in addition to active marine sediments and anthropogenic infills and infrastructure. Susceptibility of these sediments to erosion is a function of aspect with respect to wave activity and frost wedging, sediment texture, compaction and cementation, slope angle, and vegetation cover. Well-sorted sands (particularly aeolian deposits, including cliff-top loess, and sand lenses in glaciofluvial and glaciomarine units) are most vulnerable to erosion in the coastal zone, and organic deposits also fail readily. Fine gravel units within glaciofluvial and glaciomarine sequences are more likely to be eroded than are coarse gravel units. In local areas, groundwater activity has resulted in the formation of resistant or cemented horizons containing iron and manganese oxides (e.g. Peter's River, Avalon Peninsula; Victoria, Gander Bay), which act to hinder erosion. Bluff faces with slopes in excess of the critical angle of repose are liable to failure.

The presence of vegetation has long been known to stabilize slopes, although these effects have seldom been rigorously quantified (Wu *et al.*, 1979; Riestenberg and Sovonick-Dunford, 1983). In Newfoundland, areas with dense boreal forest vegetation are less susceptible to erosion than areas lacking any vegetation cover. However, the presence of tuckamore (krummholz) white spruce at cliff-top sites may actually accentuate erosion under conditions of rising sea level. Block failure of unconsolidated sediment bluffs, and of badly jointed bedrock, is accelerated where tuckamore killed by salt spray is present. The tuckamore roots act to wedge the substrate apart, reducing cohesion and promoting frost wedging, and the dead tree acts as a top-heavy obstruction to onshore winds. Sites with dead tuckamore cover erode more rapidly than sites covered with grass, *Empetrum* headland herb assemblages (Damman, 1983; Thannheiser, 1984), or boreal forests with upright trees. A similar effect is evident where a bluff-top fringe of coastal trees is subject to erosional pressure, as at Topsail United Church (Liverman *et al.* 1994a, 1994 b).

The combined effects of sediment type and vegetation cover on sensitivity are summarized in Table 4.3. Shorelines with a combination of factors indicating increased sensitivity are assigned high and very high rankings (4 and 5), whereas those with a series of low sensitivity factors are assigned very low or low rankings (1 and 2). The overall ranking for any segment of shoreline thus depends on the combination of several parameters.

Table 4.3 Sediment type and Vegetation Factors Influencing Coastal Sensitivity to Erosion

<table>
<tr><td></td><td colspan="5">Sensitivity</td></tr>
<tr><td>Factors</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Aspect</td><td>Away from prevalent wind/spray direction</td><td colspan="3">Gradational to</td><td>Directly facing prevalent wind/spray direction</td></tr>
<tr><td rowspan="2">Sediment type</td><td rowspan="2">(no examples)</td><td rowspan="2">Extensive lithified/cemented horizons</td><td>Gravel
Coarse Sand
(3.5)
Consolidated silt and clay</td><td>Peat
Medium Sand
Water-saturated silt</td><td rowspan="2">Fine sand</td></tr>
<tr><td colspan="2">Diamicton</td></tr>
<tr><td>Vegetation</td><td>forest</td><td>Grass-herbs</td><td>tuckamore</td><td>peat</td><td>No vegetation</td></tr>
</table>

4.6 Landform type

The ranking of sensitivity indices for landform types is illustrated in Table 4.4. Additional subdivisions have been established to the categories recognized by Shaw et al. (1998) to link the landform classification outlined in this report to the sensitivity criteria. Sensitivity thus varies inversely with slope normal to the shoreline. Texture also influences sensitivity, with gravel beaches being least sensitive, fine sand dominated shorelines most sensitive (due to the ability of water to readily entrain sand), and salt marshes also showing high sensitivity. Ice-bonded sediment, as occurs along periglacial shorelines, refers to permafrost terrain and is not present in Newfoundland.

Table 4.4 Ranking of sensitivity indices for landform types

Very Low (1): High Rock Cliff (Shoreline Class 3)

Low (2): Low to Moderate Rock Cliffs (Shoreline Class 3)

Low-Moderate (2.5): Rock Platforms (Shoreline Classes 1 and 2)

Moderate (3): Gravel over Rock Platform (Shoreline Classes 4 and 5)
High Energy Gravel Pocket Beach (Shoreline Class 6)
Mixed Sand and Gravel over Rock Platform (Shoreline Classes 7 and 8)
Wide Gravel Flat (Shoreline Class 13)
Bouldery Tidal Flat (Shoreline Class 24)
Bouldery Wave-washed Rögens (Shoreline Class 25)

Moderate-High (3.5): Moderate Energy Gravel Pocket Beach (Shoreline Class 6)
Mixed Sand and Gravel Pocket Beach (Shoreline Class 9)
Sand over Rock Platform (Shoreline Classes 10 and 11)
Narrow Gravel Flat (Shoreline Class 14)
High Energy Steep Gravel Beaches not associated with lagoons (Class 15)
Mixed Sand and Gravel Flats (Shoreline Classes 16 and 17)

High (4): Sand beaches at Base of Rock Cliffs (Shoreline Class 12)
High Energy Steep Gravel Beaches associated with lagoons (Class 15)
Low and Moderate Energy Steep Gravel Beaches (Shoreline Class 15)
Steep Sand and Gravel Beaches (Shoreline Class 18)
Mudflat (Shoreline Class 22)
All gravel spits and tombolos

Very High (4.5): Sand Beaches and Flats (Shoreline Classes 19, 20, 21)
Estuarine and Fringing Lagoonal (Shoreline Class 23)
Salt Marshes (Shoreline Class 26)
Exposed gypsum cliffs (Shoreline Class 27)

Extremely High (5): Ice-bonded sediment, ice-rich sediment, ice shelf, tidewater glacier;
no examples in Newfoundland

4.7 Shoreline Displacement

The recession rates of individual cliff faces can be measured by repetitive surveying of the escarpment using fixed reference points. This technique has been used by the Newfoundland and Labrador Department of Mines and Energy (Liverman *et al.* 1994a, 1994b; Batterson *et al.* 1999) to monitor recession rates of cliffs and changes in beach front positions at Point Verde, Placentia, Big Barasway, and Ship Cove, Placentia Bay; Topsail, Chamberlains, and Long Pond, Conception Bay; Holyrood Pond Barrier-St. Stephen's, St. Mary's Bay; Biscay Bay; and Portugal Cove South. The most susceptible cliff faces, at Topsail, Point Verde, and Holyrood Pond-St. Stephen's, are composed of glaciofluvial gravel with lesser sand lenses (Catto 1992, 1994a; Catto and Thistle 1993; Nichols 1995; Catto and St. Croix 1997), and are subjected to attack during the strongest storms.

The strength of specific storm events, and the angle of attack of the waves produced, together control the amount of erosion. Although a long-term erosion rate is a useful guide to the establishment of set-back limits (e.g. Taylor, 1994), and indicates where specific structures are in danger, it does not fully indicate the true hazard potential at a particular site. As the majority of the erosion is accomplished by individual storms, hazard assessment requires consideration of the probability of the maximum impact of a particular storm, rather than involving monitoring and dealing with incremental, infinitesimal removal of sediment on a daily basis. As an example, the presence of the lighthouse at Point Verde, Placentia Bay, and the periodic necessity for repairs resulting from undercutting of the cliff, has enabled long-term assessment of erosion rates. Henderson (1972) reported that the lighthouse keeper at Point Verde estimated that approximately 16 m of recession had occurred in 30 years, and suggested that in the late 1950s the recession rate was approximately 60 cm/a. Similar values were suggested for more recent erosion rates by Liverman *et al.* (1994a, 1994b), and by subsequent measurements). Although the Point Verde site has the longest (semi-quantitative) record of cliff erosion assessment in Newfoundland, this record does not extend to include potentially major events such as the hurricane of 1775 (Stevens and Staveley 1991; Stevens 1995; Ruffman 1995b, 1996) or the tsunami of 1929 (Ruffman 1995a, 1995b). These events, or future occurrences of similar magnitude, have the potential to cause much more erosion. The hurricane of 1775 caused coastal erosion and damage to structures in localities such as Northern Bay Sands that are not generally subject to high energy events. The same is true of the 1929 tsunami in localities such as Taylor's Bay and Lansey Back Cove. The monitoring record at other sites does not extend back beyond the initial observations of Forbes (1984). The absence of long-term monitoring means that present erosional rates may not serve to indicate the magnitude of previous (or future) erosional events.

Most shorelines in Newfoundland have not been measured in sufficient detail to establish precise long-term erosional rates. Shorelines subject to very severe erosion (more than 1 m/a of coastal retreat) or severe erosion (0.6-1.0 m/a retreat), and those where beach accretion is occurring, can be recognized through study of sequential aerial photographs spaced over several years. Shorelines which did not display photographic evidence of retreat, or which had not been visited in the course of this study, were arbitrarily considered as stable (2) in this study. Shorelines in many communities visited showed signs of erosion: where this could not be further quantified through aerial photograph study or other evidence, a small amount of erosion (less than 0.5 m/a) was assumed (3). Unconsolidated coastal bluffs in eastern Newfoundland where erosion rates have been monitored, such as at Middle Cove and Conception Bay South, typically show retreat rates of 0.1-0.3 m/a (e.g. Catto, 2006). Consequently, slow erosion was assumed where only qualitative evidence for erosion was present.

The criteria for the mean shoreline displacement variable follow those of Shaw et al. (1998) and Catto et al. (2003). Based on a scale of 1 to 5:

1: shoreline accretion, >0.1 m/a

2: stable

3: shoreline erosion, 0.1-0.5 m/a

4: severe shoreline erosion, 0.6-1.0 m/a

5: very severe shoreline erosion, >1.0 m/a

4.8 Tidal Range

Tidal ranges in Newfoundland lie within the microtidal and very lowest mesotidal limits, and variations in tidal range are thus less significant than along shorelines such as those of Nova Scotia and Prince Edward Island. The criteria for the tidal range variable follow those of Shaw et al. (1998) and Catto et al. (2003). Based on a scale of 1 to 5:

1: very low microtidal, < 0.5 m mean tidal range

2: microtidal, 0.5 – 1.9 m mean tidal range

3: mesotidal, 2.0 – 4.0 m mean tidal range

4: macrotidal, 4.1-6.0 m mean tidal range (no examples in Newfoundland)

5: extreme macrotidal, > 6.0 m mean tidal range (no examples in Newfoundland)

4.9 Anthropogenic Modification

Anthropogenic modification represents an additional complication. Building of roads across barrier beaches is particularly likely to promote coastal erosion, especially under the influence of rising sea level. Anthropogenic activities such as removal of beach sediment; construction of cliff-top buildings; construction of groynes, moles, piers, and sea walls which act to redirect or focus wave energy; and dredging, which also can focus wave energy, have affected the sensitivity of many localities to coastal erosion. Efforts to prevent erosion through the emplacement of riprap or the construction of coastal barriers are evident throughout Newfoundland. Similar effects have been achieved inadvertently in some locations, as with the construction of the railway embankment between Holyrood and Kelligrews, and the elevation of coastal roads on embankments.

Other anthropogenic activities have a more subtle effect. Compaction of beach sediment due to ATV pressure results in a surface that presents less frictional resistance to incoming waves, allowing them to extend further landward and resulting in enhanced erosion away from the mean high tide line (Anders and Leatherman, 1987). This effect was apparent at Salmon Cove Sands following the northeast gale of October 1992, when the base of the aeolian dune complex was eroded (Catto 1994c). Similar effects are evident at Lance Cove (southwest of Branch), Frenchmans Cove (Fortune Bay), Boxey (South Coast), Grand Bay West (Southwest coast), Eastport, and Lumsden. ATV compaction effects on gravel beaches, although less readily apparent, have also been observed at Big Barasway (Placentia Bay), Holyrood Pond Barrier-Peters River (St. Mary's Bay), Biscay Bay, Mobile (Southern Shore), throughout Conception Bay South, and at Old Shop (Trinity Bay), among many other sites.

Anthropogenic activities which result in changes in the character of the shoreline, such as textural changes, reduction in shore width, changes in slope, changes in vegetation (particularly in dunal areas), and focusing of wave energy into specific positions, are partially accounted for in the parameters listed in Tables 4.2 and 4.3. The chief factor not accounted for is assessment of the long-term effects of recent modification of the shore, especially road and dwelling construction. Both practices increase the vulnerability of the shoreline to erosion, and the potential for economic and human loss.

4.10 Summary

The complete table of Coastal Sensitivity Index Rankings, as modified for the shoreline of Newfoundland, is illustrated as Table 4.5. Calculated CSI values for selected locations along the coastline of the island of Newfoundland are presented in Table 1.1.

Analysis at the local level will invariably produce higher scores than will a broader regional analysis. Locally sensitive areas, resulting from the occurrence of specific sediment types, will be highlighted. Separation of alternating zones of high and low relief (as along a deeply indented shoreline) will result in higher scores for the low relief zones than would be produced by averaging the relief across a broader area, such as an entire 1:50,000 scale map-sheet. Consequently, the numerical CSI scores for coastal locations throughout Newfoundland produced both by Catto *et al.* (2003) and this study are generally higher for sensitive areas than the more generalized scores of Shaw *et al.* (1998). The median CSI value for all Newfoundland coastal sites determined in this study is approximately 18.5 (mean 18.0), with values locally exceeding 45 (compared to a theoretical minimum of 0.38 and a theoretical maximum of 105.6).

Qualitative assessment of the CSI scores involves dividing the numerical values into 5 categories:

Very Low Sensitivity: CSI <4.9
Low Sensitivity: CSI 5.0-14.9
Moderate Sensitivity: CSI 15.0- 24.9
High Sensitivity: CSI 25.0-34.9
Extreme Sensitivity: CSI >35.0

Thus, sites with CSI values approximating the median of 18.5 for the island of Newfoundland are considered to have moderate sensitivity to coastal erosion resulting from sea level rise.

5. Petroleum Vulnerability Index (PVI)

5.1. Introduction

Petroleum and its products represent a significant pollution hazard to the shoreline of Newfoundland. The potential for accidental spillage due to difficulties with vessels, offshore wells, or pipelines has increased with the development of the offshore petroleum industry. In addition to offshore events, accidental discharge of petroleum and gasoline at the shoreline during refinery and tanker operations (Williams *et al.,* 1985, 1988), removal and disposal of waste from vessels in port (Olson, 1994), and leakages from strictly terrestrial sources, are also matters of concern. Petroleum products can thus arrive at Newfoundland shorelines from both offshore and onshore sources.

The vulnerability of beaches in Canada to oil pollution has long been a concern. Owens (1977) provides a thorough review of all the factors involved in assessment of the impact of crude petroleum and petroleum products of differing viscosities under differing temperature conditions on shorelines throughout Canada. Discussions of environmental sensitivity for Canadian coastal systems (e.g. Owens, 1977, 1993, 1994; Reinson, 1979; Woodword-Clyde Consultants, 1981; Owens and White, 1982; Owens *et al.,* 1982; McLaren, 1980; Environment Canada, 1988; Cameron *et al.,* 1990; Dickins *et al.,* 1990; Harper and Reimer, 1991; British Columbia Ministry of the Environment, 1993) have established that sand to fine gravel beaches and flats, with relatively gentle slopes, low to moderate prevailing energy conditions, and primarily dissipative regimes, are potentially vulnerable to long-term petroleum contamination.

A second issue involves the source of the petroleum contamination. Low energy areas such as tidal mudflats and salt marshes are less likely to be contaminated by offshore spills, as these areas are generally isolated from the prevailing pattern of current and wave motion. However, oil reaching such an environment as a result of a terrestrial-based or shoreline spill would be extremely difficult to remove. Estuarine and lagoonal areas are particularly susceptible to pollution from terrestrial sources.

