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COASTAL MONITORING ON THE AVALON PENINSULA

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ABSTRACT

A new program of coastal monitoring has been jointly initiated by the provincial Geological Survey Branch and the federal Geological Survey of Canada. Monitoring of beach profiles and cliff-edge recession rates is taking place at a number of sites on the Avalon Peninsula of Newfoundland, including Placentia, Ship Cove and Big Barasway on Placentia Bay; the Holyrood Pond area of St. Mary's Bay; and the Topsail–Manuels area of Conception Bay. The sites were selected so as to cover as wide a geographic area as possible; to provide information in areas where problems already exist; and to build on existing studies. The objectives of this program are to provide long-term regular monitoring of selected sites, using the expertise residing in the Atlantic Geoscience Centre (GSC) and the advantages of accessibility for Geological Survey Branch staff. The ease of access to these sites has already allowed more frequent visits than under previous programs. Regular surveys on an annual or more frequent basis will substantially improve the value of the data, providing better estimates of mean coastal recession rates and a basis for relating variations in coastal response to the oceanographic, climatic, or geological factors that determine erosion rates.

INTRODUCTION

The Province of Newfoundland and Labrador, in particular the Island of Newfoundland, has a strong maritime influence. Most communities on the island are on the coast and the majority of the population lives and works in coastal environments. The nature and stability of the coast are therefore matters of practical importance, for they influence many aspects of land-use and development. Coastal stability can be affected by changes in mean sea level, wave climate, sediment supply, or by human intervention. Ongoing coastal erosion at many sites and a history of costly flood damage at others (Forbes, 1984; Forbes *et al.*, 1989) indicate that the coast of Newfoundland is vulnerable to environmental change. This demonstrates the need to monitor present rates of erosion and shoreline adjustment as a basis for long-term planning and appropriate decision-making in the coastal zone.

This paper describes the establishment of a monitoring program conducted jointly by the Geological Survey Branch (GSB) and the Geological Survey of Canada (GSC), concentrating initially on the Avalon Peninsula (Figure 1). The study is based on, and extends, an existing monitoring network initiated by the GSC in 1981 (Forbes, 1984, 1985; Shaw and Forbes, 1987, 1990a; Forbes *et al., in press*) and recently complemented by work at Memorial University of Newfoundland (e.g., Boger and Catto, 1993; Catto, 1993; Prentice, 1993). The objectives of this program are to provide long-term regular monitoring of selected sites, using the expertise residing in the Atlantic Geoscience Centre and the advantages of accessibility for Geological Survey Branch staff. The ease of access to these sites has already allowed more frequent visits than under previous programs. Regular surveys on an annual or more frequent basis will substantially improve the value of the data, providing better estimates of mean coastal recession rates and a basis for relating variations in coastal response to the oceanographic, climatic, or geological factors that determine erosion rates (cf. Dolan *et al.*, 1991; Solomon *et al.*, 1993).

One of the most critical factors affecting coastal stability is the rate of change in the relative mean sea level at a site. Over the past 15,000 years, relative sea levels have fluctuated considerably around the coast of Newfoundland (e.g., Grant, 1989; Catto, 1993; Liverman, 1993; Shaw and Forbes, 1993). Continuing changes in sea level are evident in tide-gauge records (Shaw and Forbes, 1990b). These can be attributed to continuing postglacial isostatic adjustment of the earth's crust and changes in ocean volume on a global scale, among other factors (e.g., Peltier and Tushingham, 1989; Gornitz, 1993). In addition to tide-gauge records during the present century, evidence for rising relative sea levels on the Newfoundland coast over the past few thousand years includes the landward encroachment of salt-marsh deposits (e.g.,

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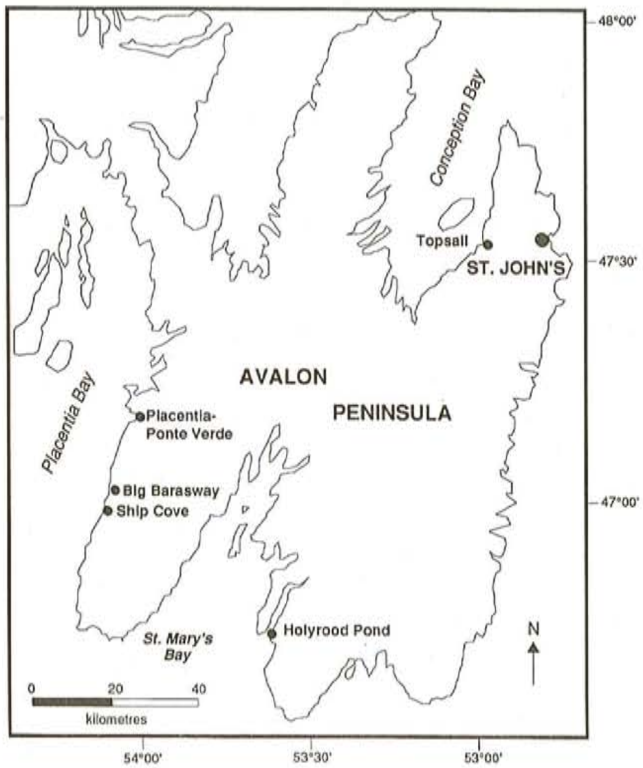

Figure 1. *Avalon Peninsula showing site locations.*

Brookes *et al.*, 1985; Shaw and Forbes, 1987, 1990a), seaward-rising ridges in prograded beach-ridge sequences (Forbes, 1985; Shaw *et al.*, 1990; Shaw and Forbes, 1992), and the transgressive nature of many littoral systems throughout the island (Forbes, 1984; Shaw and Forbes, 1990a; Forbes and Shaw, 1992). Rates of present relative sea-level rise in Newfoundland may range as high as 0.4 m per century (Shaw and Forbes, 1990b) and the possibility of more rapid rise due to the effects of global warming and the melting of polar ice masses needs to be considered in planning future coastal management strategies (Shaw *et al.*, *in press*).

