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BEACH MORPHOLOGY AND COASTAL CHANGES AT SELECTED SITES, MAINLAND NOVA SCOTIA

R.B. Taylor
S.L. Wittmann
M.J. Milne
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Cover

Aerial photograph of Crescent Beach and the Town of Lockeport, Nova Scotia. (See Figure 27)

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BEACH MORPHOLOGY AND COASTAL CHANGES AT SELECTED SITES, MAINLAND NOVA SCOTIA

Abstract

In 1981, under the auspices of the federal government Summer Canada Student Employment Program, a network of shoreline survey stations was established at sixteen shore bluff sites and seventeen beaches along the mainland coast of Nova Scotia. In addition, the physical characteristics and recent evolution for eight of the beaches were documented and a complete bibliography of previous coastal research along mainland Nova Scotia was compiled.

All of the shores examined, with the exception of Waterside Beach on Northumberland Strait, exhibit signs of landward retreat. Rates of shore bluff (till) recession average 1.1 $m \cdot a^{-1}$ and 0.4 $m \cdot a^{-1}$ respectively for the Eastern Shore and South Shore of Atlantic Nova Scotia and maximum retreat is 3.3 $m \cdot a^{-1}$ at exposed headlands. Those beaches where aggregate extraction took place in the 1950s and 1960s exhibit the greatest signs of retreat and new inlets and large washover channels developed across several of these beaches. Sand beaches along Atlantic Nova Scotia are characterized by mean foreshore slopes of 1.2° to 1.8° and are backed by a primary dune ridge that reaches 3.6 to 4.7 m above mean sea level. In contrast, the pebble-cobble beaches are steeper and characterized by well developed storm swash ridges.

Résumé

En 1981, dans le cadre du Programme d'emplois d'été pour les étudiants du gouvernement fédéral, un réseau de stations géodésiques a été établi le long de la ligne de rivage de la Nouvelle-Écosse : 16 stations ont été installés sur des falaises littorales et 17 sur des plages. En outre, les caractéristiques physiques et l'évolution récente de huit des plages ont fait l'objet de recherches sur les travaux antérieurs, ce qui a donné suite à l'établissement d'une bibliographie complète de la côte de cette provinces au regard de ces phénomènes.

Toutes les lignes de rivage examinées, sauf la plage Waterside du détroit de Northumberland, présentent des indications d'une régression vers la terre. La vitesse moyenne de régression des falaises littorales (till) est de 1,1 $m \cdot a^{-1}$ et de 0,4 $m \cdot a.^{-1}$ respectivement pour la côte est et la côte sud du côté atlantique de la Nouvelle-Écosse; la régression maximale est de 3,3 $m \cdot a^{-1}$ pour les promontoires découverts. Le degré de régression est le plus élevé pour les plages où il y a eu extraction d'agrégats au cours des années 1950 et 1960; en outre, de nouveaux goulets et des chenaux de tempête se sont formés en travers de plusieurs de ces plages. Les plages de sable le long de la côte atlantique sont caractérisées par des estrans dont la pente moyenne varie de 1,2° à 1,8° et qui sont limités du côté de la terre par une chaîne de dunes primaire dont la hauteur atteint de 3,6 à 4,7 m au-dessus du niveau moyen de la mer. Par opposition, les grèves de galets et de gros cailloux sont plus raides et sont caractérisées par la présence de marques de plage bien développées qui se sont formées lors de tempêtes.

INTRODUCTION

Objectives

Over the past decade coastal studies have been completed by various researchers at numerous shoreline sites in Nova Scotia. Results from these studies have been compiled in reports or theses scattered in government files or university libraries and only limited attempts to compile a complete bibliography of the coastal research conducted in Nova Scotia have been made. Also, there have been very few follow-up programs in a particular area once an original study was completed and thus there is little up-to-date information on recent coastal stability and evolution. The lack of longer term programs is partly due to financial constraints and partly because many of the studies are completed as part of a university degree program. Only the Nova Scotia Department of Lands and Forests has systematically resurveyed a few specific beaches, e.g. Belfry Beach, Cape Breton Island, in order to assess the impact of the artificial removal of beach sand and gravel on beach stability. The only network of semipermanent shore stations which could be utilized to conduct future surveys of coastal stability in the province, is that established in 1978 by H.D. Munroe (1980) along the Atlantic coast of mainland Nova Scotia.

In 1981, under the auspices of the federal government Summer Canada Student Employment Program, a study was initiated to (a) compile a bibliography of completed coastal research along mainland Nova Scotia, (b) establish a network of shoreline survey stations along different parts of mainland Nova Scotia, and (c) archive all the 1981 survey data on computer tapes for easy access and comparison with future field surveys. The products of this study are designed to provide the basis on which future coastal studies can build so that up-to-date-information of coastal change can be maintained and accurate information can be provided to make sound coastal management decisions.

Early in the program it was obvious that many of the larger beaches in Nova Scotia and, in fact, whole segments of shoreline, had not been previously studied in detail. As a result, the field program was expanded to include an examination and a physical description of eight beaches in the province. Two of the beaches, i.e. Cow Bay and Martinique, Halifax County, had already been studied but were re-examined in 1981 because of dramatic changes that had taken place or that are now occurring there. They were also studied because of increased interest in the Eastern Shore for parkland development. This research of selected beaches around the province provides a logical extension to the earlier study of thirteen recreational beaches by Bowen et al. (1975).

The benefits of establishing a network of shoreline survey stations are as follows: (a) areas of coast would be re-examined for the first time since the original studies; (b) where previous survey data were available from an area, an assessment of shoreline stability and rates of retreat could be calculated; (c) field checks of an area would help differentiate natural vs. artificial changes to a coast; and (d) the archiving of shoreline survey data on computer tapes would allow easier access for researchers conducting future surveys and prevent field survey data from being lost. Field information necessary to relocate and accurately resurvey the shore stations established during this project is presented in Geological Survey of Canada Open File 976. The open file also provides the 1981 field data and a brief physical description of the shore bluffs surveyed.

The project was conducted primarily over an eighteen-week period during the summer of 1981. It involved both an office and field component and was completed with the assistance of five university students. Three students, Ms. S. Wittmann, M.J. Milne, and S. Kober, were responsible for the field surveys, the physical descriptions of the eight beaches, and the analysis of temporal beach profile changes. A fourth student, Ms. L. Cheung was responsible for modifying old computer programs and developing new ones to analyze and plot the beach profile and sediment data. When Ms. Cheung left the program in July, the position was filled by Mr. M. Menzies who provided computer expertise for the group. Mr. G. Lingley, although mainly assigned to other programs, occasionally assisted in the field and in the initial analysis of two beach areas.

Background information

The shoreline of Nova Scotia includes three distinct coastal environments: (1) the sheltered wave-dominated Gulf of St. Lawrence, (2) the exposed high-wave-energy Atlantic and (3) the sheltered, tide-dominated Bay of Fundy (Owens, 1976; Owens and Bowen, 1977). Within each of the three main coastal environments, subdivisions of the coast have been identified on the basis of geology, morphology, sediments and processes. Owens and Bowen (1977) subdivided the shoreline of Nova Scotia into fifteen homogeneous segments, which included four segments along the Atlantic coast. Munroe (1980, 1982) further subdivided the Atlantic coast of mainland Nova Scotia, into twelve morphodynamic units. Shoreline types were identified and mapped by Welsted (1974) along the Bay of Fundy and later discussed by Owens (1977). The shores fringing the Gulf of St. Lawrence were examined by Owens and Harper (1972) and Owens (1974a,b).

In 1975, a report completed by Bowen et al. provided a synthesis of the processes that are important to the development and maintenance of Nova Scotia shores. The report also included specific information on the physical characteristics and evolution of thirteen major recreational beaches around the province. Although this publication is still used as a basic reference manual, considerable new research has taken place since 1975.

The focus of many recent studies has been the mapping of physical and biological characteristics of the coastal zone for environmental emergency planning. The scale of mapping has ranged from 1:350 000 (McGuire 1977, 1979, 1980) to 1:50 000 (Munroe 1980, 1982). The smaller scale maps covered all of Nova Scotia but the study by Munroe (1980) was restricted to the Atlantic coast of mainland Nova Scotia. Since the sinking of the oil tanker *Kurdistan*, detailed mapping of the coastal characteristics of Cape Breton Island has been conducted by personnel from the Atlantic Geoscience Centre, Dartmouth, Nova Scotia. Remote sensing techniques such as satellite, radar and infra-red imagery have been tested by Alfoldi (1975), Fox (1979) and Prout (1979) to assess their usefulness in mapping the coastal resources in southwest Nova Scotia.

Specific beaches or segments of coast that have been investigated since 1975 include: Martinique Beach (Keeley, 1975, 1977; Holman et al., 1978; Eastwood, 1977); Lawrencetown Beach (Hattie, 1977, Hoskin, 1983), Hartling and Kings Bays (Urquhart, 1977), Melmerby Beach (Campbell, 1982), and Crescent Beach (Wittmann, 1982). Recent studies oriented toward coastal erosion problems, were completed at Cow Bay beach (Huntley, personal communication, 1976), Advocate Harbour (Lewis, 1979; Kolberg and Duncan 1979) and the Minas Basin (Atlantic Air Survey, 1976). In 1981 the Nova Scotia Department of Environment began a study of coastal erosion at selected sites along the Minas Basin and Northumberland Strait shores.

Analyses of the composition and geochemical characteristics of glacial tills in the province were completed by Nielsen (1976) and Stea and Fowler (1978); and geological maps for the province were completed by Keppie (1979) and Bujak and Donohoe (1980). These studies furnish information about the local bedrock and surficial materials which provide the main source of sediment for beach development.

Surveys of the physical and sedimentological characteristics of the nearshore are of considerable importance when trying to understand the operative processes and recent evolution of the coastline. Geological studies of the nearshore have focused on St. Margarets Bay (Piper and Keen, 1976; Hughes, 1979; Piper, 1980) and on Mahone Bay (Barnes, 1976; Barnes and Piper, 1978; Letson, 1980) and elsewhere along the South shore of Nova Scotia (Piper, 1980, 1983).

New evidence about recent sea level changes has been obtained through analyses of cores collected in bays and estuaries by Scott (1977, 1980) and Scott and Medioli (1979, 1980). This field evidence was utilized by Quinlan and Beaumont (1981) in their model of postglacial relative sea level changes in Atlantic Canada. Four zones of relative sea level were proposed. For instance, sea level along Atlantic Nova Scotia is presently at a postglacial high, whereas sea level along the Bay of Fundy and Northumberland Strait fell only until about 5000-6000 years BP when levels began to rise. These studies and the continued work of Grant (1980) in southwestern Nova Scotia have considerable importance when trying to understand the recent evolution and stability of specific beach systems.

Acknowledgments

This project was initiated and funded under the Summer Canada Student Employment Program. Additional funding for the field program and the writing of the report came from the Atlantic Geoscience Centre, a division of the Geological Survey of Canada. We are indebted to Dr. D.J.W. Piper and D. Frobel of the Atlantic Geoscience Centre and J. Easton of the Geology Department of Dalhousie University for generously allowing us to use their unpublished field data on the Eastern and South Shores of Nova Scotia. They also assisted us in locating bench marks which they had previously established along the coast. We also acknowledge Dr. D.A. Huntley of the Department of Oceanography, Dalhousie University, for releasing to us his unpublished report on Cow Bay Beach.

The report and project could not have been completed without the assistance of many individuals and government agencies including: C. Brisco, L. Lewis, Nova Scotia Department of Environment; H. Doane of the Canada-Nova Scotia Flood Damage Reduction Program; and H. Kolstee, Nova Scotia Department of Agriculture. Personnel of the Nova Scotia Department of Lands and Forests who were particularly helpful during the project were the Librarians at the Air Photo Library in Halifax, E.H. Crowell of the Musquodoboit Harbour District Office and B. Turner of the Shelburne District Office. Invaluable information about the history and human impact on specific beaches was gained through conversations with local residents: Mrs. W.M. Landymore (Conrads Beach), Mr. E. McLean (Waterside Beach) and Mr. W. Rector (Advocate Harbour Beach).

Logistics and financial guidance during the summer field program was given by K. Robertson of the Atlantic Geoscience Centre and Dr. H. Millward, Chairman of the Geography Department of St. Mary's University, assisted with the contract to the students for the writing of this report. Critical review of a draft manuscript by Drs. D.J.W. Piper, A.J. Bowen and P.J. Ricketts and further discussions with these reviewers and D.L. Forbes has led to a much improved final report and are gratefully acknowledged.

GEOMORPHOLOGY OF SELECTED BEACHES ALONG MAINLAND NOVA SCOTIA

Introduction

A major objective of the 1981 field program was to examine the physical characteristics and recent evolution of selected beaches around the province which have not been previously studied in detail, and to re-examine beaches on the Eastern Shore which have recently experienced or are now undergoing dramatic morphological changes. Field studies were conducted at eight beaches over a four week period. Five of the beaches are on the Atlantic coast; one in the more sheltered wave environment of St. Mary's Bay, one at the eastern end of the Bay of Fundy where a long wave fetch and a large tidal range occurs, and one on Northumberland Strait which has a sheltered wave environment.

Similar field procedures were carried out at all eight beaches. The general morphological features of each beach were mapped and are illustrated in this report using the symbols listed in Table 1. At least three profiles were established at each beach and surficial sediment samples were collected at all or most of the profile stations. Sites for beach profiles were selected to illustrate variability in the shore-normal morphology along each beach. All profiles were surveyed at low tide stage and were extended offshore from the backshore lagoon or marsh, as far as one could wade. From the beach profiles, measurements of backshore and foreshore width and slope were determined as well as measurements of individual shore features, e.g. storm ridges or dunes. Surficial sediment samples were collected from high tide levels and from sand dunes where they existed. Since only surficial samples were collected, only information about recent process events or specific seasonal conditions, i.e. summer conditions is provided. Standard sieving techniques were employed to analyze the sediment samples and statis-

Table 1. Key to symbols used on morphological maps produced for each of the eight primary beaches studied in 1981.

	SAND
	GRAVEL
	COBBLES (BEACH DEPOSITS)
	SHORE BLUFFS
	ROAD
	PATH/OLD ROAD
	MARSH
	GRASS
	WOODED AREAS
	BEDROCK
	STREAM/CREEK (ARROW DENOTES DIRECTION OF FLOW)
2	PROFILE TRANSECT
	WATER
	SAND DUNES
	DYKE
	PIER/WHARF
BM	BENCH MARK
TBM	TEMPORARY BENCH MARK
HHTL	HIGHER HIGH TIDE LEVEL
LLTL	LOWER LOW TIDE LEVEL
MSL	MEAN SEA LEVEL
	BOULDERS
	OLD BEACH RIDGES
	WOODEN WALKWAYS

tical measures of the sediment characteristics were obtained from a modified computer program developed originally by Dr. B. Greenwood of Scarborough College, Toronto. Only graphic statistics (Folk and Ward, 1957) are presented in this report. Where the beaches were composed of coarse gravel or cobbles, the size of sediment was determined by measuring the three axes of 25 to 50 clasts. In some cases photographs were taken of the clasts and the axes were measured in the office. These measurements were substituted into standard formulae (Sneed and Folk, 1958) to calculate mean grain size, sphericity and roundness of the sediment.

Lastly, visual observations were made of the physical characteristics of each beach and the processes that were occurring on the date of the survey. These observations were then put into the context of the overall development of the beach and its recent evolution by using aerial photographs, old charts, previous published reports and information gathered during conversations with local residents. The airphotos provided information for the last 40 to 50 years, while maps and marine charts went back to the early 1700s. In a few cases, the recent geological evolution of a specific area was well known, so the results of those studies are included in the discussion of beach evolution. For all beaches, the impact of human activities on beach development is assessed.

Physical characteristics and evolution of specific beaches

Waterside Beach, Pictou County

Physical and geological setting

Waterside Beach is situated on the Northumberland Strait at the Caribou Island causeway, 16 km north-northeast of Pictou (Fig. 1, 2). The beach is 0.5 km in length with an approximate width of 150 m. It is bounded to the west by a headland 10 m in height and to the east by a resistant, 6 m high knoll (Fig. 3), both developed in red sandstone of the Pictou Formation overlain by unconsolidated muds, clays and cobbles. The present sand beach is backed by low, well vegetated dunes overlying a series of relict beach ridges which extend 100 to 150 m south to a freshwater marsh. The marsh borders the provincial access road to Caribou Island. To the east, adjacent to Waterside Beach, another pocket beach is forming (Fig. 2). It is bounded to the east by the eroding headland of Gully Head. Both beaches have gentle offshore topography with surf zones of 30 m or more. Northumberland Strait is a low wave energy environment especially between May and September when wave heights range from 1 to 2 m with 1 m heights predominating. Higher wave heights of 4 m occur during the fall and early spring (Unpublished Wave Data – A.E.S.,Bedford, N.S.). Sea ice covers the Strait during February and March. The mixed semi-diurnal tides range from 1.3 to 2.0 m.

Detailed beach morphology

Foreshore zone. The beach face is composed of fine red sand and has a gently dipping slope of less than 2° (Table 2, Fig. 4). Foreshore width varies but there is a general widening towards the western and eastern ends of the beach. Lag deposits underlain by bedrock are present at the base and extend offshore from both the western headland and the knoll. Also, a band of pebble-cobble material extends 150 m southwards from the western headland (Fig. 2,5).

Backshore zone. A well defined summer berm, with a relief of 1 m extends along the upper beach slope. Above HTL, the beach slope rises gently to the base of a low dune ridge which averages 1.3 m in height (Fig. 6, Table 2). Both the dune ridge and the relict beach ridges situated farther inland are well vegetated with primary colonizers. The dune ridge shows little evidence of degradation except to the east of the wooden boardwalk where recreational activity is exceptionally intense. Landward of the dune ridge the backshore slope is gentle and extends 175 m southward to a freshwater marsh.

Beach sediment characteristics

The sediment composition of the foreshore zone is fine to medium sand, ranging from 1.35 to 2.74 phi mean clast size. Along the lower foreshore the sand is finer and better sorted than the sand sampled at high tide level (Table 3). The mean sorting coefficient of the sand along the lower foreshore was 0.32 phi. Alongshore, the sediment characteristics suggest that there is a net transfer of material in a west to east direction. The main source of sediment is from cliff erosion alongshore.

Beach development and evolution

Waterside Beach has experienced a gradual progradation over at least the last 45 years, as indicated by aerial photographs. The resistant knoll, currently entrenched within

Table 2. Morphological characteristics of Waterside Beach, Pictou County, August, 1981.

Profile number	Beach		Foreshore zone			Backshore zone
	width[1] (m)	height[2] (m)	width (m)	height (m)	slope (o)	dune height[3] (m)
1	107	3.1	64	1.9	1.7	1.2
2	147	4.6	79	1.6	1.2	1.7
3	188	2.6	71	1.3	1.0	1.2
4	228	3.4	83	1.7	1.2	1.2

[1] MHTL to landward edge of beach ridges or seaward edge of ponds.
[2] Mean sea level to highest point of beach.
[3] Base to crest of seaward slope of dune.

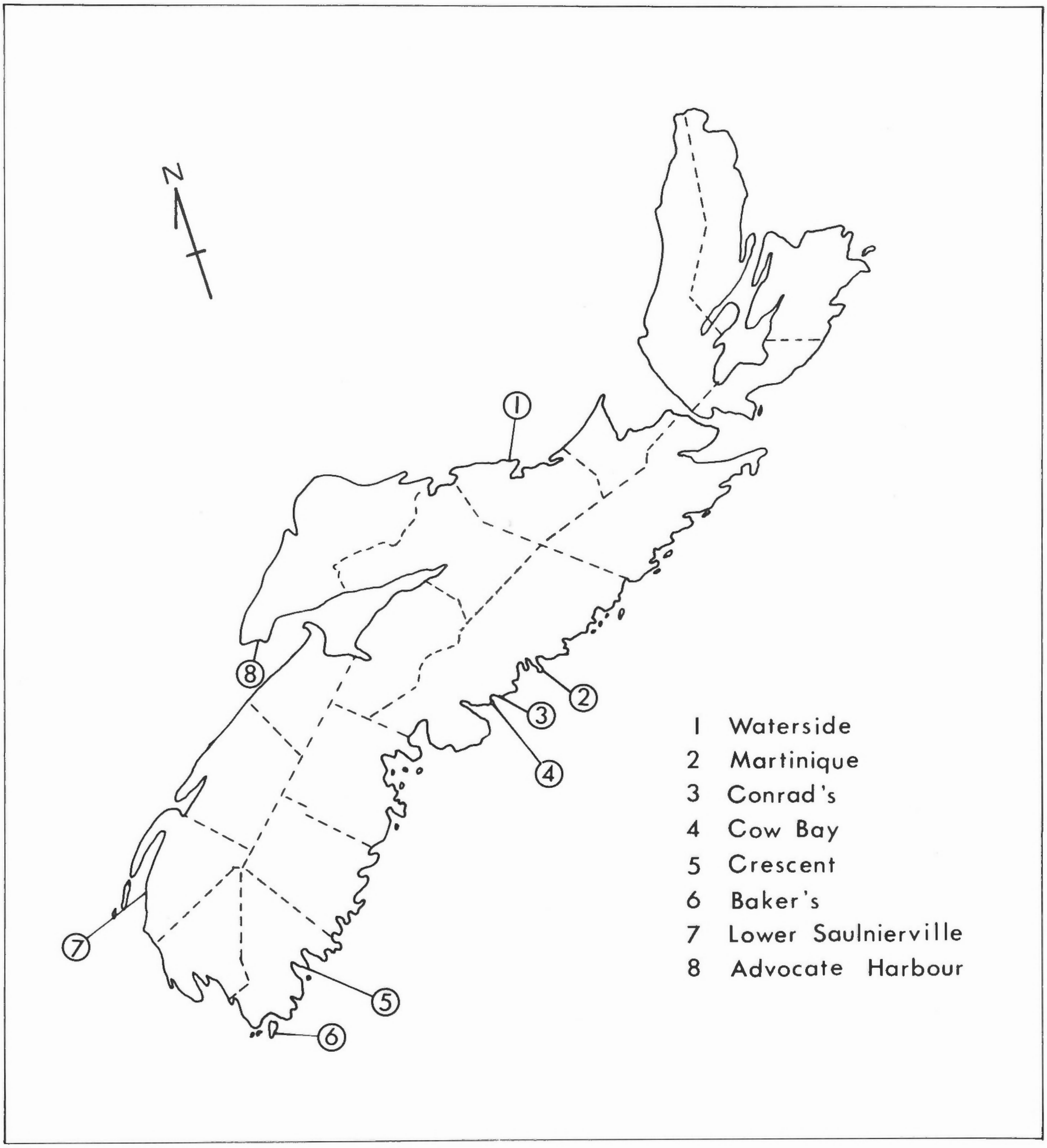

Figure 1. Location of the eight beaches along mainland Nova Scotia that were examined in detail during 1981. At each beach, the physical characteristics and recent evolution were documented.

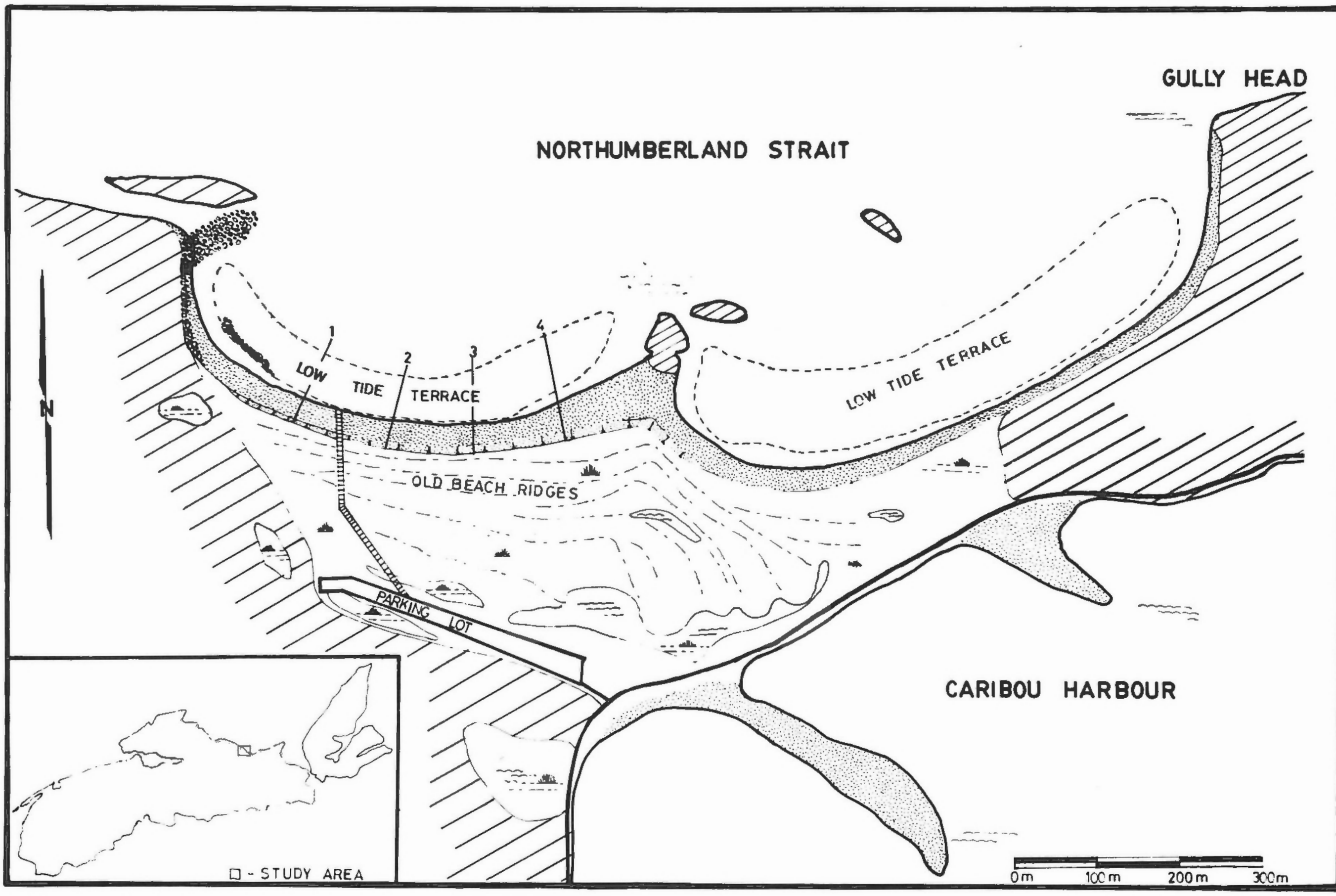

Figure 2. Morphological map of Waterside Beach, Pictou County based on colour airphoto 79301-144 (Maritime Resource Management Service (MRMS) Amherst N.S.) taken on June 7, 1979. The key to symbols used is given in Table 1.

Figure 3. A 6 m high knoll of glacial till overlying Pictou Formation sandstone, bounds the eastern end of Waterside Beach. (GSC 190817)

Figure 4. A wide sandflat characterizes the lower foreshore zone of Waterside Beach. Note the 6 m high knoll (shown in Fig. 3) in the back-centre of this photograph. (GSC 190816)

Table 3. Sedimentological characteristics of Waterside Beach, Pictou County, August 1, 1981.

Profile number	Mean grain size (∅)			Sorting (∅)			Skewness		
	LTL	HTL	Dune	LTL	HTL	Dune	LTL	HTL	Dune
1	2.64	—	—	0.36	—	—	−0.10	—	—
2	2.61	1.35	—	0.31	0.76	—	−0.22	−0.12	—
3	2.74	—	2.41	0.28	—	0.43	−0.01	—	+0.03
4	2.18	1.81	—	0.33	0.55	—	−0.12	−0.01	—

Figure 5. Pebble-cobble sediments are exposed across the lower foreshore zone at the western end of Watersides Beach shown here. (GSC 190827)

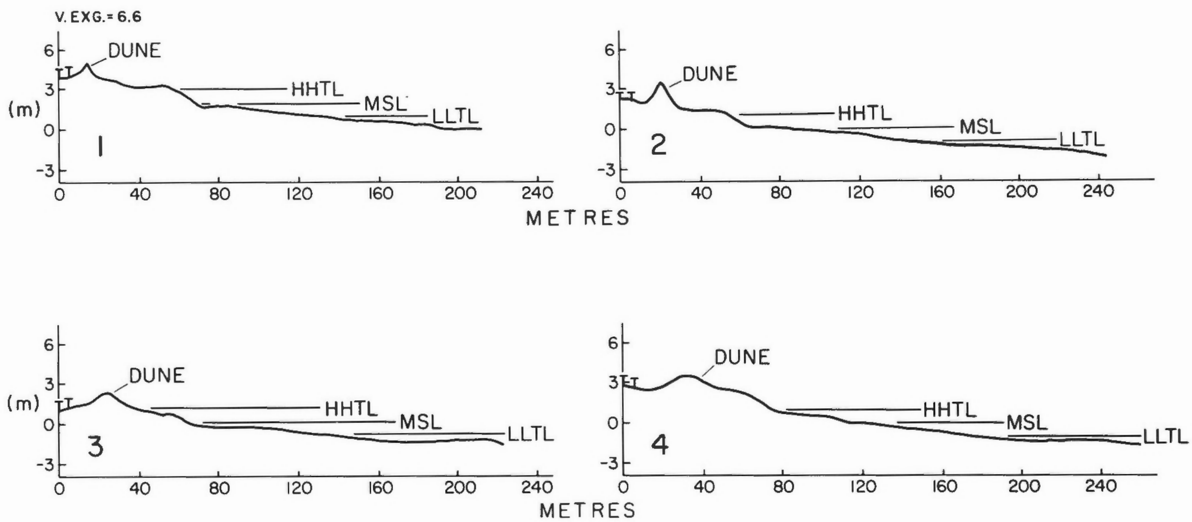

Figure 6. Four profiles were surveyed across Waterside Beach, August 1, 1981, which illustrate the beach morphology. Location of the profiles is shown on Figure 2.

the beach system, was a separate island in 1936. However, a tombolo was developing in the lee of the island at that time (Fig. 7). The formation of five prominent relict beach ridges which have prograded toward Caribou Island (Fig. 7), suggests that the predominate direction of sediment transport is west to east. The oldest ridge or spit extended into Caribou Harbour and enclosed three lagoons or ponds. Subsequent development of other beach ridges resulted in the formation of a larger lagoon which eventually was also cut off from the sea. The gradual replacement of marine water with freshwater in the lagoon has resulted in the growth of bullrushes and other freshwater plants. On the 1964 airphotos a ditch cut through the relict beach ridges to the sea on the Northumberland Strait side is visible. It was dug by two persons determined to build a canal which would eliminate the inconvenience of circumnavigating Caribou Island and provide access for boat launching on the northern side of the causeway (Mr. E. McLean, personal communication 1982). Remnants of the ditch are still visible today.

