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A QUANTITATIVE, PHOTOGRAMMETRIC ANALYSIS OF NARRAGANSETT BAY, RHODE ISLAND SHORELINE CHANGES, 1938-1975

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by

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ABSTRACT

The shoreline of Narragansett Bay, R.I. was analyzed for erosion and accretion rates using photogrammetric techniques. Vertical aerial photographs were used to map the 1938 and 1975 shorelines. Comparative mapping of the shorelines was done utilizing a zoom-transfer scope which enabled elimination of photographic distortion. A digital planimeter was used to make areal measurements of erosion and accretion. The 360 km of shoreline was first mapped and divided into segments according to its composition: beach, dune, cliff, or man-made structure. These segments were then measured for changes in area. Changes in beach area were presented in conjunction with shoreline surficial composition.

Areas of high erosion and accretion rates are discussed in relation to probable causal factors, such as relative erosional resistance of beach material, wave fetch, wind characteristics, bathymetry, tidal current velocity data, and local river discharge.

Areas of greatest sediment movement during the study period were cuspate shoreforms. The greatest amounts of shoreline change not engineered by man were found at McCurry and Sandy Points, on Aquidneck Island. This change is attributed to the migration of the shoreforms and is measured at a maximum of 1.7 m/yr of erosion and accretion for McCurry Point and 1.5 m/yr and 0.6 m/yr of erosion and accretion respectively for Sandy Point. Areas of little or no erosion ususally occurred in protected coves, on bedrock beaches, and at man-made engineering structures. Approximately 30% of the shoreline of the bay showed little or no erosion from 1938-1975. Average erosion for those beach areas exhibiting change was 0.3 cm/yr.

A sediment budget analysis was conducted to determine the volume of sediment eroded from and added to the shoreline and to determine what percentage of eroded sediment was redeposited along the shoreline. Values were calculated for total sediment volumes and for volume percentage of cobbles and pebble, gravel, sand and silt-sized particles. Of all the sediment eroded from the shoreline, 40% was redeposited. Sand-sized material showed the highest shoreline redeposition rate for both outwash and till shorelines. Silt-sized particles were not redeposited.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

Page

Page

Page

Page

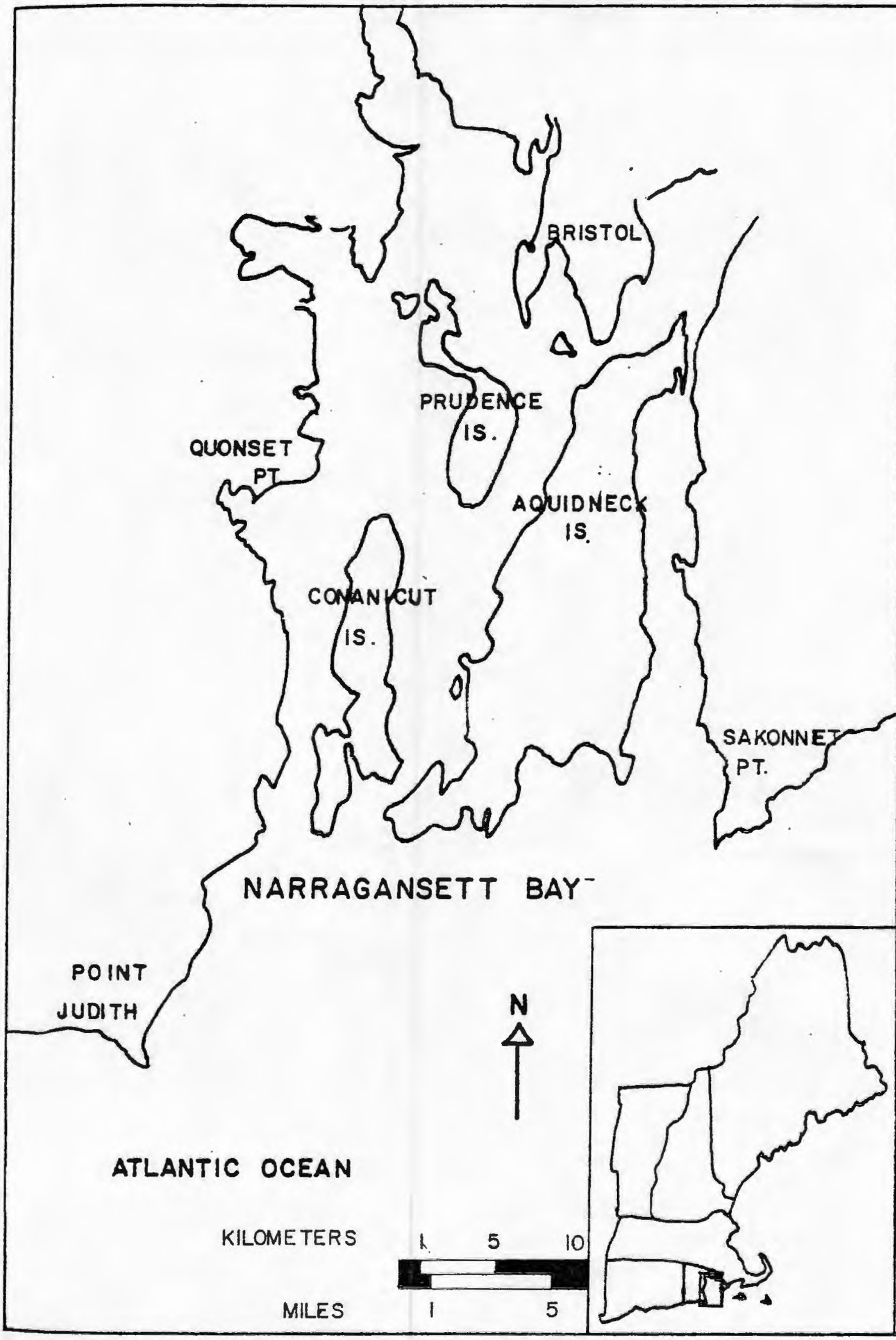
INTRODUCTION

Narragansett Bay covers approximately 259 square kilometers in the southeast corner of the State of Rhode Island. It extends from the state capitol of Providence in the north, 32 kilometers south to Rhode Island Sound and the Atlantic Ocean. It contains three major islands: Aquidneck, Conanicut, and Prudence Islands. There are numerous smaller islands. The three entrants to this estuary are West Passage, East Passage, and the Sakonnet River.

The three major causes of increased erosion along the shorelines of the United States are hurricanes and severe storms, recent eustatic sea level rise, and interference by man with natural shoreline processes (El Ashry, 1971). The Narragansett Bay shoreline is subject to all three factors. As land use along the perimeter of the bay expands with growing population and industrialization, proper planning and design must be utilized for the protection of the shoreline and, consequently, of the use to which the shore is to be put.

The present study provides quantitative data that are directly applicable to decision-making concerning proper land use and shore protection. The Narragansett Bay shore is mapped with the use of 1938 and 1975 vertical aerial photographs and a zoom-transfer scope. Average erosion and accretion area change rates for the period 1938 to 1975

Figure 1. Location Map.


BRISTOL
PRUDENCE IS.
QUONSET PT.
AQUIDNECK IS.
CONANICUT IS.
SAKONNET PT.
NARRAGANSETT BAY
POINT JUDITH
N
ATLANTIC OCEAN
KILOMETERS
1 5 10
MILES
1 5

are measured with a digital planimeter. Change rates are computed for high tide line and top of dune, cliff, or man-made structure line. The latter three will be designated for general discussion as "back beach line".

Since one of the factors affecting erosion susceptibility is the composition of the material being eroded, change rates are measured and expressed according to shoreline composition. Results are presented as shoreline area and volume change per year.

A sediment budget analysis is performed to give a general idea of how much sediment eroded from the shore during the study period was lost from circulation, and how much was redeposited on the shore. Grain size analyses are used to determine in a general way the behavior of cobble and pebble, gravel, sand, and silt-sized material.

The movement of sediment and the development of shoreline deposits, such as cuspate shoreforms, are discussed in conjunction with existing wind, wave, current, bathymetric, and construction data.

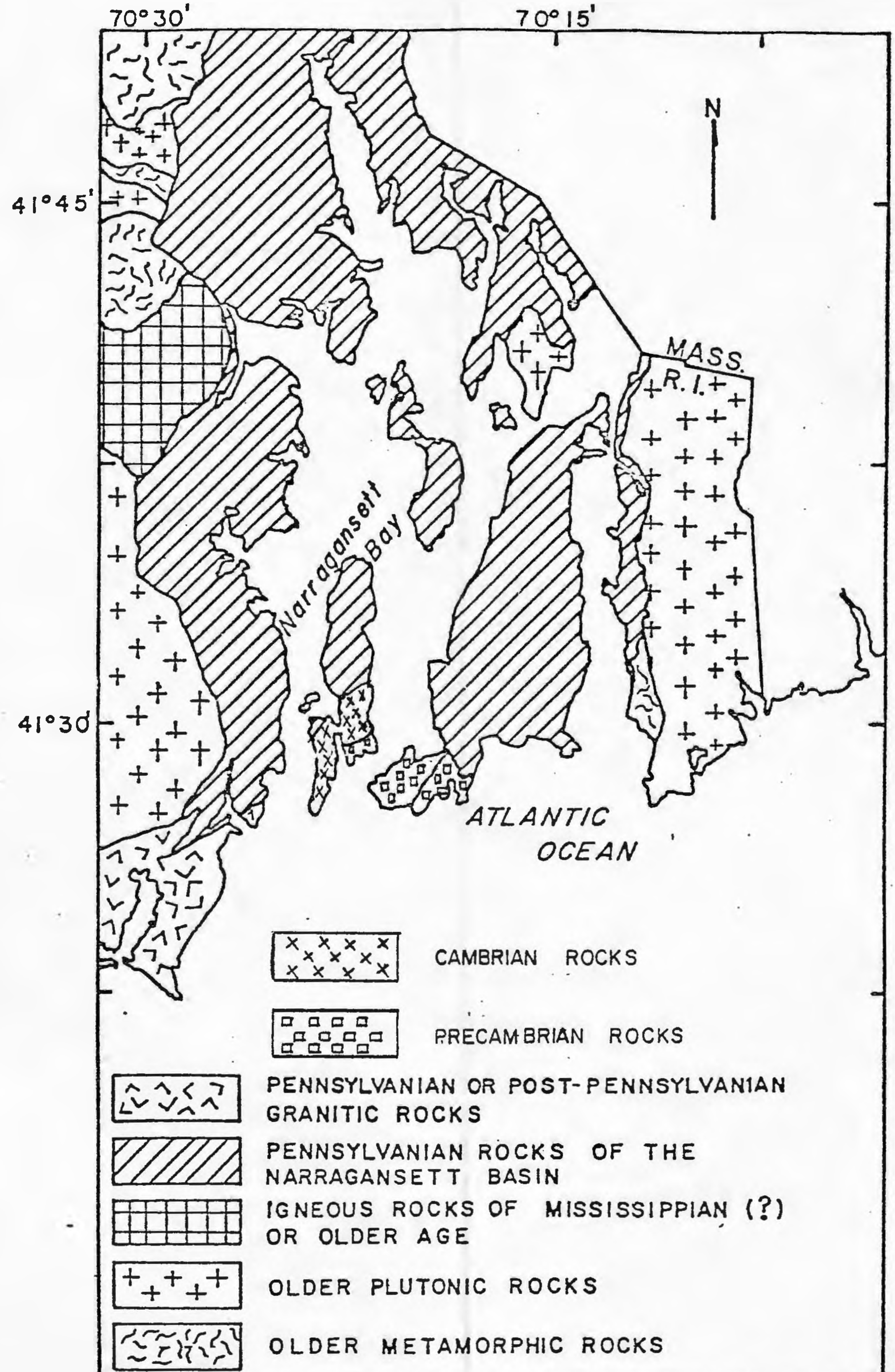
GEOLOGIC SETTING

BEDROCK GEOLOGY

Narragansett Bay is geologically a part of the Narragansett Basin, which underlies the eastern half of Rhode Island and part of Massachusetts (Fig. 2). It is a topographic as well as a sedimentary basin, and Narragansett Bay is the lowest and drowned portion. (Quinn, 1953). The basin extends 56 kilometers north of the bay head, and its structure limits the East-West boundaries of the bay (Fisher, 1970). The basin contains conglomerate, sandstone, whale, and meta-anthracite, which are Pennsylvanian in age; the basin developed as part of the Appalachian Revolution (Quinn, 1953). There have been at least two deformations in the area. The northern part of the basin is almost unmetamorphosed, but metamorphic grade increases toward the southeast to sillimanite grade. (Skehan and Murray, 1979). Although basin rocks are less resistant to erosion than the surrounding rocks, resistance increases with metamorphic grade to the southeast. (Upson, 1964).

The structural trend of the basin rocks in the vicinity of Narragansett Bay is nearly north-south. (Skehan and Murray, 1979). Johnson (1925) believes this trend to be the cause of the north-south elongation of the bay's islands and passages. Prior to the last glaciation, what is now the bay was

Figure 2. Generalized Bedrock Geology of the Narragansett Bay Region. (After Quinn, 1971, Shipman, 1978, and Skehan, et al, 1981).


70°30'
70°15'
41°45'
41°30'
N
MASS.
R.I.
Narragansett Bay
ATLANTIC OCEAN
CAMBRIAN ROCKS
PRECAMBRIAN ROCKS
PENNSYLVANIAN OR POST-PENNSYLVANIAN GRANITIC ROCKS
PENNSYLVANIAN ROCKS OF THE NARRAGANSETT BASIN
IGNEOUS ROCKS OF MISSISSIPPIAN (?) OR OLDER AGE
OLDER PLUTONIC ROCKS
OLDER METAMORPHIC ROCKS

three bedrock river valleys. The Blackstone River Valley entered the bay through the present Greenwich Bay and continued down what is known today as West Passage. (McMaster, 1969). The Providence River Valley extends into what is now East Passage, and present-day Sakonnet River flows through the Taunton-Sakonnet bedrock valley. (Upson and Spencer, 1964). These buried valleys extend into Block Island Sound. (McMaster and Ashraf, 1973). The thalwegs, or elevations at deepest points of the bedrock channels, suggest a gentle seaward gradient, resulting probably from subaerial erosion by a stream system. The thalwegs are 112 meters below mean sea level in the eastern and southern portions of the bay. (Upson and Spencer, 1964).

The Narragansett Pier Granite, younger than the basin rocks, crops out along the southwest portion of the bay. The Metacom Granite Gneiss, a Paleozoic Plutonic rock, underlies parts of Bristol. Present on Conanicut Island are not only Pennsylvanian rocks, but also Precambrian metamorphosed tuff, conglomerate, and quartzite and porphyritic granite (Skehan et al., 1976)(Quinn, 1971). Work by Skehan et al., 1976, Skehan et al., 1978, Murray and Skehan, 1979, and Skehan et al. 1981 has detailed the Cambrian in the Jamestown Fort Burnside and Dutch Island formations as well as the Precambrian rocks in the Fort Weatherill area. Newport exhibits Precambrian tuff, conglomerate, quartzite, porphyritic granite, and slate and quartzite as well as Pennsylvanian rocks (Skehan et al., 1976)(Quinn, 1971). The Common Fence Point/ Almy Pt. section of Portsmouth includes a horst exposing Metacom Granite Gneiss. The Church Point area of Little Compton displays the mica-chlorite schist of Sakonnet, and the Sakonnet Point-south shore area is underlain by the Bulgarmarsh Granite.

GLACIAL GEOLOGY

Glaciation began in the region approximately three million years ago. Associated with glaciation in the Narragansett Bay area was a pro-glacial lake, as indicated by the presence of varves which nearly fill the old bedrock chanels in the northern sections of the bay. (McMaster lecture, 1980). In the bay proper, the eroded bedrock surface is generally overlain by till, which is itself overlain by a thick body of mainly fine-grained material consisting of clays, silts, and fine sands. (Upson and Spender, 1964). Overlying this is another till in some localities and outwash deposits in other localities. (McMaster lecture, 1980). Estuarine deposits overlie an erosional unconformity (Upson and Spender, 1964).

SEALEVEL

The last advance and retreat of glacial ice in the area was 20,000 to 22,000 years ago, in early Wisconsin time. (Schafer and Hartshorn, 1965). Sea level rise has been occurring since that time, a result of the gradual melting of present-day ice caps.

Narragansett Bay is referred to by Fisher (1970) as a coastal feature of post-glacial submergence. Average sea level rise, measured by a tidal gauge at Newport, is presently 0.3 cm. per year. (Hicks, 1974). Hicks (1972) cites evidence that there has been a progressive relative rise in the height of the world's oceans since 1934. Monitoring stations operated by the National Oceanic and Atmospheric Administration at Newport and on Prudence Island showed a rapid sea level rise from 1934 to 1940, a decline in the rise rate until 1954, a levelling off of the rate of rise from 1954 to 1956, and a relatively rapid rise from 1966 to 1972. Yearly variability was attributed to changes in atmospheric pressure, winds, river discharge, ocean currents, salt content of the water, and water temperature. Depending on the linearity of the sea level rise curve, salt water first entered the bay, thus making it an estuary, 7,000 to 9,000 years ago. (McMaster, lecture, 1980). The estuarine deposits presently in the bay probably represent this last major eustatic rise in sea level. (Upson and Spencer, 1964).

Narragansett Bay has been placed geomorphically into a number of existing classification systems. Johnson (1925) classified the bay region as a delta plain shoreline. This is based on the pre-glacial topography of the area, and refers to the river valleys that constitute the passages of the bay. Similarly, the bay can be classified as an embayed river valley. (Shepard and Wanless, 1971). In Shepard's classification of coasts and shorelines, the general coastal region could be designated a glaciated coast type that has been modified by marine agencies. (McMaster, 1960).

ESTUARINE CHARACTERISTICS OF NARRAGANSETT BAY

To attempt to understand the dynamics of sediment movement along the shorelines of the bay it is important to have some background information on the estuarine characteristics of the bay; on its patterns of and factors contributing to water circulation, suspended and bottom sediments and other physical characteristics.

Narragansett Bay has been classified as a partially mixed, two-layered estuary with less saline water moving out of the bay and more saline water flowing into the bay. It has also been classified as a Pritchard (1955) type B or Tommel and Farmer (1952) type 2 estuary. (Hicks, 1959). According to Hicks (1959), the salt balance in the bay is maintained under steady-state conditions, by horizontal and vertical advection and vertical eddy diffusion. Hess (1974) referred to Narragansett Bay as a wide, shallow estuarine system dominated by tidal effects, and Fisher (1970) called it the largest drowned river estuary in southern New England.