The coastal response to rising sea level is a function of the rate and variability of sea-level change, the physiographic setting, wave exposure, storm frequency and intensity, sediment type and availability, and shoreline characteristics (which determine the morphodynamic response to individual events that reshape the shore profile), among other factors (e.g., Bruun, 1962; Dean *et al.*, 1987; Forbes *et al.*, 1989; Orford *et al.*, 1991). Barrier-beach systems may remain relatively stable for long intervals (decades to centuries), followed by rapid changes when thresholds of stability are exceeded (Forbes *et al.*, 1991; Carter *et al.*, 1993). As experience of high water levels in the Great Lakes has shown (Moulton and Cuthbert, 1987), unconsolidated bluffs can be particularly susceptible to accelerated erosion because higher water levels enable larger waves to reach the shoreline and allow runup to the toe of the bluffs. Erosion rates in such settings depend on many factors including shoreface slope and composition, beach characteristics, wave climate, cliff lithology and geotechnical properties. Detailed and site-specific studies are required to determine the interplay between these factors and the main controls on erosion at any one location.

VULNERABILITY TO COASTAL HAZARDS IN NEWFOUNDLAND

Coastal hazards in Newfoundland are comparatively minor relative to those in many other parts of the world, due to the steep and rocky coastline that characterizes much of the region. Certain areas are vulnerable because of their geomorphic setting. The most serious natural disaster recorded along the Newfoundland coast resulted from tsunami runup along the southern coast of the Burin Peninsula following the 1929 Grand Banks earthquake and caused significant loss of life. Although tsunami waves remain the most potentially damaging hazard in the region, the probability of such an event is very low (Forbes, 1984). More chronic problems requiring appropriate land-use planning or engineering intervention involve areas of development on beach-ridge complexes or other low-lying coastal areas subject to storm-surge flooding; road links across barriers subject to overwash and breaching; and construction of homes or other infrastructure close to eroding coastal cliffs, especially bluffs cut in unconsolidated Quaternary deposits. Vulnerability to coastal hazards can be increased by inappropriate activities, such as removal of beach material, large-scale quarrying immediately landward of eroding cliffs, or other expansion of development into vulnerable areas.

A number of communities and roads on the Avalon Peninsula are known to be vulnerable to wave runup, flooding, or erosion (Shaw *et al.*, *in press*). Placentia (Plate 1, Figure 2) has been flooded regularly in storms over the past decade or more (Shawmont Martec Limited, 1984; Forbes, 1984; Forbes *et al.*, 1989). Recent defences against flooding have been constructed in Placentia at a cost of more than $3 million (R. Dillon, Department of Municipal Affairs, personal communication, September 1993). Much of the area on the landward side of the beach–ridge complex lies below mean high water level and only a restricted tidal range within the estuary protects this area from more frequent flooding (Shaw *et al.*, *in press*). Although the original choice of this site for a 16th Century fishing community was appropriate (Forbes, 1985), it is not a suitable location for modern suburban expansion. Development has accelerated in this area over the past 15 years with the construction of a senior citizens' residence, a new school, and several large commercial buildings.

Another vulnerable area on the Avalon Peninsula is the stretch of highway that crosses the mouth of Holyrood Pond. Despite the unusually high elevation of the barrier crest (more than 7 m above mean sea level; Forbes, 1984, 1985) this road has been washed out at least twice in recent years (during storms in January 1982 and March 1985) and the community of St. Vincent's has been flooded. In an effort to raise the barrier crest and limit future incidents of this kind, an artificial gravel ridge and wooden seawall have been constructed in the past few years. The effectiveness of this

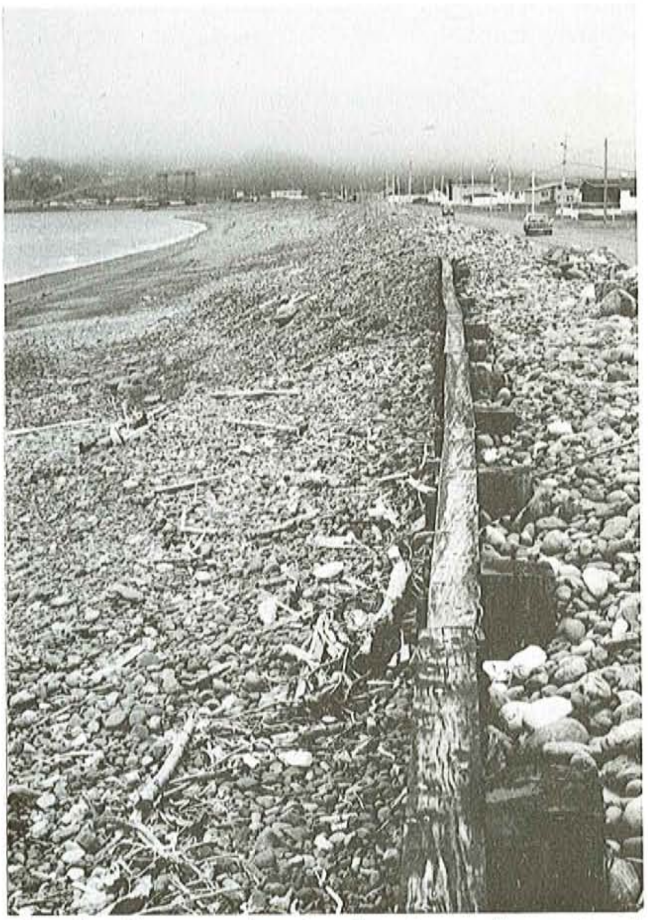

Plate 1. *View east along beach and seawall near line 3, Placentia, July 1993.*

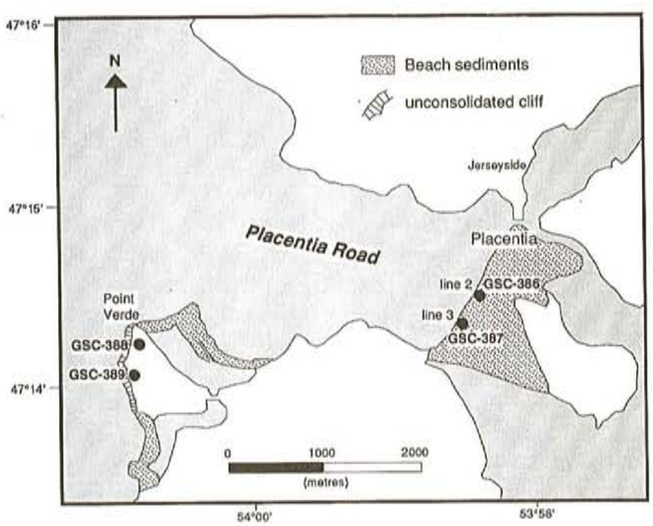

Figure 2. *Point Verde and Placentia study areas, showing beaches, survey line and benchmark locations.*