Prior to the construction of the causeway in 1922, Caribou Island was accessible either by boat or by crossing the tidal flats by foot at low tide. In 1922 a wooden structure was built to allow vehicle passage and remained in place until the present rock and gravel roadway was constructed in 1947. By 1954 the shifting mud flats were infilled by sediment to form a pocket beach that extended to the rock knoll. Between 1936 and 1954 Waterside Beach increased in width from 237 to 300 m and the pocket beach east of Waterside also prograded seaward. Since then, both beaches have become stabilized by

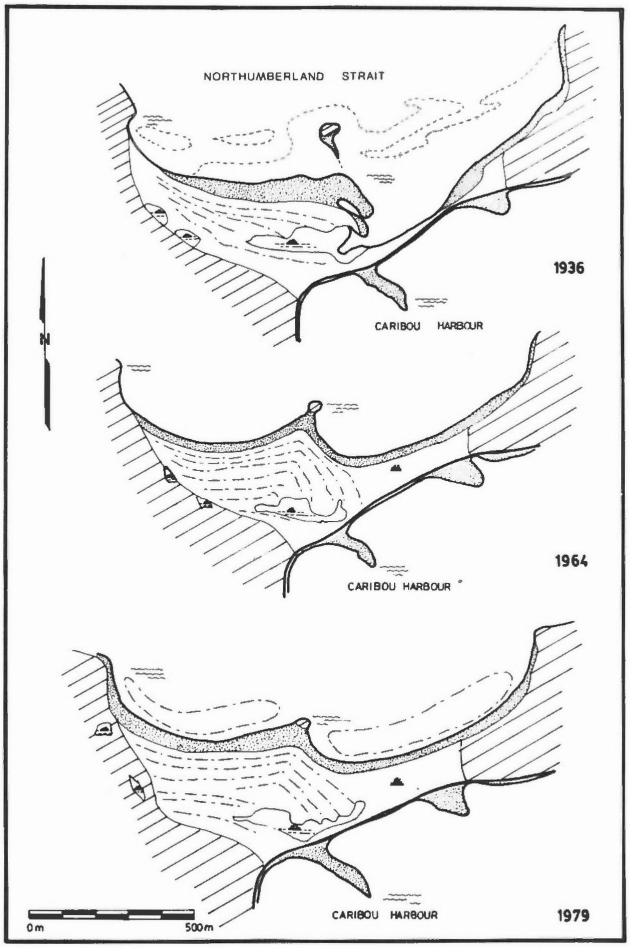

Figure 7. The recent evolution of Waterside Beach is drawn on the basis of airphotos taken in 1936, 1964 and 1979. Since 1936 this beach has prograded seaward at an estimated rate of 2.6 $m \cdot a^{-1}$.

vegetation and in 1979 the two beaches had increased to 350 m and 150 m in width, respectively.

Waterside Beach was privately owned until 1976 when the provincial department of Lands and Forests bought 145 acres for the purpose of park construction. Recreational facilities in the form of parking lots, boardwalks to the beach, picnic tables and restrooms were built at the beach site between 1979 and 1981. Waterside was officially declared a Roadside Park in the Royal Gazette by an Order in Council on June 12, 1980. It is enjoyed during the summer months by the residents of the local area.

For the future, all evidence points to a continued progradation of the beach system. A gradual straightening of the shoreline will proceed until the whole of West Gully is infilled, providing that sufficient sediment is available. Since the coastline is composed of soft, recessive bedrock and the cliffs to the west are rapidly eroding, there is an abundant source of sediment for beach development.

Martinique Beach, Halifax County

Physical and geological setting

Martinique Beach is 50 km northeast of Halifax along the Atlantic coast between Petpeswick Inlet and Musquodoboit Harbour (Fig. 1,8). The beach is 3.5 km long and joins Flying Point Island to the mainland (Fig. 9). Anchored between a series of rock outcrops such as at Whale Point, the beach is characterized by a gradual sloping sand foreshore backed by a single primary dune ridge in the backshore. Martinique Beach shelters on its landward side the Musquodoboit River estuary and an extensive salt marsh. The mouth of the estuary lies 2 km east of Flying Point Island. There are no islands offshore so the beach is well exposed to wind and wave attack. The predominant wind direction is from the west-northwest in winter and from the south to south-southwest in summer. The surf zone varies in width from 100 m along the main part of the beach to 50 m adjacent to Flying Point Island. During the summer of 1974, the waves recorded on seven occasions by Keeley and Bowen (1977) had a period of 7 to 14 s and a breaker height of 1.0 to 2.4 m. These authors also reported that longshore currents were variable. On four of the seven days the current had a westerly component; the peak velocity was 1.17 $m \cdot s^{-1}$. The tidal range in this area is 1.4 to 1.9 m. The offshore gradient is low and regular, and in 1981 the sandy bottom was covered by ripples oriented in a southwest to northeast direction. The amplitude of the ripples decreased eastward alongshore toward Flying Point Island.

Considerable research into the sedimentological and morphological conditions of Martinique Beach was completed in the mid-1970s. A brief physical description of the beach and a detailed account of the vegetation cover was provided by Bowen et al. (1975). This was followed by a detailed examination of seasonal beach changes and nearshore currents by Keeley (1975, 1977), Keeley and Bowen (1977), Holman et al. (1978) and Frobel (personal communication, 1981). Also, sediment from a small section of the beach was analyzed by Eastwood (1977) in an attempt to relate it to possible sources, beach morphology, and nearshore processes. The present report provides up-to-date information on the physical condition of the beach and where applicable compares the field observations of 1981 to those made during the preceding studies. Since the beach was cut by storms in the late 1970s, there has been increased concern by Parks officials and the public about the integrity of the beach. The scientific community is interested in Martinique Beach because it is representative of many of the Atlantic beaches and may provide a better understanding of the events that lead to the complete failure of a beach and how a beach re-establishes a dynamic equilibrium (Boyd et al., 1982).

Detailed beach morphology

On August 18, 1981, seven profiles were surveyed along Martinique Beach. Unfortunately, many of the bench marks from the 1976 survey were gone but, with the assistance of D. Frobel of the Bedford Institute of Oceanography, new bench marks were located in approximately the same positions (Fig. 9, 10).

Figure 8. Oblique aerial photograph of Martinique Beach taken September 29, 1976. Note the washover fan at the eastern end of the beach (photograph by R. Belanger). GSC 190864

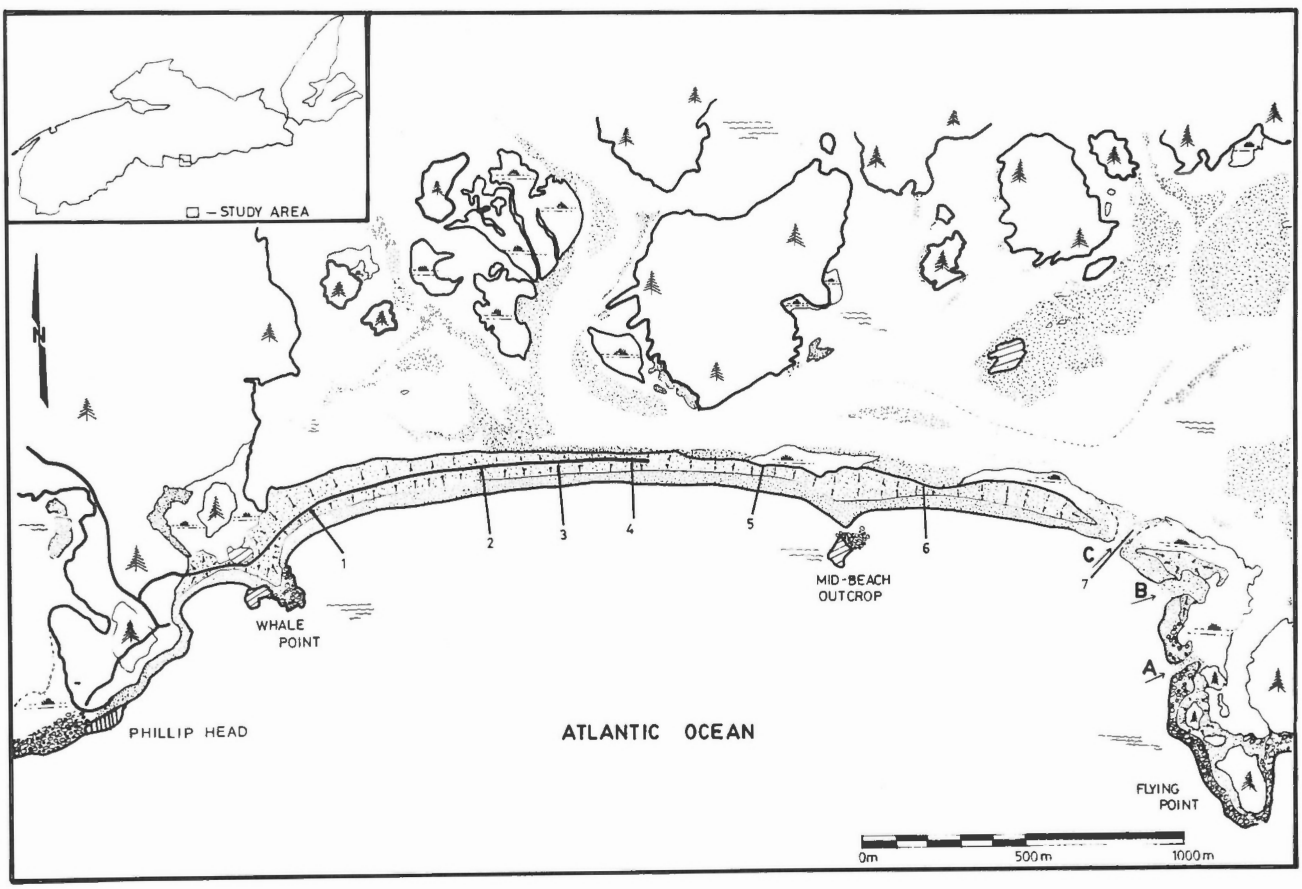

Figure 9. Morphological map of Martinique Beach. Key to symbols used is given in Table 1.

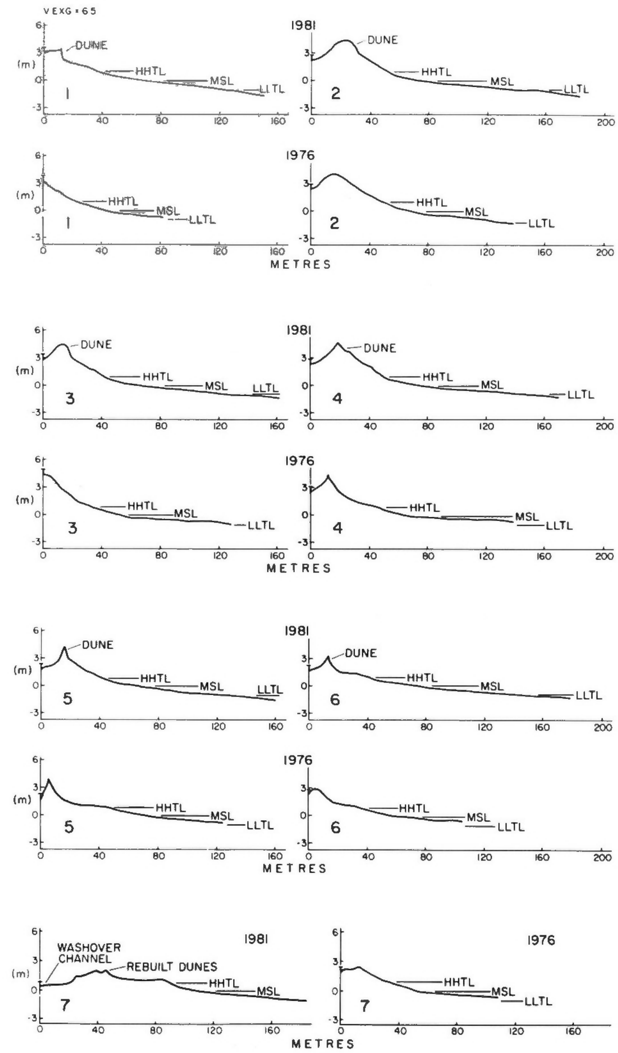

Figure 10. A comparison of beach profiles surveyed in August 1976 and 1981 along Martinique Beach. Profiles of the same number are not superimposed because many of the original bench marks could not be located.

Table 4. Morphological characteristics of Martinique Beach, Halifax County. August 18, 19, 1981.

Profile number	Beach		Foreshore zone			Backshore zone
	width[1] (m)	height[2] (m)	width (m)	height (m)	slope (o)	dune height[3] (m)
1	150	3.3	61.5	2.0	1.9	1.1
2	100	4.4	62.5	2.0	1.8	1.3
3	70	4.5	60.5	2.1	2.0	1.2
4	70	4.7	59.0	2.3	2.2	1.1
5	50	4.4	63.0	1.9	1.7	1.6
6	60	3.2	81.0	1.9	1.3	1.4
7	40	2.5	60.0	1.8	1.7	0.6

[1] MHTL to seaward edge of lagoon.
[2] Highest point on beach above mean sea level.
[3] Base to crest of seaward side of dune.

Foreshore zone. The foreshore width and gradient remained relatively constant alongshore except for profile 6 where it was wider and consequently more gradual sloping (Table 4). In 1981 the mean slope of the beach at profiles 1 to 5 was 1.9°, which is similar to that observed for the same sites in August 1976 (Frobel, personal communication, 1981) but is much more gradual than the 3.3° slope reported by Keeley (1977) for August 1974. In 1976 the foreshore slope decreased from profile 2 to 4 but increased in the same direction in 1981. The differences observed at profile 2 over the three surveys are illustrated in Figure 11. In 1981 the foreshore slope was steepest just below high tide line and flattest near low tide line (Fig. 10). Exposures of Meguma slates are present at Whale Point, Flying Point, and the outcrop at mid-beach.

Backshore zone. The width of the backshore, as measured from high tide line on both sides of the beach, decreases from 150 m at the west end to only 40 m at profile 7 where the breach occurred (Table 4). At most profiles there was a well developed summer berm with an average height of 0.3 m. Back of the berm a single primary dune ridge extends the length of the beach, rising from 3.2 to 4.7 m above mean sea level from profile 1 to 5. The height of the dunes from their base to the crest ranges from 0.6 m to 1.6 m (Table 4). With the exception of profile 7 where foredunes were forming, the rest of the dune system was characterized by a steep, erosional, seaward slope. Bowen and Keeley (1977) reported dune heights of 1 to 4 m at the same sites in 1974, thus the dunes particularly near profile 5 are either retreating very rapidly or have decreased in height.

Except for the low-lying eastern end of the beach and a few footpaths, the top and back of the dune system is well vegetated. At the eastern end of the beach there have been two severe washover events in the past five years. The large, sandy washover fan east of profile 7 (Fig. 9,12) has started to revegetate naturally, whereas at profile 7 (the breach), only after repeated attempts to artificially trap sand, have plants begun to grow in the bands of flotsam at the base of the foredunes. Another consequence of the washover events has been the infilling with sediment of the marsh and tidal flats behind the beach.

Beach sediment characteristics

In August 1981 sediment samples were collected at six sites alongshore (Table 5). The mean size of the sand fraction collected from the foreshore slope varied from 0.40 to 2.74 phi. It was found that the sand at low tide line was finer and better sorted than that at high tide line. The poorest sorted sediment was at profile 2 (Fig. 9), whereas the sand was moderate to very well sorted elsewhere alongshore. Above the summer berm, some slaty gravel was scattered across the beach surface to the base of the dunes. Only one sample of dune sand was collected and it had a mean size of 2.71 phi, similar to the sand on the lower foreshore.

In comparison with previous sedimentological studies of Martinique Beach, the sand sampled in 1981 was better sorted and of a smaller size. For instance, the range in mean sediment size for the foreshore in 1974 was 1.7 to 3.0 phi

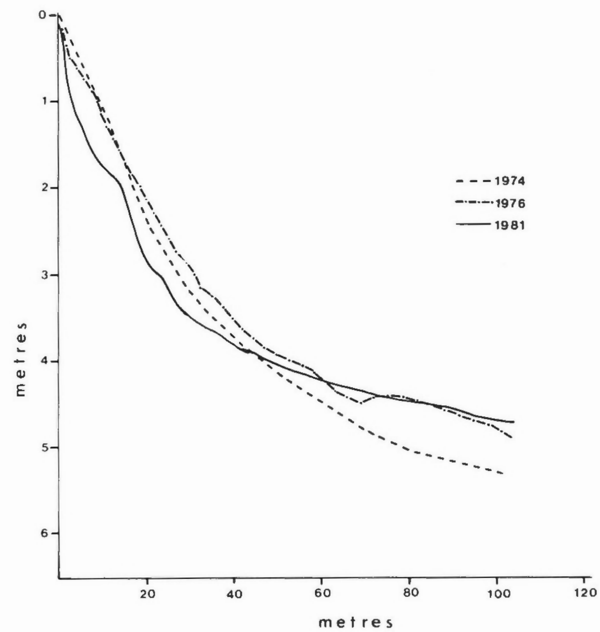

Figure 11. Surveys have been completed at profile 2 on three occasions in August 1974 (Keeley, 1977), 1976 (Frobel, personal communication) and 1981.

Table 5. Sedimentological characteristics of Martinique Beach, Halifax County (August 18, 1981).

Profile number	Mean grain size (∅)			Sorting (∅)			Skewness		
	LTL	HTL	Dune	LTL	HTL	Dune	LTL	HTL	Dune
1	2.62	2.62	—	0.29	0.29	—	−0.04	−0.26	—
2	2.56	0.40	—	0.68	1.94	—	−0.52	−0.16	—
3	—	—	—	—	—	—	—	—	—
4	2.72	—	2.71	0.24	—	0.25	−0.17	—	−0.13
5	2.72	1.11	—	0.26	0.84	—	−0.08	0.03	—
6	2.74	2.72	—	0.23	0.22	—	−0.04	−0.16	—
7	2.72	—	—	0.20	—	—	−0.17	—	—

(Keeley, 1977) and in 1976 it was -0.35 to 2.57 phi (Eastwood, 1977). A sample of dune sand in 1976, taken from the same profile as in 1981, was 0.61 phi, which was much coarser than in 1981. The coarser nature of beach sediment observed in 1974 is partially explained by the sampling period which extended over the spring and fall seasons when coarser substrate materials are often exposed by higher energy waves. Nevertheless, there does seem to have been a general decrease in sediment size between the mid- 1970s and 1980s. The sediment characteristics from 1981 support the hypothesis of Keeley (1977) that gradations in the mean grain size along the beach diminish as summer progresses because the sand transported onshore also shows little gradation in grain size. Even though the trends in sediment size are slight, it is interesting to note that the best trend of decreasing grain size from east to west alongshore was at low tide line in 1981, whereas in 1974 it was along the upper beach. Eastwood (1977) and Keeley (1977) both observed a bimodality in their beach samples which they attributed to the source of the sediment. In 1981 the coarse clasts were absent from much of the beach surface, hence the samples were much more unimodal. For Martinique Beach, the source of the gravel is the bedrock outcrops of Meguma slates, e.g., Whale Point, Flying Point Island. The main source of sand is from offshore; however, some of the sand is derived from the drumlinoid shore bluffs to the west, e.g., Philip Head. The erosion of these shore bluffs also provides gravel-cobble clasts for the shingle beaches adjoining the shore bluffs.

Beach development and evolution

A 1763 map from the Atlantic Neptune Series shows a continuous sand shoal fringing the shoreline from Collies Head to Flying Point Island (Fig. 13a). Martinique Beach was much wider than today; however, it was only attached to Philip Head. It was not attached to the mainland or Flying Point Island. One hundred years later maps showed that the beach was joined to the mainland and Flying Point Island (Fig. 13b). The latter was attached by a low, narrow section of beach which enclosed at least one small body of water. Between Philip Head and Collies Head there were a couple of embayments that were not closed off by shingle beaches as they are today. Historic and geologic evidence suggests that Martinique Beach has been gradually retreating landward for for at least the last few hundred years.

Between 1945 and 1974 there were no significant morphological changes in the beach, apart from its gradual retreat landward. Bowen et al. (1975) have suggested an estimated rate of retreat of 0.4 $m \cdot a^{-1}$ for this beach. Dramatic changes to the beach began after 1974, particularly at the low lying eastern end of the beach. Although an inlet had already cut through the cobble barrier attached to the west end of Flying Point, by 1945 it was nearly infilled with shingle (A – Fig. 9). Since then this breach widened from an estimated 5 m in 1945 to 50 m in 1960, and then decreased to 30 m width in 1974 (Fig. 12). Water only overtops the breach at higher tidal stages or during storms when it carries sediment into the marsh behind.

An extensive washover fan (B – Fig. 9,12) formed between 1974 and 1976, covered in a considerable extent of marsh. During a severe storm in early 1977 the beach was again breached by waves at profile 7 (C – Fig. 9,14,15). The resultant cut was reported to be deep and wide enough to bring a small boat through at high tide (E. Crowell, N.S. Department of Lands and Forests; personal communication, 1981). A deposit of overwashed sediments now extends an estimated 100 m from high tide line to the edge of the main tidal channel which flows behind the beach.

Elsewhere along the rest of the beach, a comparison of beach surveys from 1981 and the mid-1970s (Keeley, 1974; Frobel, personal communication, 1981) shows that the upper beach, especially at the seaward face of the dune, has experienced considerable erosion. At profile 6 (Fig. 10) it is estimated that 9 m of dune sediment has been cut away in five years.

Figure 12. By 1945 an inlet had formed just west of Flying Point. Today this inlet is only overwashed during storms and higher tidal stages. Between 1974 and 1976 a major washover fan formed to the west of the inlet. (See Fig. 9 for location of these features – photographs by R. Belanger). GSC 190866

The foreshore slope, although eroded in some cases, generally assumed a shallower gradient in 1981 than in 1976. A comparison of the beach profiles at Site 2, using the three years of survey data, supports the observation of erosion on the upper beach face and accretion across the lower foreshore. Since all of the profiles were surveyed in August there are no seasonal effects to consider. Two studies of seasonal beach changes on Martinique Beach were completed in the 1970s. Keeley (1975) examined changes from April to October 1974 and Frobel surveyed the same area over a 12-month period in 1976. Results from the latter study have not been published yet, but the profiles from August 1976 are shown in Figure 10. Like many other Atlantic beaches there is a distinct winter-summer seasonal cycle. In 1974 there was a gradual building of the beach to a maximum level in September or October, and then by December the beach was combed down and steepened once more. The cycle is in response to storm conditions and changing wind and wave directions over the year. In summer the waves are predominantly from the southwest, whereas in the winter they are from the east-northeast (Keeley, 1977).

Martinique Beach was not heavily used by the public for recreational activities until the paving of the access road in 1970. Prior to this, the backshore had been the victim of dirt biking activities and the western beach had been mined on a small scale for local use.

In 1967 the beach was bought by the Provincial Department of Lands and Forests and deemed a protected beach under the Nova Scotia Beach Protection Act. In 1971 it attained picnic park status, and in 1976 beach access and parking by vehicles became restricted. With the prohibiting of vehicles from the beach, the vegetation flourished and recolonized old trails.

Since the storm in 1977 which cut the beach at profile 7 (C – Fig. 9) the Provincial Lands and Forests officials have concentrated their efforts on repairing this breach (Fig. 15). In May and June 1977 coniferous trees were dumped at the breach and a straight sand fence was erected across the channel. By the spring of 1978, all efforts had washed away. During late summer and fall of 1978 a new fence was positioned at the washover in a zig-zag pattern. By January of 1979 the fence had succeeded in trapping sand blown from various directions over the backshore. A one-metre high artificial dune was created (Fig. 15b) which nearly reached the top of the snow fence. In 1979 history repeated itself and both sand and fence were again washed away. However, enough sand had accumulated to prevent a complete breaching. In October 1979 the Department of Lands and Forests reinstalled another zig-zag sand fence and a straight fence 10 m landward of the first fence. Both fences were intact in August 1981 and nearly completely buried by sand (Fig. 15d). Foredunes have begun to form seaward of the artificial dune and vegetation was beginning to colonize them. These measures by the Department of Lands and Forests are certainly helpful in stabilizing a weak point in the beach system but the effect may only be short term because of the rapid rate at which the dunes are eroding just west of this site. The whole eastern end of Martinique Beach is low lying and vulnerable to major storms. It should also be remembered that if the maps were accurate, this part of the beach was an inlet in 1763 and so it is natural that it could happen again.

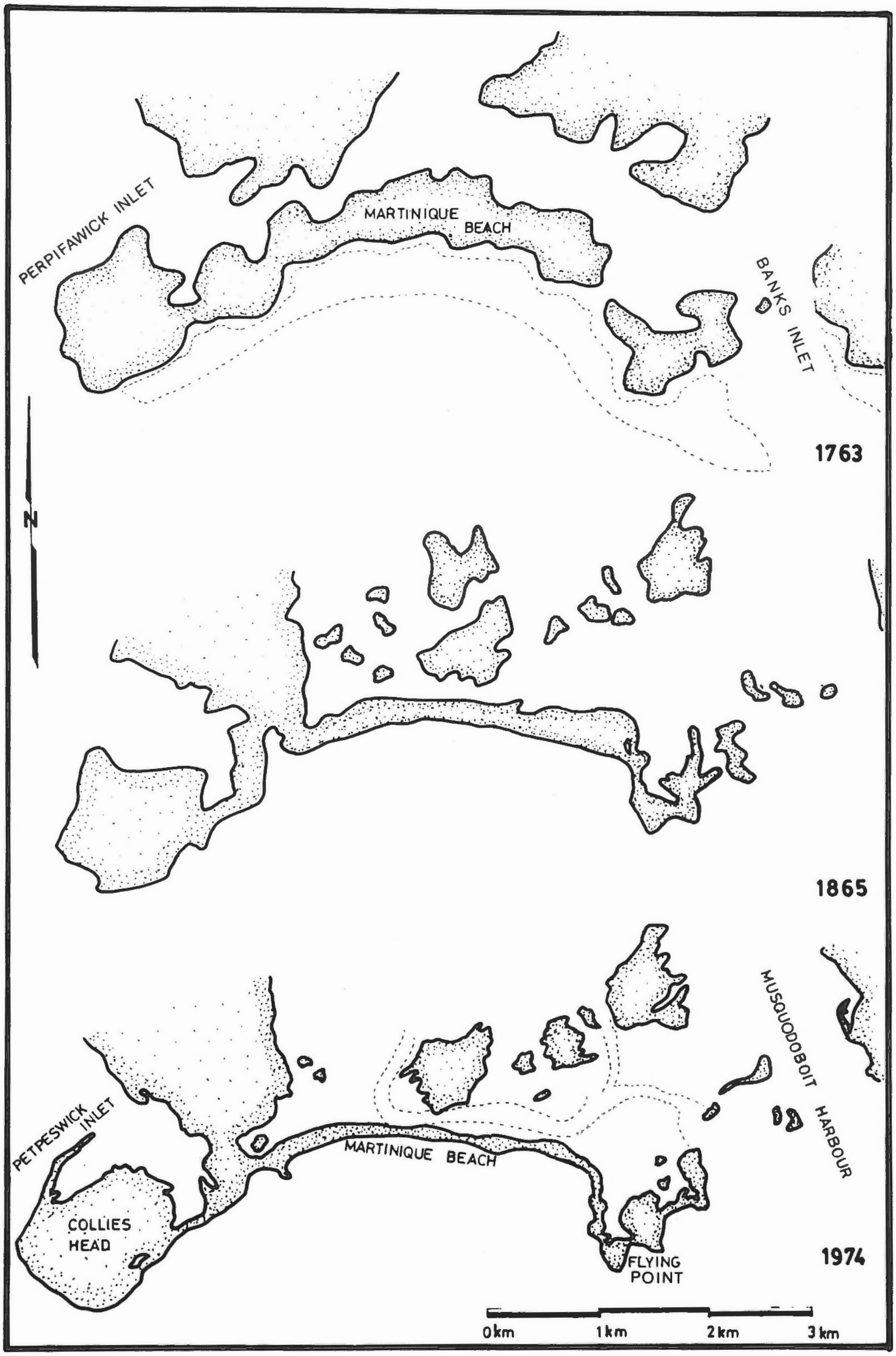

Figure 13. The evolution of Martinique Beach was determined from a 1763 map of the Atlantic Neptune Series, the Church Map of 1865 and a 1974 topographic map. Since 1865 Martinique Beach has become thinner and evidence of landward retreat is found at its eastern end. Embayments once found along the western end of the system are now closed off by narrow gravel beaches.

Figure 14. During a severe storm in 1977 a breach was cut through Martinique Beach (Dashed Lines). Despite efforts to build up dunes in the breach, washover occurred again during the winters of 1978 and 1979. See Figure 15 for ground photographs of the breach site (photographs by R. Belanger). GSC 190863

Figure 15. October 1975 (a) narrow washover channels were evident and by the winter of 1977 the beach was breached (Fig. 14). By January 1979 dunes were developed (b) with the aid of snow fencing but by August 1979 (c) the fence and dunes were washed away again. In September 1981 the dunes were partially vegetated and no further breaches were evident (a,b,c photographs by E. Crowell). (a) (GSC 190818), (b) (GSC 190819), (c) (GSC 190820), (d) (GSC 190788)

Conrads Beach, Halifax County

Physical and geological setting

Conrads Beach is 15 km east of Dartmouth along the eastern shore of Nova Scotia (Fig. 1,16). This beach, like others near the Halifax-Dartmouth metropolitan area, is a favourite spot for recreational activities, especially in the summer. Except for shingle storm ridges at both ends of Conrads Beach, it is predominantly a sand beach. It lies between Fox Point in the east and Conrads Head to the west (Fig. 16). Prior to 1962 the beach was continuous between those points but then an inlet formed and cut it into two segments (Fig. 17). West of the inlet the beach is characterized by a pebble-cobble storm ridge fringed by a wide, gradually sloping sand foreshore. This portion of Conrads Beach is low, and a major washover fan has developed at the western end (Fig. 16). Conrads Head, a 5 to 10 m high eroded shore bluff composed of glacial till, is a significant source of beach sediment. East of the inlet the beach is much wider, 87 to 120 m, and has dunes which extend to a maximum elevation of 4.5 m above mean sea level. Back of the modern beach are relict beach ridges and an extensive marsh area. Fox Point, a cobble-boulder lag deposit from a former glacial (?) feature, has been transformed by the sea from an extension of land to a very small island, which today has been nearly completely eroded away. Fox Point was once joined to Egg Island (Fig. 20), but it too has been eroded and is now merely a bouldery shoal. Now, the ridge which once joined Fox Point to Egg Island is covered by a maximum of 3.7 m of water (C.H.S. – Chart 4347 – 1974). There are other similar submerged cobble-boulder lag deposits nearby; one extends normal to shore off Conrads Head, and smaller coarse lag deposits occur at the mouth of the inlet and 300 m farther offshore (Fig. 16). During storm conditions waves break on these shoals, thus they provide some protection to the beach system. Recent bathymetric charts (C.H.S. – Chart 4347 – 1974) indicate that a very gradual slope of less than 1° extends to a depth of 5.5 m. Between the cobble-boulder shoals the bottom is sandy. Sand waves or mega-ripples show on the 1974 colour aerial photographs west of the inlet.

