Geological Survey of Canada
Commission géologique du Canada

Field Trip Guidebook

Eastern Shore of Nova Scotia Coastal Response to Sea-Level Rise and Human Interference

R.B. Taylor, J. Shaw, D.L. Forbes and D. Frobel

OPEN FILE REPORT
3244

Natural Resources Canada
Ressources Naturelles Canada

Field Trip Guidebook

Eastern Shore of Nova Scotia Coastal Response To Sea-Level Rise and Human Interference

R.B. Taylor, J. Shaw, D.L. Forbes and D. Frobel

Geological Survey of Canada (Atlantic)
P.O. Box 1006
Dartmouth, Nova Scotia
B2Y 4A2

Geological Survey of Canada
Open File Report
3244

February 1996

The field guide was originally prepared for the Canadian Coastal Conference
October 18-21, 1995, Dartmouth, Nova Scotia

Front Cover: View of a wave surging over top of Story Head Beach, Nova Scotia. The process illustrates how low gravel barrier beaches are rolled landward by wave overwash processes. The wave photographed between 12:00-12:30 ADT, August 15, 1995, was generated by Hurricane Felix as it passed near Bermuda on August 14, 1995. At the time of the photo, there was no wind and deep water wave heights of 6 to 7 m were recorded at wave buoys offshore of Halifax. Two persons are circled at the west end of the beach for scale (photo by R.Taylor).

TABLE OF CONTENTS

INTRODUCTION

Welcome to Nova Scotia, "Canada's Ocean Playground" where diverse and interesting coastal landscapes await you. It is hoped that you will have time to explore several parts of the province during your stay and that this field trip will provide you with a brief introduction to the evolution of these glaciated coasts. Segments of the field guide have been derived from the publication by Shaw *et al.*, 1993 and the coastal portions of an earlier field guide by Stea *et al.* 1992. Our field trip to the Eastern Shore will take us to the birth place of the evolutionary models for transgressive sedimentation of drumlin dominated shores by Boyd *et al.*, 1987, and by Orford *et al.*, 1991b. It is also the site of some of the fastest migrating coarse-clast beaches in the province which has provided the authors with great opportunities to observe the short term evolution of these shore types. These shores, because of their proximity to the Halifax-Dartmouth metropolitan area, also provide some of the best examples of the effects of human interference on coastal stability. We hope that you will enjoy your trip.

PHYSICAL SETTING

Mainland Nova Scotia (Fig.1) forms a prominent peninsula on the eastern seaboard of Canada. Cape Breton Island continues the general line of the mainland to the northeast. The coastline of Nova Scotia can be subdivided into three regions (Owens and Bowen, 1977; Owens, 1994) comprising (1) the Gulf of St. Lawrence and Northumberland Strait shores, which are microtidal, exposed to locally generated wind waves for 7 to 8 months of each year, and ice-covered during the winter; (2) the Bay of Fundy shores, which are tide–dominated, with large tidal ranges of 13 to 16 m at the head of the bay; and (3) the more exposed open Atlantic coast, which is low, mesotidal, and dominated by storm wave processes. This field trip focuses on the Eastern Shore which is part of the Atlantic coast of Nova Scotia.

The Atlantic coast of Nova Scotia is highly indented, with long narrow embayments, intervening headlands, and numerous rocky offshore islands. Many of the embayments originated as preglacial consequent streams which were overdeepened by glacial erosion and which have subsequently been drowned by the Holocene transgression. The resulting estuaries and their analogues in relict estuarine basins on the inner shelf are the principal sinks for sands and finer sediments in the coastal zone (Piper *et al.*, 1986; Carter *et al.*, 1989, 1990c; Forbes *et al.*, 1991a). Close to the steep upland shores of Cape Breton Island, elevations reach almost 300 m, but relief is much more subdued elsewhere along the outer Atlantic coast, where low-lying coastal embayments and marshes are common.

Glacial erosion and deposition have provided the main source of sediment for beach development. Glacial deposits are found as a thin mantle over bedrock and as thick deposits organised into fields of drumlins (Piper *et al.*, 1986; Forbes and Taylor, 1987). Multiple tills at some localities show a range of grain-size distributions (Stea and Fowler, 1979; and Sonnichsen, 1984).

WAVES, SURGES, TIDES

The coastal waters are largely ice–free, excepting estuaries and lagoons which may wholly or partly freeze during winter. Pack ice drifting south out of the Gulf of St. Lawrence via Cabot Strait can influence the outer coast in late winter. Annual deep–water significant wave heights are in the 7–8 m range and the 10–year significant wave heights (1970 to 1980) were 9–12 m with periods of 10 to 14 seconds (Neu, 1982). Surges are generated by cyclonic depressions passing northeastward across the region and also by occasional tropical storms moving north along the U.S. eastern seaboard. Positive surges of up to at least 1.1 m can occur; the average occurrence rate of surges above 0.6 m is 3-7 times per year (Galbraith, 1979).

Mean tidal range decreases from 3.7 m in southwestern Nova Scotia to less than 1 m in northern Cape Breton Island (Canadian Hydrographic Service, 1991). Tides at Halifax are semidiurnal, with a range of 1.5 m on a mean tide, and 2.1 m on a large tide.

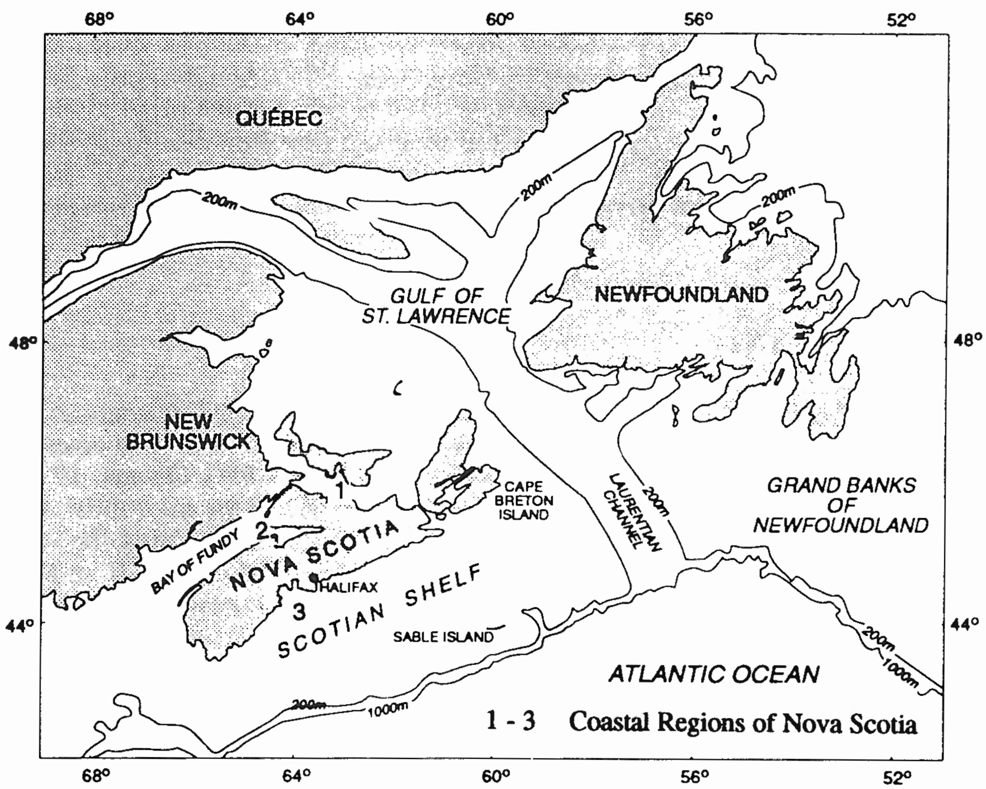


Figure 1 Location of Nova Scotia in eastern Canada and generalised bathymetry of the adjacent continental shelf.

LONG-TERM RELATIVE SEA-LEVEL TRENDS

Changes of relative sea level in Nova Scotia have resulted from the interplay between discharge of glacial meltwater from late Quaternary ice sheets and isostatic adjustments of the crust (*cf.* Tushingham and Peltier, 1991; Quinlan and Beaumont, 1981, 1982). Figure 2 shows the sea-level curve for the inner Scotian Shelf published by Shaw et al. (1993). This curve is based on core data obtained from just offshore in the Halifax region (Forbes *et al.*, 1988, 1991a), together with data from other sources (Scott, 1977; Hall, 1985; Honig, 1987). It is constrained by the ages of salt-marsh materials at index points 5 and 13. Arguably, it could be steeper than indicated, with relative sea level as high as -10 m at 6000 BP, constrained by index point 19. However, the material dated for index point 19 is wood, which may be allochthonous. Index point 11 indicates that the (-20 m) sill of Bedford Basin, Halifax, was overtopped by 5830 BP. We have indicated an envelope containing possible sea-level curves, and have suggested a likely curve.

The sea level curve subsequently published by Stea et al. (1994) was similar to the curve shown in Fig. 2 for the period after 10 ka but for the period older than 10 ka it shows a low stand at -65 m at circa 11.65 ka, and a rapid rise (1.5-2.0 m/century) until 11 ka, followed by the period of slow rise around 10 ka as shown in Fig. 2.

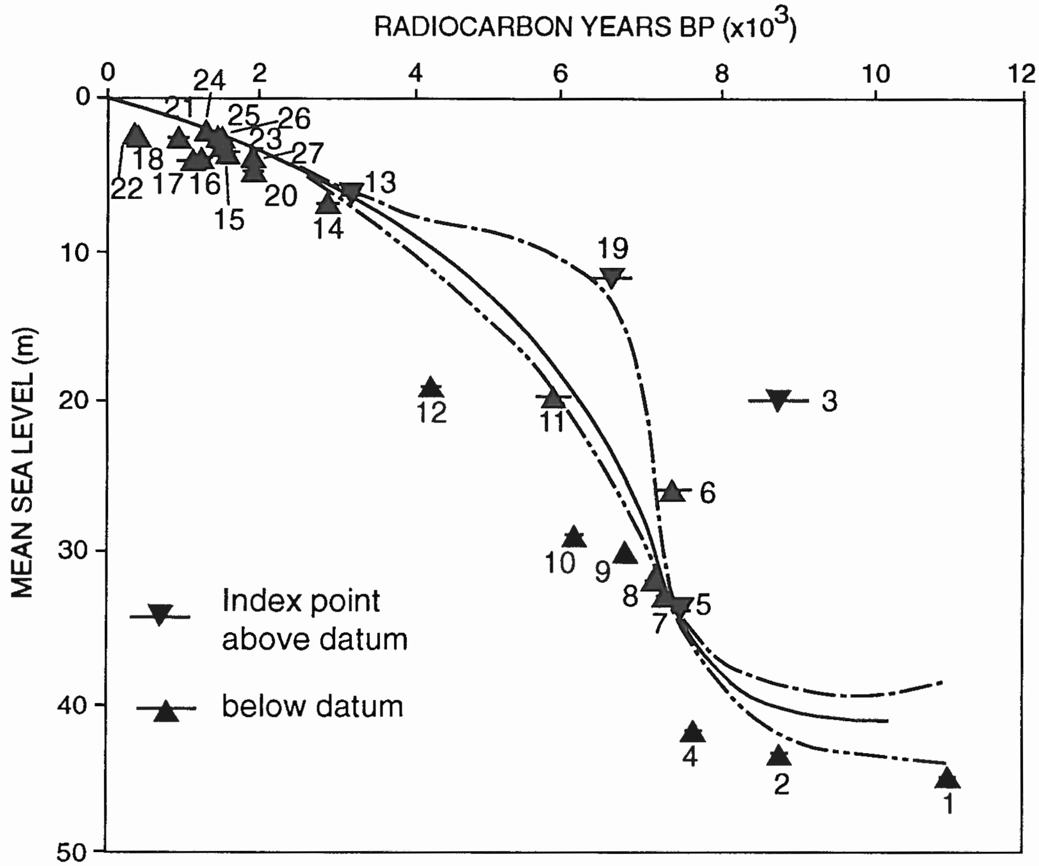


Figure 2 Relative sea-level changes on the inner Scotian Shelf during the past 10 ka, based on new and published radiocarbon dates (Forbes *et al.*, 1988, 1991a; Scott, 1977; Hall, 1985; Honig, 1987). The error bars (horizontal lines) are equivalent to two standard deviations. The solid graph represents the most likely sea-level curve and the dashed graphs define an envelope of possible sea-level curves.

Rates of sea-level change

Relative sea level was below -40 m at 10,000 radiocarbon years BP, and rose rapidly from 8000 BP to 6000 BP. Thereafter, relative sea level increased less rapidly, and ca. 2000 BP the average submergence rate dropped below 2 m/ka. The highest rate of increase during the Holocene was approximately 11 m/ka at about 7500 BP (see Fig. 3). The peak acceleration of sea-level rise was 8 m/ka^2 at 8000 BP, and the peak deceleration was 4 m/ka^2 at 6500 BP.

The rate of change registered by the Halifax tide gauge clearly exceeds the rates observed over the most recent few millennia. In fact, to find a comparable rate, we have to look as far back as 4500 BP. If the Intergovernmental Panel on Climate Change (IPCC) forecasts are used, then, by simply adding the projected increase to the rise now occurring, the rate of sea-level rise by 2070 would be 10 m/ka. This rate almost equals the maximum rate of sea-level rise during the Holocene transgression.

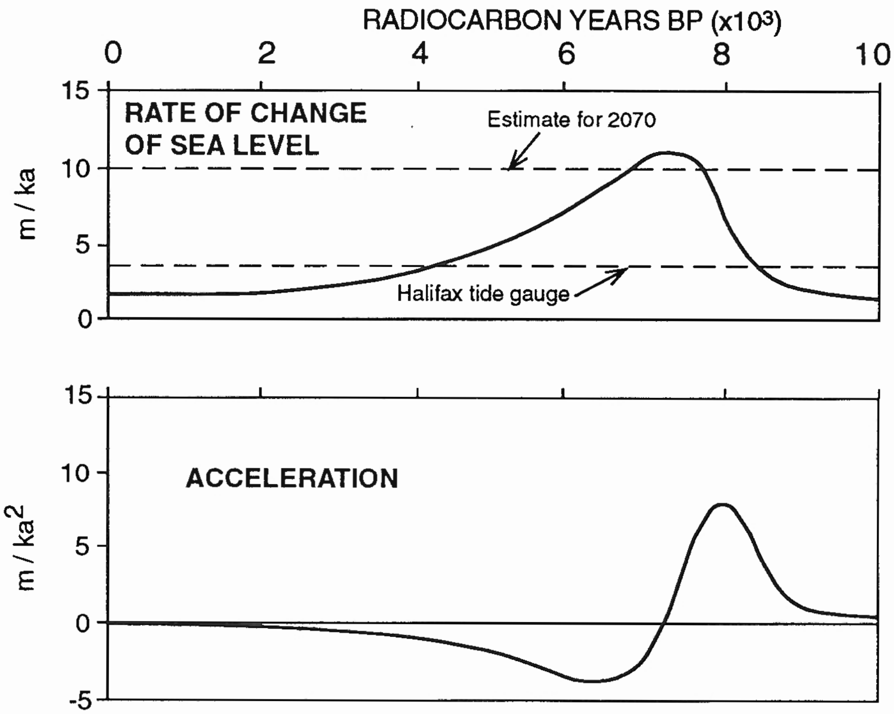


Figure 3 Rates of sea-level during the Holocene in the Halifax area.

Smooth or fluctuating sea-level rise?

We must be cautious in assuming that sea-level rise during the Holocene in Nova Scotia has been smooth. van de Plassche (1991) and Thomas and Varekamp (1991) claimed that late Holocene sea-level rise was stepped, so that alternating periods of greater and lesser relative sea-level rise were embedded within an overall submergence. Tanner (1992) found evidence in the Gulf of Mexico of three drops and two rises of sea level in the past 3.0 - 3.5 ka, with amplitudes of 1-2 m. He suggested that the most recent oscillation corresponded with the Little Ice Age and that the current sea-level rise is the recovery from a lowstand during that period. Closer to the study area, the Holocene transgression in the Tantramar marshes of New Brunswick is thought to have been interrupted at least 4 times during the past 3000 years (Grant, 1989).

TIDE-GAUGE EVIDENCE FOR RECENT SEA-LEVEL RISE

Relative sea level has been rising during the past century in Nova Scotia. Tide records were kept by the British Admiralty at Halifax in 1851-52 and 1861-62 (Shaw and Forbes, 1990) but the earliest data presently available to researchers date from the 1890s, when a network of tidal stations was established in eastern Canada by Dawson (1918). Unfortunately, monitoring ceased at most stations just after the turn of the century. The Halifax record begins in 1896, ends in 1905, and recommences in 1920 (Canadian Hydrographic Service, 1951). Marine Environmental Data Services (MEDS) archives in Ottawa contain the main body of tidal data from Halifax and other tidal stations. Based on the continuous record since 1920, mean sea level has risen at 3.63 mm/a (Fig. 4a); based on the complete data set, the rate of rise in mean sea level since 1896 is 3.18 mm/a. These are comparable to other published rates: Middleton and Thompson (1986) found a trend of 3.75 mm/a in data for the period 1920-82; Carrera and Vaníćek (1988) had similar findings. Figure 4b shows that the rate of sea level rise has fluctuated somewhat and has slackened during the past decade.

level rise has fluctuated somewhat and has slackened during the past decade.
Comparable rates of sea-level rise have been recorded at other locations in eastern Canada where long tidal records exist (Shaw and Forbes, 1990). Apart from Halifax, most tidal records from Nova Scotia are relatively short. The Yarmouth data set includes isolated values from 1900 and 1956, but the continuous data set does not begin until 1967. At Pictou, the records are continuous back to 1965; there are also records from 1957-58 and about 20 years of data from the turn of the century. Additional tidal records beginning in the late 1960s or early 1970s are available from several other locations. Carrera *et al.* (1990) tackled the problem of how to extract trends of sea-level change from these relatively short records; their results are shown in figure 5.

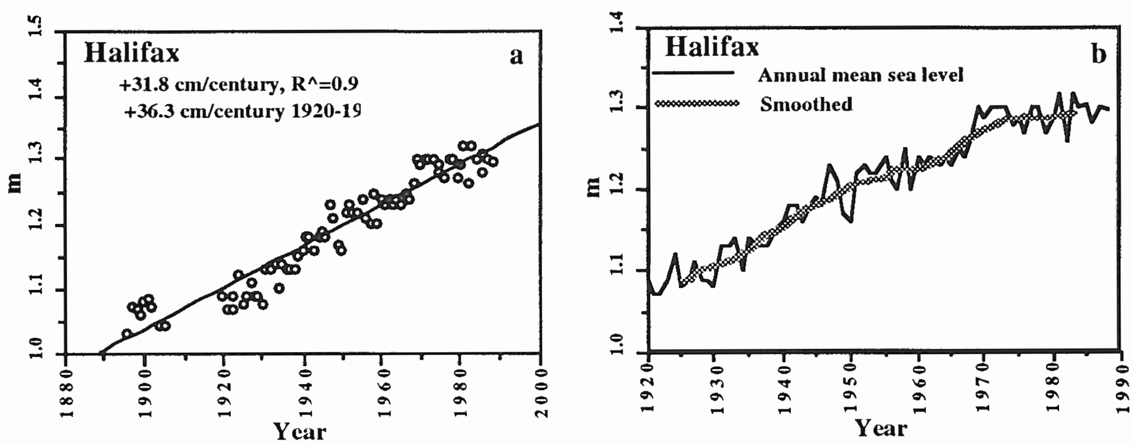


Figure 4 (a) Tide gauge records for Halifax, N.S. The datum at Halifax was raised by 0.29 m on 1st January, 1987. These records are reduced to the datum prior to that date. Mean sea level over the period 1896-1988 increased at a mean rate of 31.8 cm/century. Based only on the period 1920-1988 (MEDS data) the rate is 36.3 cm/century. (b) The Halifax record for the period 1920-1988, with an 11-year moving average superimposed.

EARLY TO MIDDLE HOLOCENE COASTAL CHANGE

As sea level rose, former lakes occupying silled basins near the coast were invaded by the sea. For example St. Margarets Bay and Mahone Bay on the South Shore were invaded by the sea at about 11,500 and 4,500 radiocarbon years BP, respectively (Piper and Keen, 1976; Barnes and Piper, 1978). Where drumlin fields were flooded, a stepped progression of wave-cut cobble-boulder shoals marks the distribution of former drumlins (Wang and Piper, 1982; Piper *et al.* 1986). Along the south Cape Breton Island shore, the maximum early Holocene lowering of sea level was about 50 m below present; below this level the undulating till surfaces are preserved (Wang and Piper, 1982).