Ranking of the vulnerability of the coastal environments of Newfoundland to petroleum pollution thus requires consideration of the geomorphology and sedimentology of the shoreline, the dynamics and energy, the biological assemblages, and the location with respect to potential offshore and onshore sources of contamination. Previous quantitative vulnerability assessments for selected beaches were provided by Catto et al. (2003), Etheridge (2005), Catto and Etheridge (2005), and McNeil (2009).

Assessment of vulnerability requires consideration of both sensitivity and exposure. *Sensitivity* is defined here as the potential degree to which a shoreline could be affected by a petroleum contamination event. Sensitivity involves consideration of the physical attributes of the shoreline.

Exposure is related to the probability that a particular hazard or phenomenon can occur; in this case, petroleum contamination. In this context, exposure refers to the conditions that could result in contamination.

Vulnerability is the degree to which a system is adversely affected by a hazard. Vulnerability is the combined product of exposure and sensitivity. A Canadian city may have a high degree of exposure to snow, but the sensitivity is low because people have developed well-practiced strategies to cope (adaptive capacity). If a heat wave struck, with temperatures rising to 40°C, that same city would be highly sensitive: people without prior experience (low previous exposure) to heat waves would have great difficulty coping, and would be vulnerable. Conversely, Las Vegas is not vulnerable to heat waves (they are common, and people have developed adaptive capacity) but would be very vulnerable to a snowstorm (very rare occurrence, but high sensitivity). The frequency of occurrence is not the only factor influencing vulnerability. If the effects of the hazard are too great, such as with a large tsunami, any community along the coastline may be vulnerable.

In this study, the sensitivity and exposure of shorelines to petroleum contamination were considered separately. The two results were then multiplied to generate a numerical assessment of the overall vulnerability of petroleum contamination. The results for selected shorelines around Newfoundland are presented in Table 1.1.

5.2 Petroleum Sensitivity parameters

Three parameters were considered in the assessment of sensitivity (Table 5.1). The Shoreline Class and sediment type has a major influence on sensitivity (e.g. Catto et al., 2003; Etheridge, 2005; McNeil, 2009). Values from 1 to 5 were assigned for each shoreline Class, with 1 representing the least sensitive shorelines and 5 the most.

Table 5.1 Petroleum Sensitivity Parameters

Petroleum Sensitivity Parameters	*Shoreline Class and sediment type* ***(S)***	*Energy Level* ***(E)***	*Energy Regime* ***(R)***
1: Very Low Sensitivity	1, 2, 3: bedrock	Very high	Highly Reflective
2: Low Sensitivity	3: weak rock cliffs 4, 5: gravel	High	Moderately Reflective
2.5: Low-Moderate Sensitivity	6, 13, 14: pebble gravel 15: gravel 18: mixed sand and gravel	Moderate-High	Slightly Reflective
3: Moderate Sensitivity	7,8, 9, 16, 17, 25: mixed sand and gravel 6, 13, 14: pebble-cobble gravel	Moderate	Transitional
3.5: Moderate-High Sensitivity	11,12: sand	Low-Moderate	Slightly Dissipative
4: High Sensitivity	10,19,20,21: med.-fine sand 22: mud 24: boulder tidal flat 27: gypsum cliffs	Low	Moderately Dissipative
5: Very High Sensitivity	23, 26: organics	Very Low	Highly Dissipative

Maximum Sensitivity Value = S *E* R = 125

Coastlines with higher energy levels generally are less sensitive to long-term petroleum contamination, because the oil is often remobilized by subsequent wave activity. This process, known as self-cleaning (see Etheridge, 2005; McNeil, 2009) is most effective on high energy, steeply sloped, reflective beaches, where much of the incident wave energy is reflected back to sea. Conversely, low energy beaches are less likely to effectively self-clean. Dissipative systems, where the wave energy is largely expended offshore, are also less likely to self-clean than are reflective systems.

Although most reflective systems in Newfoundland also have higher energy levels than do the dissipative systems, this relationship is not universally true. Consequently, two variables are considered in the calculation of the sensitivity value. The energy level, from high to low, and the energy regime, from highly reflective to highly dissipative, were each scaled from 1 to 5, with 5 representing the highest sensitivity (Table 5.1).

The product of the three variables, S *E* R, provides a numerical estimate of relative sensitivity to petroleum contamination. The maximum possible sensitivity value is 125; the minimum possible value is 1.

5.3 Petroleum Exposure parameters

Exposure to petroleum contamination was assessed considering that the most likely source was due to accidental or deliberate discharges from marine vessels at sea. Previous studies involving assessment of both marine debris sources and petroleum contamination (Catto et al., 2003; Pink, 2004; Etheridge, 2005; Etheridge and Catto, 2005; McNeil, 2009) have determined that marine vessel traffic is a dominant source of debris and petroleum arriving at eastern Newfoundland beaches, and that the prevailing current directions greatly limit the possibility of transport of debris or petroleum from permanent offshore installations. Consequently, the marine exposure factor was regarded as the most significant determinant of petroleum exposure on beach environments. The degree of marine exposure was assessed a value from 1 to 5 for each site (Table 5.2). The square of the marine exposure value was used in assessment of petroleum exposure.

Contamination from terrestrial sources is present in communities, particularly those where there is substantial vessel traffic. Contamination can also result from motor vehicle accidents, leakage of onshore tanks, and similar sources. Terrestrial exposure was assessed for each site on a scale of 1 to 2.5 (Table 5.2).

The nature of current movement influences how oil will be distributed subsequent to its initial arrival in the marine system. Shore-parallel transport will allow petroleum to spread laterally along the shoreline, whereas shore-normal conditions will confine the oil within an embayment. Current transport influence was assessed for each site on a scale of 1 to 2 (Table 5.2).

The product of the three variables, M^2*T*D, provides a numerical estimate of relative exposure to petroleum contamination. The maximum possible sensitivity value is 125; the minimum possible value is 1.

Table 5.2 Petroleum Exposure Parameters

Petroleum Exposure Parameters	*Marine Exposure* ***(M)***	*Terrestrial Exposure* ***(T)***	*Current Direction* ***(D)***
1	sheltered from the open ocean	none	Shore-normal
1.5	---	Adjacent to road	Shore-oblique
2	partially sheltered	In community	Shore-parallel
2.5	---	High Traffic area	---
3	open to the ocean, but not facing prevalent wind or effective storm direction	---	---
4	partially exposed to prevalent wind or effective storm direction	---	---
5	completely exposed to prevalent wind or effective storm direction	---	---

Maximum Exposure Value = $M^2*T*D = 125$

5.4. Petroleum Vulnerability Index (PVI)

The Petroleum Vulnerability Index was calculated by multiplying the sensitivity and exposure parameters, and then determining the square root, as:

$$PVI = \sqrt{\{(S * E * R)(M^2 * T * D)\}}$$

The maximum possible value for the PVI is $\sqrt{(125)*(125)} = 125$; the minimum possible value is 1. Calculated PVI values for selected locations along the coastline of the island of Newfoundland are presented in Table 1.1. The median PVI value for all Newfoundland coastal sites determined in this study is approximately 17 (mean 17.1), with values locally exceeding 35 (compared to a theoretical minimum of 1, and a theoretical maximum of 125).

Assessment of the PVI scores involves dividing the numerical values into 5 categories:

Very Low Sensitivity: PVI <15.0
Low Sensitivity: PVI 15.0-19.9
Moderate Sensitivity: PVI 20.0-29.9
High Sensitivity: PVI 30.0-34.9
Extreme Sensitivity: PVI >35.0

Thus, sites with PVI values approximating the median of 17 for the island of Newfoundland are considered to have low to moderate vulnerability to petroleum contamination.

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Table 4.5 Coastal Sensitivity Index for Newfoundland

Variable	*Very Low (1)*	*Low (2)*	*Moderate (3)*	*High (4)*	*Very High (5)*
Relief (m)	>30	21-30 (E, NE, S) 15-30 (W)	15 - 20 m (E, NE, S); 11 - 15 m (W; non-embayed shorelines E, NE, S)	11-15 m (embayed shorelines E, NE, S) 7-11 m (E, NE, S) 4-11 m (W)	<7 m (E, NE, S) <4 m (W)
Rock / Sediment Type and Related Factors	Not jointed; not aligned facing prevalent storm direction; Quartzite; forest cover	Scattered joints; Fine granite; Quartz sandstone; Orthogneiss; Coastal barrens	Moderate jointing; frost action evident; diabase; rhyolite; arkosic sandstone; paragneiss; basalt; feldspathic sandstone; dolomite; grass-herb cover	Pervasive Jointing; frost action evident; trachyte; argillite; slate; pelite; ignimbrite; gabbro; coarse granite; feldspathic conglomerate; limestone; tuckamore; peat	Facing prevalent storm direction; Gypsum; Fine Sand; no vegetation cover
Landform	Fjord, high rock cliffs, fjard (shoreline Class 3)	Moderate and Low Rock Cliffs (shoreline class 3); Rock Platforms (shoreline Cl. 1 & 2) assigned as 2.5	Shoreline classes 4,5, 6 (high energy), 7, 8, 13, 24, 25; Shoreline classes 6(mod. Energy), 9, 10, 11, 14, 16, 17, and 15 (high energy but without lagoon) assigned as 3.5	Shoreline Classes 12, 15 (with lagoon; or low to moderate energy), 18, 22; all gravel spits and tombolos Shoreline classes 19,20,21, 23, 26, 27 assigned as 4.5	none
Sea-level Change	Falling more than 5 mm/a	Falling between 2-5 mm/a	Change between 0 and 2 mm/a	Rising between 2.1 to 4 mm/a	Rising more than 4 mm/a
Shoreline Displacement (m/a)	>0.1 Accreting	0 Stable	-0.1 to –0.5 eroding	-0.6 to –1.0 eroding	Eroding more than 1.0 m/a
Tidal Range (m)	<0.50 microtidal or nontidal	0.5 to 1.9 microtidal	2.0 to 4.0 mesotidal	4.1 to 6.0 macrotidal	>6.0 strongly macrotidal
One year maximum wave height (m)	0 to 2.9	3.0 to 4.9	5.0 to 5.9	6.0 to 6.9	>6.9

area	location	material	class	CEI	CSI	PVI
White Bay-Baie Verte	Jacksons Arm	p,c	6	5.6	9.1	6.0
	Sops Arm	s, p, c	9	2.6	16.8	12.0
	Sops Arm park	s, p, c	18	5.2	25.1	16.4
	Giles Cove	s, p, c	9	4.2	16.8	8.5
	Burnt Head Cove	p,c	6	2.9	9.1	8.5
	Pollards Point	p,c	15	4.2	19.1	10.4
	Spear Cove	p,c	15	2.8	16.8	8.5
	Little Spear Cove	p,c	15	8.4	19.1	10.4
	Saltwater Cove	p,c	15	6.4	19.1	10.4
	Hampden R. mouth	s, p, c	18	3.2	22.5	24.0
	Hampden	s, p, c	17,18	11.3	26.9	24.0
	Galeville	p,c	15	12.6	30.2	12.0
	Georges Cove	c	6	9.1	26.9	12.0
	The Beaches	p, c	15	14.5	45.8	15.0
	Purbeck's Cove	s, p, c	15,18	12.0	20.5	15.6
	Westport	p,c	6,15	11.2	17.1	15.6
	Pound Cove	p,c	6,15	11.2	17.1	15.6
	Western Arm	s, p, c	9	3.5	10.3	12.0
	Bear Cove	s, p, c	15,18	4.5	10.6	15.6
	Back Cove	p,c	15	9.6	21.2	15.6
	Middle Arm	s, p, c	3,23	4.5	17.0	10.4
	Southern Arm	s, p, c	3,6,18	6.0	11.2	12.0
	Seal Cove	s, p, c	6,18	9.0	20.1	15.6
	Beach Cove	p, c	3,6	7.2	12.9	15.6
	Lobster Harbour	p, c	3,6	7.2	11.8	15.6
	Wild Cove	s	3,12,20	10.8	27.3	25.1
	Little Lobster Harbour	p, c	3,6	7.2	11.8	15.6
	Hard Bay	p, c	3,6	7.2	11.8	15.6
	Barrys Cove	p, c	3,6	6.4	15.2	15.6
	Bishie Cove	p, c	3,6	6.4	11.8	15.6
	Cook In Cove	p, c	3,6	6.4	11.8	15.6
	Fleur de Lys E	p, c	5	7.2	21.5	20.8

Fleur de Lys C	p, c	15	7.2	18.2	20.8
Fleur de Lys W	p, c	8	5.4	15.8	20.8
Fleur de Lys R. mouth	p, c	6	4.2	20.3	19.6
Caplin Cove	p, c	3,6	6.4	11.8	18.2
Coachman's Cove	p, c	5	9.6	21.0	18.2
Coachman's Cove C	p, c	15	7.2	29.7	18.2
Coachman's Cove S	s, p, c	8	11.3	32.2	24.0
Slaughter House Cove	s, p, c	5,6,8	9.6	28.9	24.0
Schooner Cove	s, p, c	8	4.5	12.9	24.0
Lower Sisters Cove	s, p, c	9	3.5	10.7	18.2
Upper Sisters Cove	r	3	2.0	8.6	7.3
Sandy Point Baie Verte	s, p, c	8	4.2	11.5	14.7
Baie Verte	s, p, c	18	3.8	17.1	20.0
Baie Verte S	s, p, c	8	3.0	14.2	20.0
Baie Verte R. mouth	s, p, c	23	3.4	12.9	21.9
Apsey Cove	s, p, c	3,9	3.5	10.7	12.7
Green Cove	s, p, c	3,9	4.0	11.4	12.7
Deer Cove	s, p, c	9	9.5	12.3	12.7
Devils Cove	s, p, c	9	14.0	12.2	12.7
Ming's Bight	s, p, c	3,18	12.0	24.2	24.0
Ming's Bight South Broo	p, c	3,6	6.3	12.9	25.5
Grand Cove	p, c	3,6	4.0	8.6	12.7
Hardy Harbour	p, c	3,6	3.5	10.5	12.7
Pacquet	s, p, c	9,18	9.0	12.1	18.0
Woodstock	s, p, c	9,18	6.0	12.1	18.0
Gooseberry Cove	s, p, c	3,9	14.0	16.1	18.0
Grand Cove	s, p, c	3,9	14.0	16.1	18.0
Harbour Round	s, p, c	3,9,18	12.0	22.6	22.0
Brent's Cove	s, p, c	18	12.0	24.3	22.0
Big Cove	p, c	3,6	9.6	16.1	18.0
Hill Graplin Cove	p, c	3,6	9.6	16.1	18.0
La Scie W	s, p, c	9	7.0	22.7	24.0
La Scie C	s, p, c	18	10.5	28.8	23.2

La Scie E	s, p, c	9,18	5.5	19.1	22.0
Reddits Cove	p, c	3,6	9.6	16.1	18.0
Cape St. John	r	3	2.5	6.1	5.0
Cape Cove	p, c	3,6	10.0	7.8	13.9
Manful Bight	p, c	3,6	8.5	7.8	13.9
Shoe Cove	s, p, c	3,9	7.9	15.4	18.0
Beaver Cove	p, c	3,6	7.6	14.9	18.0
Tilt Cove	p, c	3,6	7.6	14.9	18.0
Balsam Bud Cove	p, c	3,6	9.6	16.5	15.6
Round Harbour	p, c	3,6	9.6	18.2	15.6
Snooks Arm	p, c	3,6	8.8	17.3	15.6
Wild Bight	r	3	2.0	6.1	7.1
Indian Burying Ground C	p, c	3,6	7.6	14.9	15.6
Bobby Cove	p, c	3,6	7.6	14.9	15.6
Betts Cove	r	3	2.0	6.1	7.1
Betts Bight	r	3	2.5	7.2	7.1
Nipper's Harbour	p, c	6	7.2	14.9	15.6
Nipper's Hr Noble Cove	p, c	3,6	9.8	18.2	17.0
Rogues Harbour	p, c	3,6	7.2	14.9	15.6
Stocking Harbour	p, c	3,6	7.2	14.9	15.6
Smith's Hr.	p, c	3,6	7.2	14.9	15.6
Ricks' Cove	p, c	6	7.2	14.9	15.6
Winterhouse Cove	p, c	3,6	2.4	19.7	17.0
Burlington	p, c	6	3.6	19.7	18.0
Middle Arm	p, c	6	2.4	15.7	12.7
Rattling Brook N	p, c	6	3.6	13.9	12.7
Rattling Brook S	s, p, c	6,8	3.9	14.5	12.7
Corner Brook Cove	s, p, c	3,8	3.6	15.7	12.7
Kings Point N	s, p, c	8	2.9	15.7	24.0
Kings Point C	s, p, c	16	2.6	19.7	24.0
Kings Point S	s, p, c	9,16	2.6	15.7	20.8
Manful Point	p, c	6	3.6	15.7	17.0
Birchy Cove Head	r	3	1.8	12.8	7.0