METEOROLOGY

The mean annual temperature of the Narragansett Bay area is approximately 10^{o}C. (U.S. Army Corps of Engineers, 1964); -2.8^{o}-0.0^{o}C. in January and February and 20.0^{o}-21.7^{o}C in July (Alexander, 1966), average annual precipitation is approximately 100 cm/yr. Prevailing winds are northwesterly during the winter and southwesterly during the summer. (U.S. Army Corps of Engineers, 1964). The dominant wind direction is northeasterly. Winds rarely come from the east. (Hess, 1974).

The hurricane of September 21, 1938, the most damaging to the region since 1635, occurred two months previous to the earliest aerial photographs available. Flood was at 3.75 meters above mean sea level. (Butto et al., 1965), and winds were recorded at 27.2 cm/sec. Most damage was caused by winds and flooding; there was very little damage due directly to waves. (White, 1980, personal commun.). Average erosion rate figures for this report might be considerably greater if all of 1938 could be included in the measurements. The most damaging storm to occur during the study period was Hurricane Carol of August 31, 1954.

DEPTH

The bay is an average of 10 meters deep and 6 kilometers wide. The mean depth of West Passage and of the Sakonnet River is approximately 8 meters. Mean depth at the entrances to West Passage and the Sakonnet River is approximately 18 meters. For East Passage, the mean depth at its entrance is approximately 27 meters. The greatest depth recorded in East Passage, and in the whole bay, is 62 meters. (Collins, 1976).

TIDES

Tides in the bay are semidiurnal, with a mean tidal range of 1.1 meters at the entrances and 1.4 meters at the bay head. Spring tidal ranges are 1.3 meters and 1.7 meters, respectively. (Hicks, 1959). There is a tidal stage lag of 10 minutes between the entrance of West Passage and Wickford. The flushing rate of the bay is 42-59 days. (Alexander, 1966), and the maximum flood or ebb velocity over most of the bay's surface is approximately 0.5 to 1.0 knots. (McMaster, 1960).

WATER CIRCULATION

Of the causes of water motion in the bay, the ocean tides of Rhode Island Sound, entering the bay at 20 to 40 cm. per second, are the most influencial. (White, 1980 , personal commun.). Hicks (1959) shows tidal currents ranging from 50 to 140 cm. per second. Winds are the second most important factor, causing current rates ranging from 2 to 15 cm. per second. (Weisberg and Sturges, 1973). Hurricanes and other large storms are extremely important at the times of their occurrence; water velocity recorded during the hurricane of 1938 was 120 cm. per second. Sewage and other outfall discharges affect circulation only locally, within a few square meters of their origins. River discharges have been measured at 2 cm. per second. (White, 1980, personal commun.). River runoff at Rome Point has been measured at 88 cubic feet per second. (2490 liters per second). (Hicks, 1959). The direction of river discharge and outfall discharges is affected by the Coriolis acceleration. In narrow passages, the current tends toward the rightward shore. In Greenwich Bay, for instance, the Coriolis acceleration causes a counter-clockwise circulation. (Levine, 1972). Longshore currents, responsible for sediment movement parallel to shore, result from the arrival of waves at the beach at an oblique angle.

Natural seiching has a relatively minor effect on overall circulation. According to Haight (1938), the period of the bay is 5.72 hours. White (1980, pers. commun.) assigns a 4.8 hour value to the North-South period component, and a 1.9 hour value to the East-West component. The uneven distribution of salt causes density currents that are responsible for velocities ranging from 1 to 5 cm. per second. The salinity of the ocean is approximately 33 ppt; at Sabin Point, salinity is approximately 23 ppt. (Hicks, 1959).

SUSPENDED SEDIMENT

Morton (1966) supplies the following information concerning suspended sediment movement in Narragansett Bay: Most of the sediment entering the bay from tributaries is deposited near the head of the bay. Ten percent of the tributary sediment load, or 910 grans per second, is transported through the bay. Bottom currents entering the bay at its mouth carry much suspended material. One area of deposition is located near the geographic center of the bay during the Fall months. The average deposition rate of suspended material is 0.092 grams per centimeter squared per year. There is an average of 3.17 mg/liter of suspended material in the bay.

BOTTOM SEDIMENTS

While suspended sediment movement and water circulation in the bay are important, the distribution of bottom sediments and their origins can also aid in the determination of where sediment from the shoreline moves, resulting in erosion and accretion.

According to McMaster (1960), clayey-silt and sandy, silty clay are the most abundant bottom sediments in the bay, although sands are locally important. There is no predominant clay type of sediment. Bottom sediments are derived primarily from unconsolidated subaerial and subaqueous glacial and post-glacial deposits. Clayey silt and sandy, silty clay have accumulated mostly in the more protected middle and upper reaches of the bay passages. Areas that show marked gradational changes in sediment texture probably indicate significant local variations in bottom current activity.

PREVIOUS STUDIES

Numerous studies have used aerial photographs to map and/or measure coastal features. Listed here are studies that are also regional and long-term in aspect. The first studies describing long-term shoreline erosion and accretion were qualitative and used oblique aerial photographs (Shepard, 1950). Vertical aerial photographs can be used with careful attention to accuracy in quantitative efforts. Long-term refers to a time period of say ten to sixty years. The term regional refers to an area ranging in size from say that of Narragansett Bay to that of Chesapeake Bay. Coastal studies are considered here to include those concerned with land areas directly affected by shoreline erosion and accretion.

El Ashry and Wanless (1968) made measurements of Outer Banks beaches based on sequential vertical aerial photographs between Capes Hatteras and Fear on the North Carolina Coast. His quantitative method, though documented, was not detailed. The primary objective of Stafford (1971) was to develop and evaluate a procedure for using aerial photographs to measure coastal erosion and accretion rates. He encouraged the use of the high tide line in the technique, rather than the water line, which changes from hour to hour. He made this argument in spite of the necessity of locating and mapping the high tide line. Wahls (1973) used the methods developed by

Stafford (1971) and Stafford and Langfelder (1971) to update their North Carolina Beach erosion survey. Langfelder et al. (1974) used aerial photographs from 1938 to 1971 and historical maps to portray changes in the coastal inlets of North Carolina.

Stephen et al. (1975) used vertical aerial photographs from 1939 and 1973 and Stafford's technique to measure erosion and accretion of the beaches in Charleston County, South Carolina and attempted to explain the accretion and erosion for specific areas. Gatto (1975) used historical and recent aerial photographs to estimate shoreline positions and rates of erosion and accretion on the entire outer coast of Cape Cod Massachusetts from Long Point at Provincetown to Monomoy Point. The direction and magnitude of movement of the Alabama shoreline and changes of nearshore bottoms were documented by the Geological Survey of Alabama (1976), by use of vertical aerial photographs in conjunction with earlier nautical charts, NOAA topo sheets, USGS topographic maps, and satellite imagery.

Recent studies have been done at the University of Rhode Island Geology Dept. under the direction of Dr. John J. Fisher. Simpson (1977) measured changes in washover lobes along the southern coast of Rhode Island using Stafford's technique. A zoom-transfer scope was used for photograph scale matching, and a square grid-point counting system was used to measure changes in land area between the years

1939 and 1975. Regan (1976) measured high tide line and dune line changes along the south shore of Rhode Island from Napatree Point to Point Judith. Four sets of vertical aerial photographs were used from 1939-1972. Each photograph was microruled to check for deviations from nominal scale. Transects were made at 300 meter intervals along the beach at which measurements of erosion or accretion were made. Goetz (1980) measured cliff and beachline changes on Nantucket Island, Massachusetts using four sets of aerial photographs from 1938-1970. A zoom-transfer scope was used, and a square grid-point counting technique was used for shoreline segments 305 meters in length. Riegler (1980) used photographs from 1938, 1952, 1963, 1971, and 1977 to measure high tide line and cliff line changes of the Boston Harbor Islands, Massachusetts. Area measurements were made with a digital planimeter.

ADVANTAGES AND DISADVANTAGES OF AERIAL PHOTOGRAMMETRIC SHORELINE SURVEYS

At the inception of a quantitative shoreline survey it is important to consider the pros and cons of the use of aerial photographs as the primary data source. For a shoreline the length of the Narragansett Bay Shoreline with the photogrammetric coverage already in existance for the area two obvious advantages of a photogrammetrically based project are immediately apparent.

In general, aerial photographs are good for analyzing and accompanying descriptions of wave and beach processes. (Shepard, 1950). They provide a permanent record of the location and condition of the beach at a specific point in time. In contrast, the dates on maps and charts indicate the time of the editions of the map or chart, not the time that mapping was done. Aerial photographs provide a wealth of ground detail, whereas maps and charts by nature show selected detail. In addition, maps use varying datums for the land/water interface. Considered as a whole, the coastal regions of the United States have been aerially photographed more frequently than maps or charts have been updated. (Stafford and Langfelder, 1971). A major advantage of the photogrammetric method is the low cost relative to other types of surveys. One problem encountered in field survey methods is that of extrapolating short-term data to long-term trends. (Stafford and

Langfelder, 1971).

There are potential disadvantages inherent in a photogrammetric study. These can in many cases be alleviated or minimized by proper techniques. Stafford and Langfelder (1971) point out that shoreline conditions at the time of a photograph may not be average shoreline conditions, and therefore not necessarily comparable to other photographs. To offset this potential problem, a standard has been developed by which aerial photographs for beach survey purposes should always be taken at low tide on a clear day with the sun high in the sky and low vegetative cover, as in early spring or fall. Slight seasonal variations in shoreline location are not as detrimental to long-term studies, including the present one, as it is for short-term studies, since seasonal variations tend to be averaged out over the period of a long-term study.

Uncorrected errors in the photographic image can cause several different types of errors in a photogrammetric survey. For instance, the actual scale of a photograph may differ significantly from nominal (average) scale due to small altitude changes of the aircraft from which the photographs are taken. (Keller, 1975). Ground control scale verification survey measurements can be made to measure that difference. Simpson (1977) and Regan (1976) corrected the nominal scale on every quadrant of every photograph used as a control for both altitude variation and tilt.

Other errors in the photographic image can include camera tilt (Avery, 1968) and radial distortion (Tanner, 1977). Tilt can be eliminated by use of the Zoom-tranfer scope, as discussed in the methodology section of this paper. Radial distortion can be alleviated by exclusive use of the middle ninth of each photo where possible. Relief distortions (Tanner, 1977) occur with elevation differences in the terrain. This problem was not encountered in the present study because of the low relief along the R.I. coast. Uneven paper shrinkage (Avery, 1968) is corrected by use of the zoom-transfer scope or by the use of resin-coated paper. Photograph images that display film buckling (Tanner, 1977) should not be used.

For an exclusively photogrammetric survey, only horizontal changes can be recorded. (Stafford and Langfelder, 1971). For volume changes, additional field measurements are necessary, because the vertical relief component of the beach (±2 meters) at this photographic scale cannot be accurately measured.

METHODOLOGY

INTRODUCTION

Vertical aerial photographs from 1938 and 1975 were utilized to map and measure erosion and accretion of the Narragansett Bay shoreline. A zoom-transfer scope and digital planimeter were used for vertical aerial photographs taken in 1980, but were not in existance during laboratory work on this project.

PHOTOGRAMMETRY

The 1975 photographs used in this study were obtained from Aerial Data Reduction Associates, Inc., Peacedale, Rhode Island and are part of the 058 series. Flights on April 11th, 14th, and 24rd, 1975 produced 214 photographs at a nominal scale of 1:12,000.

Mapping of the 1975 shoreline was accomplished by tracing the high tide line and the back beach line onto mylar sheets. The mylar was dimensionally stable, and in the interest of accuracy, the center ninth of each photo only was traced. To aid in the determination of the exact location of the high tide line and back beach line, a stereoscope was used. Two photographs contiguous in the flight line could be placed together and viewed with a stereoscope to show three-dimensional clarification of features. This procedure produced vertical exaggeration, which enhanced the accurate location of changes in slope and beach features such as storm surge debris lines or top of

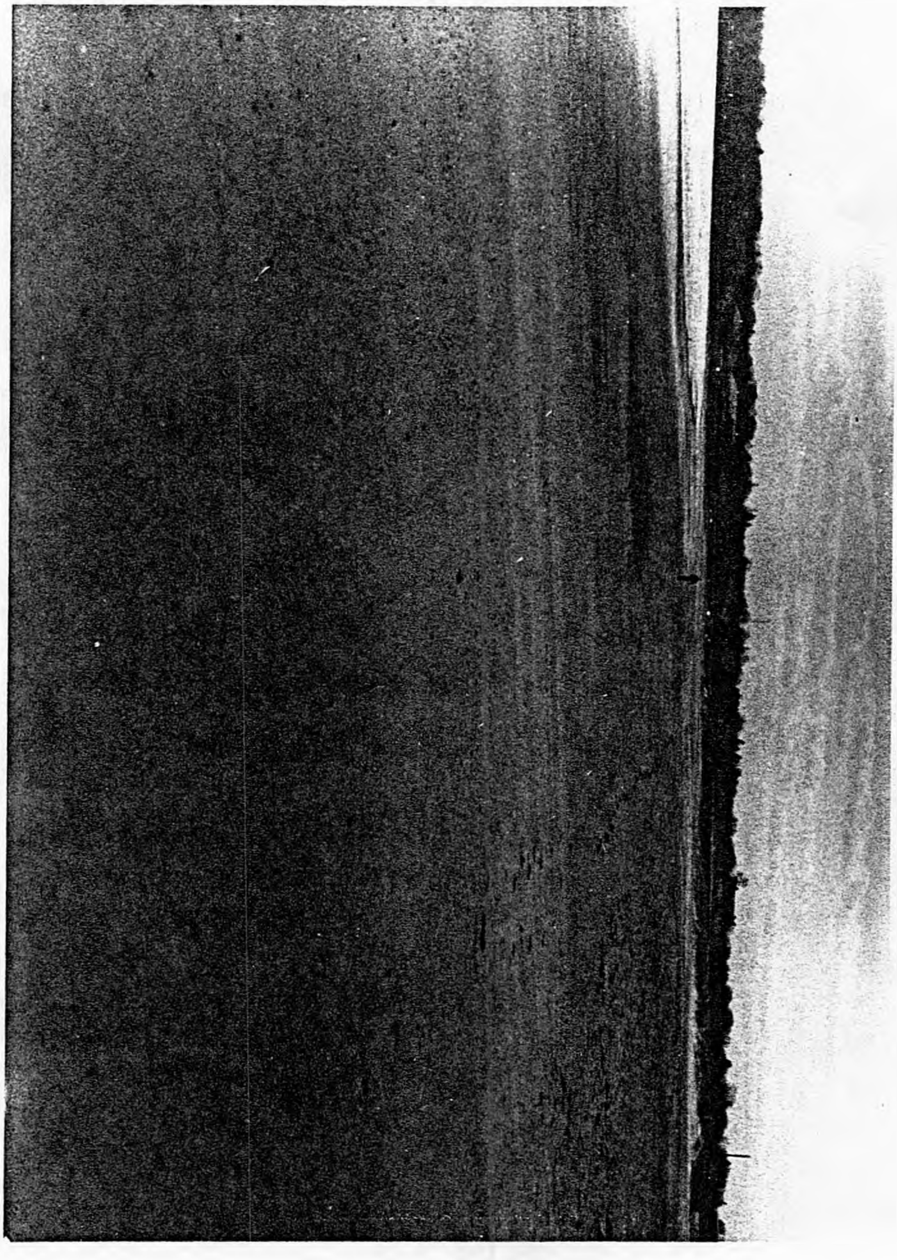


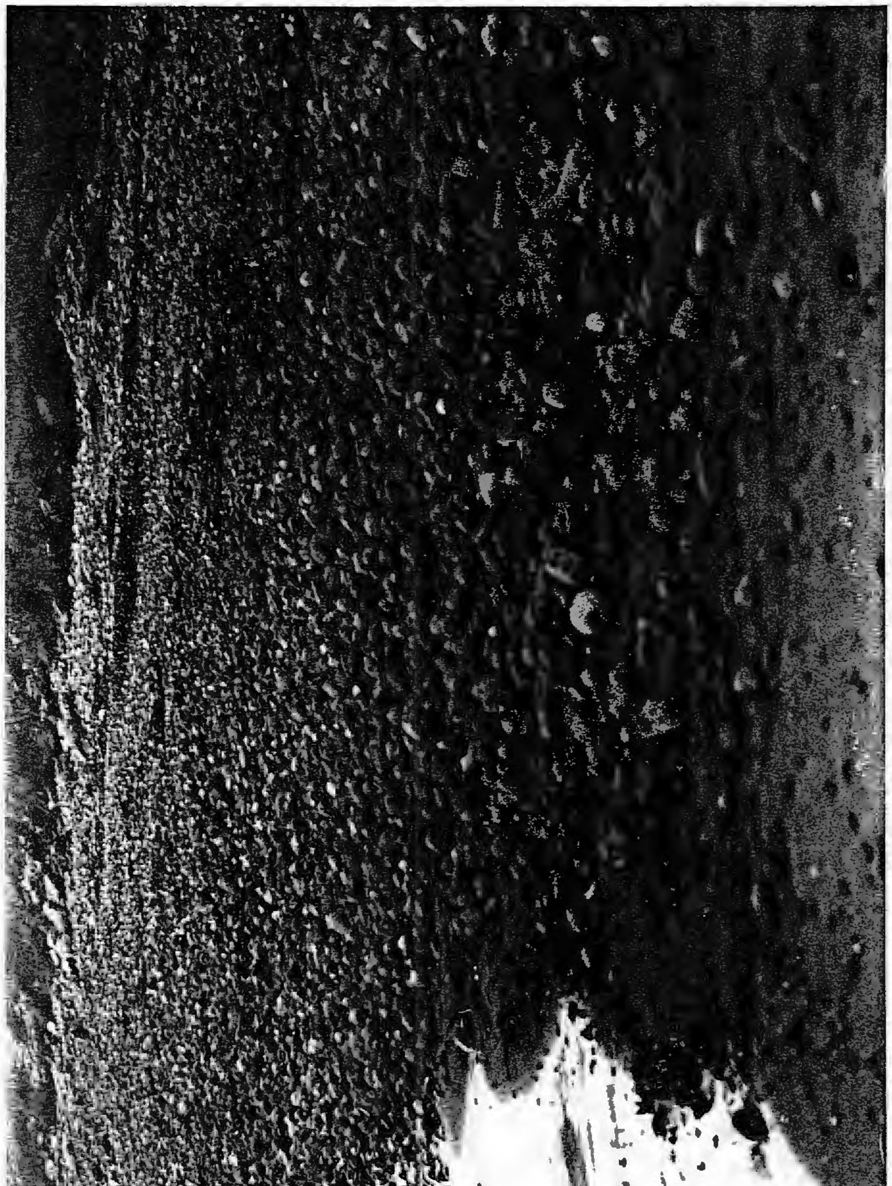
Figure 3. Ground Photograph, Sandy Beach.
Narragansett Beach, Narragansett.

dune, man-made structure, or cliff crest lines.

