REGIONAL VARIABILITY, PHYSICAL SHORELINE TYPES AND MORPHO-DYNAMIC UNITS OF THE ATLANTIC COAST OF MAINLAND NOVA SCOTIA

by

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Preface

This open file report is an abridged version of a longer report prepared by H.D. Munroe for the Geological Survey of Canada. It provides a systematic description of the coastline of mainland Nova Scotia. It is this baseline information which is of value, in the event of oil spills, or in regional coastal management planning.

The open file report comprises a general description of the mainland Atlantic coast of Nova Scotia, including the recognition of different shoreline types. The coast is classified into twelve morpho-dynamic units. Appendices provide information on 139 beach stations, and 1:50,000 maps of shoreline characteristics, and oblique aerial photographs (slides) of the entire study area.

Introduction

Early work on the Atlantic coast of Nova Scotia was primarily concerned with the origin and development of shoreline morphology (Goldthwait, 1924; Johnson, 1925). Geomorphic evidence of glacial action and post glacial sea level change was first pointed out by these early authors. More recent work includes that of Nolan (1963) on beach sediment composition, studies of the sedimentary structures of beach deposits by Gees and Lyall (1969), and work on the consequences of the use of beach material as a source of aggregate for construction (Bowen et al., 1975; Bowen and Piper, 1976; Huntley, 1976). Several studies related to oil spill clean-up have been completed for the shoreline of Chedabucto Bay (Owens, 1971; Owens and Drapeau, 1973; Drapeau, 1972; Owens and Rashid, 1976).

Surficial deposits on mainland Nova Scotia have been investigated by various authors (Barnes, 1976; Barnes and Piper, 1975; Grant, 1963, 1970, 1971; Nielsen, 1976; McNeill, 1951, 1974). The most complete work was done by McNeill (1974) who prepared maps showing surficial deposits on mainland Nova Scotia and parts of Cape Breton.

In a recent synthesis of the coastal environments of the Maritime Provinces, Owens and Bowen (1977) classified the Atlantic coast of mainland Nova Scotia as essentially a single unit. The objective of this study is to document coastal zone variability of the Atlantic coast of mainland Nova Scotia in order to subdivide it into a number of morpho-dynamic units. This provides a logical basis for selecting sites for future detailed study and allows accurate generalizations to be made about the entire coastline. The data bank resulting from this study can be expanded and refined by input from coastal zone projects that may be carried out in other disciplines.

A modified version of the zonal method (Hayes et al., 1973) was used to collect field data for the study area. Semi-permanent profile stations were established during 1978 at 139 pre-selected locations along the coast. Wave period, angle of wave approach, breaker height, breaker type, longshore current velocity and direction; wind velocity and direction were recorded at each station. All stations were described, sketched, photographed, located on 1:15840 scale maps, and surveyed to obtain the beach and nearshore profile (Appendix 2). Sand beaches were systematically sampled and analysed in the laboratory whereas only visual estimates of mean grain size were made on beaches made up of coarser material.

Field data was supplemented by information extracted from vertical aerial photographs and oblique hand held aerial photography taken during the study period, to determine sedimentologic and geomorphic variability within the coastal zone of the study area. The variability of shoreline material is displayed on coastal inventory maps at a scale of 1:50,000 (Appendix 4).

This report provides an account of the geological and geomorphological nature of the coastal zone, with inferences of the dominant processes operative in nearshore waters, for Atlantic Nova Scotia from the Strait of Canso to the Bay of Fundy (Fig. 1). It describes major landforms, sediments, and physical processes of the shore zone. Subdivisions of the study area are identified on the basis of shoreline morphology; the nature of unconsolidated beach sediment and sediment availability; hinterland relief; nearshore bathymetry; wave climate and degree of coastline exposure; and tidal range.

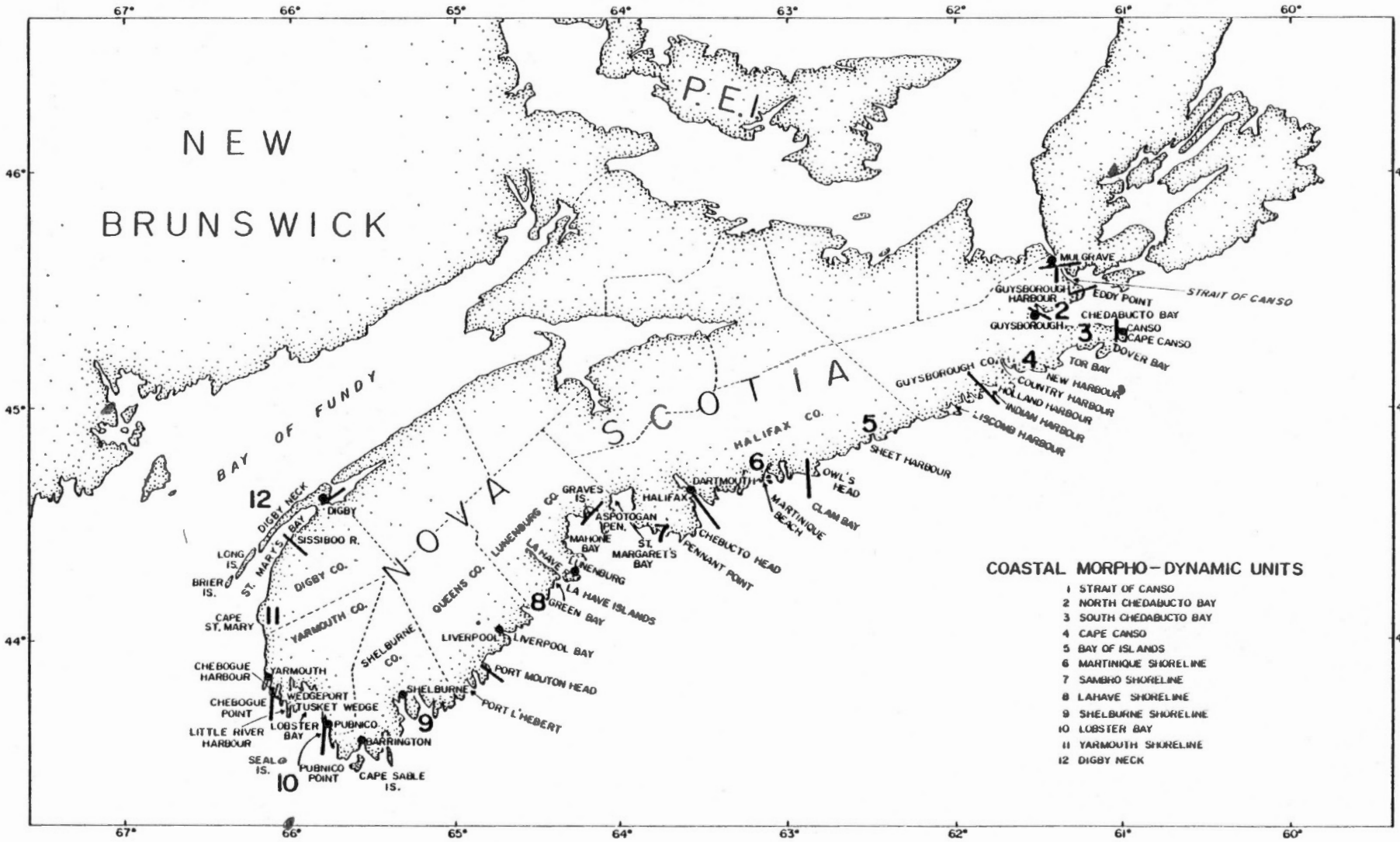

Figure 1. Location of study area, place names mentioned in text, and morpho-dynamic units.

Geologic, Physiographic, and Oceanographic Setting

Almost all the study area lies within the Atlantic Uplands physiographic unit. This comprises lower Paleozoic metasedimentary and volcanic rocks and Devonian granites. The surface of the Atlantic Uplands is a dissected peneplane, with elevations decreasing from the northwest toward the Atlantic Ocean. In the northwestern part of the study area, Digby Neck is part of the North Mountain Uplands physiographic unit, formed of Triassic basalts. On this narrow peninsula elevations rarely exceed 100 m. Triassic sedimentary strata underlie the Annapolis Valley and Minas Basin Lowland units. Relief in these units is generally less than 100 m.

Prevailing winds in the study area blow from the northwest quadrant during the winter and early spring. During the summer and early autumn winds are directed out of the southwest. Light seasonal winds however are frequently interrupted by those associated with low pressure systems passing over the study area. In the summer months, centres of low pressure systems move up the Bay of Fundy and over the northern part of Nova Scotia, whereas in the winter months, storm centres follow a path along the southeast coast. Extra tropical cyclones move in an easterly direction over the study area.

Tides throughout the study area are mixed semidiurnal. Average tidal ranges are less than 2 metres for most of the province. However in the southwestern district the tide range increases markedly toward the Bay of Fundy. A mesotidal (2-4 m) environment exists between Port LeHebert and Wedgeport, whereas macrotidal (greater than 4 m) tides occur along the shorelines of the rest of Yarmouth County and Digby County.

Approximately 10 months of the year the coast is exposed to Atlantic Ocean waves. For about two months local ice in estuaries, bays, and inlets shelters beaches from wave activity. In Chedabucto Bay this period may be longer due to the presence of pack ice.