Birchy Cove	p, c	3,6	2.7	22.3	22.0
Shilly Cove	r	3	3.2	17.2	7.0
Jacksons Cove	s, p, c	9,18	9.0	33.2	22.3
Eastern Point	r	3	2.7	16.8	7.0
Patricks Point beach	s, p, c	3,9,18	16.0	19.5	15.6
Langdons Point	s, p, c	9	14.0	16.8	20.8
Langdons Cove	s, p, c	9,18	16.0	19.5	17.0
Western Point	s, p, c	3,16,9	14.0	20.8	18.0
Nickey's Nose Cove	s, p, c	3,9	16.0	19.5	18.0
Salmon Cove	s, p, c	3,9,18	15.5	19.5	17.0
Harrys Harbour	s, p, c	3,9,18	12.0	19.7	17.0
Rushy Pond Cove	s, p, c	9,18	12.0	14.9	20.8
Silverdale	s, p, c	9	7.9	14.9	20.8
Welsh Cove	s, p, c	3,9	7.9	14.9	20.8
Middle Arm	s, p, c	3,9	6.8	10.5	8.5
Southern Arm	s, p, c	3,9	6.8	10.5	8.5
Wild Bight	s, p, c	18	12.0	14.9	20.8
Little Bay	s, p, c	18	11.0	13.3	19.0
St. Patricks	s, p, c	3,9	10.5	22.3	25.5
Little Bay Islands	s, p, c	9	5.0	8.9	24.0
Little Ward Harbour	s, p, c	3,9,15	10.5	13.3	18.0
Saltwater Pond	s, p, c	3,9	3.2	8.9	15.6
Springdale E	s, p, c	9	3.1	17.2	28.5
Springdale Island Rock C	s, p, c	9	2.9	16.9	25.5
Springdale Lw Wolf Cv	s, p, c	9,18	2.6	16.6	28.5
Indian Brook delta	s, p, c	16,18	1.4	8.3	15.6
Riverhead Br Halls Bay	s, p, c	16,18	2.6	12.2	15.6
Beachside	s, p, c	18	2.6	16.6	18.0
Wolfs Cove	s, p, c	9,18	2.6	13.6	18.0
Southbrook	s, p, c	16,18	2.6	14.4	20.8
Boot Harbour	p, c	3,6	7.2	14.4	20.8
Shoal Arm	p, c	3,6	4.8	12.2	10.4
Shoal Arm Point	s, p, c	8,18	2.6	13.6	10.4

Woodford's Arm	s, p, c	3,5,8,18	4.8	15.7	10.4
Nipper's Harbour	s, p, c	3,16	7.0	8.6	22.0
Stag Cove	s, p, c	9	6.0	9.2	22.0
Haywards Bight	s, p, c	3,9	7.0	8.6	22.0
Port Anson	s, p, c	6,9	7.0	8.6	22.0
Miles Cove	s, p, c	9	7.0	8.6	22.0
Burnt Point	r	3	2.0	4.3	5.0
Jerry Harbour	s, p, c	9,9	7.0	8.6	22.0
Shoal Point	r	3	3.0	5.4	5.0
Paddock's Bight	s, p, c	3,9	8.4	9.8	10.4
Island Point	s, p, c	9	7.0	8.6	10.4
Rowsell Cove	s, p, c	3,9	7.0	8.6	10.4
Wellman's Cove	p, c	3,6	6.4	8.6	10.4
China Head	r	3	2.0	4.3	5.0
Lobster Harbour	s, p, c	6,9	7.0	8.6	10.4
Charley's Cove	s, p, c	9	7.0	8.6	10.4
Morrey's Cove	s, p, c	3,9	8.5	10.3	15.6
Bear Cove	s, p, c	3,9	9.4	16.4	15.6
Roberts Arm	s, p, c	9,18	10.5	17.2	25.5
Hammer Cove	p, c	3,6	9.4	16.4	15.6
Measles Cove	p, c	3,6	9.4	16.4	15.6
Tilley Cove	p, c	3,6	9.4	16.4	15.6
Flat Rock Tickle Causew	p, c	3,6	10.5	17.2	20.0
Kelly Head	r	3	6.8	14.2	10.4
Pelleys Island	s, p, c	9	7.0	16.4	15.6
Bumblebee Cove	s, p, c	3,9	7.2	16.4	15.6
Pilley's Tickle Causeway	r	3	5.4	14.2	9.8
Head Harbour	p, c	6,3	8.8	18.2	15.6
Long Arm	s, p, c	3, 9	4.6	9.1	10.4
Shoal Cove	s, p, c	3, 9	4.3	8.4	10.4
Hynes Cove	s, p, c	3,9	6.2	9.8	10.4
Brighton Tickle	s, p, c	3,9	4.2	8.6	15.6
Brighton	s, p, c	9,18	7.0	24.2	20.8

Brighton N	s, p, c	3,9	6.2	12.5	18.0
Caplin Cove	r	3	2.0	4.6	4.0
Great Triton Harbour	s, p, c	6,18	8.0	14.5	18.0
Triton W	s, p, c	6,18	12.0	17.2	15.6
Little Triton Harbour	s, p, c	3,6,9	7.2	14.5	18.0
Shag Cliff Bight	r	3	2.5	8.5	7.3
Ragged Point	r	3	2.5	8.5	7.3
Grand Dismal Cove	r	3	2.0	7.4	7.3
Sisters Point	r	3	2.5	8.5	7.3
Harbour Round I	r	3	2.0	7.4	7.3
Jim's Head	r	3	2.5	6.1	5.7
Jim's Cove	s, p, c	9	3.0	8.5	7.3
Card's Hr.	s, p, c	6,9,18	4.8	25.2	20.8
Butlers Bight	s, p, c	9	3.6	8.5	7.3
Lushes' Bight	p, c	3, 6	3.6	8.5	7.3
North China Head	p, c	3, 6	3.6	6.1	14.9
Caplin Cove Long Island	p, c	3, 6	4.8	6.1	14.9
Beaumont North	p, c	3, 6	4.8	6.1	14.9
Ward's Harbour	p, c	3, 6	4.8	6.1	14.9
Chipman Hill	r	3	2.0	6.1	14.9
Indian Tickle	r	3	2.0	6.1	14.9
Quinton Cove	s, p, c	3,9	3.0	8.5	7.3
Burnt Head	p, c	2	7.5	8.5	7.3
Beaumont	s, p, c	3,9	7.0	10.5	10.4
Cutwell Arm	s, p, c	9	5.3	8.5	7.3
Burnt Harbour	s, p, c	3,9	7.0	10.5	10.4
Gull Cliff	r	3	2.5	9.3	7.3
Milkboy Cove	p, c	3,6	2.0	8.5	7.3
Tommys Arm	p, c	3,6	7.2	12.8	12.7
Sops Arm Badger Bay	p, c	3,6	7.2	12.8	14.7
Husseys Cove	p, c	3,6	6.4	11.4	12.7
Herring Cove	p, c	3,6	6.4	11.4	12.7
Kettle Cove	p, c	6,3	7.2	10.5	10.4

Burton's Harbour	p, c	3,6	7.2	10.5	10.4
Julies Harbour	p, c	3,6	5.4	10.5	12.7
Bird Island Cove	r	3	3.0	10.5	12.7
Shoal Arm Brook	s, p, c	3,6,18	5.4	8.2	12.7
Black Duck Cove	p, c	3,6	7.2	9.5	10.4
Gull Island Cove	s, p, c	3,9	8.6	10.5	10.4
Beaver Bight	p, c	3,6	7.2	9.5	10.4
Wild Bight	p, c	3,6	7.2	9.5	10.4
Green Point	r	3	3.0	6.2	7.3
Little Cove	s, p, c	3,18	5.4	9.5	10.4
Cannon Head	p, c	3,6	4.0	6.2	7.3
White Point	r	3	5.0	4.2	8.0
Seal Bay Head	r	3	5.0	4.2	8.0
Side Harbour	p, c	3,6	7.2	9.5	15.6
Indian Cove	p, c	6	7.2	9.5	15.6
Corner Point	p, c	3,6	7.2	9.5	15.6
Mill Cove	p, c	3,6	7.2	9.5	15.6
Seal Bay Brook delta	s, p, c	3,16	7.9	19.7	15.6
Big Cove	p, c	3,6	7.2	11.2	15.6
Lower Sparrow Cove	p, c	3,6	7.2	9.5	15.6
Sparrow Point	r	3	3.0	4.2	8.0
Birchy Cove	p, c	3,6	3.6	4.2	8.0
Locks Harbour	p, c	3,6	7.2	9.5	15.6
Thimble Head	r	3	3.0	5.3	7.3
Leading Tickles	p, c	6	14.0	21.1	16.0
Leading Tickles W	p, c	6	9.0	17.6	16.0
Leading Tickles E	p, c	6	4.8	14.5	16.0
Lady Cove	p, c	3,6	4.8	12.3	15.6
Wild Bight Point	r	3	2.0	11.7	10.4
Wild Bight	s, p, c	3,9	3.0	12.3	15.6
Lanning's Cove	r	3	2.0	11.7	10.4
Budgell Harbour	s, p, c	3,9	8.4	12.9	15.6
Mill Cove	s, p, c	3,9	10.5	13.4	15.6

Beson Cove	r	3	2.5	11.8	10.4
Little Northwest Arm	s, p, c	3,9	8.4	12.9	15.6
Beaver Brook Cove	s, p, c	9	7.9	17.5	15.6
West Arm Brook	s, p, c	9,18	3.5	24.9	20.8
Point Leamington	s, p, c	9	3.5	24.9	27.7
Tea Arm	s, p, c	9	7.9	11.7	15.6
Mouse Cove	s, p, c	9	8.6	12.9	14.9
Paradise Cove	s, p, c	9	7.9	17.5	15.6
Bulley's Cove	p, c	3,6	3.2	11.7	14.9
Bob's Cove	r	3	0.6	9.1	7.3
Saunders Cove	s, p, c	16,18	8.4	12.9	19.1
Ritters Arm	s, p, c	18	8.4	12.9	19.1
Indian Cove	s, p, c	9	4.8	12.9	19.1
Little Indian Cove	s, p, c	9	8.4	12.9	19.1
Bill's Point	r	3	2.0	11.7	7.3
Jim's Head	r	3	4.0	11.7	7.3
Sand Cove	s, p, c	9	12.0	21.8	27.0
Fox Cove	s, p, c	9	10.5	18.5	27.0
Southeast Arm Point	r	3	2.5	11.7	7.3
Southeast Arm	s, p, c	9	7.9	17.5	15.6
Cottrell's Cove	p, c	3,6	6.3	17.5	15.6
Moore's Cove	p, c	3,6	4.8	15.7	15.6
Rowsell Cove	p, c	3,6	4.8	9.8	15.6
Josiah Spencer Cove	p, c	6	4.8	9.8	14.9
Jacob Cove	p, c	6	4.8	10.5	14.9
Farewell Cove	p, c	6	5.2	10.5	14.9
Fleury Bight	p, c	3,6	5.2	8.6	14.9
Deep Water Head	r	3	2.5	4.6	6.9
Shoal Point	r	3	2.5	4.6	6.9
Bellens Point	p, c	3,6	3.2	4.6	14.9
Fortune Harbour	s, p, c	3,6,18	5.7	21.0	27.0
Squid Cove	s, p, c	18	4.9	16.4	14.9
Webber Bight	p, c	3,6	6.2	16.2	15.6

Indian Cove	s, p, c	3,9	7.2	10.5	14.9
Caplin Cove	p, c	3,6	7.2	10.5	15.6
Waldron Cove	p, c	3,6,13	7.4	11.7	15.6
Blow-me-down	p, c	3,6	7.4	10.5	19.1
Black Gulch	p, c	3,6	7.4	10.5	19.1
Point of Bay	s, p, c	9,18	7.9	11.2	19.1
Phillips Head	s, p, c	3,9,18	7.9	23.5	24.0
Northern Arm	s, p, c	9,18,24	7.9	23.5	24.0
Botwood	s, p, c	18,16,24	18.0	28.8	26.8
Peterview	s, p, c	9,18	13.5	23.5	24.0
Norris Arm	s, p, c	9,16,18,23	13.5	23.5	24.0
Norris Arm North	s, p, c	9,18	9.0	21.4	22.0
Laurenceton	s, p, c	9,18	12.0	28.8	26.8
Porterville	s, p, c	3,9	14.0	22.1	22.0
Browns Arm	s, p, c	16	15.0	26.9	24.0
Stanhope	s, p, c	9,18	16.0	28.8	26.8
Mason's Cove	s, p, c	18	9.0	16.8	24.0
Embree	s, p, c	16	11.5	16.8	24.0
Little Burnt Bay	s, p, c	3,9,16	14.0	16.8	24.0
Lewisporte N	s, p, c	9,18	8.4	16.6	29.4
Lewisporte C	s, p, c	18	12.0	19.2	34.9
Lewisporte S	s, p, c	3,18	6.0	16.6	29.4
Michael's Hr.	s, p, c	16,18	16.0	19.2	29.4
Campbellton W	s, p, c	9	7.9	23.5	25.0
Campbellton C	p, c	9	7.9	26.9	29.4
Campbellton E	s, p, c	8,18	8.0	22.7	29.4
Indian Cove Neck	s, p, c	16	7.9	22.7	22.0
Comfort Cove	s, p, c	3,8	9.0	23.4	22.0
Comfort Cove Newstead	s, p, c	8,9	6.6	19.2	19.6
Loon Bay N	s, p, c	18,3	4.0	23.4	22.0
Loon Bay C	s, p, c	18	8.0	33.2	25.5
Loon Harbour	s, p, c	18	2.0	19.2	22.0
Loon Bay E	s, p, c	18,8	12.0	23.4	25.5

South Harbour	s, p, c	3,16	9.2	16.8	19.6
Baytona N	s, p, c	8	6.0	16.6	22.0
Baytona	s, p, c	8	6.8	14.5	22.0
Birchy Bay Head	s, p, c	16	6.2	16.4	19.6
Birchy Bay W	s, p, c	3,8	9.0	14.5	19.6
Birchy Bay	s, p, c	18	12.0	16.4	22.0
Birchy Bay E	s, p, c	8,2	11.3	14.5	19.6
The Reach	s, p, c	8,3	6.8	19.8	22.0
Boyd's Cove	s, p, c	18	6.8	27.1	31.2
Boyd's Cove N	s, p, c	8,3	9.0	19.4	25.5
Chapel Island Causeway	s, p, c	8,18	6.8	19.4	19.6
Dildo Run Curtis Causev	s, p, c	3,7	7.5	19.4	19.6
Dildo Run N Causeway	s, p, c	4, 7	3.8	19.4	15.9
Strongs Island Causeway	s, p, c	18	8.0	23.5	19.6
Strongs Island	s, p, c	3,9	6.8	19.2	22.0
Summerford E	s, p, c	9	6.8	19.2	19.6
Summerford C	s, p, c	18	8.0	23.5	19.6
Summerford W	s, p, c	9,18	8.0	23.5	22.0
Summerford Village Cv	s, p, c	9,18	6.8	19.2	19.6
Intricate Harbour	p, c	2,3	7.5	16.6	15.9
Cottles Island	s, p, c	8	9.0	21.0	19.6
Lukes Arm	s, p, c	9	6.0	16.6	15.9
Puzzle Harbour	r	3	2.0	16.6	20.8
Bridgeport Harbour	p, c	5	9.0	21.0	19.6
Little Bridgeport Hr	p, c	3,5	1.6	16.4	14.9
Morton Cove	p, c	3,6	12.0	21.0	19.6
Whale's Gulch	p, c	3,4,5	9.0	16.4	14.9
Dicky Head	r	3	2.5	7.4	8.0
Sam Cove	p, c	6	7.2	16.6	14.7
Pearce Harbour	r	3	2.5	7.4	8.0
Pomley Cove	p, c	15	12.8	17.2	15.9
Moreton's Hr Head	r	3	2.5	7.4	8.0
Cross Cove	r	3	2.0	7.4	8.0