structure remains to be assessed. Immediately east of the Holyrood Pond barrier, the road runs close to the edge of 25 m high unconsolidated cliffs and may be vulnerable to erosion. Other areas where structures have been built to protect roads include the tombolo linking Powles Peninsula to the mainland in Trepassey. Here as elsewhere, seawall defences may have limited life expectancy because of increased wave reflection, beach steepening, gravel overtopping, and rising sea levels.

It is desirable to limit development in areas where large-scale expenditures on coastal protection of limited viability will be required to prevent serious property loss. Such areas include low-lying coastal sites susceptible to increased flood risk in the event of accelerated sea-level rise. They also include locations where coastal recession may lead to land loss and endanger dwellings or other structures. In this case, reliable information on rates of coastal erosion and the potential for accelerated erosion are necessary in order to establish reasonable set-back limits for new development. In both cases, long-term monitoring and a more comprehensive knowledge of coastal processes are key ingredients in the search for suitable planning strategies to ensure appropriate development.

MONITORING PROGRAM

In 1993, in response to the needs and problems outlined above, a small-scale collaboration for coastal monitoring was initiated between the GSB and the GSC to supplement longer term infrequent monitoring by the GSC. This program is concentrated on the Avalon Peninsula, where it is possible for GSB geologists to make frequent site visits. Two kinds of monitoring activities have been developed, one to determine erosion rates of unconsolidated bluffs, the other to provide some understanding of beach dynamics and stability.

SITE LOCATIONS

Four areas were chosen for study (Figure 1), one in Conception Bay (the Topsail–Chamberlains area), two in Placentia Bay (Placentia–Pointe Verde and Big Barasway–Ship Cove) and one in St. Mary's Bay (Holyrood Pond–St. Stephens). The sites were selected so as to cover as wide a geographic area as possible; to provide information in areas where problems already exist; and to build on existing studies. As described earlier, the Placentia and Holyrood Pond areas have experienced numerous problems associated with wave overtopping and flooding. The GSC has been monitoring coastal stability at these sites for more than 10 years. The Topsail–Chamberlains area was severely affected by a major storm in October 1992, and appears to be experiencing increased erosion rates in recent years (N.R. Catto, Memorial University, personal communication, 1993). Some detailed monitoring and investigation of Topsail Beach was undertaken in the early 1980's by the GSC and more recently by Prentice (1993). The Ship Cove and Big Barasway beaches are small gravel barriers of differing character that have been the subject of detailed monitoring and study since 1991 (R. Boger, personal communication, 1993; Boger and Catto, 1993).

METHODS

Benchmarks were installed at each site by placing 3-inch diameter aluminum caps on 2 m lengths of rebar driven into the ground. The location of each benchmark was determined using a Magellan NavStar-5000 Global Positioning System (GPS) receiver. At each GPS site, 32 readings were averaged and recorded relative to the NAD83 datum. The standard deviations for these positions were generally less than 5 m. In the case of cliff-top sites, benchmarks were placed 10 to 25 m back from the cliff edge. Distances were measured to the top of the cliff using a fibre tape along bearings determined by Brunton compass. Where possible, other markers (e.g., fence posts, structures, prominent boulders) were used to supplement the benchmarks. At most sites, at least four measurements to cliff edge were obtained. In the case of beach sites, benchmarks were placed landward of the active beachface to ensure that they will not be overwhelmed by beach erosion or sedimentation. Profiles were measured using a simple paired-staff levelling and tape system. The profile data (incremental distance and elevation seaward along the profile) were entered into a microcomputer and archived on 3.5 inch diskettes. Elevations were referred to mean water level determined from tide tables (CHS, 1991) or by reference to geodetic benchmarks where accessible. At some sites (Placentia, Big Barasway, and Ship Cove), profile lines established in previous years (Forbes, 1985; Boger and Catto, 1993) were successfully located and resurveyed.

PLACENTIA BAY SITES

The beaches of Placentia, Big Barasway, and Ship Cove are developed along the eastern shoreline of Placentia Bay (Figure 1). Big Barasway and Ship Cove occupy adjacent embayments 12 and 15 km south of Placentia, respectively. Protective structures at Placentia reflect a long history of occupation. Big Barasway and Ship Cove are relatively pristine, yet both have also been subjected to some artificial modification. The beaches at all three sites, like most others in Newfoundland, are derived from local deposits of glacial or proglacial sediment (Forbes and Taylor, 1987; Forbes and Syvitski, *in press*) and their stability depends in part on continued supply from these sources. Erosion at Point Verde has already removed most or all of the deposit, which fed construction of the Placentia beach-ridge plain (Figure 2). The beach at Big Barasway is associated with existing cliff exposures to the north and south and a former source in the middle of the system. The Ship Cove beach is also derived from adjacent active cliff sources.

The outer coast sites (Big Barasway and Ship Cove) are exposed to ocean waves approaching up the bay from the south and southwest. Fetches are restricted by the central landmass of Newfoundland to the north and northwest, the Burin Peninsula to the west, and the Avalon Peninsula to the east. Therefore, southwesterly storms have the most pronounced geomorphic effect in this area, although locally generated waves from the west and northwest may also be effective and are assumed to dominate the wave climate in the more protected Placentia site. The 1-, 10- and 100-year significant wave height in deep water were estimated to be 8, 11, and 15 m, respectively by Neu (1982). Although Placentia Bay is usually free of ice during the winter storm season, occasional pack-ice intrusion has been observed (e.g., in March of 1985). The tides are mixed semi-diurnal with a maximum range of 2.5 m.