The high tide line was located with the aid of tonal changes on the image of the beach face and with tidal data for April 11th, 14th, and 23rd 1975. Based on shadows on the photographs, the flights appear to have been between 10:00 am and 2:00 pm. High tide on April 11 was at 8:37 am and 8:54 pm. On April 14, high tide was at 10:17 am and 10:35 pm, and on the 23rd it occured at 6:30 am and 6:54 pm. Awareness of the point in the tidal cycle present in a photograph helps to distinguish between the high tide line and storm surge line. During tracing of the back beach line, constant referral was made to the photograph in stereo, to insure tracing of the crest of the dune, cliff, or man-made structure.

The 1938 photographs utilized in this study were obtained from the National Archives in Washington, D.C., and are part of the GS F series. Flown on December 13, 1978, they are the earliest available vertical aerial photographs of Narragansett Bay. The photographs are at a nominal scale of 1:24,000, and 106 photos were used. The 1938 high tide line and back beach line were mapped onto the same mylar sheets as the 1975 photos to allow direct comparison and measurement of shoreline changes. The 1938 photos, like the 1975 photos, were viewed with the stereoscope before and during mapping and were viewed in conjunction with tidal data at the time of day of each photo to accurately identify the high tide

Figure 4. Ground Photograph, Cobble Beach.
South Ferry, Narragansett.



line and back beach line.

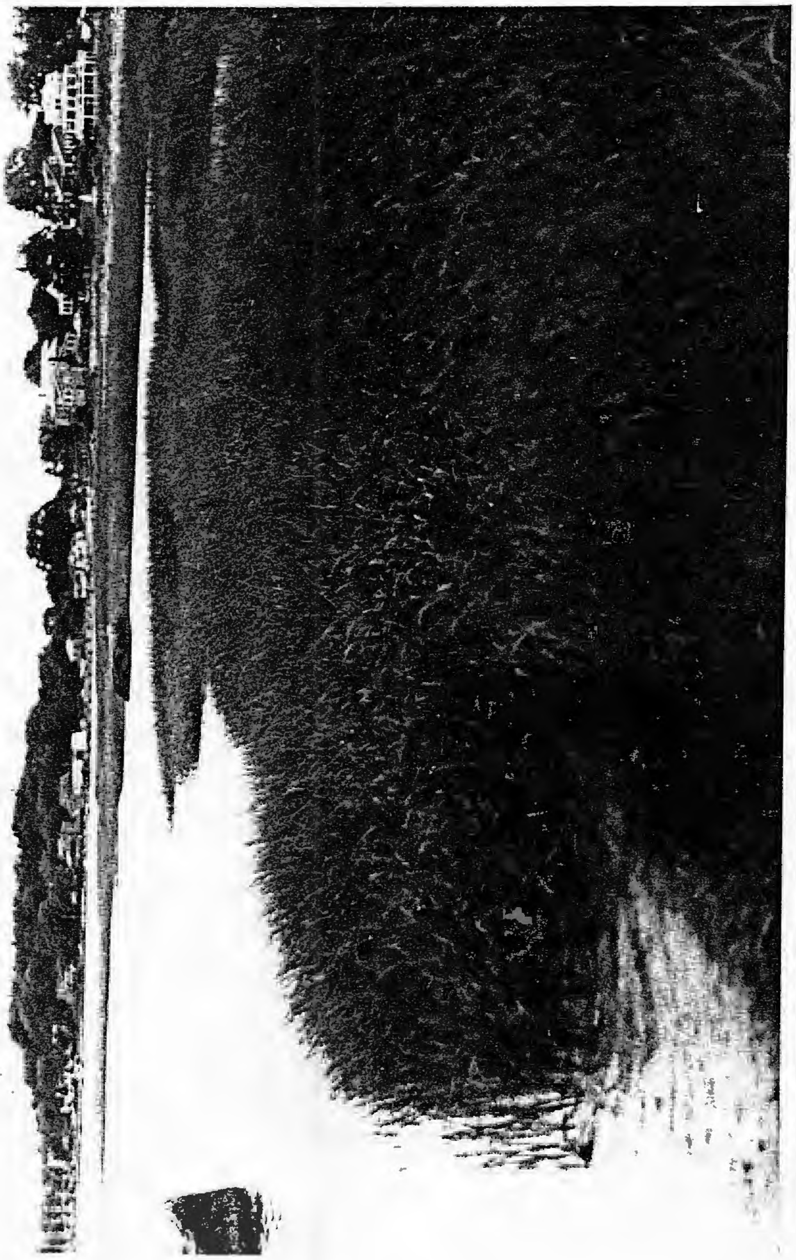
In the interpretation of HTC & BBL locations, as with any mapping using remote sensing methods, results of more than one investigator may not agree. A check is often made by comparing the interpretations of two or more investigators. For the Narragansett Bay shoreline, the western shore high tideline and back beach line was mapped by Nancy Friedrich of the Univ. of Rhode Island, as wel as by the author. The maps by the investigators were almost identical. Planimeter measurements were made by the author on selected areas of the work of each investigator. Agreement was 99.6%.

The difference in scale between the two sets of photographs necessitated some method of bringing the two scales together for comparative mapping. For this study a Bausch and Lomb zoom-transfer scope was used. It permits viewing and mapping of images of two photographs simultaneously at precisely the same scale. The zoom-transfer scope can also remove photographic distortion effects such as tilt, elevation change, radial distorition, photographic paper shrinkage, and earth curvature with the use of an amomorphic/zoom x-y direction correction. The process was generally more difficult with the 1938 photographs than with the more recent ones, largely because of the smaller scale.

SHORELINE TYPE DESIGNATIONS

Once all mapping onto mylar sheets was completed, the entire shoreline was divided into various compositional types. This was to enable comparison of actual erosion or

Figure 5. Ground Photograph, Marsh Beach. Common Fence Point, Portsmouth.



accretion with the grainsize of the beach or dune or cliff material. The shoreline types were based only on the material present at the surface and readily exposed to wave or other erosive action. Type designations were as follows: bedrock beach (symbolized in figures and charts as RB), cobble beach (CB), sand beach, (SB), dune (D), gentle slope (S), rock cliff (RC), marsh (SH), and man-made structure (M).

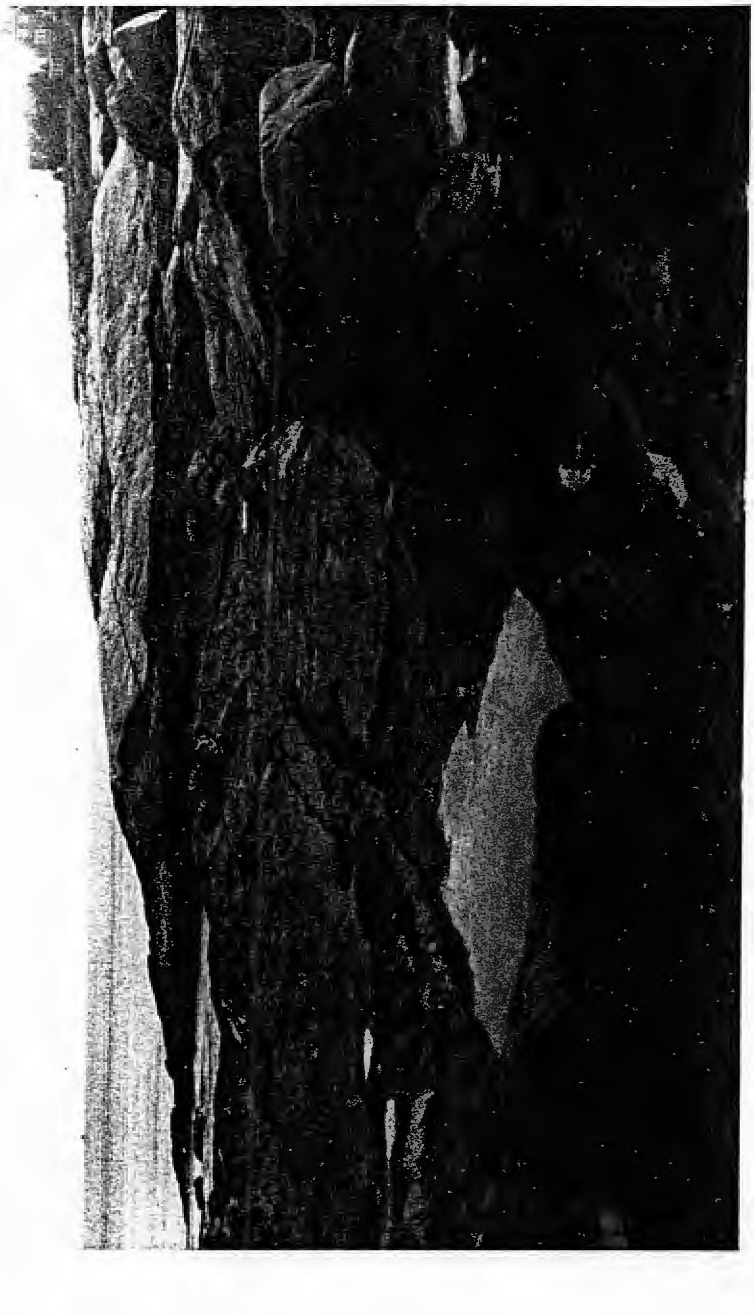
Type designations were determined in the laboratory by stereoscopic viewing of the vertical aerial photographs, and by study of oblique and ground photos. The Rhode Island Shoreline Type Inventory (Tippie, 1975, unpub.) was also utilized for preliminary shoreline designation. Field verification of shoreline types was made by boat, helicopter, and ground surveys. Shoreline types were indicated on the maps of the shoreline on the mylar sheets.

For discussion of results, the above-listed shoreline types were grouped according to the types of geologic deposit most likely to affect erosion or accretion. These groupings, influenced by work by Abu Al-Saud (personal commun. 1979), were designated beach and barrier spit, glacial outwash gravel and sand, glacial till, bedrock, and engineering structure. Designations of specific areas depended on both the shoreline types described above and on designations made by Abu Al-Saud.

AREA CHANGE MEASUREMENTS

Measurement of shoreline change was made from the mylar

Figure 6. Ground Photograph, Rock Beach. Hazard Rocks, Narragansett.



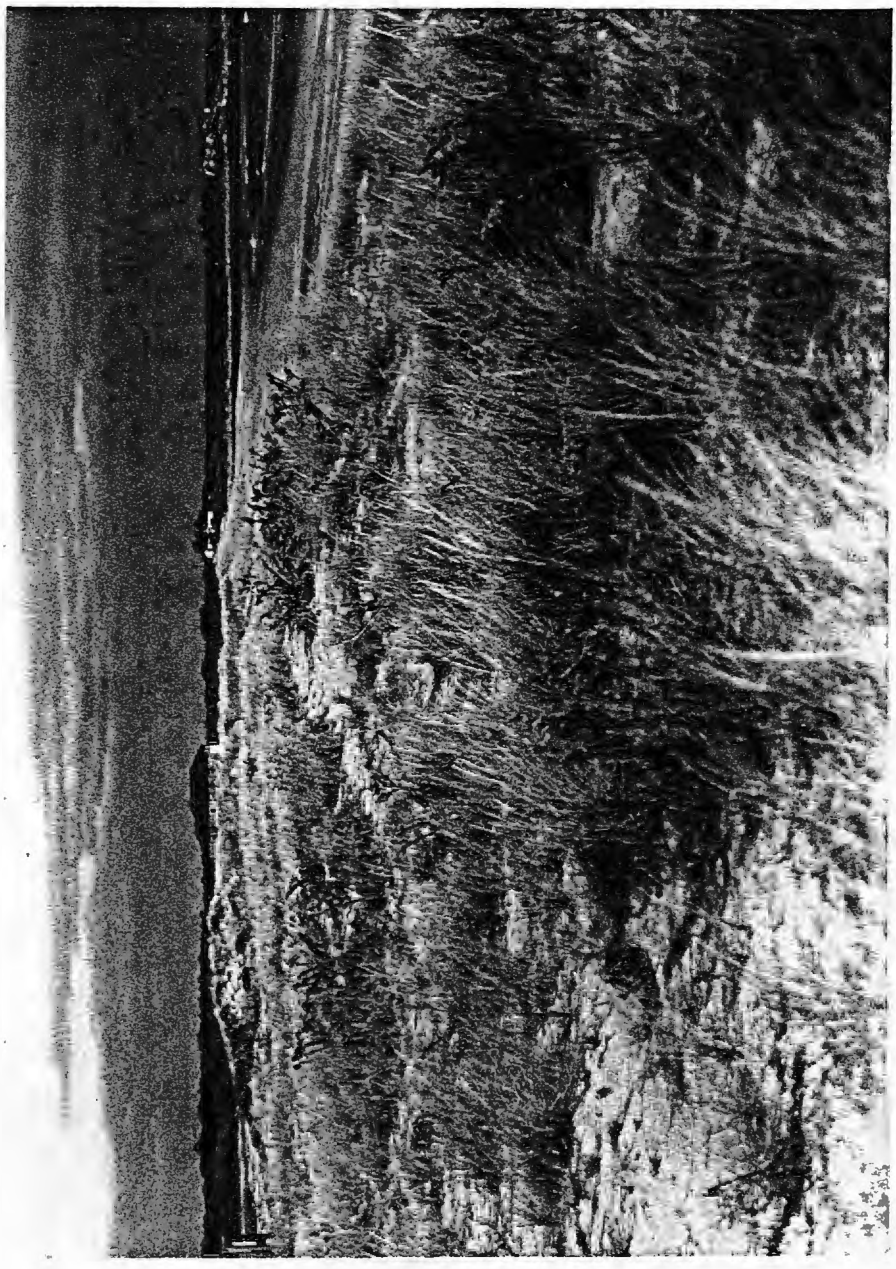
sheets by use of a Lasico digital planimeter calibrated to the 1:12,000 scale. With this instrumentation, areas can be directly measured and read immediately from the digital readout. Area measurements are made in less time and with accuracy than with either the grid-point count method (Simpson, 1977) or the microrule-transect method (Regan, 1976).

For area measurements by the planimeter, every change in beach, dune, or cliff type was considered a boundary between segments. The segment lengths ranged from 24.1 to 386.2 meters, with an average length of 193.1 meters.

For each segment of shoreline, five planimeter area measurements were made and averaged. Where the average erosion or accretion was less than 0.1 meter per year, per meter length of shoreline, the limit of the planimeter technique at that scale was reached, and the average change rate for that segment was indicated as zero on the graphs. Accuracy was 97% with the use of the planimeter for this project. This was determined by comparison of field measurements of tennis courts and parks with planimeter measurements of the same features. Photographs used for this were from the 16 205 series taken on April 21, 1972 at a nominal scale of 1:12,000.

Measurements were made for each segment between the 1975 and 1938 high tide lines, and the 1975 and 1938 back beach lines. Hence there are two change rates for

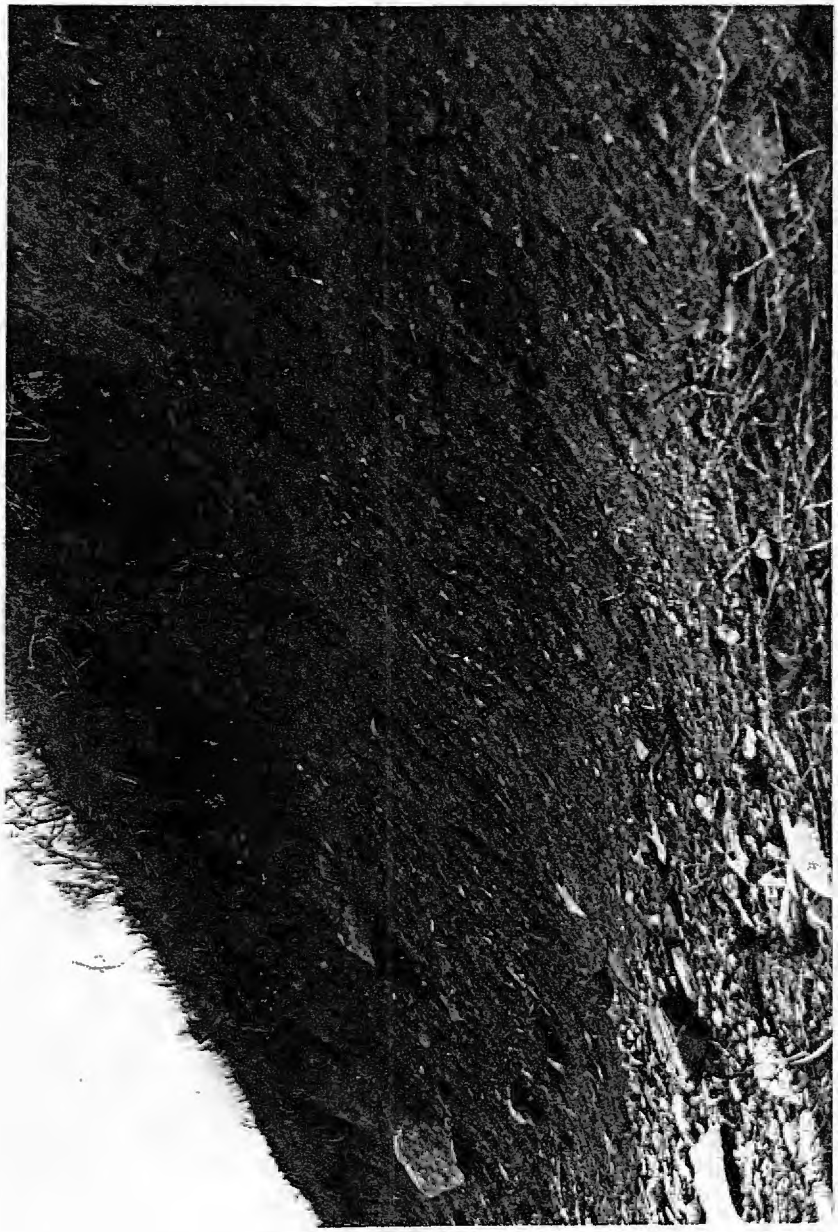
Figure 7. Ground Photograph, Dunes.
Narragansett Beach, Narragansett.



each segment: one for the beach face, and one for the dune, cliff, or mad-made structure at the back of the beach.

A sediment budget analysis was prepared, necessitating the use of volumetric shoreline changes. The scope and nature of this project did not allow for direct volumetric measurements to be made, since vertical changes could not be measured at this photographic scale. It is volumes of material that move, not areas. Since the actual measurements made for this study were areal measurements, the graphs are presented in that form. In order to make an estimation of corresponding volumetric changes at the high tide line, one average figure of 8.44 m^3/m^2 is used. See Appendix III. Heights of the crest at the back beach line were taken from U.S. Geological Survey topographic maps.