Moreton's Harbour	s, p, c	6,15,18	9.0	21.0	19.6
Beachy Cove	s, p, c	6,7,18	16.0	23.5	25.5
Wild Bight Head	r	3	2.5	7.4	8.0
Wild Bight	s, p, c	2,3,8	8.0	10.2	15.9
Webber Bight	p, c	2,3,4,5	10.8	21.0	25.5
Tizzards Harbour Head	p, c	2,3	2.5	6.2	12.1
Tizzards Harbour	s, p, c	8,18	12.0	21.0	25.5
Sam Jean's Cove	p, c	3,6	4.0	10.1	15.9
Chanceport Harbour	s, p, c	9,18	8.0	10.1	23.4
Chanceport	p, c	15	4.2	15.4	23.4
Bridger Cove	p, c	15	6.0	21.0	25.5
Carters Cove	s, p, c	18	13.0	28.8	25.5
Virgin Arm	s, p, c	8,9,18	5.3	22.7	23.4
Fairbank	s, p, c	6,9,18	7.0	22.7	23.4
Tilt Cove	s, p, c	9	2.6	17.9	17.0
Squid Cove	s, p, c	7,18	3.0	19.2	17.0
Burnt Cove	s, p, c	18	9.0	19.2	17.0
Salt Pans	s, p, c	18	6.0	19.2	17.0
Hillgrade	p, c	6	4.8	18.4	18.0
Byrne Cove	p, c	6	3.6	18.4	18.0
Newville	p, c	5	1.8	16.4	17.0
Little Byrne Cove	p, c	5	3.6	16.4	17.0
Indian Cove	s, p, c	3,8	4.5	18.4	20.8
Lobster Harbour	r	3	3.6	8.6	8.0
Twillingate Island Cause	r	3	2.0	14.9	12.1
Black Duck Cove	s, p, c	8	5.6	8.6	18.0
Kettle Cove	s, p, c	8	9.0	9.2	15.9
Moses Point	p, c	5	4.5	8.5	15.9
Manuel's Cove	s, p, c	8,18	12.0	21.0	20.8
Bayview	s, p, c	8	7.9	18.2	20.8
Gillard's Cove	s, p, c	8	7.9	18.2	20.8
Bluff Head Cove	s, p, c	8	7.2	17.6	20.8
Rodney Cove	s, p, c	18	12.0	21.0	20.8

Robins Cove	s, p, c	8,18	9.0	18.2	20.8
Old House Cove	s, p, c	18	12.0	28.8	20.8
Dumpling Cove	s, p, c	8	9.0	28.8	20.8
Batrix Island tombolo	s, p, c	3,18	15.0	33.2	28.8
Back Harbour	s, p, c	8,18	6.0	22.5	20.8
Bread and Butter Point	r	3	2.5	12.1	12.1
Mudford Cove	p, c	6	9.6	21.0	20.8
Crow Head	p, c	6	6.0	18.5	15.9
Lower Head	r	3	2.0	7.4	12.1
Sleepy Cove	p, c	6	8.0	12.1	15.9
Devil's Cove Head Light	r	3	2.5	6.8	7.1
Devils Cove	p, c	6	10.0	16.5	15.9
Horney Head	p, c	3,6	2.5	6.8	12.1
Connert Head Cove	r	3	2.5	9.8	12.1
Wild Cove	s, p, c	18	15.0	27.1	25.5
Twillingate W	s, p, c	18	9.0	22.3	25.5
Twillingate Shoal Tickle	s, p, c	18	8.0	27.1	25.5
Twillingate C	s, p, c	8	12.0	24.3	25.5
Twillingate E	s, p, c	3,8	9.0	22.3	25.5
Jenkins Cove	s, p, c	18	16.0	24.3	25.5
Gillesport	s, p, c	3,9	14.0	21.9	25.5
Durrell	s, p, c	6,8	14.0	21.9	25.5
Spillers Cove	r	3	2.5	6.1	5.7
Clam Rock Head	r	3	2.5	6.1	5.7
Codjack Cove	p, c	6	6.0	20.3	12.7
Gunning Head	r	3	2.5	6.1	5.7
Burn's Point	p, c	2,3	6.0	9.6	12.7
Little Harbour	p, c	3,6	9.6	20.3	12.7
Purcell's Harbour	p, c	6	6.0	15.4	12.7
Merritts Harbour	s, p, c	3,8	3.6	18.1	12.7
Salt Harbour	s, p, c	8	4.8	18.1	12.7
Sunnyside	r	3	6.0	12.1	5.7
Hatchet Harbour	s, p, c	8,9	7.2	11.6	18.0

Burnt Arm	s, p, c	3,8	2.3	12.1	12.7
Toogood Arm	s, p, c	5,8	9.0	26.3	24.0
Green Cove	s, p, c	8	10.0	18.1	22.0
Pikes Arm	r	3	12.0	21.4	11.0
Herring Neck	s, p, c	8	9.0	18.5	22.0
Cobbs Arm	s, p, c	8	12.0	25.7	24.0
Milliners Arm	s, p, c	8,18	9.0	19.6	12.7
Beaver Cove	s, p, c	7,8,15	10.5	23.5	24.0
Port Albert	s, p, c	3,9	13.1	34.5	31.2
Farewell	s, p, c	3,9	4.5	19.6	18.0
Change Islands ferry tm	r	3	1.5	8.6	11.0
Change I Deep Cove	p, c	3,6	4.0	8.6	11.0
Change I Red Rock Cove	p, c	3,6	4.0	8.6	11.0
Change I Fox Cove	p, c	6	4.0	8.6	11.0
Change I Paines Cove	p, c	3,6	6.0	8.6	11.0
Change I Skinner Cove	p, c	6	4.8	8.6	11.0
Fogo Stag Harbour	s, p, c	3,6,18	6.0	17.1	12.7
Island Harbour	p, c	6	7.2	18.1	12.7
Deep Bay	p, c	3,6	7.2	18.1	12.7
Hare Bay	p, c	3,6	4.8	14.9	12.7
Fogo Seal Cove	p, c	3,6	7.0	18.1	12.7
Fogo Back Cove	p, c	3,6	8.0	17.3	12.7
Fogo Harbour	p, c	3,6	9.0	18.1	18.0
Shoal Bay	p, c	3,6	6.4	18.2	12.7
Barr'd Islands	p, c	3,6	12.0	18.2	12.7
Joe Batts Arm	p, c	6	9.0	17.3	18.0
Joe Batts Arm E	p, c	3,6	12.0	18.2	18.0
Sandy Cove	s, p, c	3,6,9	10.5	17.3	14.9
Tilting	p, c	3,6	5.6	12.1	14.9
Cape Fogo	r	3	2.1	8.6	7.1
Cape Cove	r	3	2.4	8.6	7.1
Kippen Cove	p, c	3,6	6.4	18.2	12.7
Wild Cove	p, c	6,3	6.4	18.2	12.7

Seldom Harbour E	p, c	6	3.2	12.1	12.7
Seldom Harbour W	p, c	3,6	3.6	12.1	12.7
LittleSeldom Harbour	p, c	6,3	5.4	18.2	12.7
Dog Bay	p, c	4,5,6	5.4	19.6	14.9
Stoneville	s, p, c	5	8.4	24.9	19.1
Dog Bay Head	s, p	18	8.4	22.3	19.1
Horwood	s, p	18	8.4	22.3	19.1
Shoal Bay	s, p	8	7.2	24.9	19.1
Fox Island	r	2	2.3	22.4	8.0
Rodgers Cove	s, p, c	18	12.0	24.9	19.1
Victoria Cove	s, p, c	18	13.5	24.9	19.1
Victoria Cove E	s, p, c	18	13.5	24.9	19.1
Wings Point	s, p, c	18	13.5	24.9	19.1
Clarkes Head N	s, p, c	18	13.5	24.9	19.1
Clarkes Head	s, p, c	18	13.5	24.9	19.1
Gander Bay S	s, p, c	18	9.0	24.9	19.1
Gander Bay	s, p, c	18,8	9.0	24.9	19.1
Main Point	s, p, c	8,18	13.5	24.9	19.1
Mann Point	s, p, c	8	6.8	23.4	19.1
Beaver Cove	s, p, c	5,8	9.6	23.4	19.1
Frederickton	s, p, c	5,8	5.4	20.3	19.1
Noggin Point	s, p, c	2,8	7.2	20.3	19.1
Noggin Cove	s, p, c	8,18	12.0	23.4	19.1
Gaze Point	s, p, c	5,2,18	10.0	23.4	22.0
Carmanville N	s, p, c	18	12.0	23.4	22.0
Carmanville C	s, p, c	8,16	9.0	23.4	22.0
Carmanville S	s, p, c	3,8	4.0	20.3	22.0
Teakettle Point	p, c	2,5	6.0	14.2	15.6
Twillick Point	r	2	12.5	15.1	15.6
Middle Arm W	s, p, c	2,25	5.0	13.6	17.0
Middle Arm C	s, p, c	25	4.0	13.6	17.0
Middle Arm E	s, p, c	8	6.8	13.6	15.6
Eastern Arm W	p, c	5	9.0	14.2	17.0

Eastern Arm C	s, p, c	25	5.0	13.6	17.0
Eastern Arm E	s, p, c	25,8	5.6	13.6	17.0
Rocky Point	p, c	5	15.0	16.6	15.6
Aspen Cove	s, p, c	16	15.0	23.4	25.5
Aspen Cove E	s, p, c	17,18	10.5	23.4	25.5
Ladle Cove W	s, p, c	8,17	13.1	23.4	25.5
Ladle Cove E	s, p, c	15,18	17.5	24.9	25.5
Ragged Point	p, c	5	15.0	23.4	22.0
White Point	s, p, c	5,8	6.8	22.5	25.5
Ragged Harbour Head	s, p, c	16,8	15.0	31.1	25.5
Musgrave Harbour	s, p, c	18/21	22.5	39.4	25.5
Doting Cove	s, p, c	16/19	27.0	39.4	25.5
Deadmans Point	r	2	10.0	26.2	12.2
Deadmans Bay	s, p	5,8,11,19	16.8	31.1	25.5
Deadmans Bay E	s, p	19,20,11	27.0	39.4	27.7
Cat Island	r	2	2.5	26.2	12.2
Lumsden W	s, p	18/21	20.4	31.1	27.7
Lumsden E	s, p	11/8,20,19	24.0	39.4	27.7
Lumsden South	s	19,20,21	19.2	37.1	27.7
Windmill Head	r	2	10.0	26.2	12.2
Windmill Bight	s	19,8/11	27.0	37.1	27.7
North Bill	s, p	2,8	12.0	26.2	22.0
Cape Freels N	s, p	16/19	35.0	37.1	27.7
Cape Freels	s	18/21	40.0	39.4	27.7
Cape Freels S	s	11,19,20	40.0	37.1	27.7
Newtown	p, c	2,5	6.6	18.6	14.7
Templeman	r	2	6.0	18.6	9.8
Seal Cove	p, c	5	6.0	26.3	22.0
Pound Cove	p, c	5	4.0	18.6	14.7
Coal Harbour Point	p, c	5	6.0	18.6	14.7
Wesleyville	p, c	5	4.4	18.6	14.7
Brookfield	p, c	5	4.4	18.6	14.7
Hermits Cove Point	p, c	2	6.0	21.4	9.8

Badgers Quay	p, c	2,5	4.4	18.6	14.7
Pool's Island	p, c	2,5	8.3	20.3	14.7
Valleyfield	p, c	5	4.8	18.6	14.7
Business Cove	p, c	3,5	4.8	18.6	14.7
Pudding Bag Cove	r	3	1.0	16.6	6.4
Loo Cove	p, c	2,3	1.5	16.6	7.8
Shamblers Cove causewa	r	3	5.5	20.3	8.5
Greenspond	p, c	2,3,5	4.8	20.3	14.7
Batterton Island	p, c	2	4.0	18.6	14.7
Broad Cove	r	3	2.0	17.2	6.4
Fox Head	r	3	2.0	19.2	7.8
Fox Bay	r	3	1.5	17.2	6.4
Shoe Cove Point	r	3	2.0	19.2	7.8
Newport	r	3	1.0	12.1	6.4
Cat Cove	r	3	3.2	18.2	6.4
North Arm	s, p, c	3,9	3.2	14.6	7.8
Indian Bay	s, p, c	3,9	3.2	18.5	15.6
Parsons Point	s, p, c	3,18	6.0	16.4	15.6
Indian Bay Brook	s, p, c	3,9	2.0	14.6	15.6
Southwest Arm	s, p, c	3,9	4.8	18.5	15.6
Centreville	s, p, c	9,18	9.0	18.5	22.0
Wareham	s, p, c	9,18	6.3	22.0	18.0
Black Duck Cove	s, p, c	3,9	5.3	19.6	15.6
Powell Cove	s, p, c	3,9	5.3	19.6	15.6
Northwest Arm	s, p, c	3,9	5.3	19.6	15.6
Trinity BB	s, p, c	9,18	5.6	22.0	18.0
Southwest Arm	s, p, c	3,9,18	6.6	19.6	15.6
Drake Cove	s, p, c	3,9	3.2	21.0	18.0
Gut Cove	p, c	3,6	3.2	21.0	18.0
Chalky Head Cove	p, c	3,6	4.8	22.0	18.0
Birchy Head Lockyers B	r	3	1.0	6.8	6.4
Dover	s, p, c	9,18	7.2	27.1	22.0
Hare Bay E	s, p, c	9	6.3	24.6	18.0

Hare Bay	s, p, c	9	6.3	23.5	22.0
Boutcher's Cove	s, p, c	3,16	3.5	23.5	22.0
Lower Dark Cove	s, p, c	9,17,18	5.6	23.5	22.0
Middle Brook	s, p, c	16	1.8	21.9	18.0
Dark Cove	s, p, c	16,24	4.0	21.9	22.0
Gambo N	s, p, c	16	4.0	21.9	22.0
Gambo C	s, p, c	16,24	6.0	20.3	29.7
Gambo S	s, p, c	17,18	8.4	21.9	29.7
Hay Cove	s, p, c	16,18	5.6	23.5	22.0
Cat Gut	r	3	1.5	8.6	5.2
Iris Cove	p, c	3,6	6.4	23.5	22.0
Great Content Cove	p, c	3,6	6.4	23.5	22.0
Little Content Cove	p, c	3,6	6.4	23.5	22.0
Dog Cove	p, c	3,6	6.4	23.5	22.0
Beaches Head	r	3	1.0	10.5	8.0
Beaches Cove	s, p, c	3,18	6.4	23.4	22.0
Black Duck Cove	s, p, c	3,9	3.6	13.5	14.7
Northwest Arm	p, c	3,6	1.6	10.5	14.7
Rocky Bay	p, c	3,6	3.2	14.2	14.7
Norton Cove	s, p, c	3,9	3.2	14.2	14.7
Saunders Cove	s, p, c	9	5.3	13.5	14.7
Glovertown	s, p, c	18	3.1	20.2	17.0
Glovertown South	s, p, c	18,9	3.1	20.2	17.0
Traytown	s, p, c	13,16,18	2.3	9.6	14.7
Traytown causeway	s, p, c	9	2.5	9.6	14.7
Cary Cove	s, p, c	3,9	7.0	10.5	14.7
Long Reach	s, p, c	3,9	7.0	10.5	14.7
Fair and False Bay	s, p, c	3,9	7.9	11.8	12.7
Squid Island	r	3	2.0	19.2	9.8
Burnside	s, p, c	3,6,9	8.0	13.6	12.7
St. Brendans	s, p, c	18	16.0	27.1	15.6
Haywards Cove	s, p, c	9	8.4	24.5	12.7
Dock Cove	s, p, c	15,18	12.0	25.4	12.7