Placentia and Point Verde

The Placentia townsite occupies a pebble–cobble beach–ridge plain constructed by beach progradation over the past 2000 to 2500 years (Shaw and Forbes, 1988). The beach ridges are clearly visible on aerial photographs (see Figure 2 of Forbes, 1985). These reveal several distinct phases of varying progradational style and realignment (Forbes and Shaw, 1992). The modern beach forms a gentle arc, approximately 1.2 km long, dominated in the western and central area by large boulder cusps. Sand and finer gravel occupy the lower beachface and sand is present in the nearshore. The original source of the beach material, presumed to be ice-contact outwash deposits near Point Verde at the mouth of Placentia Road (Figure 2), is now exhausted and the beach has undergone progressive realignment through erosion at the proximal (western) end and accretion toward the east. The present tidal channel (The Gut) is artificially stabilized and attempts were made to enhance accretion on the beach and diminish sedimentation on the ebb shoal by construction of two groynes in the early 1980's. Sediment has accumulated against the groynes but additional gravel in any quantity can only be derived from erosion of the beach to the west. The attempt to stabilize the western beach by construction of a seawall may ultimately be doomed without continued large expenditures, as erosion and beachface steepening in that area may lead to overtopping and eventual destruction of the wall.

Placentia has had a long history of flood damage over the last century, aggravated by urban development over the past 15 to 25 years into the area lying directly back of the modern beach. Flooding occurs either as a result of high water levels in the estuary (which may be caused by storm runoff, storm surge, high tides, or a combination of these) or as a result of storm wave runup and overtopping along the outer beach, or both. The most damaging flood event was in January 1982, when high waves were superimposed on very high tides. Wave overtopping occurred near line 3 and overwashing developed in the vicinity of line 2 (Shawmont Martec Limited, 1984; Figure 2). Damage associated with this flood was estimated at $750,000 (newspaper reports cited by Forbes, 1984). Severe flooding also occurred in December 1983 and (less severe) at Christmas 1992. The provincial Department of Municipal Affairs has responded to this problem by constructing shoreline defences. The most recent were completed in 1993 at a cost in excess of $3 million and consist of a 1.5-m-high steel casing along the inner channel bank and construction of an extension to the existing sea wall (Plate 1).

Benchmarks have been installed at two locations along the top of unconsolidated cliffs at Point Verde, to allow measurement of cliff erosion. Although data on cliff recession rates at Point Verde will only become available as measurements are repeated over the coming months and years, structures associated with the lighthouse have been lost over the cliff in recent time (Plate 2) and erosion is clearly active. A boulder-lag platform on the northeast side of Point Verde is believed to mark the location of a former part of the ice-contact deposit, thought to have been the source of most beach sediment at Placentia.

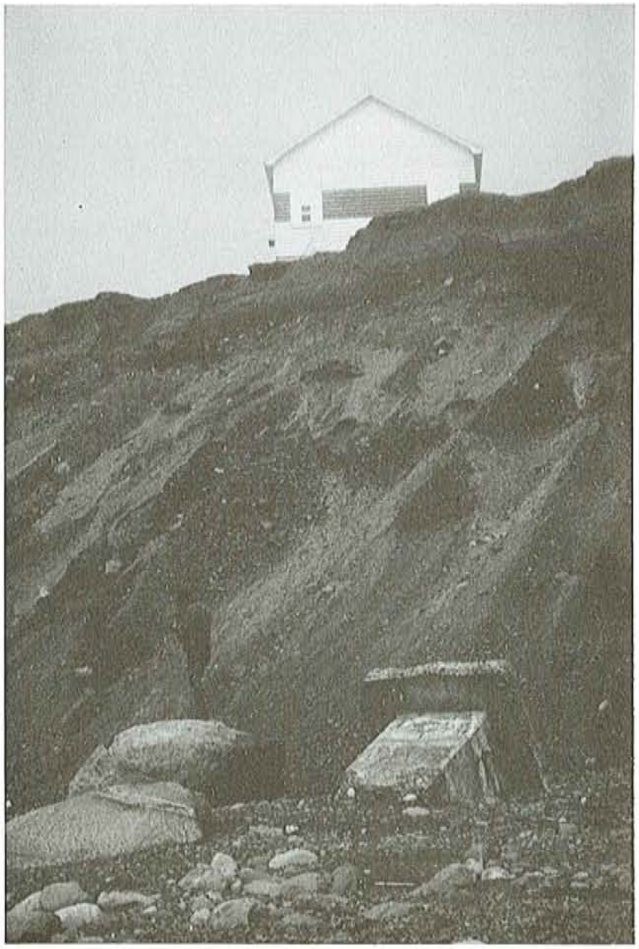

Plate 2. *Cliff at Point Verde, showing erosion of cliffs developed in ice-contact diamicton, sands, and gravels, and collapse of structures associated with the Point Verde light.*

Benchmarks were also installed at two previous survey lines on the beach at Placentia and the beach profiles at these sites were resurveyed (Figure 3). The results show a landward shift of the mean water line of 5.7 m at line 2 and 3.5 m at line 3 over the 10 years between 12th June, 1983 and 15th July, 1993. More detailed analysis indicates that between 2.5 and 2.8 m above mean water level at line 2, on the face of a cusped upper berm, the horizontal displacement was less than 1 m among four profiles surveyed in June 1983, March 1985, May 1988, and July 1993. The profiles show substantial variations on top of the berm and the natural beach crest at an elevation of 4.5 m above mean water level where the natural beach has been replaced by artificial fill against the seaward face of an extended seawall that rises to 5.9 m. At line 3, the foreshore profiles of May 1988 and July 1993 are almost indistinguishable up to 1.5 m above mean water level, but a later survey (September 1st, 1993) shows 0.3 to 0.4 m vertical accretion on the upper foreshore. Large changes