On the inner Scotian Shelf, off the Eastern Shore just east of Halifax (Fig. 1), fragmentary evidence of former coastal environments has been obtained. Using high-resolution shallow seismic reflection techniques it has been possible to locate remnant deposits of estuarine, freshwater and salt-marsh sediments down to present depths of at least 45 m (Forbes *et al.*, 1988, 1991a). Sedimentary sequences observed from coring these deposits (Honig, 1988) closely resemble those observed from cores within existing estuaries (Honig, 1987; Carter *et al.*, 1989, 1990c). From the radiocarbon dating of shell and peat material found in the cores (Table 10 of Forbes *et al.*, 1988), it is clear that estuaries were present in the region in the early and mid-Holocene. Salt marshes were also present, even during the peak of the transgression at about 7500 BP (Forbes *et al.*, 1988; Fig. 6 of Shaw and Forbes, 1990). These estuarine and salt-marsh environments must have developed behind protective barriers, of which little evidence remains.

1987), although some gravel was abandoned on the inner shelf, forming an extensive surface veneer (Forbes and Boyd, 1989). Only in special settings have recognisable barrier deposits remained trapped on the inner shelf of eastern Canada (*cf.* Forbes *et al.*, 1991b).

Mean rates of coastal retreat have been calculated for the coastal segment between Chezzetcook Inlet and Ship Harbour. At about 10,000 radiocarbon years BP, the average position of the coast was 10.0 km seaward of its present location; at 7000 and 5000 BP, the positions were 4.1 km and 1.5 km, respectively. These changes in shoreline position indicate mean retreat rates of about 2.0 m/a (10,000 to 7000 BP), 1.3 m/a (7000 to 5000 BP), and 0.3 m/a (5000 BP to the present) (Shaw *et al.*, 1993).

LATE HOLOCENE IMPACTS

Compared with the early Holocene, much more is known about how the coast responded to sea-level changes during the past several millennia, primarily because beach deposits formed during the latter period still exist. Among the factors that control coastal evolution, sediment supply is of great importance (Forbes *et al.*, 1989; Shaw *et al.*, 1990). While coastal retreat may be pervasive, it is often counterbalanced by local stability or even progradation where relatively large volumes of sediment are supplied to the littoral zone (Forbes *et al.*, 1990; Orford *et al.*, 1991b), either by erosion of glacial deposits (Boyd *et al.*, 1987) or from the disintegration of older beach systems (Sonnichsen, 1984). As we will see during the fieldtrip, on some parts of the Atlantic coast of Nova Scotia the delicate balance sometimes achieved in the natural coastal system has been altered by human interference.

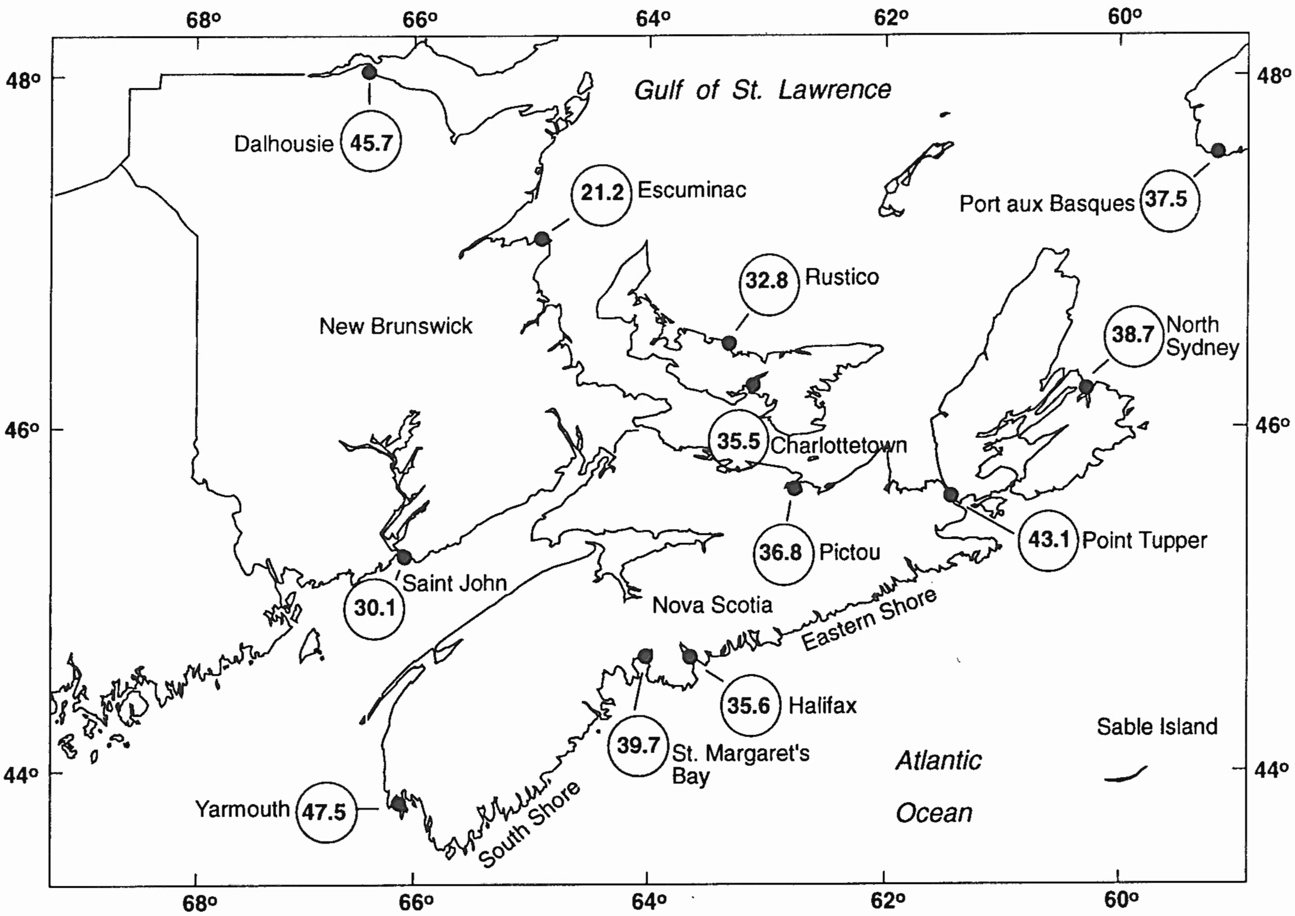


Figure 5 Rates of relative sea-level rise (cm/century) derived from tidal records at selected locations in Atlantic Canada (after Carrera *et al.*, 1990).

ITINERARY

Saturday October 21, 1995

Time	Event
08:15	Muster at Holiday Inn, Dartmouth
08:30	Bus leaves Holiday Inn for Eastern Shore
08:45 - 09:00	Stop 1. Woodside Ferry Terminal
09:20 - 10:10	Stop 2. Cow Bay Beach
10:40 - 11:10	Stop 3. Conrad Island Park Reserve
11:15 - 12:15	Stop 4. Lawrencetown Head and Beach
12:15 - 13:15	Lunch Stop
13:35 - 14:15	Stop 5 Grand Desert Cliffs
14:25 - 14:40	Stop 6 Chezzetcook Marsh
15:10 - 15:35	Stop 7 Miseners Long Beach
15:40 - 16:45	Stop 8 Story Head Beach
16:45	Bus returns to Dartmouth
17:30	Arrive Dartmouth Holiday Inn

(For Locations refer to route map at back of field guide)

Figure 6 Detailed route map from the start of the field trip (Holiday Inn, Dartmouth) to Stop 1, at the Woodside Ferry Terminal, Dartmouth.

Stop 1. Woodside Ferry Terminal

Purpose: Examine digital bathymetry images of Halifax Harbour and discuss anthropogenic impact.

Route: Depart 08:30 Dartmouth Holiday Inn by bus. Turn right onto Wyse Road and follow it past the Dartmouth Museum to the first stop light. Turn left onto Alderney Drive and proceed along the Dartmouth waterfront until the 5th stop light (Shoppers Drug Mart / Medical Centre). Turn right onto Portland Street and at the next stop light turn right onto Pleasant Street. Follow Pleasant Street for ~2.5 km past the Nova Scotia and Dartmouth hospitals to a stop light with a Tim Hortons and A&W. Turn right and right again into the upper parking lot of the Woodside Ferry Terminal. Stop at the far northwest corner of the parking lot. Arrive at 08:45.

En Route To Stop

Dartmouth began in the 1750s because its forests provided an easily accessible supply of wood for the new thriving settlement and military base of Halifax which was founded in 1749. Dartmouth was incorporated as a city in 1961 and it will soon become part of the " super city " that includes Halifax, Dartmouth, Bedford and Halifax County. Several points of interest that you may look for on route to our first stop include: Dartmouth Heritage Museum, the oldest cemetery in Dartmouth which overlooks Halifax harbour, the Dartmouth waterfront development including the Library, Ferry Terminal, the Peace Pavillion and the Shubenacadie Canal which leads to a natural water route across the province to the Bay of Fundy. The route we follow has always been one of the main routes to the Eastern Shore and you will see several houses built during the 1800s (Fig 6).

Halifax Harbour

A second ferry terminal on the Dartmouth side of Halifax Harbour was established here at Woodside in 1990, in the expectation that commuters would leave their vehicles here and take the ferry, rather that drive across the bridge. Traffic has been much less than was expected!

At this stop we will focus on the recent history of the harbour, and work that has been done by the Geological Survey of Canada (Atlantic). From the hill above the ferry terminal we have good views of the harbour. Just across from us lies Halifax, dominated by the drumlin at Citadel Hill. Looking to the left we see one of two container terminals in the area; the other is in Bedford Basin. Immediately west of the container terminal is Point Pleasant Park, one of the most heavily used parks in Halifax. Georges Island is uninhabited. Looking to the right of Citadel Hill we see the Naval Dockyards stretching into the distance. The nearest bridge, the Angus L. Macdonald bridge, was constructed in the 1960s. The loan is still being paid off! In the far distance is the newer Murray A. MacKay bridge, under which lies the Bedford Institute of Oceanography, home to the Geological Survey of Canada (Atlantic) and the Department of Fisheries and Oceans, among others. The Bedford Basin, just beyond the bridge, was the starting point for convoys in World War II.

Halifax was founded in 1749 by the British, and soon became their most important military base north of the New England colonies. Following the French/English wars it remained a major naval base, but in the 19th century it also grew into a major industrial centre. The growth of industries after 1850 contributed to a significant increase in contaminents being added to the harbour. The muddy sediments in Halifax Harbour and Bedford Basin have been contaminated by metals (including Hg, Zn, Pb and Cu) due to input of untreated sewage and industrial wastes (Buckley and Winters, 1992; Buckley *et al.*, 1995). Contaminant concentrations became significant after 1880, rose rapidly after 1900 and peaked from 1950-1980. The work of Buckley and his collaborators has played a role in the choice of a location for a future sewage treatment plant. Although sewage outfalls are usually located far out to sea, the Halifax Harbour Task Force recommended an outfall location to the east of Georges Island, where contaminants would be stored in muddy deposits trapped in the harbour.

Digital bathymetric images show the muddy depositional area in the harbour. To the north, the sea bed in the Narrows is hard, with deposits of bouldery till and ridges of bedrock. The Halifax explosion of 1917 occurred here, but had no noticable effect on the sea bed. The swath image shows several drumlins, the most conspicuous of which is Georges Island, which is surrounded by a non-depositional 'moat'. A small lump visible on the flank of the island is the wreck of the old car ferry, the Governor Cornwallis, which burned and sank in 1923. This and other shipwrecks in the harbour are described in the poster by Robert Miller and Gordon Fader (1995).

South of Georges Island the bottom is mostly hard, and east-west bedrock trends can be identified. Close to the west side of the harbour, linear sedimentary furrows occur in fine-grained bottom sediments. Careful examination reveals a host of small features, including relict beach ridges, former shorelines, bridge footings, dredge spoils, jack-up oil rig spudcan impressions, shipwrecks, propeller-scoured areas and the 'Trongate Depression' - the impression made in the sea bed by the *Trongate* ,a military vessel, which caught fire and was sunk by the navy in 1942.

In the harbour approaches, evidence of higher wave-energy levels (relative to inside the harbour) is provided by the presence of eroding till bluffs, gravel beaches and spits. The remainder of the trip will focus on the outer coast where these coastal features are better developed and more easily observed.

Stop 2. Cow Bay / Silver Sands Beach

Purpose: To provide an introduction to marine processes; relative sea level history; barrier beach types; and to illustrate the dramatic effects of human interference on shoreline stability.

Route: Leaving stop 1 at 09:00 continue along Pleasant Street and Highway 322 southeast past CFB Shearwater, the car port and two oil refineries, to the town of Eastern Passage. Continue on the same road which curves toward the left in Eastern Passage where it becomes Cow Bay Road. Travel 4.7 km and turn right on Cow Bay Road just past the sign for the village of Cow Bay. Continue along Cow Bay Road until you see a large statue of a moose. Park in the turnoff at the moose. Arrive 09:20.

En Route To Stop

Our route takes us through the Woodside "light" industrial area as well as the heavy industrial part of Halifax-Dartmouth where the Esso and Ultramar (now shut down) oil refineries exist. The route also takes us past CFB Shearwater an airbase that is gradually being changed over from a government military base to one partially operated by a community based corporation. As we reach CFB Shearwater we will get good views of McNabs and Lawlor Islands, the two large islands in outer Halifax Harbour. Ives Cove at the south end of McNabs Island was initially selected as the site of the new sewage treatment facility for Halifax -Dartmouth but plans now appear to be on hold in favor of several smaller treatment plants located around the harbour. The Friends of McNabs, who oppose the treatment plant, are actively trying to get McNabs Island designated as a park area. As we pass through Eastern Passage you may get a brief glimpse of an active fishing port that has recently been undergoing a face lift as part of the infrastructure program. Lobsters are the primary commodity caught by these fishermen who fish Halifax Harbour and the inshore waters east and west of Halifax.

Cow Bay /Silver Sands Beach

The moose and Silver Sands Beach have one thing in common - they are all that is left of a much grander beginning. Once a large number of animal statues were found at this beach but several corroded, washed away or were shipped to a artificial animal park in New Brunswick. They were created by Winston Bronnum in the late 1950s.

Silver Sands Beach has been a favourite recreational spot for residents of Halifax-Dartmouth since the early 1900s (McIntosh, 1916). McIntosh writes "a drive of six miles by automobile or carriage over a macadamized road from Dartmouth through Woodside and along the harbour-front to Eastern Passage, followed by that over a less level and less smooth road for four miles is the usual way of reaching the locality (Cow Bay). The recently constructed "Halifax and Eastern" railway passes within about a mile of the beach and will likely have a station near ".

Silver Sands beach provides us with a good spot to briefly describe the types of barrier beaches that exist along Atlantic Nova Scotia (Forbes *et al.*,1990). The five major barrier types include: (1) prograded beach ridge complexes; (2) high reflective gravel storm ridges; (3) low wave washover dominated gravel barriers; (4) trailing spits and fringing ridges; (5) sandy barriers with low dunes.

It should be recognized that this implies no specific sequence of forms, though beach and barrier evolution may well proceed through one type to one or more others -Silver Sands beach evolved from a progradational complex, type 1, to the type 3 low transgessive barrier that we see today. Switching back and forth may also occur, for example from drift-alignment to swash-alignment and back (Orford *et al..*, 1991b). It is also possible to identify a number of combined forms such as sand dominated barriers with dunes backed by progradational sequences (Stops 3 and 4, Conrads-Lawrencetown Beach complex). Because the 1990 classification was intended to elucidate conditions on gravel-dominated features of the Eastern Shore, sandy systems were lumped into a single category, despite the scope for further subdivision of this type. Furthermore, type 4 incorporates two distinct forms, trailing ridges and spits which are predominately drift-aligned and fringing beaches which can be swash- or drift-aligned (Stea *et al.*, 1992).

Silver Sands beach is presently a low gravel barrier that would fall into the category of a type 3 barrier. It fronts Cow Bay Lake which is connected to the sea by a narrow inlet at the far western end of the beach. Silver Sands beach has not always looked as it does today. At the turn of the century the Cow Bay Lake was freshwater but there was an outlet to the sea into a lagoon at the west end of the beach (Fig. 7). Circa 1901 a storm closed the outlet to the lagoon and the ponded water broke through the barrier again at a site approx 100 yards farther east. A breakwater was built to provide a boat harbour. Since then Cow Bay Lake has been brackish. In 1916 the average width of the beach was 400 feet (121 m) but there was evidence of wave washover fans on the pond shore. McIntosh (1916) provides an excellent description of the beach. He describes, from east to west, a gentle sloping beach with sand dunes backed by scrubby spruce along the lake; a series of three treed, cobble beach ridges separated by sand patches between drumlins "B" and "C" and a low old beach ridge backed by low marsh and fronted by low beach with sand dunes between drumlin "C" and "D" (Fig. 7). West of of drumlin "D" the modern beach ridge was high and steep. It was nearly 3m above the fan shaped beach ridges that existed in the backshore and it was higher than the older backshore ridge that existed east of drumlin "C". The age of the older ridges is unknown but the largest tree on the backshore ridge contained 120 annual growth rings which means its growth began in the mid 1700s but the beach ridge is probably much older. It is interesting that McIntosh shows two drumlins toward the west end of the beach yet today there is only one lag shoal visible on the lower foreshore and he does not show a drumlin where we can now see a lag shoal fronting the small pond at the east end of the beach.

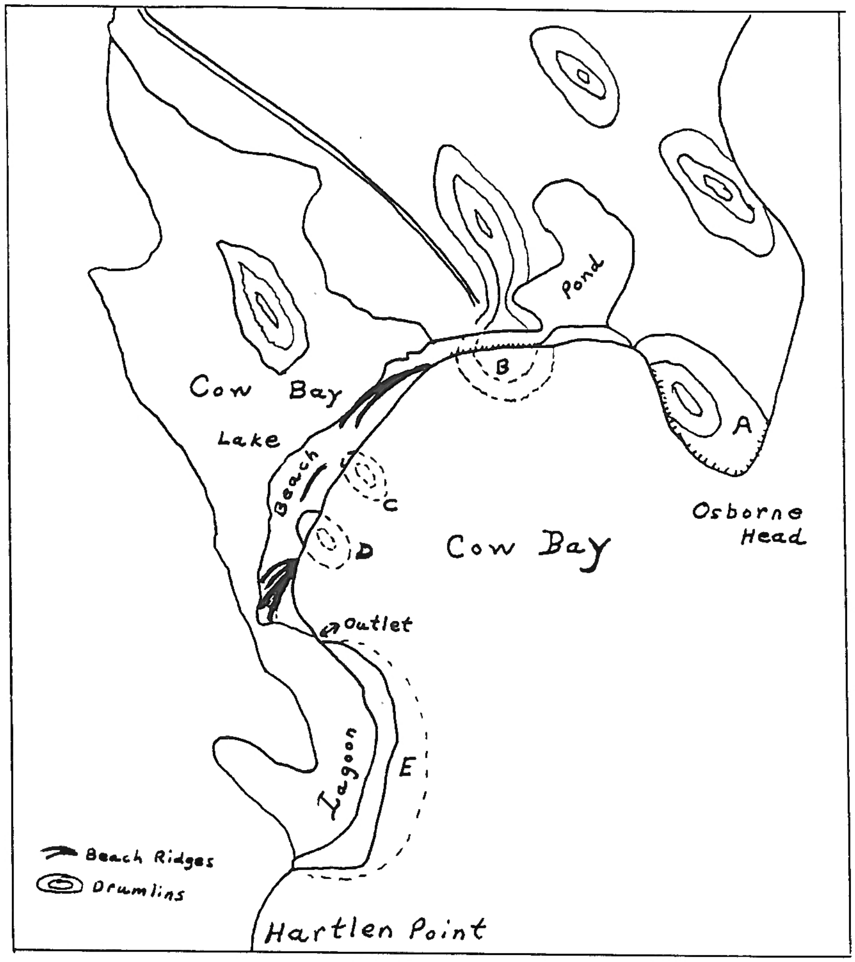


Figure 7 Sketch of Silver Sands beach *circa* 1916 showing the position of older backshore beach ridges and probable location of former drumlins which acted as anchor points and sediment sources for beach development (from McIntosh, 1916). "E" is the remains of an old glacial mound and the dashed lines represent the probable position of the older shoreline.

We will walk a short way along the beach so that some of the physical characteristics of the beach can be more closely observed and we can better sense the effects of human activities on this beach. Initially it was thought that from 1931, when the first air photos were available, until 1954, Cow Bay beach was fairly stable. However an aerial oblique photo taken in 1941 shows a nearly continuous stand of trees along the part of the beach where we are standing, a part of the beach which in 1945 had only a discontinuous tree cover and in 1954 even fewer trees. Evidence of instability is also observed on the 1941 photos in the form of wave overwash deposits within the treed backshore.