Figure 8. Ground Photograph, Glacial Till Cliff.
Round Pond, Little Compton.



RESULTS OF SHORELINE CHANGE MEASUREMENTS

INTRODUCTION

The shoreline has been divided into six sections for the presentation of area changes (Fig. 2):

1) The Western shore of the bay, with Point Judith at the Southernmost point and Gaspee Point in the North and including the municipalities of Narragansett, North Kingstown, and Warwick, (segments 1 - 257).
2) The northern boundary of the bay from Bullock Point in the West to the Massachusetts/Rhode Island border East of Bristol Narrows, including East Providence, Barrington, Warren, and Bristol (segments 258 - 379).
3) Prudence Island (segments 380 - 484).
4) Conanicut Island (Jamestown), (segments 485 - 638).
5) Aquidneck Island, also known as Rhode Island, and containing the municipalities of Portsmouth, Middletown, and Newport, (segments 639 - 923).
6) The Eastern shore of the Sakonnet River, and the South Shore, including the towns of Tiverton and Little Compton from 1.6 km. south of the Massachusetts/Rhode Island border at Fall River to the Massachusetts/Rhode Island border at Quicksand Pont on the South Shore, (segments 924 - 1062).

SHORELINE CHANGES: POINT JUDITH TO GASPEE POINT

The Western shoreline of Narragansett Bay from Point Judith to Gaspee Point (figs. 9-27), like most areas of the bay, exhibits numerous outcrops of bedrock and deposits of glacial material. Barrier beaches and cuspate shoreforms, however, have developed to a greater extent on this west shore of West Passage than in other sections around the bay. There are four barrier beaches on this shore: Narragansett, Bonnet Shores and Rome Pt. beaches. The six cuspate shoreforms in West Passage are South Ferry, Casey Point, Plum Beach Point, Greene Point, Conimicut Point, and Gaspee Point. Quonset Point was a cuspate shoreform until World War Two, when the U.S. Navy filled and stabilized the area to build a navy base and a series of air strips. Quonset, Conomicut, and Gaspee Point cuspate shoreforms are much larger than the three to the south.

Pt. Judith-Plum Pt. (Fig. A), (Fig. A_1, A_2, segments 1-34), (Fig. A_3, A_4, segments 35-73),(Fig. A_5, A_6, segments 74-88).

Erosion from Point Judith to Scarborough Beach (segments 1-10) ranged from 0.0 to 0.8 m/yr. at the high tide line. Erosion at the top of the man-made structure line at the back of the beach ranged from 0.0 to 0.4 m/yr. where there was measurable erosion. No measurable accretion occurred at the high tide line or back beach

KEY

EROSION & ACCRETION GRAPHS

COBBLE BEACH

MAN MADE STRUCTURE

SANDY BEACH

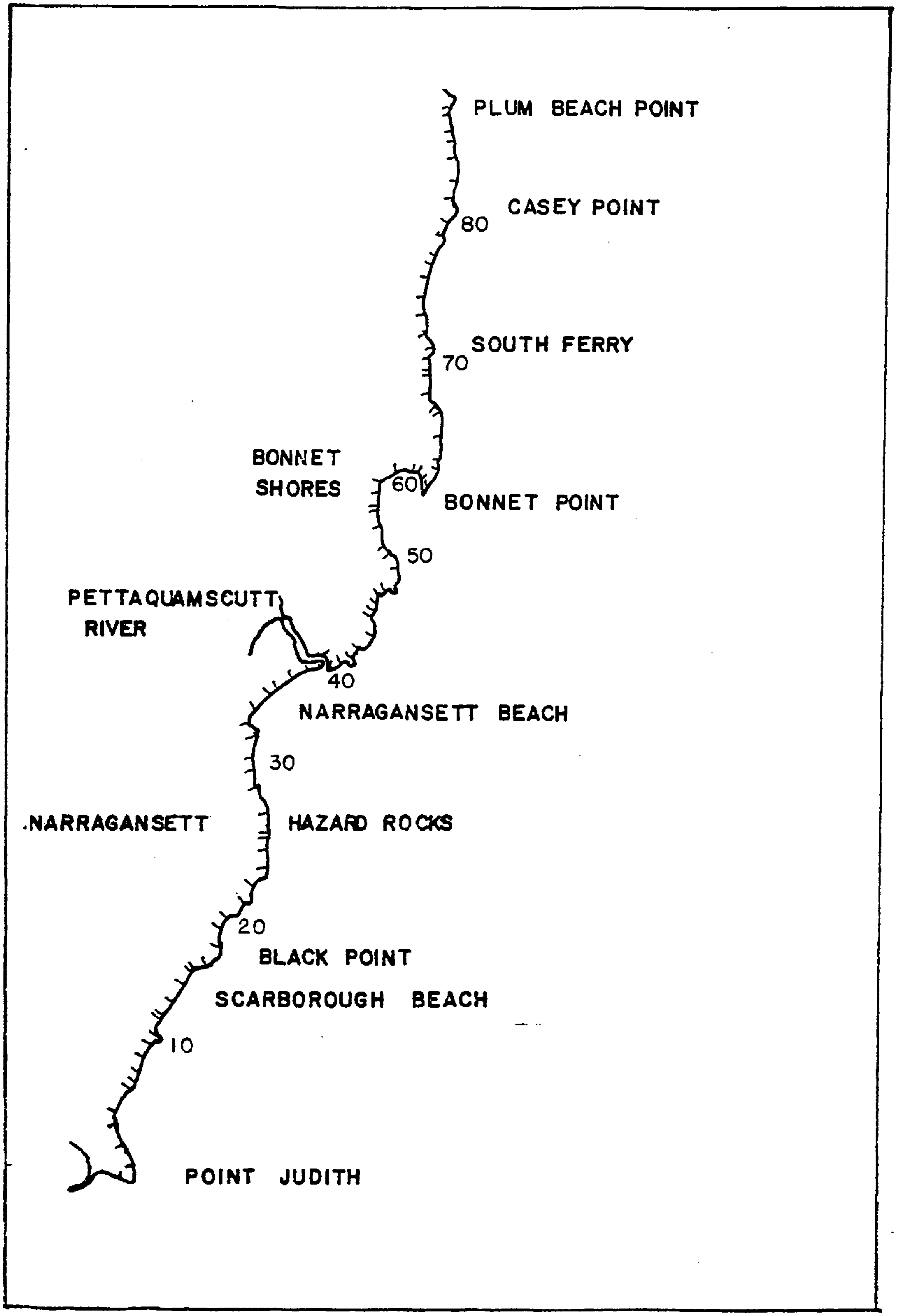
GENTLE SLOPE

MARSH

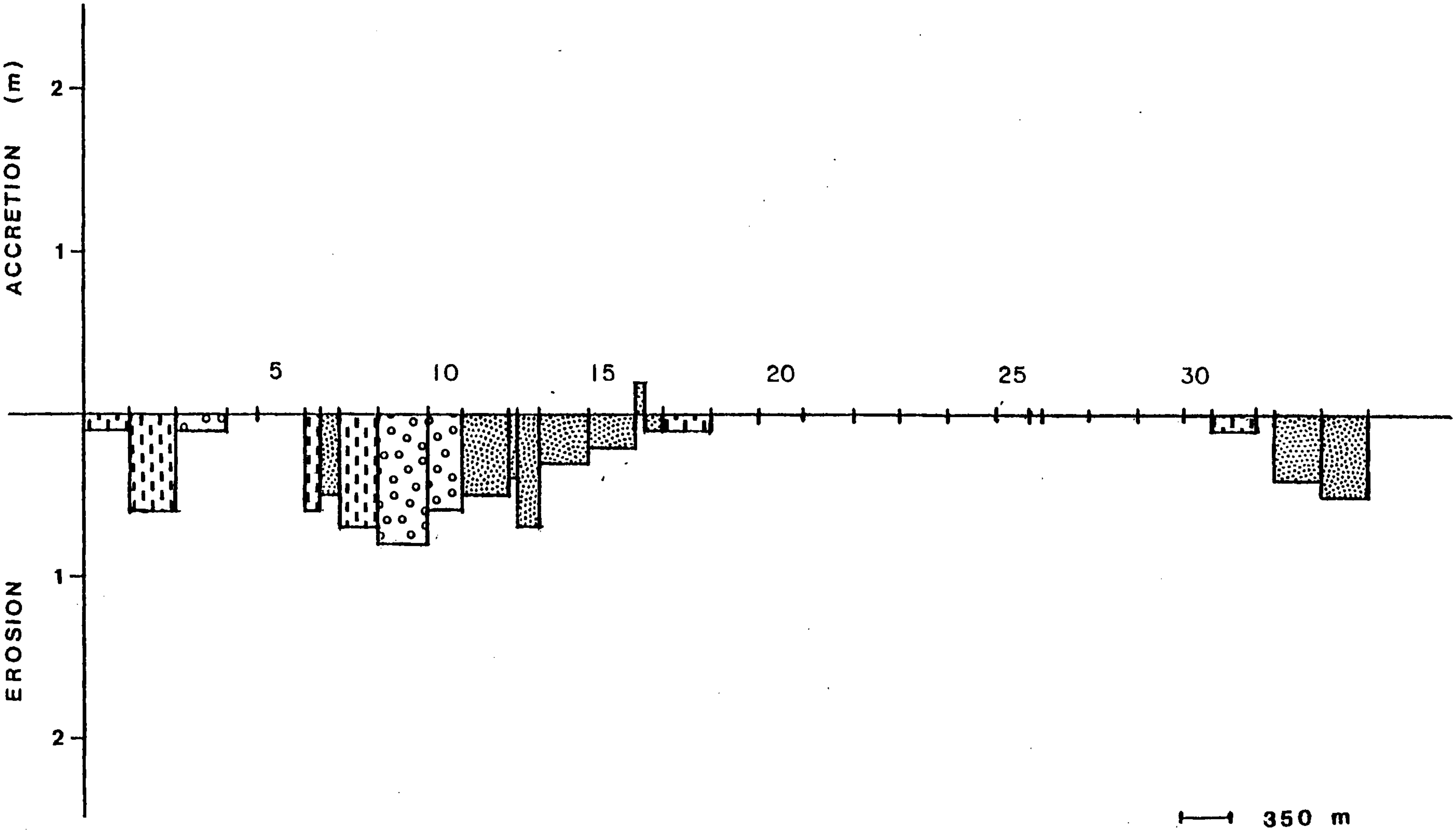
DUNE

205 SEGMENT NUMBER

Figure 9. Shoreline Segment Location Map:
Point Judith - Plum Beach Point.

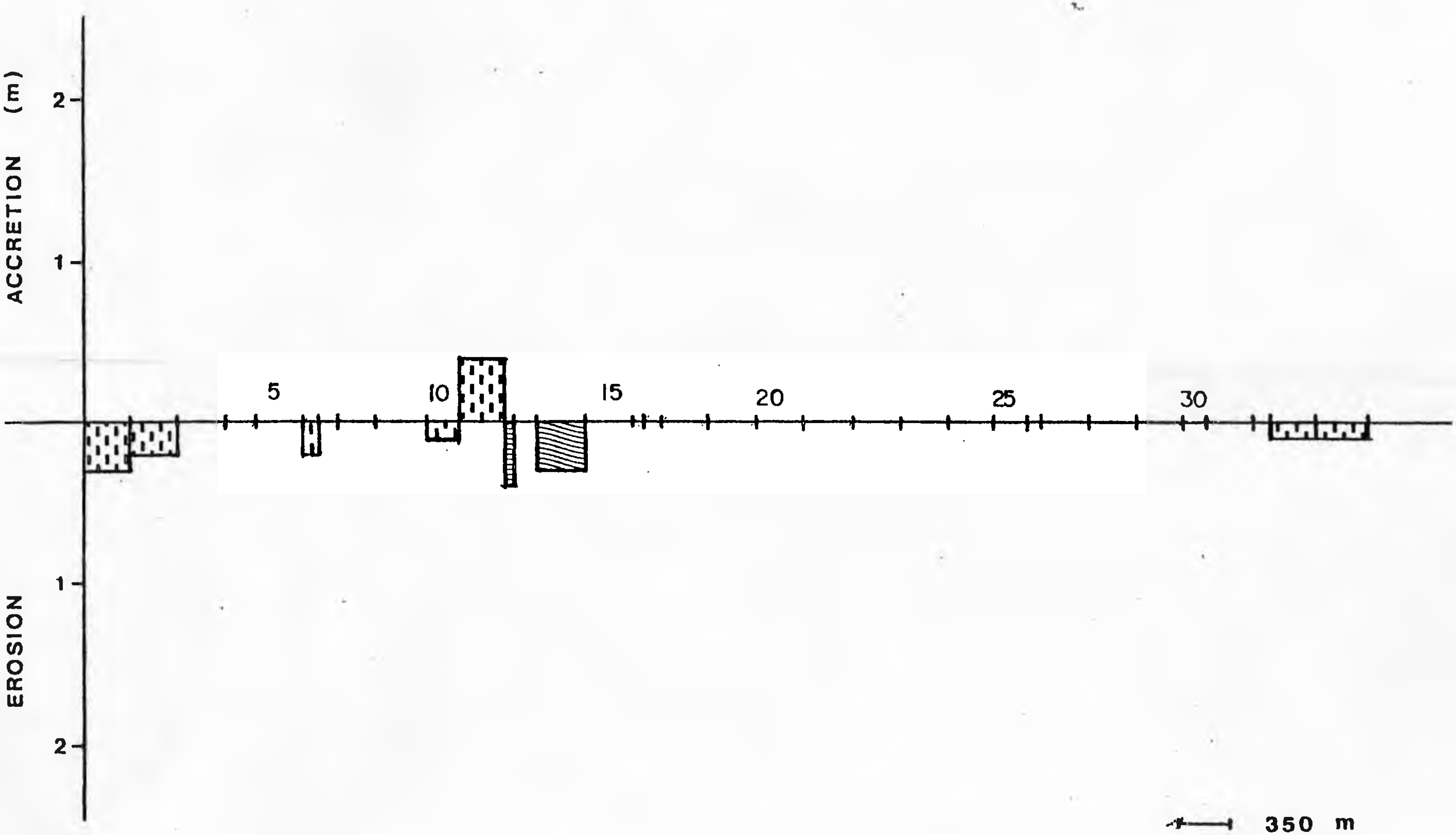

PLUM BEACH POINT
CASEY POINT
80
SOUTH FERRY
70
BONNET
SHORES
60
BONNET POINT
50
PETTAQUAMSCUTT
RIVER
40
NARRAGANSETT BEACH
30
NARRAGANSETT
HAZARD ROCKS
20
BLACK POINT
SCARBOROUGH BEACH
10
POINT JUDITH