Sea level rise in the study area has been continuous for the past 5000 years at an average rate of 30 cm per century (Grant, 1971, 1975; Vanicek, 1976; Scott, 1979). Wave refraction diagrams were computed for an 8.0 second wave approaching from the southwest for the study area from Dover Bay, Guysborough County to St. Mary's Bay in Digby County (Appendix 1) using offshore wave data (Neu, 1971). The greatest frequency of occurrence for an 8.0 second wave from the southwest is during the months of June and August (Neu, 1971).

Several sections of shoreline along the Atlantic coast of Nova Scotia are exposed to incoming soutwesterly waves. In these areas waves undergo little refraction as they approach the shoreline in relatively deep water. Exposed sections of shoreline occur from Lower Whitehaven to Eastern Head, Guysborough County, from Pennant Point west to Indian Harbour, Halifax County and from Yarmouth north to the Digby County boundary.

Significant portions of the Atlantic coastline are moderately exposed to incoming waves. Areas of moderate exposure generally have a lower nearshore gradient. Incoming waves undergo a greater degree of refraction which results in beach zones of high and low wave energy. High energy zones are usually headlands, upon which there is a convergence of wave orthogonals due to refraction. Conversely inlets and bays are low energy zones due to wave orthogonal divergence. Moderately exposed

shorelines are found in Guysborough County between New Harbour and Liscombe Harbour, Halifax County from Owl's Head to Halifax Harbour, and along the south shore extending from Lunenburg to Cape Sable in Shelburne County.

Sheltered shorelines are those which receive very little wave energy; embayment shorelines are of this type. In the nearshore zones of these shorelines approaching waves are highly refracted and much of the wave energy is spent due to wave orthogonal divergence. Other shorelines of low wave energy are those where shoals and islands are present. They protect the shoreline from wave attack by acting as natural breakwaters.

Shoreline Types

Within the study area there are two main types of shoreline, rock outcrop and beaches of unconsolidated sediment. Beaches are further subdivided on the basis of sediment characteristics, i.e. size and sorting, which reflect the degree of wave energy modifying them. The distribution of rock outcrop shores and sediment types observed along the study area are display on 15 map sheets at a scale of 1.50,000, available with this report (Appendix 4). Information plotted on the maps is based on data collected at 139 stations along the coast and supplemented by information drawn from vertical aerial photographs, and low altitude oblique colour slides which were taken on several overflights during the field season. Backshore deposits of unconsolidated material were mapped using data from soil survey maps and reports (Nova Scotia Department of Agriculture); surficial geology maps (McNeill, 1974; Grant, 1971) and aggregate material maps (Fowler and Dickie, 1978).

Shores of Rock Outcrop

1. Bedrock shoreline - void of unconsolidated beach material-this type of shore makes up 429 km or 21% by length of the study area (Fig. 2).

Bedrock shore occurs in three areas: the Eastern Shore in the vicinity of Cape Canso; the South Shore between Halifax Harbour and Liverpool; and Digby Neck, including Long Island and Brier Island.

The Cape Canso area from Fox Island to Tor Bay is underlain by granite. Soil cover in this area is less than 30 cm and is made up of decomposed organic material (N.S. Soil Survey Report #14). It is because of this extreme lack of sediment that 26.5% of the total length of bedrock shore occurs in this area.

The section of coast between Halifax Harbour and Mahone Bay, where 26% of the bedrock shore occurs, is also underlain by Devonian granite. The Sambro section of coastline and the south portion of the Aspotogan Peninsula are both exposed to incoming waves which transport unconsolidated beach material into coves and inlets leaving resistant granite rock exposed. A total length of 88 km of bedrock shore occurs between the Lahave River and Liverpool Bay. This section of the coastline is sediment poor, with little till cover.

Approximately 21% of the bedrock shore of the study area occurs on Digby Neck. Weathering of minerals in the basalt has reduced its resistivity to wave attack, and low cliffs along the north shore of the neck show signs of wave erosion. However, on the southeast side of Digby Neck, the cliffs are not as exposed and are more nearly vertical. Digby Neck is

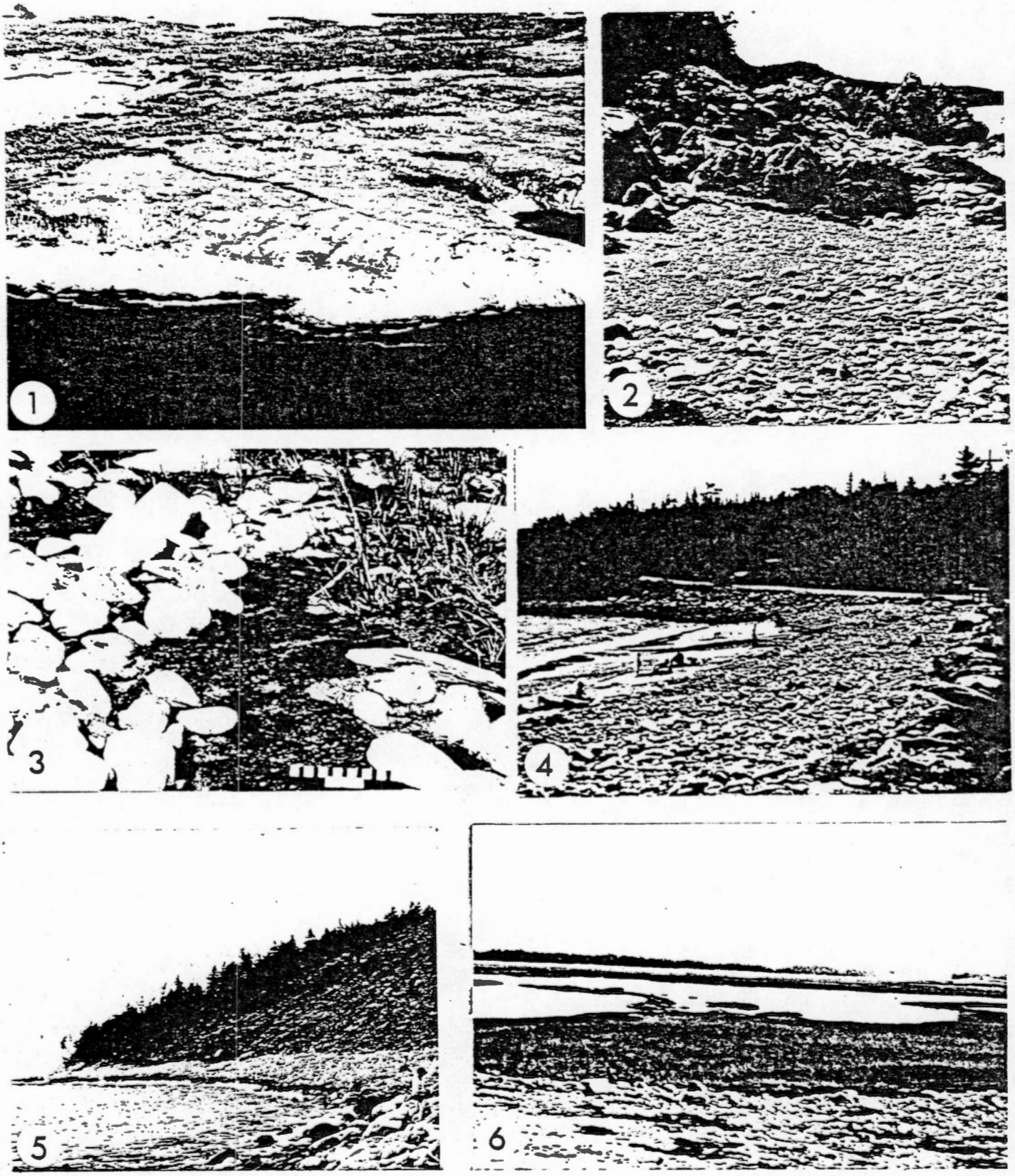

Figure 2. Examples of shoreline types found along the Atlantic coast of mainland Nova Scotia: 1. Bedrock shoreline, Chebucto Head; 2. sediment veneer over bedrock; 3. Pebble-boulder beach, Sheet Harbour area; 4. Pocket Beach, Fox Point; 5. Pebble-cobble beach at base of eroding drumlin, Holland Harbour; 6. Salt Marsh, Lobster Bay.

a sediment poor shoreline that is exposed to waves approaching from the Gulf of Maine.

2. Pebble-cobble shoreline - Some sections of rock outcrop shore have pebble-cobble deposits near the upper swash limit. Shores of this type account for 185 km or 8% of the Atlantic Coast. Pebble-cobble shoreline is characteristic of an area of limited sediment supply, that is exposed to high energy wave attack.

3. Sediment veneer shoreline - Rock outcrop shore partially covered with a thin layer of sand or poorly sorted material ranging in size from pebbles to boulders (Fig. 2) composes 3% of the study area. This shoreline type is common in sediment poor districts which are exposed to moderate levels of wave energy.

Beaches

1. Pebble-boulder beach - Beaches made up of a lag of very poorly sorted material that varies in size from pebble to boulder, constitute 429 km or 21% by length of the study area. Pebble-boulder beaches are found in areas that are sheltered from Atlantic Ocean swell waves, such as in large bays and inlets and in the lee of nearshore islands and shoals . Within these environments, locally generated waves are of insufficient energy to transport the large sediment clasts. Only ice is capable of altering beach morphology. Pebble-boulder beaches should not be confused with pocket beaches that are made up of sediment that has been transported and sorted.

2. Pebble-cobble beach - Beaches made up of material in the pebble-cobble size range are the most common along the Atlantic coast of Nova Scotia. They account for 676 km or about 30% of the study area. Well

rounded granite clasts intermixed with resistant fragments of the Goldenville Formation are the main beach materials on exposed stretches of coast. In sheltered embayments the beaches can be made up of less resistant clasts which generally are not as well sorted as the sediment on beaches exposed to higher wave energy.