Management Issues: The most dramatic changes to the beach complex occurred between 1954 and 1971 when an estimated 2 million tons of sediment was removed from the beach (D. Huntley, pers. comm. 1976). In 1954 a complex system of barrier beaches existed from Hartlen Point to Osborne Head (Fig. 8). By 1960 the western end of the beach complex had collapsed and reduced to a series of submerged shoals and the inlet had widened. At the eastern end a road was built closing off a small portion of Cow Bay lake to facilitate the extraction of sediment. By 1964 the beach was reduced to an average of 42 to 54% of its 1954 width.

By 1974 five recurved ridges which once formed part of the distal (west) end of the beach were thinned and incorporated into the Hartlen Point side of the beach complex, as a new natural inlet was cut through to Cow Bay Lake just to the east of the ridges. Rapid retreat of the barrier beach occurred

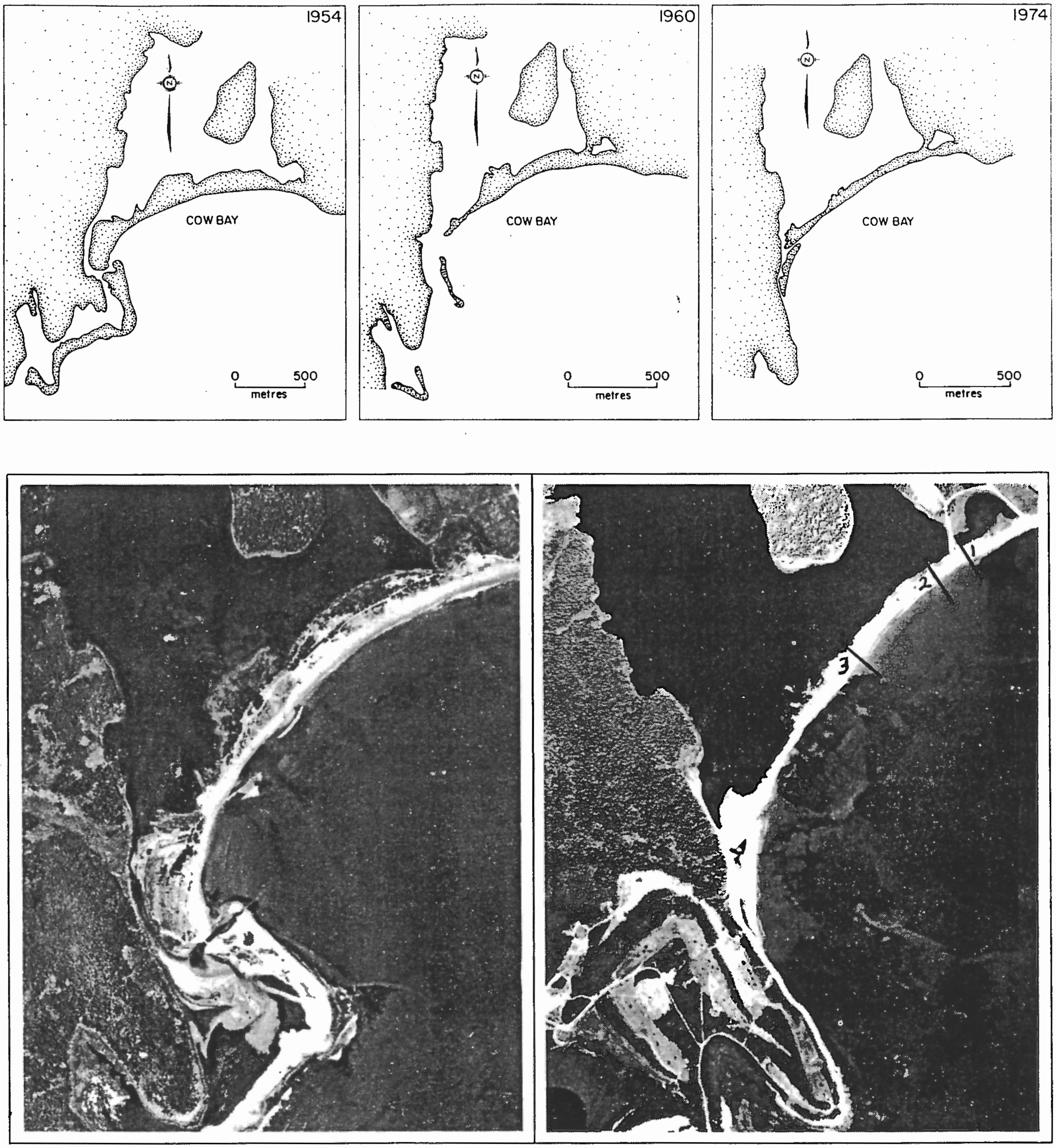


Figure 8 Silver Sands beach was literally trucked away in the late 1950s and early 1960s when beach sediment extraction was at its peak. These maps, based on air photos, illustrate the sequence of beach changes between 1954 and 1974. Vertical air photographs illustrate the detailed beach morphology that existed in 1954 (bottom left, from NAPL, Ottawa; photo A14146-35) and in 1974 which shows the location of beach survey lines (bottom right, MRMS, Amherst; photo 74123-107) (from Lewis and Keen, 1990)

at the central and western end of the barrier through wave washover processes. By the early 1980s the trees on the backshore were reduced to a few old stumps (Fig. 9). Evidence of barrier beach retreat includes peat deposits exposed on the lower foreshore, particularly across and adjacent to the lag shoals and the continued infilling of the small pond at the east end of the beach by washover deposits. Even the foundation of the "dance hall" that we are standing beside was infilled by gravels as the beach retreated landward (Munroe, 1982; Taylor et al., 1985). Since the early 1980s wave washover was greatest at the east end of the beach (line 1, Fig.8) and a large influx of sediment has accumulated as flood tidal deposits at the west end of Cow Bay Lake resulting in recent rapid growth of marsh vegetation. By 1991 the beach narrowed and its crest elevation increased from 2.94 m to 4.13 m above geodetic datum at survey lines 1 to 3. Wave washover has nearly ceased at line 3, the site of extensive wave overwash in the 1970s, and wave overwash is now more extensive toward the east end of the beach. Surveys since 1978 have shown that there was crestal build-up in the mid-1980s followed by a reduction in crest elevation after 1990 (Fig. 10).

Figure 9 By 1981, as Cow Bay Beach migrated landward, wave overwash deposits had partially infilled the foundation of a building and all that was left of a once forested backshore was a couple of dead trees (GSC photo 190808, Taylor *et al.* 1985). Survey line 2 (Fig.8, 10) is aligned across the beach at the building foundation.

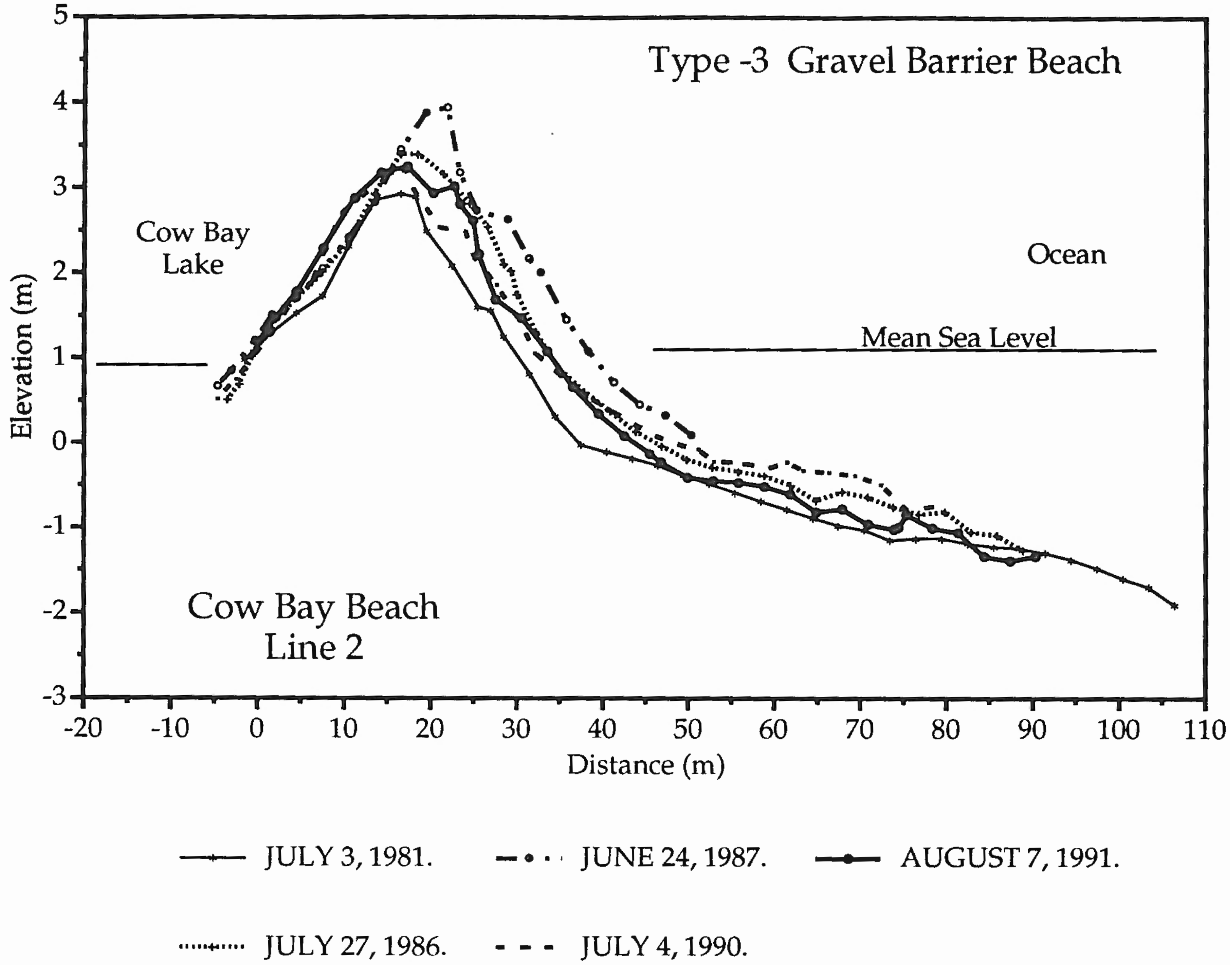


Figure 10 Sequential cross-sectional beach surveys at line 2 (Fig.8 and 9) illustrate an increase in beach crest elevation during the 1980s and little change to the backshore. After 1990 the beach crest decreased in height resulting in a renewal of wave overwash along this part of Silver Sands Beach.

Stop 3. Conrad Island Park Reserve

Purpose: To examine a type 5 sandy barrier beach; to discuss dune growth in response to natural opening and closing of tidal inlets and reduction in sediment supply.

Route: Leaving Stop 2 at 10:10 follow the coastal road through the village of Cow Bay to Rainbow Haven where we turn left onto Bissett Road. Follow Bissett Road back to the outskirts of Dartmouth to the junction with Highway 207 (Cole Harbour Road). Turn right onto highway 207 and continue driving for 10.9 km past the sign for West Lawrencetown, past Atlantic View School and turn right at Conrad Road (opposite the Lawrencetown Community Centre and ball field). Follow this paved road 2 km until you reach the sea and the parking lot at Conrad Island Park Reserve. Arrive: 10:40. From the parking lot walk along the boardwalk to the beach.

En Route To Stop

Upon leaving Silver Sands beach we cross a gravel barrier that has been reinforced on its seaward side by large rip rap to protect the highway from erosion. This graphically illustrates the problem of establishing permanent structures on mobile features. The next headland is Osborne Head, the site of a military gunnery school built following WWII and it was actively used until 1995. In the village of Cow Bay there are several historic buildings such as the Cow Bay Hall, circa 1888, and the Anglican church, circa 1892, situated along a picturesque section of coast. I will pass around a photo from 1941 that shows the church and the highway which at that time existed along the seaward side of the church, rather than the landward side as you can see today. To the right there are good examples of truncated drumlin headlands that display the two types of glacial tills found in this area. The lower grey till is the Hartlen Till and the upper reddish till,which is the most common along this shore, is the Lawrencetown Till. Bissett Road which we follow for some distance is named after a prominent landowner of the area in the 1800s. Leaving the outskirts of Dartmouth there is a superb view at the crest of a hill of the Cole Harbour marsh, and the sandy barrier beach Rainbow Haven at the outer coast. "Breakheart" hill as it is locally known was the focus of Cole Harbour farmers in 1819 when they petitioned the government to remove these bothersome hills which as you can imagine were a pain to climb up and down on the way to town with produce. The highway winds along the head of the estuaries where there has been a dramatic increase in new residences built along the shores. Occasionally and especially at the head of West Marsh, just before Stop 3, the remnants of the "Halifax and Eastern" railroad that ran along the Eastern shore are visible. Attempts are being made to make the railway into a recreational trail system "rails for trails".

Conrad Island Park Reserve

Conrads Beach as it is locally known has been described by Taylor *et al.* (1985) and Nichol and Boyd (1993). It is part of a large complex beach system that extends 6 km eastward to Half Island Point (Figs. 11, 23). We will examine this system in two parts. Initially we will discuss the sand beach that extends from Conrod Head to Fox Point and the impact of recent inlet opening and closure on beach stability; we will then go by bus to Lawrencetown Head where we get a better aerial view of the beach system and then we will walk to Lawrencetown Beach, the other major portion of this coastal complex.

Conrads Beach fronts West Marsh which is drained by the Eel River. The river flows under the bridge we passed over, to Lawrencetown Inlet farther east where it joins the ocean. Conrod Head supplies sediment to the beach as did Fox Point and several other islets at one time. Fox Point also provided an anchor point for the well defined tombolo-beach ridge complex that developed. This will be better viewed from Lawrencetown Head, the next stop. Boyd *et al.* (1987) developed their transgressive coastal sedimentation model (Fig. 15) primarily on observations from the Conrads to Lawrencetown beach and estuary complex.

<u>Management Issues:</u> The beach and adjacent lands were granted to several families in the mid-1700s. Farming of marsh hay took place in West Marsh and some of the strangely oriented lag shoal features in the backshore are the remnants of a former track that crossed to the beach from the western shore of West Marsh. Fox Point was preserved for the fishery. Several fishing sheds and a wharf were actively used until the mid-1900s when Fox Point became separated from the main shoreline. It was at the same time that vast quantities of gravel began to be extracted from the beach. Blowouts developed around the sediment extraction pits and loading platforms are still visible at the east end of the beach. The loss of sediment is also attributed to the breakdown of the western part of the beach where the first washover fans developed and eventually led to the breaching of the beach in or about 1962. In the 1960s and 1970s local residents completed a major cleanup of the garbage on the beach and the placed the boulders at the road to prohibit vehicle traffic on the dunes. The beach became protected under the Nova Scotia Beach Protection Act and was slowly acquired from local landowners by the provincial government to make it part of a heritage coastal park system (Fig. 11) that included Lawrencetown Beach which we will visit at the next stop. A problem that has developed is that Lawrencetown has all the facilities for bathing etc., but Conrads is the warmer and more popular beach for local residents yet it has no facilities. Another recent management issue has been the protection of the Piping Plover from recreational users and their pets. This is one of a handleful of beaches where the Piping Plover breeds. In late spring and summer volunteers post signs and try to keep people and animals away from the dunes along the western part of the beach. From a coastal geomorphology point of view this has greatly enhanced the growth and continuity of the dune vegetation and the rapid buildup of dunes along the west end of the beach since the early 1980s. The action has also enhanced the natural sealing of the inlet because of the spread of dune grass and its subsequent trapping of sand.

Next we will walk to the former inlet to briefly discuss the recent physical evolution of this beach. Historical maps and vertical air photos suggest that Conrads beach was a continuous barrier between Conrod Head and Fox Point until 1962 when an inlet was cut through the barrier (Fig. 12) to West Marsh (Taylor *et al.*, 1985). The accumulation of West Marsh flood tidal deposits, which extend as much as 1.1 km inland (Nichol and Boyd, 1993) does not predate the first settlers by very much time as indicated by a C^{14} age of 305± 60 years BP obtained from a peat sample collected from beneath the flood tidal deposits at 1.03 m below sea level (Nichol and Boyd, 1993). It appears that by the 1960s flood tidal deposits had begun to severely choke off the mouth of the Eel River. Water levels rose in West Marsh and either during a storm or during Hurricane Francis in 1962, the beach was cut and an inlet developed and was maintained until the winter of 1989 and 1990 when it was infilled and closed off again. The seaward end of the inlet was by the large boulder you see just offshore. At the time of the breach the western part of the beach consisted of a gravel storm ridge overlying a wide sandflat; the general morphology of the beach east of the inlet was essentially similar to today's but there has been recent dune progradation adjacent to the inlet area.

Sediment supply to Conrads Beach has decreased with the loss of adjacent headlands, e.g. Fox Island and Egg Island and further reduced by the artifical removal of gravel in the 1950s and 1960s. With the opening of the inlet, large amounts of sediment were transported into West Marsh (Fig. 12). An additional loss of sediment has occurred as a result of the closure of the inlet and dune building following the inlet closure.

Survey lines were first established in 1981, 19 years after the inlet had formed. Seven subsequent surveys have been completed. During the 1980s, apart from minor seasonal buildups in the form of a berm, the beach slope has continued to steepen and deepen (Fig. 13). Concurrently, the pebble cobble storm ridge aggraded by as much as 0.4 m at line 1 and it spread westward along the seaward base of the dunes from Fox Point. At the same time pebble cobble material continued to migrate landward over top of the seaward duneline. During most surveys sand levels increased westward from line 1 to 4 where sand accumulated in the upper beach and dunes.

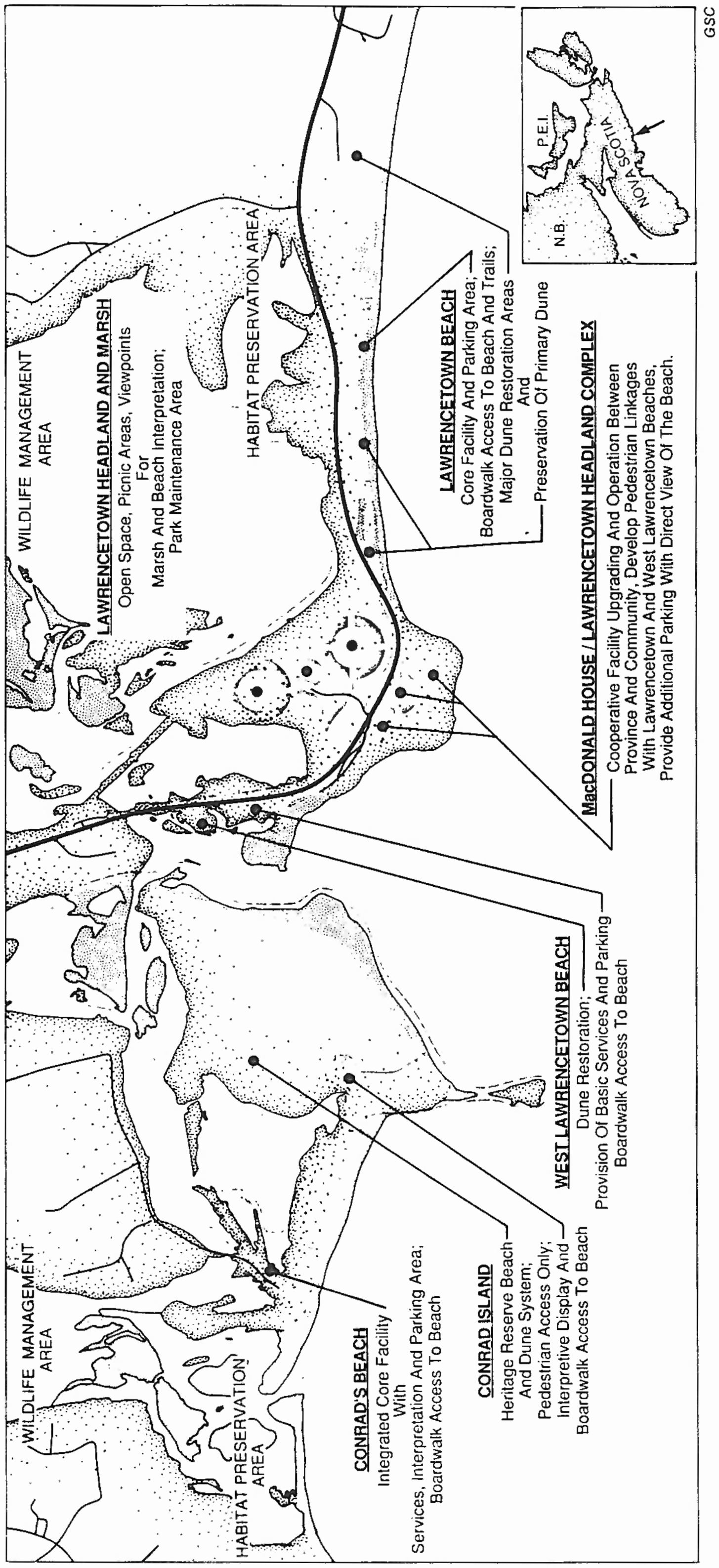


Figure 11 Conceptual plan for a coastal heritage park along the Eastern Shore of Nova Scotia, in particular at Conrads and Lawrencetown beaches (from Nova Scotia Department of Lands and Forests, 1984). The source for the shoreline position is not provided on the original map.