Inland, the low lying marshes are drained by a major channel that flows from West Marsh (Fig. 16) to the sea via an outlet east of Fox Point. This channel also cuts Conrads Beach from the mainland but access to the beach is possible using a combination bridge and causeway. When the new inlet cut through Conrads Beach, water began draining from West Marsh through it and less water flowed eastward along the traditional channel. Now both the east and west ends of the channel are infilling with flood tidal deposits.

Detailed beach morphology

Four beach profiles were established on July 16, 1981, between the inlet and Fox Point (Fig. 18). They provide the basis of the morphological information provided below.

Foreshore zone. The foreshore is a wide, low gradient sand slope that merges with a steep pebble-cobble beach east of profile 1 (Fig. 17). Its slope decreases slightly from profile 4 eastward (Table 6) and it is associated with a corresponding

Table 6. Morphological characteristics of Conrads Beach, Halifax County, July 25, 1981.

Profile number	Beach		Foreshore zone			Backshore zone	
	width[1] (m)	height[2] (m)	width (m)	height (m)	slope (o)	dune height[3]	storm ridge[4] slope (o)
1	87	2.7	48	0.9	1.0	0.8	2.8
2	120	3.6	57	1.1	1.1	1.5	2.4
3	114	3.7	51	1.1	1.3	1.7	2.6
4	87	4.5	53	1.3	1.4	2.4	—

[1] MHTL to seaward edge of marsh.
[2] Mean sea level to highest point on beach.
[3] Base to crest of seaward slope of dune.
[4] Base to crest of seaward slope of storm ridge.

decrease in berm development alongshore. Profiles 1 and 2 are backed by a well defined shingle storm ridge whereas only scattered pebbles cover the upper foreshore farther west (Fig. 19). The size of the pebbles at profiles 1 and 2 range from -3 to -5 phi clast size on the lower foreshore to a maximum of -7 phi at the storm ridge. The only depositional beach features observed were sand bars or a welded sand berm along the lower foreshore zone between the inlet and profile 4. These features are created by tidal currents flowing from the inlet, waves, or the combined action of both processes. Subsurface drainage of the marshland, beneath the beach adjacent to the inlet is still occurring just as it did before the inlet was formed, although the flow is probably less today.

Backshore zone. A dune system, cut by footpaths and remnant excavation sites for sediment removal, is found along the backshore. The height of the dunes increases westward alongshore to profile 4 where they are 2.4 m high from base to crest, or 4.5 m above mean sea level (Table 6). The backshore slope of the dunes is steeper and better vegetated than the seaward side. Foredunes are forming in several places but primarily at the base of the old dune line adjacent to the inlet. Back of the main dune line there are a couple of low relict beach ridges that are lined by small trees many of which have died or are dying, because of increased water levels in the marshland. A very extensive series of relict beach ridges exists inland and east of Fox Point which was the anchor point for their development. The height of these relict beach ridges above geodatum varies from 1.8 m behind the main study area to 5.2 m along the more recent ridges east of Fox Point (N.S. Department of Lands and Forests, Map E-5-56, 1975).

Beach sediment characteristics

Surficial sediment samples were collected at three of the four profiles in July 1981 to determine the general characteristics of the foreshore zone (Table 7). Although gravel is scattered across the beach surface, only the sand was analyzed. There are insufficient samples to make conclusive statements about processes but some trends in sediment characteristics are detected alongshore. Excluding the pebble-cobble clasts at the east end of the beach, the size of the sand grains decreases and the sorting increases in a west-to-east direction alongshore. All of the sand sampled, except at high tide line of profile 4, was well to very well sorted. The mean grain size for all samples collected from the foreshore zone was 2.5 phi. The dune sands sampled from profile 3 were slightly coarser (Table 7).

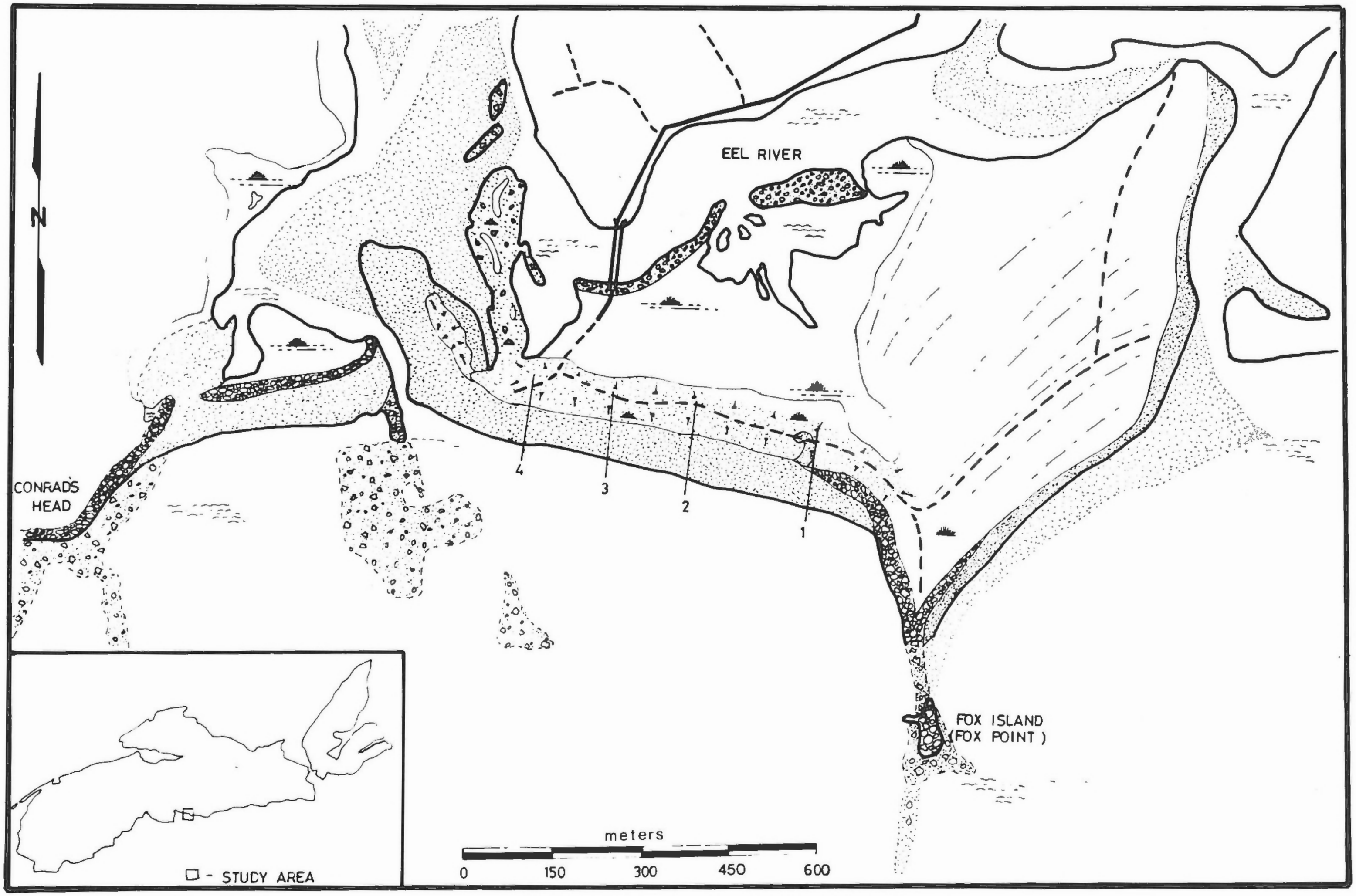

Figure 16. Morphological map of Conrads Beach, Halifax County (see Table 1 for key to symbols).

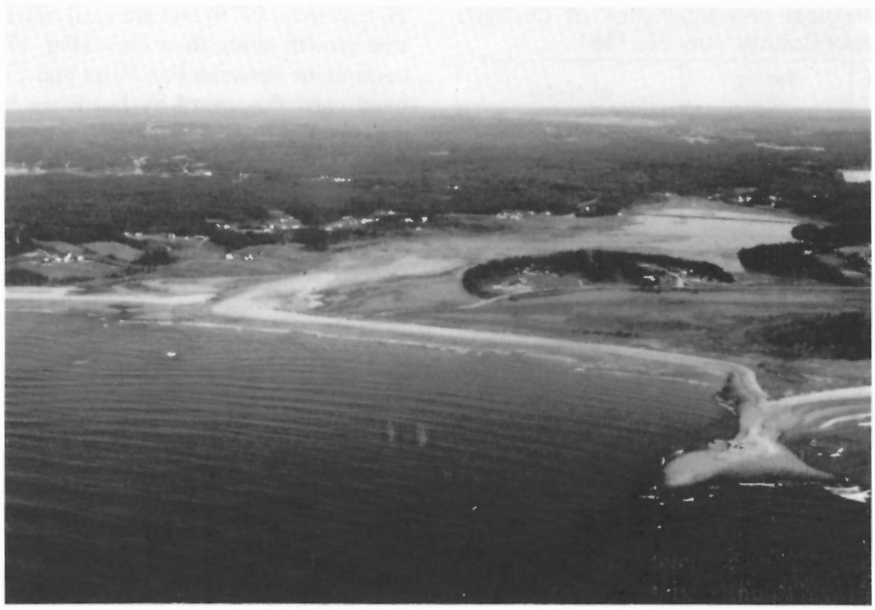

Figure 17. Oblique aerial view of Conrads Beach, November 17, 1978. Fox Point is at the right hand corner of the photo and West Marsh is in the background. Note the extensive flood tidal deposits that are accumulating (photograph by H.D. Munroe). (GSC 190822)

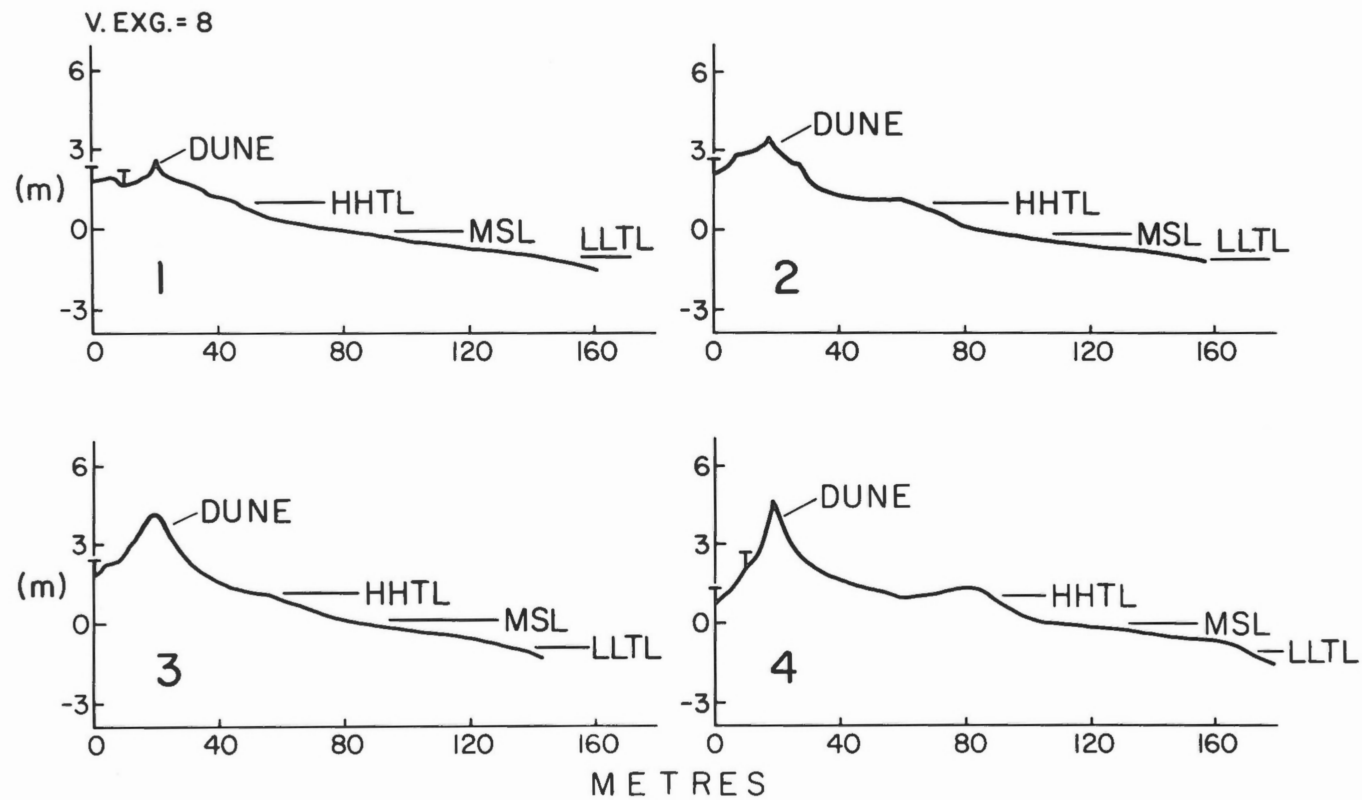

Figure 18. Cross-sectional beach profiles were completed at four sites on July 16, 1981.

Table 7. Sedimentological characteristics of Conrads Beach, Halifax County. July 25, 1981.

Profile number	Mean grain size (∅)			Sorting (∅)			Skewness		
	LTL	HTL	Dune	LTL	HTL	Dune	LTL	HTL	Dune
2	2.59	2.57	—	0.34	0.32	—	−0.24	−0.24	—
3	2.48	—	2.03	0.50	—	0.47	−0.37	—	−0.06
4	2.53	2.18	—	0.39	0.64	—	−0.29	−0.27	—

With respect to the gravel component of Conrads Beach, the largest clasts were at the east end of the beach and in the storm ridge at profile 1 where the maximum size was -7 phi. Pebbles decreased in size westward along the storm ridge toward profile 2 where they were only -4 to -5 phi.

The trends in sediment size characteristics alongshore support beach morphological evidence, that sand is being transported eastward alongshore and is covering a subsurface deposit of gravel, at least at profiles 1 and 2.

Beach development and evolution

An examination of coastal morphological features on old maps and aerial photographs provides clues for the reconstruction of the recent geological evolution of the Conrads Beach system. Historical articles, land grant maps, and conversations with local people provide a historic perspective of the human impact on this beach.

On maps drawn in the mid-1700s, Conrads Beach was a continuous system from Fox Point to Conrads Head (Fig. 20). The beach was backed by Eel River, which drained West Marsh and emptied into the Atlantic Ocean east of Fox Point. The general configuration of Conrads Beach remained essentially the same until the 1960s (Fig. 20). The most dramatic changes to the beach have occurred since 1962.

An absolute date for the formation of Conrads Beach is not available because it would require detailed coring of the marshes and relict beach ridges. However, the morphology and pattern of beach features do suggest a sequence of events that has led to the development of the present beach system. After the retreat of the late Wisconsinan glacial ice from the Atlantic coast some 12 000 to 13 000 years B.P., sea level rose until today it is at a postglacial high (Quinlan and Beaumont, 1981). During this period waves eroded the outer islands and headlands composed of glacial till and formed depositional coastal features farther landward or between them. Such was the case at Conrads Beach where beach ridges were built in the shelter of Egg and Fox islands. At this time there was also a long peninsula that extended offshore of Conrads Head, and several small islands seaward of the present inlet. These relict features have been destroyed by wave action and the only evidence of their existence is the cobble-boulder shoals in the nearshore (Fig.16). Beach ridges were built westward and northeastward from Conrads Head at the expense of the offshore islands. Where the present inlet exists, small islands probably acted as an anchorage for the joining of the two spits. Today, the relict beach ridges lie at 1.8 to 3.3 m above geodatum (N.S. Department of Lands and Forests map, 1975) and are easily distinguishable because of tree growth along their crest (Fig. 17). Once the beach was continuous between Fox Point and Conrads Head, the sediment carried seaward by Eel River began to infill the area back of the beach. Although early maps do not show any inlets cutting Conrads Beach, there is morphological evidence, e.g, drainage channels in marsh, that a small breach may have existed just west of Fox Point where the beach is lower. It is also possible that a small inlet existed there before the beach became continuous, but this suggests that beach development was only eastward toward, and not westward from, Fox Point. The headlands continued to erode and sediment was deposited landward of the beach system. Measurements of the extent of boulder lag offshore of Conrads Head and Egg Island suggest that 300 to 400 m of headland was eroded by 1974. If an erosion rate of 1.5 $m \cdot a^{-1}$ is assumed for the nearby shore bluffs, then Conrads Head began eroding 266 years ago or in the early 1700s. This estimate is thought to be fairly accurate because a local resident remembers that the shoal off Conrads Head, which was exposed, was called 'Green's Rock' which was named after the settler who owned the land by the early 1800s.

As the headlands continued to wear back, Conrads Beach also slowly retreated landward. In contrast, the beach east of Fox Point was prograding and a series of sand beach ridges, which extended up to 5.2 m above geodatum (N.S. Department of Lands and Forests map, 1975), were developed seaward of the original beach ridges. The primary source of sediment for their development was from the eroding shore bluffs to the east.

By 1954 (Fig. 20) Fox Point had become an island and most of the other nearby islands had been nearly completely destroyed by waves. At this time Conrads Beach consisted of a sand beach, bounded at either end by well developed shingle beach ridges. However, during the 1950s and early 1960s, vast amounts of sediment, particularly gravel, were removed from the beach west of Fox Point. The loss of the protective cover of gravel severely reduced the beach stability. Overwash fans became common occurences at the western end of the beach and blowouts developed around the man-made pits in the backshore. Local residents recall that they could hear water flowing beneath the shingle beach in the 1950s where the new inlet finally opened. By the 1960s, flood tidal deposits at the mouth of Eel River were so extensive that water levels began to rise in the marsh behind Conrads Beach. In 1962 during a severe fall storm, the beach was cut (Mrs. W.M. Landymore, personal communication, 1982).

The inlet still exists at the same site today. Since 1962, the beach west of the inlet has been overwashed during most storms and only a very short, thin ridge of shingle remains. Flood tides have transported large amounts of sand landward across the marsh and estuary, and since 1974 the tidal flats have extended at least 150 m farther landward and now reach Eel River channel. During recent years, flood tidal flats have also accreted considerably, at the mouth of Eel River. Conrads Beach will continue to retreat if sea levels continue to rise, and further breaches of the beach could easily occur west of the inlet and at two small cuts in the dunes just west of Fox Point. These cuts resulted from the excavation of beach sedi-

Figure 19. View of Conrads Beach looking west from profile 1. Here the sand foreshore is backed by a shingle storm ridge and a low dune ridge. (GSC 190823)

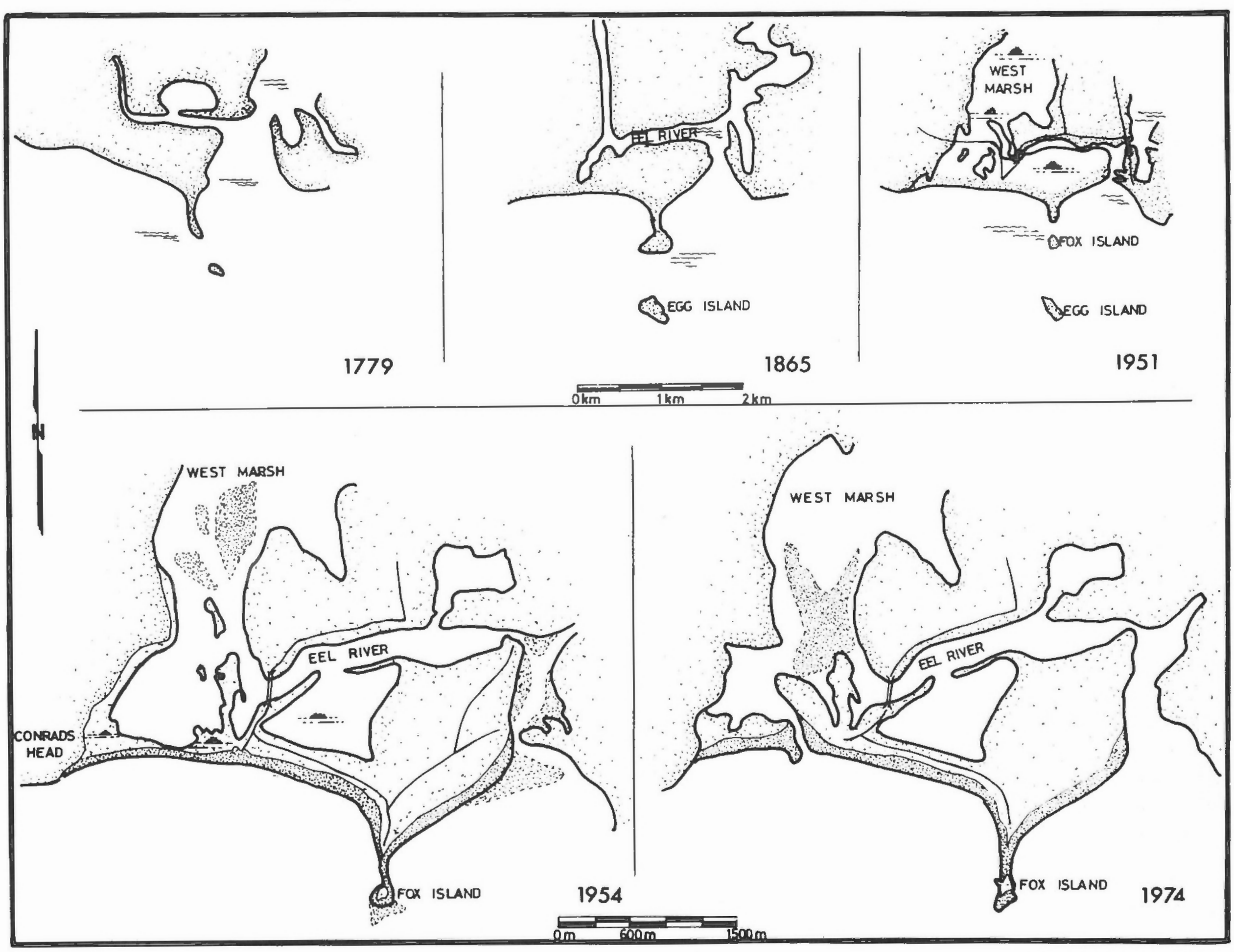

Figure 20. The configuration of Conrads Beach has remained essentially the same from 1779 to 1962 when an inlet was cut through the beach. The 1954 and 1974 maps are based on recent aerial photography and the 1951 map is from a topographic map which was based on surveys completed in the early 1900s.

ment and subsequent wind erosion. There is also recent evidence that the beach east of Fox Point is now eroding, particularly adjacent to the point. The sediment is being carried landward via the nearby inlet to the east (Fig. 20).

In 1754, 20 000 acres of land around Lawrencetown, including Conrads Beach, was granted to 20 families who settled in the area. By 1865 there were 25 names listed in the Lawrencetown directory. There is no evidence that the beach was being used for anything special at this time; however, farming of marsh hay in West Marsh did occur during the 1800s. Egg Island and Fox Point were preserved for the fishery. Huts and a large wharf were built and actively used on Fox Point until it became separated from the mainland in the mid-1900s. Remains of the wharf are still found on Fox Island and its presence is one reason why the island continues to resist complete destruction by waves. The 1951 topographic map, which was based on surveys conducted in the early 1900s, shows trails across the west end of the marsh and beach, and a bridge across the mouth of Eel River (Fig. 20). By 1954 the bridge was gone and the trail across west marsh was erased by rising water levels. The only link to Conrads Beach was across the bridge and causeway which exists today.

The human activity most destructive to the beach occurred in the 1950s and 1960s when sediment was extracted from along the beach. The removal of sediment reduced the height and stability of the beach and resulted in it being cut in two by an inlet (Fig. 20). During the 1960s and 1970s a group concerned about the integrity of Conrads Beach began to clear all garbage and old car bodies from the beach, and built a barricade on the causeway to prevent further vehicular traffic on the beach. Conrads Beach was recently designated as a protected beach under the Nova Scotia Beaches Protection Act.

Cow Bay Beach, Halifax County

Physical and geological setting

Cow Bay Beach, located northeast of the entrance to Halifax Harbour (Fig. 1,21), is a narrow bayhead beach with an average width of 75 m and a length of 1100 m. The beach, crescentic in shape, is aligned in a northwesterly direction. It encloses Cow Bay Lake which is connected to the sea by a 20 m wide inlet at the southwestern end of the beach (Fig. 21). Cow Bay is bounded to the northeast by an eroding drumlin headland, Osborne Head, and to the southwest by the rapidly eroding shore bluffs of Hartlen Point. Both headlands are composed of glacial deposits overlying metamorphosed slate of the Halifax Formation (Nielsen, 1976; Keppie, 1979; Bujak and Donohoe, 1980). There are no exposures of bedrock along Cow Bay Beach.

Offshore, Cow Bay is relatively shallow, particularly along the western shore where shoals exist as remnants of the former beach system. Maximum water depths of 9.1 m (C.H.S. Chart 4347, 1974) occur off Osborne Head at the entrance to Cow Bay.

Cow Bay Lake is saline and very shallow at its southwestern end where extensive flood tidal deposits have accumulated. Most of the sediment has been deposited since the late 1950s when a wide inlet formed at the western end of the beach. The exact position and width of this inlet has changed several times since then, but it has always remained at the western end of the beach. Ebb deposits are much smaller and have been confined to the western shore of Cow Bay.

Detailed beach morphology

Foreshore zone. Cow Bay Beach has two main morphological units: a low, gradually sloping foreshore, backed by a steep, pebble-cobble storm ridge (Fig. 23). The foreshore slope of 3.0° to 3.8° is composed of a sand veneer 30 cm thick over a pebble-cobble base along the entire length of the beach except at the northeastern end and near the midpoint of the beach. At these two locations the lower foreshore and shallow nearshore are covered by a pebble-boulder lag deposit (Fig. 24). D. Johnson (1919) suggested using the previous work of McIntosh (1916), that Cow Bay Beach was a complex tombolo connecting a series of drumlins, which have since been consumed by the waves. The two pebble-boulder lag deposits on the lower foreshore are the remnants of those drumlins.

Backshore zone. In the backshore, a single continuous, pebble-cobble storm ridge exists except near the inlet where there are three storm ridges. The main storm ridge becomes steeper and the crest elevation increases toward the southwest end of the beach (Fig. 25, Table 8). At the northeastern end of the beach, overwash deposits have infilled the back of the storm ridge creating a more gentle profile.

For the most part the beach backshore is devoid of vegetation except for a few patches of small shrubs and grasses scattered along the backslope at the edge of the lagoon. Only the trunks of a few dead trees remain of the once forested backshore.

West of the inlet to Cow Bay Lake, the shore is characterized by a cobble storm ridge and a coarse sand and pebble foreshore. No quantitative surveys or sampling of sediment were conducted in 1981 along the shore west of the inlet.

Table 8. Morphological characteristics of Cow Bay Beach, Halifax County. July 3, 1981.

Profile number	Beach		Foreshore zone		Backshore zone		
	width[1] (m)	height[2] (m)	slope (o)	width (m)	storm ridge height[3] (m)	storm ridge slope[3] (o)	maximum extent[4] of overwash (m)
M	90	2.8	3.8	42	0.7	7.1	67
2	65	3.3	3.0	30	2.6	8.3	—
3	51	3.6	3.7	24	2.9	12.7	—

[1] MHTL to seaward edge of lagoon.
[2] Mean sea level to highest point on beach.
[3] Base to crest of seaward slope of main storm ridge.
[4] Mean sea level to landward limit of overwash deposits.