POINT JUDITH — NARRAGANSETT BEACH



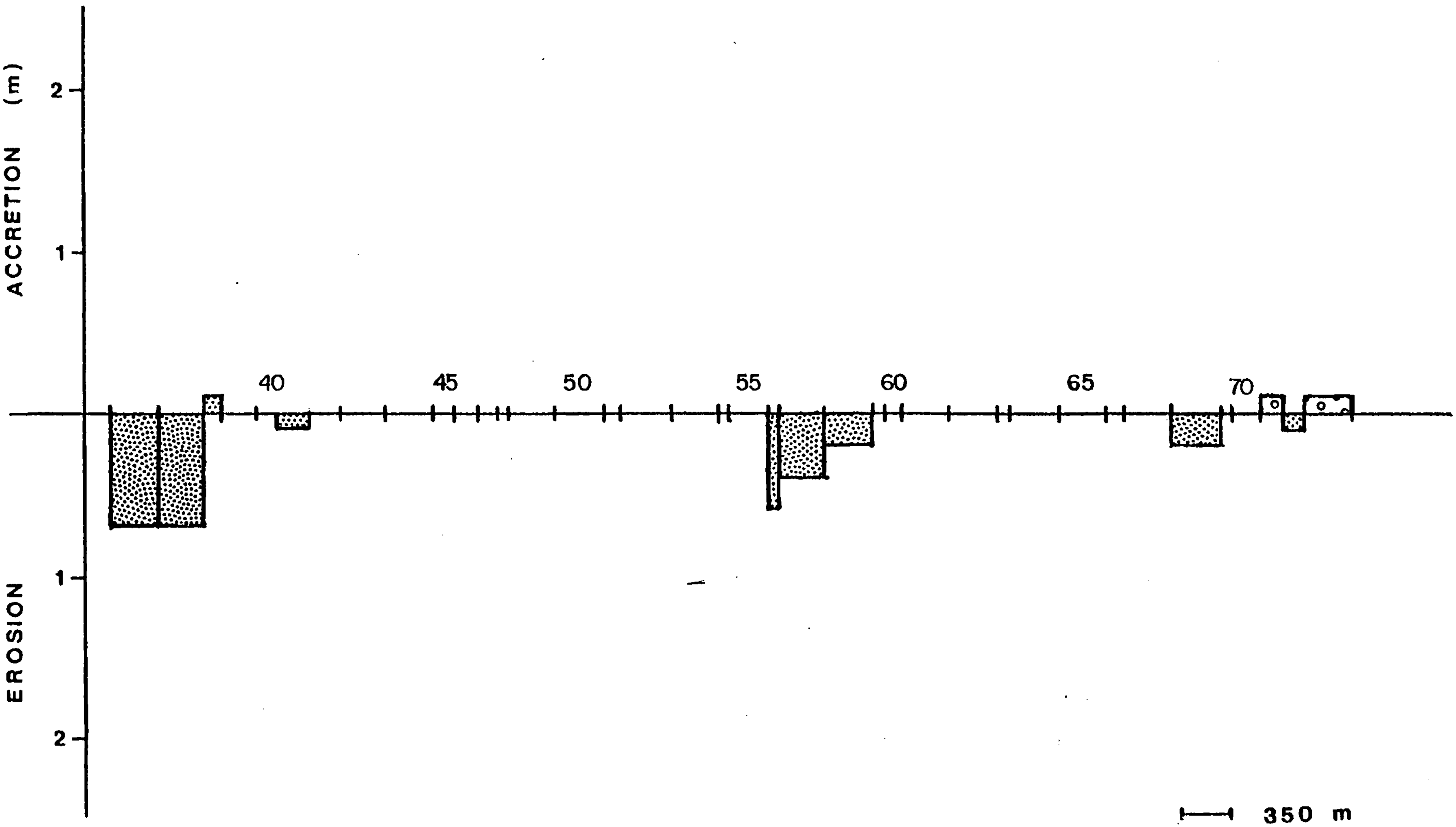
AVERAGE HIGH TIDE LINE CHANGE

POINT JUDITH — NARRAGANSETT BEACH



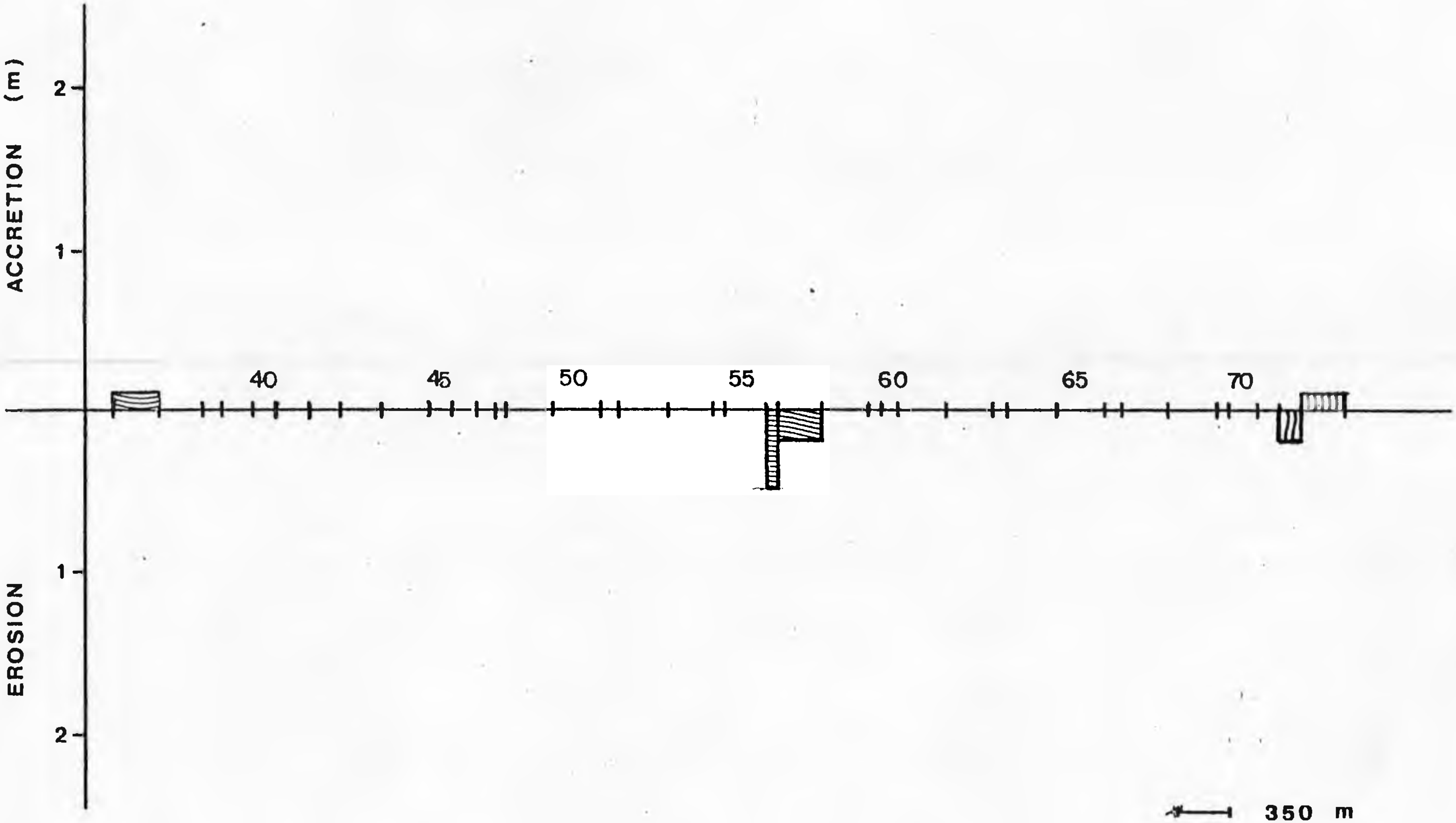
AVERAGE BACK BEACH LINE CHANGE

NARRAGANSETT BEACH — SOUTH FERRY

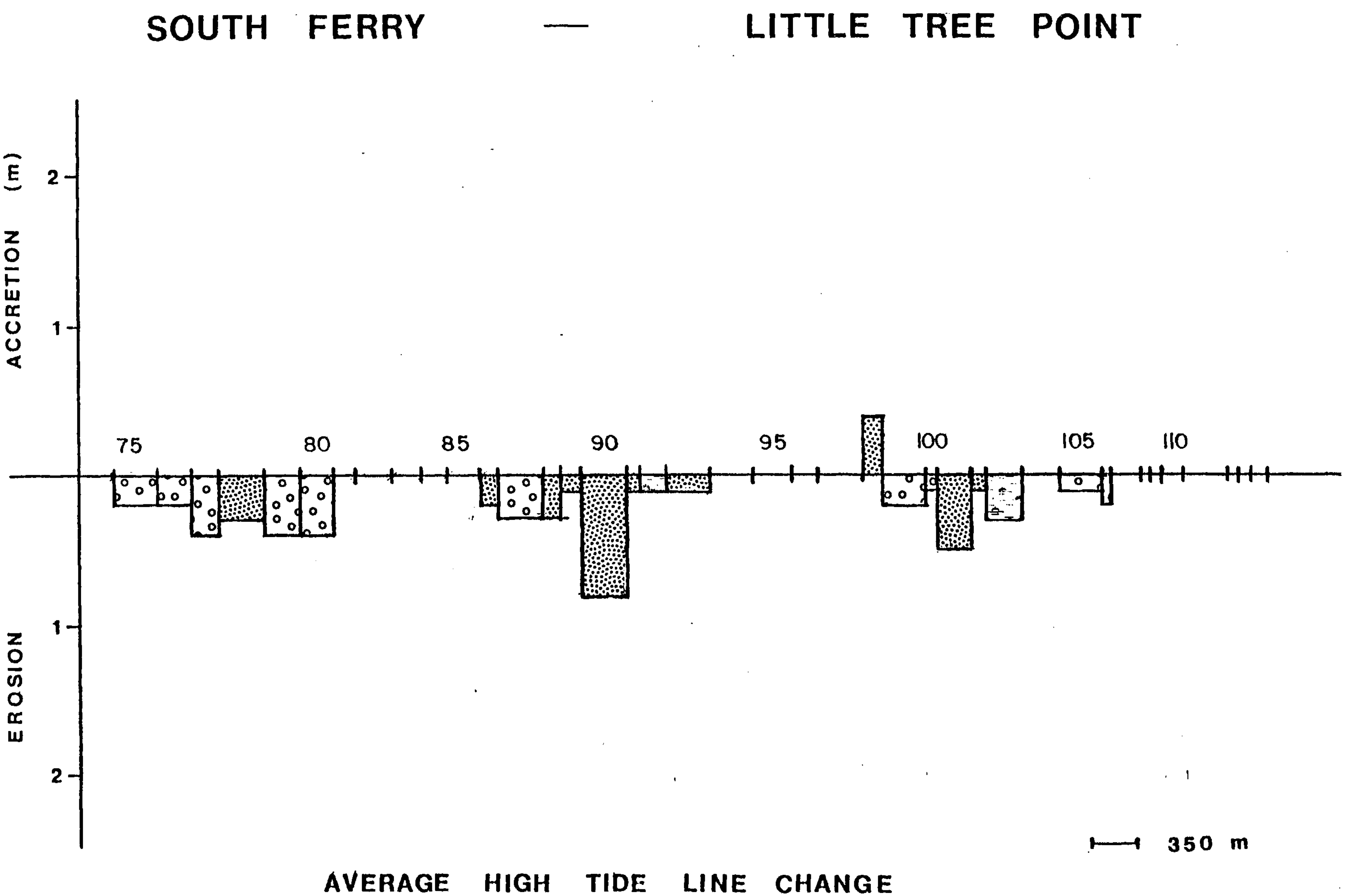


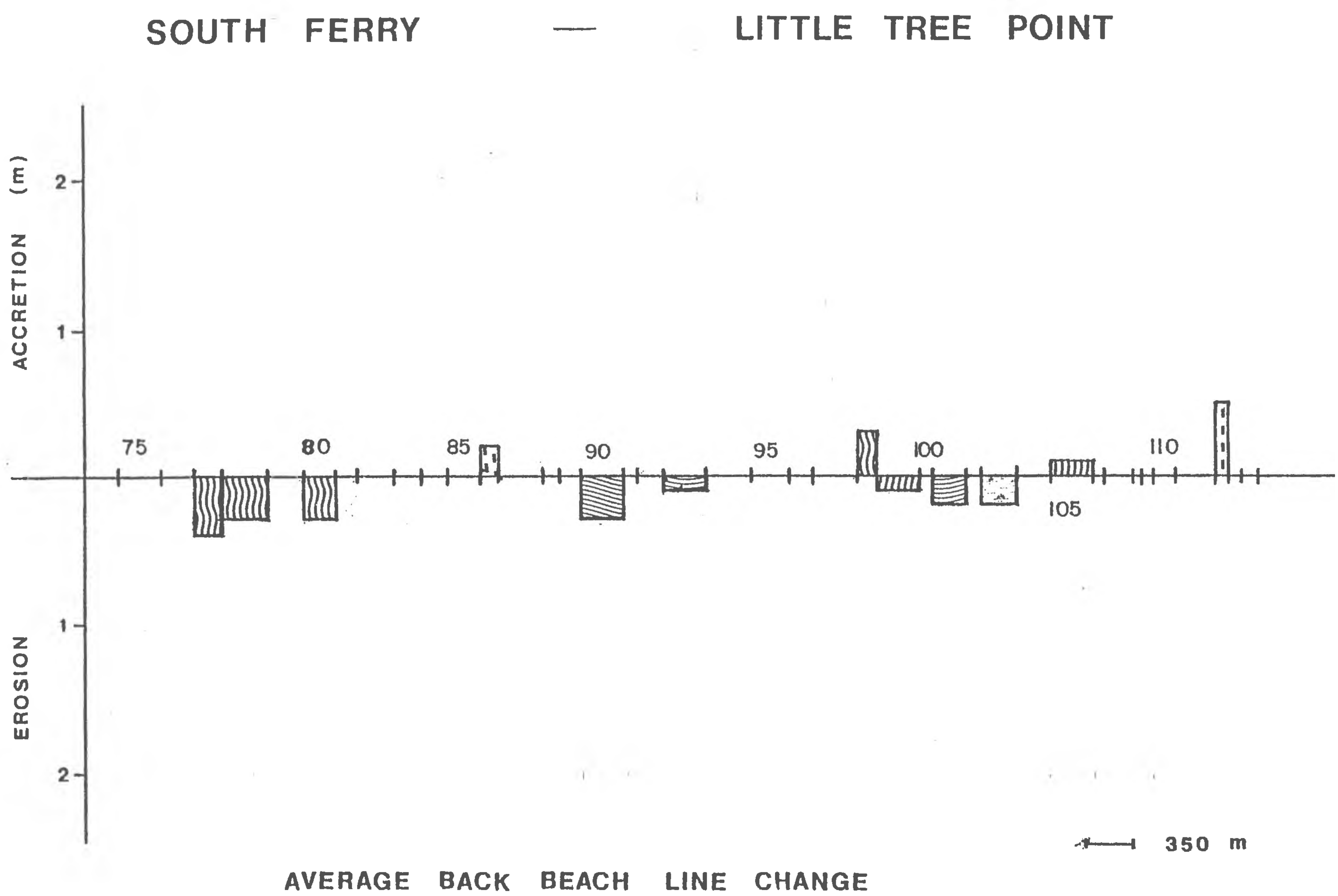
AVERAGE HIGH TIDE LINE CHANGE

NARRAGANSETT BEACH — SOUTH FERRY



AVERAGE BACK BEACH LINE CHANGE


SOUTH FERRY — LITTLE TREE POINT
ACCRETION (m)
EROSION
2
1
1
2
75
80
85
90
95
100
105
110
350 m
AVERAGE HIGH TIDE LINE CHANGE



SOUTH FERRY — LITTLE TREE POINT
ACCRETION (m)
EROSION
2
1
1
2
75
80
85
90
95
100
105
110
350 m
AVERAGE BACK BEACH LINE CHANGE

35f

line during the study period. Scarborough Beach (segments 12-17) experienced erosion at both the top-of-dune line and at the high tide line. Erosion of the beach face reached an average of 0.7 m/yr, at segment 13. Net accretion of 0.4 m/yr occurred in the back beach line at segment 11. This apparent accretion is attributed to the building of the parking lot. The shore from Scarborough Beach to Narragansett Beach is dominated by bedrock, and while erosion was observed on the aerial photographs, it was too slight to be measureable. Narragansett Beach, (segments 33-38, Fig. A_1, A_2), in contrast, exhibited erosion of up to 0.4 to 0.7 m/yr at the high tide line. At the North end of Narragansett Beach, where the mouth of the Pettaquamscutt River meets the ocean, (segment 38), there was a small amount of net accretion (0.1 m/yr). The slight accretionary change found at the dune line is attributed to the presence of a seawall and a series of additional protective man-made structures along the back of the beach. No measurable shoreline change was found between Narragansett Beach and Bonnet Shores, but the barrier beach at Bonnet Shores (segments 56-60), exhibited up to 0.6 m/yr and 0.5 m/yr of erosion at the high tide line and top-of-dune line, respectively.

Very little erosion or accretion occurred between Bonnet Shores and South Ferry (segments 61-70), but at

South Ferry there was erosion of the south side (0.2 m/yr) behind the beach and 0.1 m/yr on the beach face), and accretion on the north side, of 0.1 m/yr.

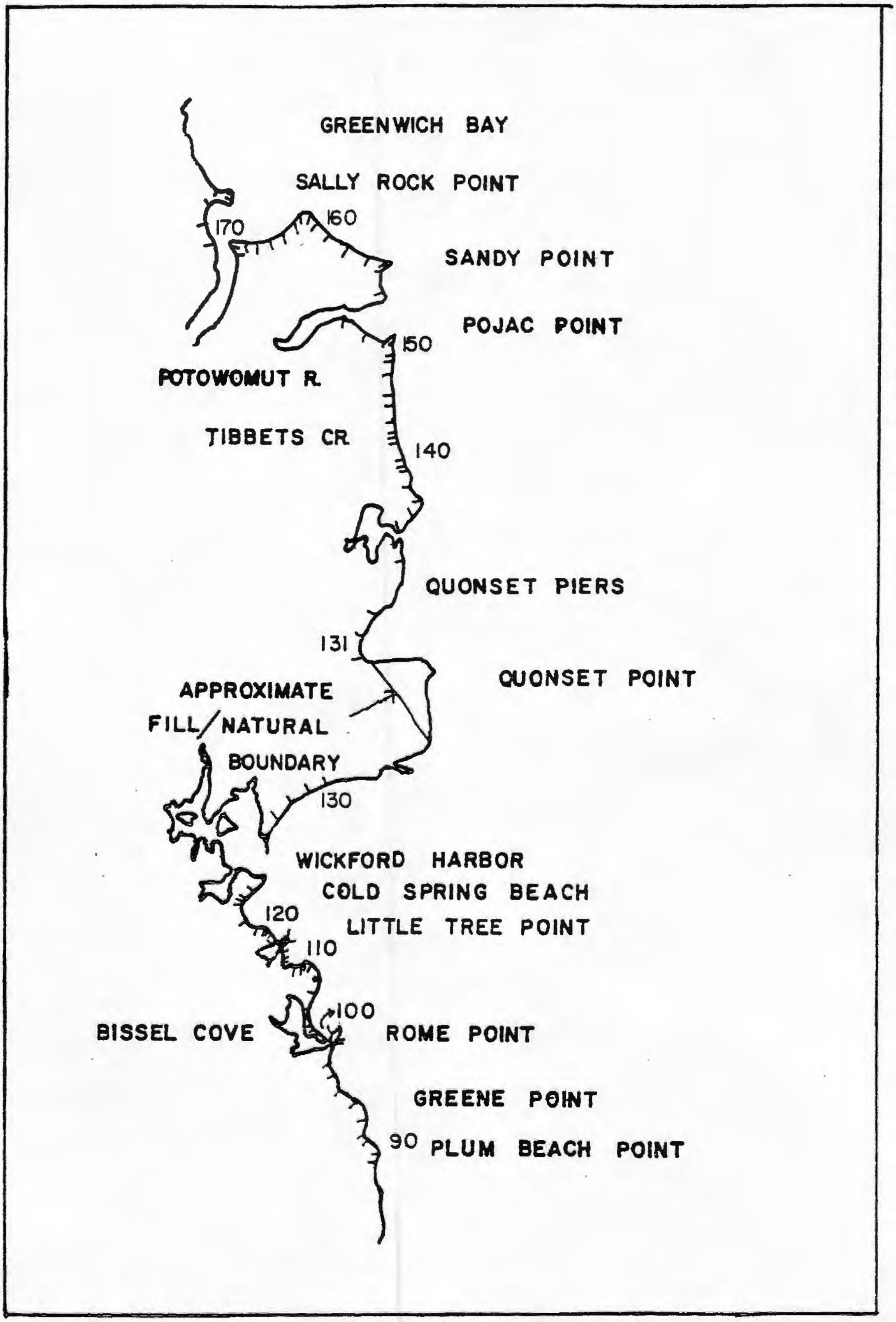
Between South Ferry and Casey Point (segments 73-77) there was erosion of both the beach face and glacial material behind the beach face of up to 0.4 m/yr. The south side of Casey Pt. (segment 80) eroded at a rate of 0.5 m/yr, and the north side of the cuspate shoreform at Casey Point (segment 81) showed accretion on the aerial photographs, but the change was so slight as to be unmeasurable.

Very little shoreline change was detected between Casey Point and Plum Beach Point (segments 82-88), except for segments 86-88 to the immediate south of Plum Beach Point, where erosion of 0.2-0.3 m/yr occurred. At Plum Beach Point (segments 89-90) net erosion was measured on the North Side (segment 90) at 0.8 m/yr at the high tide line and 0.3 m/yr at the top of the dune. Erosion of 0.1 m/yr at the high tide line was detected on the south side of Plum Beach Point (segment 89).