Pebble cobble beaches are most common in areas of ample sediment supply, i.e. till deposits, such as along the north shore of Chedabucto Bay. Along the South and East shores of Nova Scotia actively eroding drumlins are the primary source of pebble-cobble clasts for beach development (Fig. 2).

3. Sand (sand to cobble) beach - Sand beaches account for only 5% of the Atlantic coastline. Very few of the beaches that occur between Mulgrave and Clam Harbour are made up of sand. The shoreline from Owl's Head west to Halifax Harbour has by length 25% sand and sand-cobble beaches, which reflects the greater sediment abundance within the littoral zone of this district. West of Halifax Harbour to Mahone Bay, fine grained beaches are few. Continuing from Mahone Bay west to Pubnico Point sand beaches are more common and make up 16% of the shoreline and between Chebogue Point and the Sissiboo River, 22% of the shoreline is sand beach. About 75% of the sand beaches examined contained some proportion of cobbles. The cobbles are generally concentrated at the storm swash limit, but in some instances, a cobble substrate is found beneath sand covered foreshore slopes.

4. Pocket beach - Pocket beaches form in small coves that commonly occur along a rocky shoreline (Fig. 2). Sediment on pocket beaches varies from sand to pebble size and is often bimodal. Beaches of this type are

found from Liverpool Harbour to Chedabucto Bay, but only make up 2% of the length of the Atlantic Coast.

Vegetated Shoreline

On the Eastern Shore between Clam Harbour and Indian Harbour, many protected portions of the coast have beaches that support an intertidal growth of salt tolerant grasses, mainly Spartina. The grasses sparsely vegetate the intertidal area which is about 2 m wide in this environment. Growth of the grasses is supported by a thin layer of biogenic sediment which may cover outcrop or aggregate material of almost any size. Vegetated beaches of this type make up about 2% of the Atlantic coast and are different from salt marsh shorelines.

Salt Marsh Shoreline

Intertidal zones vegetated with salt-tolerant grasses are found in the southwestern part of the study area (Fig. 2). Salt marshes are most extensive between St. Anne Point and Chebogue Point in Yarmouth County. In mesotidal embayments, sheltered from incoming waves, like Lobster Bay and Moose Harbour, salt marsh vegetation can flourish. Salt marshes in this district cover approximately 3407 hectares, and account for 198 km or 8% of the Atlantic coastline.

Morpho-Dynamic Units

Morpho-dynamic units are coastal segments that exhibit distinctive combinations of parameters such as strand morphology; hinterland relief;

sediment supply; tide range; wave climate and degree of coastline exposure. Twelve morpho-dynamic units are distinguished in the study area (Table 1).

Canso Strait

The Strait of Canso shoreline is rectilinear, probably related to a fault trend enlarged by subaerial erosion at times of lowered sea level. Wave activity in the Strait is minimal. The area is restricted from Atlantic Ocean waves, and available fetch dimensions are such that locally generated waves do not greatly modify the shoreline morphology. Shoreline outcrops of Triassic sedimentary strata and glacial till that vary from 1 to 2 m in thickness, show little sign of erosion due to wave attack in this area.

Hinterland relief and nearshore slope both decreases toward Eddy Point, the south limit of this unit. The Canso Strait morpho-dynamic unit is distinguished from others in this region by a low energy wave climate and a recti-linear shoreline form.

North Chedabucto

From Eddy Point to Guysborough town the north Chedabucto unit is easily differentiated from others in this area by its cuspate shoreline morphology and abundant sediment supply. Unconsolidated material from actively eroding drumlins is supplied to the littoral zone where it is reworked by wave activity. Depositional beaches in the form of barrier spits cutting off lagoons give this shoreline its characteristic cuspate morphology. Maximum elevations of drumlin bluffs, the main topographic feature of this unit, are about 30 m. Nearshore slope values are lower

TABLE 1

COASTAL MORPHO-DYNAMIC UNITS

Name of Unit	Extent of Unit	Length of Unit (km)	Number of Profile Stations	Mean* Breaker Height (cm)	Tide Range (m)	Type of Bedrock	Beach/Shore Type		Sediment Sources
							Rock Outcrop	Beaches	
Strait of Canso	Pirate Harbour to Eddy Point	13.6	2	14	1.3	60% Canso Gp. 24% Horton Gp. 16% Windsor Gp.	16% pebble-cobble	84% pebble-cobble	till cover less than 2 m thick
North Chedabucto Bay	Eddy Point to Guysborough Harbour	32.7	4	24	1.3	24% Canso Gp. 67% Horton Gp. 9% Annapolis Fm.		98% pebble-cobble 2% pebble-boulder	eroding drumlin bluff approx. 10 m high
South Chedabucto Bay	Guysborough Harbour to Fox Island	38.6	2	calm	1.3	50% Goldenville Fm. 15% granite 15% Halifax Fm. 12% Horton Gp. 8% Annapolis Fm.	8% bedrock 50% pebble-cobble	25% pebble-cobble 17% pocket beach	sediment poor no significant supply
Cape Canso	Fox Island to Indian Harbour	283.7	14	27	1.4	41% Goldenville Fm. 36% Granite 23% Halifax Fm.	46% bedrock 7% pebble-cobble 1% sediment veneer	32% pebble-cobble 13% pebble-boulder 1% pocket beach	sediment poor small quantities supplied locally from anomalous drumlins

TABLE 1 (Cont'd)

Name of Unit	Extent of Unit	Length of Unit (km)	Number of Profile Stations	Mean* Breaker Height (cm)	Tide Range (m)	Type of Bedrock	Beach/Shore Type		Sediment Sources
							Rock Outcrop	Beaches	
Bay of Islands	Indian Harbour to Owls Head	275.2	16	7	1.7	95% Goldenville Fm. 5% Halifax Fm.	6% bedrock 3.5% sediment veneer 0.5% pebble-cobble	53% pebble-boulder 32% pebble-cobble 3.5% sand 1.5% pocket beach	moderate supply of till on mainland
Martinique Shoreline	Owls head to Halifax Harbour	86.7	13	50	1.6	91% Goldenville Fm. 18% Halifax Fm.	2% bedrock 8% sediment veneer 6% pebble-cobble	56% pebble-cobble 14% pocket beach 8% sand-cobble 6% sand	reworked beach sand and eroding drumlin bluffs less than 10 m high
Sambro Shore	Halifax Harbour to East side of Mahone Bay	307.3	13	14	1.8	83% granite 9% Halifax Fm. 4% Goldenville Fm. 4% Windsor Gp.	41% bedrock 10% pebble-cobble 10.5% sediment veneer	33% pebble-boulder 4% pebble-cobble 1% sand 0.5% pocket beach	exposed shore is sediment poor. Bays are supplied by drumlin till

TABLE 1 (Cont'd)

Name of Unit	Extent of Unit	Length of Unit (km)	Number of Profile Stations	Mean* Breaker Height (cm)	Tide Range (m)	Type of Bedrock	Beach/Shore Type		Sediment Sources
							Rock Outcrop	Beaches	
LaHave Shore	East side of Mahone Bay to Mouton Head	382.6	26	25	1.6m	40% Halifax Fm. 37% Goldenville Fm. 16% Windsor Gp. 7% granite	23% bedrock 13% pebble-cobble 3% sediment veneer	24% pebble-boulder 20% pebble-cobble 10% vegetated 4% sand-pebble 3% sand	reworked relict sed. No significant present day supply
Shelburne Shoreline	Mouton head to Pubnico Point	374.9	27	31	2.2m	59% Goldenville Fm. 21% granite 20% Halifax Fm.	8% pebble-cobble 0.2% bedrock 0.3% sediment veneer	44.5% pebble-cobble 22% pebble-boulder 15% marsh 9.5% sand 0.5% pocket beach	relict sediment and some drumlin erosion
Lobster Bay	Pubnico Point to Chebogue Point	169.5	6	calm	3.1m	72% Goldenville Fm. 14% granite 14% Halifax Fm.		77% marsh 12% pebble-boulder 11% pebble-cobble	some erosion of till in area of Tusket Wedge

TABLE 1 (Cont'd)

Name of Unit	Extent of Unit	Length of Unit (km)	Number of Profile Stations	Mean* Breaker Height (cm)	Tide Range (m)	Type of Bedrock	Beach/Shore Type		Sediment Sources
							Rock Outcrop	Beaches	
Yarmouth Shoreline	Chebogue Point to Sissiboo River	135.8	9	53	5.6m	32% Goldenville Fm. 29% Halifax Fm. 39% White RK. Fm.	13.5% bedrock 14% pebble-cobble	39% pebble-cobble 22% sand 8% vegetation 0.5% pebble-boulder 3% pocket beach	till from sheets and drumlins outwash material and reworked beach sediment
Digby Neck	Sissiboo River to Digby	190.5	7	35	6.5	77% Basalt 13% Annapolis Fm. 10% Goldenville Fm.	56% bedrock 4% pebble-cobble	36% pebble-cobble 3% sand 1% pebble-boulder	sediment poor St. Mary's Bay is supplied red shale and some outwash material

KEY TO TYPES OF BEDROCK

Canso Group - sandstone, shale
Horton Group - conglomerate, sandstone, shale
Windsor Group - limestone, shale
Annapolis Formation - conglomerate, sandstone, red shale
Goldenville Formation - quartzite
Halifax Formation - slate
White Rock Formation - quartzite with interbedded slate
*Wave Breaker Heights are averaged from instantaneous observations collected at each profile site within the Morpho-dynamic Unit.

for north Chedabucto than those calculated for the Canso Strait morphodynamic unit.