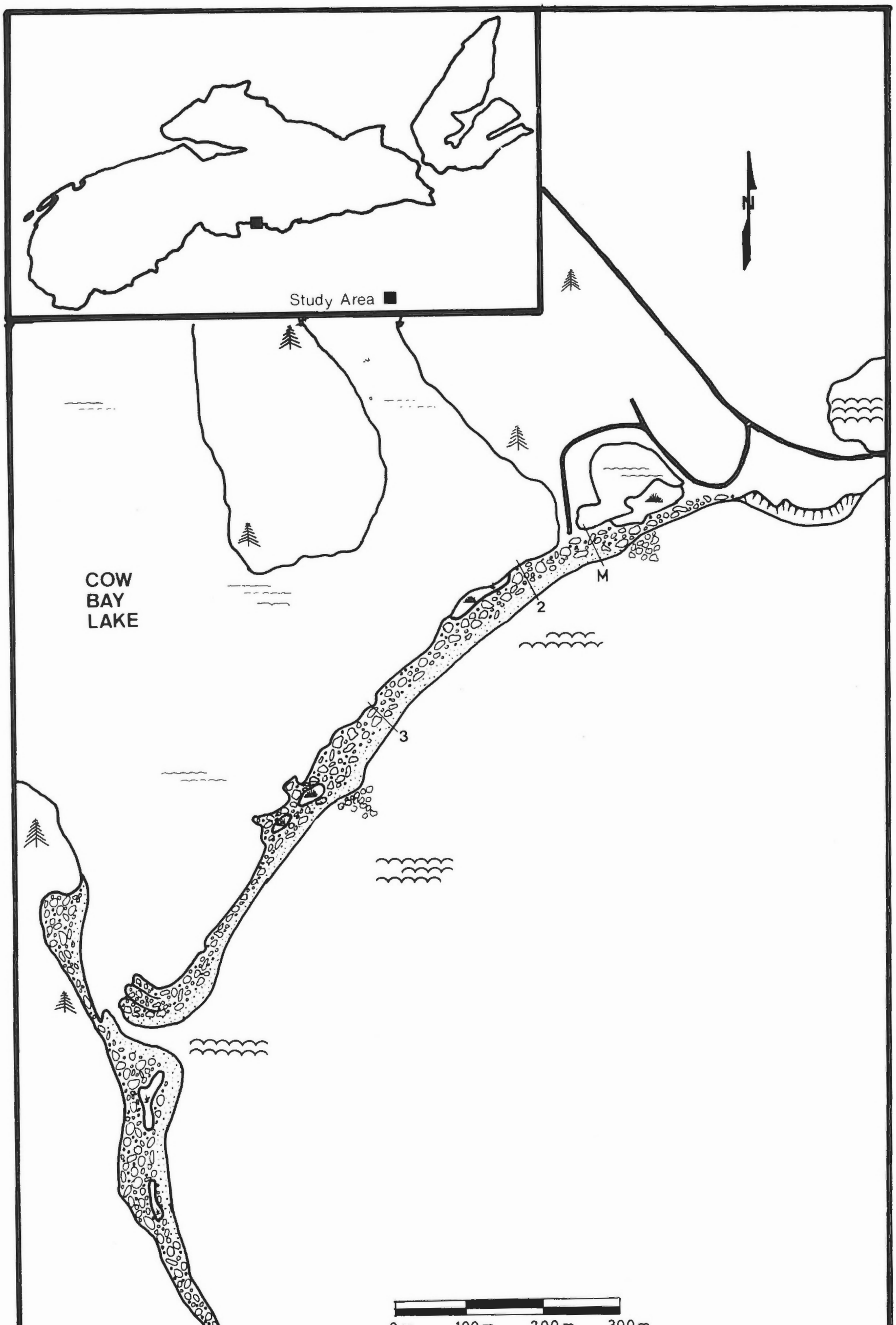

Figure 21. Morphological map of Cow Bay Beach drawn from 1974 aerial photography (74123-107-MRMS, Amherst, N.S., taken on August 11, 1974).

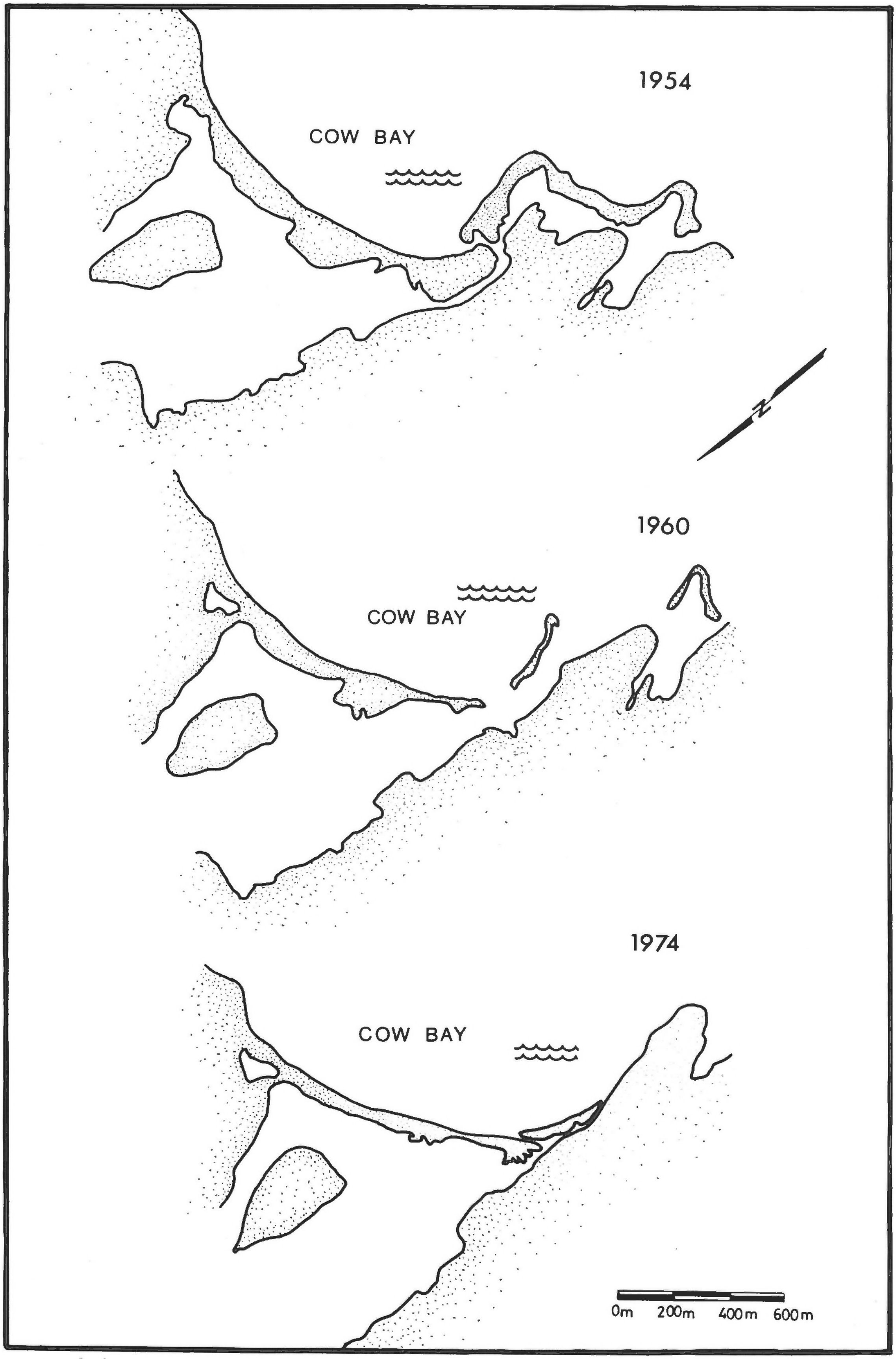

Figure 22. Maps of Cow Bay Beach based on aerial photographs illustrate the dramatic reduction in its size following the removal of beach sediment during the period 1954 to 1971.

Figure 23. View of Cow Bay Beach looking eastward from profile 3. The lower foreshore zone is covered by a sand veneer which increases in thickness downslope. (GSC 190850)

Figure 24. Cobble-boulder lag deposit at the east end of Cow Bay Beach is the remnant of a former glacial deposit. (GSC 190846)

Beach sediment characteristics

The principal sources of beach sediment are the shore bluffs of glacial debris at the headlands of Cow Bay. Osborne Head, receded at an estimated rate of 1.2 m·a^{-1} during 1945-66 despite the presence of protective walls at the base of the bluff (Huntley, personal communication, 1976). Hartlen Point receded 2.1 m·a^{-1} from 1964-74 (Huntley, personal communication, 1976) and a maximum of 3.0 m·a^{-1} during 1980-81. The small cliff immediately east of the beach also contributes to the local sediment budget.

The plan shape of Cow Bay Beach and the increased number of beach ridges near the inlet suggest that the dominant sediment transport is from east to west. It appears that the sediment eroded from Hartlen Point does not contribute significantly to Cow Bay Beach. Surface sediment samples collected from near low tide level in July 1981 also indicate a westerly transport of sediment. Mean clast size varied from 1.89 phi at profile M to 2.06 phi at profile 3. All samples were moderately well sorted and near symmetrical in distribution (Table 9). Across the beach the coarsest sediment was at the top of the storm ridge, and just offshore where lag deposits of former drumlins exist. The a-axis of the largest material was commonly 500 mm. Cobbles of 80 to 250 mm a-axis occurred at the top of the storm ridge, whereas at or near high tide level the clasts were 50 to 130 mm in a-axis. The coarse storm ridge sediments are only moved during storm wave conditions, whereas the smaller clasts found near high tide level represent the largest material transported during 'normal' wave conditions.

Beach development and evolution

Cow Bay or Silver Sands Beach as it is often referred to, has been a favourite recreational spot for the residents of Halifax-Dartmouth since the early 1900s (McIntosh, 1916). From 1931, when the first airphotos were available, until 1954, Cow Bay Beach appeared stable (Huntley, personal communication, 1976). However, the removal of an estimated two million tons of sediment from the beach between 1954 and 1971 had dramatic effects (Fig. 22) on the stability of the system. In 1954 a complex system of barrier beaches existed from Hartlen Point to the east end of Cow Bay (Fig. 22a). A well developed series of storm ridges existed at the western end of Cow Bay and the backshore was extensively covered by trees.

By 1960 the western end of the system had collapsed, the beach was reduced to shoals and the inlet to Cow Bay Lake had widened considerably. The shoreline along Cow Bay lake also appears to have receded and forested areas disappeared. A new road was built along the beach to facilitate the extraction of sediment. At the eastern end of the beach, it cut across Cow Bay lake creating the small pond which exists today. At this time there is also evidence of excavation at the small shore bluff at the eastern end of Cow Bay Beach. From 1954 to 1960 Cow Bay Beach became much thinner and much more unstable. Huntley (personal communication, 1976) found that by 1964 the beach was reduced to an average of 42 to 56 per cent of its 1954 width.

Table 9. Sedimentological characteristics of the Lower Foreshore Zone of Cow Bay Beach, Halifax County, July 3, 1981.

Profile number	Mean grain size (∅)	Sorting (∅)	Skewness
M	1.89	0.60	−0.08
2	2.00	0.63	+0.18
3	2.06	0.55	−0.12

By 1973 the beach had been further reduced in width but some recovery was observed at the western end where the inlet was nearly closed off by a series of five recurved beach ridges. These ridges were connected to the rest of the beach by a very narrow beach ridge and overwash deposits. The backshore continued to degrade and overwash was evident near profile M. A year later, in 1974, sediment accumulated along the western end of the beach and infilled the inlet. The closure of the inlet is thought to have occured between June and August 1974 (Huntley, personal communication, 1976). A new inlet opened in the narrowest stretch of beach just east of the recurved ridges during the winter of 1975-76 and the number of recurved beach ridges was reduced to three from five by 1976. In the mid-1970s the beach became protected under the Provincial Beaches Protection and Preservation Act (1975).

In 1981 there was no significant change in the overall morphology of the beach system but there were signs that the beach was still retreating. For example, peat deposits were exposed at the west end of the beach (Fig. 26a) and the foundation of the dance hall was infilled by cobbles. Only a couple of old tree trunks still remained near the dance hall foundation and they were at the top of the cobble storm ridge (Fig. 26b). A comparison of beach profile survey data from 1981 with surveys completed earlier in the 1970s provides quantitative information about beach change. In June 1974 the slope of the beach foreshore at the front of the old dance hall was 5.7° whereas in 1981 it was 3°. At the western end of the beach the slopes of the lower beach face and the storm ridge were 3.7° and 12.7° respectively in 1981 (Table 8), whereas in 1974 the slope of the lower beach face was 7 to 14° (Huntley, personal communication, 1976). At profile M, which was established in 1978 (Munroe, 1980), the upper foreshore slope increased from 4.5° to 6.5° by 1981, the storm ridge was built up by 0.8 m and the backshore was infilled by overwash deposits.

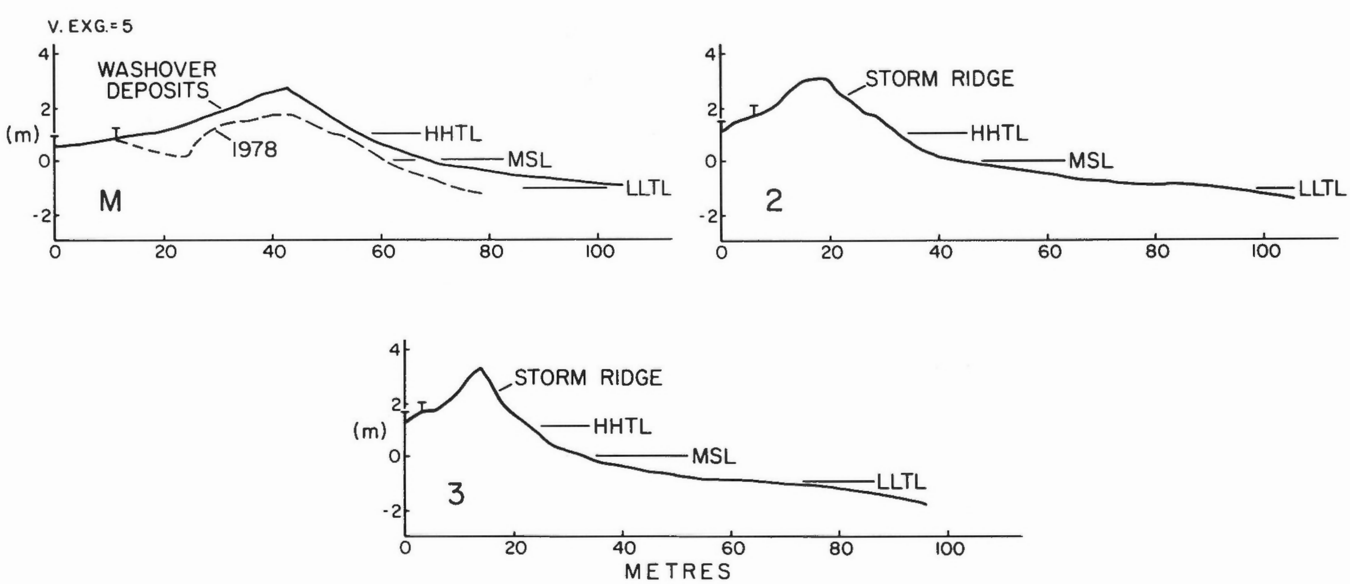

Figure 25. Profiles were surveyed across Cow Bay Beach on July 3, 1981. Since 1978 the storm ridge at profile M has increased in height 0.8 m.

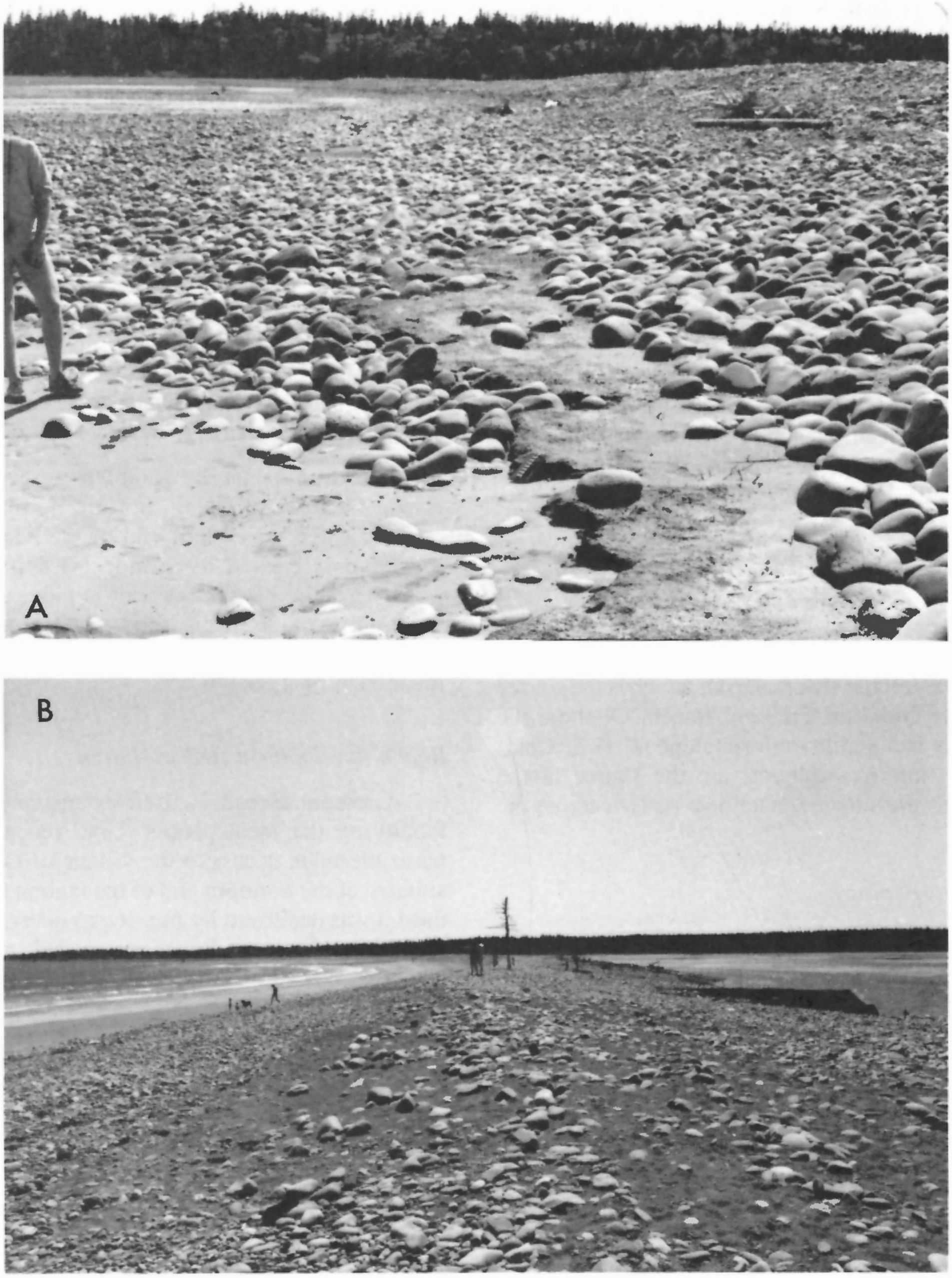

Figure 26. In 1981, Cow Bay beach still exhibits signs of retreating landward (a) peat is exposed on the lower foreshore west of profile 3 and (b) the dance hall foundation is now infilling with gravel storm deposits. Only a couple of dead trees remain from a once well forested backshore. (a) GSC 190814, (b) GSC #190808

The lack of overall recovery of the beach since 1971 suggests that there is a scarcity of sediment available for rebuilding. Field surveys in 1981 indicate that the beach is still transgressing slowly but there also appears to be local accretion at the eastern end of the beach. Nevertheless, the beach will probably continue to slowly retreat in the near future, and it is possible that a new breach at the narrow western end of the system could occur during winter storms.

Crescent Beach, Shelburne County

Physical and geological setting

Crescent Beach is 0.8 km in length and joins the mainland of southwestern Nova Scotia to Locke Island, the site of the town of Lockeport (Fig. 1,27). The beach serves as a recreational facility for the residents of the area and also as a transportation and communications link with the island via a provincial road that extends the length of the beach.

Table 10. Morphological characteristics of Crescent Beach, Shelburne County, July 21, 1981.

Profile number	Beach		Foreshore zone		Backshore zone
	width[1] (m)	height[2] (m)	width (m)	slope (o)	dune height[3] (m)
1	130	4.1	23.4	2.1	3.2
2	110	3.7	22.6	1.6	3.6
M	90	4.5	25.2	1.7	3.9
3	20	1.4	27.8	1.3	0.7

[1] MHTL to seaward edge of lagoon (#3 only to top of beach).
[2] Mean sea level to highest point of beach.
[3] Base to crest of seaward slope of dune.

Two small pocket beaches are located on the mainland just southwest of Crescent Beach. Both beaches are composed of fine white sand with low vegetated dune ridges in the backshore. A small outcrop of Goldenville greywacke, exposed at the western end of Crescent Beach, acts as a boundary between this system and the first pocket beach; a resistant knoll of Goldenville slate separates the two pocket beaches (Fig. 27).

East of Crescent Beach, the shoreline of Locke Island is composed of pebble-cobble size material, which is the source of the larger clasts found on Crescent Beach. Offshore the bottom topography is a gentle uniform slope (C.H.S. Chart 4327, 1970). The bottom sediments are the source of the beach sands. Shoals are situated in a linear pattern across the mouth of the bay.

Detailed beach morphology

In July 1981 four profiles were surveyed across Crescent Beach including the profile established in 1978 by Munroe (1980) (Fig. 28,29).

Foreshore. The beach face is composed of fine white sand and exhibits very little morphological variation alongshore. The width decreases as the gradient increases toward the western end of the beach (Table 10), and the lower slope is characterized by shallow sand ripples oriented parallel to shore (Fig. 30).

Backshore. The backshore of Crescent Beach includes a dune system, tidal flats, and a lagoon (Fig. 28). A summer berm extends the length of the beach but is better developed at the western end of the system. The sediment composition of the berm progressively coarsens toward the east end of the beach where pebble/cobbles are concentrated in a deposit that extends 3 to 4 m seaward of the dune ridge. Coarse clasts are also scattered across the foreshore slope.

The dune ridge reaches its highest elevation of 3.9 m at profile M and gradually lowers to less than 1.0 m in the east (Table 10). Vegetation cover is sparse across the main dune ridge except across the eastern dunes and where new foredunes are forming. Parts of the dunes are covered by pebbles which were not deposited by natural processes but rather by man (Fig. 31). In October 1963, a severe storm transported 15 to 20 cm of dune sediment onto the roadway behind the beach. The people of Lockeport, concerned over the possible loss of the dunes, bulldozed material from the foreshore and berm onto potential breach sites along the dune face. Where dumping was concentrated, pebbles are still found at a depth of 0.5 m beneath the backslope and 0.2 m beneath the seaward slope.

The backshore wetlands, consisting of a lagoon and tidal flats, are separated from the dune system by a paved road. The flats are only vegetated with grasses on the higher ground which is not subject to flooding except in extreme tidal conditions.

Beach sediment characteristics

Surficial sediment collected along the profile transects (Fig. 28) was well to very well sorted sand which ranged from 2.3 to 2.9 phi mean size (Table 11).

The finest material sampled was at profile 2 and the coarsest was at profile 1. Sorting normal to shore is only evident at the far eastern end of the beach where the sand foreshore is backed by pebble (-3.5 phi) storm deposits. Elsewhere, the beach sediment is more uniform in size and there are no significant trends in sorting normal to shore. Dune sediment was only sampled at profile 2 where it was a mean size of 2.37 phi.

Beach development and evolution

Crescent Beach is used extensively as a recreational facility by the local people. Until recently, the beach was never the main access to the village of Lockeport. A bridge situated at the northern end of the lagoon served that purpose until it was destroyed by fire. It was never repaired and so the road along Crescent Beach was paved.

The plan form of Crescent Beach adapts well to the model of bayhead beach development proposed by Davies (1958). He suggested that the plan of sand bayhead beaches is dominated by long swell which becomes refracted as it passes through a bay. Sediment accumulates at either end of the beach because of longshore currents which are set up by waves striking obliquely to the sides of the bay. In theory, the accumulation of sediment leads to a sharpening of the beach curve and in turn material is transported inward across the face of the beach and a dynamic equilibrium is achieved. Although the plan of Crescent Beach appears to have remained the same for a long time, it would require additional research to confirm that it is in fact in equilibrium with present littoral processes.

Crescent Beach has had a long history of man's interference. The people of Lockeport have long taken an interest in protecting their recreational facility. The present day dune

Table 11. Sedimentological characteristics of Crescent Beach, Shelburne County, July 21, 1981.

Profile number	Mean grain size (∅)			Sorting (∅)			Skewness		
	LTL	HTL	Dune	LTL	HTL	Dune	LTL	HTL	Dune
1	2.31	—	—	0.33	—	—	0.06	—	—
2	2.91	2.90	2.37	0.35	0.31	0.51	0.09	0.21	−0.08
3	2.74	—	—	0.36	—	—	−0.14	—	—

system was initiated by the residents of the area. At the turn of the century there was only a low unvegetated sand bar connecting the mainland to the island. A 'winter works' program was implemented whereby the loggers of the area each contributed a cord of wood for the construction of cribwork over the bar to trap sediment and prevent it from blowing inland to the lagoon. The result was a dune system similar to that observed today. However, deterioration of the dunes has been taking place for some time. Wind and wave attack as well as human trampling of the vegetation have all accelerated erosion. In an effort to protect the dune system, the town has erected three wooden access stairs over the dune crests to the beach face. Vehicle access onto the beach is no longer permitted and the beach was placed under the auspices of the provincial Department of Lands and Forests through the Beaches Protection Act on July 13, 1967. A program for revegetating the dunes is required to stabilize the sediment, however such a program has met with only partial success in the past.

Although Crescent Beach appears to be in an overall state of degradation, a comparison of beach profiles between 1978 and 1981 shows that there was 23 m^3 of sand accumulation at profile M.

Sediment supply to Crescent Beach does not appear to be overabundant and if sea level continues to rise at an average of 30 cm per century (Grant, 1970), the beach can only maintain its profile in equilibrium by retreating. Crescent Beach can no longer do this either in a series of successive failures or in a steady landward transgression because of the road running the length of the beach. However, since there are no serious washovers or points of immediate failure in the system, the relative stability of Crescent Beach appears good for now.

Figure 27. Aerial photograph of Crescent Beach and the Town of Lockeport, Shelburne County (from airphoto 78330 MRMS, Amherst, N.S., taken on June 10, 1978).

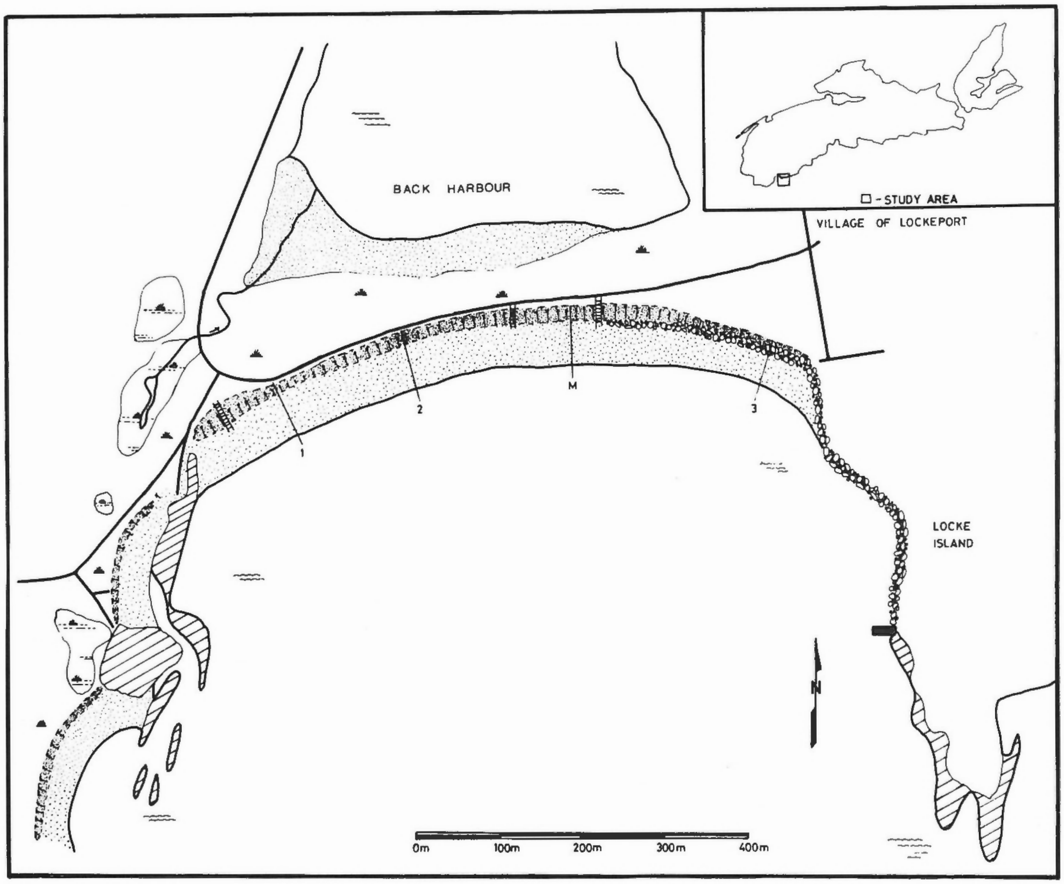

Figure 28. Morphological map of Crescent Beach, Shelburne County. It is drawn using the 1978 aerial photograph shown in Figure 27. The key to symbols is given in Table 1.

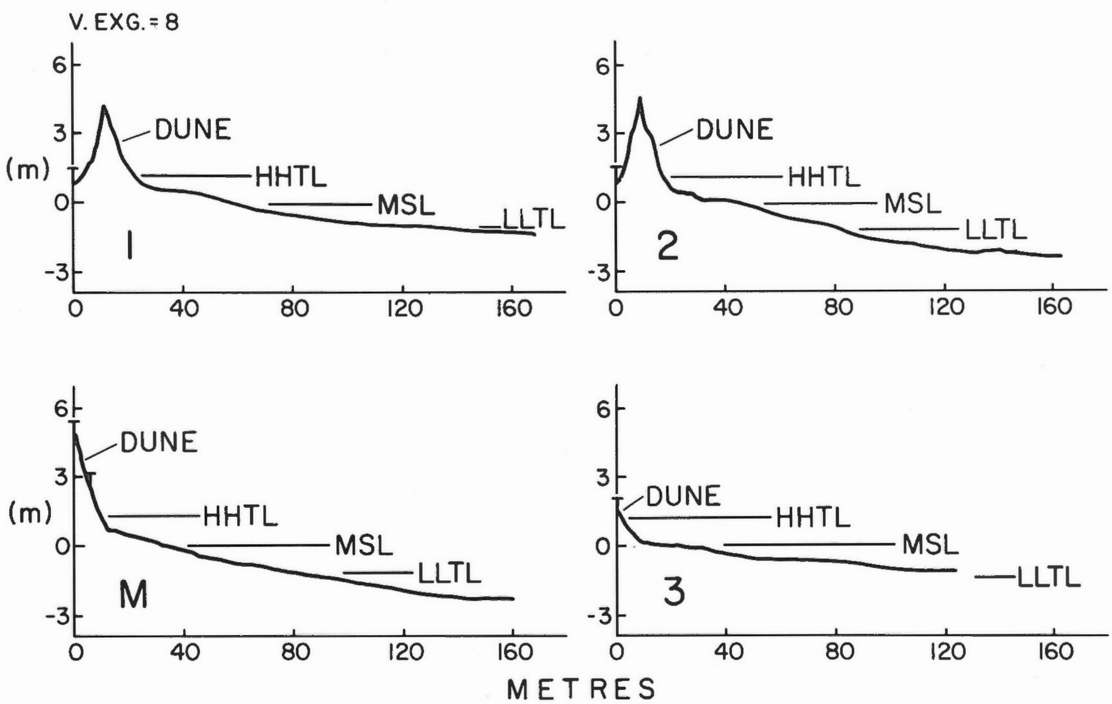

Figure 29. Four profiles were surveyed across Crescent Beach on July 21, 1981, including profile M established by Munroe in 1978. Tidal levels as marked may be too high because of storm conditions at time of the survey.