Shalloway Cove	s, p, c	9	7.9	17.9	12.7
Stock Cove	p, c	3,6	6.4	20.3	12.7
Damnable Bay	r	3	2.0	16.6	9.8
St. Chad's	s, p, c	3,6,9	7.2	26.9	19.1
Baldric Head	r	3	2.0	21.4	9.8
Carman Cove	s, p, c	3,9	10.5	21.4	19.1
Eastport N	s	3,12	14.4	40.1	25.5
Northwest Brook outlet	s	20,21	21.6	39.4	25.5
Eastport	s	12,20,21	27.0	45.5	28.4
Southwest Br Eastport	s	3,20	27.0	39.4	25.5
Dark Cove	s, p	3,9	9.0	19.6	8.5
Cow Head	s, p	3,9	2.5	17.0	8.5
Bishops Harbour	p, c	3,6	11.2	23.5	14.7
Salvage	p, c	3,6	4.8	19.2	14.7
Net Point	r	3	2.0	8.6	5.1
Broomclose Harbour	s, p, c	3,9	2.5	8.6	5.1
Little Barrow Harbour	r	3	2.5	8.6	5.1
Barrow Harbour	r	3	2.5	8.6	5.1
Padners Cove	r	3	0.8	8.6	5.1
Scotts Tickle	r	3	2.4	8.6	5.1
Sandy Cove	s	21	21.6	35.2	20.8
Happy Adventure	s, p, c	3,9	14.0	19.2	14.7
Holbrook Head	r	3	2.5	11.5	5.1
North Broad Cove	p, c	3,6	4.8	19.2	14.7
Matchim Cove	p, c	3,6	4.8	19.2	14.7
Buckley Point	r	3	4.8	19.2	5.1
Buckley Cove	p, c	3,9	2.6	9.8	8.5
Newman Sound	r	3	0.8	9.8	14.7
Big Brook Outlet	s, p, c	9,24	1.8	11.7	18.0
Cannings Cove	s, p, c	3,9	7.0	9.8	12.7
Hefferns Cove	s, p, c	3,9	7.9	10.9	12.7
Minchin Cove	s, p, c	3,9	7.9	10.9	12.7
South Broad Cove	s, p, c	3,9	7.9	10.9	12.7

Little Harbour	r	3	7.9	10.4	8.5
Lions Den	s, p, c	3,9	9.0	10.9	12.7
Dumpling Cove	p, c	3,6	7.2	10.4	12.7
Bread Cove	p, c	3,6	7.2	10.4	12.7
Charlottetown	s, p, c	18	18.0	25.7	15.6
Yudle Cove	s, p, c	9	7.2	18.2	14.7
Platter Cove	s, p, c	18	5.4	17.2	14.7
Northwest River outlet	s, p, c	16,18	6.0	20.3	15.6
Port Blandford	w, s, p	24	5.4	20.3	15.6
Southwest River outlet	w, s, p	24	5.4	16.7	15.6
Love Cove	s, p, c	18	9.0	18.2	14.7
Bunyans Cove	s, p, c	9 16 18	13.5	25.7	18.0
Chain Rock Cove	p, c	3,6	4.8	20.3	12.7
Connecting Point	r	3	3.0	5.3	8.5
Cannings Cove	s, p, c	9,18	12.0	20.3	12.7
Man Point	r	3	3.0	5.3	8.5
Musgravetown N	s, p, c	3,9	7.9	20.3	18.0
Musgravetown S	s, p, c	9,18	9.0	27.1	22.0
Honeybun Point	s, p, c	9	14.0	21.7	18.0
Bloomfield	s, p, c	9,18	9.0	22.4	18.0
Southwest Arm	s, p, c	16,9	5.3	20.3	15.6
Mosquito Cove	s, p, c	3,9	7.9	22.4	15.6
Lethbridge	s, p, c	9	7.9	22.0	15.6
Sandy Cove	s, p, c	9,18	5.0	20.3	15.6
Bear Cove	s, p, c	3,9	5.3	19.5	12.7
Powers Cove	s, p, c	9	5.3	19.5	12.7
Brooklyn	s, p, c	9	10.5	20.3	15.6
Lovers Cove	s, p, c	9	14.0	21.2	15.6
Sattlings Cove	s, p, c	16,18	9.0	20.3	15.6
Portland	s, p, c	9	14.0	21.2	18.0
Jamestown	s, p, c	6,15	12.0	23.5	18.0
Dicks Cove	p, c	6, 3	4.8	20.3	15.6
Pudding Cove	p, c	9	6.2	16.6	12.7

Chance Head	r	3	2.5	6.8	8.5
Great Chance Harbour	p, c	9	7.2	12.2	12.7
Little Chance Harbour	r	3	6.2	7.2	8.5
Maiden Hair Cove	p, c	3,6	6.2	6.8	12.7
Weeks Point	r	3	1.5	13.6	8.5
Quintons Cove	r	3	1.0	13.6	8.5
Peary Cove	p, c	4	1.0	14.7	11.5
Loders Cove	s, p, c	9	1.0	14.7	11.5
Winter Brook	p, c	3,6	4.8	15.4	11.5
Winter Brook outlet	p, c	6	3.6	15.9	12.7
Keefes Cove	p, c	6	8.4	16.6	11.5
Nut Cove	p, c	6	3.2	16.6	11.5
Landers Cove	p, c	6	3.2	15.4	11.5
Saltwater Pond	p, c	3,6	2.4	15.4	11.5
Bottom Cove	p, c	6	2.4	16.6	12.7
Little Harbour	p, c	3,6	4.8	16.6	11.5
Sweet Bay	p, c	6,15	5.4	16.6	12.7
Nolans Point	p, c	6	4.8	16.6	11.5
Cutler Head	r	3	3.8	6.8	6.1
Kate Head	r	3	3.8	6.8	8.5
Kate Harbour	p, c	3,6	9.6	23.5	12.7
Southward Head	r	3	2.0	13.6	6.1
Matthew Cove	r	3	2.0	15.2	8.5
Pinchers Point	r	3	5.0	14.2	8.5
Charleston	s, p, c	9	1.6	22.0	12.2
Southern Bay	s, p, c	18,9	6.0	23.5	14.7
Princeton	s, p, c	3,18	9.0	28.8	14.7
Long Beach	p, c	6,15	8.0	25.7	14.7
Summerville	s, p, c	15	11.2	28.8	14.7
Indian Arm Head	p, c	3,6	3.6	28.8	12.7
Plate Cove West	s, p, c	15	10.8	37.1	12.0
Plate Cove East	p, c	15	14.4	33.2	12.0
Open Hall	p, c	6,15	12.5	33.2	12.0

	Red Cliff	p, c	6	11.2	30.5	12.7
	Tickle Cove	p, c	3,6,15	11.2	37.1	12.7
	Deep Cove	p, c	3,6	14.4	32.2	12.7
	Keels	p, c	1,2,4	12.5	32.2	12.0
	Backside Cove	p, c	2,3,4	14.4	33.4	12.0
	Duntara	p, c	3,6,15	17.5	37.1	12.0
	Broad Head	r	3	5.0	13.6	6.1
	King's Cove	p, c	3,6,15	14.4	34.6	12.0
	Stock Cove	p, c	15	18.0	34.6	12.0
	Knight's Cove	p, c	3,6,15	18.0	34.6	12.0
	Knight's Point	r	2,3	5.0	19.2	6.1
	Hodderville	p, c	1,2,4,5	12.0	24.0	12.0
	Wild Bay	p, c	1,2,4,5	14.0	27.2	12.0
	Monk Bay	p, c	1,4	16.0	30.4	12.0
	Black Bay	p, c	1,2,4,5	14.0	30.4	12.0
	Upper Amherst Cove	p, c	1,4	16.0	33.4	18.0
	Middle Amherst Cove	p, c	15	18.0	33.4	18.0
	Amherst Cove	p, c	1,4	12.0	29.4	18.0
	Newmans Cove	p, c	5,15	16.0	27.1	14.7
	Birchy Cove	p, c	5,15	16.0	27.1	14.7
	Danson Cove	p, c	6,15	17.5	24.3	14.7
	Burnt Head	p, c	3,6	17.5	16.6	12.0
	Bonavista Canaille Point	p, c	3,6	17.5	16.6	14.7
	Bonavista S	s, p, c	18	20.0	37.1	19.6
	Bonavista Squarry I	p, c	15	17.5	25.4	18.0
	Bonavista Moses Point	p, c	2,3	12.5	24.0	18.0
	Bonavista Bayleys Cove	s, p, c	18	20.0	37.1	19.6
Trinity Bay	Bonavista N	p, c	6	12.0	26.3	19.6
	Bonavista Red Cove	p, c	6,15	13.0	20.3	18.0
	Cape Bonavista	p, c	3,6	3.8	14.5	12.2
	Dungeon Prov. Park	p, c	2,3,6	12.0	14.2	12.2
	Lance Cove	p, c	6	18.0	19.1	12.2
	Spillers Cove	p, c	6	18.0	19.1	12.2

Lancaster	p, c	6	18.0	17.8	14.7
Elliston	s,p,c	13/15/16	19.7	20.3	13.6
Maberly	p, c	5,2,6	16.5	16.8	13.6
Little Catalina	s,p	8	15.0	24.1	18.0
Catalina	s,p,c	18	18.0	31.1	22.0
Port Union	s, p	8	14.6	17.3	22.0
Melrose	s, p	18	16.2	27.6	22.0
English Harbour	s, p,c	15,18,17,6	18.9	20.1	22.0
Champneys	s, p	6,18	16.5	19.5	22.0
Champneys West	s, p	18	21.6	20.1	22.0
Port Rexton	s, p	16,18	18.9	20.8	18.0
Trinity East	s, p	5,18	16.5	19.2	14.7
Trinity	s, p	5,18	18.7	18.6	14.7
Goose Cove	s, p	8,18	16.5	18.3	12.0
Dunfield	s, p	8,18	18.7	29.3	18.0
Trouty	p, c	5	7.2	9.3	12.0
Old Bonaventure	p, c	6	10.8	16.8	18.0
New Bonaventure	p, c	6	11.6	30.1	12.0
Perleys Harbour	p, c	3,6	10.8	11.8	12.0
Irelands Eye	r	3	2.9	13.9	12.0
British Harbour	r	3	1.5	14.1	12.0
Delbys Cove	p, c	6	3.2	16.8	14.7
Popes Harbour	p, c	5	3.6	14.1	14.7
Burgoynes Cove	s, p	15, 18	7.2	16.8	18.0
Clifton	s, p	15, 18	3.6	16.4	18.0
Waterville	p, c	3, 6	2.1	14.8	14.7
Monroe	s, p	8	2.7	16.4	14.7
Gin Cove	r	3	1.2	16.4	12.0
Somerset	s, p	8	2.7	16.4	14.7
Harcourt	p, c	2,5	3.2	16.4	14.7
Barton	s, p	6,9	3.2	14.9	14.7
Georges Brook	s, p, c	14, 17	3.9	16.4	18.0
Milton	s, p, c	8	6.8	16.4	18.0

Random Island Causewa	s, p, c	8,15	7.5	19.8	14.7
Snooks Harbour	s, p, c	18	13.5	16.4	18.0
Aspey Brook	s, p, c	9	11.8	16.4	14.7
Aspen Cove	p, c	3,6	5.4	16.4	14.7
Petley	p, c	15	10.8	16.4	18.0
Britannia	p, c	15	11.2	16.4	18.0
Lower Lance Cove	p, c	13,15	10.8	16.4	14.7
Thoroughfare	p, c	4,5	7.2	14.9	14.7
Deer Harbour Random I	r	3	2.3	14.9	13.9
Salmon Cove	p, c	3,6	5.9	14.9	13.9
Hickmans Harbour	p, c	3,5,6	4.8	16.4	13.9
Hickmans Harbour W	p, c	5,6	7.2	14.9	13.9
Lady Cove	s, p, c	8,18	9.9	14.9	14.7
Weybridge	s, p, c	5,8	7.2	14.9	14.7
Elliots Cove	s, p, c	8	6.8	14.9	14.7
Shoal Harbour	s, p, c	8,18	9.9	16.4	14.7
Clarenville Red Beach	s, p, c	18	10.2	17.4	17.0
Clarenville	s, p, c	8,18	9.9	16.4	17.0
Clarenville S	s, p, c	8,16,18	10.4	16.4	17.0
Russells Cove	p, c	6	7.2	15.5	14.7
Deep Bight	s, p, c	16/18	12.7	15.5	14.7
Adeyton	s, p, c	6,9,15	7.9	15.5	14.7
Maggotty Cove	p, c	3,15	2.4	16.4	13.9
Fords Harbour	p, c	3, 6	3.6	16.4	13.9
Loreburn	p, c	3, 6	3.6	14.8	14.7
St. Jones Within	p, c	5	7.2	15.5	14.7
Hatchet Cove	p, c	3,6	3.6	15.5	13.9
Hillview	p, c	15	6.5	15.5	14.7
Northwest Brook	p, c	15	7.2	21.7	14.7
Queens Cove	p, c	15	7.2	16.8	14.7
Leonards Cove	p, c	6	6.5	16.8	13.9
Long Beach	p, c	15	9.1	21.7	14.7
Island Cove	p, c	15	7.2	16.8	14.7

Hodges Cove	p,c	14,15	10.1	16.8	15.9
Caplin Cove	p,c	6,15	11.7	18.6	14.7
Little Hearts Ease W	p,c	3,6	1.2	14.8	14.7
Hearts Ease Pond	p,c	5,6	1.2	18.6	14.7
Little Hearts Ease	p,c	3,4,5	2.4	21.7	13.9
Southport	p,c	2,5	6.6	18.6	14.7
Gooseberry Cove	p,c	6	7.4	18.6	13.9
Ganny Cove	p,c	5,6	5.6	14.8	13.9
Hearts Ease Inlet	p,c	3, 6	5.4	14.2	12.0
St. Jones Harbour	p,c	3,6	2.9	16.8	13.9
Deer Harbour	p,c	3,6,15	4.2	21.1	14.7
Shoal Harbour	p,c	3,6	1.8	16.8	13.9
Sunnyside Central Bay	s,p,c	15/18	9.8	16.8	18.0
Sunnyside	s,p,c	6,15/18	9.6	21.7	19.6
Sunnyside E	s,p,c	6,15/18	8.6	21.7	20.8
Sunnyside S	p,c	15	9.2	16.8	19.6
Little Mosquito Cove	r	3	1.5	18.6	4.0
Great Mosquito Cove	p,c	3,6	5.4	14.8	4.0
Chance Cove	p,c	15	9.6	22.3	19.6
Bellevue Beach	s,p,c	13/16,14/17	15.8	17.8	22.0
Bellevue	p,c	15	19.2	31.8	20.8
Tickle Bay	s,p,c	15/18,15	11.2	27.8	19.6
Thornlea	p,c	6,15	12.6	5.3	15.6
Collier Bay	p,c	3,15	14.5	20.1	19.6
Long Cove	p,c	15	12.6	11.9	14.7
Normans Cove	p,c	6,15	14.5	13.1	19.6
Chapel Arm	p,c	6,15	11.2	22.9	20.8
Spread Eagle	p,c	6,15	14.4	21.1	14.7
Old Shop	p,c	5,15	9.1	16.7	15.6
Dildo South	p,c	5,15	12.6	20.2	19.6
Broad Cove	p,c	5	9.2	15.5	15.6
Dildo	p,c	15	7.2	22.7	19.6
New Harbour	p,c	15	9.6	22.3	19.6