Grain size on beaches of this unit varies from pebble to cobble. Intertidal zones consist of finer material that ranges in size from very coarse sand to pebble. Cobbles are usually resistant fragments of Goldenville quartzite whereas the finer material is less resistant sandstone and arkose from local Triassic strata. Lithology and size of beach material closely matches that of the local eroding drumlins. Waves directed toward beaches of this unit are of two different types: Atlantic Ocean waves that refract around Cape Canso ledge and locally generated waves. Neu (1970) reported that most of the wave energy in Chedabucto Bay occurs in the 7 to 12 seconds period band. Due to the available fetch limitations within the bay, locally generated waves usually have periods of less than 9 seconds.

South Chedabucto

Extending from Guysborough town to Fox Island, the South Chedabucto unit is underlain by rocks of the Meguma Group. The identifying features of the unit are: a rectilinear strand, low near-vertical cliffs along the backshore, a limited sediment supply, and a steep nearshore slope. These features all reflect the faulted origin of this shoreline (Johnson, 1925). The characteristics of this unit offer a sharp contrast to the cuspate sediment rich north Chedabucto unit which has a very gradual nearshore slope, although both the north and south Chedabucto units are exposed to essentially the same wave climate.

Most of the South Chedabucto Bay unit has bedrock shores, with pocket beaches occurring at either end of the unit. Grain size of pocket beach sediment varies from medium sand to cobble.

Cape Canso

The Cape Canso unit lies between Fox Island and Indian Harbour, Guysborough County. The irregular shoreline of this unit, with its large open bays and long, narrow, NNE-trending fault line harbours is exposed to the Atlantic Ocean wave climate. Shoreline form and wave climate differentiate this from other units already examined.

A layer of till less than 1 m thick covers the Devonian granite and meta-sedimentary rocks belonging to the Meguma Group that underlie this area. Relief in the coastal zone rarely exceeds 30 m.

Bedrock shores makes up much of the strand of this unit. Sand beaches occur in New Harbour Cove and near Berry Island at the west entrance to Tor Bay and there is a bimodal sand-cobble beach in Indian Harbour. There is no obvious present day input of sand into any of these beach systems. Pebble-cobble beaches are common where there is sediment being supplied by actively eroding drumlins. The relationship between pebble-cobble beaches and eroding drumlins is best displayed at Holland Head at the east entrance to Indian Harbour (Fig. 2)

Bay of Islands

The portion of coastline from Indian Harbour, Guysborough County to Owl's Head, Halifax County is the Bay of Islands unit. Nearshore islands and shoals aligned with the strand of this unit provide a complex pattern

of bathymetry such that the open ocean waves expend most of their energy in the nearshore zone and not on the shoreline. Serving as a natural breakwater to incoming waves the structurally aligned nearshore islands are the dominant characteristic that distinguishes this unit from the previous Cape Canso unit.

The Bay of Islands coastal zone has numerous deposits of unconsolidated glacial material. However, wave energy expended on the beaches is not sufficient to rework and sort the beach sediment. Beaches are only wider near particular sediment sources which suggests that there is little longshore transport along this sheltered environment. Portions of shoreline that do receive moderate amounts of wave energy have well sorted pebble-cobble beaches. The double tombolo spits that join two islands to form Sober Island are examples of such beaches.

Martinique

The Martinique unit extends from Owl's Head to Halifax Harbour. Shoreline morphology and an ample sediment supply differentiate this section from the Bay of Islands and Cape Canso units. Backshore drumlin bluffs have maximum elevations of 30 m in this unit. With no nearshore islands, beaches of this unit receive the full force of open ocean waves. This is especially true for beaches like Martinique, that have a low nearshore slope.

Beaches of this unit are composed of resistant pebble-cobble (of Goldenville formation lithology); medium grained sand; or are bimodal sand-cobble. Actively eroding drumlin bluffs, that become more frequent toward Halifax, serve to provide sediment to the littoral zone under present day

conditions. Bimodal sediment beaches and sand beaches are most common in this unit.

Sambro

The Sambro unit takes in the coastal zone from the west entrance of Halifax Harbour to Graves Island in Mahone Bay. The area is underlain by Meguma Group rocks and Devonian granite. Mississippian strata of the Windsor Group rest unconformable on top of the granite around the perimeters of Mahone and St. Margaret's Bays.

The Cape Canso unit, part of which is also underlain by granite, is similar to the Sambro unit. However, a steep nearshore slope; high onshore relief; a greater supply of sediment available to the littoral zone; and a strand morphology marked by two unusually large bays, distinguish this morpho-dynamic unit from the Cape Canso unit. Exposed portions of this unit, like Chebucto Head, receive the full force of ocean waves whereas shorelines within St. Margaret's Bay and Mahone Bay are sheltered and only exposed to locally generated waves.

Bedrock shores occur along exposed portions of this unit (Fig.2). Beaches of unsorted pebble-boulder size material are found in harbours and bays that are sheltered from wave activity. In St. Margaret's Bay some beaches are composed of sand and cobble; however, due to the lack of wave activity, these beaches do not display the lateral sand-cobble distribution common to more exposed beaches.

LaHave

The LaHave morpho-dynamic unit reaches from Graves Island to Mouton Head. Embayed shoreline morphology differentiates this unit from other units. Wave approaching the shoreline east of the LaHave Islands dissipate some of their energy in the bathymetrically complex nearshore zone. West of the LaHave Islands isobaths generally parallel the shoreline, which has steeper nearshore slopes and therefore is more exposed to the ocean wave climate.

Maximum relief in the LaHave unit is 90 m. Along the backshore drumlin bluffs have elevations of 20 m in the vicinity of Lunenburg, but this relief decreases toward the southwest.

Beaches in Mahone Bay are made up of poorly sorted material derived from drumlins. Relict sand beaches are frequent from Green Bay southwest to Mouton Head and where they are adjacent to actively eroding drumlins substantial quantities of cobble have been added to the beach. Since eroding drumlin bluffs decrease in frequency toward Mouton Head, the amount of cobble clasts observed on the sand beaches also decreases in that direction.

Shelburne

The Shelburne unit reaches from Mouton Head to Pubnico Point. In the areas of Barrington and Port Mouton, this unit is underlain by Devonian granites. The remainder of the unit is underlain by meta-sedimentary rocks of the Meguma Group. A limited supply of unconsolidated material is available to the littoral zone in some districts; for the most part the nearshore zone of this unit is sediment starved. The Shelburne unit occurs

in a mesotidal (2-4 m) environment. All other units previously discussed occurred in a microtidal (<2 m) environment.

The irregular strand form of this unit is somewhat similar to the Martinique unit. Unlike the Martinique section, this unit has larger bays and inlets; a greater tidal range; a more complex nearshore bathymetry; and very few actively eroding drumlins. Both units are exposed to the ocean wave climate. Approaching waves would undergo a greater degree of refraction and expend more energy in the Shelburne nearshore zone than that of the Martinique unit.

Beaches in this unit are made up of a relict sediment, no significant modern day supply of unconsolidated material is available for beach development. Depositional barriers and spits are less frequent at inlet entrances of this section than the Martinique unit. Sheltered beaches occurring in harbours and inlets of this unit, are made up of pebble-boulder size material. More exposed beaches are composed of relict sediment; either sand or cobble.

Lobster Bay

From Pubnico Point to Chebogue Point the Lobster Bay unit is a salt marsh environment. Only parts of the Tusket Wedge and Pubnico shorelines are not obscured by salt marsh vegetation. This unit is sheltered from incoming waves by a low nearshore slope, and an intricate nearshore bathymetry. Tusket Wedge extends south as a series of shoals out to and beyond Seal Island, thereby sheltering Lobster Bay from waves from the southwest. Numerous drumlin islands and shoals at the entrance to Lobster Bay also help dissipate the energy of incoming waves. Chebogue Harbour and

Little River Harbour are also protected by a similar bathymetry. A low energy, sheltered environment and a mesotidal range promote the growth of salt marsh vegetation within this unit.

Yarmouth

This unit takes in the shoreline from Chebogue Point to the Sissiboo River. This and the remaining units all occur in a macrotidal (>4 m) environment. Except for an area around Yarmouth which is underlain by the White Rock Formation, this unit rests on rocks of the Meguma Group. In terms of coastal dynamics, the macrotidal environment distinguishes this unit from other units examined so far. A distinctive, yet variable shoreline form, and a moderate sediment supply to the littoral zone from several sources also serve to distinguish this from previous units.

Beaches from Yarmouth north to Cape St. Mary are composed of what is probably relict sand with some modern day input from eroding drumlin deposits.

North of Cape St. Mary to Pointe à Tom the shoreline is characterized by near vertical rock cliffs that have average heights of about 12 m. Where a present day source is absent, relict sediment of the pebble-cobble size composes intertidal beaches that occur at the base of cliffs along this portion of the unit.

Depositional barrier spits and open beaches extend from Pointe à Tom north to the Sissiboo River. Material is supplied to the beaches from a number of glacial deposits. Shoreline morphology of the northern section of this unit indicates a net longshore transport toward the north.