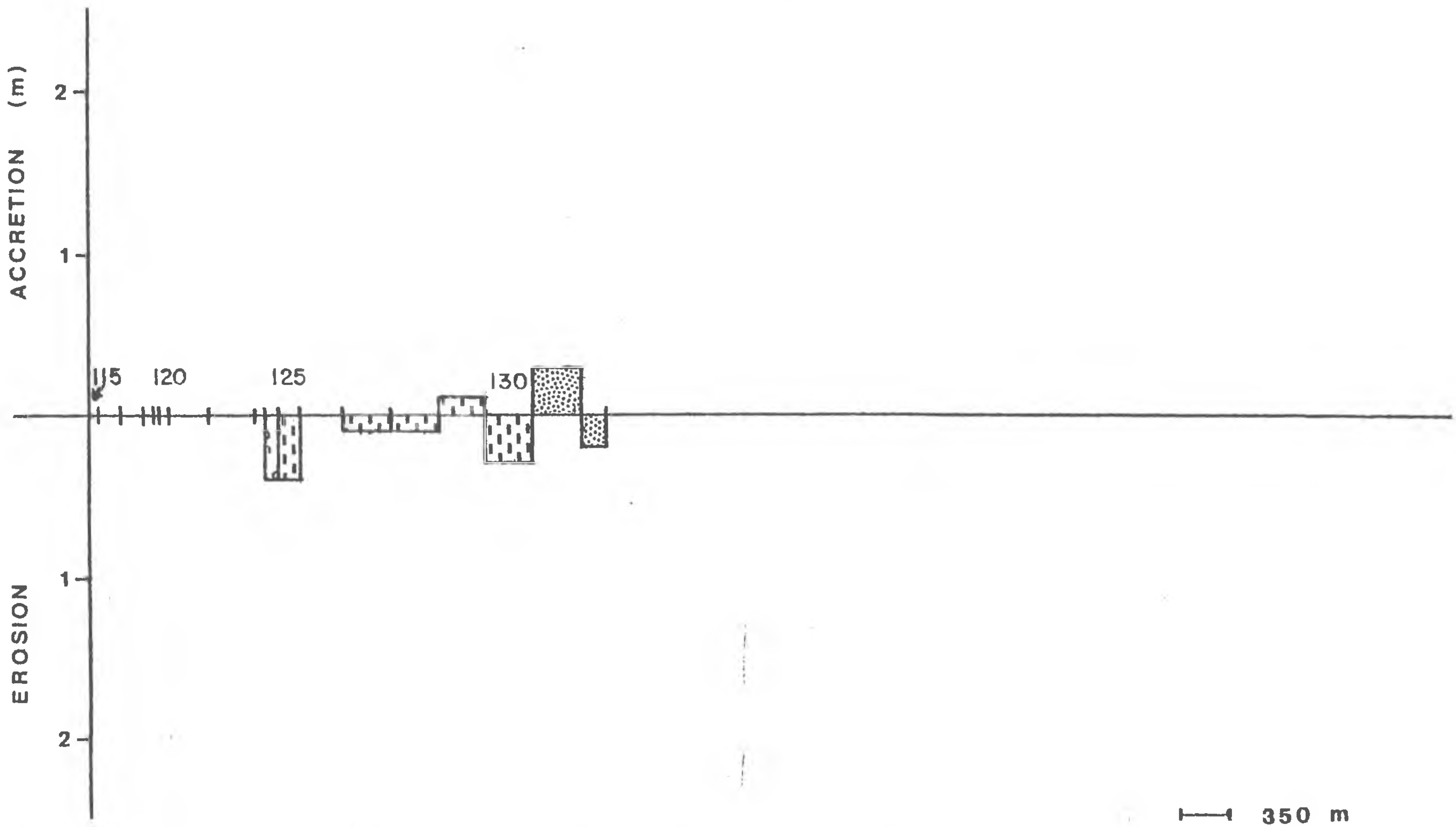
Plum Beach Point-Greenwich Bay (Fig. B);(Fig. A_5, A_6, segments 89-114),(Fig. A_7, A_8, segments 115-132),(Fig. A_9, A_{10}, segments 133-169).

Segment 91, bridging the gap between Plum Beach Point and Greene Point, eroded an average of 0.1 m/yr at the high tide line. Segment 92, the South side of Greene Point, eroded 0.1 m/yr. The erosion on a small portion of Greene

Figure 16. Shoreline Segment Location Map: Plum Beach Point - Greenwich Bay.

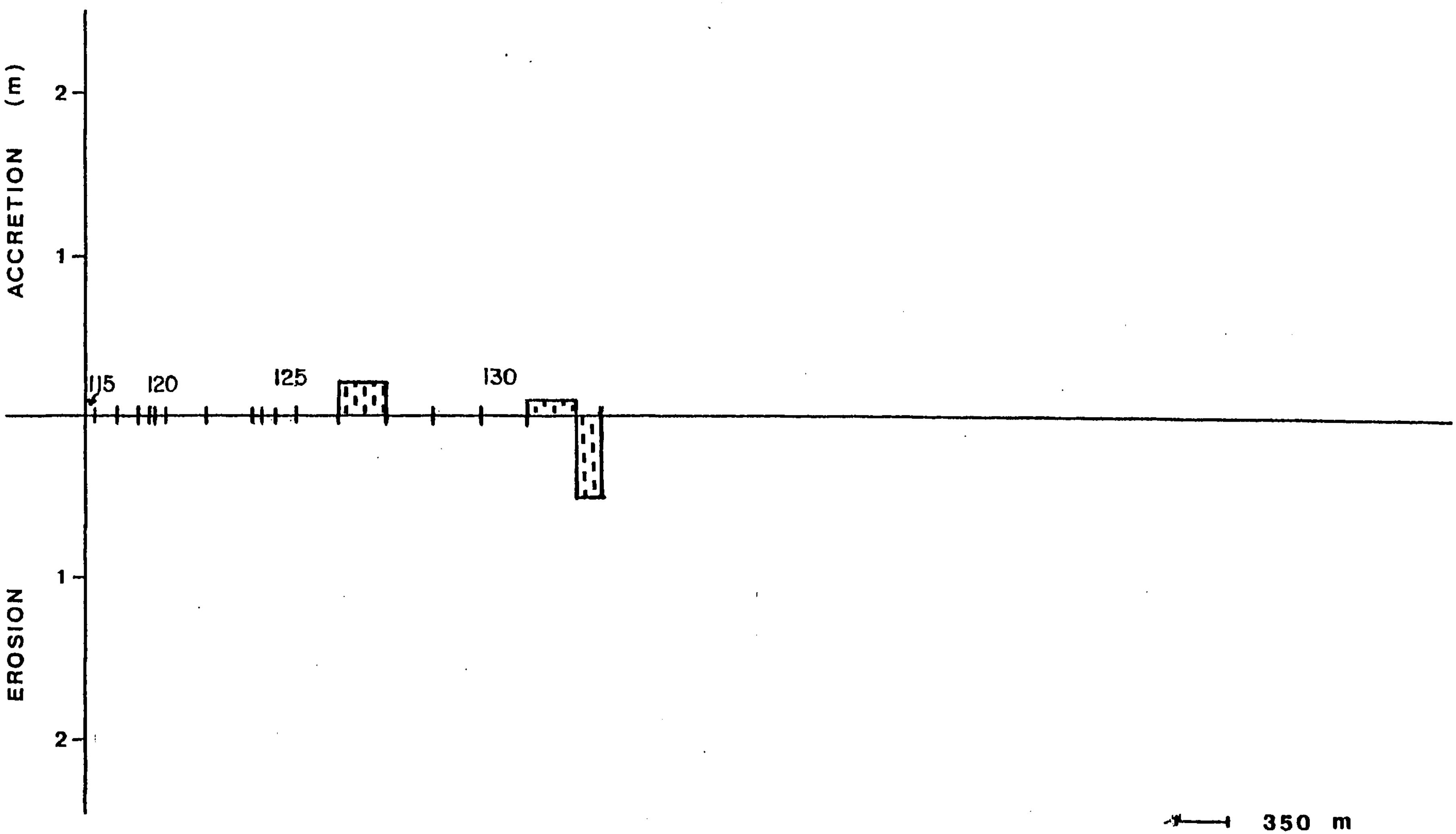

GREENWICH BAY
SALLY ROCK POINT
170
160
SANDY POINT
POJAC POINT
150
POTOWOMUT R.
TIBBETS CR.
140
QUONSET PIERS
131
QUONSET POINT
APPROXIMATE
FILL/NATURAL
BOUNDARY
130
WICKFORD HARBOR
COLD SPRING BEACH
120
LITTLE TREE POINT
110
100
BISSEL COVE
ROME POINT
GREENE POINT
90
PLUM BEACH POINT

LITTLE TREE POINT — QUONSET PIERS

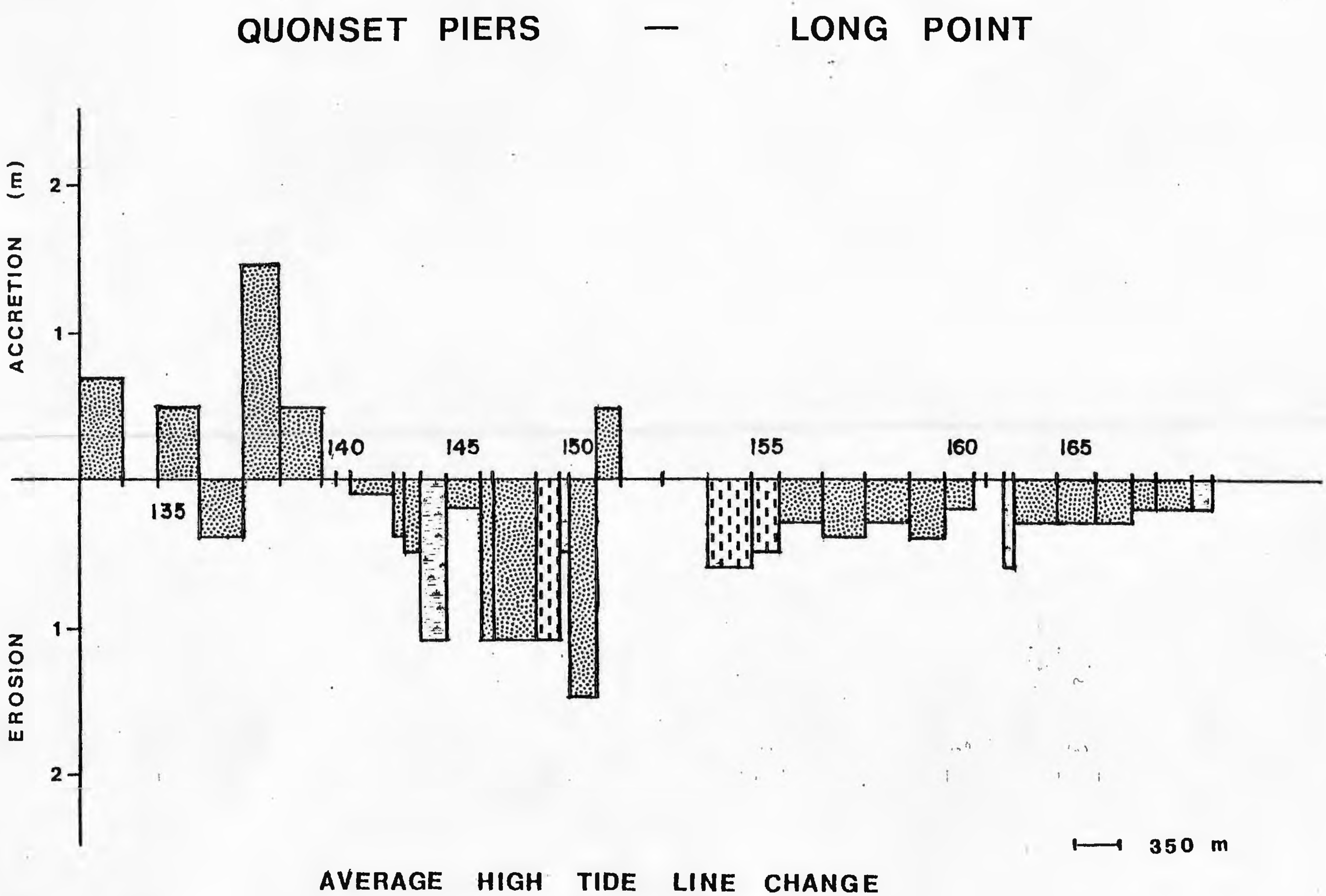


AVERAGE HIGH TIDE LINE CHANGE

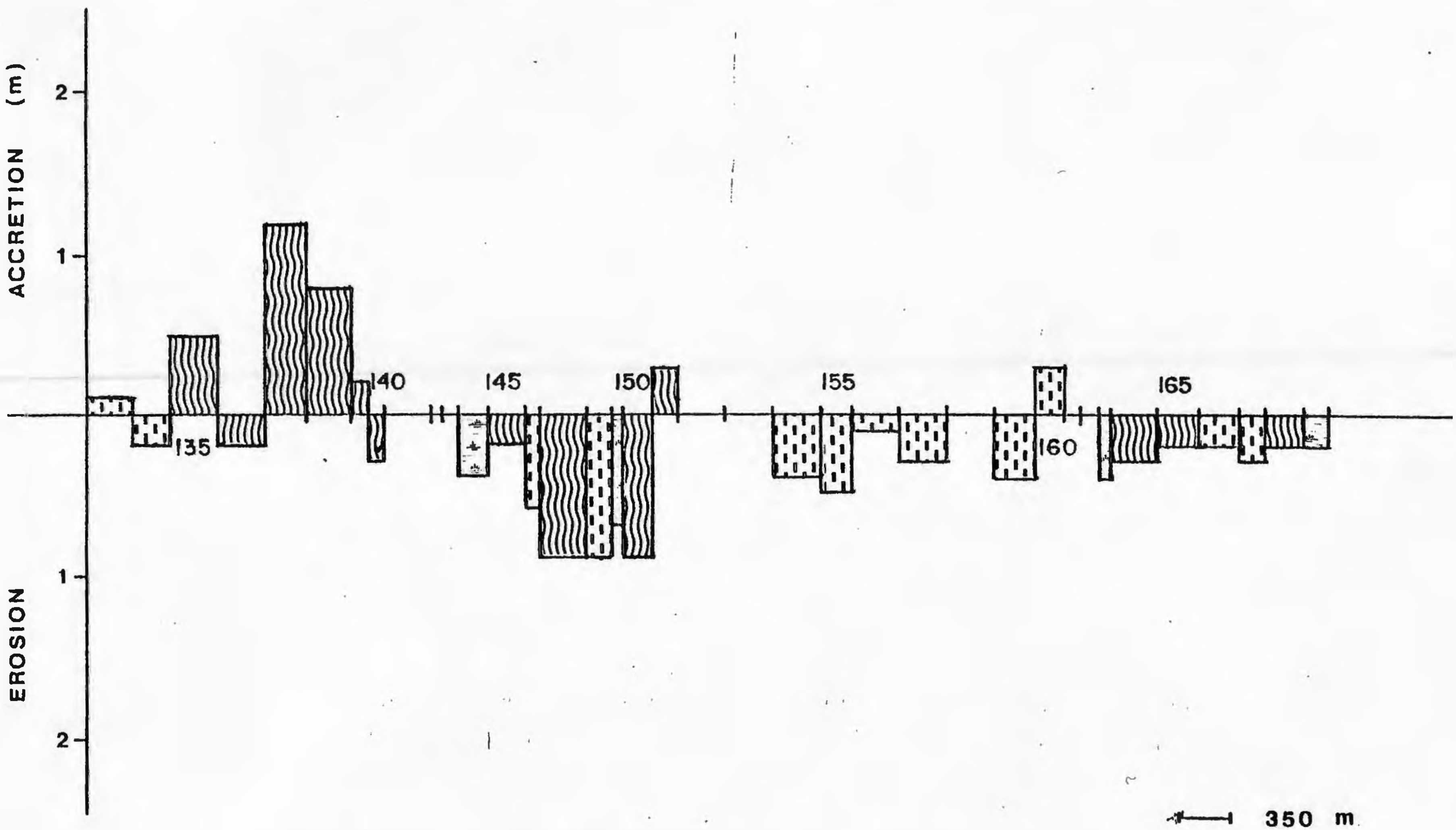
LITTLE TREE POINT — QUONSET PIERS



AVERAGE BACK BEACH LINE CHANGE


QUONSET PIERS — LONG POINT
ACCRETION (m)
EROSION
2
1
1
2
135
140
145
150
155
160
165
350 m
AVERAGE HIGH TIDE LINE CHANGE

QUONSET PIERS — LONG POINT



AVERAGE BACK BEACH LINE CHANGE

Point's north side was observed but not measurable.

Between Greene Point and Rome Point there was no change, but accretion of 0.5 m/yr (high tide line) and 0.4 m/yr (back-of-beach) occurred along the southeast side of Rome Point (segment 98). The tip of Rome Point and its northwest side exhibited erosion of 0.1-0.2 m/yr. Bissel Cove (segments 101-105) showed net erosion: reaching 0.5 m/yr at the southeast end of the cove.

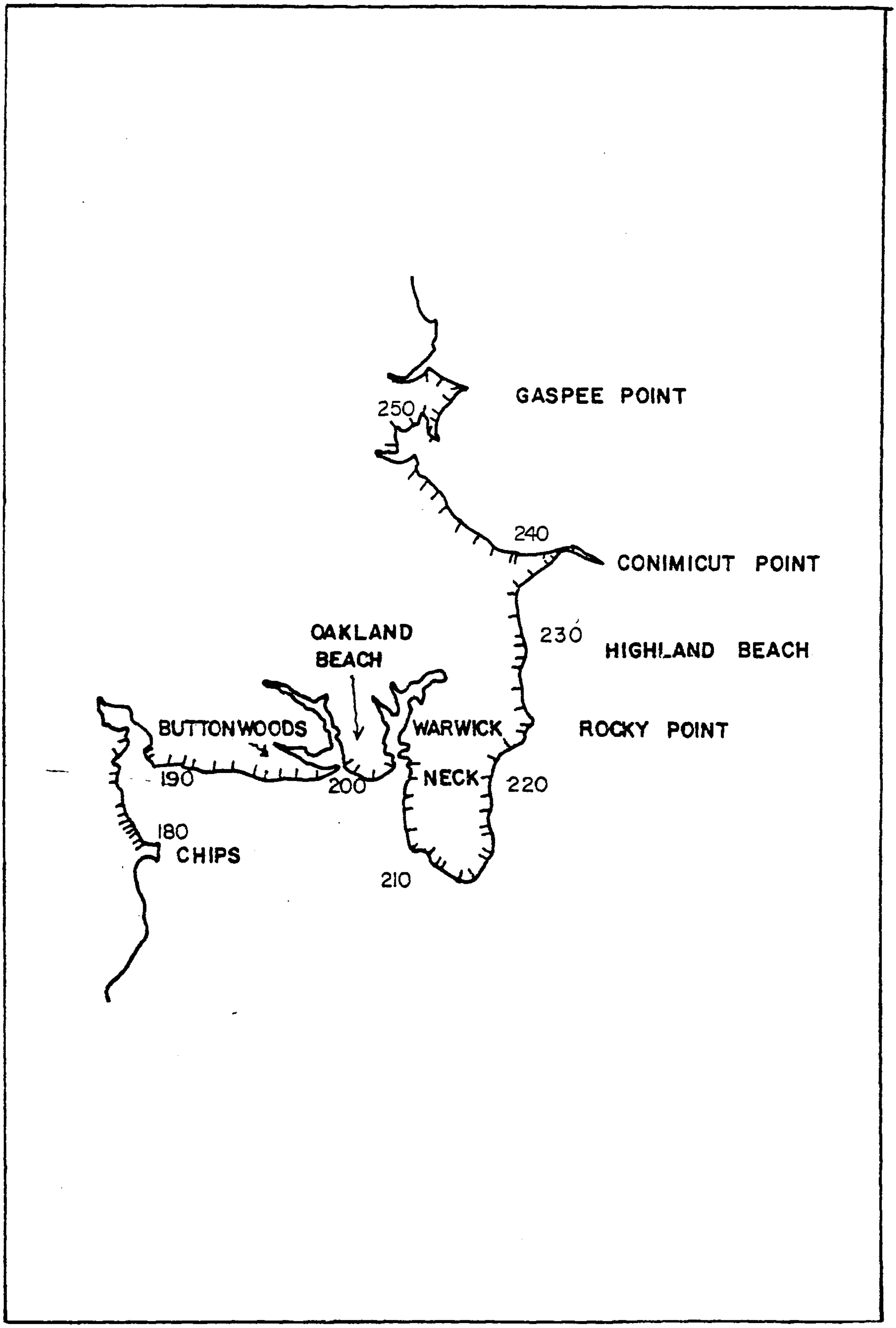
No change was measured at Little Tree Point or Cold Spring Beach, but erosion and accretion occurred between segments 127 and 130 at Quonset Point. The entire cuspate shoreform at Quonset Point is located between segments 130 and 131. The land area at Quonset Point was increased by 400 acres and the landscape was altered profoundly by landfill operations from 1939-1941 (R.I. Historical Society, 1979). There are no diagnostic features common to both 1938 and 1975 photographs of Quonset Point, and comparative mapping and subsequent shoreline change measurement could not be accomplished. Segment 131 showed a positive change of 0.1 m/yr at the back beach line and 0.3 m/yr at the high tide line. Segment 132 showed net erosion: 0.5 m/yr at the back beach line and 0.2 m/yr at the high tide line. Segments 131 and 132 are not included in the figures, since shoreline changes occurred to the north and south but were too large to be measured.