Hopeall	p,c	15	9.6	22.9	19.6
Green's Harbour	p,c	15	9.6	23.6	19.6
Whiteway Bay	p,c	15	10.8	22.9	19.6
Cavendish	p,c	15	9.6	22.3	19.6
Islington	p,c	13/15	11.7	22.3	19.6
Hearts Delight S	p,c	15	10.8	24.6	19.6
Hearts Delight C	s,p,c	15,15/18	11.3	28.5	19.6
Hearts Delight N	s,p,c	6,9,15/18	15.8	22.3	19.6
Hearts Desire	s,p,c	15/18	14.1	28.1	19.6
Seal Cove	r	3	3.1	23.6	9.8
Hearts Content S	p,c	15	7.2	18.6	19.6
Hearts Content C	p,c	15	7.2	28.1	19.6
Hearts Content N	s,p,c	15/18	13.5	22.3	19.6
Norther Point	r	3	3.8	18.6	9.8
Bacon Cove	p,c	3,5,6	12	15.5	17.0
Fitters Cove	s,p,c	2,5,6,15/18	13.5	29.9	19.6
New Perlican W	p,c	15	7.2	30.1	19.6
New Perlican E	s,p,c	6,15,18	16.9	29.6	19.6
Turks Cove	s,p,c	6,15/18	22.5	28.5	19.6
Winterton S	p,c	6,15	7.2	18.6	17.0
Winterton C	s,p,c	15/18	21.1	29.9	19.6
Caplin Cove	s,p,c	18	18	21.1	17.0
Hants Harbour W	p, c	15,6	5.9	18.6	19.6
Hants Harbour	p, c	14/15	12.6	22.9	17.3
New Chelsea	p, c	14/15,16	12.6	28.9	17.3
New Chelsea E	s, p, c	15/18	9	22.9	19.6
New Melbourne N	s, p, c	17/18	16.9	28.9	19.6
New Melbourne	s, p, c	14/17/18	22.5	28.9	17.3
Brownsdale	s, p, c	9,14/15	15.8	21.7	17.3
Sibleys Cove	p, c	3,15	12.6	25.7	17.0
Lead Cove	p, c	3,6	12.6	21.7	17.3
Old Perlican Mizzen Cv	s, p, c	3,6,15	13.5	18.6	17.0
Old Perlican C	s, p, c	14/15	18.0	22.9	19.6

	Old Perlican N	s, p, c	15	13.5	22.9	19.6
	Cooks Cove	s, p, c	15,18	12.7	26.6	17.3
	Daniels Cove	s, p, c	14,15	14.8	17.8	17.3
Conception Bay	Heart Cove	s, p, c	2,9	19.1	12.7	17.0
	Grates Cove	p, c	15	20.5	22.9	17.3
	Red Head Cove	p, c	3,15	6.3	20.5	14.7
	Backside	s, p, c	6,8	14.6	19.9	12.7
	Bay de Verde	p, c	3,15	12.6	19.9	17.3
	Baccalieu Island	p, c	3,6	9.0	12.7	12.7
	Kettle Cove	s, p, c	8,18	11.6	26.6	14.7
	Low Point	s, p, c	8,18	12.3	26.6	14.7
	Caplin Cove	s, p, c	15,18	18.0	30.1	15.0
	Lower Island Cove	s, p, c	15,18	17.5	25.1	15.0
	Jobs Cove	s, p, c	6,15	24.0	23.9	15.0
	Burnt Point	p, c	4,5,6	13.5	12.7	14.7
	Gull Island	s, p, c	15,18	20.2	22.9	15.0
	Long Beach	s, p, c	5,15	12.8	20.1	14.7
	Northern Bay	s,p	3,5,9	12.6	22.9	15.0
	Northern Bay Sands	s	11,12,17, 19,20	14.4	37.9	39.1
	Smooth Cove	p, c	3,6	9.6	19.9	15.0
	Ochre Pit Cove	s, p, c	5,6,15	11.5	22.3	14.7
	Western Bay N	p, c	5,6	8.1	22.3	14.7
	Western Bay	s, p, c	4,15/18	9.2	28.1	15.0
	Western Bay E	s, p, c	5,8,15	7.9	22.3	15.0
	Bradleys Cove	s, p, c	5,8	17.8	20.1	14.7
	Adams Cove	s, p, c	5	10.2	19.1	15.0
	Blackhead	p, c	3,6,15	10.8	21.2	14.7
	Broad Cove	p, c	6,15	11.1	23.2	14.7
	Broad Cove E	p, c	3,6	10.8	21.2	15.0
	Small Point	p, c	3,6	10.8	19.1	14.7
	Kingston	p, c	2,3,5	9.9	20.1	15.0
	Perrys Cove N	s, p, c	4/7,5/8	10.6	19.1	14.7
	Perrys Cove	s, p, c	5,4/7	10.1	20.1	14.7

Salmon Cove	s	17,19,20	28.8	37.9	36.0
Clements Cove	p, c	14/15,6	16.8	23.6	15.0
Crockers Cove	p, c	3,6,15	15.8	22.9	14.7
Carbonear N	p, c	6,15	10.8	20.1	19.6
Carbonear C	p, c	14/15	13.5	22.9	19.6
Carbonear E	p, c	15	10.8	20.1	19.6
Bristols Hope	p, c	14/15,6	15.8	22.9	14.1
Harbour Grace N	p, c	14/15	13.3	18.1	18.0
Harbour Grace C	p, c	15	13.3	20.5	19.6
Harbour Grace Riverhea	w, s, p	23	16.2	22.3	19.6
Harbour Grace Southside	p, c	13/14/15	8.5	20.5	22.0
Bryants Cove	p, c	6,15	15.8	21.7	14.1
Upper Island Cove	p, c	15	15.4	19.1	19.6
Bishops Cove	s, p,c	14,15,9	15.8	22.9	18.0
Spaniards Bay N	p, c	5,15	14.6	22.9	19.6
Spaniards Bay S	p, c	14/15	22.8	28.1	24.0
Bay Roberts N	p, c	15	13.8	22.9	19.6
Frenchs Cove	p, c	6,9	14.9	19.1	18.0
Mercers Cove	p, c	6,9	14.9	19.1	18.0
Bay Roberts	s, p, c	15/18	16.4	22.9	24.0
Coleys Point	s, p, c	17,18	21.1	30.4	24.0
South West Bay	s, p, c	17,18	19.8	28.9	24.0
Upper Back Cove	p, c	3,6	12.1	16.7	18.0
Hibbs Cove	p, c	3,6	12.6	18.9	18.0
Ship Cove	s, p, c	15/18,18	13.5	30.0	18.0
Port de Grave	p, c	6,14	12.6	22.9	21.5
Bareneed E	p, c	6	7.2	16.7	18.0
Bareneed	p, c	6	3.0	16.7	18.0
Clarkes Beach	p, c	15	22.8	22.9	24.0
South River	s, p, c	17	20.2	22.9	24.0
Cupids	p, c	14,15	11.9	22.9	21.5
Sharks Cove	p, c	5	10.5	19.1	18.0
North Head	p, c	3,6	11.9	17.8	18.0

Brigus	s, p, c	,3,6,9	10.8	19.6	21.5
Turks Gut Marysvale	p, c	3,6	3.2	9.5	8.2
Colliers	s, p, c	15,14/17	16.9	30.2	24.0
Burkes Cove	s, p, c	15/18	16.9	22.9	22.0
James Cove	p, c	6,15	8.9	14.7	18.0
Brakes Cove	p, c	6,3	14.6	19.6	18.0
Bacon Cove	p, c	3,6,8,15	14.6	22.3	21.5
Kitchuses	p, c	3,6	12.6	14.7	21.5
Conception Harbour	s, p, c	15/18,14	14.8	32.6	24.0
Middle Arm	s, p, c	6/9,3	14.6	25.9	18.0
Broad Cove	s, p, c	15/18	16.9	33.9	21.5
Avondale	s, p, c	14/17,18	12.2	30.9	24.0
Gallows Cove	s, p, c	3,6/9	14.6	21.7	21.5
Harbour Main west	p, c	5,15	12.2	21.1	24.0
Harbour Main east	s, p, c	15/18,14,6	15.8	15.3	21.5
Chapel Cove	p, c	5,6,15	16.9	24.7	26.8
Healys Cove	p, c	3,6	8.9	15.3	21.5
North Arm	p, c	6,15	16.9	21.7	26.8
Holyrood Lucy Beach	p, c	15	14.7	21.7	26.8
Holyrood	p, c	14/15	17.1	26.1	26.8
Indian Pond	s, p, c	17/18	16.9	32.1	26.8
Seal Cove	s, p, c	17,18	17.5	29.1	21.5
Lance Cove CBS	s, p, c	17/18	16.8	29.1	21.5
Upper Gullies	s, p, c	18	15.9	29.1	26.8
Kelligrews	s, p, c	17/18	16.9	32.1	21.5
Foxtrap	s, p, c	16/18	18.5	32.1	21.5
Long Pond	s, p, c	18	27.5	32.1	26.8
Manuels	s, p, c	16/18	30.0	32.1	26.8
Chamberlains	s, p, c	16,18	30.0	32.1	26.8
Topsail	s, p, c	16/18	27.5	32.1	26.8
St. Phillips	s, p, c	6,15/18	16.8	16.3	21.5
Lance Cove Bell I.	p, c	6	14.5	28.9	21.5
The Beach Bell I.	p, c	15	16.8	28.9	21.5

	Portugal Cove	p, c	2,6	15.9	16.9	17.9
	Portugal Cove N	p, c	6,2	14.7	5.9	14.7
Atlantic Coast	Bauline	p, c	3,6	9.6	11.0	17.3
	Cape St Francis	r	3	3.8	5.9	5.0
	Pouch Cove	p, c	15	15.8	19.1	17.3
	Shoe Cove	p, c	6	5.4	13.4	6.0
	Red Head Cove	p, c	3,6	12.8	16.6	14.7
	Flat Rock	c	1,2,6	11.2	21.2	17.3
	Torbay	p, c	3,6,15	18.6	22.9	24.5
	Middle Cove	s, p, c	15/18,3,6	20.0	28.9	21.5
	Outer Cove	s, p, c	3,6,18	18.6	22.9	21.5
	Robin Hood Bay	p, c	3,6	12.8	13.6	14.7
	Quidi Vidi	p, c	3,6	9.6	16.8	9.0
	St. Johns Harbour	anthr	anthr	2.0	15.0	n/a
	Freshwater Bay	p, c	3,6,15	22.4	24.5	14.7
	Blackhead Bay	p, c	2,5	18.6	22.9	21.5
	Spear Bay	p, c	2,5	17.6	19.4	21.5
	Maddox Cove	p, c	6,15	18.6	21.7	21.5
	Petty Harbour	p, c	6	15.5	20.5	19.4
	Bread and Cheese Bay B	p, c	3,6	12.6	19.6	14.7
	Bay Bulls	p, c	6,9,15	13.5	22.9	19.4
	Carpenters Cv Bay Bulls	p, c	6,15	12.6	19.6	14.7
	Bear Cv Witless Bay	p, c	8	14.4	19.6	19.4
	Witless Bay	p, c	13/15	13.5	20.5	19.4
	Gallows Cv Witless Bay	p, c	3,6	12.6	18.6	19.4
	Mobile	p, c	3,6,15	12.6	21.2	19.6
	Tors Cove	p, c	6,15	11.6	17.8	19.4
	Burnt Cove	p, c	6,15,3	10.7	20.5	19.6
	St. Michaels	p, c	6,15	11.6	21.7	21.5
	Bauline East	p, c	13,15,3	12.6	16.4	21.5
	La Manche	p, c	6,15	11.6	15.2	19.4
	Brigus South	s, p, c	15, 18	7.9	23.2	9.5
	Island Cove	p, c	3,6	9.6	15.9	13.9

Admirals Cove	p, c	6	8.6	15.9	13.9
Shore Cove	p, c	3,6	8.6	15.9	13.9
Spout Cv Cape Broyle	p, c	6,15	9.6	15.9	13.9
Church Cove	p, c	15	10.6	18.4	13.9
Cape Broyle	p, c	6,15	11.6	22.9	14.7
Broad Cove Calvert	p, c	6	10.6	15.9	14.7
Calvert	p, c	6,15	14.4	21.7	14.7
Lance Cove Calvert	p, c	3,6	11.6	18.4	13.9
Ferryland N	p, c	6,9	8.4	24.5	14.7
Ferryland Head	p, c	3,6	6.4	15.9	12.3
Ferryland	s, p, c	15, 18	32.0	28.7	13.9
Ferryland S	p, c	13/15,6	14.4	22.6	14.7
Aquaforte	p, c	15	14.4	18.3	25.5
Aquaforte River Mouth	p, c	3,6,15	6.4	22.9	25.5
Port Kirwan E	p, c	3,6	4.8	18.3	13.9
Port Kirwan	p, c	3,15	8.4	19.6	14.7
Fermeuse	p, c	15	6.6	20.5	14.7
Kingmans	p, c	6	8.4	22.6	14.7
Renews N	p, c	15	6.6	20.5	13.9
Renews	p, c	6,15	8.4	20.5	14.7
Bear Cove	p, c	15	10.1	20.5	9.5
Cappahayden	p, c	6,15	8.4	18.9	14.7
Seal Cove	p, c	6,15	8.4	18.9	13.9
Shoe Cove	p, c	3,6,15	5.6	11.8	13.9
Chance Cove	p, c	15	8.4	22.9	13.9
Frenchman’s Cove	p, c	3,6	7.6	8.0	8.7
Long Beach	p, c	15	16.8	25.2	13.9
Mistaken Point	r	3	5.0	8.0	8.7
Drook	p, c	6	19.2	15.7	8.7
Pigeon Cove	c	6	12.6	11.8	12.3
Portugal Cove South	s, p, c	13,16	18.0	27.4	34.6
Biscay Bay	s, p, c	13,16	18.0	26.6	30.9
Mutton Bay	p, c	15	18.0	23.2	20.0

	Trepassey Causeway	p, c	15	25.6	23.2	22.0
	Powles Head	r	3	4.0	8.0	8.7
	Trepassey	p, c	15	15.3	22.9	20.0
	Trepassey W	s, p, c	13,15	12.4	19.2	18.0
St. Marys Bay	Shoal Point	s, p, c	13,15	11.4	19.2	18.0
	Daniels Point	p, c	15	16.8	20.5	18.0
	St. Shotts	s, p, c	13,14	19.5	20.5	20.0
	St Shores	p, c	6	17.3	16.1	18.0
	Peters River	s, p, c	15,13	17.5	22.3	20.0
	Mill Gut	s, p, c	13,15	18.2	22.3	20.0
	St. Stephens	p, c	15	17.5	22.9	20.0
	St. Vincents	s, p, c	13,15	32.0	23.8	20.0
	Gaskiers	r	2	4.5	18.4	12.0
	Point LaHaye	s, p, c	13,15	26.3	23.4	18.0
	St. Marys	p, c	15	9.6	21.2	15.7
	Riverhead	w, s, p	6,15,23	15.3	24.8	18.0
	Beachy Cove	p, c	15	26.3	29.1	15.7
	Mall Bay	p, c	6,15	22.5	23.9	20.0
	Shoal Bay	s, p, c	13,14,15,9	22.1	23.1	20.0
	Admirals Beach	p, c	3,15	14.4	19.2	18.0
	O’Donnells	p, c	13,14,15	16.8	25.2	20.0
	St. Josephs	p, c	6,15	5.6	19.2	18.0
	New Bridge	s, p, c	17/18	14.4	22.3	20.0
	St. Catherines	w, s, p	23	5.4	25.5	28.5
	Mount Carmel	s, p, c	15/18	11.8	26.5	14.7
	Mitchells Brook	s, p, c	18	12.3	22.3	14.7
	Harricott	p, c	15	14.6	19.9	18.0
	Colinet	s, p, c	15,23	12.2	26.7	14.7
	North Harbour	p, c	6	12.6	18.1	14.7
	Dog Cove	p, c	15	15.8	21.7	8.5
	Big Barachois	s, p, c	14,15,13/16	15.8	34.0	18.0
	Little Barachois	s, p, c	6,18	11.9	26.8	14.7
	Wild Cove	p, c	3,6	5.4	23.4	16.7