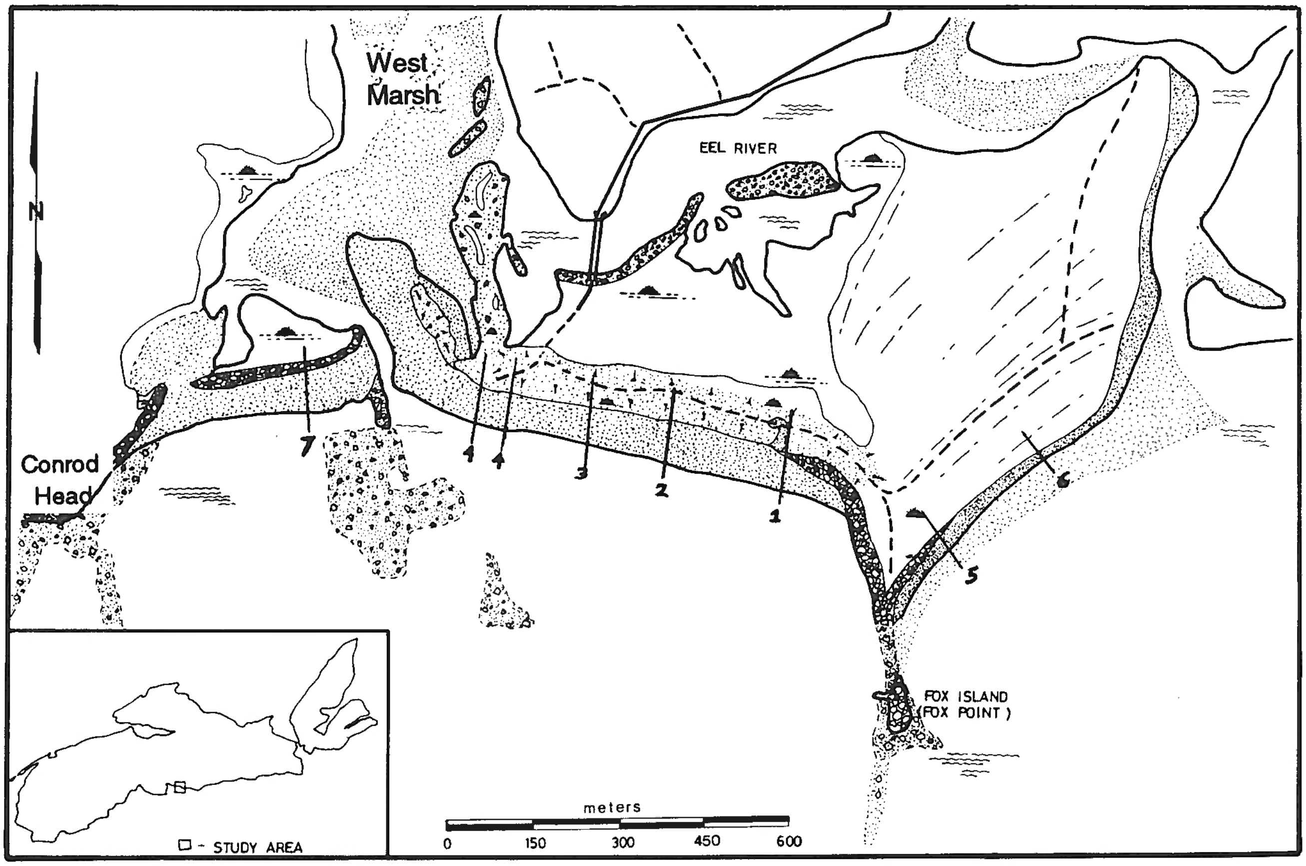


Figure 12 Map of Conrads Beach based on the 1974 air photos which show the extent of the tidal inlet and associated flood-tidal deposits and the location of lag sediment shoals offshore. The location of our beach survey lines are also indicated.

Since the inlet closure, a seaward duneline as much as 3.3 m in elevation has grown at lines 3 and 4. In 1981 the beach west of the inlet consisted of a narrow, low gravel ridge which was overwashed during most storms (Fig. 12). Following the closure of the inlet and the progradation of the sand beach, there was increased aeolian deposition in the backshore. By 1995, the dunes west of the former inlet had grown to nearly 4 m elevation which was just slightly lower than the crest elevation of the older dunes east of the inlet. During the early 1990s, closer to Fox Point, the character of the lower intertidal/ upper shoreface was changing from a more planar slope to a better defined bar and trough topography. The change may reflect the steepening of the slope (Fig.13). Occasional overtopping by waves e.g. Felix 1995, in the former inlet location suggests that the potential for inlet reopening still exists.

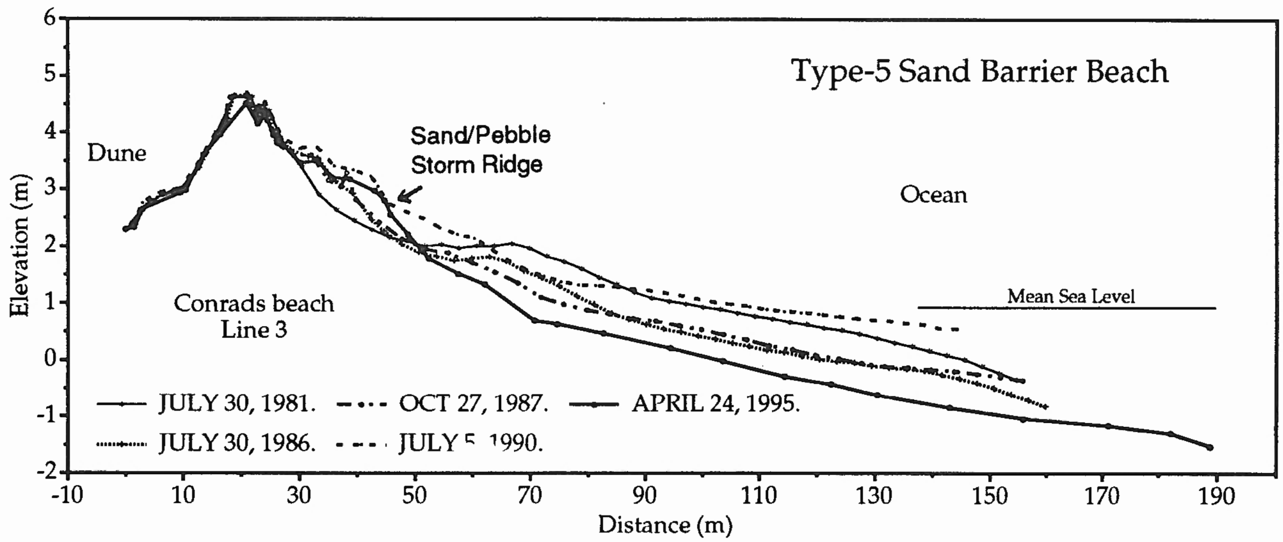


Figure 13 Sequential cross-sectional beach surveys at line 3 just to the east of the main boardwalk shows the initial dune progradation in the early 1980s and the subsequent formation of a gravel storm ridge overlapping the seaward edge of the dunes. Surveys in 1990 (although slightly offline) also show an increased accumulation of sediment across the upper shoreface which may have been associated with the closing of the inlet or with the events that closed the inlet. Profile is drawn at same scale as the gravel barrier beaches but was reduced by 50% to fit on the page.

Stop 4. Lawrencetown Head and Beach

Purpose: To view the large sandy barrier beach and dune complex between Conrad Island Park Reserve (Stop 3) and Lawrencetown Beach and the tidal inlet system at the mouth of Lawrencetown Lake. Discuss transgressive valley-fill processes, changing inlet positions, barrier evolution, headland retreat, and associated changes in coastal configuration during the past 2000 years.

Route: Leaving Stop 3 at 11:10, proceed back to Route 207. Follow it eastward about 2.5 km to the bridge over Lawrencetown Inlet. Continue across the small sand beach complex to the drumlin headland. Pull off to the right into the parking lot by the of the large house at the top of the hill. Arrive 11:15. We will leave the bus stopping at several places as we walk around the seaward edge of the headland on route to Lawrencetown Beach. The bus will pick us up at Lawrencetown Beach and return us to the Tea House for lunch.

En Route to Stop

The route from Conrads Beach to Lawrencetown Head takes us back to highway 207 where we get a different view of the Eel River outlet and the prograded beach ridge system at the east end of Conrads Beach. At the bridge we cross over the inlet to Lawrencetown Lake. A better view of the coastal features will be available at the next stop, at the top of the headland just in front of us.

Lawrencetown Head and Vicinity

From Lawrencetown Head on a clear day, there is a great panoramic view of the Eastern Shore from the white granite cliffs of Chebucto Head, located on the west side of Halifax Harbour to the red cliffs of Half Island Point to the east. The latter cliffs are the primary source of new sediment supplied to the Lawrencetown embayment. Since 1980 mean rates of cliff top retreat at Half Island Point have been 1.3 m/a and as much as 3.4 m/a (Taylor *et al.*, 1995).

From the parking area at the house, we first have a view west across Lawrencetown Inlet, the present tidal channel connecting the ocean to Lawrencetown Lake is to the right and the Eel River which connects to West Marsh is farther west. A wave-modified ebb-tidal delta backed by several flood - tidal deltas fills the triangular embayment between Lawrencetown Head and Fox Point opposite. The far shore consists of a partially wooded dune ridge complex believed to have developed in a relatively protected setting behind a former drumlin headland extending from Egg Island (submerged shoal 1 km offshore) to Fox Point (Fig. 6, Boyd *et al* ., 1987). Field surveys in 1987 and 1995 indicate that the dune scarp has receded by as much as 3 m in places which may partly reflect shifts in the position of the ebb delta but it more likely reflects the increased tidal flows in the Eel River with its resumption as the only channel connecting West Marsh to the Ocean. Between 1962 and 1989 a second inlet had cut through the central part of Conrads Beach to West Marsh capturing a large proportion of the water flowing in and out of West Marsh.

Boyd *et al.* (1985) report that the position of the inlet throat is a function of the meandering character of the tidal inlet channel and sand deposition along Stony Beach (adjacent to Lawrencetown Head). The ebb tidal delta is best developed during the lower wave energy period of summer and in winter as wave energy increases sand is transported from the ebb delta onshore. This process together with increased onshore and longshore sediment transport from the west cause a deflection of the main ebb channel eastward, closer to Lawrencetown Head.

The changing positions of tidal inlets and the associated transgressive infilling of the seaward part of Lawrencetown Lake have been the focus of a study by Honig (1987). The opening of the present Lawrencetown Inlet marked the start of stage 5 (Fig.14) sometime circa 500 years B.P. (Hoskin, 1983; Honig, 1987). A detailed bottom coring program in Lawrencetown Lake revealed active flood-tidal deposits and extensive tidal sand sheets overlapping a sequence of Holocene units, including estuarine muds, tidal channel sands, former flood-delta sands and distal sand sheets ranging from a few hundred years to 3 ka in age (Honig, 1987; Boyd and Honig, 1992). A number of older units were associated with an opening on the east side of Lawrencetown Head, through the western section of the present Lawrencetown Beach. This can be better seen and discussed when we walk around to the other side of the headland.

Lawrencetown Head is the site of one of our shore cliff monitoring sites. A series of stakes established along the cliff have been measured at 1-3 yr intervals since 1980. Between 1980 and 1987 the mean cliff top retreat was 0.26 m/a with a maximum of 0.6 m/a in the early 1980s. Since 1991 the rate has decreased to 0.1 m/a at the location of the stakes because of the increased protection offered by the small foreland at the base of the cliff. At the southeast corner of the drumlin a comparison of air photos from 1954 and the present, shows that an estimated 33 m (0.8 m/a) of cliff top has been lost.

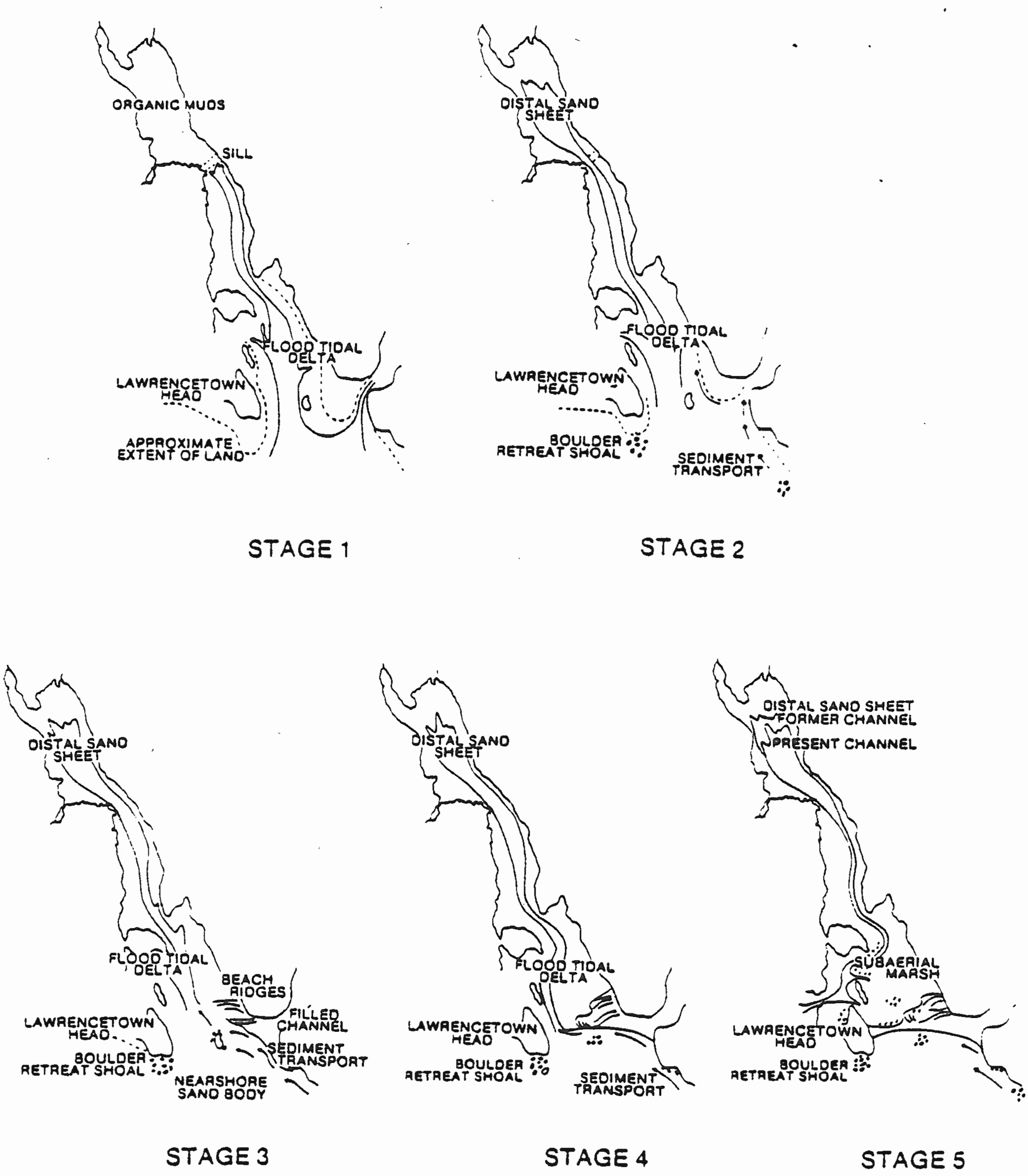


Figure 14 Five stages in the development of Lawrencetown Lake and beach over the past 3000 years (from Honig, 1987).

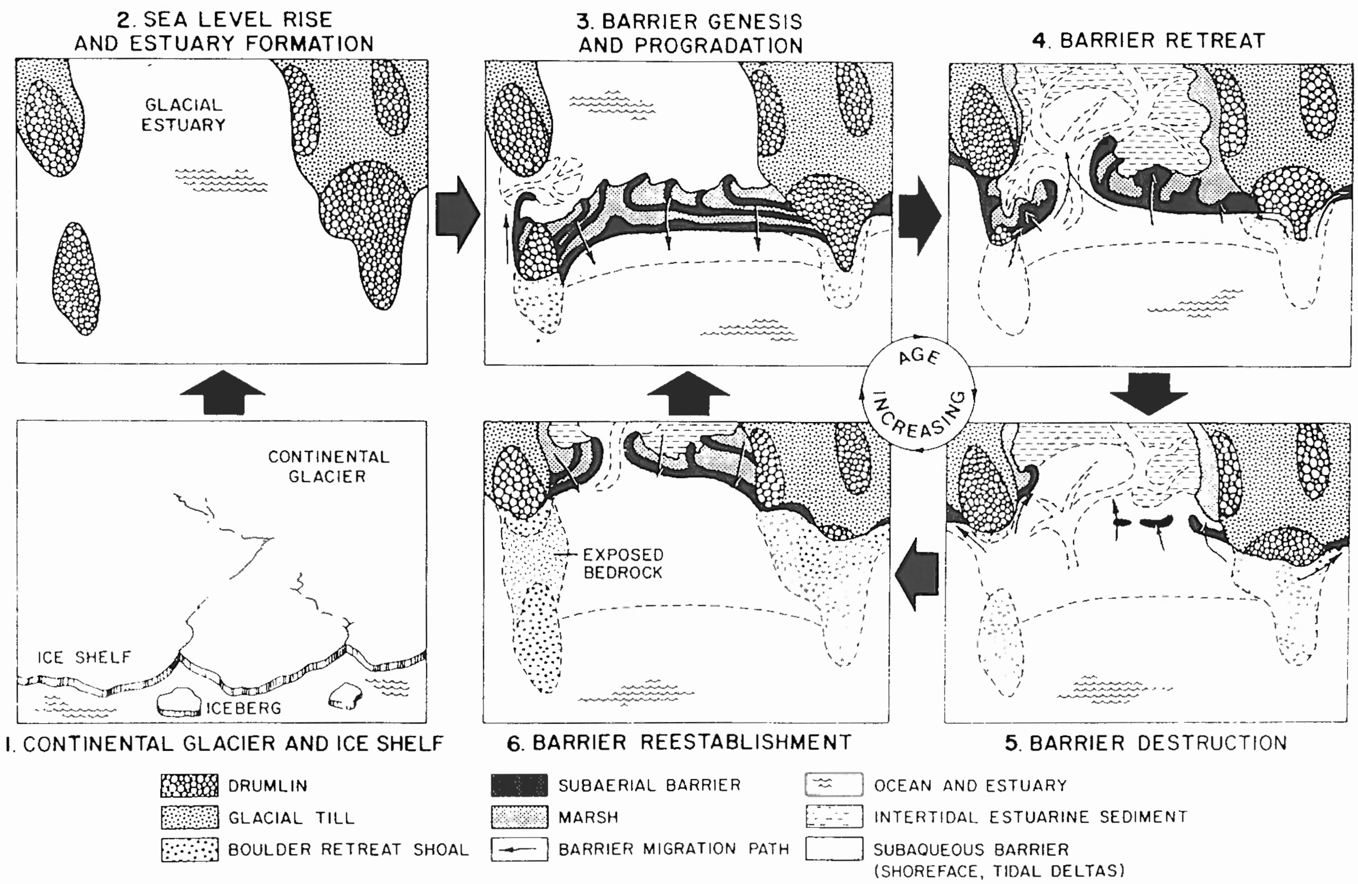


Figure 15 Boyd *et al.*, (1987) using Lawrencetown beach and vicinity developed a six-stage evolutionary model for coastal sedimentation along the Eastern Shore. Sediment is initially supplied by Pleistocene glacial sources (Stage 1). Following deglaciation, a relative rise in sea level causes coastal transgression, transforming glacial valleys to embayments (Stage 2). A reworking of glacial deposits by marine processes produces prograding barrier systems (Stage 3) and as sediment supply decreases barriers retreat (Stage 4) and lose sediment to washover, dune and tidal inlet sinks; finally they are destroyed (Stage 5). In Stage 6 the barriers encounter new sediment sources or anchor points and reestablish themselves further landward.

At the eastern corner of the headland we get a good view of the Lawrencetown Beach complex which is a very popular recreational area, particularly for surfing. Today the beach is a continuous mixed sand and gravel barrier, sandier at the western end and gravel-dominated at the east end. Dunes in the backshore reach nearly 6 m elevation (above geodetic datum) near the canteen and decrease to less than 5 m nearer the houses at the east end of the beach.