At Allen Harbor (segments 133-137) accretion rates reached 1.2 - 1.5 m/yr for the back beach line and high tide line, respectively. Erosion was predominant between Allen Harbor and the east side of Pojac Point, where it peaked at 0.9 m/yr at the back beach line and 1.5 m/yr at the high tide line. Pojac Point (segments 150 and 151) has experienced a net migration to the West; accretion on the western shore netted 0.3 m/yr at the back beach line and 0.5 m/yr at the high tide line. West of Pojac Point and along the southern shore of the Potowomut River at segments 152 and 153, no change was recorded.

North of the Potowomut River to Sandy Point 0.4 - 0.5 m/yr (segment 154) of net erosion took place; the Sandy Point cuspate shoreform was much narrower in 1975 than in 1938. The northern side of Sandy Point (segment 156) experienced 0.1-0.2 m/yr of erosion. Similar erosion rates prevailed to segment 161, just to the east of Sally Rock Point in Greenwich Bay. From the West shore of Sally Rock Point to Long Point (segments 163-169) there is erosion of 0.2-0.4 m/yr for the back beach line and high tide line.

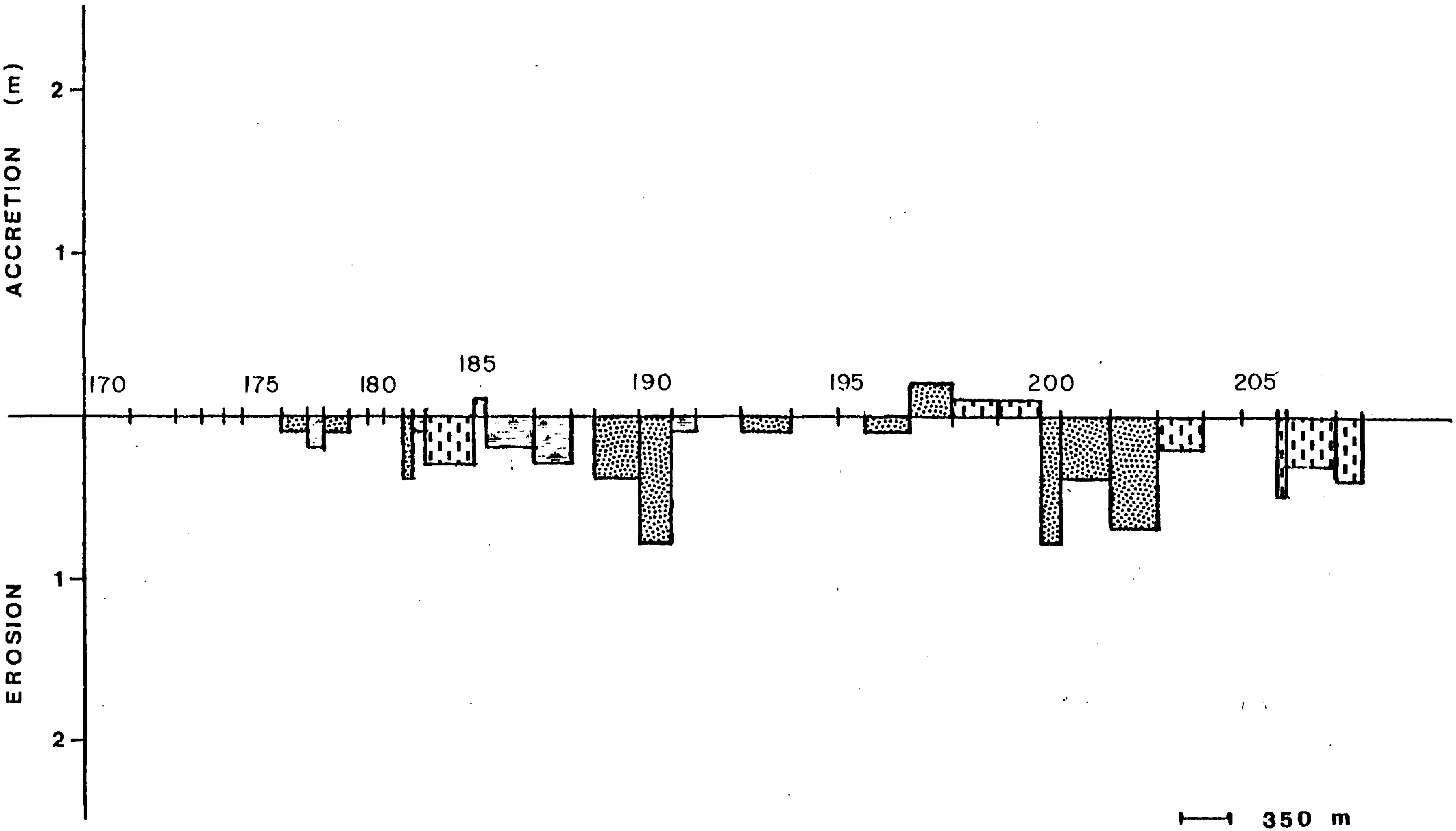
Greenwich Bay-Gaspee Pt. (Fig. C);(Fig. A_{11}, A_{12}, segments 170-208);(Fig. A_{13}, A_{14}, segments 209-242); (Fig. A_{15}, A_{16}, segments 243-257).

Figure 21. Shoreline Segment Location Map:
Greenwich Bay - Gaspee Point.



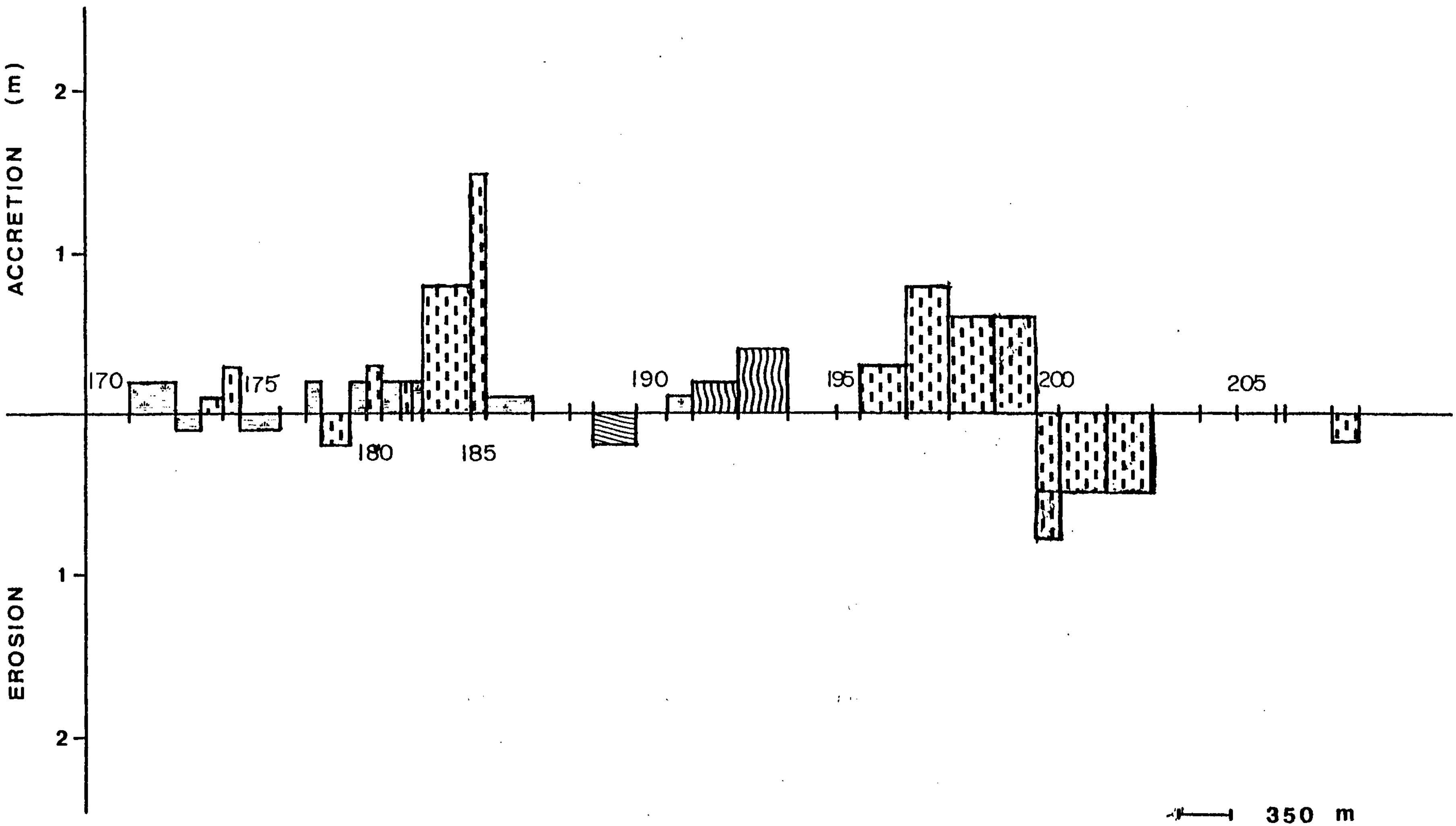
GASPEE POINT
250
240
CONIMICUT POINT
230
HIGHLAND BEACH
OAKLAND
BEACH
BUTTONWOODS
WARWICK
ROCKY POINT
190
200
NECK
220
180
CHIPS
210