Digby Neck

The Digby Neck unit takes in the portion of coast from the Sissiboo River to Digby. The coastal unit rests on the Goldenville Formation, from Sissiboo River to the head of the St. Mary's Bay; the Annapolis Formation, at the head of St. Mary's Bay; and the North Moutain Basalt, along the remainder of the unit. Like the South Chedabucto unit, this unit has a recti-linear shoreline and a limited sediment supply. However, a macro-tidal environment and greater relief distinguish this unit from the south Chedabucto unit. The northwest portion of Digby Neck is an exposed shoreline whereas the section within St. Mary's Bay is somewhat sheltered from wave attack. Maximum relief in this unit is 100 m. Low steep outcrop cliffs on the southern shoreline have average elevations of 30 m. Nearshore slopes are steep on the northwest shoreline, but are lower within St. Mary's Bay.

Glacial outwash and raised beach deposits (Grant, 1971) are the major source of sediment supplied to the littoral zone between the head of St. Mary's Bay and the Sissiboo River (N.S. Soil Survey Report #11, 1962). The tidal flat at the head of St. Mary's Bay receives its sediment from eroding outcrops of sandstone belonging to the Annapolis Group. From Griffen Cove to Digby, beaches occur as intertidal deposits. Outwash material on Digby Neck is important only locally as a source of sediment.

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Appendices

Appendix 1. Wave refraction diagrams for 8 sec waves from the southwest.

Appendix 2. Beach stations-maps and directions how to locate them and beach profile diagrams.

Appendix 3. Summary statistics for sediment sampled at beach stations.

Appendix 4. 1:50,000 maps of shoreline materials and major landforms along the Atlantic coast of mainland Nova Scotia.

Appendix 5. Oblique aerial photographs (slides) of the study area and ground photos from beach stations.

Appendix 6. Field survey data for beach profile stations.

APPENDIX 1

Wave refraction diagrams for 8 sec waves from the southwest.

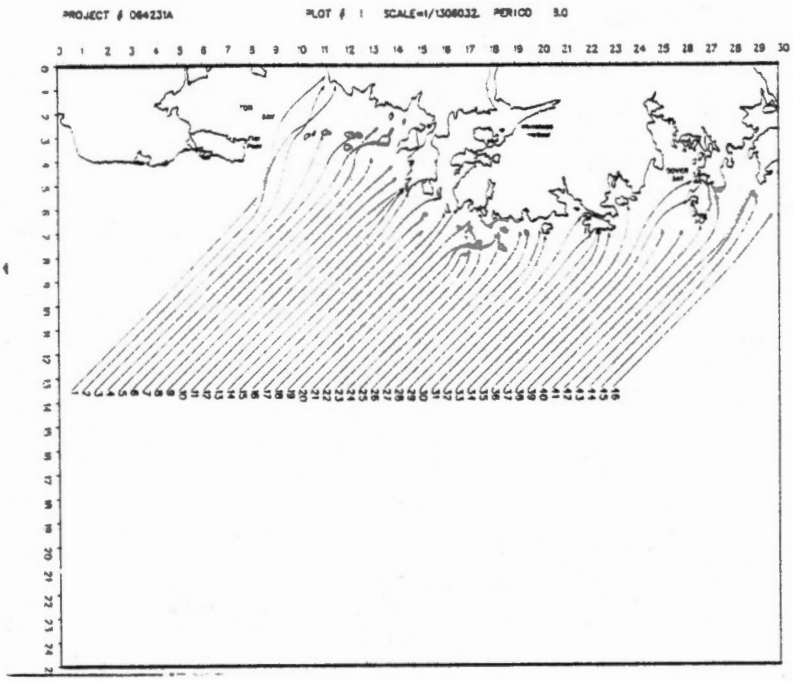

Fig. 1 Wave refraction diagram drawn for an 8.0 second wave approaching from the southwest; most common during the summer season. Exposed shoreline where incoming waves undergo little refraction, occurs in the Lower Whitehaven area.

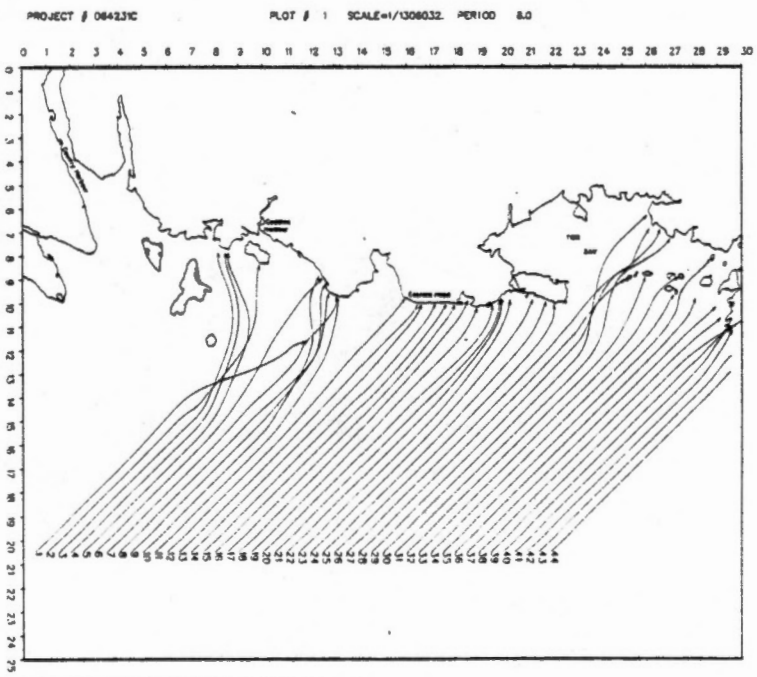

Fig. 2 West of Lower Whitehaven lies Eastern Head; another portion of coast that is exposed to incoming waves (8.0 sec. from SW) as indicated by this wave refraction diagram.

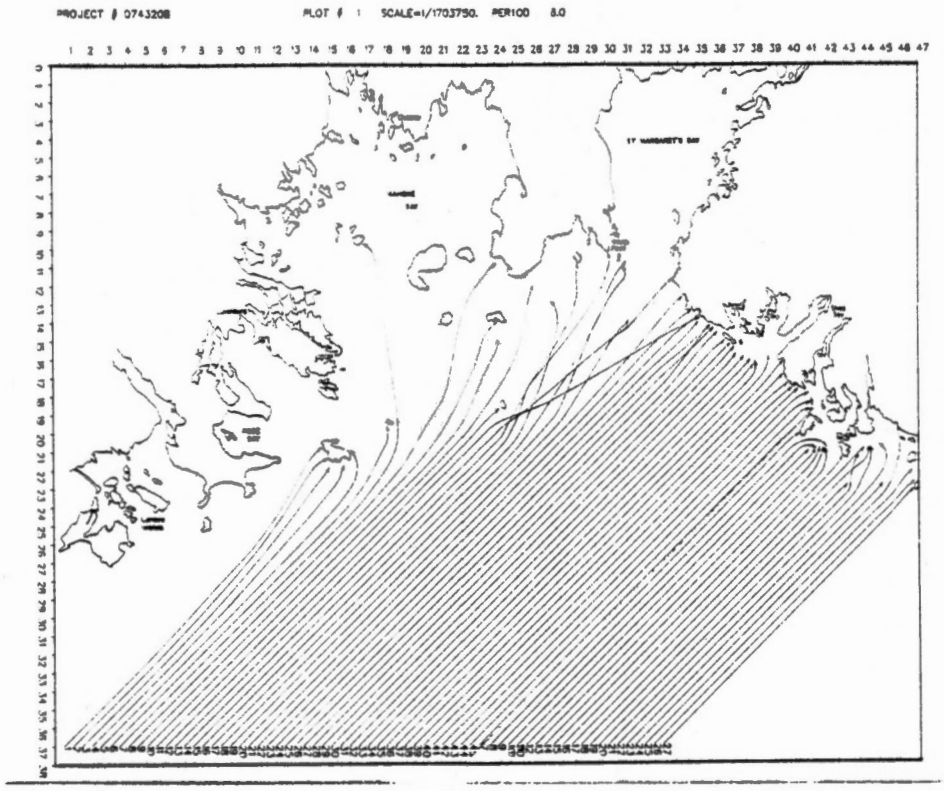

Fig. 3 Wave refraction diagram indicates that portions of the coast from Pennant Point west to Indian Harbour are exposed to waves (8 sec) from the southwest.

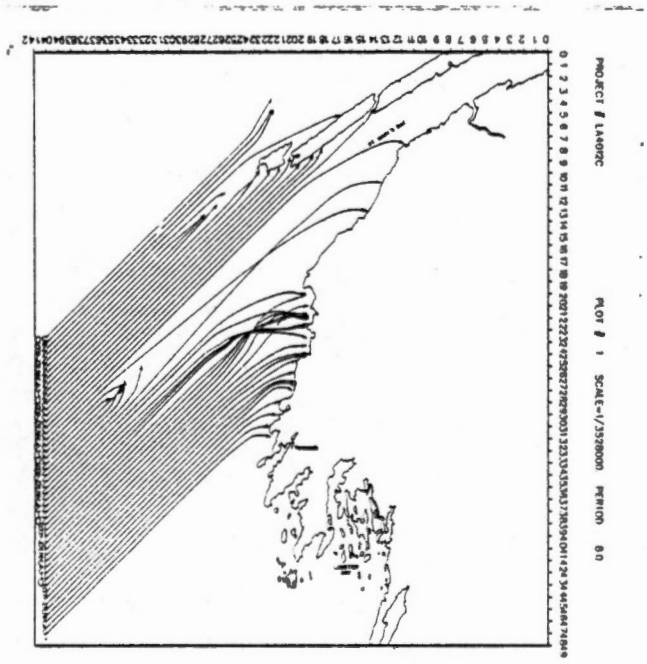

Fig. 4 The coast from Yarmouth north to Digby County is exposed to wave attack from the southwest. Waves undergo little refraction in their approach to this coast.