Management Issue: Development of a provincial park at Lawrencetown in the mid-1980s (Fig. 11) restricted vehicular and pedestrian travel to controlled parking areas and boardwalks. This has allowed the dunes to revegetate and rebuild since the early 1980s when they had become severely degraded by sand extraction activities and heavy vehicular and pedestrian traffic during the previous three decades.

Lawrencetown Beach was not always a continuous barrier between Half Island Point and Lawrencetown Head but rather it has prograded during the past 2000 years B.P. from a series of smaller beach ridge complexes. Sediment was initially derived from four drumlin sources: Lawrencetown Head, Half Island Point, a headland between Lawrencetown Lake and Porters Lake (the estuarine system occupying the next valley to the east) and a drumlin that now exists as a submerged retreat shoal near the mid portion of the barrier (Boyd *et al.*, 1987). The relict cliff line between Lawrencetown Lake and Porters Lake at the landward side of the highway was eroded at a time when Porters Lake had an opening to the ocean through the present east end of Lawrencetown Beach (Fig. 14). Sediment supplied from the three eastern drumlins infilled the embayment closing off the inlet to Porters Lake by about 1.6 ka B.P. (Laidler 1990; (fig.14, stage 3)). Seismic surveys of depth to bedrock by Oakey (1985) suggest that the area now marked by a series of beach ridges aligned quasi-parallel to the present shoreline is underlain by 8-15 m of sediment. An exception is the former channel into Porters Lake where bedrock was interpreted at 16-24 m depth. The mid-barrier drumlin acted as an anchor and sediment source for a small drift-aligned spit complex observed today as a series of low beach ridges lying normal to the present coastline, (just back of the highway and canteen building). These beach ridges marked the eastern edge of a former inlet connected to Lawrencetown Lake (Fig. 14 , Stage 4). Interpretations of seismic reflection and ground penetrating radar surveys suggest that the former inlet probably once extended to nearly 28 m depth (unpub. 1990 data courtesy of Brian Todd and 1993 data courtesy of Tony Lapierre). The final phase of barrier building resulted in the closing of the western inlet to Lawrencetown Lake and the formation of a continuous barrier across the embayment as we see today (Boyd *et al.,* 1987). Beach ridge formation at Lawrencetown Beach began about 800 years B.P. and was completed by 350 years B.P. according to Hoskin (1983) who completed a morphological reconstruction using ridge morphology, C^{14} dating and historical maps.

We have only just begun to routinely survey this beach so there is little quantitative information on recent morphological changes other than from a single survey line at the east end of the beach where the storm ridge has prograded 3 m seaward since 1978. The build-up appears to have been at the expense of the lower beachface which has been scoured and also retreated 3 m landward. Rip currents are frequently observed off this beach together with strong shore parallel currents. Higher energy wave events such as "Hurricane Felix 1995" comb down the beachface leaving a planar beach slope.

Stop 5. Grand Desert Headland

Purpose: To view the mouth of Chezzetcook Inlet and the associated outer shores of drumlins and attached spits and barrier beaches, including views of Story Head (Stop 8) which marks the eastern entrance to the inlet. To discuss initial retreat phase of drumlins as beaches are pushed landward exposing them to wave attack and the factors which affect their rate of retreat.

Route: Leaving Lawrencetown Head at 13:15, proceed across Lawrencetown Beach to Seaforth, and Grand Desert following Route 207. Proceed past the general store and turn right onto Dyke road. Follow Dyke Road 0.7 km and turn right onto a dirt road that leads to the top of the drumlin. Proceed to the end of the road (0.5 km) where we will have to leave the bus and walk to the seaward edge of the drumlin. Arrive 13:35. It is a 5-7 min walk to the cliff edge.

En Route to Stop

The route from Lawrencetown Beach to Grand Desert takes us across the beach ridge plain and below the relict drumlin cliff at the east end of the beach and then across former inlet to Porters Lake and over the present tidal channnel at Rocky Run. After a short section of road some distance back of the coast, we pass around the landward margin of a salt marsh near Three Fathom Harbour and shortly afterward come out to the coast at a small pocket barrier on the west side of Gaetz Head. Gaetz Head is a fine example of a partially truncated drumlin headland which we will be able to view from the next stop. The road passes on the landward side of Gaetz Head and behind several other drumlins which have become the site of many new residences. As we enter the community of Grand Desert, the road follows along the landward shore of a small estuary / lagoon that is being closed off at its mouth by sediment derived from the rapid retreat of the outer shores. The Nova Scotia Department of Highways artifically opens a channel through the barrier beach at the mouth of the estuary to prevent flooding of this road in the spring. The inlet has become more and more short lived as the adjacent drumlin headland retreats farther landward and waves quickly choke the channel with sediment. As we reach the crest of the drumlin near the next stop we get a good view of the mouth of Chezzetcook Inlet and the beaches of the outer estuary, e.g. Story Head Beach (Stop 8).

Grand Desert Shore Cliff

Permission to access this site has been obtained from the Department of National Defence.
Please note:

- **take extreme care near the top of the shore cliff.**
- **watch out for falling trees rocks and other objects at the base of the cliff.**
- **do not pick up any metal or other unknown objects. Live ammunition is still washing up on shore as the beach migrates landward past the former WWII bombing range.**

We will walk to the seaward edge of the drumlin headland. It began to retreat in the late 1970s when the barrier beach that once protected it, migrated landward past the headland exposing it to wave attack (Fig. 16). Looking first to the left we see at the seaward end of the barrier, the lag shoal which marks the former position of Cape Antrim or Cape Entry, another drumlin. It formed the eastern anchor and sediment source for the Cape Antrim barrier. In the late 1960s the rate of retreat for Cape Antrim increased from 2 to 6 m/a and in the 1970s it increased to more than 12 m/a (Covill *et al.*, 1995). Residents recall that the headland disappeared in only a couple of years once it was eroded past its crest. One reason for the rapid erosion of Cape Antrim was its composition which was much finer than some of the other drumlins such as Story Head. During the mid 1960s a breach also developed at the western end of the barrier beach that stretched from Cape Antrim to Gaetz Head, but it was soon sealed off as the barrier was pushed against the land. During the 1970s the barrier to our left migrated at an average rate of 14 m/a and then slowed to 6 m/a based on measurements from sequential air photos (Covill *et al.*, 1995).

Depending on the waves on the day of the trip you may see them breaking on at least two submarine ridges that appear to run parallel to shore and may represent former positions of the barrier. In 1991 a survey across the nearshore delineated two ridges in water depths of less than 6 m. A 2 m deep trough which may have once been the location of the former lagoon existed between the ridges. Our field surveys began in 1988 when a series of cliff-top recession markers were established along the length of the cliff. The present cliff top decreases from 10.1 m in the east to 3.1 m above geodetic datum at the west end. Since 1988 the position of the cliff top has retreated 30-38 m or 4.5 to 5.5 m/a. Erosion has maintained a fairly straight cliff plan by attacking, more vigorously, at portions that extend farther seaward. Ground water seepage becomes an important factor in the retreat process, as we will see when we visit the base of the cliff.

For those of you interested in the stratigraphy of glacial features this cliff face presents a wonderful opportunity to see the detailed stratigraphy across the width of 1-2 drumlins without having to clean off the face. From a coastal point of view we are interested in how the stratigraphy affects the way waves and ground water erode the cliff face. The thing to note is the abundance of finer material and the absence of boulder clasts which restricts the development of a protective armour at the base of the cliff. Secondly, there are arched inclusions of wet sandy beds which appear to be preferential sites

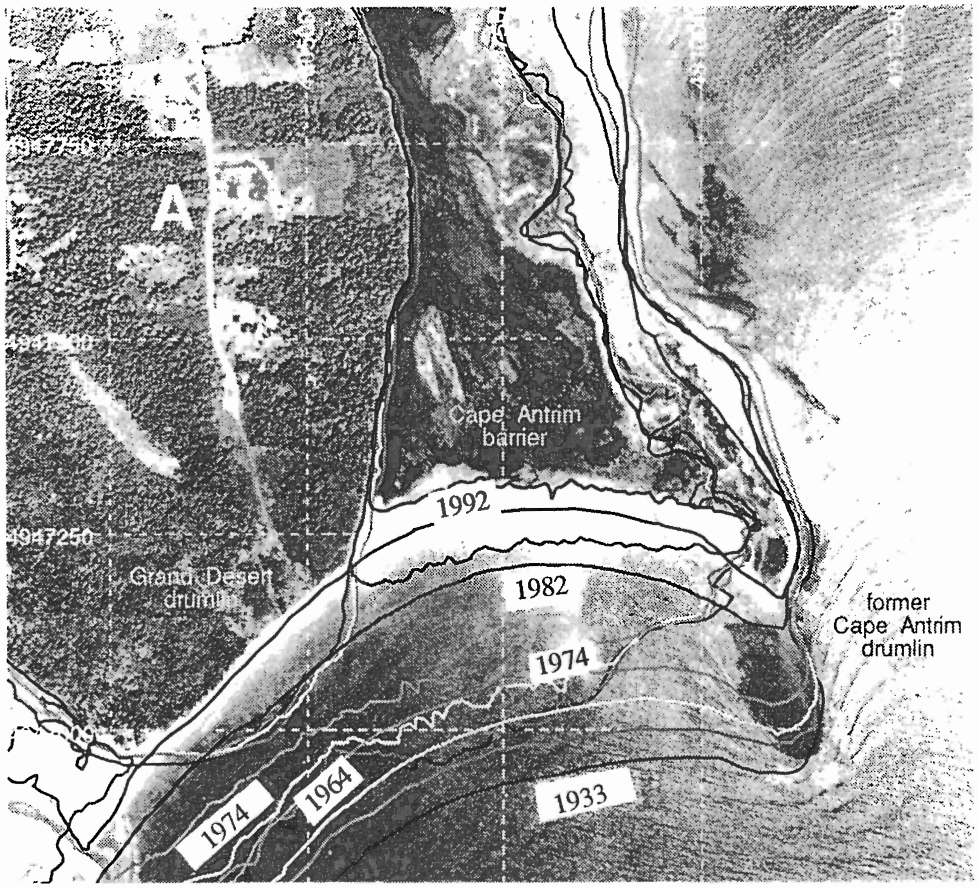


Figure 16. Shoreline changes (1933 to 1992) at the southeast entrance to Chezzetcook Inlet showing the rapid landward retreat of Cape Antrim Barrier (from Covill *et al.*, 1995).

for waves to create caves and blowholes. Once the hollows are enlarged, the upper cliff face breaks away as a massive slump deposit. Also, the presence of an eroded till surface across the beachface enhances swash runup and wave attack of the cliff and restricts the accumulation of material. In winter when the cliff face is frozen the waves can form hollows which lead to vertical slabs of cliff material breaking off. Along the stream valley, which appears to separate the drumlins, the sediment is more saturated and slopewash processes are more common. Where is all the sediment going to? It is common to observe a plume of red sediment on the sea surface just offshore which is one transport mechanism for removing the fines; secondly, sands are being thrown up over the top of the drumlin and the beach at the western end of the cliff, and washed over the Cape Antrim barrier; thirdly, sediment is swept into the adjacent lagoon (to the west) as flood tidal deposits when the inlet is opened by the N.S. Department of Transport, and lastly, the lagoon which used to exist between the drumlin and the barrier beach. As the old lagoon muds are scoured by breaking waves, they are replaced by eroded cliff material. The next stage is to complete a total sediment budget study to see if all of the eroded material can be accounted for.

Stop 6 Chezzetcook Inlet

Purpose: View a salt marsh and discuss estuary infilling.

Route: Leave stop 5 at 14:15. Return and turn right onto highway 207 via Dyke Road and travel northward past the large Roman Catholic church 3.4 km to Shore Road. Before we go down Shore Road we will go up onto old road to get a good view of the estuary. Possible photo opportunity & drive back onto highway 207 and return to Shore Road and stop along the road just past the few houses. Arrive 14:25.

En Route to Stop:

Our route takes us through the historic settlement of West Chezzetcook which was first settled by Acadians after the French-British war ended in 1763. Most of the first settlers came from the Bay of Fundy while others were from Cape Breton Island. Many of the bricks used to build the large church in 1894 were from a local company run by the Bellefontaine family (Labelle, 1995). The source of the clay used to make the bricks is not known. It was from the workers at the local brick factory that the people who began the Shaw Brick Company, which we are more familiar with today, learned their trade (pers. com. 1995, R. Labelle). Other activities of note in Chezzetcook included the exporting of timber, sand and gravel and the building of schooners as large as 80 tons in the mid to late 1800s. Marsh hay was also harvested in the estuary.

Chezzetcook Inlet

As argued by Boyd and Honig (1992), the Eastern Shore estuaries can be classified as wave-dominated salt-marsh estuaries; they have a relatively minor fluvial input. At this stop we are in the quiescent inner estuary zone of Chezzetcook Inlet, dominated by salt-marsh and intertidal flat environments. There are about 80,000 acres of salt marsh land in Nova Scotia, of which 43,000 acres have been dyked. The marshes were formerly major producers of food in estuarine regions. The vegetation near this stop is predominantly Spartina alterniflora, the typical middle salt-marsh grass; Spartina patens dominates the high salt marshes.

David B. Scott and his co-authors have published a number of papers that focus on salt-marshes and sea-level rise. Scott pioneered the use of foraminifera to determine former sea levels (cf. Scott and Medioli, 1978) and has worked extensively in the Chezzetcook area (cf. Scott, 1977, 1980; Scott and Medioli, 1980). He has shown that the Chezzetcook estuary formed as a result of sea-level rise after 6600 years BP, and that about 12 m of mud has accumulated since that time. He has argued that the salt marsh is a recent phenomenon: "the few centimetres of sediment caused by land clearance upset the balance of the estuary, which was formerly a mud flat".

On the drive from Grand Desert you will have observed the gradient in the impact of wave activity in Chezzetcook Inlet. Looking south from the head of the marsh we can see drumlin islands, some of which are being trimmed by wave action which act as foci for small flying spits. Conrods Island is a good example.

The middle and outer estuary zone receive sediment influxes as a result of adjustment of the outer coast to sea-level rise. Thus, at Red Island (Fig. 17) the development of flying spits has been accompanied by the development of sandy flood deltas. Between Black Island and Gros Point (Carter *et al.*, 1992) the bay is being infilled by three deltas, and Spartina marsh is developing (Note we will get a better view of these sites on route to the next stop, Fig. 17). The colonisation of the flood deltas and other environments in Chezzetcook by salt marsh results in 'regressive stratigraphies' - that is, a sequence such as intertidal mud flat, salt marsh, freshwater marsh develops despite rapid sea-level rise (see Jennings *et al.*,1993, 1995). This makes it difficult to interpret sea-level signals in marsh stratigraphies: how can we distinguish between marsh response to forcing by relative sea level and by sediment supply (Jennings *et al.*, 1995)?

We will now drive around the head of the inlet and south to examine coastal changes near the mouth of this wave-dominated estuary.

Stop 7. Miseners Long Beach

Purpose: To illustrate the character of a type 2 gravel barrier.

Route: Depart stop 6 at 14:40. Drive along Shore Road until it rejoins highway 207. Turn right onto the highway and follow it to a stop sign. Turn right and continue 0.2 km to the next stop sign at Highway 7. Turn right onto Highway 7 toward Musquodoboit Hbr.. Turn right just past the former post office (now a video and convenience store), follow signs for Highway 107 and East Chezzetcook. Curve to right at the top of the small hill and follow the signs to East Chezzetcook. Follow this road south through East Chezzetcook and continue for about 8 km south to the end of the paved surface where the road branches. Miseners Long Beach lies at the end of the left fork and Story Head Beach lies at the end of the right fork. Arrive Miseners Long Beach at 15:10.

En Route to Stop

The route around the head of Chezzetcook Inlet provides us with a good view of the supratidal marshes and the new highway that was built across it. The road winds through the old settlement of East Chezzetcook and along the east shore of the inlet. Red Island, (Fig. 17) discussed earlier, is visible nearer the outer part of Chezzetcook Inlet. Human activities have also played affected sedimentation in this area of the Inlet. In the 1950s and 1960s schooners used to come from Halifax and dredge sediment from the bottom of Chezzetcook Inlet just seaward of Conrod Island. The sand was used in the plaster industry. The build-up of subaerial features may well have been delayed by this action. There were also two large breakwall structures built in the estuary: one at an oblique angle to Red Island and the other to the SW of Conrod Island. Both have had significant effects on the sedimentation patterns in the mid to outer estuary.

Chezzetcook Inlet contains a rich and extensive mix of saltmarsh, tidal flat estuarine and related habitats. It is frequented during the summer by large numbers of Great Blue Herons and occassionally by more exotic relatives such as the Great Egret. Large numbers of geese are seen in the outer estuary in the fall and late winter.

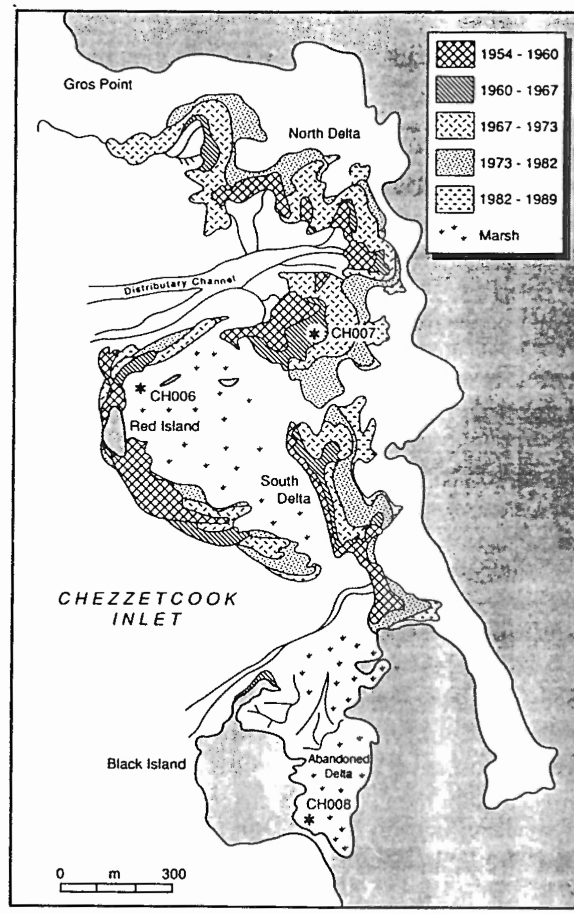


Fig. 17 Rapid accumulation of sediment is occurring adjacent to Red Island, located in the southeast part of Chezzetcook Inlet. The extension of spits and expansion of marsh have been the net result. Much of the sediment has been derived from the erosion of shore cliffs and the landward retreat of barrier beaches at the mouth of Chezzetcook Inlet (Carter *et al.*, 1992).

Miseners Long Beach

This beach is representative of the type 2 barrier, which is dominated, at least in the central part of the beach, by a single, high pebble-cobble storm ridge that extends to nearly 5 m above geodetic datum. The barrier at present has no significant source of new sediment. A comparison of sequential aerial photographs since 1954 suggests that the barrier has been relatively stable showing only minor landward migration as the crest grew slowly higher and narrower. Wave washover lobes along the back of the central barrier suggest that wave washover was more frequent when the barrier was lower, possibly during or before the 1950s. Since our field surveys began in 1985 there has been minor wave overtopping but wave overwash has been restricted to the far eastern corner, the western end (adjacent to where we are standing) and occasionally near the small island that joins the central part of the barrier. Since 1985 very little change has been recorded across the backshore and barrier crest but there has been considerable reworking of the beachface and the upper shoreface sand wedge (Fig.18a). It is this sand wedge that acts as an important buffer for the storm ridge against wave attack. The steep and highly reflective upper beachface is often characterised by well developed and often multi-tiered cusps. Thinning of the barrier crest has occurred on a couple of occasions such as in the fall of 1991 when a succession of storms, including the Halloween Storm, scoured and substantially cut back the barrier crest (Fig. 18). The storm ridge was rebuilt before breaching could occur but it is possible that this is the mechanism (of crest scouring and retreat) by which a type 2 barrier evolves into an unstable type 3 gravel barrier such as Story Head (our next stop). Conversely, if the shoreface becomes deeper, waves can break closer inshore changing the beach from a low type 3 or type 5 barrier to a high steep type 2 barrier as gravel is added to the beach crest. Such was the case at Long Beach following the sediment extraction activities in the 1950s (pers com. Earl Wilcox,1995).

We will take a walk out to the middle part of the barrier where you can better observe the height and steepness of the storm ridge, and we will discuss the effects of shore ice on barrier beach stability.