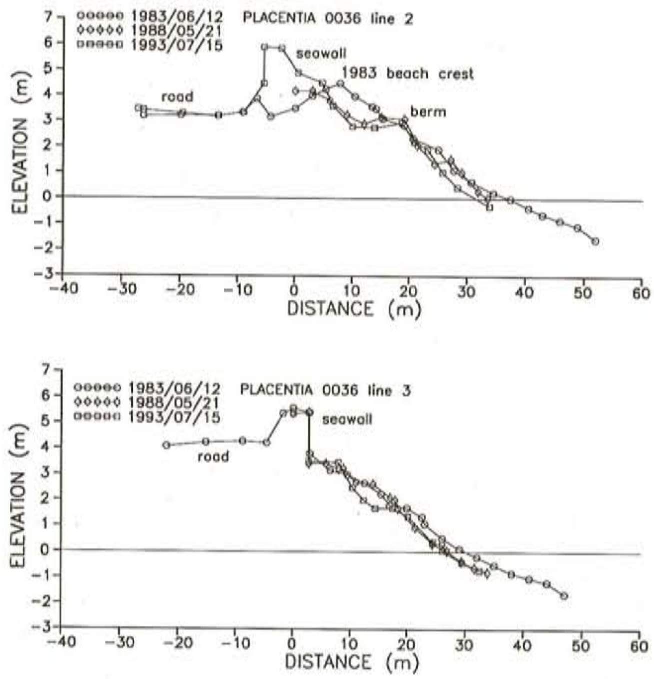

Figure 3. *Surveyed profiles at lines 2 and 3, Placentia, in 1983, 1988, and 1993.*

between profiles above this level reflect remodelling of the cobble—boulder cusps on that part of the beach. The elevation of the gravel against the base of the seawall varied less than 0.4 m between the three profiles.

Big Barasway

The 1.3-km-long beach system at Big Barasway (Figure 4) consists of two baymouth barrier beaches, separated by a 200-m-long vegetated island. The baymouth barriers merge into fringing beaches at each end. Barrier widths range from 25 to 95 m and crest heights from 2.0 to 4.8 m above mean water level. The greater widths are associated with washover fans along the back of the barrier. The beach consists mostly of cobbles and boulders with some pebbles and sand. A stream outlet is located 400 m from the north end of the beach and a gently sloping subtidal platform extends for 500 m alongshore in the central area. The overall shape of this barrier is a seaward-convex arc. In this respect, it differs from most other beaches along the eastern shore of Placentia Bay.

The rocky headlands bordering the south end of the beach are flanked by bluffs of unconsolidated diamicton 1 to 5 m thick. To the north, the beach continues for 1.5 km along the base of a 70-m-high cliff exposure of glacial sediments. A 200-m-long island is vegetated with spruce and flanked on the seaward side by beach gravels. The sediments forming the island consist of diamicton overlain by peat and a thin soil. The stream outlet at the northern end of the beach appears to remain open at all times and widened by more than 5 m between 1992 and 1993.

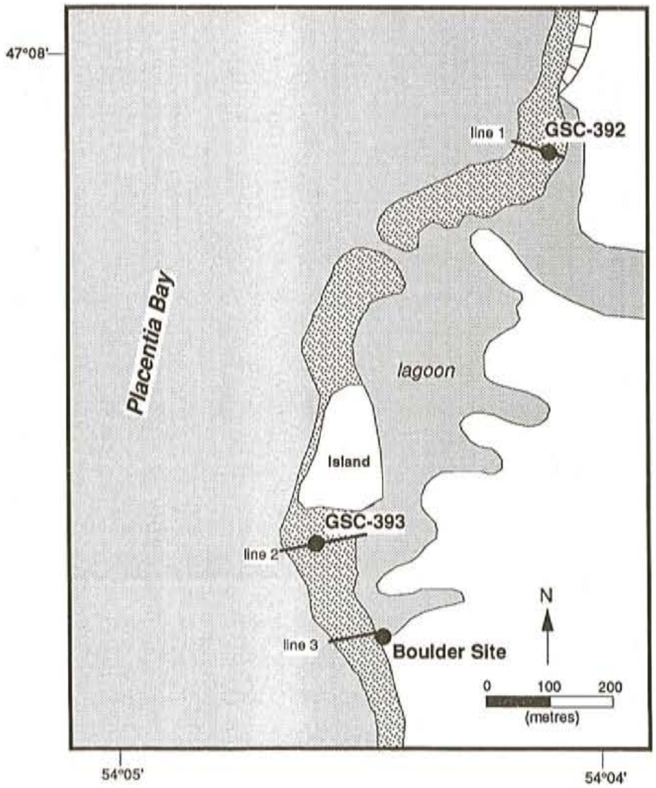

Figure 4. *Sketch map of Big Barasway study area, showing benchmark locations and survey lines.*

Three beach profile lines were established at Big Barasway in positions designed to extend the monitoring initiated by Boger (unpublished data). Line 1 was located on the northern segment in the same position as Boger's line BB-34; lines 2 and 3 were established at the south end at the locations of lines BB-10 and BB-6, respectively, of Boger (unpublished data).

Although the dominant direction of longshore transport is northward, the development of separate and distinctive flow cells, each with differing dynamics and sedimentation, results in strong differences between the northern and southern segments of the system. Beach profiles at the south end show high elevations and steep, occasionally cusped, beachface slopes (Figure 5), in contrast to the lower crest height at the north end of the barrier. In the vicinity of line 2, the crest elevation decreases to about 3 m and large washover fans are present along the back of the barrier (Figure 5). Overall, the Big Barasway beach shows a seasonal pattern of net accretion during the summer (May to September) and net erosion during other months of the year, except at the extreme north end, where sediment moves on- and offshore throughout the year depending on the intensity and direction of storm events. Two years of monitoring from July 1991 to July 1993 revealed substantial horizontal profile excursions in the vicinity of mean water level near line 2 (Boger, unpublished data).