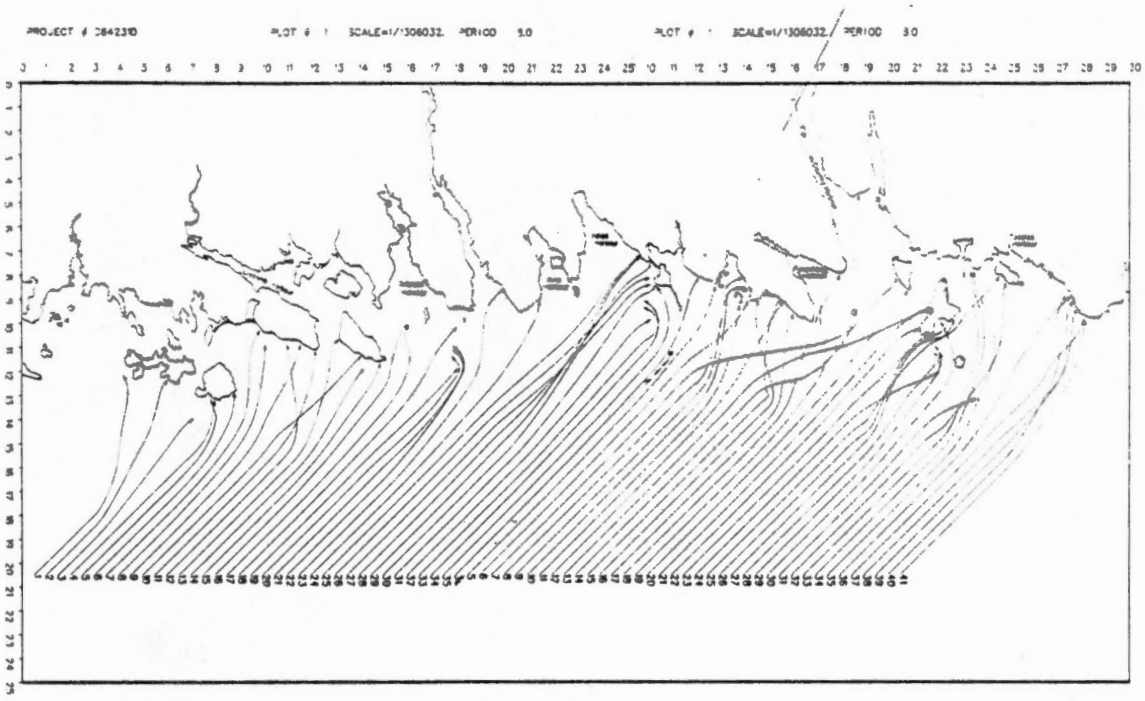

Fig. 5 Moderately exposed sections of coast occur between Liscomb Harbour and New Harbour. Along this irregular shoreline 8 sec period waves are refracted such that most of their energy is expended on headlands.

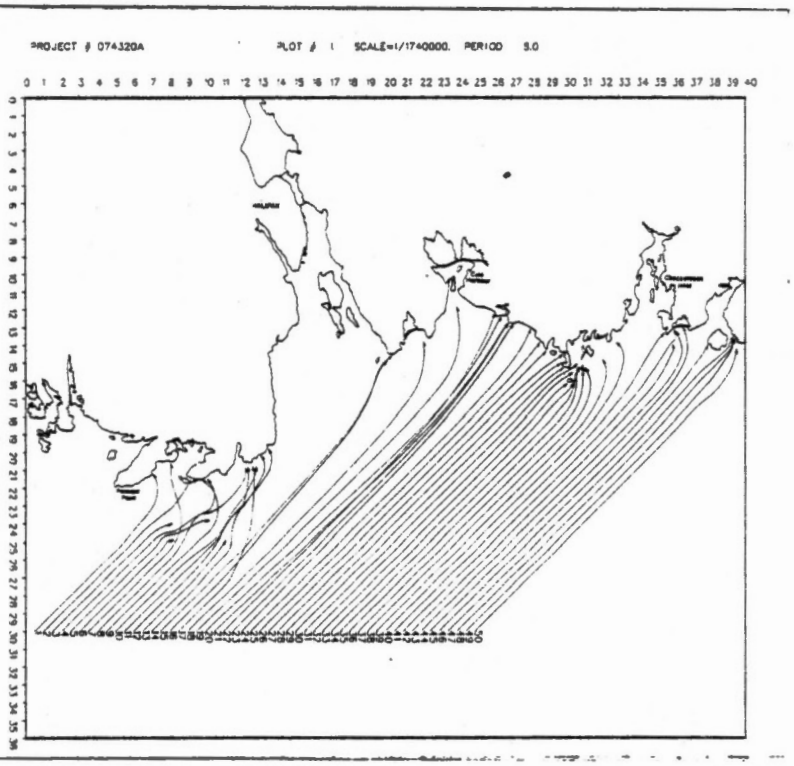

Fig. 6 Waves approaching the shoreline between Owl's Head and Halifax are refracted by the nearshore bathymetry. This district is moderately exposed to wave attack from the southwest.

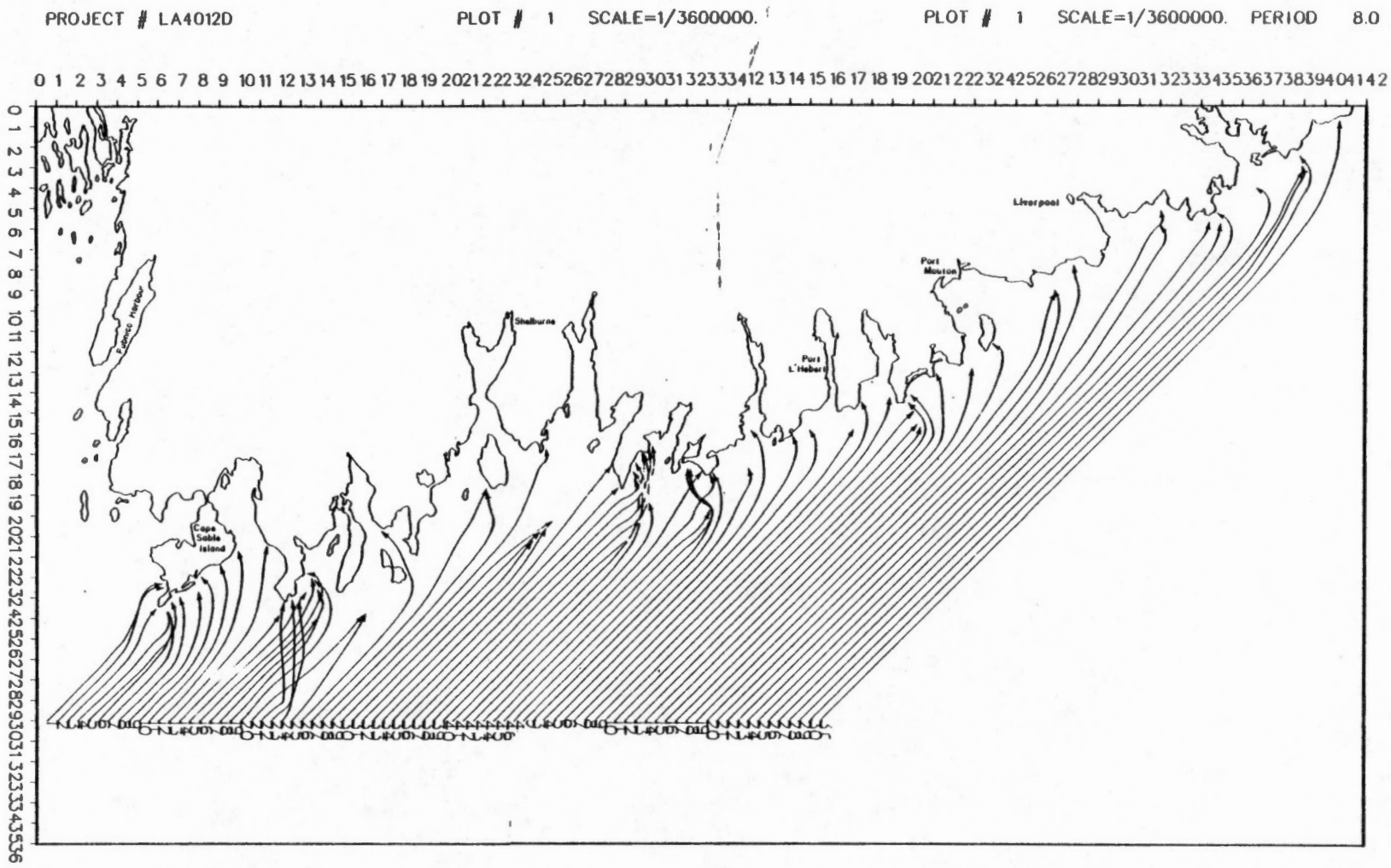

Fig. 7 Moderately exposed shoreline between Lunenburg and Cape Sable Island. As shown by this wave refraction diagram, waves with an 8.0 second period approaching from the southwest, are refracted by nearshore shoals and also by the shoreline slope.