Figure 30. View looking west along Crescent Beach, showing shallow ripples formed across the foreshore zone and the dune ridge along the backshore. (GSC 190834)

Figure 31. View of dune ridge at back of Crescent Beach. The coarse surficial clasts represent a lag deposit of sediment deposited at potential breaches in the dune system by local residents in the early 1960s. (GSC 190835)

Bakers Beach, Shelburne County

Physical and geological setting

Bakers Beach is located on the eastern shore of Cape Sable Island, northwest of the village of South Side (Fig. 1,32). This white sand beach is representative of the shores of southeastern Cape Sable Island. The beach extends southwestward from Bull's Head approximately 2 km to a small unnamed headland. The headlands range from 2 to 4 m in height and are composed of unconsolidated glacial till containing gneisses and migmatites of the Meguma Group (Keppie, 1979; Bujak and Donohoe, 1980). Inland, Bakers Beach is backed by a large lagoon known as Baker Inlet (Fig. 32). The inlet drains south through a narrow straight channel into South Side Inlet. The straight nature of this channel suggests that it is man-made possibly for drainage purposes but there is no evidence to support this theory.

Approximately 2 km offshore there are two large shoals, Donald Shoal and Stoney Island Shoal. Situated in water depths greater than six fathoms, neither is exposed at low tide. The only island is Stoney Island, 0.5 km from Bull's Head. The slope between the breaker zone and swash zone, marked by sand waves on the 1976 aerial photographs, is smooth and regular. The beach is exposed to the Atlantic, particularly to wind and wave attack from the southeast. The tidal range for the area has a mean of 1.89 m and a spring maximum of 2.59 m (Fisheries and Oceans, 1981).

Detailed beach morphology

Foreshore zone. A cobble-boulder lag deposit cuts the beach into two parts, one of 0.5 km length and one of 1.5 km length to the northeast. The width of the foreshore at the smaller system is 54 m, while that of the larger system averaged 76 m (Fig. 32,33). The average slope of the beach is 1.4° (Table 12). The midsection of the larger system is characterized by a distinct swash bar and summer berm, both of which become progressively better developed towards Bull's Head. At the time of field observations the berm had been eroded by waves into a cuspate pattern. The spacing of the cusps was approximately 20 m from crest to crest (Fig. 34).

Table 12. Morphological characteristics of Bakers Beach, Shelburne County, July 19, 1981.

Profile number	Beach		Foreshore zone			Backshore zone
	width[1] (m)	height[2] (m)	height[3]	width (m)	slope (o)	dune height[3] (m)
1	120	2.6	1.38	54	1.4	—
2	100	3.0	1.67	78	1.2	—
3	150	3.4	1.81	75	1.4	1.5
4	100	4.2	1.73	74	1.3	2.2

[1] MHTL to edge of lagoon or landward extent of overwash.
[2] Mean sea level to highest point on the beach.
[3] Base to crest of seaward slope of dune.

Backshore zone. Above high tide at the western part of the beach, there was new growth of sandwort and sea rocket suggesting that it was more sheltered, thus allowing vegetation to stabilize and foredunes to prograde, whereas along the rest of the beach new growth has been restricted to the 1981 drift line. The dune ridge is one metre in height and fringed on the seaward side by a narrow band of cobbles which disappears towards Bull's Head where dunes 2 to 3 m in height are fringed by elongated wind shadow skirts (Fig. 35). The sand skirts have been built as sediment was transported by southwest winds from the backshore and deposited in the lee of the dune ridge. Due to the mobile nature of the sand, no vegetation has been able to establish itself on the face of these dunes. Farther inland marram grass covers most of the backshore.

Beach sediment characteristics

Sediment sampled from the foreshore zone was well sorted and composed of fine sand. Mean grain size of sediment near low tide and high tide levels was 2.56 phi and 2.6 phi, respectively (Table 13). Of the samples collected near low tide the coarsest and most poorly sorted sediment was found adjacent the headlands and the finest and best sorted sand was at profiles 2 and 3 (Fig. 32). Pebble storm deposits ranging from -4 to -5 phi clasts also line the top of the beach face at profiles 1 and 2. Dune sand was equally well sorted but slightly coarser (2.13 phi) than the sediment observed across the foreshore zone.

The distribution and uniformity of the sediment sampled suggests that sediment transport is both alongshore from the headlands as well as offshore-onshore from offshore sand deposits that are clearly visible on recent aerial photographs of Bakers Beach.

Beach development and evolution

A 1776 map of Cape Sable Island from the Atlantic Neptune Series (Fig. 36) shows an appreciable breach through the middle of Bakers Beach, forming a large inlet. Today the only evidence of this inlet is a relict flood delta situated between two stands of coniferous trees along Baker Inlet.

Table 13. Sedimentological characteristics of Bakers Beach, Shelburne County, July 19, 1981.

Profile number	Mean grain size (∅)			Sorting (∅)			Skewness		
	LTL	HTL	Dune	LTL	HTL	Dune	LTL	HTL	Dune
1	2.54	2.61	—	0.44	0.32	—	0.33	−0.26	—
2	2.66	2.58	—	0.38	0.41	—	−0.16	−0.34	—
3	2.62	—	2.13	0.37	—	0.44	−0.21	—	0.09
4	2.53	2.61	—	0.51	0.41	—	−0.36	−0.31	—

On the map by A.F. Church in 1882 (Fig. 36), the inlet was infilled and a continuous beach system existed. Dune ridges had begun to develop, especially towards Bull's Head and an access road extended the full length of the backshore.

By 1927, aerial photographs of Bakers Beach showed that the beach was overwashed and perhaps breached immediately northeast of profile 1 (Fig. 32) where there is still a small vegetated alluvial fan. Along the backshore near profile 1, the extent of overwash has varied since 1935 when this part of the beach was fringed by an erosional scarp, the backshore was fairly well vegetated, and only relict overwash deposits existed. In contrast, in 1955 extensive sheet overwash deposits covered the whole of Bakers Beach as far inland as the road and one channelized deposit reached Bakers Inlet. By 1967 these overwash deposits were again partially vegetated and a nearly continuous strip of vegetation lined the top of the beach. On the 1978 airphotos, there is a reduction in the vegetation cover possibly due to increased overwash activity.

On the 1955 airphotos, two well defined spits extended landward from Stoney Island. The larger and more easterly of the two connected Stoney Island to the mainland at Bull's Head. Since then, waves and rising sea levels have eroded the spits and cut Stoney Island from the mainland.

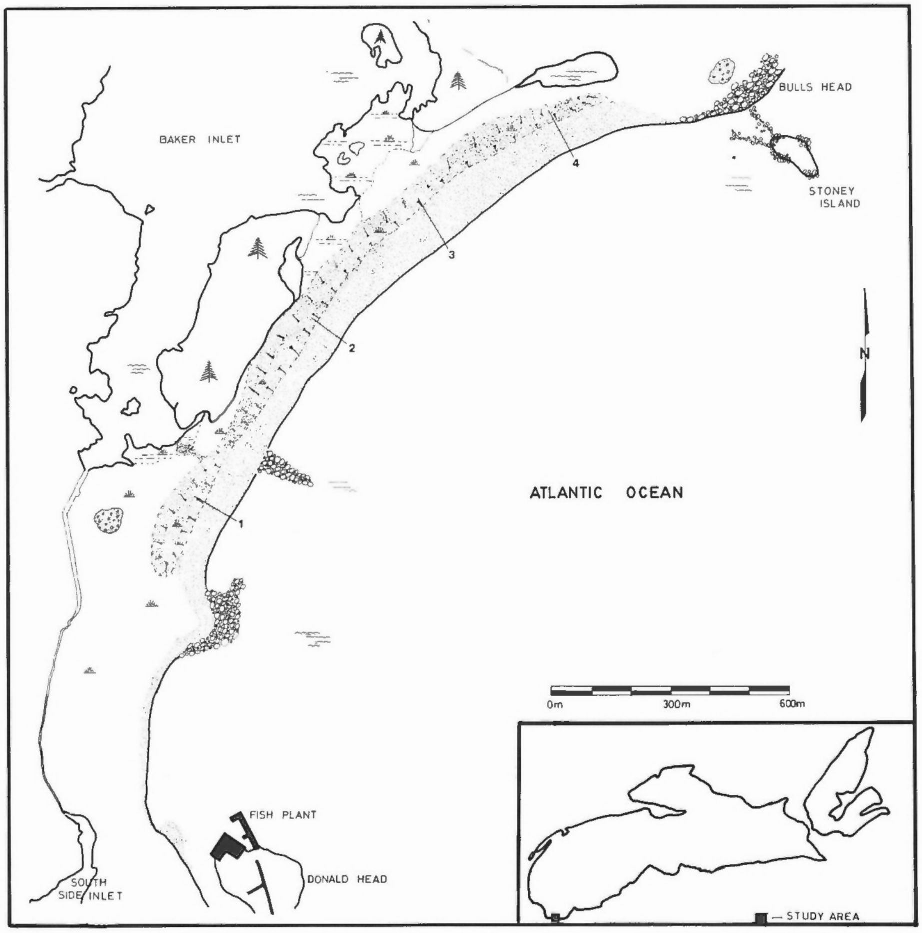

Figure 32. Morphological map of Bakers Beach, Shelburne County. Information is taken from 1978 airphoto 78327-53 (MRMS, Amherst, N.S., June 11, 1978). See Table 1 for key to symbols.

The 1981 field observations suggest that Bakers Beach is now prograding, particularly near profile 1. There sandwort and sea rocket have begun to grow from the flotsam deposited above high tide line. Those plants, by stabilizing the sand, have led to the preservation and development of foredunes. At the eastern end of the beach, the large dunes are extending seaward with the accumulation of windblown sand from the backshore, but the sand is too mobile for plant growth.

The till headlands are actively eroding. Cliff recession stakes were installed on the unnamed headland to monitor future rates of retreat. The boulders found alongshore are the remnants of old glacial deposits that have been cut back by waves and left as shoals. Should Bakers Beach continue to transgress, the large cobble-boulder lag deposit observed on the beach (Fig. 32) may, too, become a shoal. However, the lack of major change in beach morphology since 1927 suggests that the beach may be in a dynamic equilibrium, despite the major overwash events in the early 1950s. In the backshore, the aerial photographs reveal that Bakers Inlet has been successively infilling, particularly in the two lowlying areas where former inlets are thought to have occurred.

With respect to human impact on the beach, all man-made structures existing today have been present since the first available aerial photographs of the area. These include the Cape Sable Island fish packing plant wharves, docks, and facilities at Donald Head, and the straight channel (canal?) draining Baker Inlet into South Side Inlet. There are gravel pits on Bull's Head as well as just north of the unnamed headland but the beach itself is not known to have been mined.

Bakers Beach is not a protected beach under the jurisdiction of the Nova Scotia Beach Protection Act and is much abused by people. The road along the dune system and the many trails branching from it are the result of recreational driving and dirt-biking. Garbage and old cars were dumped in the backshore particularly in the large blowouts at the north-eastern end of the beach. Human activity which has destroyed much of the marram grass covering the backshore, may, if left unchecked contribute to the destruction of the beach system as a whole.

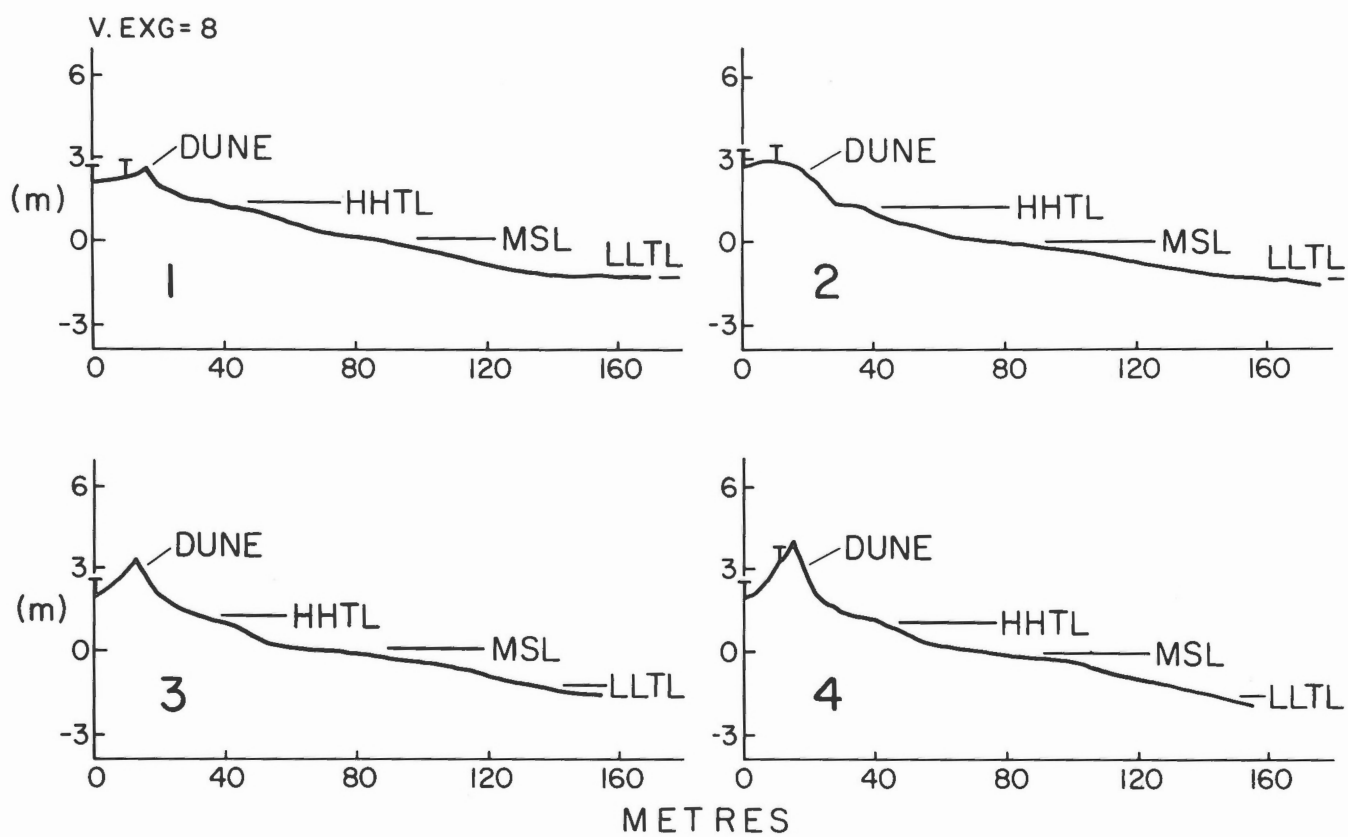

Figure 33. Beach profiles surveyed across Bakers Beach on July 19, 1981. Location of profiles is shown in Figure 32.

Figure 34. View to the east along the central portion of Bakers Beach showing the berm and lower beach face. (GSC 190841)

Figure 35. At the eastern end of Bakers Beach, dunes have developed to 3 m in height and are fringed by wind shadow skirts oriented toward the northeast. (GSC 190840)

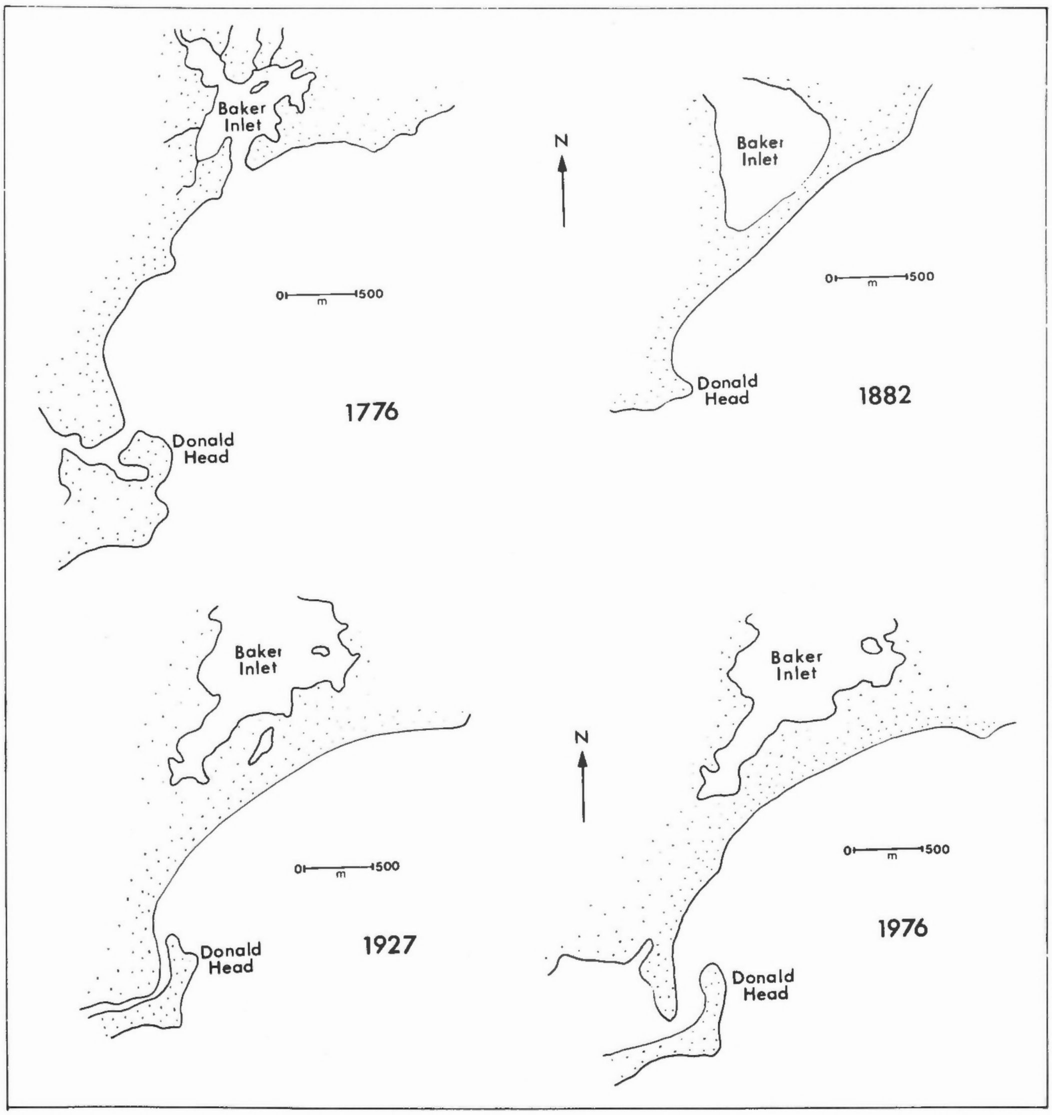

Figure 36. Morphological evolution of Bakers Beach from 1776 (Atlantic Neptune Map) to 1976 showing how Bakers Inlet was closed off from the sea.

Lower Saulnierville Beach, Digby County

Physical and geological setting

Lower Saulnierville Beach is located along St. Mary's Bay between the villages of Meteghan River and Saulnierville in southwestern Nova Scotia (Fig. 1,37). The segment of beach examined in detail is representative of much of the shoreline between Meteghan and Church Point. The study area is 2.2 km long (Fig. 37,38). It is bounded to the north and south by 5 to 8 m high shore bluffs, which are composed of sandy-boulder glacial deposits (Fig. 39). The beach is characterized by a low shingle storm ridge and a wide intertidal zone. Back of the beach, there is a marshy lowland and several ponds which drain through the beach to the sea. Bedrock is extensively exposed in the intertidal zone along the northern two-thirds of the study area. It is metamorphosed greywacke, and slate of the Goldenville Formation (Keppie, 1979). Lower Saulnierville Beach is rarely used either as a recreational facility or as a source of aggregate because the heterogeneous nature of the sediment makes it unattractive.

Offshore, the study area is fringed by a 300 to 400 m wide bedrock terrace. The bottom gradient, to a depth of 5 m, is less than one degree (C.H.S. Chart 4324, 1968).

Lower Saulnierville Beach lies in a partially sheltered wave environment and is only exposed to higher energy waves from a southwest to west direction. To the north and northwest the beach is protected by Digby Neck, Long Island, and Brier Island. Tides recorded at Meteghan are semi–diurnal with a mean range of 4.5 m (Fisheries and Oceans, 1981) which makes this a macro-tidal environment. The tidal currents offshore range from 0.4 to 0.5 $m \cdot s^{-1}$ (C.H.S. Chart 4324, 1968).

Detailed beach characteristics

Foreshore zone. The morphology and sediment composition of the foreshore zone is not homogeneous alongshore. Adjacent to profile 3 (Fig. 40, 41a) there is a gradually sloping beach composed of granules of 1.76 phi size. A low, wide swash bar is exposed at low tide along the lower foreshore slope. In contrast, near profiles 1 and 2 the foreshore is composed of a mixture of sand to boulder clasts. Sand and pebbles cover the upper slope but the low intertidal is a wide bedrock platform covered by boulders and cobbles (Fig. 41). Sand deposits are intermittent alongshore. They correspond to areas adjacent to eroding shore till bluffs, e.g., south of profile 3, or where sand is carried seaward by surface or subsurface drainage channels from inland ponds or streams.

A series of very distinctive coastal features occur in the intertidal zone along this part of the Nova Scotian coastline. They are low relief submarine boulder or cobble ridges that project perpendicular to the shore (Fig. 38). The ridges are irregularly spaced alongshore and do not correspond to any geomorphic features observed on the nearby shore. One of the ridges, located between profiles 1 and 2, was surveyed in 1981. It was 210 m long, 30 m wide at the seaward edge, and

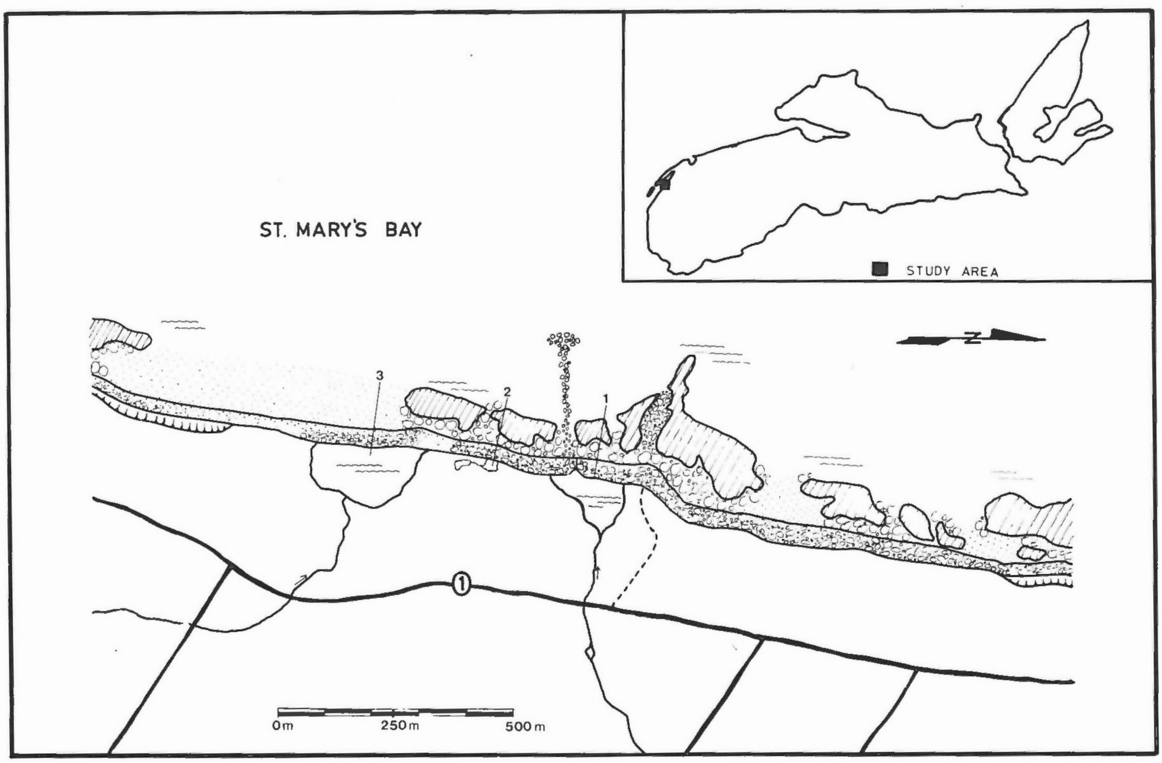

Figure 37. Morphological map of Lower Saulnierville Beach, Digby County. See Table 1 for key to symbols.

Figure 38. Aerial view of study area at Lower Saulnierville showing the distinct transverse ridges. (From 1967 airphoto A19880-90, NAPL). Ridge 1 was 210 m long and 15 m wide when surveyed in 1981.

had an average width of 15 m. Many of the ridges are bifurcated or fan-shaped at their seaward edge. The surface of the ridge is composed of uniform, well rounded cobbles tightly compacted into a 'pavement' and larger boulders are observed along the edge of the feature. In the ridge surveyed, the cobbles are smaller and more rounded than the beach sediment nearby; however, the submarine ridge just north of profile 1 (Fig. 37,38) is composed of cobbles and boulders similar to those found on shore or along the nearshore. There is no clear explanation for these submarine ridges. They are found along the submerged shores of southwestern Nova Scotia and along northern Chedabucto Bay in northeastern Nova Scotia. Near Lower Saulnierville the ridges have remained virtually unchanged for as long as the local people can remember. One possible explanation is that the ridges are formed of lag deposits from relict glacial features which have been eroded away during rising sea levels. However, Grant (1980) suggested that not all of the ridges can be explained that easily. They may be the remnants of tombolos composed of glacial debris deposited in the shelter of islands which once existed where the present day ridges widen into a fan shape. The surficial deposits on the island and tombolo were removed by waves during rising sea levels, leaving the cobble-boulder lag. Such features are observed today along the southeastern coast of Cape Breton.

Backshore. The backshore is characterized by a low, poorly developed gravel-cobble storm ridge, which is continuous alongshore except where it is cut by drainage channels from the larger ponds. The height of the storm ridge is 1.0 to 1.7 m and its slope varies from 3° to 6.5° (Table 14). Smaller storm or swash ridges are found between high tide level and the crest of the beach. Sediment composition is variable but generally the largest clasts of -7 to -8 phi are at the crest of the beach. The coarsest and most angular sediment is observed on the storm ridge at profile 2 (Fig. 41b) whereas the finest sediment was at profile 1. A particle shape analysis was completed for three samples taken from the major storm ridge at profile 1. The three axes and a roundness measure were determined for 50 clasts in each sample. The pebbles were poorly rounded, very bladed in shape, and were a mean size of -5.3 phi. Sphericity values using the maximum projection equation of Sneed and Folk (1958) varied from 0.3 to 0.8. Pebbles at the base of the storm ridge were the most spherical. No significant trends in particle morphology were observed from the top to the base of the storm ridge.

Table 14. Morphological characteristics of Lower Saulnierville Beach, Digby County, July 15, 1981.

Profile number	Beach		Foreshore zone			Backshore zone	
	width[1] (m)	height[2] (m)	width	height (m)	slope (o)	height[3] (m)	slope[3] (o)
1	132	3.7	119.0	3.97	1.9	0.57	3.0
2	115	3.3	104.0	3.47	1.9	1.02	6.5
3	104	4.0	90.0	4.26	2.7	0.50	4.1

[1] MHTL to landward edge of overwash or storm ridges.
[2] Mean sea level to highest point on beach.
[3] Top to base of seaward slope of main storm ridge.

Vegetation cover is limited to the main drift line on the seaward face of the storm ridge, whereas the backslope is covered by low scrub brush.

Shore bluffs at both ends of the study area are actively eroding and providing some beach material. Markers were established in 1981 at the northern bluffs for monitoring future rates of recession.

Beach development and evolution

Lower Saulnierville Beach has not been extensively utilized nor affected by the local people, possibly because of its unaesthetic appearance of bedrock and mixed sediment and the extensive wetlands in the backshore. There is farming on the higher, better drained land farther inland and to the north and south of the study area. Lower Saulnierville Beach is currently in a transgressive sequence. A comparison of aerial photography from 1967 and 1978 indicates that the ponds and wetlands are considerably smaller now because of infill by overwash deposits and increased drainage from the ponds by larger drainage channels. A debris line or old shoreline on the 1978 airphotos marks the former upper limit of the wetlands and ponds.

Sediment accumulation on the south side of the break-wall at Meteghan River and observations from a previous study at Mavillette Beach farther south near Cape St. Mary (Bowen et al., 1975) both suggest that there is a south-to-north transport of sediment alongshore. Plumes of suspended sediment offshore of Lower Saulnierville also suggest a similar direction of transport. However, the fact that there is very little sediment accumulation against the transverse ridges offshore and that sand deposits are restricted to beaches adjacent to eroding shore bluffs suggests that there is a limited supply of sediment and only localized transport. Only the fine sediment is carried in suspension away from the study area. The extensive exposures of bedrock in the nearshore also indicate limited sediment availability and sediment accretion. As this shoreline transgresses it will be interesting to see if the transverse cobble ridges will become exposed farther inland or whether they will end at the present shoreline. In any case, these features will continue to protect the beach because of wave energy dissipation. As the shore transgresses, the coastal plan should remain the same unless one of the beaches fronting the larger ponds fails and allows rapid inundation of the coastal lowlands.