Ship Cove

The beach at Ship Cove (Figure 6) is 500 m long. The northern 200 m forms a bayhead barrier. The barrier width

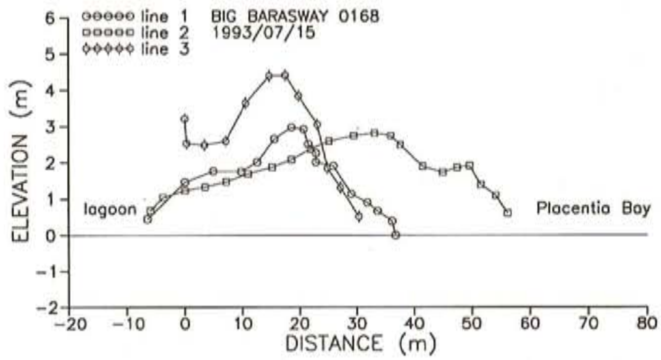

Figure 5. *Beach profiles at lines 1, 2, and 3, Big Barasway, as surveyed in July 1993.*

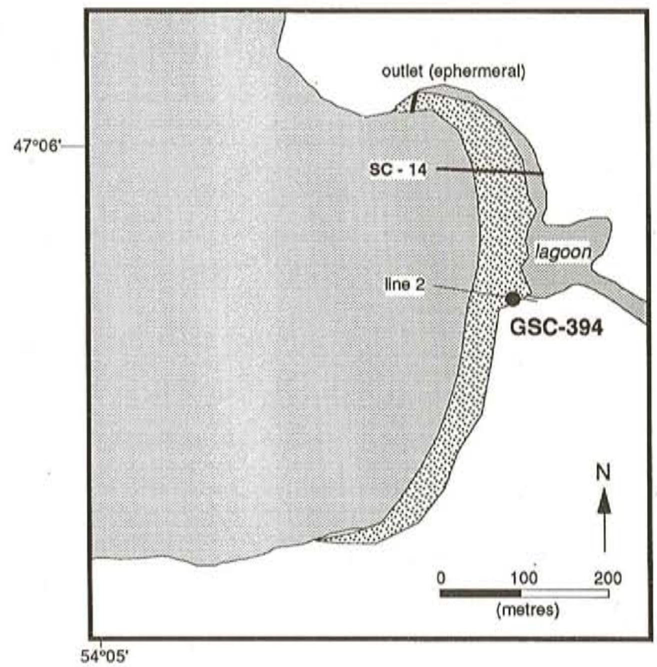

Figure 6. *Sketch map of Ship Cove study area, showing benchmark locations, line 2 (this survey), and line SC-14 (Boger, unpublished data).*

ranges from 40 to 60 m and the crest height from 4.0 to 5.5 m above mean sea level (narrower and lower in the vicinity of the outlet stream). Headlands at both ends of the cove consist of siltstone and sandstone overlain by up to 5 m of unconsolidated diamicton. The sediment on the beach consists of well-sorted, well-rounded, bladed and discose pebbles and cobbles, except at the southern end where sand and granules predominate. Clasts on berm crests are well imbricated. Tiers of cusps with wavelengths ranging from 1 to 20 m are common.

A single benchmark was established close to the centre of Ship Cove in the approximate position of line SC-11 of Boger (unpublished data). The profile shows a crest elevation of 5.1 m and a wide berm at 2.0 m. As at Big Barasway, the beach at Ship Cove shows a cyclical pattern of net sediment accumulation during the summer and net removal during the stormier months of the year, as shown by beach profiles at line SC-14 of R. Boger (unpublished data) (Figure 7). Overtopping of the beach during storm events supplies sediment to the landward side of the beach ridge, and steepens the profile. Throughout the summer, landward movement of sediment steepens the middle beachface. During the autumn, the slope decreases as sediment is removed seaward. Substantial erosion during a major storm in December 1991 revealed an underlying cobble–boulder framework (Plate 3). Sediment stripped from the upper beachface by this storm has not been replenished. Ice-foot development at Ship Cove, as at Big Barasway, tends to reduce overwashing during the winter months. In contrast to Big Barasway, where the stream outlet is stable, the outlet at Ship Cove can open and close on an hourly to daily basis in mid to late summer, depending on the volume of stream discharge and the level of wave activity. When the outlet is closed, freshwater drains seaward by seepage. Aggregate removal at the south end of the beach and artificial relocation of the outlet toward the north has resulted in changes in the sediment supply, particularly through removal of finer grain sizes, and possibly has increased wave runup.

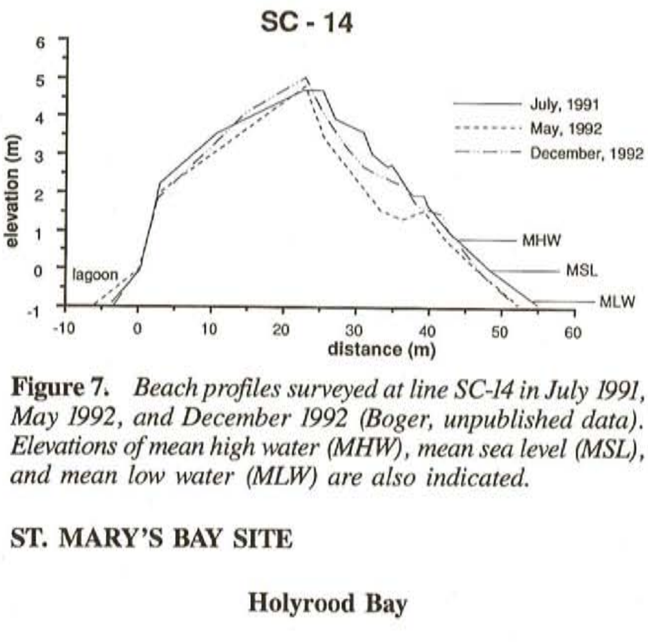

Figure 7. *Beach profiles surveyed at line SC-14 in July 1991, May 1992, and December 1992 (Boger, unpublished data). Elevations of mean high water (MHW), mean sea level (MSL), and mean low water (MLW) are also indicated.*