In winter, air and sea temperatures cold enough to form shorefast ice occur infrequently and usually for only a few days at a time along the Eastern Shore. In fact little has been written about the occurrence of shorefast ice, its character and effect on shoreline stability along Atlantic Nova Scotia because of the perception that ice is a non issue, except possibly in the lagoons. In most winters a narrow band of shorefast ice, or frozen sediment forms at or just above the high tide level. In sands the frozen layer usually is restricted to the surface sediment which can easily be broken up into slabs and redistributed or melted. The presence of a frozen upper beachface can enhance wave run-up and in some cases wave overtopping. If the backshore becomes frozen, seepage through the beach or wave overwashing can result in channels being cut and preserved in the backshore until thaw causes collapse of the channel walls. Frozen lagoon shores and lagoon shorefast ice also enhance the transport of beach sediment out onto the lagoon ice and its subsequent deposition in the lagoon during the next thaw.

The shorefast ice formed in 1992 and 1993 along the Atlantic shores of Nova Scotia was the most significant since the 1920s, according to some local residents. In 1993 shorefast ice and nearshore brash ice were a major factor in understanding the impact of the so called the "storm of the century" March 13,14 along the coast of Atlantic Nova Scotia. For example, lets examine the sequence of shorefast ice development at Miseners Long Beach between March 9 and 16, 1993. By March 9th the upper beach face was covered by a well defined icefoot composed mainly of drifted snow. The most seaward extent of icefoot was at the rocky promentories because of the greater support provided by the rocks. The seaward edge of the icefoot was 2.5 m in height and some large chunks of the icefoot were starting to break off as the salt water soaked the icefoot. The presence of brash ice overtop of the icefoot and scattered across the backshore suggested that higher energy waves had recently cut back the icefoot. During March 13 and 14, the "storm of the century", which was tracking up the eastern US seaboard, brought snow, rain and winds of up to 110 km/hr. The old icefoot was further eroded as the storm intensified but it became protected as the embayments filled with brash and slush ice. The new zone of shorefast ice extended to beyond the rocks you see in front of you. It was marked on its

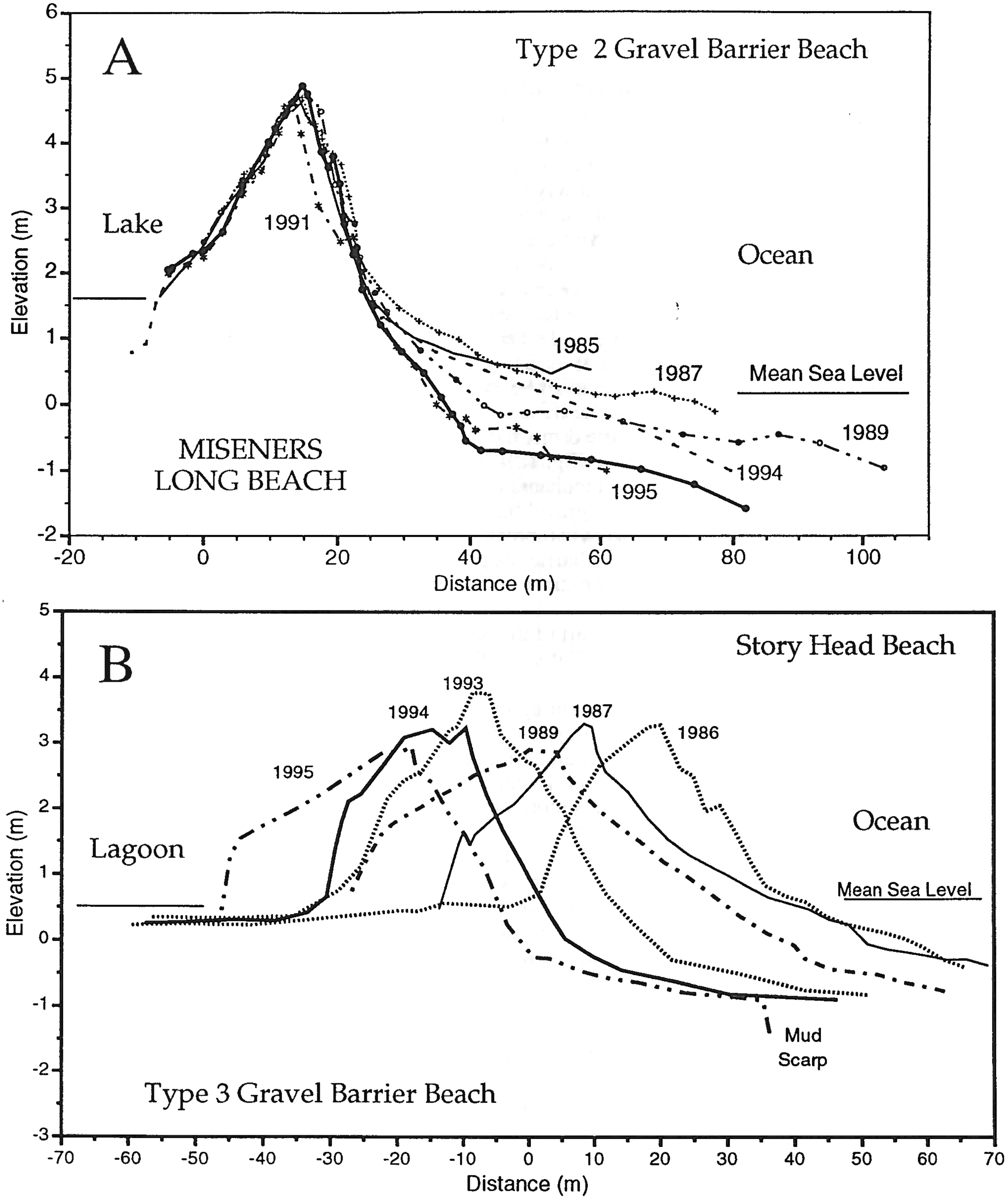


Figure 18 Field surveys completed at Miseners Long Beach (Stop 7) and Story Head Beach (Stop 8) illustrate the sharp contrast in beach changes that occur at a type 2 versus a type 3 barrier. At Miseners Beach, an example of a type 2 barrier, little change is observed on the backshore and crest, but reworking of the beachface is considerable. At Story Head, a type 3 barrier, there has been complete reworking of the barrier sediment as it rolled landward.

seaward side with a well defined slush icefoot and some partially formed ice volcanoes. Wave energy was expended against the seaward edge of the icefoot rather than the beach, thus the wave breaker zone was effectively shifted seaward, in some embayments by as much as 40-50 m. By March 16th most of the slush ice had disappeared, but a second icefoot had formed seaward of the March 9th icefoot. Both were crumpling because of increasing air temperatures, breaking waves and their saturation by salt water. The net effect of the ice appears to have been (1) to protect the upper beach from severe wave attack, particularly landward of the rock outcrops, and (2) to shift the breaker zone seaward which may have caused increased scouring at the base of the icefoot offshore but this could not be checked by surveys following the ablation of the icefoot.

Stop 8. Story Head Beach

Purpose: To examine one of the most rapidly moving gravel barriers on the Eastern Shore. Discuss aspects of sediment supply, barrier migration processes including wave overwash, swash alignment and controls of substrate, and lagoon morphology on barrier stability and migration. Rapid barrier migration and the effects on cross-shore variations in sediment character are also visible and will be discussed.

Route: Depart stop 7 at 15:35. Drive back up the dirt road to the fork in the road at the end of the pavement and turn left toward Story Head Beach. Arrive at 15:40.

Story Head Beach

Story Head Beach is a 40-60 m wide swash-aligned, barrier which is representative of a type 2 low gravel barrier. Story Head Beach stretches between a lag shoal, once the location of Miseners Island, (Fig.19) and Story Head a drumlin headland with a 8-15 m high seaward cliffline (Carter *et al.*, 1990a,b). Initially both drumlins at Miseners Island and Story Head supplied sediment to Story Head Beach but by the early 1980s Miseners Island was eroded away and by December 1986 a breach began to develop between Story Head and the swash aligned part of the barrier. The longshore supply of sediment to the barrier decreased as the breach deepened and widened during the next 5 years.

The parking area where we are now is just seaward of a former homestead owned by Seymour Conrad and the road used to extend farther seaward to where a bridge crossed a small tidal channel, passable by small boats, to Miseners Island. In the 1920s two farms existed on the island but now all that remains is the broad intertidal and subtidal boulder retreat shoal that you see just seaward of us. The boulders that line the road were established in the 1960s as a way to protect it from erosion as trucks hauled sediment from Miseners Island and Story Head Beach. Story Head Beach also provided an access route for vehicles driving to Fishermans Beach (to our right) where only a few of the original fishing sheds still exist.

Evidence from the 1854 hydrographic chart, early 20th century topographic surveys, and air photographs of the site taken in 1945 and 1954, indicate that the barrier was relatively stable, with a mean migration rate of less than 2 m/a for many decades. A dramatic change occurred circa 1954, possibly triggered by Hurricane Edna in September of that year, by a susceptible morphodynamic configuration caused by aggregate extraction, and possibly by a general increase in storminess during the first part of the 1950s. Between 1954 and 1992, the barrier moved an average of 258 m landward during the 38 yr period (Fig. 19, Covill *et al.*, 1995). Maximum retreat was recorded between 1966 and 1974 when the barrier moved an average of 10-12 m/a. Between 1954 and 1982 Miseners Island was completely eroded away (total area of 35465 m^2.). Maximum retreat rates for the drumlin of 9.4 m/a occurred between 1966 and 1974 (Covill *et al.*, 1995). Ground surveys completed since 1985 show that the migration rate at the beach crest has slowed to between 2.6 and 4.3 m/a.

Our surveys which began in 1985 bracket one complete rollover sequence of the barrier, which has taken 9 to 10 years.

In its rapid retreat after 1954 the beach abandoned a part of its former volume of gravel on the shoreface (Fig. 20) as an overstepped remnant (Forbes *et al.*, 1991b). Continued rapid barrier rollover and shoreface retreat have been facilitated by a 6 m, and possibly an 18 m, thick fill of estuarine sand and mud which form the intertidal flats and shallow subtidal back-barrier basin. Not only has this provided a shallow 'runway' for the fast moving barrier but it provides a readily erodable substrate across the shoreface. During the past few years the surface of the upper shoreface has switched from a sand cover with scattered cobbles and boulders to a very slippery, compacted mud. Also, along the upper shoreface there is a 1-2 m high scarp which has retreated landward at a similar pace to the subaerial barrier beach. Since 1985 the top edge of this subtidal scarp has retreated 35 m (Fig. 20). Much of that retreat occurred since 1991 when the retreat rate accelerated to between 4 and 5.5 m/a as the estuarine muds were exposed to breaking waves following the general loss of sand cover either pulled offshore into the depression created by the landward retreat of the scarp (Fig.20) or carried into the breach and added to the west end of the barrier beach. As the mud cap was chipped away, the underlying, more easily erodable, estuarine sands became exposed.

Before 1960 Story Head Beach was a continuous barrier but as Miseners Island retreated the barrier became breached at the eastern end in 1962 resulting in the growth of a drift-aligned spit into "Miseners" Lake which we can see to the east of us. This inlet has remained open because of the closure of the channel at the bridge and the absence of a new sediment supply. The next break in Story Head Barrier came in 1986-87 when a breach developed at the 'hinge point' between the trailing drift aligned gravel ridge extending northward from Story Head and the swash-aligned barrier. The requirement for a continuing and possibly increasing sediment supply to the end of the trailing ridge (Carter *et al.*, 1987; Forbes *et al.*, 1991b) in order to maintain the integrity of the barrier was seen as a weak link as wave washover continued to force the barrier landward and caused a stretching of the arc. The breach has continued to deepen and it is now a broad intertidal shoal that separates the drift-aligned, from the swash-aligned parts of the system. A third breach was cut through the drift-aligned ridge soon after and adjacent to the second. The westward end of Story Head Barrier has been rapidly extended and pushed northwestward so that today there is only a small tidal channel separating it from Fishermans Beach. Local residents have observed other short-lived breaches in the barrier particularly toward the eastern end but the cuts have always been quickly infilled by sediment and repaired naturally before a permanent inlet could develop.

It was from Story Head and other beaches in and adjacent to Chezzetcook that Orford *et al.*, 1991b based their evolutionary model of gravel barriers (Fig. 21). Three stages were proposed (a) start with the initiation of small drift aligned forms at the edge of an erosional front as sea level rises; (b) there is a period of consolidation and stabilization when drift-aligned may become swash-aligned and take on a variety of forms including the barrier types 1, 2, 3, of Forbes et al. (1990). The third stage is associated with the breakdown of the barriers as sediment supply decreases and sea level continues to rise. Drift-aligned forms may break into cells and swash-aligned may be breached, revert to drift-aligned, become segmented or overstepped. How do you think that Story Head will evolve in the near future?

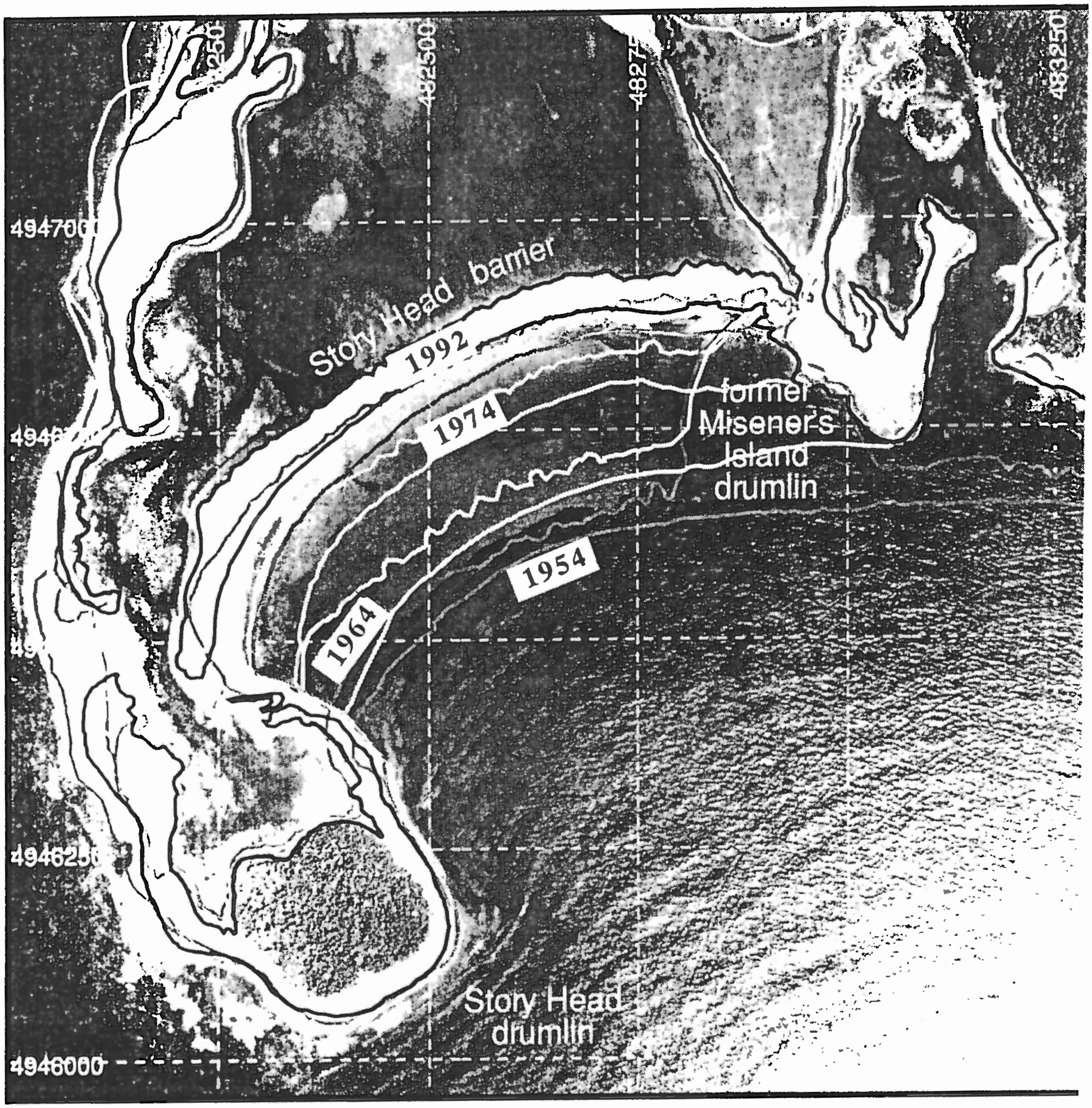


Figure 19 Story Head drumlin headland, barrier beach and the now-vanished Miseners Island. Shoreline positions are taken from rectified air photos from 1954 to 1992 (from Covill *et al.*, 1995).

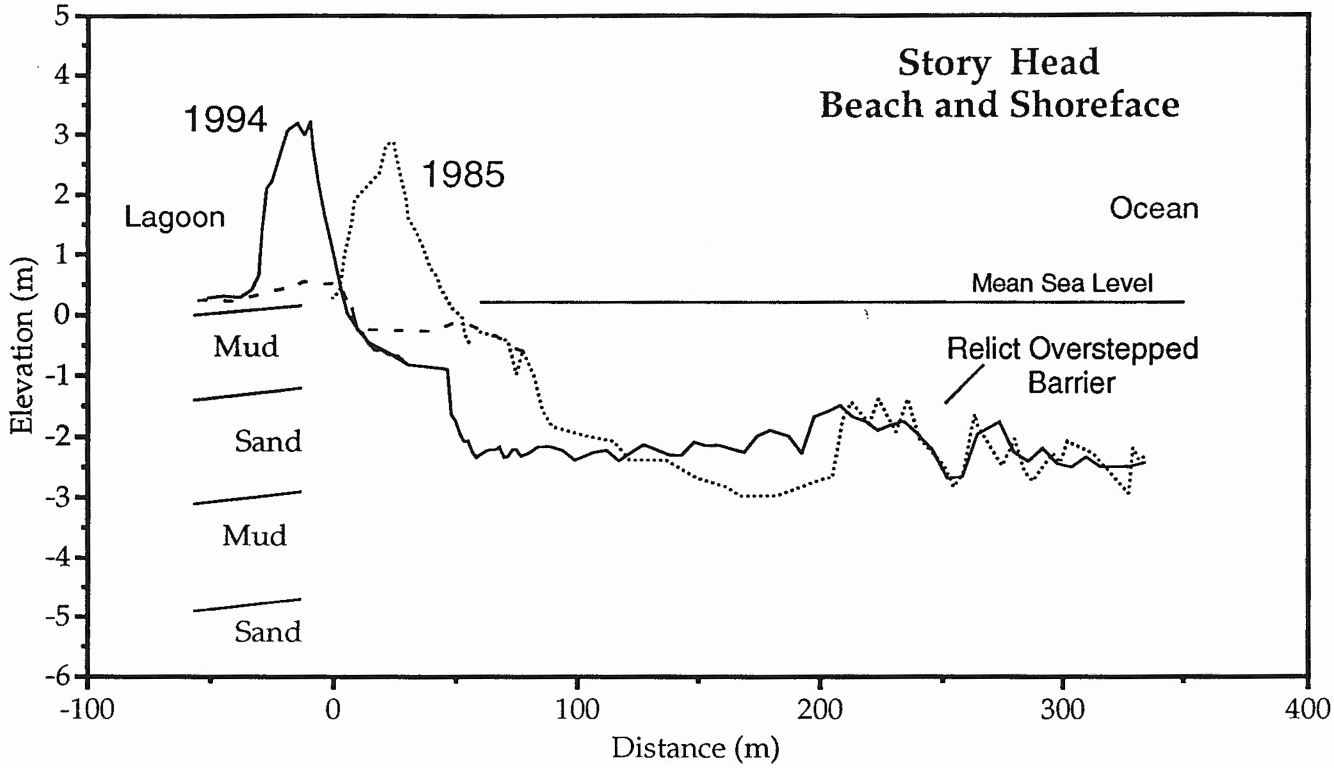


Figure 20 Cross-sectional view of Story Head Beach and shoreface in 1985 and 1994 with the back basin stratigraphy. During the nine years the shoreface scarp retreated 35 m landward and the depression landward of the relict overstepped barrier was infilled by sediment. By 1994 the seabed landward of the scarp was a slippery compacted mud surface with only scattered occurrences of cobbles and boulders. The sand cover observed in 1985 had been removed by the early 1990s.