Figure 39. Lower Saulnierville beach is bounded to the south and north by low glacial till bluffs. Location of this till bluff is shown on Figure 38 (arrow). (GSC 190832)

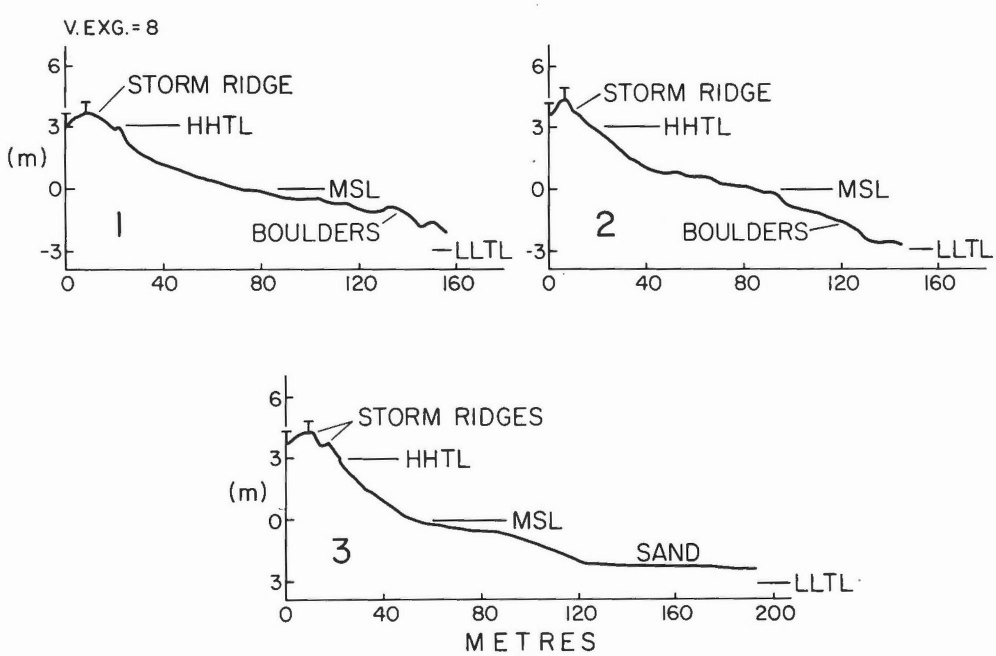

Figure 40. Three beach profiles (see Fig. 37 for location) were surveyed across Lower Saulnierville Beach on July 15, 1981.

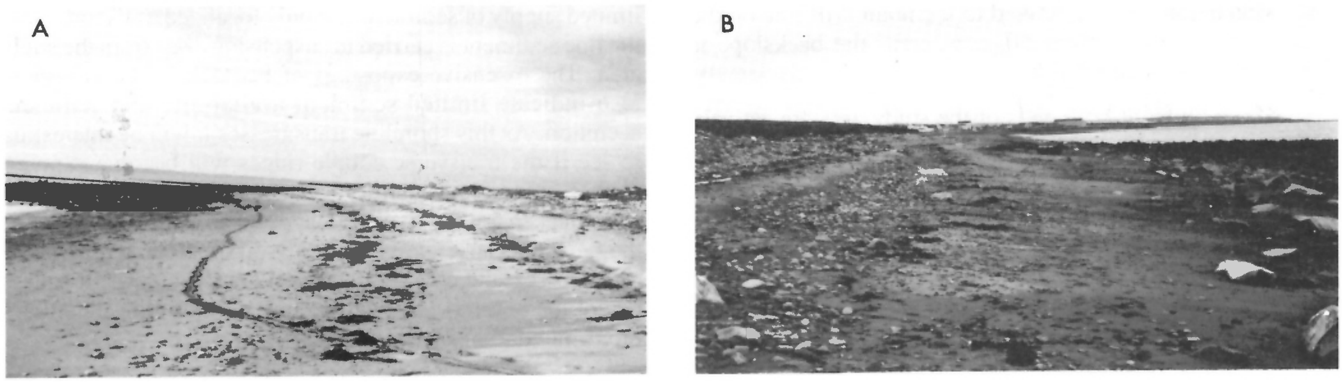

Figure 41. Views of Lower Saulnierville Beach – (A) at profile 3 the beach face is covered by sand whereas (B) near profiles 1 and 2 a very heterogeneous mixture of sediment exists. A cobble-boulder lag deposit covers the lower intertidal and nearshore zones all alongshore. (A) GSC 190829, (B) GSC 190830

Advocate Harbour Beach, Cumberland County

Physical and geological setting

Advocate Harbour Beach, locally known as Big Beach, is situated at the southwestern tip of the isthmus of Chignecto (Fig. 42). The area is part of a sedimentary lowland composed of Carboniferous and Triassic clastic rocks (Swift and Borns, 1967). To the north are the east-west trending Cobequid Hills which form part of an extensive igneous and metamorphic highland. The surficial deposits of the Advocate Harbour area are part of the Five Islands Formation, a late Pleistocene outwash deposit (Swift and Borns, 1967). The stratified sand and gravel deposits locally attain a thickness of over 60 m and can be divided into a glaciomarine and a glaciofluvial lithosome.

Advocate Harbour Beach consists of two converging spits which nearly completely enclose the harbour (Fig. 42). The spits extend from Cape Chignecto, a 210 m high granite headland to the west, and from Cape D'Or, a 150 m high headland composed of Triassic basalt, to the east. The part of Advocate Harbour Beach studied extends 3.5 km from the village of West Advocate in a southeasterly direction to the entrance of the harbour. The western 1.8 km of the spit forms the seaside protection for the low-lying dyked marshlands in the backshore. The marsh extends 1.3 km northward to the paved highway and the village of Advocate Harbour. The marsh, first put under cultivation in the 1700s by the Acadians, is not intensively used today. Large areas remain vacant, used only intermittently for the pasturing of livestock. An earthen dyke and cribwork constructed in 1958 separates the marsh from the tidal flats of the harbour. The flats extend from the mouth of Advocate River to the present beach.

The harbour is exposed to southwest winds which coincide with maximum fetch – the length of the Bay of Fundy; however, to the west-northwest it is protected by Cape Chignecto which limits wave fetch to 32 km.

The semi-diurnal tides in Advocate Bay have a mean range of 9.1 m and a spring tidal range of 12.6 m. Offshore tidal currents are strong. In the Minas Passage area south of Advocate Bay, current velocities of 5 $m \cdot s^{-1}$ have been recorded. The strong tidal currents have produced large water gyres in Advocate Bay (Kolberg and Duncan, 1979). On an incoming tide an anti-cyclonic gyre is generated and on the ebb tide a cyclonic gyre is initiated just northeast of Cape D'Or (Fig. 43). Using wave hindcast techniques Kolberg and Duncan (1979) estimated that in severe southwesterly gales, waves in the order of 3.7 m to 4.6 m high can reach Advocate Harbour Beach resulting in wave overwash at high water.

Detailed beach morphology

Foreshore zone. The foreshore of Advocate Harbour Beach is a homogeneous unit with few morphological changes alongshore (Table 15). Advocate, by virtue of its sediment composition, a gravel, pebble/cobble matrix, has a steep foreshore gradient. The slope which ranges from 5.6° to 7.7°, increases as beach width decreases in an east to west direction along the study area (Fig. 44). Sediment at the lower foreshore, also increases in mean clast size westward.

Backshore zone. Above high tide limit, shingle storm ridges extend upslope to the beach crest. Storm ridges are found along the entire length of the beach, although they vary in number and size (Table 15). The steepest storm ridges are

Table 15. Morphological characteristics of Advocate Harbour Beach, Cumberland County. July 28, 29, 1981

Profile number	Beach		Foreshore zone			Backshore zone			
						storm ridges			
	width[1] (m)	height[2] (m)	width (m)	height (m)	slope (o)	number	slope (°)[3]		
							upper	middle	lower
1	89	6.5	69.5	6.8	5.6	1	6.2	—	—
2	75	7.2	60.8	6.9	6.4	2	8.7	—	8.2
3	72	7.3	52.5	6.2	6.7	2	8.4	—	8.7
4	49	7.9	60.8	7.7	7.2	2	13.1	—	10.8
5	43	8.7	60.8	7.9	7.4	2	19.8	—	14.0
6	52	8.8	62.6	8.5	7.7	3	11.8	17.0	17.0

[1] MHTL to edge of marshland (1-3), and to seaward edge of road (4-6).
[2] Mean sea level to highest point on beach.
[3] Base to crest of seaward slope of each storm ridge.

in the vicinity of profiles 5 and 6. Since vegetation only grows at the top or back of the beach crest, the storm ridges are assumed to be mobile. Driftwood is scattered across all of the upper beach slope but is concentrated at the beach crest (Fig. 45).

The backslope increases in gradient and height from profiles 1 to 6. West of the dyke, the backslope was bulldozed by the local residents in order to increase beach height and prevent overwash (Fig. 48). Where the beach is lower, the backslope is characterized by overwash fans and channels (Fig. 46).

Farther inland of the beach there are two distinct geomorphological units separated by the Advocate dyke. To the east of the dyke is an extensive tidal flat which is covered by a well developed dendritic drainage system. Lewis (1979) concluded from an analysis of the drainage system that the present harbour entrance has always been the drainage outlet. The only marsh is at the southwest corner between the dyke and the beach. To the west of the dyke, there is marsh and pastureland.

Beach sediment characteristics

The Advocate Harbour Beach foreshore slope is composed of poorly sorted granule to pebble size clasts (Table 16). The samples collected were either bimodal or polymodal and the larger clasts were composed of basalt or granite (Fig. 47). At the base of the foreshore slope the mean size of sediment increased in an east to west direction alongshore. Across the beach the sediment at high tide was slightly coarser and better sorted (except at profile 1) than sediment on the lower beach face. This trend of increasing sediment size upslope contrasts with the one observed by Wightman (1976) who studied the fabric and grain size of both the modern and raised beach ridges of Advocate Harbour. The difference arises because of the less detailed sampling scheme used in the present study.

Across the backshore zone the largest clasts are at the beach crest where cobbles overlie a granule-pebble base. Sediment size decreases downslope from the beach crest, and the smallest clasts are found in recently formed swash ridges. Visual observations suggest that the mean size of the sediment increases toward the west, as it did on the foreshore zone.

Table 16. Sedimentological characteristics of Advocate Harbour Beach, Cumberland County, July 28, 29, 1981.

Profile number	Mean grain size (∅)		Sorting (∅)		Skewness	
	LTL	HTL	LTL	HTL	LTL	HTL
1	−2.13	−2.78	1.11	1.73	−0.05	−0.14
2	−1.68	—	2.03	—	−0.25	—
3	−2.54	−4.29	1.36	0.54	−0.43	−0.03
4	−1.33	—	1.33	—	−0.08	—
5	−3.23	−3.72	1.80	0.53	−0.26	−0.09
6	−3.25	—	1.93	—	—	—

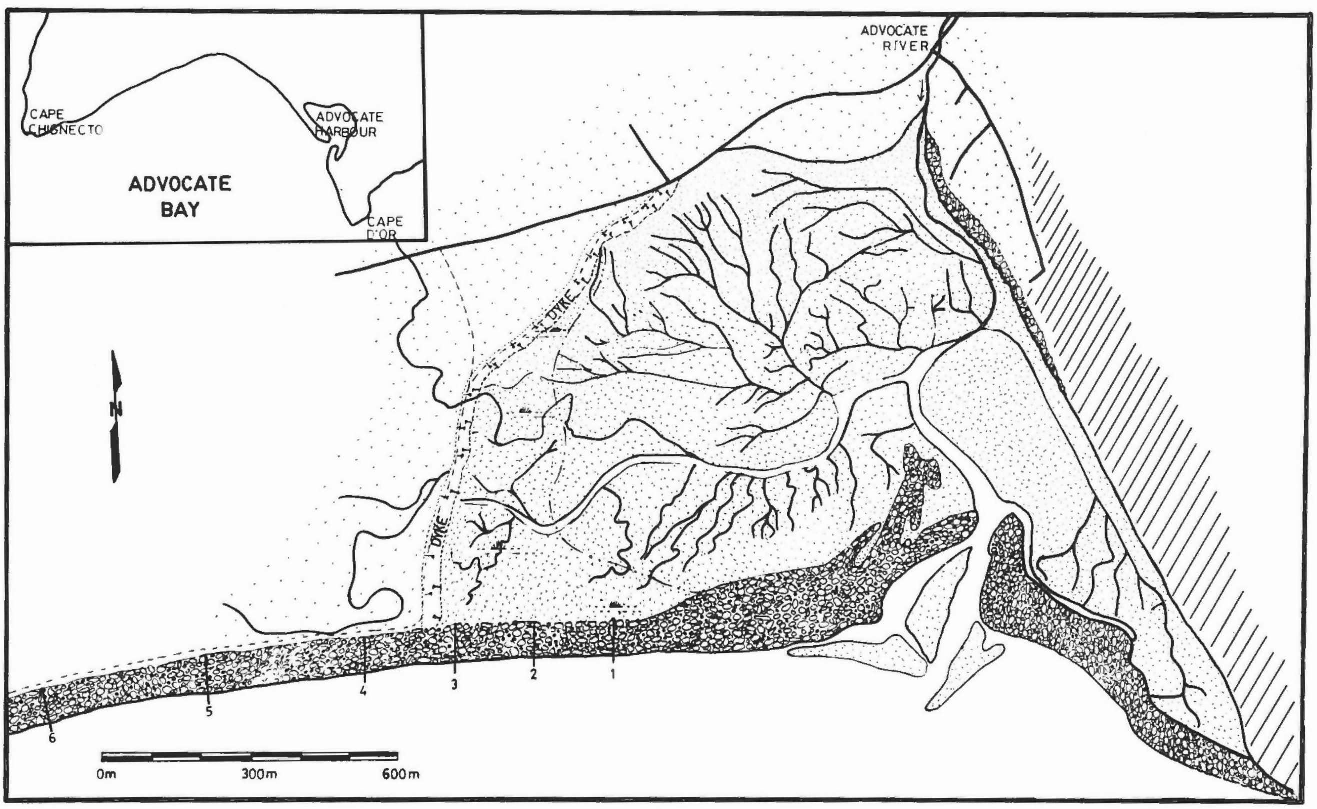

Figure 42. Morphological map of Advocate Harbour Beach, Cumberland County, based on 1975 airphotos 75041-11,19, (MRMS Amherst, N.S.). See Table 1 for key to symbols.

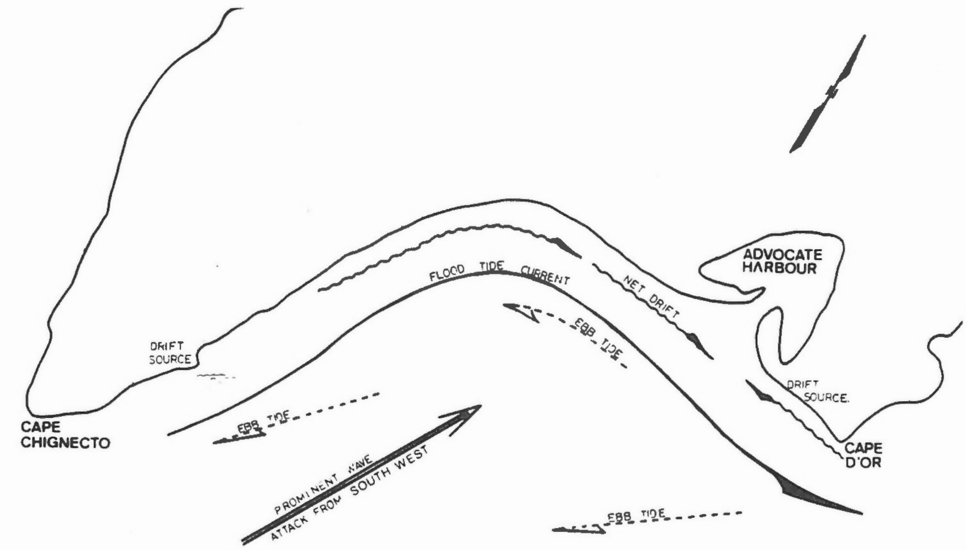

Figure 43. Strong tidal currents exist offshore of Advocate Harbour. They flow in a cyclonic direction on the ebb tide and anti-cyclonic direction on the flood tide (Kolberg and Duncan 1979).

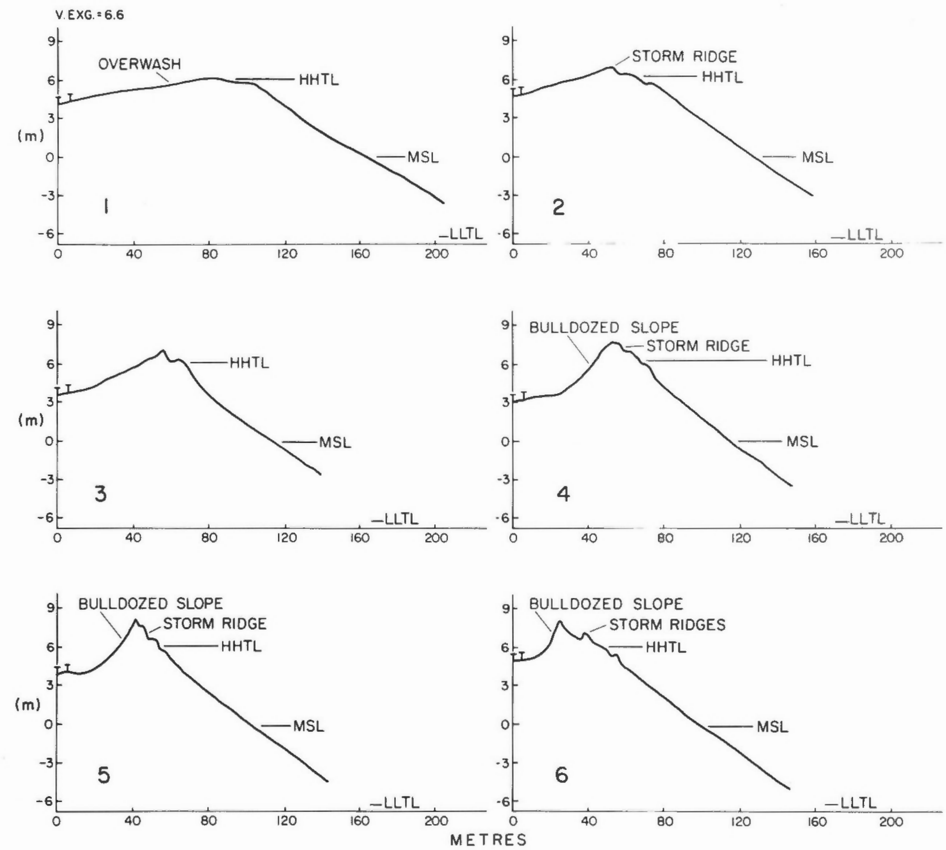

Figure 44. Six beach profiles surveyed along Advocate Harbour Beach on July 28, 29, 1981 show the changes in beach morphology alongshore. Beach slope increases from profile 1 to 6 located on Figure 42.

Figure 45. Driftwood is scattered across all of the upper beach slope but is concentrated at the beach crest of Advocate Harbour Beach. (GSC 190837)

Figure 46. At the east end of Advocate Harbour Beach where the beach is lower, there are extensive washover features. (GSC 190831)

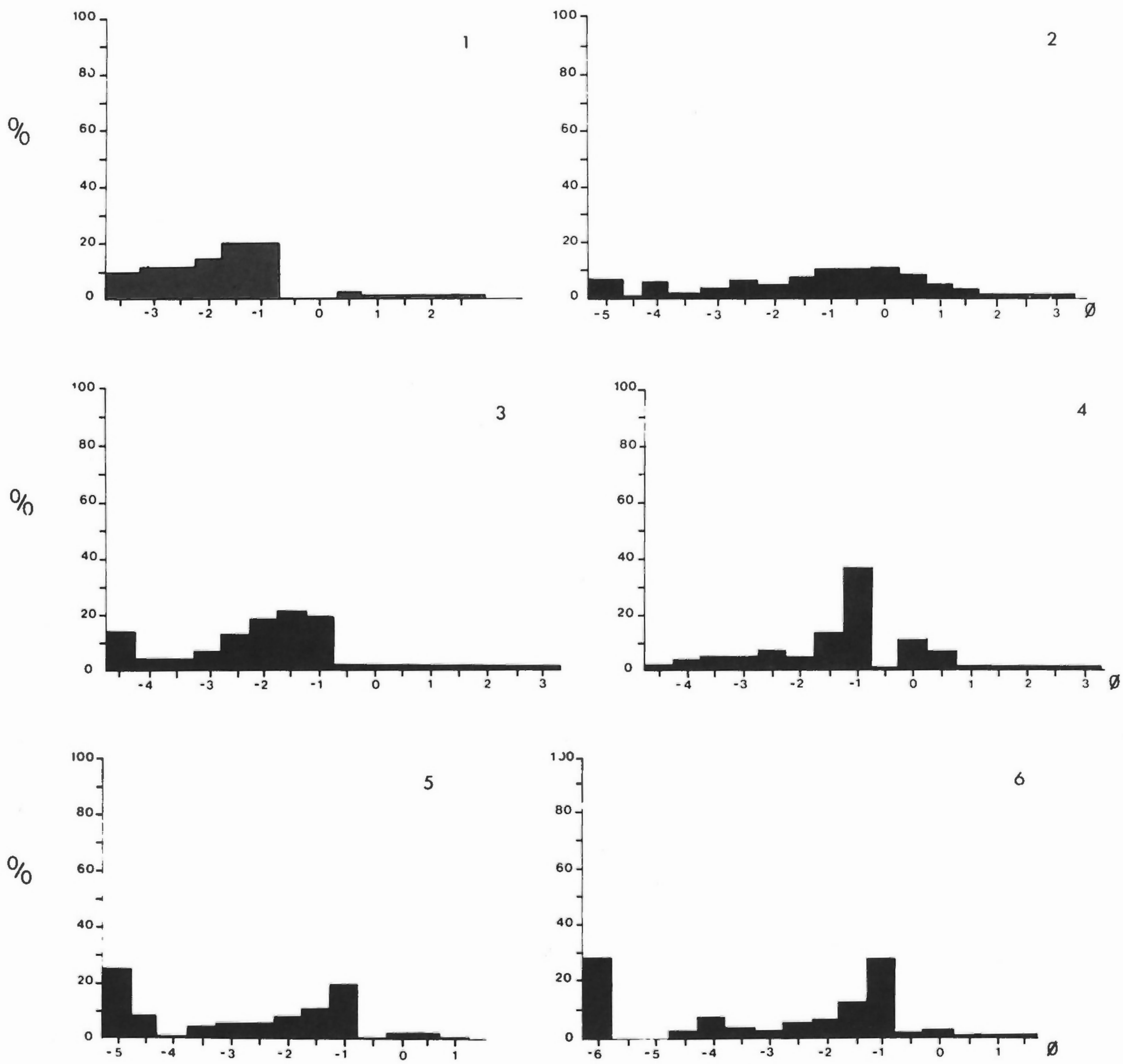

Figure 47. Histograms of the sediment sampled from the lower foreshore slope at each of the beach profiles. The bimodal distribution of some samples is attributed to the primary source of the sediment which is stratified sand and gravel glacial outwash deposits. The larger clasts are primarily basalt and granite.

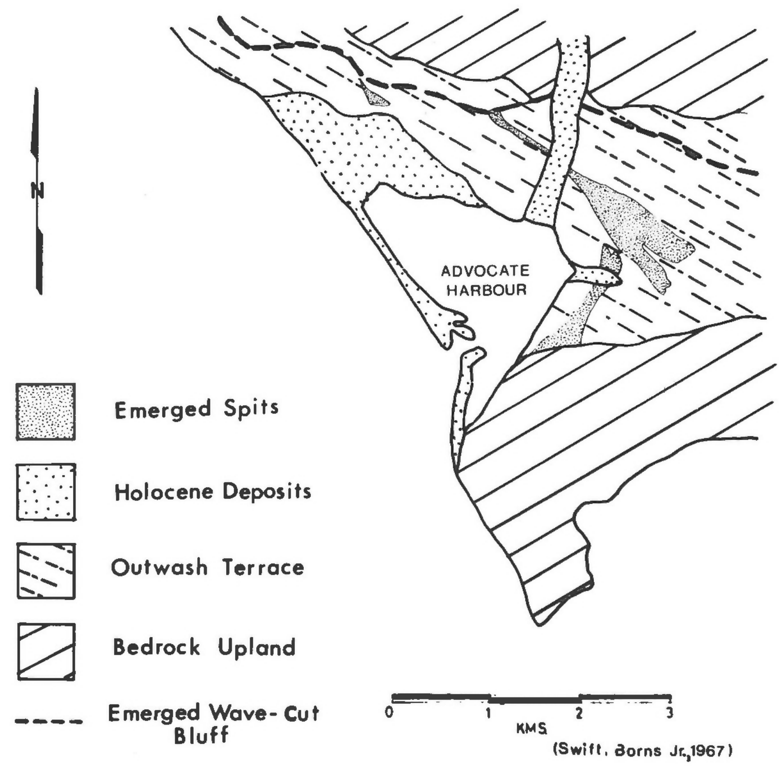

Figure 48. During the late Pleistocene, ridges resembling the present day spits were formed on the outwash terrace north of the present day Advocate Harbour (after Swift and Borns, 1967).

The nature and composition of the sediment samples collected along Advocate Harbour Beach suggest that they are primarily derived from local glacial outwash deposits exposed alongshore and offshore.

Beach development and evolution

The similarity in morphology between emerged and modern coastal features at Advocate Harbour led Swift and Borns (1967) to conclude that the factors governing wave attack and longshore drift have not changed since the late Pleistocene. However, sediment structures observed in the raised features suggest that they were formed under a much reduced tidal range. Wightman (1976) estimated a maximum paleotidal range of 3.4 m.

Swift and Borns (1967) presented a sequence of events that led to the deposition of the glacial outwash terrace that occurs along the north shore of the Minas Basin. The graded outwash plain that extends into the Minas Basin consists of an upper glaciofluvial unit and a lower glaciomarine unit separated by an erosional surface. As the ice dissipated in the Minas Basin it was followed by rising sea levels. In the valleys along the north shore of the Minas Basin the ice was replaced by prograding deltas which became dissected as they emerged. Subaerial alluvial fans subsequently prograded across the rising deltaic plain and buried the dissected surface. Then, as the supply of outwash debris decreased, the terrace continued to emerge and rivers entrenched themselves forming the present drainage system. After emergence became negligible, sea level continued to rise to its present level resulting in a gradual landward retreat of the modern shoreline.

The description of the upper glaciofluvial unit and the lower glaciomarine unit are important to consider when trying to determine the present source of beach sediment. Swift and Borns (1967) described the lower glaciomarine member as consisting of beds of openwork gravels rich in sedimentary clasts. In contrast, the upper unit was rich in metamorphic and igneous clasts and contained more of a mixture of sand and gravel. The latter unit was deposited when the ice margin was on the Cobequid Hills whereas the lower deposits were laid down when the ice margin rested on the sedimentary lowland. The present beach sediment more closely resembles the upper glaciofluvial unit known as the Saints Rest Member (Swift and Borns, 1967).

The retreat of Advocate Harbour Beach over the last 60 years is best illustrated by changes to 'Spruce Island'. Local residents describe 'Spruce Island' as a 50 acre grove of trees that was located east of the dyke along Advocate Harbour Beach (Fig. 42). It was a favourite picnic site in the early 1900s. By 1945 only part of 'Spruce Island' was visible on the airphotos and today only three tree stumps remain nearly buried by wave overwash material. Local residents estimate that the beach near 'Spruce Island' has retreated 100 m over the last 50 to 60 years. Beach ridges at the entrance to Advocate Harbour have also experienced minor changes since 1939 (Cameron, 1965).

During storm and extreme high tide stages, Advocate Harbour Beach is subject to wave overwash and percolation which is of concern to the local residents who are afraid that the lowlands behind the beach will flood one day. During the Groundhog Day storm of February 2, 1976, the marshland was flooded and the beach threatened to breach in several places. Following the storm a program was initiated with the Department of Agriculture to bulldoze the backslope of the beach west of the dyke. By adding sediment to the top of the beach, the crest elevation was artificially raised above the limit of natural deposition. By increasing the height of the beach, the width of the main storm ridge was decreased thus increasing water percolation through the beach during storms. Residents also built an access road to the beach along the edge of the marsh and they dumped armour rock at the base of the beach slope as another protective measure.

There are no known artificial factors, e.g. beach mining, that would have upset the equilibrium of Advocate Harbour Beach in the past, therefore it is assumed that the beach is retreating as part of a natural process not easily combatted by engineering projects. The only consolation to local residents is that as the beach retreats, more sediment may be made available for beach maintenance and development.

BEACH CHANGES AND COASTAL BLUFF RECESSION

Introduction

As part of the 1981 study, a network of shore stations was surveyed at selected shore bluffs and beaches along the coasts of mainland Nova Scotia. The objective was to establish bench marks along representative coastal segments so that accurate measurements of coastal morphological change could be measured in the future. Some of the survey stations were selected from sites previously established by other researchers, some were selected on the basis of files kept by the Nova Scotia Department of Environment on rapidly eroding shoreline and others were established at new sites. Where shore bluff recession stations or beach profiles had been established prior to 1981, a discussion of changes since the last survey is provided in this section. The first part of the section provides a brief physical description of each beach resurveyed and the morphological changes observed. The second part discusses factors affecting shore bluff recession, rates of erosion previously measured in the province, and then discusses rates of recession observed, primarily between 1980 and 1981, at eight shore bluff sites along the Atlantic coast.

Beach surveys

In 1981, surveys were completed at ten beaches where bench marks had been previously established (Fig. 49). The purpose was to determine the type and amount of change that had taken place at each of the beaches since the original surveys. At seven of the ten sites, the bench marks had been established by H.D. Munroe (1980) who had set up a series of 139 single profile stations along the Atlantic and Gulf of Maine coasts of Nova Scotia during the summer of 1978. The two beaches surveyed in Guysborough County were first monitored by E.H. Owens (1973). He had examined changes over a three-year period at two Chedabucto Bay beaches that had been contaminated by Bunker-C oil after the grounding of the oil tanker *Arrow* in 1970. The other beach resurveyed in 1981 was Crescent Beach, Lunenburg County, where morphological changes had been monitored over a five-month period during the winter of 1980 by S. Wittmann (1982).

A quantitative analysis of beach change was only possible at sites where old bench marks were found and sufficient information was available to accurately superimpose subsequent profiles. Where bench marks could not be found then only a qualitative analysis of change is attempted and the profiles are not superimposed on each other.

Beach access, profile location maps and the 1981 field survey data are available in Geological Survey of Canada Open File 976.

In all beach surveys, the Emery pole method (Emery, 1963) was utilized with the exception of Crescent Beach, Lunenburg County. There, standard levelling procedures, incorporating transit and stadia rod, were used because the fragile state of the dune system would not tolerate excessive trampling.

Where old profile markers could not be located, new markers (iron T-bars) or permanent structures (fence posts, telephone and power poles) were used to re-establish bench marks in the approximate location of the previous profile. Silva compass bearings running normal to the shore accompany resurveys where temporary bench marks (TBM) were not established. All surveys were conducted at low tide.