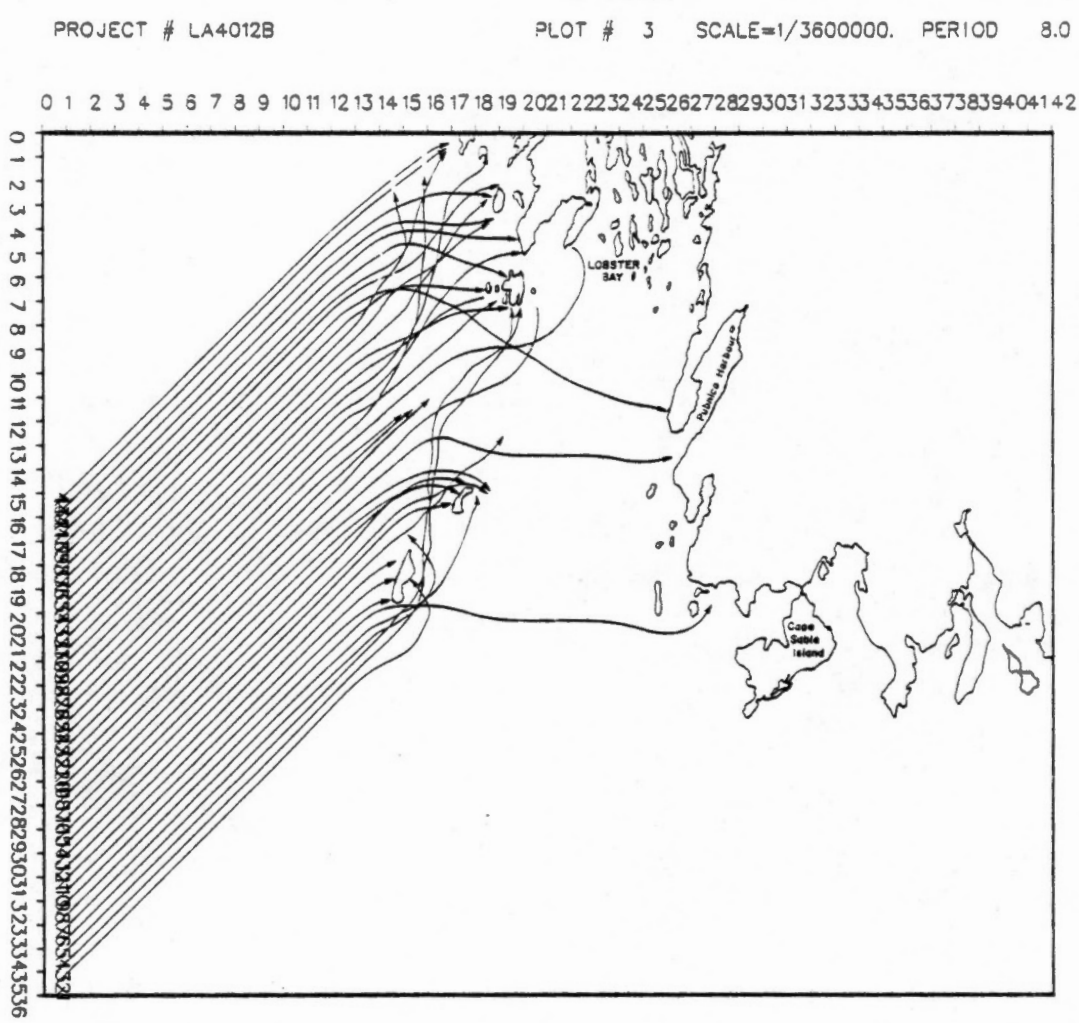

Fig. 8 A complex nearshore bathymetry shelters the shoreline of Lobster Bay from incoming waves, thus enhancing salt marsh development. Wave refraction diagram is for 8.0 second waves approaching from the southwest.

APPENDIX 3

Summary statistics for sediment sampled at beach stations.

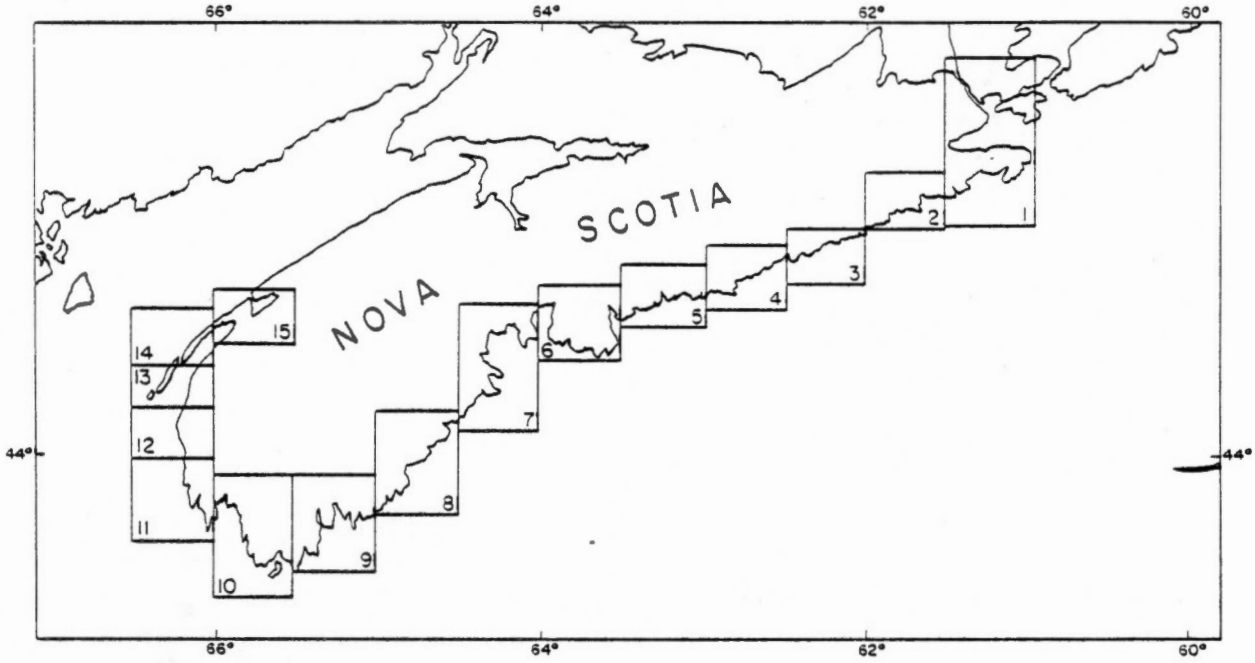

Figure 3. Key to map sheets in Appendix 4.

APPENDIX 5

Oblique aerial photographs (slides) of the study area and ground photos from beach stations.

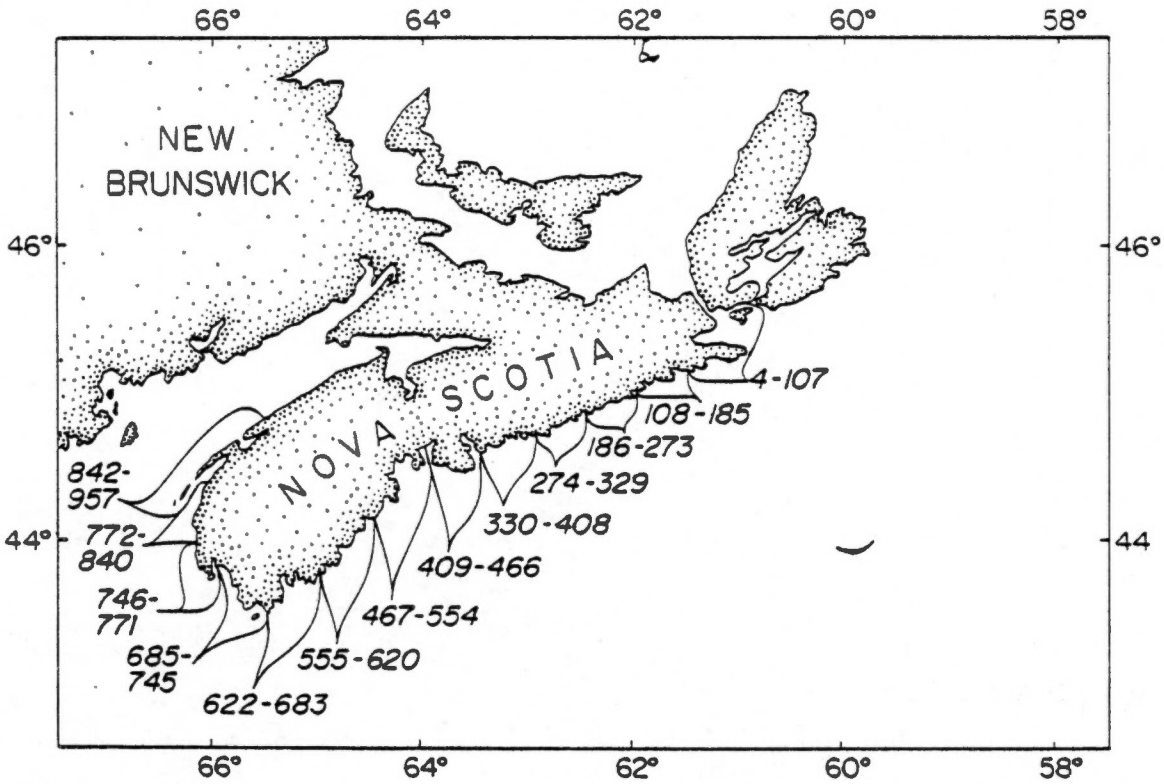

Figure 4: Index map showing locations of aerial oblique coastal photographs (slides) taken along the study area.