ST. MARY'S BAY SITE

Holyrood Bay

Holyrood Bay is situated on the exposed southeastern coast of St. Mary's Bay, with little protection from southerly or southwesterly wave approach (Figure 1). The beach extends in a broad arc about 6 km long between St. Vincent's in the northwest and the mouth of Peter's River at the southeast end (Figure 8). The northern 2 km of the beach form a major barrier across the mouth of Holyrood Pond. This barrier rests on diamicton over a bedrock sill, with water depths falling off rapidly to more than 100 m landward of the beach (Forbes, 1984). The barrier is typically about 200 m wide, with a natural crest elevation of about 7.5 m above mean water level (Forbes, 1984, 1985; Forbes and Taylor, 1987). This has now been raised by construction of an artificial berm and wooden seawall extending more than 1 km along the beach from St. Vincent's. The dominant size fraction at the west end of the

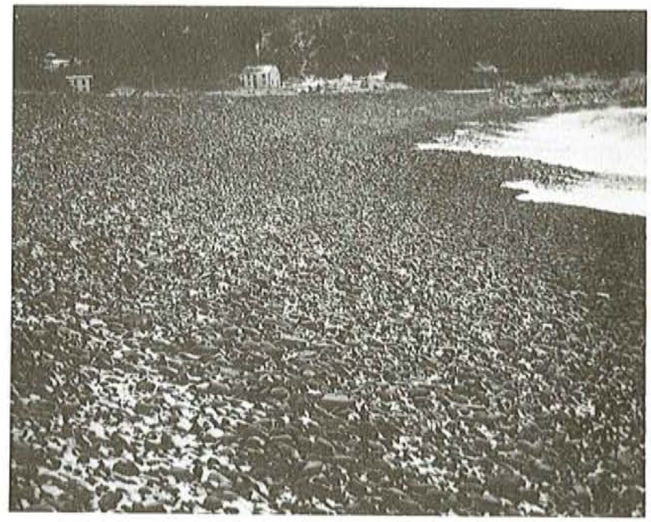

Plate 3. *View south of Ship Cove beach, showing exposure of internal framework by storm erosion, December, 1991.*

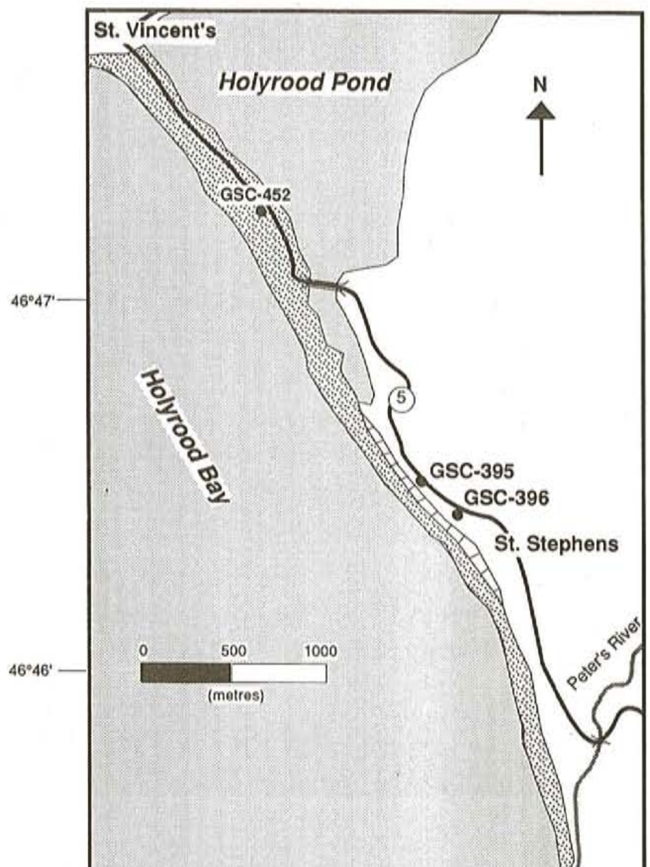

Figure 8. *Sketch map of Holyrood Bay study area, showing benchmark locations.*

beach (the Holyrood Pond barrier) is coarse sand, but granule and fine pebble sizes are present and often concentrated on the lower beachface. Grain size coarsens southeastward to Peter's River, where the beach is dominated by coarse pebble and cobble-size material (Forbes, 1985). The lower beachface is frequently reworked and takes a variety of forms ranging from a steep lower berm to a gently sloping surface terminating in a subtidal terrace. A high step is often present in the breaker zone, but wave energy is typically so high that extension of profiles across the step has not been possible.

Two major storms (in January 1982 and March 1985) produced high runup and overwashing of the natural barrier crest. On these occasions, broad washover channels were cut across the barrier, removing parts of the highway that runs along the backslope. In the 1982 storm, boulders and large ice floes were deposited near the barrier crest. During the 1985 storm event, large-scale reworking of the upper beachface involved the formation of a high terrace, the face of which was sculpted into very large cusps with wavelengths of more than 90 m (Forbes, 1985). Although formed during a single storm event, these features were little changed over at least five years; faint vestiges of the large-scale cusp morphology were still detectable in 1993.

The supply of sediment for this beach system, among the largest on the island, is derived from a complex sequence of glacial ice-contact diamictons, and sands and gravels in cliffs up to 30 m high (Eyles and Slatt, 1977). These occur above an interglacial bedrock bench west of St. Vincent's and along the back of the beach in the central part of the bay between Holyrood Pond and St. Stephens.

Two benchmarks were placed on top of the cliffs in the central area near St. Stephens during the summer of 1993. The cliff in this area consists of an actively eroding bluff 15 to 25 m high with a wide gravel beach at its base. The coastal road approaches within 50 m of the cliff top in this area and is potentially threatened by erosion. Measurements to the cliff edge were taken on 9 lines normal to baselines established through the benchmarks. Although reliable estimates of cliff recession at this location will have to await future surveys, a short-term retreat rate of 0.3 m per year was observed over a 20 month interval by Forbes (1984).