Hadleyville, Guysborough County

The beach at Hadleyville is on the northern coast of Chedabucto Bay. The coastline of the area is part of a submerged, undulating lowland area with glacial deposits exposed along the shore as cliffs. The glacial till overlies unresistant Horton Group (Mississippian) red sandstones and shales (Owens, 1971). Beach sediment ranges from sand in the intertidal zone to cobbles in the storm ridges. The backshore zone contains small pockets of swamp and a large lagoon situated at the western end of the beach. Aggregate is currently being removed from the beach east of the lagoon. Sediment transport is alongshore from the west at Murdoch Head to Oyster Point, east of the beach.

Bench marks used by Owens (1973) could not be located, consequently new stakes were placed at the western and eastern ends of the beach system and were designated BIO #1 and BIO #4, respectively (Fig. 50). The steep sloping beach is characterized by a high cobble crest. Effects of aggregate mining are evident at profile 4 (1981) where the backslope has been greatly steepened by sediment removal. A

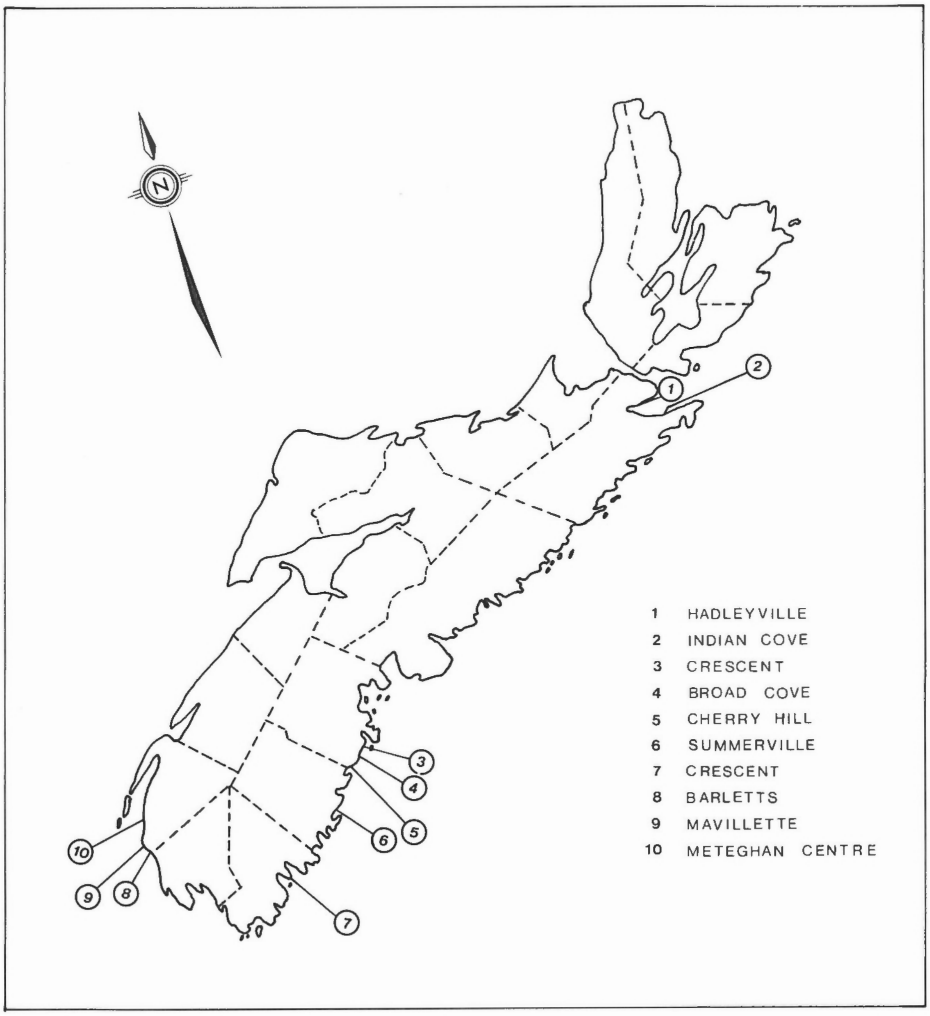

Figure 49. Location map showing the ten beaches along mainland Nova Scotia where surveys were conducted to assess beach change over the last three to five years.

low tide step is present at profile 4 but not at profile 1 (Fig. 50). Traces of residue oil, possibly from the *Arrow* spill (?) were still observed in the bay during 1981.

Indian Cove, Guysborough County

Indian Cove is a coarse sand/shingle pocket beach situated on the southern coast of Chedabucto Bay. The beach is a result of long-term sediment accumulation in a narrow bay which was formed along a northwest-southeast trending fault line (Owens, 1973). Rock cliffs and platforms in Carboniferous rocks occur alongshore. Since there are no till deposits the main source of beach material is found offshore (Owens, 1973).

Bench marks established by Owens (1973) could not be located, hence new markers were established – BIO #1, 3, 6 on the telephone poles north of the lagoon and #7 was placed directly behind the Lands and Forests' Beach Protection sign.

A well developed summer berm/storm ridge has formed along this beach (Fig. 50). In places near profiles 3 and 6, the backshore beach cobbles are being removed by residents for construction purposes which has resulted in a sizeable hole being excavated behind the beach crest. A low tide step with an average relief of 1.0 m, was observed at all profiles. As at Hadleyville Beach, traces of oil of unknown origin were observed in the water during the 1981 field studies.

Crescent Beach, Lunenburg County

Crescent Beach is on the southwestern coastline of Nova Scotia, a few kilometres north of the Petite River estuary and Rissers Beach Provincial Park. The beach connects the mainland to George Island, part of a series of islands known collectively as the Lahave Islands. The beach is characterized by a wide, flat foreshore backed by 2 to 4.5 m high sand dunes which are currently undergoing severe degradation. A paved access road runs the length of the beach along the back of the dune system. North of this road, tidal flats and a saltwater marsh occupy the backshore. The main source of sediment for the beach is offshore in Green Bay.

Two previous field surveys were conducted along this beach, one in August 1978 by Munroe (1980) and another through the winter of 1980-81 by Wittmann (1982, Fig. 51).

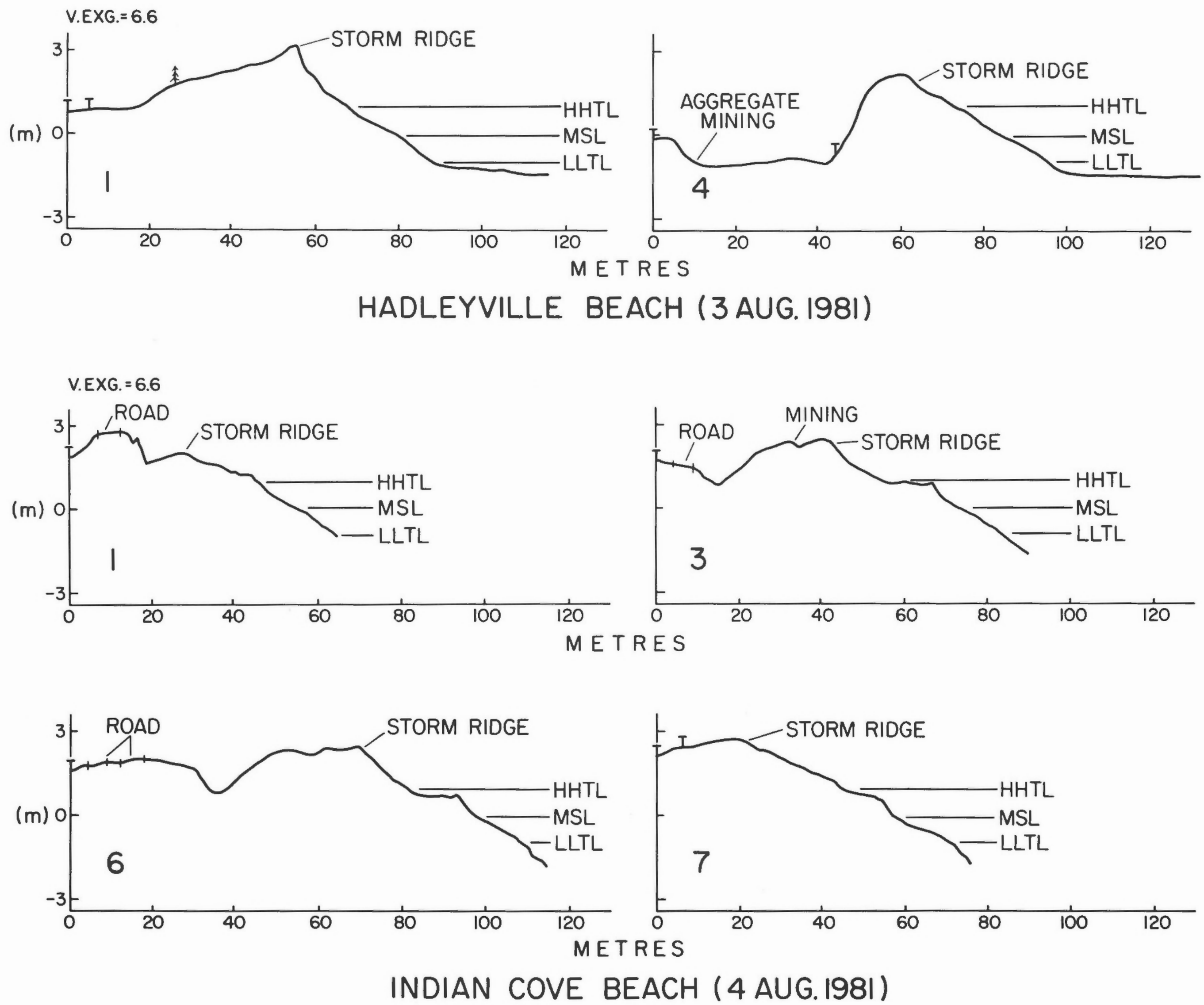

Figure 50. New beach profiles were established at Hadleyville and Indian Cove beaches, Guysborough County on August 3, 4, 1981. Former bench marks established by Owens (1973) could not be located.

Between 1978 and 1981 the beach at profile M has experienced a total net accretion of 47 m^3. Forty-two per cent of this accretion took place between the dune ridge and the shore revetment which contrasts with the dune at profile 3 which suffered a loss of 7 m^3 during the winter of 1980-81. Although the beach at profile 38 experienced a net loss of sediment between October 1980 and July 1981 the change was much less than at the other two sites. The reduced changes at profile 38 is attributed to its more sheltered position at the eastern end of Crescent Beach.

Broad Cove, Lunenburg County

Broad Cove Beach is an exposed location along the Atlantic coast, just south of the hamlet of Broad Cove (Fig. 49). The beach is composed of pebbles and cobbles and is characterized by a steep foreshore slope topped by high, narrow cobble storm ridges. The northern end of the system is backed by glacial till deposits, a probable source of beach sediment. At the southern end of the pocket beach, bedrock of the Goldenville Formation is exposed. In the backshore, a lagoon is separated from the beach by a highway but drainage outlets beneath the road connect it to the sea.

Both the 1978 (Munroe, 1980) and the 1981 surveys illustrate similar beach slope but the seaward storm ridge was built 1.75 m higher and moved slightly landward by 1981 (Fig. 52). The foreshore gradient in 1978 and 1981 was 12.3° and 13.4° respectively. Minor accretion was also observed at the base of the foreshore slope in 1981. Net sediment change between the two successive profiles was 9 m^3 of accretion.

Cherry Hill Beach, Lunenburg County

Cherry Hill Beach is a sand-shingle spit extending 1.8 km in a southwesterly direction from the mainland into Hell

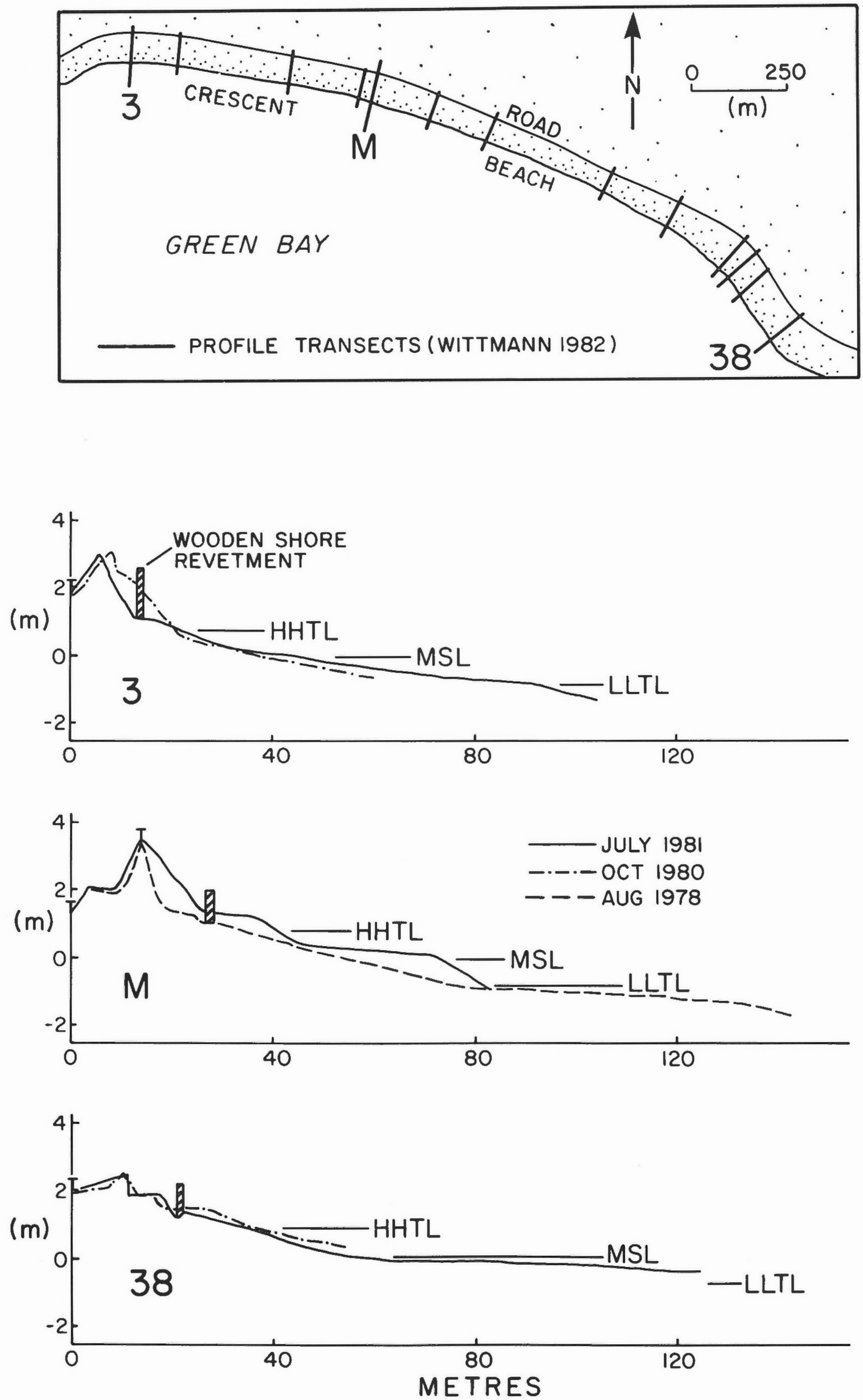

Figure 51. Three profiles were resurveyed at Crescent Beach, Lunenburg County on July 23, 1981. Profiles 3, 38 were previously surveyed by Wittmann (1982) and profile M was set up by Munroe (1980) in 1978.

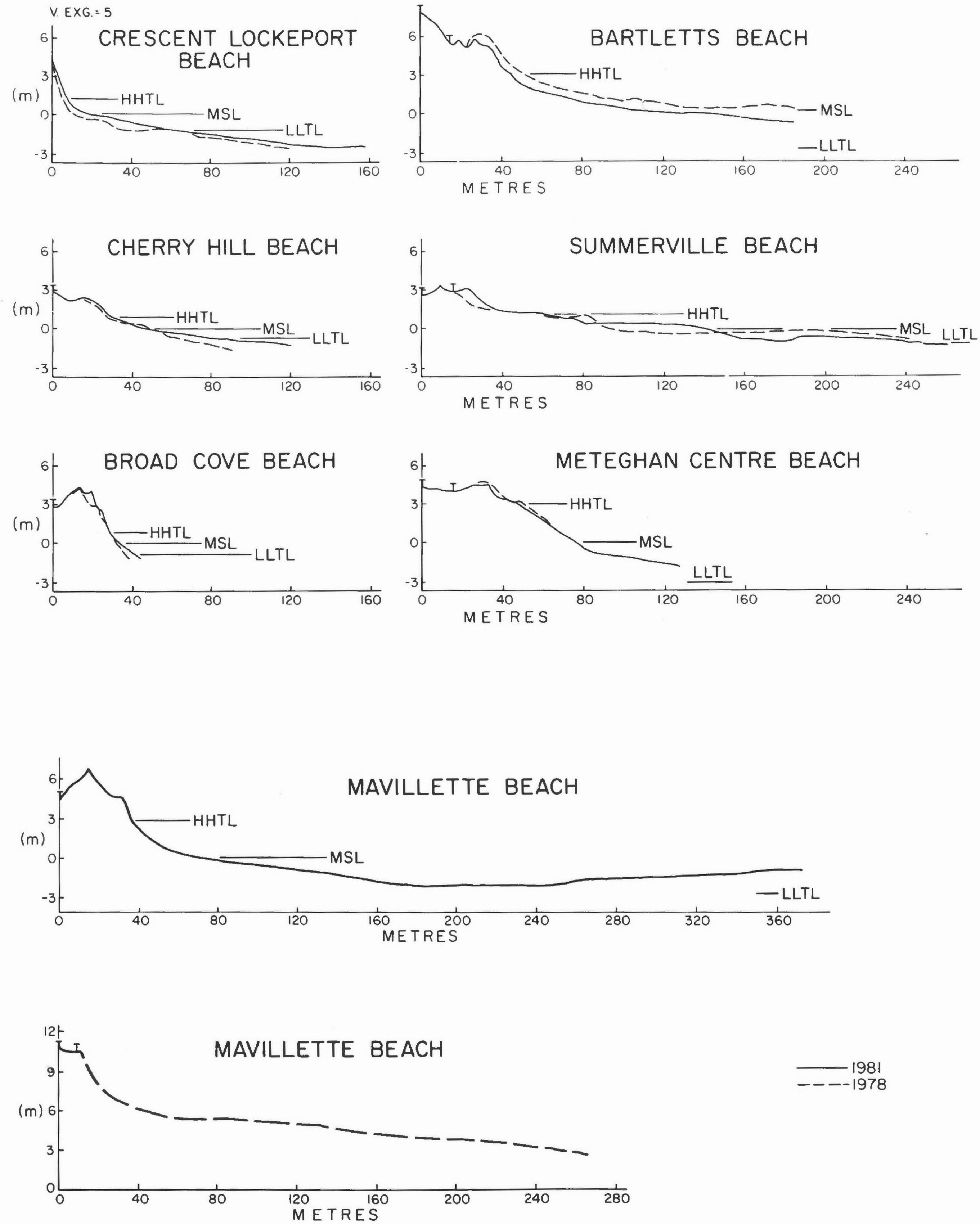

Figure 52. Profiles surveyed in 1978 and 1981 are superimposed on each other to show changes over the three year period. The profiles surveyed at Mavillette Beach are not superimposed on each other because of uncertainties in aligning the bench marks.

Bay (Fig. 49). A saltwater marsh lies to the north of the beach system. The beach face is composed of fine white sand and is backed along its entire length by cobble storm ridges which, in places, attain elevations of 3 to 4 m above high tide limit. Beach sediment is derived from the headland at Pollock Point and from offshore. At the northeastern end of the spit, a dune system lies behind the storm ridges. Although generally well vegetated, the dunes are experiencing severe erosion where they are intensively used for recreational activities.

Between 1978 and 1981 there was a net sediment gain of 30 m^3 at one profile (Fig. 52). Most of the accretion was at the cobble storm ridge and below mean sea level where the beach slope decreased from 1.2° in 1978 to 0.6° in 1981. A summer berm was evident on the profile in both years but in 1978 it was better developed and situated lower on the beach face than in 1981.

Summerville Beach, Queens County

Summerville Beach is a sand spit extending in a southwesterly direction across the head of Port Mouton Bay (Fig. 49). The spit is backed by the saltwater estuary of the Broad River. Neither the Broad River nor the local bedrock of greywackes and slates are significant sources of sediment for the system. The spit is composed of fine white sand which is transported in a southwesterly direction alongshore, possibly from offshore or from farther alongshore.

In the backshore, a single, low, narrow, vegetated dune ridge found at the north end of the spit, progressively widens and becomes higher toward the southern part of the spit. Although the dunes are well vegetated large deflation surfaces have occurred as a result of human recreational activities. In an attempt to protect the dune system from further degradation, wooden access walkways have been constructed across the dunes and picnic areas have been limited to the stable backshore farther inland.

Between 1978 and 1981, the profile surveyed at Summerville Beach experienced a net gain of 11 m^3 of sediment (Fig. 52). In the backshore, sediment transported by southwest winds accumulated at the seaward dune ridge, and across the foreshore zone a ridge and runnel system accounted for the remainder of the net positive change. However, ridge and runnel development is dependent on local wave conditions and is generally an ephemeral feature created during calmer wave conditions. A berm was present on the upper beach face in both years but it was better developed in 1978. A net loss of sediment was recorded in 1981 at the base of the foreshore slope and just offshore of this profile.

Crescent Beach, Shelburne County

Crescent Beach is a bayhead beach which joins the mainland of southwest Nova Scotia to Locke Island where the village of Lockeport is situated. It was studied in July 1981 and a more detailed physical description of it is provided in the preceeding section of this report.

Over the three year period, August 1978 to July 1981, 23 m^3 of sand accumulated across the upper beach face, the dune ridge and just offshore (Fig. 52). The foreshore slope was more gradual in 1981 (1.7°) than in 1978 (2.8°) but there was a better defined berm and swash bar in 1978. Net sediment accretion at the crest of the sand dune was 0.4 m over the three years.

Bartletts Beach, Digby County

Bartletts is a sand beach on the southwestern shore of the province (Fig. 49). The predominantly sand foreshore is backed by a cobble ridge which extends to the base of a dune system. Dune morphology changes from three ridges to only one at the northern extent of the system. To the northeast is a lagoon which is connected to the sea by a narrow tidal channel which acts as the southern boundary of the dune ridges.

Sediment is transported to the beach from the south. A longshore current, generated by the prevailing southwesterlies in the spring and summer months, moves both sand and pebble/cobble material onto the beach face.

Between July 1978 and July 1981 Bartletts Beach was severely eroded. The crest of the seaward dune has been steepened and the entire beach face was combed down (Fig. 52). Net sediment loss at this profile over the three-year period was 114 m^3. Despite the erosion, a ridge and runnel system characterized the lower foreshore slope during both surveys.

Mavillette Beach, Digby County

Mavillette Beach is just south of Cape St. Mary (Fig. 49). A large productive salt marsh and a high dune system occupy the backshore. The dunes, narrow at the southwestern end of the beach, progressively widen to approximately 500 m in the northwest where three dune ridges are present. This area is prograding while the southern end is eroding. Human impact on this beach is significant. It was recently made into a picnic park by the provincial Department of Lands and Forests. As a result the dune system has been affected – numerous walking trails cross the dune ridges and severe deflation hollows have developed.

The foreshore area is very broad with sandflats exposed at low tide. Sediment composition ranges from predominantly fine sands to a scattering of cobble material. The main source of beach sediment is the glacial till located to the south of Mavillette Beach. The headland at Cape St. Mary acts as a trap for this northward moving sediment which results in an abundant sediment supply for Mavillette Beach.

In 1981 two profiles were surveyed, however neither could be accurately aligned with former surveys conducted in 1978 (Munroe, 1980) and in the mid 1970s (Bowen et al., 1975) because of the loss of original bench marks. Visual observations suggest that the beach face and seaward dune ridge have maintained a similar morphology from 1978 to 1981 and that only minor net accretion resulted. Sediment accumulation also was observed in 1981 across the sandflats exposed at low tide (Fig. 52).

Meteghan Centre Beach, Digby County

Meteghan Centre beach is on the southwestern coastline of Nova Scotia, just north of Point Noire (Fig. 49). The beach fronts directly onto the Gulf of Maine and is exposed to the prevailing southwest winds during the spring and summer months. Beach composition is a mixture of sand and shingle which is representative of much of the shoreline in this area. An extensive low tide terrace at least 50 m wide, covered by large cobbles and boulders, fringes the beach, which is backed by a metre high bank of glacial till. Farther inland, the backshore is well vegetated with grasses and secondary plants such as rose bushes and morning glories.

A comparison of surveys made in 1978 (Munroe, 1980) and 1981 indicates that the beach face has changed but the net change was negligible (<5 m^3 sediment loss). The vegetated backslope appears stable, however an erosional scarp has developed along the seaward edge of the glacial till bank.

Coastal bluff recession

This section focuses on recession rates for shore bluffs composed of soft, recessive rocks or unconsolidated erodible material. Although coastal cliffs of resistant rock are found along the Nova Scotia shoreline, they are generally associated with geologic structures, e.g. faults, and show very low rates of erosion. The best developed shore bluffs are formed in the softer rocks or unconsolidated materials. These bluffs also experience the fastest rate of retreat. Shore bluffs can be a major source of sediment for the nearby depositional coastal features. They can also be the focus of much public attention if their rate of retreat is significant, particularly in a residential or recreational area. On the basis of office files kept by the Nova Scotia Department of Environment, the largest number of public enquiries and concerns of erosion pertain to the shores of Northumberland Strait, Cobequid Bay and select areas along the Eastern Shore and South Shore of the province. Groups such as the West Colchester Rural Development Association have been formed to solicit government support for protective structures along rapidly eroding segments of coast, e.g. Economy and Five Islands. Recently a pilot project was launched by the Nova Scotia Department of Environment to examine the causes and seek solutions to the problem of coastline erosion especially along the shores of Northumberland Strait and Cobequid Bay.

A search of published and unpublished reports and field notes in various university and government departments showed that coastal bluff recession studies have been completed in several parts of the province (Table 17). The objective of many of the studies was to calculate the amount of sediment derived from the coastal bluffs so that a sediment budget could be calculated for a specific segment of coast. For the most part, the rates of bluff recession were calculated by comparing known points on sequential aerial photographs and/or from ground photos (e.g. Gosselin, 1972; Atlantic Air Survey, 1976). In only a few cases were repeated ground surveys made. Problems in accuracy were encountered in determining recession rates from airphotos and these are discussed by Gosselin (1972) and in the Atlantic Air Survey report (1976).

Table 17. Shore bluff recession rates (in metres per year ($m \cdot a^{-1}$) for selected areas of mainland Nova Scotia.

location	years of survey	rock type	rate ($m \cdot a^{-1}$) mean	max.	method/source
Northumberland Strait	1954-72	Till	0.3	0.9	airphotos/ Gosselin (1972)
	"	Carboniferous sandstone, conglomerate	0.3	0.6	airphotos/ Gosselin (1972)
Bay of Fundy	1939-64	till over	0.5	—	airphotos/Amos and Long (1980)
Five Islands	"	Triassic red wacke	—	1.5	
Spencers Point	"	siltstone	—	1.6	" "
Amherst Shore	50 yrs	till	0.3	—	ground survey/ Bowen et al. (1975)
Atlantic Coast					
Osborne Head	1945-66	till	—	1.2	airphotos/ AAA report (1970)
Hartlen Point	1945-66	"	—	1.8	" "
	1964-74		—	2.1	airphotos/ Huntley (pers. comm., 1976)
Blandford Head	1976-78	till	0.1	0.5	ground survey/ Piper (pers. comm., 1978)
Covey Point	"	"	0.4	0.4	" "
Hartling Bay	1945-65	till	0.8	1.5	ground survey/ Urquhart (1977)
Kings Bay	1945-65	till	—	0.4	" "

Factors affecting coastal bluff recession

The major problem in all measurement studies of shore bluff recession is the variability of erosion both spatially, i.e. along the crest of the bluff and between the toe and the crest of the bluff; and temporally, i.e. from season to season and year to year. Rates of shore bluff erosion depend on four main factors: (a) composition and geology of the bluff, (b) marine processes, (c) subaerial slope processes, (d) vegetation cover and the effect of man.

Shore Bluff Composition

The rock type, bedding, jointing or the composition of unconsolidated sediments affect the nature and rates of erosion. For instance, where resistant rocks overlie softer rocks, waves undercut the base of the cliffs and large blocks of the upper beds break off, e.g. Indian Point to Glace Bay, Cape Breton Island. Where horizontally bedded, easily eroded, Carboniferous sandstones occur, a flat intertidal platform can be created, e.g. Northumberland Strait. Landward dipping coastal rocks often result in overhanging cliffs. Shore bluffs composed of unconsolidated glacial deposits, e.g. drumlins, are quickly eroded by waves and subaerial slope processes. In some cases, such as in Mahone Bay, an entire field of drumlins has been completely eroded away, leaving offshore shoals of boulder lag or bedrock (Johnson, 1925; Piper, 1980). Generally rates of erosion are greater for bluffs composed of sandy alluvial deposits than the compacted clayey till deposits. Rates of recession along the Atlantic coast for shore bluffs composed of glacial deposits have exceeded 2 $m \cdot a^{-1}$ but usually average 1 $m \cdot a^{-1}$ (Table 17).

Marine processes

Shore bluff erosion is a function of exposure to waves, the amount of cliff inundated at high tide and the frequency of major storms. Waves breaking at a shore expend considerable energy and transport sediment on, off or alongshore. Bluffs at headlands are exposed to greater wave attack than those in sheltered bays or in the lee of islands. Moreover, bluffs fringed by a beach or nearshore shoals are more protected from waves than bluffs where a steep nearshore slope exists and/or where the toe of the bluff is devoid of talus or beach material. Bluffs along a sediment starved segment of coast are generally subject to greater erosion by waves. Fluctuations in water level at the toe of the bluff control the amount of bluff face affected by waves. In Cobequid Bay, the larger tidal range results in greater inundation by water of the bluff face than along the Atlantic shores, but the Atlantic shores are subject to higher energy waves. The frequency of large magnitude storms, e.g. Groundhog Day storm of 1976, also affects the rate of erosion because water levels are raised above normal due to wind set-up or storm surge, so that parts of the bluff, not normally reached by waves are affected.