	Jigging Cove	s, p, c	6,15,18	16.9	26.8	14.7
	Branch	p, c	14,15	18.0	22.9	19.6
	Gull Cove	s	19	25.4	21.1	32.9
Placentia Bay	Point Lance Cove	s	10,19	36.0	36.1	49.0
	Golden Bay	s, p	3,6,7,8	28.8	21.1	28.3
	Cape St. Mary's	r	3	5.0	4.0	5.0
	St. Brides	p, c	14,15	16.8	22.9	21.9
	Cusletts Cove	p, c	6,14,15	12.6	22.9	21.9
	Angels Cove	p, c	13,15,6	15.6	22.3	21.9
	Patricks Cove	p, c	6,13,15	12.6	22.3	21.9
	Gooseberry Cove	s, p,c	13,15	24.0	22.3	22.4
	Ship Cove	p, c	13,15	16.8	22.3	21.9
	Big Barasway	p, c	13,15	14.4	22.3	17.9
	Little Barasway	p, c	14,15	16.8	22.9	21.9
	Point Verde	p, c	13,15	24.0	24.6	21.9
	Placentia	p, c	13,15	21.0	27.8	22.4
	Jerseyside	p, c	15,18	12.8	24.5	21.9
	Freshwater	p, c	6,14,15	11.2	27.8	21.9
	Argentia	s, p,c	16	21.0	26.1	22.4
	Broad Cove Point	p, c	15	14.4	27.8	17.9
	Fox Harbour	p, c	15	22.4	27.8	17.9
	The Neck	p, c	13,15	16.5	27.8	17.9
	Ship Harbour	p, c	6,15	16.8	21.2	17.9
	Big Seal Cove	p, c	6,15	16.8	21.2	21.9
	Long Harbour	p, c	15	12.1	25.2	22.4
	Mount Arlington	p, c	6,15	9.6	21.2	21.9
	St Croix Bay	p, c	3,6,15	9.6	21.2	21.9
	Bald Head Bay	p, c	13,14, 15	12.6	21.2	21.9
	Fair Haven	s, p, c	18/15,14/15	15.9	31.9	26.8
	Great Pinchgut	p, c	3,6,15	14.2	24.5	21.9
	Pumbly Cove	p, c	3,4,15	13.6	22.9	21.9
	Little Harbour	p, c	4,15	15.9	24.5	21.9
	La Manche	p, c	13,14,15	16.2	23.6	22.4

Little Southern Harbour	p, c	13,14,15	14.3	24.5	26.8
Great Southern Harbour	s, p, c	15/18,14/13	13.6	24.5	26.8
Arnolds Cove	p, c	15,18	19.2	27.3	33.5
Whiffen Head	r	3	3.2	22.3	15.8
Come-by-Chance	w, s, p, c	24	9.9	26.1	33.9
Goose Cove	s, p, c	16, 23	12.0	27.8	15.6
North Harbour	s, p, c	15,18	16.0	25.9	21.9
Garden Cove	s, p, c	15,18	7.4	34.1	14.7
Black River	s, p, c	15,23	8.2	25.2	21.9
Swift Current	s, p, c	15,18	8.0	34.1	14.7
Woody Island Cove	p, c	17,18	12.0	34.8	14.7
Davis Cove	p, c	6,15	8.5	24.5	18.0
Clattice Harbour	p, c	6,15	15.6	16.5	18.0
St. Leonards	p, c	15	12.2	24.5	15.9
St. Kyrans	p, c	15	12.6	24.5	15.9
Little Paradise	p, c	6	9.6	21.5	15.9
Great Paradise	p, c	6	8.4	21.5	15.9
South East Bight	p, c	6,15	10.1	24.5	14.7
Monkstown	p, c	8	7.2	21.5	15.9
Petit Forte	p, c	14,15	12.0	27.8	15.9
Bar Haven	s, p, c	9,15	15.8	21.5	15.9
Glendon Cove	s, p, c	6, 9	20.8	18.4	18.0
Spencers Cove	s, p	16	8.4	16.5	14.7
Haystack	s, p, c	16,17	6.7	18.4	14.7
Harbour Buffett	s, p, c	16	8.4	16.5	14.7
Coffin Cove	s, p, c	16	6.7	18.4	14.7
Kingwell	p, c	15	8.4	16.5	18.0
Great Brule	s, p, c	16,18	8.4	16.5	18.0
Indian Harbour	p, c	6,9	8.4	16.5	14.7
Merasheen	p, c	14,15	6.7	18.4	14.7
Red Island	p, c	15	14.3	16.5	14.7
Isle Valen	p, c	3,6	5.6	18.4	11.3
Tacks Beach	p, c	17	5.6	18.4	18.0

Burnt Island	s, p, c	15,17	8.2	33.4	18.0
St. Josephs	s, p, c	13,15,16	8.2	31.8	17.9
Little Harbour	p, c	3,4,6	7.5	26.1	17.9
Bay de l’Eau	s, p, c	9,16,20,23	9.2	33.4	14.7
Brookside	s, p, c	16,18	9.4	34.8	17.9
Boat Harbour	s, p, c	9,16,17	8.2	32.5	17.9
Parkers Cove	s, p, c	16	8.2	32.5	17.9
Baine Harbour	s, p, c	16,17,18	9.3	34.8	14.7
Rushoon	s, p, c	16,17,18	10.2	33.4	14.7
East Broad Cove	s, p, c	16,18	9.3	33.4	14.7
West Broad Cove	s, p, c	16,18	13.5	33.4	14.7
Red Harbour	p, c	3,6,15	7.2	26.2	14.7
Jean de Baie	s, p, c	16,18	16.9	26.2	17.9
Rock Harbour	p, c	6,15	14.5	22.7	17.9
Spanish Room	s, p, c	16	11.5	30.1	22.0
Cow Head	s	19,20	32.4	33.9	29.4
Cashel Cove	s, p, c	16,18	11.6	29.9	17.0
Mooring Cove	s, p, c	17	12.2	30.1	17.0
Marystown	s, p, c	17,18	11.5	30.1	17.0
Little Bay	s, p, c	18	10.9	30.9	17.0
Beau Bois	p, c	15	16.8	24.5	19.6
Duricle Cove	p, c	15	14.5	24.5	19.6
Fox Cove	p, c	15	16.5	24.5	19.6
Mortier	p, c	15	16.7	24.5	19.6
Port au Bras	p, c	16	16.9	28.1	19.6
Bulls Cove	s, p, c	16,18	7.5	29.2	17.0
Burin	s, p, c	15,18	7.5	22.9	19.6
Collins Cove	p, c	15	5.6	17.9	17.0
Burin Bay	p, c	15	7.4	17.9	19.6
Little Salmonier	w, s, p	23	7.4	32.1	14.7
Burin Bay Arm	s	21	7.5	34.1	17.0
Salt Pond	w, s, p	23	7.4	28.5	12.0
Lewins Cove	s, p, c	17	5.9	24.5	19.6

	Bay View	s, p, c	18	6.4	24.5	19.6
	Salmonier	s, p, c	18	6.5	29.9	19.6
	Epworth	s, p, c	18	6.0	26.1	18.0
	Wandsworth	p, c	6	6.0	21.2	17.0
	Corbin	s, p, c	15	9.3	24.5	18.0
	Little St. Lawrence	s, p, c	15,18	13.4	22.9	18.0
	Herring Cv St Lawrence	p,c	5	12.2	21.2	17.0
	St Lawrence	p,c	13, 15	16.9	24.5	18.0
	Shoal Cove	s, p, c	16	16.4	24.5	18.0
	Salt Cove	s, p, c	16,19	17.5	26.6	22.1
	Little Lawn	s, p, c	16,18	17.5	26.6	18.0
	Lawn	s, p, c	16,17,18	15.0	33.9	18.0
	Lansey Back Cove	w, s	22	24.0	28.9	32.0
	Roundabout	s, p, c	16,19	28.8	33.9	18.3
	Pump Cove	s, p	16,17	16.8	31.8	18.0
	Lords Cove	s, p, c	16,18	11.3	34.1	26.0
	Taylors Bay	s, p, c	16,18	27.0	31.8	26.0
	Nantes Cove	p, c	4	7.2	18.5	8.0
	Point au Gaul	s, p, c	16,18	30.0	30.1	26.0
	Blow Hole Point	s, p, c	16,18	11.3	28.1	26.0
	Lamaline	s, p, c	16,17,18	16.9	31.8	26.0
	Allans Island causeway	s, p, c	18	40.0	34.2	10.0
	Allan Island Lighthouse	r, c	3,5	10.0	11.0	5.0
	Piercey Point	s, p, c	4,18	16.0	16.7	26.0
	Calmer	s, p, c	19,22,23	31.9	32.3	32.0
	Point May	s, p, c	4,16	26.3	28.1	26.0
	Lories	p, c	4	12.0	29.9	26.0
Fortune Bay	Lannon Cove	s, p, c	18	16.0	29.9	26.0
	Point Crewe	p, c	4	12.0	21.2	26.0
	Little Dantzic Cove	s, p, c	8	12.0	19.1	21.0
	Great Dantzic Cove	s, p	3,9	14.4	20.1	21.0
	Fortune Head	s, p, c	3,9	6.0	7.3	10.0
	Fortune Harbour	s, p, c	9	8.8	23.9	21.0

Fortune E	s, p, c	9,18	26.3	26.7	18.9
Grand Bank E	s, p, c	18	8.0	29.4	21.0
Grand Bank W	s, p, c	9	21.4	26.7	18.9
Kellys Cove	s, p, c	8	9.0	23.4	18.9
L'Anse au Loup	s, p, c	16,17,18	16.0	30.1	21.0
Molliers	s, p, c	18	16.0	30.1	21.0
Grand Beach	s, p, c	8,18	16.0	31.8	21.0
Frenchmans Cove PP	s, p	16,17	25.2	30.9	29.4
Frenchmans Cove	s, p	16,17,18	28.8	30.1	29.4
Garnish	s, p	9,16,18	17.3	30.1	21.0
Doughball Cove	s, p	16,18	17.3	30.9	21.0
Brown Harbour	s, p	16	17.3	30.9	18.9
Tilt Cove	s, p	18	15.9	26.8	12.2
Point Rosie	s, p	5,18	13.4	26.8	12.2
Grand Jersey Cove	s, p	18	15.6	26.8	12.2
Grand John	s, p	18	15.6	26.8	12.2
St. Bernards	s, p	18	12.6	28.9	18.0
Jacques Fontaine	s, p	18	12.6	28.9	18.0
Jacques Fontaine Gut	s, p	17,18	19.7	30.1	18.0
Bay L'Argent	s, p	9,18	13.5	25.1	12.2
Little Bay East	s, p	3,9,18	12.6	24.1	15.6
Little Harbour East	s, p, c	3,9,18	6.3	23.8	15.6
Harbour Mille	s, p, c	3,9,18	14.0	25.1	15.6
Terrenceville	s, p	9,16,18	18.0	28.1	22.0
Terrenceville W	w, s, p	24	14.4	23.8	18.0
Grand LaPierre	s, p	16,18,9,24	8.4	25.5	27.0
English Harbour East	s, p, c	9,18	11.3	24.1	15.6
Femme	s, p, c	3,9	7.5	17.8	12.2
Tranmer Cove	s, p, c	3,9	7.5	19.2	12.2
Andersons Cove	s, p, c	3,9	7.5	13.7	12.2
Hare Harbour	s, p, c	3,9	8.2	19.8	12.2
Tickle Harbour	s, p, c	2,3,9	2.5	27.9	12.2
Rencontre East	s, p, c	3,9,17,18	7.0	25.9	15.6

	Doctors Harbour	s, p, c	3,9,18	15.8	24.3	13.9
	Lally Cove	s, p, c	3,9,17,18	5.6	22.5	13.9
	Parsons Cove	s, p, c	9,17,18	10.5	21.1	13.9
	Bay du Nord	s, p, c	2,9	13.5	15.2	12.2
	Pools Cove	s, p, c	18	12.0	32.1	19.6
	Cinq Islands Bay	s, p, c	3,9	5.0	17.6	18.0
	Corbin	s, p, c	3,18	4.5	23.9	18.0
	Belloram	s, p, c	17,18,9	11.3	24.7	19.6
	St Jacques	s, p, c	16, 18	11.5	25.3	18.0
	English Harbour West	s, p, c	17, 18	11.2	23.9	18.0
	Mose Ambrose	s, p, c	17,18	22.5	26.7	18.0
	Little MaJambe	s, p	18	20.9	23.6	18.0
	Boxey Back Cove	s, p	9,17,18	19.8	26.7	18.0
	Boxey	s, p	9,16,17,18	22.7	30.1	18.0
	Saltwater Cove	s, p, c	16,13	16.3	25.2	19.6
	Coombs Cove	s, p, c	13,16	16.9	26.1	18.0
	Blunder Cove	p, c	3,6	6.4	16.7	13.9
	Wreck Cove	s, p, c	3,6,18	11.4	23.2	18.0
	Jersey Harbour	s, p, c	9,18	11.3	21.2	19.6
	Harbour Breton	s, p, c	8,9,17,18	11.3	21.2	18.0
	Deadmans Bight	s, p	18	31.6	27.4	22.0
	Dawsons Cove	s, p	18	33.7	27.8	22.0
	Seal Cove	s, p	18	29.3	26.7	22.0
Hermitage Bay	Beck Bay	s, p, c	16	26.2	26.7	18.0
	Pass Island	s, p, c	9	14.4	18.4	8.7
	Grole	s, p, c	18	16.9	27.4	22.0
	Hermitage	s, p	9,18	14.4	25.6	29.4
	Furbys Cove	s, p	9,18	14.4	25.6	22.0
	Hardys Cove	s, p	3,9,18	12.2	23.9	22.0
	Gaultois	s, p, c	3,6	12.0	14.4	14.7
	Conne River	s, p	9,18	8.2	23.1	19.6
	Morrisville	s, p	17,18	9.0	27.6	19.6
	Milltown	s, p	9	4.2	16.9	19.6