Since the papers by Orford *et al*., (1991a, b) the analysis of field surveys has revealed new information about the landward migration of swash-aligned barriers. Measurements of barrier crest retreat using vertical air photos taken at 5-10 year intervals suggest a rapid, but uniform, retreat along the whole barrier, however more frequent longshore beach crest surveys reveal a non-uniform rate of retreat alongshore. Crest retreat in places was as much as 15 to 17 m in less than 2 years, which was considerably higher than the rates measured from the air photographs. Sequential maps (1986 to 1995) of barrier crest position along the swash-aligned portion of the barrier show the following changes (Fig. 22, 23 a-f): (a) in 1986 large scale changes occurred along the west end and between lines 9 and 12; (b) between 1986 and 1988 crest retreat was greatest along the central part of the beach, particularly at lines 10 and 11; (c) between 1988 and 1990 the largest crest retreat was nearer the ends of the beach, near lines 4 and 12; (d) from December 1990-1991 crest retreat occurred along much of the beach, but it continued to be faster toward the ends of the beach; (e) fewer crest surveys were completed between 1991 and 1993, but the crest remained fairly stationary, in fact it began to shift slightly seaward at lines 4 and 12. However, crest stability was short lived; (f) during the winter of 1993-94 crest retreat intensified at lines 4 and 11 and since 1994 retreat has again increased between lines 11 and 9 as it did in 1986. At the same time Story Head Beach was extended westward and landward as the breach widened between the drift-aligned portion of the barrier (Fig. 22).

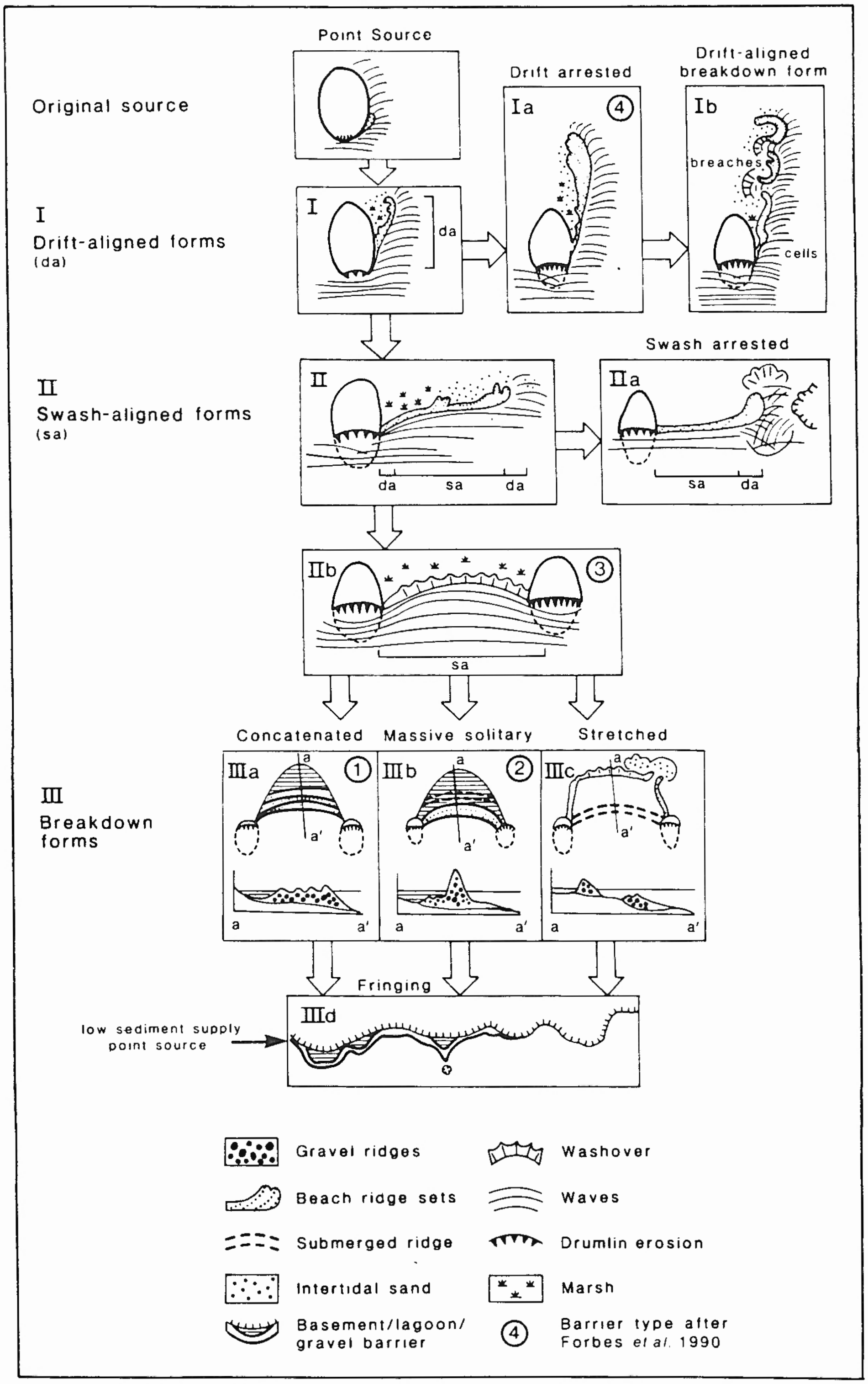


Figure 21 A conceptual model for the initiation, establishment and breakdown of gravel barriers was developed by Orford *et al.,* (1991b). The model illustrates changes expected along drift- and swash-aligned gravel barriers. The barrier types proposed by Forbes *et al.*, (1990) are shown as circled numbers.

If one analyses the beach surveys from Story Head Beach, the maximum crest elevation has shifted westward from line 11 in 1991 to line 10 in 1993, line 9 in 1994 and line 8 in 1995.

It has been argued elsewhere that the dominant process by which gravel barriers migrate landward is through rollover caused by wave overwash (Orford *et al.,* 1991b). Such is also the case at Story Head Beach as confirmed by the prominent wave washover lobes that mark its backslope. Episodic events where a significant storm surge occurred or during larger events such as hurricanes Gloria, in 1985, Gabrielle and Hugo in 1989 and Felix in 1995 (see cover) which generated large scale swell were responsible for massive overwashing and a landward translation of some parts of the barrier. For example at line 4, the beach crest was pushed nearly 11 m landward, lowered by 0.7 m and washover deposits extended the backslope 13 m farther landward during the events of 1989. Washover is greatest where the crest is reduced to less than 2.9 m elevation. As high tide was approached during hurricane Felix the lower crest areas were affected by discrete overwash, which at high tide stage switched to continuous sheet overwash, but as the tide ebbed and the storm continued washover depressions in the crest deepened and became the focus of future wave washover. This process reduces or prohibits waves from overwashing the adjacent higher beach crest. With time the washover lobes are built to elevations higher than the adjacent backshore. Some sediment is transported into the lower backshore areas by washover that spills off the sides of the original lobe but large scale deposition does not begin until subsequent storm events push the higher adjacent beach crest into the washover channel and into the lower backshore to create a new washover lobe, thus abandoning the original washover channel. The events that trigger a type 2-high gravel barrier to become a type 3 -low gravel barrier are still unanswered. This is what we are monitoring at Miseners Long Beach in the adjacent coastal compartment. Similarly it is anticipated that our field surveys at the other beaches we have visited will help to answer when and why the different barrier beach types evolve into a new phase of development.

To recap, the impacts of sea-level rise on the shores of atlantic Nova Scotia have been summarized in a sketch by John Shaw (Fig. 24). They include: (A) increased shore cliff retreat (Grand Desert, Stop 5); (B) destruction of islands that protect estuaries and act as anchor points for coastal barriers (Story Head, Stop 8); (C) exposure of new sediment sources by coastal retreat (Chezzetcook Inlet, Stop 5, 6 and 8); (D) rapid barrier retreat Cow Bay, Grand Desert and Story Head Barriers (Stop 2, 5 and 8); (E) temporary stability of some barriers Miseners, Conrads, Lawrencetown Stop 3, 4 and 7), (F) initiation of new beaches and tidal flats (Lawrencetown Chezzetcook Stop 4 and 6); (G) transition from freshwater to salt marsh (Cow Bay Lake, West Marsh Lawrencetown Lake Chezzetcook Inlet, (stops 2, 3, 4 and 6).

ACKNOWLEDGEMENTS

We wish to thank all the students and staff who have assisted us in the collection of the field data that has been used in the compilation of this field guide. we also acknowledge the assistance of Andy Sherin who produced the route map at the end of the field guide. Steve Solomon and Kimberly Edwardson who provided critical reviews of the original field guide are also gratefully acknowledged for their effort.

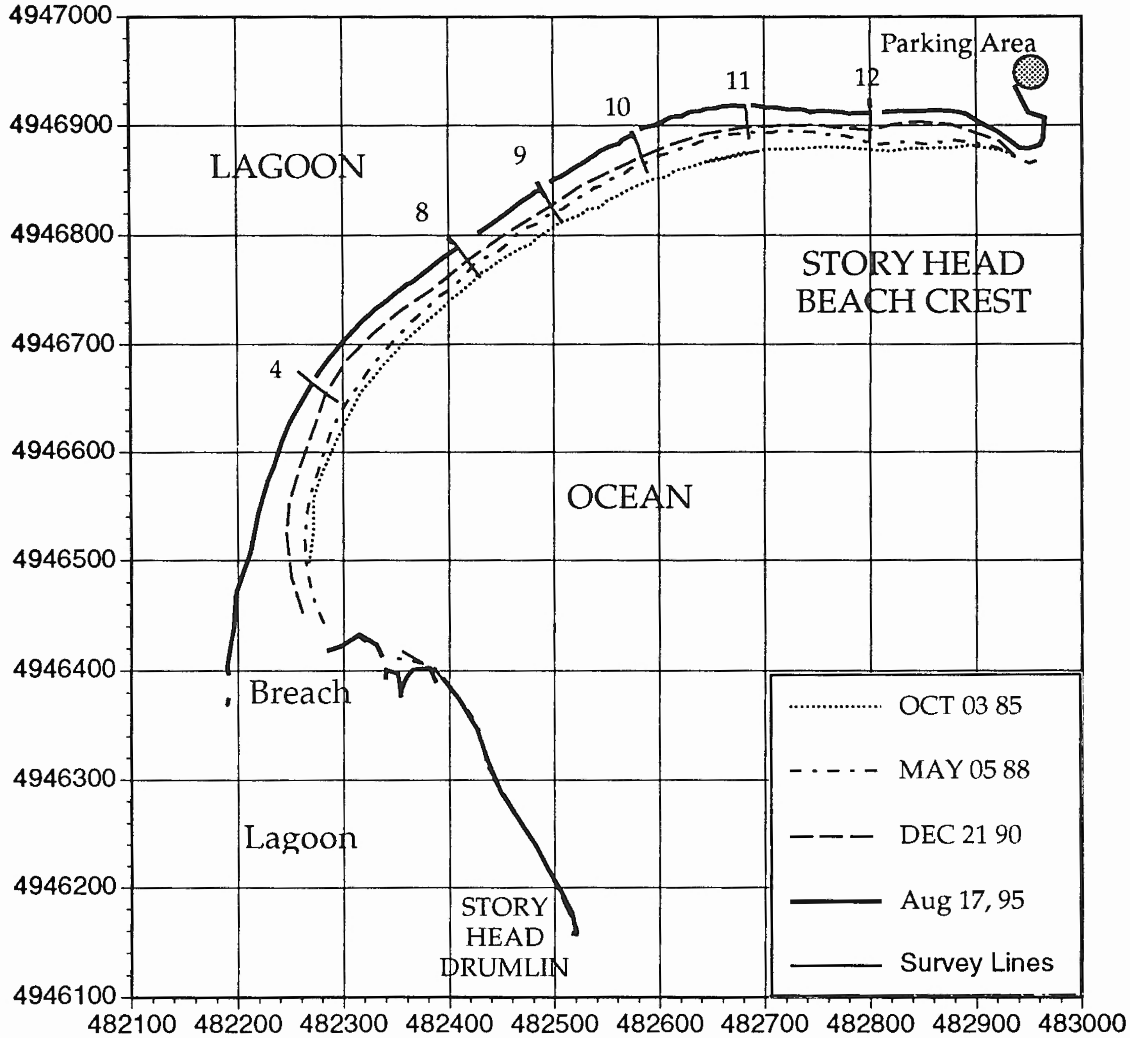
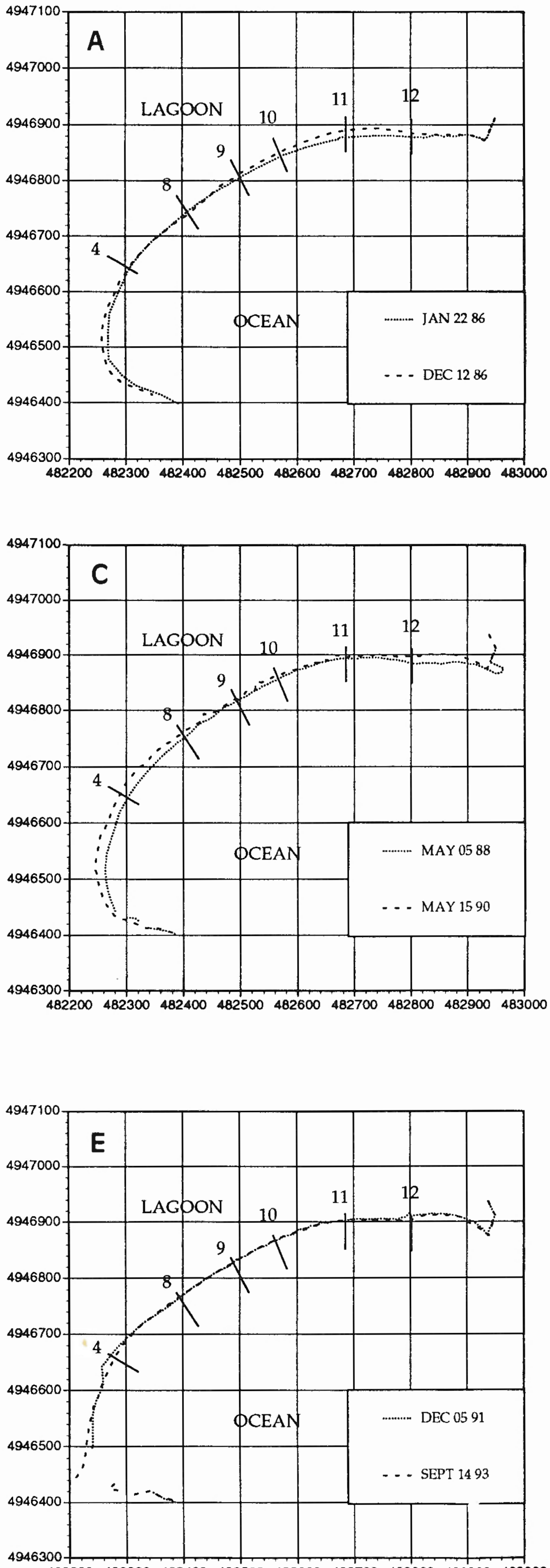
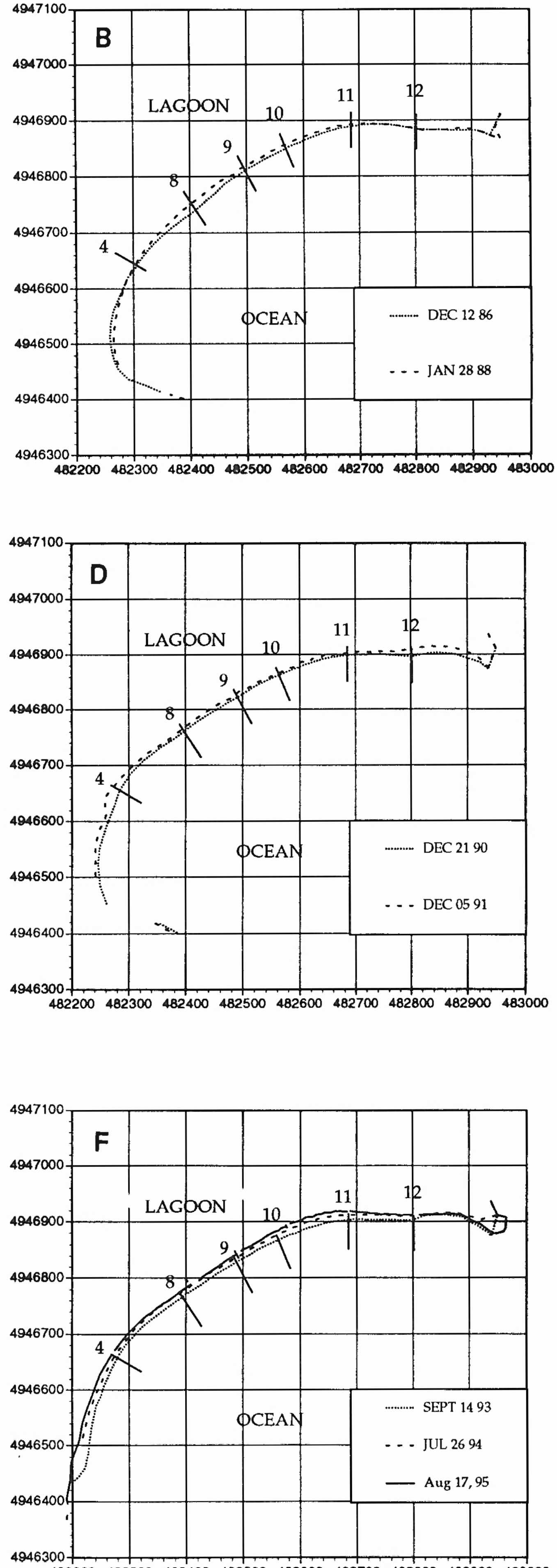


Figure 22. Compilation of beach crest positions for Story Head barrier, plotted at a 2 to 5 year interval suggest that strong pulses of landward retreat occur along the beach at different times. The plot also illustrates the widening of the breach and westward extension of the barrier since the late 1980s.

Figure 23 (next page). When sequential plots of barrier crest position at Story Head are plotted on a 1 to 2 year interval, the pulses of landward retreat become more apparent. The segments of rapid retreat have a subsequent effect on other adjacent parts of the barrier. Landward retreat of the barrier appears to be cyclic and transmitted alongshore like a wave. For example, the barrier crest has been progressively lowered in a westward direction from line 11 to line 8 since 1993.



Story Head Beach Crest
1986-1995



Story Head Beach Crest
1986-1995

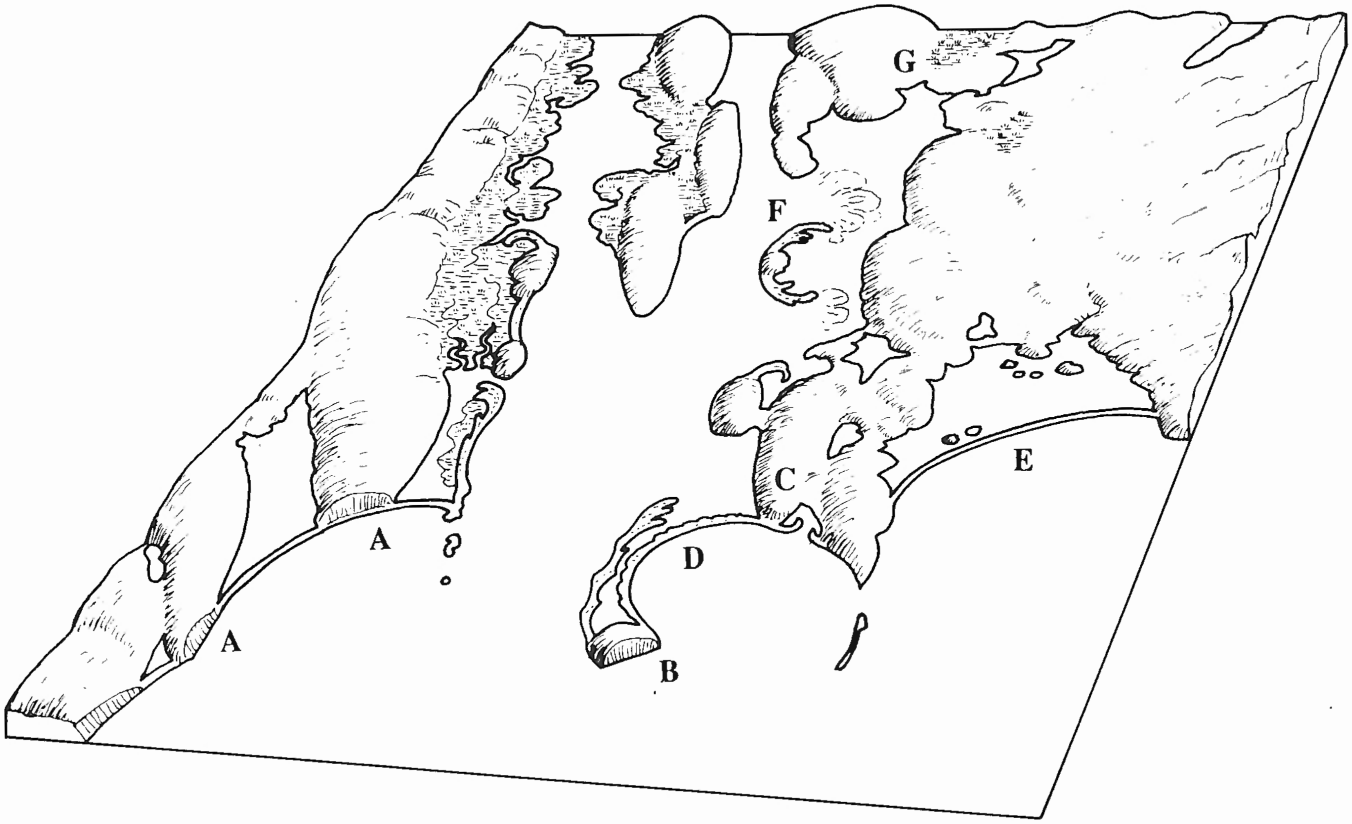


Figure 24. This sketch of the Chezzetcook area of Nova Scotia by John Shaw summarizes the impacts of a sea level rise on coastal stability. The impacts include: (A) increased coastal bluff retreat; (B) destruction of islands which anchor barriers and protect estuaries; (C) exposure of new sediment sources; (D) rapid migration of barriers and recycling of shoreface sediment; (E) temporary stability of some barriers; (F) growth of new beaches, barriers and tidal flats; (G) switching from freshwater to salt marsh. The impact of man, if left unchecked, can accelerate the impacts listed above and in some cases cause the stages of natural barrier evolution to be interupted, reversed or skipped entirely.