Subaerial processes

Shore bluff stability is affected by groundwater seepage and surface runoff which can lead to mass wasting and slumping. Groundwater seeps through permeable sediment until it reaches a less permeable layer where the water then flows toward the bluff face. Thus, the effect of groundwater seepage depends on the composition of the bluff. During spring melt or following heavy precipitation, the increased pore water lessens the cohesion of the materials or it may saturate upper permeable layers causing increased weight or load on the lower slope. The result is often slope failure and slumping and sliding occurs because the slope is attempting to establish a more stable angle of repose. Surface runoff often leads to rill and gully erosion of the bluff face. Freezing and ice wedging tend to shatter rock faces which lead to the build-up of talus deposits at the base of the slope.

Vegetation cover and impact of man

People adversely affect shore bluff stability where they strip the adjacent land of trees and other vegetation for agriculture or development, e.g. cottages. This leads to more rapid surface water runoff and subsequently increased erosion. Low shore bluffs can often be stabilized by vegetation cover, however vegetation has less effect on the stability of higher bluffs where undercutting by waves occurs.

Coastal bluff recession rates

Recent ground surveys in select coastal locations were made by Urquhart (1977), Piper (personal communications, 1976, 1978) Letson (1982) and Easton (personal communication, 1980), and the Nova Scotia Department of Environment is presently examining coastal erosion along Cobequid Bay and Northumberland Strait. However, there has been no attempt to set up a network of permanent survey stations around the province to facilitate future ground surveys of coastal recession. In an attempt to remedy this situation, ground surveys were conducted in 1981 at 16 shore bluff sites around the province (Fig. 53). Eight of the sites (5 to 12) had been previously established by Piper or Easton (personal communication, 1980) of the Geology Department of Dalhousie University. Two of these sites – Blandford Head and Covey Point – were first measured in 1976, the rest in 1980. New bench marks were established at sites 1 to 4 and 13 to 16 (Fig. 53) for the following reasons: all were representative of the shore bluffs in their vicinity; in some cases they were adjacent to the primary beach study areas of this report (previously described) and/or they were locations where public concern had been raised about the rapid rates of shore recession. All of the bluff sites monitored were composed of unconsolidated glacial sediments except at Cape John and Five Islands where glacial deposits covered a much greater thickness of recessive Carboniferous or Triassic sandstones (Fig. 54a). In the following only the bluff recession sites established prior to 1981 are discussed because they have been measured more than once. Detailed field information which is required to locate and conduct future surveys at the 16 sites, along with a brief physical description of each bluff, is available in Geological Survey of Canada Open File 976.

Eastern Shore

Along the Eastern Shore, five shore bluff recession sites were set up in 1980 and revisited in July and August 1981. Unfortunately the original bench marks could not be found at Collies Head and problems were encountered when trying to repeat the 1980 profiles at Lawrencetown, hence three new survey lines were established at each site.

Site 5 – Philip Head. In July 1980 three survey lines were set up at the crest of an eroded drumlin at the west end of Martinique Beach (Easton, personal communication, 1980). Despite observations of minor basal erosion by waves and minor gullying on the upper slope, a resurvey in July 1981 suggested no change at the crest of the bluff (Table 18) over the one-year period. The face of the drumlin had a concave slope in 1981 and was fringed by a narrow pebble-cobble beach and an extensive boulder lag deposit offshore (Fig. 54c).

Site 7 – Half Island Point. At the extreme easterly end of Terminal Beach, which is the eastern extension of Lawrencetown Beach, is a 15-20 m high headland. Six survey lines were established at the apex of the headland in July 1980 (Easton, personal communication, 1980) and resurveyed in July 1981. As expected, the maximum erosion was at the eastern tip of the headland where 3.3 m of bluff was lost (Table 18). The least erosion was at the sides of the headland especially along the western side. A lag deposit of large boulders at the base of the slope offered some protection to the headland but gullying and rillwash had modified the upper bluff face. Where change was recorded, the average rate of recession was 1.5 $m \cdot a^{-1}$.

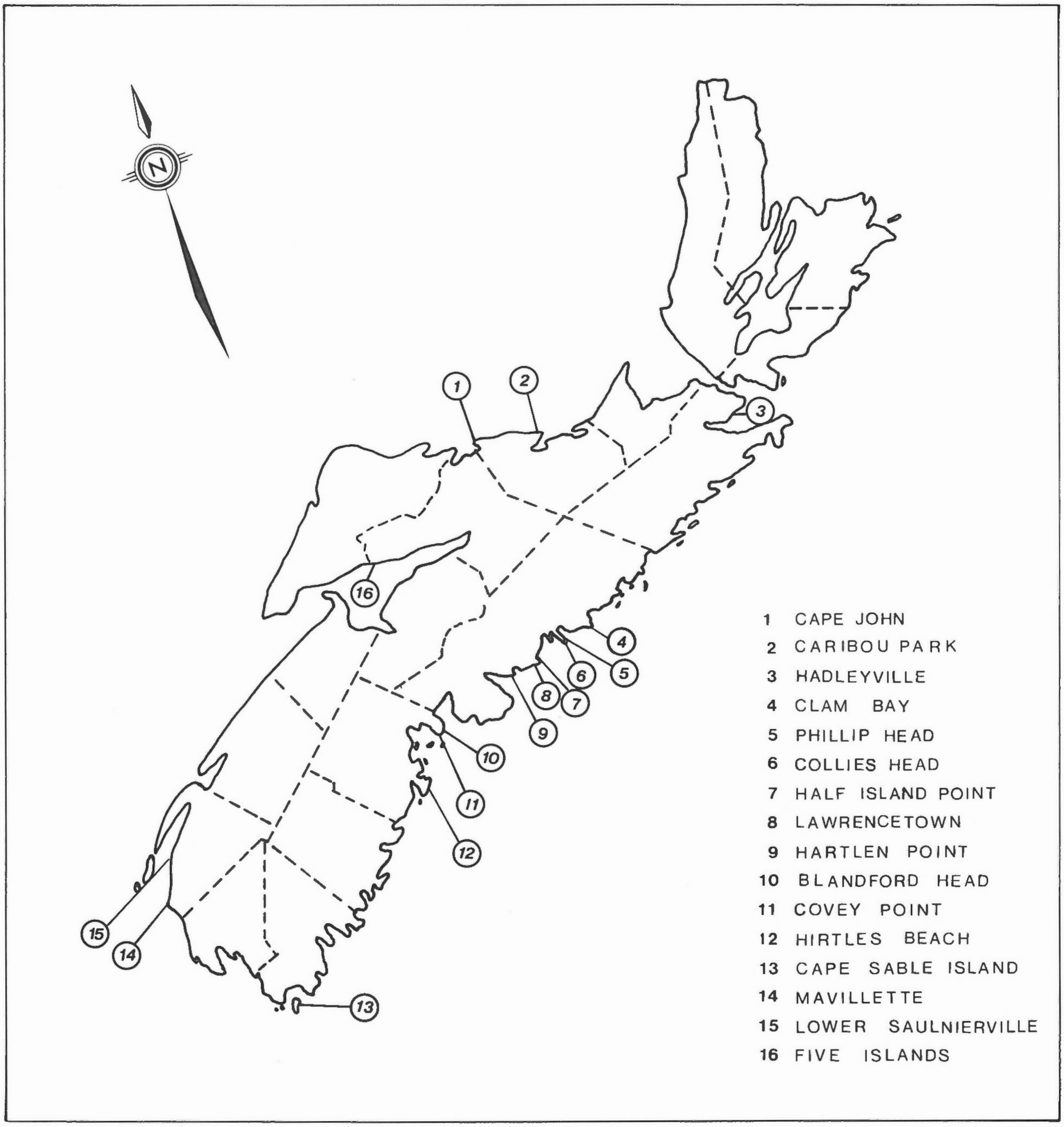

Figure 53. Location map of sites where coastal bluff recession stakes were established and measured in 1981 along mainland Nova Scotia.

Table 18. Shore bluff recession rates for selected areas of the Eastern Shore and South Shore of Nova Scotia.

location	years of survey	number of survey lines	composition	height (m)	rate of recession ($m \cdot a^{-1}$) maximum	mean
(A) *EASTERN SHORE*						
5. Philip Head	1980-81	3	till	5-7	0.1	stable
7. Half Island Point	1980-81	6	till	15-20	3.3	1.5
9. Hartlen Point						
(a) North	1973-81	2	till	<10	1.1	0.8
	1980-81	1	till	<10	1.6	1.6
(b) South	1980-81	3	till	<10	3.0	1.4
(B) *SOUTH SHORE*						
10. Blandford Head	1978-81	10	till	8	0.5	0.2
11. Covey Point	1978-81	1	till	1.4	0.1	0.1
12. Hirtles Beach	1980-81	7	till	15	1.2	0.5

Site 9 – Hartlen Point. Eroded shore bluffs of glacial till of less than 10 m thickness constitute the shoreline at Hartlen Point which is at the eastern entrance to Halifax Harbour. The bluffs are fringed by a cobble-pebble beach and extensive shoals of boulder lag deposits. The shore bluffs are composed of an older grey basal till overlain by a red clay till. Nielsen (1976) estimated the sediment composition of Hartlen Point as 55% mud, 25% sand and 20% clasts > 2 mm size. Survey lines were completed in two areas of Hartlen Point in July 1980 (Easton, personal communication, 1980):

(i) Hartlen Point South – three survey lines were established in 1980 but one bench mark had to be replaced in July 1981. Rates of recession, due to a combination of slope and marine processes, ranged from 0.6 to 3.0 $m \cdot a^{-1}$ (Table 18).

(ii) Hartlen Point North – in 1973, D. Piper of Dalhousie University completed two lines to the bluff crest. A repeat of those lines in 1981 indicated a mean recession rate of 0.8 $m \cdot a^{-1}$ (Table 18). Three additional survey lines were completed in 1980 from a series of wooden power poles which ran along the edge of the bluff. By June 1981 the power poles had been replaced by a new power line 80 m farther inland. At one of the older poles where the base still remained, the rate of bluff recession was 1.6 $m \cdot a^{-1}$. A new series of four survey lines was established in 1981 utilizing the new line of power poles. Rates of bluff recession at Hartlen Point have always been high, up to 2.1 $m \cdot a^{-1}$ (Huntley, personal communication, 1976), but measurements in 1981 of both 1973 and 1980 survey lines showed that considerable variation in recession rates, i.e. 0.6 to over 3.0 $m \cdot a^{-1}$, can take place. Slumping which is isolated to short sections of bluff and an irregular nearshore topography which affects the wave energy reaching shore are thought to be two of the main reasons for the fluctuation in recession rates recorded along Hartlen Point.

South Shore

Three bluff recession sites were established prior to 1981. Sites 10 and 11 are located at the eastern entrance to Mahone Bay and Site 12 is at Hartling Bay south of Kingsburg.

Site 10 – Blandford Head. This low headland is located along the southwest shore of Aspotogan Peninsula. Two sets of survey lines were first measured here in 1976 and then again in 1978 (Piper, personal communication, 1978). Surveys along the southern part of the headland could not be repeated in 1981 because the original bench marks could not be found. However, this slope, which is well covered by grass and spruce trees, appears to have stabilized since 1978. A lag deposit of boulders also protects the base of the bluff from wave undercutting.

Along the north side of Blandford Head, ten lines were measured to the bluff edge from fence posts 10 m apart. From 1978 to 1981 the mean rate of bluff recession was only 0.2 $m \cdot a^{-1}$ which is considerably less than at Hartlen Point (Table 18). The lower rate of recession is primarily a function of wave exposure. Blandford Head is only exposed to the local waves formed in Mahone Bay. It is protected from the higher energy Atlantic waves by the Tancook Islands and East Ironbound Island. In 1981 slumping and soil creep appeared to be the main agents of erosion along the 8 m high shore bluffs. In comparison with the period 1976-1978, the mean rate of erosion at the bluff crest has increased by 0.1 $m \cdot a^{-1}$ over the last three years. These shore bluffs are composed of a poorly sorted glacial till and are fringed by a lag deposit of boulders at the toe of the bluff.

Site 11 – Covey Point. On the northern tip of Shoal Cove, along the Aspotogan Peninsula, there is a low shore bank less than 2 m high. A Nova Scotia survey marker exists just back of the bank edge. Piper (personal communication, 1978) observed a recession rate of 0.4 $m \cdot a^{-1}$ for Covey Point between 1976 and 1978 but by 1981 there had been less than 0.2 m of total erosion (Tables 17,18). The stability of this bank is accounted for by a protective barrier of boulders which has been deposited in front of the bluff during the last three years, presumably to reduce erosion. The bank is composed of a poorly sorted till and is fringed by a narrow shingle beach. This site was visited in 1981 because of the availability of previous recession data, but now because of the protective boulders, Covey Point is a less desirable place for determining future rates of natural shoreline recession.

Site 12 – Hirtles Beach. Near the east end of Hartling Bay there is a 15 m high truncated drumlin (Fig. 54e). Seven stakes, located along the crest of the bluff, were originally measured by Easton (personal communication, 1980) in August 1980. Three of the stakes were replaced in 1981, using the 1980 survey data, because the original stakes could not be found. Between 1980 and 1981 the maximum recorded bluff erosion was 1.2 m at the western end of the drumlin. The mean rate of recession over the one-year period was only 0.5 m (Table 18). A cliff recession study by Urquhart (1977)

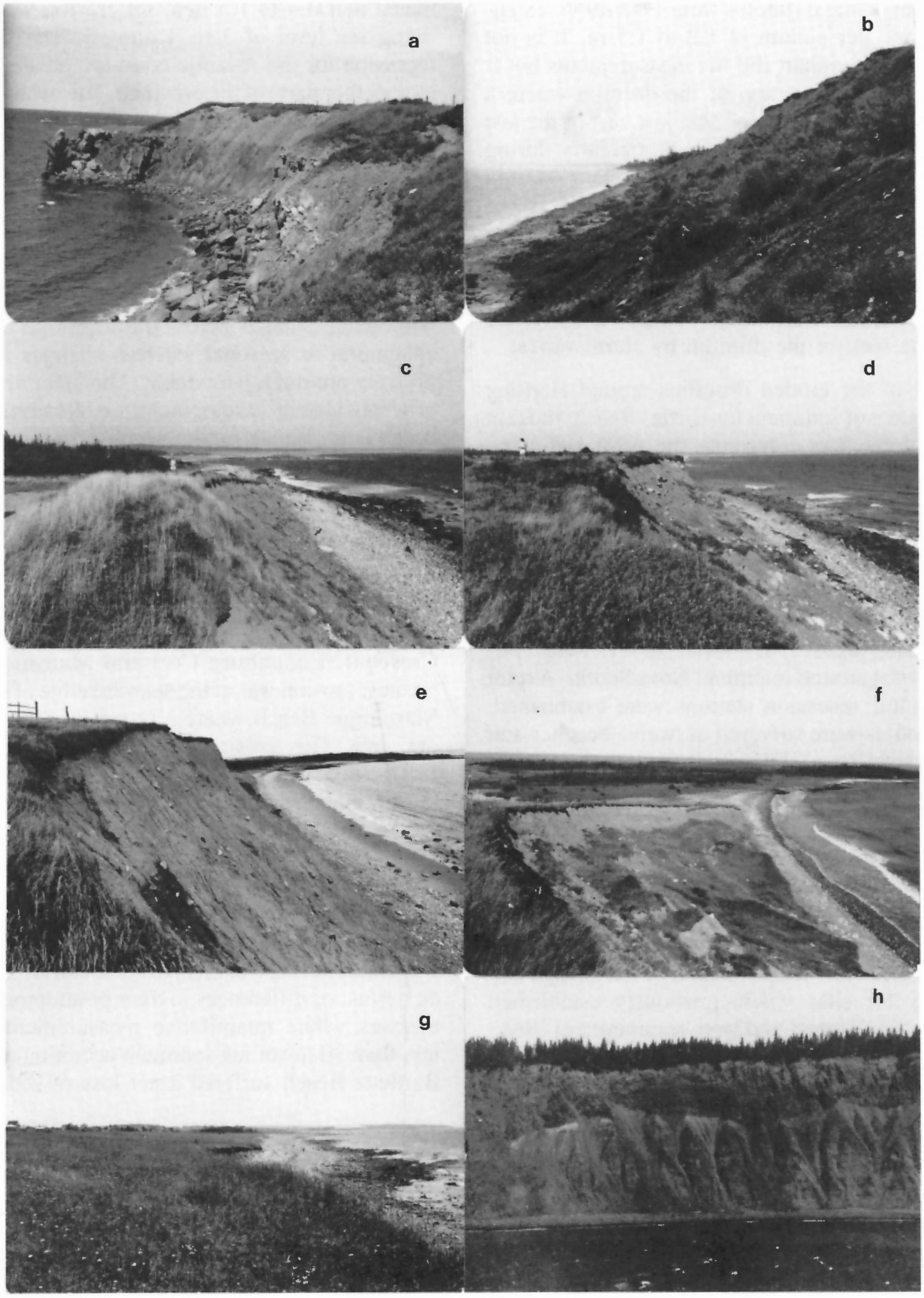

Figure 54. Examples of coastal bluff morphology and composition at sites measured in 1981 (a) Cape John, Carboniferous sandstones, GSC 190802; (b) Caribou Park, GSC 190796; (c) Philip Head, GSC 190795; (d) Collies Head, GSC 190807; (e) Hirtles Beach, glacial till, GSC 190865; (f) major slump just east of stake 126, Hirtles Beach, GSC 190785; and (g) low till bank north of lower Saulnierville Beach, GSC 190853; (h) Five Islands Provincial Park, Cretaceous basalt over Triassic sandstone, GSC 190869. Site locations are as shown in Figure 53.

of the same drumlin, using airphotos from 1945-1965, calculated an erosion rate per annum of 1.2 to 1.5 m. It is not known exactly where Urquhart did his measurements but it could well have crossed a portion of the drumlin where a massive slump scar now exists (Fig. 54f) just east of the last recession stake. Slumping and gullying particularly during the spring thaw, are the major agents of erosion. This drumlin is composed of 53% mud, 39% sand and 8% gravel (Urquhart, 1977) which makes it more susceptible to gullying and soil creep by groundwater and surface runoff. The fine fraction of the tills is added to the nearshore, the boulders remain at the base of the drumlin and the gravel clasts are concentrated at the base of the drumlin by storm waves.

Although all of the eroded drumlins around Hartling Bay are a major source of sediment for Hirtles Beach, those at the eastern end of the bay contribute the most sediment. Urquhart (1977) observed that cliff recession varied from 1.5 $m \cdot a^{-1}$ at the eastern most drumlin to 0.1 $m \cdot a^{-1}$ at the westernmost drumlin over the period 1945 to 1965.

SUMMARY AND CONCLUSIONS

During July and August 1981 coastal surveys were completed at selected sites around mainland Nova Scotia. A total of sixteen shore bluff recession stations were established, cross-sectional profiles were surveyed at twelve beaches and the physical characteristics and recent evolution of eight beaches were documented.

One of the main objectives of the study was to set up a network of shoreline survey stations around the province to facilitate future monitoring of coastal change. Thus, it will be several years before sufficient information is collected to formulate accurate conclusions about rates of coastal change. For now, rates of shore bluff recession and beach change can be discussed only for sites where previously established bench marks were found intact and were resurveyed in 1981.

Shore Bluff Recession

Between 1978 and 1981 the average rate of erosion at five sites along the Atlantic coast of Nova Scotia was 0.9 $m \cdot a^{-1}$. The maximum rate of recession of 3.3 $m \cdot a^{-1}$ was experienced at Half Island Point, an exposed headland. All five shore bluffs (Table 18) were composed of glacial till and varied from 8 to 20 m in elevation. Measurements collected at Covey Point were not used in these computations because man had altered the site by lining the shore with boulders. Rates of recession differed between sites along the exposed Eastern Shore and those along the South Shore where numerous islands protect the mainland shores from the full force of waves. The mean rate of retreat at sites along the Eastern Shore was 1.1 $m \cdot a^{-1}$ whereas it was only 0.4 $m \cdot a^{-1}$ along the South Shore. A comparison of the average maximum recession rates measured in the field over the past three years with those determined using airphotos for the period 1945 to 1974 suggests that rates of erosion have remained relatively constant (0.8 $m \cdot a^{-1}$) along the South Shore and have increased from 1.4 $m \cdot a^{-1}$ to 1.8 $m \cdot a^{-1}$ along the Eastern Shore. Much of the erosion can be attributed to rising sea levels. Bowen et al. (1975) and Huntley (personal communication, 1976) estimated that 0.4 to 1.5 $m \cdot a^{-1}$ of erosion would occur given a rising sea level of 3 to 4 $mm \cdot a^{-1}$. The maximum rates of recession for the Atlantic coast are greater than those found along other parts of the province. The mean maximum rates of recession for shore bluffs along the Minas Basin and Northumberland Strait were 1.6 $m \cdot a^{-1}$ (Amos and Long, 1980) and 0.7 $m \cdot a^{-1}$ (Gosselin, 1972) respectively.

Beach Changes

A beach is a very dynamic landform constantly changing in response to varying conditions and processes. Morphological changes across the foreshore zone are generally ephemeral or seasonal whereas changes in backshore morphology are more permanent. The latter are better indicators of what stage of development, i.e. erosional or accretional, a beach is in. Bench marks which were set up in 1978 at nine beaches along the Atlantic coast of Nova Scotia by Munroe (1980) were resurveyed in 1981 (Table 19). Only Bartletts Beach in southwestern Nova Scotia experienced major changes. At the profile surveyed, 114 m^3 of sediment was eroded since 1978. The crest of the seaward dune was steepened and the entire foreshore slope combed down. Degradation of the sand dunes also was observed at Cherry Hill, Crescent (Lunenburg Co.) and Martinique beaches. The greatest erosion was at the seaward edge of the dune system at Martinique Beach where a retreat of 9 m was estimated for one area. This erosion took place over the period 1976 to 1981. Between 1978 and 1981 the pebble-cobble storm ridges at Cow Bay and Broad Cove beaches were built up by 0.8 to 1.8 m which suggests that significant storms have occurred since 1978. At Cow Bay the ridge crest remained in the same position whereas at Broad Cove the crest retreated landward. Despite these changes, most of the beaches showed little difference in form over the three years. Most recorded change was either because of changes in location of specific features, eg berms, or differences in their development. At six of eight beaches where quantitative measurements were recorded, less than 30 m^3 of net sediment accretion occurred, and only Bartletts Beach suffered a net loss of sediment.

Characteristics of selected beaches of Nova Scotia

In 1981 eight beaches were examined and their physical characteristics and recent evolution were documented. The general morphological and sedimentological characteristics of each beach are summarized in Table 20. From these surveys several conclusions can be reached.

(a) All of the beaches with the exception of Watersides on Northumberland Strait, exhibit signs of retreating landward. Beach width has decreased and cobble-boulder lag deposits are all that remain of former headlands, drumlins and islands. Where large woodlots or forests once grew, there are now only a few remaining dead tree stumps. Peat deposits are exposed along the lower foreshore zone and erosional dune scarps are observed at the top of the beach. It is the beaches along the Eastern Shore, e.g. Cow Bay, Conrads and Martinique, that have suffered the greatest destruction and retreat. Over the last 20 years, inlets or large washover channels have formed across all three beaches. The inlet at Conrads Beach formed in 1962, at Cow Bay an inlet formed during the winter of 1975-76 and severe washovers occurred at the east end of Martinique Beach during the winters of 1977, 1978 and 1979. As a consequence of these events, ponds, lagoons and salt marshes have been extensively infilled by flood tidal deposits. This represents one mechanism by which a beach retreats landward. Beaches examined along the South Shore did not exhibit such catastrophic changes and are thought to be retreating more slowly.

In contrast to the beaches on the Atlantic coast, Waterside Beach has prograded and built up from a tidal flat environment in 1922 to a beach over 200 m wide in 1979. On the basis of measurements made on sequential airphotos, the rate of beach progradation at Waterside between 1936 and 1979 is estimated to be 2.6 $m \cdot a^{-1}$.

(b) Man has profoundly affected the morphology and recent evolution of most of the beaches studied. In the past, man has been primarily a destructive force whereas today he plays more of a constructive role. For instance, the extensive removal of beach sediment from Conrads, Cow Bay and other beaches in the 1950s and 1960s greatly affected the equilibrium of each beach system and led to rapid destruction and retreat. The driving of all-terrain vehicles across dune systems damaged the vegetation which protects the beaches from wind erosion. This led to dune blowouts which often became sites of wave washover channels. On the other hand, the rapid formation of Waterside Beach is probably the result of the building of a temporary causeway in 1922 and a permanent one in 1947 to Caribou Island. At Crescent Beach, Shelburne County, the local residents built a cribwork along the sand bar at the turn of the century. This structure led to the formation of the well developed dune system observed today. At Advocate Harbour Beach, Cumberland County, the recent fear of flooding led local residents to bulldoze and raise the height of the gravel storm ridge. This action resulted in a higher beach crest but the reduced width of the beach has resulted in water flowing through it. Many of the beaches are

Table 19. Net beach changes recorded between 1978 and 1981 at selected sites along the mainland coast of Nova Scotia. The location of these sites is shown in Figure 49.

beach name	number of profiles	net change (m^3)	remarks
Meteghan Centre	1	<5	erosional scarp along till bank
Mavillette	1	<5	sediment accumulation offshore
Bartletts	1	−114	erosion across storm ridge and entire foreshore slope
Crescent (Shelburne Co.)	1	+23	accretion across top of foreshore slope and base of dune ridge
Summerville	1	+11	ridge and runnel and fore-dune development in 1981
Cherry Hill	1	+30	accretion at storm ridge and across foreshore slope
Broad Cove	1	+9	storm ridge height increased and shifted landward
Crescent (Lunenburg Co.)	3	−7 to +47	variable changes along the main dune ridge
Cow Bay	1	—	storm ridge height increased and backshore infilled by overwash deposits
Martinique	7	—	erosional scarp at seaward edge of sand dunes – up to 9 m of recession, variable changes on foreshore slope

Table 20. A summary of the morphological and sedimentological characteristics for eight selected beaches along the coast of Nova Scotia.

Beach name	Mean sea level (m)	Tidal range (m)	Morphology									Sediment					
			Beach				Backshore			Foreshore		Mean grain size (∅)			Sorting (∅)		
			width[1] (m)		height[2] (m)		Dune height[3] (m)		Storm ridge slope[4] (o)	Slope (o)		LTL	HTL	Dune	LTL	HTL	Dune
			mean	max.	mean	max.	mean	max.		mean	max.						
Waterside	1.16	1.34	168	228	3.4	4.6	1.3	1.7	—	1.3	1.7	2.45	1.58	2.41	0.32	0.66	0.43
Martinique	1.13	1.37	86	150	3.8	4.7	1.2	1.6	—	1.8	2.2	2.68	1.71	2.71	0.32	0.82	0.25
Conrads	1.19	1.40	102	120	3.6	4.5	1.6	2.4	2.6	1.2	1.4	2.53	2.38	2.03	0.41	0.48	0.47
Cow Bay	1.22	1.41	69	90	3.2	3.6	—	—	9.4	3.5	3.8	1.98	—	—	0.59	—	—
Crescent	1.19	1.68	110	130	3.4	4.5	2.9	3.9	—	1.7	2.1	2.70	2.90	2.37	0.35	0.32	0.51
Bakers	1.61	1.89	118	150	3.3	4.2	1.9	2.2	—	1.3	1.4	2.58	2.60	2.13	0.43	0.38	0.44
Lower Saulnierville	3.02	4.48	117	132	3.7	4.0	—	—	4.5	2.2	2.7	—	—	—	—	—	—
Advocate Harbour	5.82	9.14	63	89	7.7	8.8	—	—	11.9	6.8	7.7	−2.36	−3.59	—	1.64	0.93	—

[1] MHTL to seaward edge of lagoon or landward extent of overwash if no lagoon.
[2] Mean sea level to highest elevation on beach.
[3] Base to crest at seaward side of dune.
[4] Base to crest at seaward side of storm ridge.

now provincial parks e.g. Watersides, Martinique, and are protected and maintained by the Nova Scotia Department of Lands and Forests. At Martinique Beach, Lands and Forests personnel have succeeded in trapping sand and building new foredunes in the washover that occurred in 1977 at the eastern end of the beach.

(c) None of the beaches examined along the Atlantic coast exceed 150 m in width and their average height above mean sea level varies from 3.2 to 3.8 m (Table 20). The narrowest and lowest beach, and that with the steepest slope is Cow Bay which suggests that it may still be in a stage of disequilibrium. Waterside Beach is wider than the beaches along the Atlantic but its height and other morphological features, e.g. dunes, are similar to other sand beaches. The beaches at Lower Saulnierville and Advocate Harbour differ from the others because of their larger tidal ranges. Although the crest of Advocate Harbour Beach is up to 8.8 m above mean sea level, it coincided with spring high tide level at profile 1 and increases to 2.5 m above spring high tide level at profile 5 where the height of the beach crest has been artificially raised.

As expected, the steepest foreshore slope was at the pebble-cobble beaches, i.e. Advocate Harbour, and least at the sand beaches (Table 20). The average foreshore slope of the sand beaches varied from 1.3° to 1.8°. The foreshore slope of Cow Bay Beach was greater than at other sand beaches because it is composed of only a veneer of sand over a coarse sediment substrate.

Most of the sand beaches along Atlantic Nova Scotia are backed by a primary dune ridge that reaches 3.6 to 4.7 m above msl. The average height of the dune ridges (from base to crest) was 1.2 to 1.9 m except at Crescent Beach, Shelburne County where it was 2.9 m. The increased height may be a function of greater availability of sediment but is more likely because of the effect of man. The local residents not only built the cribwork which induced dune development, they also infilled potential breaches in the dune system with sediment from the foreshore in the 1960s. This was to prevent flooding of the backshore.

The five sand beaches examined were composed of sediment ranging from 1.58 to 2.9 phi size. At three of five beaches the sediment sampled at low tide level was finer and better sorted than at high tide level. At the other two beaches the reverse was true. The three coarse sediment beaches, Cow Bay, Lower Saulnierville and Advocate Harbour are composed of clasts larger than -2 phi. The coarsest material was found in the storm ridge and as lag deposits at the base of the foreshore slope. The best sorted sediment across the gravel beaches was at high tide level.

Submarine transverse coastal ridges

Submarine transverse coastal ridges were observed along several parts of the Atlantic shoreline of Nova Scotia. These features are thought to be characteristic of a submerging coastline but have not received much attention in the literature. Along the coastline studied, these ridges were best developed near Lower Saulnierville (Fig. 38). In many cases it is obvious that the ridges are coarse sediment lag deposits of former spits, tombolos or islands, that have been eroded by the sea. In other cases their formation is not so obvious, and further study of these features and their distribution is needed.

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Kings County
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See: Gees and Lyall (1969); Lyall and Gees (1967); Lyall (1969); Munroe (1980, 1982).