	Head of Bay d'Espoir	s, p	9	7.5	16.9	19.6
	St. Veronicas	w, s, p	18,24	6.3	24.3	20.8
	St. Josephs	w, s, p	9,18	8.5	27.6	20.8
	Swanger Cove	w, s, p	9,18,24	4.2	27.2	20.8
	St Albans N	s, p, c	3,9,18	8.8	28.7	23.2
	St Albans	s, p, c	9,18	8.0	27.2	23.2
South Coast	Patricks Harbour	s, p, c	3,9	11.1	21.1	10.4
	Goblin	r	3	4.6	19.9	8.5
	Great Jervis	s, p, c	3, 9	12.5	12.4	10.4
	Pushthrough	s, p, c	3, 9	12.5	16.3	10.4
	McCallum	s, p, c	3, 9	12.5	21.1	10.4
	Sagona Island	s, p, c	3,9	15.0	21.1	14.1
	Brunette Island	s, p, c	16,17,18	14.0	27.2	14.1
	Rencontre West	p, c	3,6	9.6	6.1	10.4
	Francois	p, c	6	9.6	6.1	10.4
	Grey River	s, p, c	6,9	9.6	6.1	10.4
	Ramea	s, p, c	3,6	15.0	14.5	18.0
	White Bear River	p, c	3,6	9.6	6.1	10.4
	Burgeo Short Reach	p, c	3,6	9.6	10.5	14.7
	Burgeo	s, p, c	3,6	9.6	11.2	22.0
	Sandbanks Prov Park	s	19,21	37.8	45.5	31.2
	Coombes head	s	12	34.2	33.2	22.0
	Great Barasway	s, p	16,17,18,19,20	35.5	39.4	31.2
	Billard Cove	s, p	3,8	9.8	12.9	10.4
	Northwest Arm	p, c	13,15	11.6	19.1	14.7
	Cinq Cerf Bay	p, c	3,6	9.6	6.1	10.4
	Grand Bruit	p, c	3,6	8.8	4.3	10.4
	Little Bay	p, c	3,6	9.6	6.1	10.4
	La Poile	p, c	3,6	9.6	5.4	10.4
	Harbour Le Cou	p, c	3,6	8.8	5.4	10.4
	Cairns Island	r	3	8.0	10.5	9.5
	Rose Blanche	p, c	3,6	9.6	12.1	10.4
	Diamond Cove	p, c	3,6	8.8	10.5	10.4

	Mull Face Bay	p, c	3,6		8.8	9.6	10.4
	Burnt Islands	p, c	3,6		9.6	12.1	10.4
	Coney Bay	p, c	2,6		8.8	10.6	10.4
	Otter Bay	p, c	3,6		9.6	12.1	10.4
	Isle aux Morts	p, c	3,6		8.8	9.6	10.4
	Fox Roost	p, c	3,6		9.6	12.1	10.4
	Margaree	r		3	3.0	7.4	9.5
Gulf of St Lawrence	Port aux Basques Ferry T	p, c	3,6		9.6	13.1	14.7
	Channel Port aux Basque	p, c	3,6		9.6	11.1	14.7
	Motherlake Bay C-PAB	p, c	3,6		9.6	12.7	14.7
	Mouse Island C-PAB	p, c		6	9.6	11.1	14.7
	Grand Bay East	r		3	3.0	10.4	9.5
	Grand Bay West	s	19,20		32.4	30.3	39.2
	Osmond	s	19,20		21.6	29.4	39.2
	JT Cheeseman	s		19	29.0	29.4	39.2
	Cape Ray	r		3	5.0	7.8	8.7
	Bear Cove	s, p, c	18,21		33.6	21.5	22.0
	Wreckhouse Cove	s, p, c		9	15.8	16.9	17.9
	Trainvain Brook Outlet	s, p, c		18	15.8	16.9	17.9
	St. Andrews	o, w, s, p	17,18,23,26		2.4	18.1	21.9
	Searston	s, p, c	16,17,18		16.0	18.5	22.0
	Great Codroy	o, w, s, p	23,26		6.3	13.4	17.9
	Millville	s, p, c	3,9		9.6	15.6	19.6
	Woodville	r, g	3,27		28.4	26.2	29.4
	Codroy	s, p, g	3,9,27		25.2	25.3	19.6
	Cape Anguille	r		3	5.0	7.8	10.0
	Snakes Bight	r		3	5.0	7.8	17.0
	Little Friars Cove	r		3	5.0	7.8	17.0
	Highlands	s, p, c		18	16.0	18.1	25.5
	Maidstone	s, p, c		9	16.0	14.6	25.5
	St. Davids	s, p, c	9,18		16.0	17.9	25.5
	Jeffreys	s, p, c		9	14.4	14.6	25.5
	McKay's	s, p, c		18	16.0	18.1	25.5

Robinsons	s, p, g	3,9,27		16.5	19.1	27.0
Heatherton	r		3	5.0	11.1	17.0
Fischell's	s, p, c		18	16.0	18.1	25.5
St Teresa	s, p, c		9	16.0	14.6	25.5
Flat Bay	s, p, c, g	9,27,24		30.6	19.1	27.0
Shallop Cove	s, p, c		18	16.0	18.1	25.5
St Georges	s, p, c		18	16.0	18.2	27.0
Seal Rocks	s, p, c		18	14.4	20.2	27.0
Barachois Brook	s, p, c		18	14.4	22.6	36.0
Stephenville Crossing	s, p, c	16,17,18		15.0	28.6	36.0
Stephenville Airport	s, p, c	16,17,18		15.6	23.3	36.0
Noels Pond	s, p, c		17	15.0	25.8	36.0
Stephenville	s, p, c	18,17		14.6	25.8	36.0
Kippens	s, p, c		9	21.0	17.8	27.0
Romaines	s, p, c, g	9,27		28.8	18.6	27.0
Berry Head	r		3	5.0	7.9	12.0
Port-au-Port West	s, p, c		18	16.0	28.6	12.0
Bellmans Cove	r		3	5.0	7.9	12.0
Felix Cove	s, p, c		9	21.0	19.5	27.0
Campbells Creek	s, p, c		9	21.0	19.5	27.0
Abrahams Cove	s, p, c		9	21.0	20.5	27.0
Jerrys Nose	r		3	5.0	9.0	6.9
Ship Cove	s, p, c		18	21.0	18.1	27.0
Lower Cove	s, p, c		18	21.0	18.1	27.0
Sheaves Cove	s, p, c		9	21.0	20.5	27.0
Marches Point	s, p, c		9	21.0	20.5	27.0
Red Brook	s, p, c		9	21.0	20.5	27.0
De Grau	s, p, c		9	21.0	20.5	27.0
Grand Jardin	s, p, c		9	24.5	21.3	36.0
Petit Jardin	s, p, c		9	28.0	21.3	36.0
Cape St George	r		3	5.0	4.1	6.9
Mainland	s, p, c		18	21.0	18.1	27.0
Three Rock Cove	s, p, c		18	24.0	14.2	27.0

Salmon Cove	p, c		6	14.4	7.4	20.8
Lourdes	p, c		6	14.4	7.4	20.8
Winterhouse	p, c		6	14.4	7.4	20.8
Long Point	s, p, c		18	24.0	23.3	21.2
West Bay	s, p, c	14,15,18		7.6	18.5	18.0
Picadilly	s, p, c	9,18		7.6	18.5	18.0
Boswarlos	s, p, c	9,18		12.5	18.5	18.0
Aguathuna	s, p, c		9	12.5	15.4	18.0
Point au Mal	s, p, c	14,15,17,18		15.0	15.4	18.0
Fox Island River	s, p, c	14,15,17,18		7.0	15.4	18.0
Broad Cove	s, p, c		18	32.0	14.8	22.0
Molly Ann Cove	s, p, c		9	28.0	12.2	22.0
Bear Cove	p, c		6	19.2	14.8	22.0
Little Port	p, c		15	18.0	20.8	22.0
Bottle Cove	p, c		15	14.4	19.6	22.0
Lark Harbour	p, c	13,14,15		13.5	20.8	22.0
York Harbour	p, c	14,15		14.4	18.9	27.0
Frenchmans Cove	p, c		15	18.0	18.1	22.0
Johns Beach	p, c		6	9.6	11.9	27.0
Benoits Cove	p, c		15	18.0	18.1	22.0
Halfway Point	s, p, c		18	9.6	11.9	22.0
Mount Moriah	s, p, c		9	9.6	11.9	22.0
Petries	s, p, c		9	11.2	11.9	22.0
Curling	s, p, c		9	11.2	12.4	22.0
Corner Brook	s, p, c		18	8.0	11.6	23.2
Humbermouth	w, s, p	9, 23		4.8	10.3	24.0
Wild Cove	w, s, p	21,18		9.6	18.1	24.0
Irishtown	s, p, c		9	18.8	14.6	19.6
Summerside	s, p		18	21.6	18.1	22.0
Meadows	s, p, c		9	18.8	18.1	22.0
Gillams	p, c		15	16.6	20.2	22.0
McIvers	s, p, c	13,15		16.6	22.1	24.5
Cox's Cove	p, c	14,15		16.6	16.6	19.6

	Goose Arm	s, p, c	14,15,23		3.5	5.2	4.0
	North Arm	p, c		14	7.0	5.2	4.0
Northern Peninsula	Trout River	p, c	14,15		18.0	19.7	24.5
	Curzon	p, c		6	11.2	10.1	19.6
	Woody Point	s, p, c		18	18.0	14.8	22.0
	Shoal Brook	s, p, c		18	18.0	14.8	22.0
	Winterhouse Brook	s, p, c		18	18.0	12.9	22.0
	Birchy Head	s, p, c		9	11.2	14.0	22.0
	Glenburnie	s, p, c		16	15.8	14.8	22.0
	Lomond	s, p, c	9,16		15.8	13.8	22.0
	Norris Point	s, p, c	18,15		18.0	12.9	22.0
	Rocky Harbour	p, c	4,15		15.6	15.6	22.0
	Bear Cove	p, c		15	16.8	15.0	11.3
	Lobster Cove	p, c		5	16.8	14.4	9.0
	Western Brook Pond out	s	19,20,21		32.4	26.5	39.2
	Sally Cove	s, p, c	5,18		16.8	14.4	24.0
	St. Pauls	o, s, p, c	18,24,26		7.2	11.7	26.8
	Cow Head	s, p, c	16,17,18		12.2	15.7	24.0
	Shallow Bay	s	19,20,21		27.0	22.9	31.2
	Parson's Pond	s, p, c		18	21.6	20.2	24.0
	The Arches	p, c	2,5		5.4	14.2	9.0
	Portland Creek	s		21	24.3	26.5	39.2
	Daniels Harbour	s, p, c	15,18		21.6	20.2	24.0
	Spudgels Cove	p, c		5	9.6	9.1	11.3
	Bellburns	p, c		15	9.6	10.2	12.7
	Bateau Cove	p, c		15	9.6	10.2	12.7
	River of Ponds	p, c	5,4		7.2	10.2	14.7
	Spirity Cove	p, c		5	9.6	9.1	12.7
	Hawkes Bay	p, c	4,5		9.6	9.1	12.7
	Hawkes Bay N	p, c		4	9.6	9.1	12.7
	Port Saunders E	p, c		4	7.2	8.3	11.3
	Port Saunders	p, c		5	8.4	9.1	12.7
	Port au Choix	p, c		15	21.6	16.5	14.7

Port au Choix NHS	p, c		15	21.6	17.2	19.6
Port au Choix Back Cove	p, c		15	17.4	14.3	12.7
Bustard Cove	p, c		4	9.6	8.7	11.3
Eddies Cove West	p, c		4	9.6	9.1	11.3
Barr'd Harbour	p, c	4,5		9.6	9.1	11.3
Squid Cove	s, p, c		8	11.2	14.2	19.6
Castors River	s, p, c	5,7,8		9.6	14.2	19.6
Bartletts Harbour	p, c		15	11.2	14.2	19.6
New Ferolle	p, c	5,15		12.4	14.2	19.6
Shoal Cove	p, c	4,5		9.6	9.1	11.3
Reefs Harbour	p, c	4,5		9.6	9.1	11.3
Bird Cove	p, c		4	9.6	9.1	11.3
Brig Bay	p, c	4,5		9.6	9.1	11.3
Plum Point	p, c		15	12.8	16.4	19.6
Blue Cove	p, c		5	12.8	10.3	11.3
Pond Cove	p, c		15	16.0	14.2	19.6
Forresters Point	s, p, c	5,8		14.4	14.2	19.6
Current Island	p, c		4	12.8	14.2	19.6
Black Duck Cove	p, c		15	12.8	10.9	11.3
St. Barbe	p, c		15	12.8	10.9	11.3
Anchor Point	p, c	4,5		12.8	11.2	11.3
Deadmans Cove	p, c		15	12.8	10.9	11.3
Bear Cove	s, p, c	5,8		14.4	14.2	19.6
Flowers Cove	s, p, c	5,8,15		16.0	16.4	19.6
Nameless Cove	p, c	5,15		12.8	10.9	11.3
Savage Cove	p, c		5	12.8	10.9	11.3
Sandy Cove	p, c		5	12.8	10.9	11.3
Shoal Cove East	p, c		4	12.8	10.9	11.3
Green Island Cove	p, c		5	12.8	10.9	11.3
Green Island Brook	p, c		5	12.8	10.9	11.3
Eddies Cove	p, c		5	12.8	10.9	11.3
Watts Point	r		2	5.0	9.2	5.7
Four Mile Cove	r		2	5.0	9.2	5.7

Big Brook	p, c		5	12.8	10.9	11.3
Boat Harbour	p, c	4,5		12.8	9.2	11.3
Cape Norman	p, c		4	12.8	10.9	11.3
Wild Bight	p, c		5	9.6	9.2	15.6
Cooks Harbour	p, c		5	5.4	12.4	18.0
Pistolet Bay	p, c		4	5.4	12.4	18.0
Milan Arm	p, c	4,5		5.4	10.6	15.6
Raleigh	p, c		15	6.3	12.4	12.0
Ship Cove	p, c		15	9.6	9.6	12.0
Onion Cove	p, c		15	9.6	10.1	12.0
L'Anse-aux-Meadows	p, c		4	10.2	14.3	26.0
Spillars Cove	p, c		4	10.2	14.3	20.8
Noddy Bay	p, c		15	12.8	16.2	20.8
Straitsview	p, c		5	10.2	11.5	20.8
Quirpon	p, c		4	9.6	11.5	20.8
Gunners Cove	p, c		5	9.6	11.5	20.8
Griquet	p, c		5	9.6	11.5	20.8
St Lunaire	p, c		5	9.6	11.5	20.8
Great Brehat	p, c		6	8.4	10.9	20.8
St Carols	p, c		6	8.4	10.9	20.8
St Anthony Bight	p, c		6	5.6	10.9	18.4
Marguerite Bay	p, c		15	4.8	10.4	18.4
St. Anthony	p, c		15	4.8	11.7	23.7
Cremaillere Harbour	p, c		6	8.4	11.7	20.8
Goose Cove	p, c		5	4.8	17.6	26.0
Cigale Cove	p, c		6	4.8	14.2	12.7
Irelands Bight	p, c		6	4.8	14.2	12.7
Howe Harbour	p, c		14	5.6	17.3	12.7
Locks Cove	p, c		6	5.6	14.2	12.7
Northern Arm	p, c		5	4.8	15.4	12.7
Seal Bay	p, c		4	7.2	14.6	12.7
West Brook Arm	p, c		14	7.2	14.6	12.7
Main Brook	p, c		15	7.2	16.6	13.9

	Grandois	p, c		6	8.4	9.8	18.0
	St. Juliens	p, c		5	8.4	10.1	18.0
	Croque	p, c		6	8.4	10.1	18.0
	Crouse	p, c		14	14.0	20.7	20.8
	Conche	s, p, c		8	8.4	17.6	18.0
	Englee	p, c		15	4.8	10.9	18.0
	Englee Island	p, c		15	12.8	11.5	18.0
	Englee N	p, c		6	6.0	9.9	13.9
	Bide Arm	s, p, c		9	8.0	9.9	8.0
	Dowers Harbour	s, p, c		18	8.0	9.9	8.0
	Roddickton	s, p, c	16,18		4.8	13.1	13.9
	Northwest Brook mouth	r		3	0.4	4.6	4.7
	Cloud River Mouth	r		3	0.4	4.6	4.7
	Weymouth Cove	p, c		6	5.6	5.1	8.0
	Otter Cove	p, c		6	8.4	6.9	8.0
	Wild Cove	p, c		5	7.0	6.9	8.0
White Bay	Canada Harbour	p, c		6	5.6	5.1	9.8
	Hooping Harbour	p, c		6	5.6	5.1	8.0
	Fourche Harbour	p, c		6	5.6	5.1	8.0
	Harbour Deep	p, c		6	7.0	6.9	9.8
	Cat Arm	p, c		6	5.6	5.1	8.0
	Great Coney Arm	p, c		15	10.5	19.1	9.8