REFERENCES

Barnes, N.E. and Piper, D.J.W., 1978. Late Quaternary geological history of Mahone Bay, Nova Scotia. Canadian Journal of Earth Sciences, 15; 586-593.

Boyd, R. and Honig, C., 1992. Estuarine sedimentation on the Eastern Shore of Nova Scotia. Journal of Sedimentary Petrology, 62; 569-583.

Boyd, R. Bowen, A.J. and Honig, C., 1985. Transgressive sedimentation, Eastern shore, Nova Scotia; Field Guide for 14th Arctic Workshop, Nov. 6-8, 1985, Dartmouth, N.S., 43 p.

Boyd, R., Bowen, A.J. and Hall, R.K., 1987. An evolutionary model for transgressive sedimentation on the Eastern Shore of Nova Scotia, p. 87-114. *In*: D.M. FitzGerald and P.S. Rosen, eds., Glaciated Coasts. Academic Press, San Diego.

Buckley, D.E., Smith, J.N., and Winters, G.V., 1995. Accumulation of contaminant metals in marine sediments of Halifax Harbour, Nova Scotia: environmetal factors and historical trends. Applied Geochemistry, V. 10, No. 2; 175-195.

Buckley, D.E. and Winters, G.V., 1992. Geochemical characteristics of contaminated surficial sediments in Halifax Harbour: impact of waste discharge. Canadian Journal of Earth Sciences, V. 29, No. 12; 2617-2639.

Canadian Hydrographic Service, 1951. Tidal Publication No. 30.

Canadian Hydrographic Service, 1991. Canadian tide and current tables, volume 1: Atlantic coast and Bay of Fundy. Department of Fisheries and Oceans, Ottawa, 45 p.

Carrera, G. and Vanícek, P., 1988. A comparison of present sea level linear trends from tide gauge data and radiocarbon curves in eastern Canada. Palaeogeography, Palaeoclimatology, Palaeoecology, 68; 127-134.

Carrera, G., Vanícek, P. and Craymer, M.R., 1990. The compilation of a map of recent vertical crustal movements in Canada. Unpublished report to Geodetic Survey of Canada, DSS Research Contract 50SS.23244-7-4257.

Carter, R.W.G., Orford J.D., Forbes, D.L. and Taylor, R.B., 1987. Gravel barriers, headlands and lagoons: an evolutionary model. *In:* Proceedings, Coastal Sediments '87 (New Orleans) American Society of Civil Engineering, New York, N.Y.; 1776-1792.

Carter, R.W.G., Forbes, D.L., Jennings, S.C., Orford, J.D., Shaw, J. and Taylor, R.B., 1989. Barrier and lagoon coast evolution under differing relative sea-level regimes: examples from Ireland and Nova Scotia. Marine Geology, 88; 221-242.

Carter, R.W.G., Orford J.D., Forbes, D.L. and Taylor, R.B., 1990a. Morphosedimentary development of drumlin-flank barriers with rapidly rising sea level, Story Head, Nova Scotia, Sedimentary Geology, 69; 117-138.

Carter, R.W.G., Jennings, S.C. and Orford J.D., 1990b. Headland erosion by waves; Journal of Coastal Research, V. 6, No. 3; 517-529.

Carter, R.W.G., Orford J.D. and Jennings, S.C., 1990c. The recent transgressive evolution of a paraglacial estuary as a consequence of coastal barrier breakdown: Lower Chezzetcook Inlet, Nova Scotia. Proceedings of the Skagen Symposium, 2-5 September 1990; Journal of Coastal Research, Special Issue No. 9: 564-590.

Carter, R.W.G., Orford, J.D., Jennings, S.C., Shaw, J. and Smith, J.P., 1992. Recent evolution of a paraglacial estuary under conditions of rapid sea-level rise: Chezzetcook Inlet, Nova Scotia; Proceedings of the Geologists Association, 103; 167-185.

Covill, B., Forbes, D.L. Taylor, R.B., Shaw, J., 1995. Photogrammetric analysis of coastal erosion and barrier migration near Chezzetcook Inlet, Eastern Shore, Nova Scotia; Geological Survey of Canada Open File 3027, poster.

Dawson, W.B., 1918. Reports on the tides and currents in Canadian waters issued by the Tidal and Current Survey from 1894 to 1918. Tidal and Current Survey, Ottawa.

Forbes, D.L. and Boyd, R., 1989. Submersible observations of surficial sediments and seafloor morphology on the inner Scotian Shelf, p. 71-81. *In:* D.J.W. Piper, ed., Submersible observations off the east coast of Canada. Geological Survey of Canada, Paper 88-20.

Forbes, D.L. and Taylor, R.B., 1987. Coarse-grained beach sedimentation under paraglacial conditions, Canadian Atlantic coast. *In:* D.M. FitzGerald and P.S. Rosen, eds., Glaciated Coasts, Academic Press, San Diego; 51-86.

Forbes, D.L., Boyd, R., Johnston, L., Heffler, D.E. and McLaren, S., 1988. CSS Dawson operations on inner Scotian Shelf and Sable Island Bank. Geological Survey of Canada, Open File Report 2063; 51 p.

Forbes, D.L., Taylor, R.B. and Shaw, J., 1989. Shorelines and rising sea levels in eastern Canada, Episodes, V. 12, No. 1; 23-28.

Forbes, D.L., Taylor, R.B., Shaw, J., Carter, R.W.G. and Orford, J.D., 1990. Development and stability of barrier beaches on the Atlantic coast of Nova Scotia, p. 83-98. *In:* Proceedings, Canadian Coastal Conference 1990 (Kingston, Ontario), National Research Council, Ottawa.

Forbes, D.L., Boyd, R. and Shaw, J., 1991a. Late Quaternary sediments and sea level changes on the inner Scotian Shelf. Continental Shelf Research, 11 (8-10); 1155-1179.

Forbes, D.L., Taylor, R.B., Orford, J. D., Carter, R.W.G. and Shaw, J., 1991b. Gravel-barrier migration and overstepping. Marine Geology, 97; 305-313.

Galbraith, P.W., 1979. Atlantic region storm surge project, preliminary report, MAES 79-2; Atmospheric Environment Service, Bedford; 12 p.

Grant, D.R., 1989. Quaternary geology of the Atlantic Appalachian region of Canada; Chapter 5 in Quaternary Geology of Canada and Greenland, R.J. Fulton (ed.) Geological Survey of Canada , Geology of Canada, no. 1, 393-440.

Hall, R.K., 1985. Inner shelf acoustic facies and surficial sediment distribution of the Eastern Shore, Nova Scotia. Centre for Marine Geology, Technical Report 8, Dalhousie University, Halifax; 132 p.

Honig, C.A., 1987. Estuarine sedimentation on a glaciated coast: Lawrencetown Lake, Eastern Shore, Nova Scotia. Centre for Marine Geology, Technical Report 9, Dalhousie University, Halifax; 132 p.

Honig, C.A., 1988. Identification and interpretation of foraminiferal assemblages from the Eastern Shore of Nova Scotia: vibracores 010, 030, 033, 039, Dawson Cruise No. 87042. Centre for Marine Geology, Technical Report No. 10, Dalhousie University, Halifax; 22 p.

Hoskin, S., 1983. Coastal sedimentation at Lawrencetown Beach, Eastern Shore, Nova Scotia. Centre for Marine Geology, Dalhousie University, Halifax, Technical Report 4; 46 p.

Jennings, S.C., Carter, R.W.G., and Orford, J.D., 1993. Late Holocene salt marsh development under a regime of rapid relative-sea-level rise: Chezzetcook Inlet, Nova Scotia. Implications for the interpretation of paleomarsh sequences. Canadian Journal of Earth Sciences, 30; 1374-1384.

Jennings, S.C., Carter, R.W.G., and Orford, J.D., 1995. Implications for sea-level research of salt marsh and mudflat accretionary proceses along paraglacial barrier coasts. Marine Geology, 124; 129-136.

Labelle, R., 1995. Acadian life in Chezzetcook; Pottersfield Press, Lawrencetown Beach, Nova Scotia; 96 p.

Laidler, R.B., 1990. Testate rhizopods from the sediments of a marine/freshwater transitional lake: their distribution and paleoenvironmental significance; unpubl. M.Sc. dissertation, Dalhousie University, Halifax, 138 p.

Lewis, C.F.M. and Keen, M.J., 1990. Constraints to development, Chapter 14 in Geology of the Continental Margin of Eastern Canada, M.J. Keen and G.L. Williams (ed); Geological Survey of Canada, Geology of Canada, no. 2, 743-823.

McIntosh, K., 1916. A study of Cow Bay beaches; Nova Scotian Institute of Science, Proceedings and Transactions, V. 14, part 2; 109-119.

Middleton, J.F. and Thompson, K.R., 1986. Return periods of extreme sea levels from short records. Journal of Geophysical Research, 91, C10, 11; 707 -11,716.

Miller, R. and Fader, G.B.J., 1995. The bottom of Halifax Harbour; Geological Survey of Canada Open File 3154, poster.

Munroe, H.D., 1982. Regional variability, physical shoreline types and morphodynamic units of the Atlantic coast of mainland Nova Scotia; Taylor, R.B., Piper, D.J.W. and Lewis, C.F.M. (eds) Geological Survey of Canada Open File 725; 25 p.

Neu, H.J.A., 1982. 11-year deep-water wave climate of Canadian Atlantic waters. Canadian Technical Report of Hydrography and Ocean Sciences No. 13, Fisheries and Oceans, Ottawa; 41p.

Nichol, S.L. and Boyd, R., 1993. Morphostratigraphy and facies architecture of sandy barriers along the Eastern Shore of Nova Scotia; Marine Geology, 114; 59-80.

Nova Scotia Department of Lands and Forests, 1984. Cole Harbour / Lawrencetown coastal heritage park system; map.

Oakey, G.N., 1985. Refraction seismic site survey, Lawrencetown Beach. Unpublished Report, Centre for Marine Geology, Dalhousie University, Halifax, N.S.; 7 p.

Orford, J.D., Carter, R.W.G. and Forbes, D.L., 1991a. Gravel barrier migration and sea level rise: some observations from Story head, Nova Scotia, Canada; Journal of Coastal Research 7; 477-488.

Orford, J.D., Carter, R.W.G. and Jennings, S.C., 1991b. Coarse clastic barrier environments: evolution and implications for Quaternary sea level interpretation; Quaternary International, V. 9; 87-104.

Owens, E.H., 1994. Canadian coastal environments, shoreline processes, and oil spill clean-up; Environment Canada, Ottawa. Report EPS 3/SP/5, 328 p.

Owens, E.H. and Bowen, A.J., 1977. Coastal environments of the Maritime Provinces; Maritime Sediments, V. 13; 1-31.

Piper, D.J.W. and Keen, M.J., 1976. Geological studies in St. Margaret's Bay, Nova Scotia. Geological Survey of Canada Paper 76-18; 18 p.

Piper D.J.W., Mudie, P.J., Letson, J.R.J., Barnes, N.E., and Iuliucci, R.J., 1986. The marine geology of the inner Scotian Shelf off the South Shore, Nova Scotia. Geological Survey of Canada Paper 85-19; 65p.

Quinlan, G. and Beaumont, C., 1981. A comparison of observed and theoretical postglacial relative sea level in Atlantic Canada. Canadian Journal of Earth Sciences, 18; 1146-1163.

Quinlan, G. and Beaumont, C., 1982. The deglaciation of Atlantic Canada as reconstructed from the postglacial relative sea-level record. Canadian Journal of Earth Sciences, 19; 2232-2246.

Scott, D.B., 1977. Physiographic and oceanographic characteristics Chezzetcook Inlet, Nova Scotia. Maritime Sediments, 13, 3; 73-78.

Scott, D.B., 1980. Morphological changes in an estuary: a historical and stratigraphic comparison, p. 199-205. *In*: S.B. McCann, ed., The coastline of Canada. Geological Survey of Canada, Paper 80-10.

Scott, D.B., and Medioli, F.S., 1978. Vertical zonations of marsh foraminifera as accurate indicators of former sea levels. Nature, 272, No. 5653; 528-531.

Scott, D.B. and Medioli, F.S., 1980. Quantitative studies of marsh foraminiferal distributions in Nova Scotia: implications for sea level studies. Cushman Foundation for Foraminiferal Research, Special Publication No. 17; 47 p.

Shaw, J. and Forbes, D.L., 1990. Short- and long-term relative sea-level trends in Atlantic Canada, p. 291-305. *In:* Proceedings, Canadian Coastal Conference, Kingston, Ont. National Research Council, Ottawa.

Shaw, J., Taylor, R.B. and Forbes, D.L., 1990. Coarse clastic barriers in eastern Canada: patterns of glaciogenic sediment dispersal with rising sea levels, p. 160-200. *In:* P. Bruun and N. K. Jacobsen, eds., Proceedings of the Skagen Symposium, 2-5 September 1990. Journal of Coastal Research, Special Issue No. 9.

Shaw, J., Taylor, R.B., and Forbes, D.L., 1993. Impact of the Holocene transgression on the Atlantic coastline of Nova Scotia. Géographie physique et Quaternaire, V. 47, no. 2; 221-238.

Sonnichsen, G., 1984. The relationship of coastal drumlins to barrier beach formation along the Eastern Shore of Nova Scotia. Centre for Marine Geology, Technical Report 6. Dalhousie University, Halifax; 66 p.

Stea, R.R. and Fowler, J.H., 1979. Minor and trace element variations in Wisconsinan tills, Eastern Shore region, Nova Scotia. N.S. Department of Mines and Energy, Paper 79-4; 30 p. and 3 maps.

Stea, R. R., Forbes, D.L. and Mott, R.J., 1992. Quaternary Geology and Coastal evolution of Nova Scotia; Geological Assoc. Can., Mineralogical Assoc. Can., Joint Annual Meeting, Wolfville '92, Field excursion A-6, Guidebook; 125 p.

Stea, R.R., Boyd, R., Fader, G.B.J., Courtney, R.C., Scott, D.B., and Pecore, S.S., 1994. Morphology and seismic stratigraphy of the inner continental shelf off Nova Scotia, Canada: evidence for a -65 m lowstand between 11,650 and 11, 250 C^{14} yr B.P. Marine Geology, 117; 135-154.

Tanner, W.F., 1992. Late Holocene sea-level changes from grain-size data: evidence from the Gulf of Mexico. The Holocene, 2(3); 249-254.

Taylor, R.B., Wittmann, S.L., Milne, M.J., and Kober, S.M., 1985. Beach morphology and coastal changes at selected Sites, mainland Nova Scotia; Geological Survey of Canada Paper 85-12; 59 p.

Taylor, R.B., Frobel, D., Forbes, D.L.and Parlee, K., 1995. Coastal stability and the monitoring of physical shoreline changes in Nova Scotia; Proceedings of the 1995 Canadian Coastal Conference, October 18-21, 1995, Halifax, V. 2, 829-843.

Thomas, E. and Varekamp, J.C., 1991. Paleo-environmental analyses of marsh sequences (Clinton, Connecticut): evidence for punctuated rise in relative sea level during the latest Holocene. Journal of Coastal Research, Special Issue 11; 125-158.

Tushingham, A.M. and Peltier, W.R., 1991. Ice-3G: a new global model of Late Pleistocene deglaciation based upon geophysical predictions of post-glacial relative sea level change. Journal of Geophysical Research, 96, B3; 4497-4523.

van de Plassche, O., 1991. Late Holocene sea-level fluctuations on the shore of Connecticut inferred from transgressive and regressive overlap boundaries in salt-marsh deposits. Journal of Coastal Research, Special Issue 11; 159-179.

Wang, Y. and Piper, D.J.W., 1982. Dynamic geomorphology of the drumlin coast of southeast Cape Breton Island. Maritime Sediments and Atlantic Geology, 18; 1-27.

NOTES

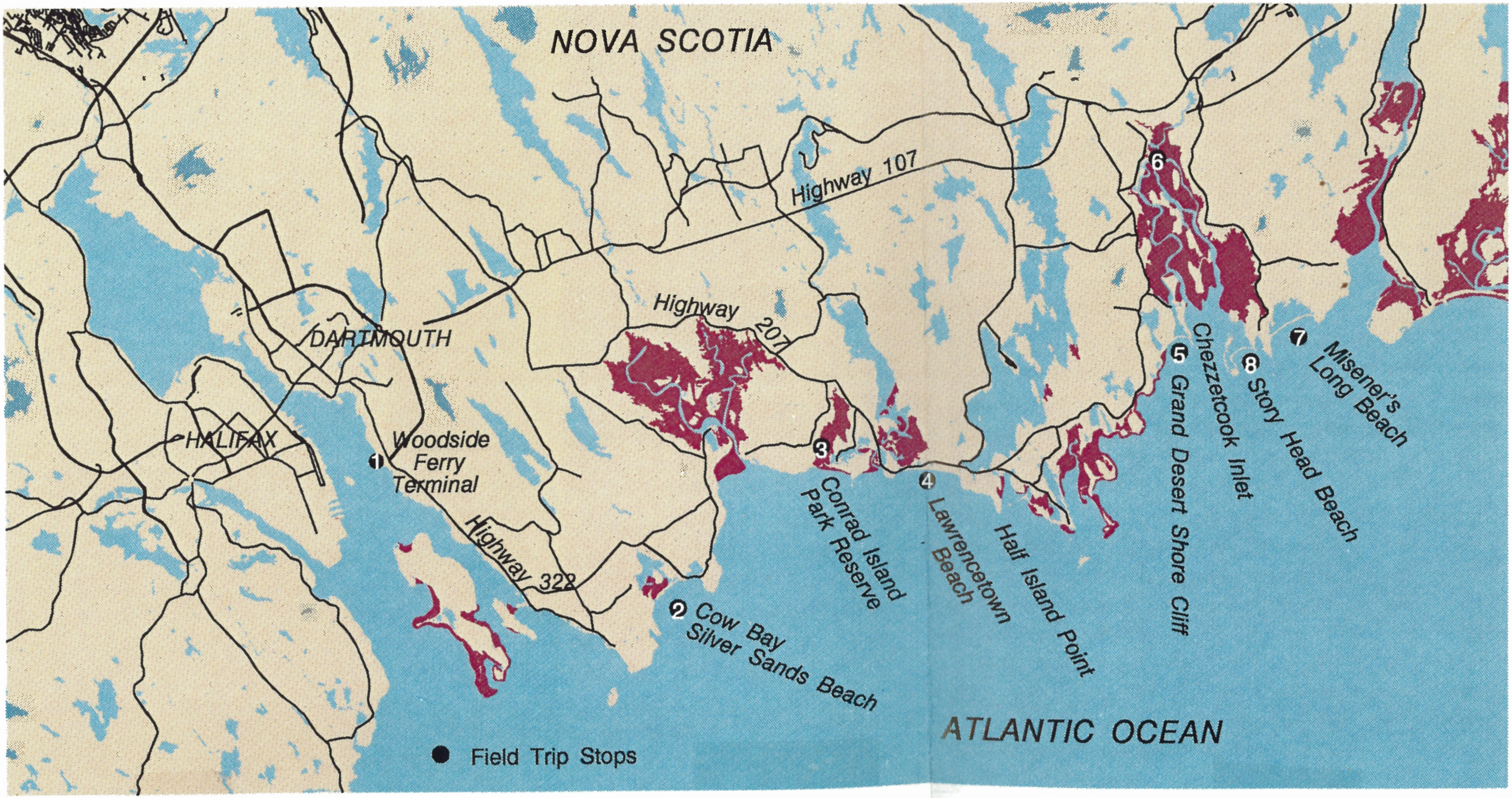


Figure 24 Route map, place names and location of field stops along the Eastern Shore of Nova Scotia.