APPENDIX 6

Field Survey Data For Beach Profile Stations

```
      PROGRAM PLOT(INPUT,OUTPUT,TAPE6=OUTPUT,TAPE24=0)
      REAL DATAX(100),DATAY(100),TRANS(6),Q(6),D(6,316)
      INTEGER PIC,A(316),B(316),C(316),WATER,SAMPA
      COMMON/LAVSA/A/LAVSB/B/LAVSC/C/LAVSD/D
      DATA TX/0.0/,TY/40.0/,        SY/4.0/,TH/0.0/,SK/0.0/
      SX=1./3.
      XMOVE=150.
      YMOVE=150.
      DATA PIC/0/,NEWPIC/0/,PIBY2/1.570796/
      CALL INITQ(316)
    5 READ * ,PRONUM,DATE,STAKHT,N, WATER
C     IF PRONUM = -0. THEN THERE ARE NO MORE PLOTS.
      IF(PRONUM .EQ. -0.) STOP
      READ *,ICHECK
      READ * ,(DATAX(I),I=1,N)
      READ * ,(DATAY(I),I=1,N)
      CALL MOOVQ(XMOVE,YMOVE)
      IPEN=0
      X=0.0
      Y=DATAY(1)/100.0
      CALL ADPTQ(X,Y,IPEN,PIC)
      IPEN=1
      Y=0.0
      DO 40 I=1,N
      DATAY(I)=DATAY(I)/100.0
      X=DATAX(I)+X
      DATAX(I)=X
      Y=DATAY(I)+Y
      DATAY(I)=Y
      CALL ADPTQ(X,Y,IPEN,PIC)
   40 CONTINUE
      XHOLD=X
C     IF ICHECK = 1 THEN THERE ARE SAMPLES.
      IF (ICHECK .NE. 1) GO TO 42
    1 READ *,SAMPA
      IF(SAMPA .EQ. -1) GO TO  42
      X=DATAX(SAMPA)
      Y=DATAY(SAMPA)-.25
      IPEN=0
      CALL ADPTQ(X,Y,IPEN,PIC)
      IPEN=1
      Y=Y-.25
      CALL ADPTQ(X,Y,IPEN,PIC)
```

```
      GO TO 1
   42 CONTINUE
C     IF WATER IS = -1 THEN THERE IS NO WATER LINE
      IF (WATER .EQ. -1) GO TO 45
      X=DATAX(WATER)
      Y=DATAY(WATER)+.25
      IPEN=0
      CALL ADPTQ(X,Y,IPEN,PIC)
      IPEN=1
      Y=Y+.25
      CALL ADPTQ(X,Y,IPEN,PIC)
   45 IPEN=0
      F=-6.
      SX=SX*3.
      CALL XFSTQ (5.,F ,SX,1.5,TH,SK,Q)
      CALL LABLQ(10HPROFILE NO,10,Q,NEWPIC)
      CALL XFSTQ(16.,F ,SX,1.5,TH,SK,Q)
      CALL NMBRQ(PRONUM,-1,1,Q,NEWPIC)
      F=F-2.
      CALL XFSTQ (5.,F ,SX,1.5,TH,SK,Q)
      CALL LABLQ(4HDATE,4,Q,NEWPIC)
      CALL XFSTQ(16.,F ,SX,1.5,TH,SK,Q)
      CALL NMBRQ(DATE,-1,1,Q,NEWPIC)
      F=F-2.
      CALL XFSTQ (5.,F ,SX,1.5,TH,SK,Q)
      CALL LABLQ(9HSTAKE HT.,9,Q,NEWPIC)
      CALL XFSTQ(16.,F ,SX,1.5,TH,SK,Q)
      CALL NMBRQ (STAKHT,-1,1,Q,NEWPIC)
      CALL XFSTQ(21.,F ,SX,1.5,TH,SK,Q)
      CALL LABLQ(2HCM,2,Q,NEWPIC)
      SX=SX/3.
      CALL XFSTQ(TX,0.0,1.,1.0,PIBY2,SK,Q)
      Y=50.0
      KK=10
      CALL AXISQ(Y,KK,0.,5.,-1.,0,Q,NEWPIC)
      CALL XFSTQ(TX,0.0,SX,1.0,TH,SK,Q)
      K=IFIX(XHOLD/20.)+1
      X=K*20.
      CALL AXISQ(X,K,0.,20.,1.0,0,Q,NEWPIC)
      CALL XFSTQ(TX,TY,SX,SY,TH,SK,TRANS)
      CALL ADELQ(PIC,TRANS,NEWPIC)
      CALL STSWQ(565,24)
      CALL DISPQ(NEWPIC,15.)
      CALL EMPTQ(PIC)
```

```
      CALL EMPTQ(NEWPIC)
      XMOVE=X*15.+200.
      YMOVE=0.0
      CALL DRAWQ(0.,0.,0)
      CALL DRAWQ(0.,0.,-1)
      GO TO 5
      END
1.        1917178.  88.       12        8
2
3.      3.      3.      1.      2.      1.      1.      3.      3.      3.
3.      1.
-75.    -82.    -79.    -39.    -68.    -85.    -89.    -128.   -34.    -20.
-28.    -4.
2.        1917178.  100.      20        16
2
3.      3.      3.      3.      3.      2.      .5      .5      2.      1.
1.      .5      .5      1.      3.      1.      2.      3.      3.      3.
-24.    -16.    -12.    -10.    -4.     -26.    -65.    -18.    -102.   -16.
-19.    -54.    -14.    -20.    -30.    -8.     -21.    -28.    -16.    -36.
3.        1917176.  96.       20        13
2
3.      3.      3.      3.      3.      3.      2.      .5      3.      2.
2.      .5      2.      3.      3.      3.      3.      3.      3.      3.
9.      -15.    7.      -24.    -27.    -13.    0.      -46.    -55.    -22.
-17.    -19.    -48.    -42.    -14.    -24.    -18.    -14.    -12.    -10.
4.        1917178.  104.      43        29
2
3.      3.      3.      3.      3.      3.      3.      3.      3.      3.
3.      3.      3.      3.      3.      3.      3.      3.      3.      3.
3.      3.      3.      3.      3.      3.      3.      3.      3.      3.
3.      3.      3.      2.      3.      3.      3.      3.      3.      3.
3.      3.      3.
46.     30.     10.     -6.     4.      8.      8.      3.      4.      6.
10.     16.     10.     10.     4.      18.     22.     22.     38.     4.
-31.    -48.    -32.    -32.    -18.    -42.    -41.    -34.    -32.    -21.
-25.    -23.    -25.    -23.    -11.    2.      2.      0.      12.     6.
-7.     0.      1.
5.        1917178.  82.       32        21
1
3.      3.      3.      3.      3.      3.      3.      3.      1.      1.
1.      1.      3.      1.      3.      3.      3.      3.      3.      3.
3.      2.      1.      1.      3.      3.      3.      3.      3.      3.
3.      3.
-10.    2.      -1.     0.      6.      5.      2.      10.     4.      4.
```

```
-80.    -69.    -51.    -31.    -48.    -38.    -44.    -32.    -26.    -27.
-32.    -18.    -21.    -9.     2.      -16.    -8.     -6.     0.      -19.
-3.     -8.
15
18
-1
6.        917178.  128.      20        20
2
3.      2.      1.      .25     3.      3.      3.      1.7     1.3     3.
2.4     .6      3.      3.      3.      3.      3.      3.      3.      2.
54.     30.     28.     -6.     -58.    -52.    20.     -30.    -16.    -56.
-46.    18.     -36.    0.      4.      -45.    -10.    -18.    4.      -14.
8.        1917178.  106.      18        14
2
3.      3.      3.      1.      3.      1.      3.      3.      3.      3.
3.      3.      3.      3.      3.      3.      3.      3.
-25.    -21.    29.      -20.   -86.    -50.    -33.    -30.    -22.    -16.
-36.    -30.    -26.    -26.    -24.    -6.     -36.    -70.
9.        1917178.  80.        38        33
2
3.      3.      3.      3.      3.      3.      3.      3.      3.      3.
3.      3.      3.      3.      3.      3.      3.      3.      3.      3.
3.      3.      3.      1.      1.      1.      3.      2.      1.      1.
3.      3.      2.      3.      3.      3.      3.      3.
-33.    0.      -12.    -13.    -6.     14.     3.      4.      2.      -5.
-1.     0.      2.      2.      2.      -1.     3.      -10.    -14.    -36.
-30.    -26.    -17.    -10.    4.      6.      -14.    -24.    -2.     0.
-51.    -32.    -21.    -30.    -24.    -26.    -23.    -26.
10.       1917178.  142.      15        15
2
3.      3.      3.      3.      3.      .6      2.4     3.      3.      3.
3.      2.      1.      3.      3.
-13.    -8.     -13.    -15.    -24.    -5.     -4.     -19.    -12.    -46.
-64.    -122.   -46.    -106.   -69.
11.       1917178.  106.      7         6
2
3.      .5      .5      2.      3.      3.      3.
-35.    -47.    0.      -29.    -31.    -78.    -23.
12.       2017178.  104.      16        15
2
3.      3.      3.      3.      3.      1.      2.      3.      3.      3.
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-20.    -23.    -49.    -24.    -22.    -24.    -52.    -28.    -25.    -32.
-38.    5.      -22.    -8.
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2
3.      3.      3.      3.      3.      3.      3.      3.      1.      3.
0.      0.      0.      0.      0.      0.      0.      0.      -76.    0.
156.      3118178.  118.      36        36
2
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157.      119178.   119.      24        22
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10.       3.        3.        1.        .04       .5        .46       3.        3.        1.7
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-0.
 EOI ENCOUNTERED.
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