CONCEPTION BAY SITES

Topsail and Chamberlains

The Topsail area is situated on the east side of Conception Bay (Figure 1) at the east end of a narrow coastal plain developed in Quaternary glacial and outwash deposits (Liverman and Taylor, 1990). North of Topsail, the coast is precipitous and rocky. The coastal alignment changes from north–south to approximately northeast–southwest at Topsail Cove. The wave climate is restricted by the Bay de Verde Peninsula across Conception Bay, by the main body of the Avalon Peninsula to the south and east, and more locally by Bell Island to the west and northwest. Although major storms from the north can cause severe damage along this coast (as in October 1992), events of this kind are infrequent. Longshore drift and sediment transport are predominantly toward the northeast, driven by waves generated within Conception Bay and approaching from the west and southwest. The area is microtidal with a maximum range of 1.3 m (CHS, 1991). Sea ice persists for up to 11 weeks in many winters and is often shorefast along the coast, providing some protection from winter storms (Prentice, 1993).

The coastline between Chamberlains Pond and Topsail Cove (Figure 9) consists mostly of low cliffs of diamicton and gravel, fronted by narrow pebble–cobble beaches. Gravel barriers have formed across Chamberlains Pond and at Topsail Beach. Topsail Beach has changed drastically over the last 50 years, with the beach migrating shoreward, its length decreasing from 2.5 to 1.6 km, and its width from 60 m to 27 m (Prentice, 1993). The system was responding to removal of sand for construction purposes in the 1940's. The sand has never been replenished. The outlet is unstable, and overwashing is a common occurrence, cutting channels and producing amalgamated washover lobes on the landward side. Sand is present in the nearshore (Forbes, unpublished data). Breaching of a similar barrier in the Manuels area, 4 km southwest of Topsail, caused considerable damage to craft moored in the backbarrier channel at the Royal Newfoundland Yacht Club in October 1992.

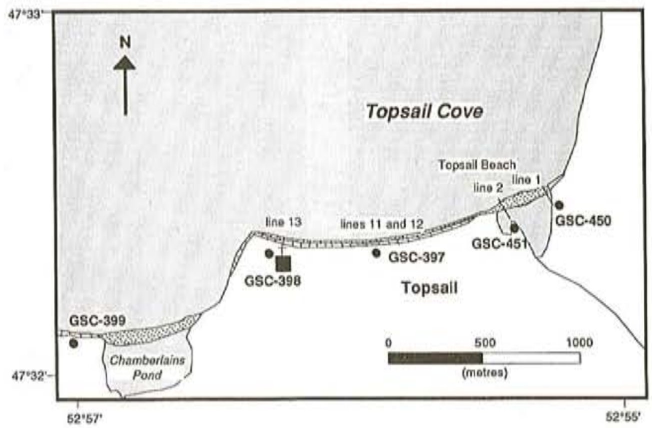

Figure 9. *Sketch map of Topsail and Chamberlains area, showing benchmark locations and survey lines.*

Three survey lines (lines 11, 12 and 13) were established along the unconsolidated cliff at Topsail (Figure 9) in July 1993, with the primary objective of enabling future determination of erosion rates by repeated surveys over the cliff. Lines 11 and 12 (benchmark GSC-397) are located on private land above a well vegetated and apparently stable slope, which drops from a height of approximately 14 m to the top of a narrow pebble–cobble beach (Figure 10). The beach is 20 m wide and rises to the base of the cliff at about 4 m above mean water level. Line 13 (benchmark GSC-398) is located near the church on the east side of the headland, where the cliff rises to an elevation of about 18 m (Figure 10). The slope here is covered with mature spruce trees up to 14 m tall and 0.4 m in diameter. Ring counts on cores recovered from three trees suggest that the slope has been stable for about 50 to 80 years. However, it is now actively eroding, resulting in downslope displacement of the trees (Plate 4).

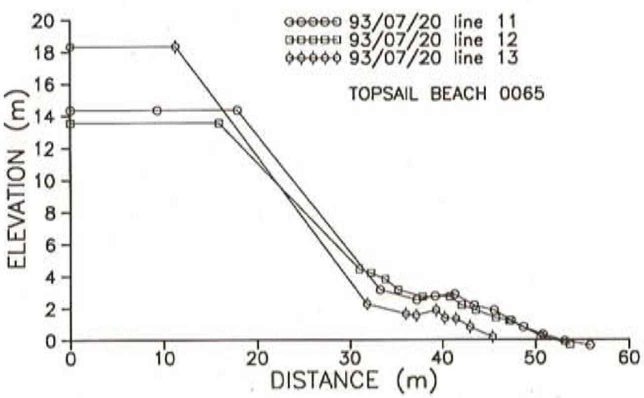

Figure 10. *Cliff and beach profiles surveyed at lines 11, 12 and 13, Topsail, in July 1993.*

Plate 4. *Eroding slope below the church at Topsail, displacing 80-year-old trees.*

Local residents suggest that erosion rates are increasing on the bluffs west of Chamberlains Pond (Figure 9), where benchmark GSC-399 was established to provide a reference point for cliff retreat measurements. The cliff in this area rises to 8 m elevation, with an active erosional face exposing diamicton and gravel, and is fronted by a narrow pebble–cobble beach rising to 2 m above mean sea level. Local landowners have reported the loss of 1 to 2 m of land at this site over the past two years, whereas the slopes at Topsail are more stable. However, the recent destabilization of the slope below the church suggests that a new phase of erosion may be developing in this area.

CONCLUSIONS

The evidence available from a variety of coastal bluffs and beaches in several areas of the Avalon Peninsula indicates slow shoreline retreat at rates typically less than 0.5 m per year. Local and short-term progradation occurs at some sites and erosion rates up to 1 m per year or more are suspected at some locations over varying lengths of time. The most severe erosion problems on the Avalon Peninsula appear to be in the areas of Point Verde and the Topsail to Manuels shore. Reliable estimates of long-term coastal land loss and erosion potential will require repeated semi-annual to annual measurements on a regular basis over a time span of at least five years.

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