LONG POINT — WARWICK NECK

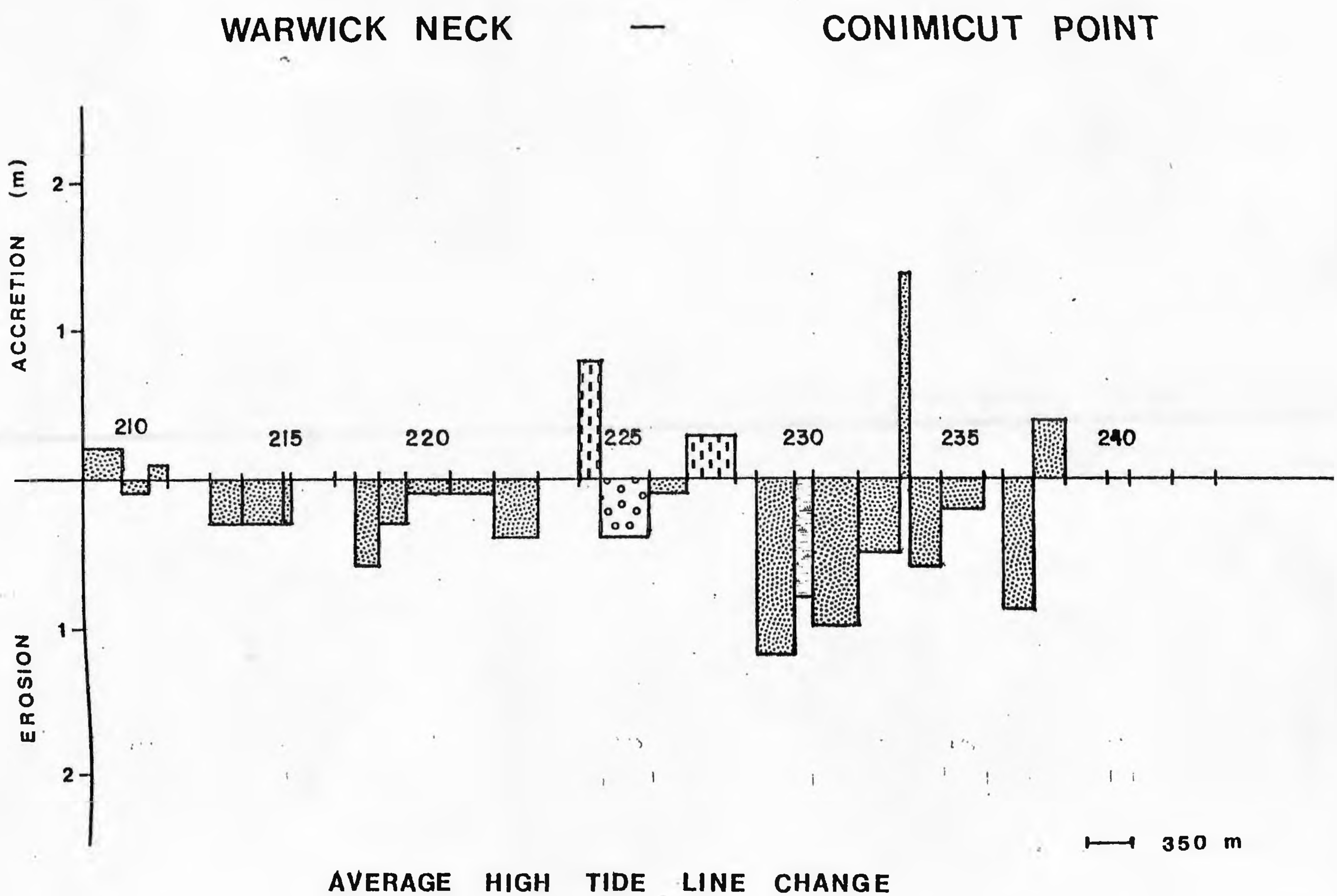


AVERAGE HIGH TIDE LINE CHANGE

LONG POINT — WARWICK NECK

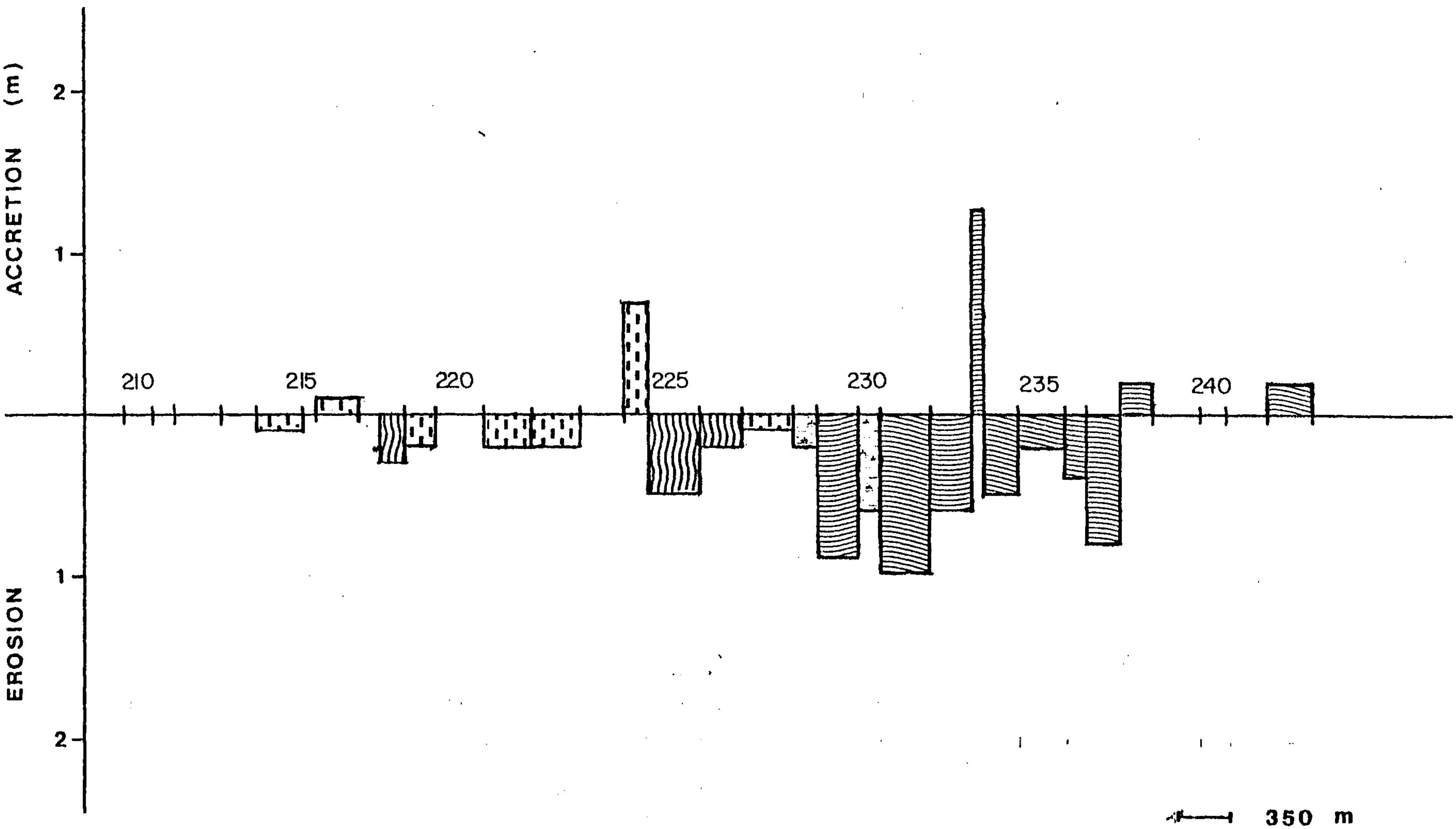


AVERAGE BACK BEACH LINE CHANGE



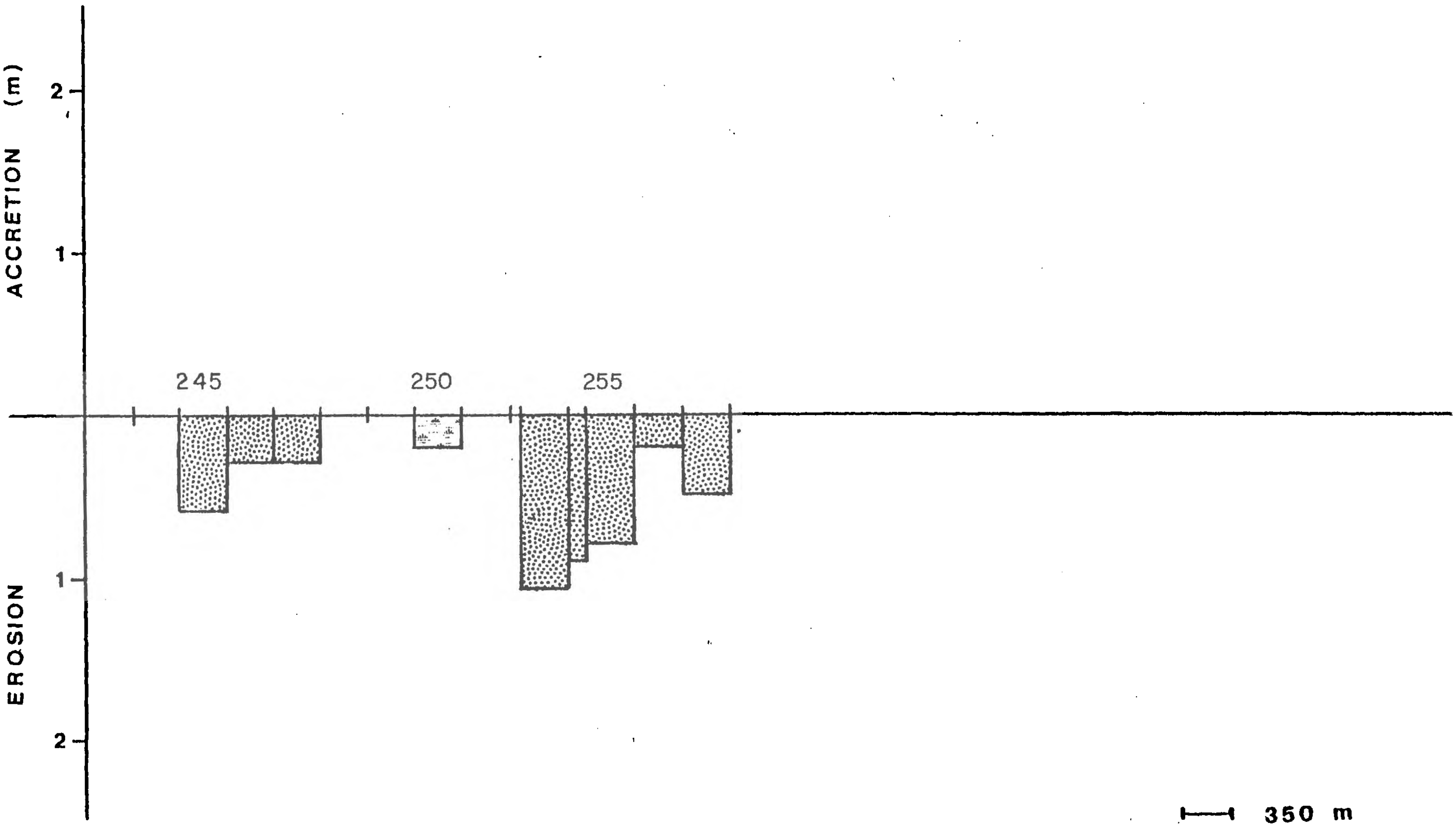
WARWICK NECK — CONIMICUT POINT
ACCRETION (m)
EROSION
2
1
1
2
210
215
220
225
230
235
240
350 m
AVERAGE HIGH TIDE LINE CHANGE

WARWICK NECK — CONIMICUT POINT



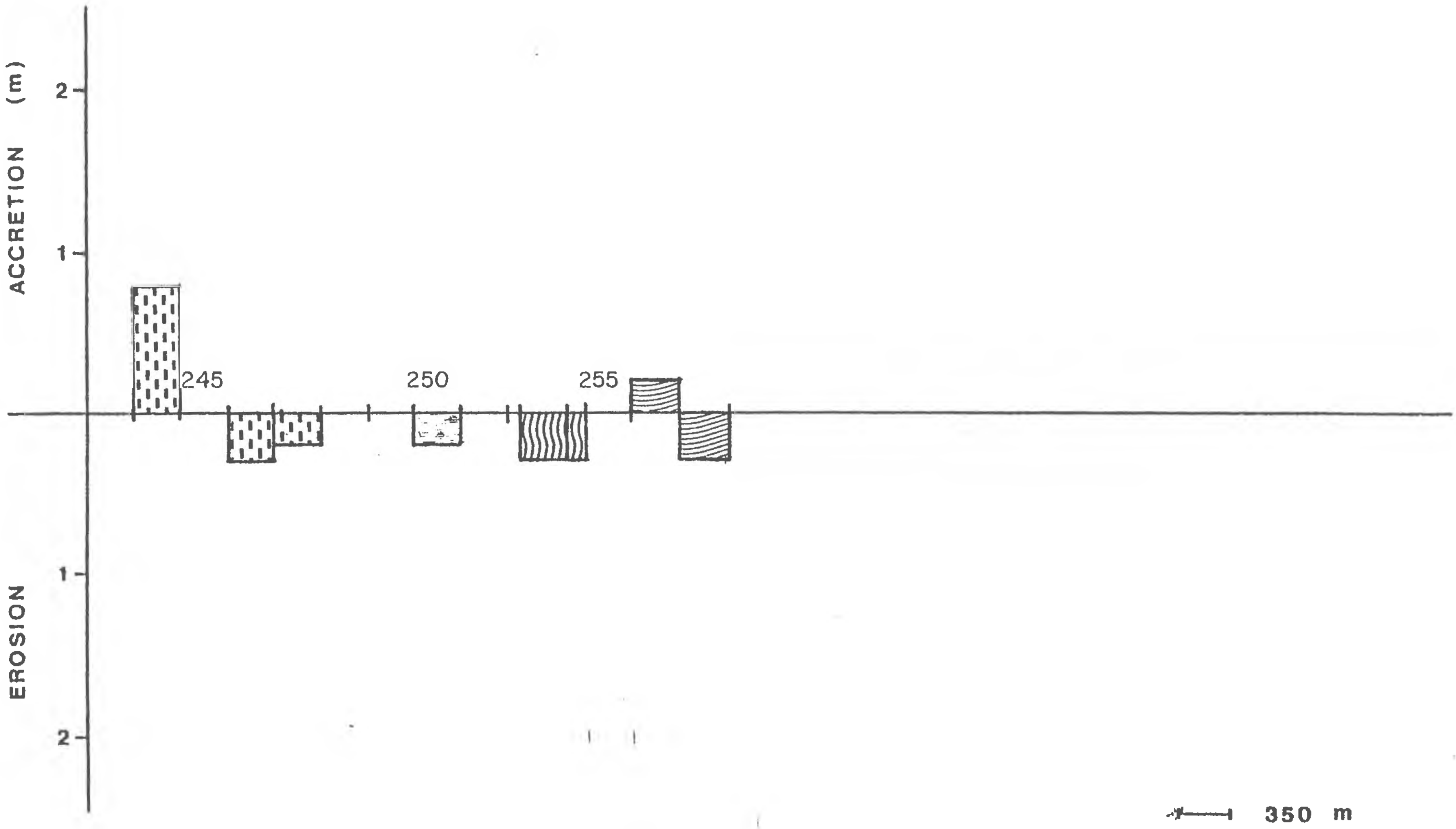
AVERAGE BACK BEACH LINE CHANGE

CONIMICUT POINT — GASPEE POINT



AVERAGE HIGH TIDE LINE CHANGE

CONIMICUT POINT — GASPEE POINT



AVERAGE BACK BEACH LINE CHANGE

Erosion dominates the high tide line measurements for almost all of Greenwich Bay (segments 156-212), although there is 0.1-0.2 m/yr accretion noted in Buttonwoods at segments 197-199. Accretion is predominant for most of the west and north shores of Greenwich Bay, largely due directly to the construction of beach protection structures. Oakland Beach (segments 200-202) displays erosion of up to 0.8 m/yr at the back beach line and high tide line during the study period.

Warwick Neck (segments 203-223) generally displays moderate erosion with a mean value of approximately 0.2 m/yr and a range from 0.0-0.6 m/yr. Rocky Point has been built out on its south side: segment 224 accreted at what would be an average rate of 0.7 m/yr at the back beach line and 0.8 m/yr at the high tide line. Segment 225, on the north side of Rocky Point, lost an average of 0.5 m/yr from the back beach line and 0.4 m/yr from the beach face.

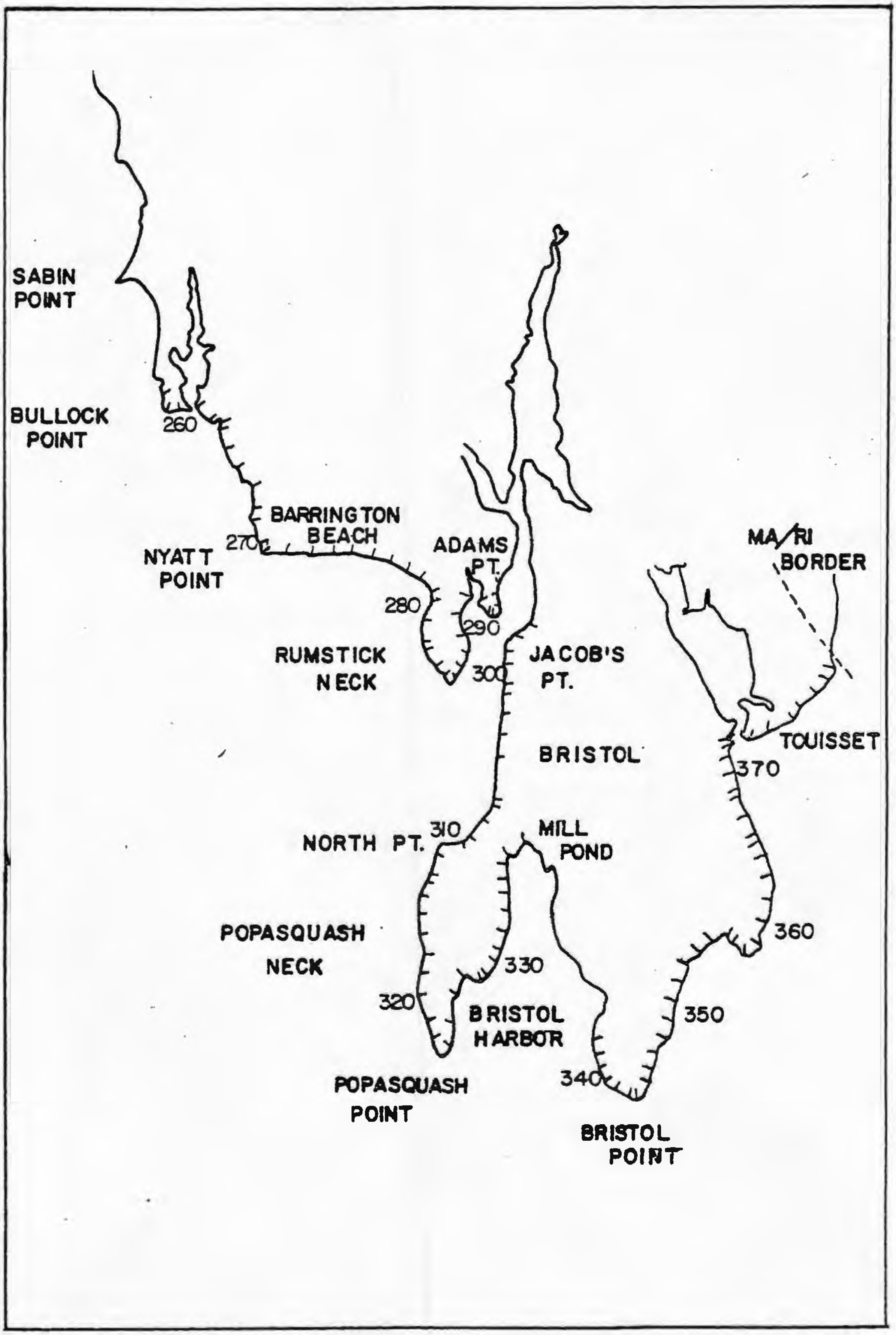
Erosion of the back beach line and high tide line continues along the shore to the Conimicut Point cuspate shoreform. The area of 1.3 and 1.4 m/yr of apparent accretion at segment 233 is due to the migration of the mouth of Old Mill Creek to the north, a process similar to inlet migration on the Outer Banks of North Carolina. Segment 234 eroded at 0.5-0.6 m/yr. due partly to creek mouth migration. The south side of Conimicut Point (segment 237) displays an average erosion rate of

0.8 m/yr at the top of the dune and 0.9 m/yr at the high tide line. Segment 238, at the north side of Conimicut Point, had an average accretion rate of 0.2 m/yr at the dune and 0.4 m/yr at the high tide line. The tip of Conimicut Point has migrated to the north. The whole shoreform has not migrated; erosion on the south side is not matched by equal erosion on the north side. Moderate erosion occurs between Conimicut Point and Occupessatuxet Cove (segments 239-247). Gaspee Point (segments 253-257) eroded at 0.2-1.1 m/yr at the dune line. The tip of Gaspee Point has made a net migration to the south.

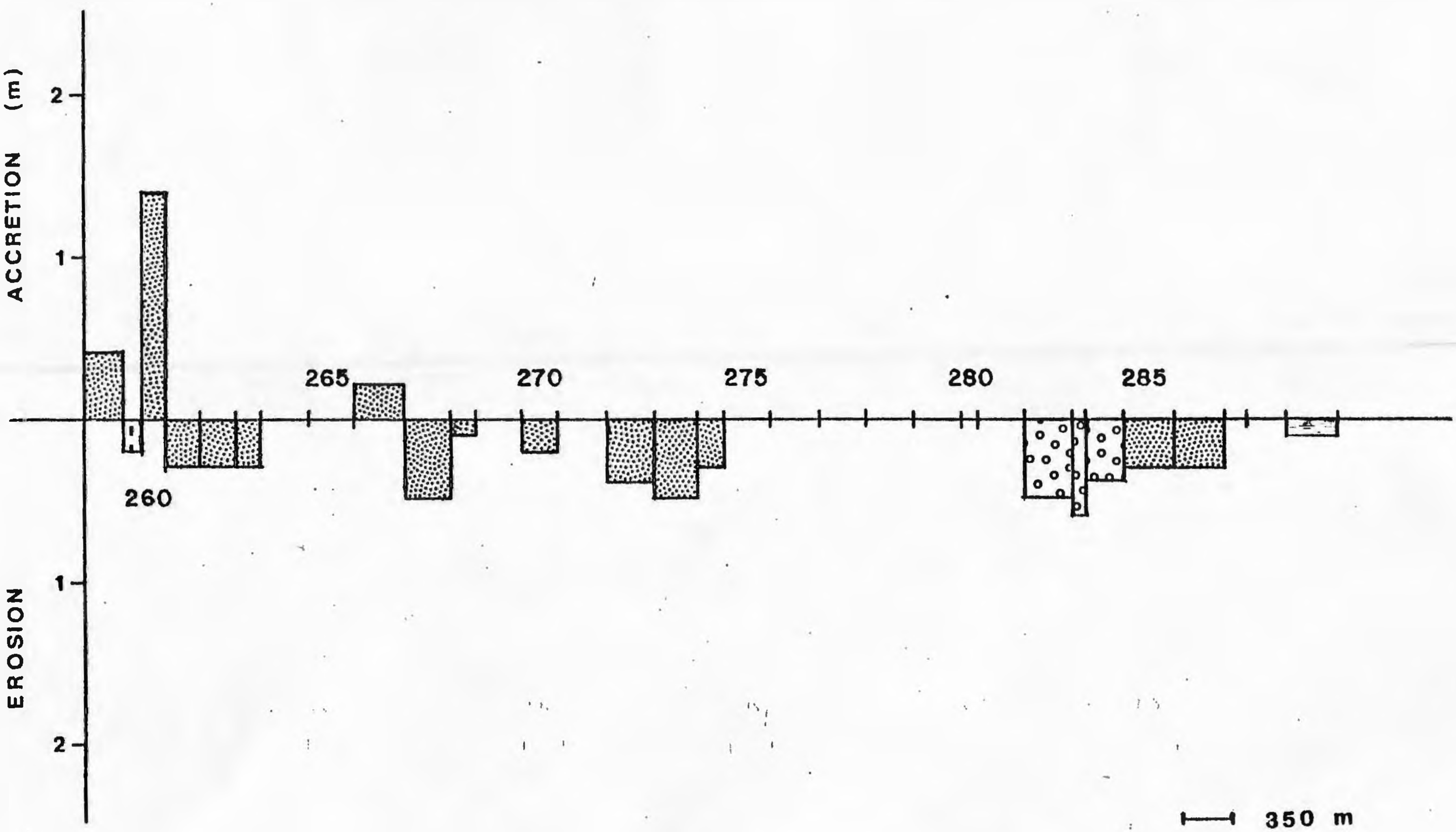
SHORELINE CHANGES: BULLOCK POINT - MASSACHUSETTS/RHODE ISLAND BORDER

Shoreline changes along the Providence River were not mapped and measured for this paper; the shores of Providence, Cranston, and most of East Providence are not included. Nearly all of these shorelines are heavily filled or otherwise engineered, and their erosion and accretion rates have little bearing on natural processes. An example is Fields Point, which in 1939 was a series of recurved spits, and in 1951 was filled in to create a series of docks. (R.I. Historical Society, 1979). Sabin Point was not included because of the lack of availability of 1938 aerial photo coverage.

Figure 28. Shoreline Segment Locaiton Map: Bullock Point - Massachusetts/Rhode Island Border.

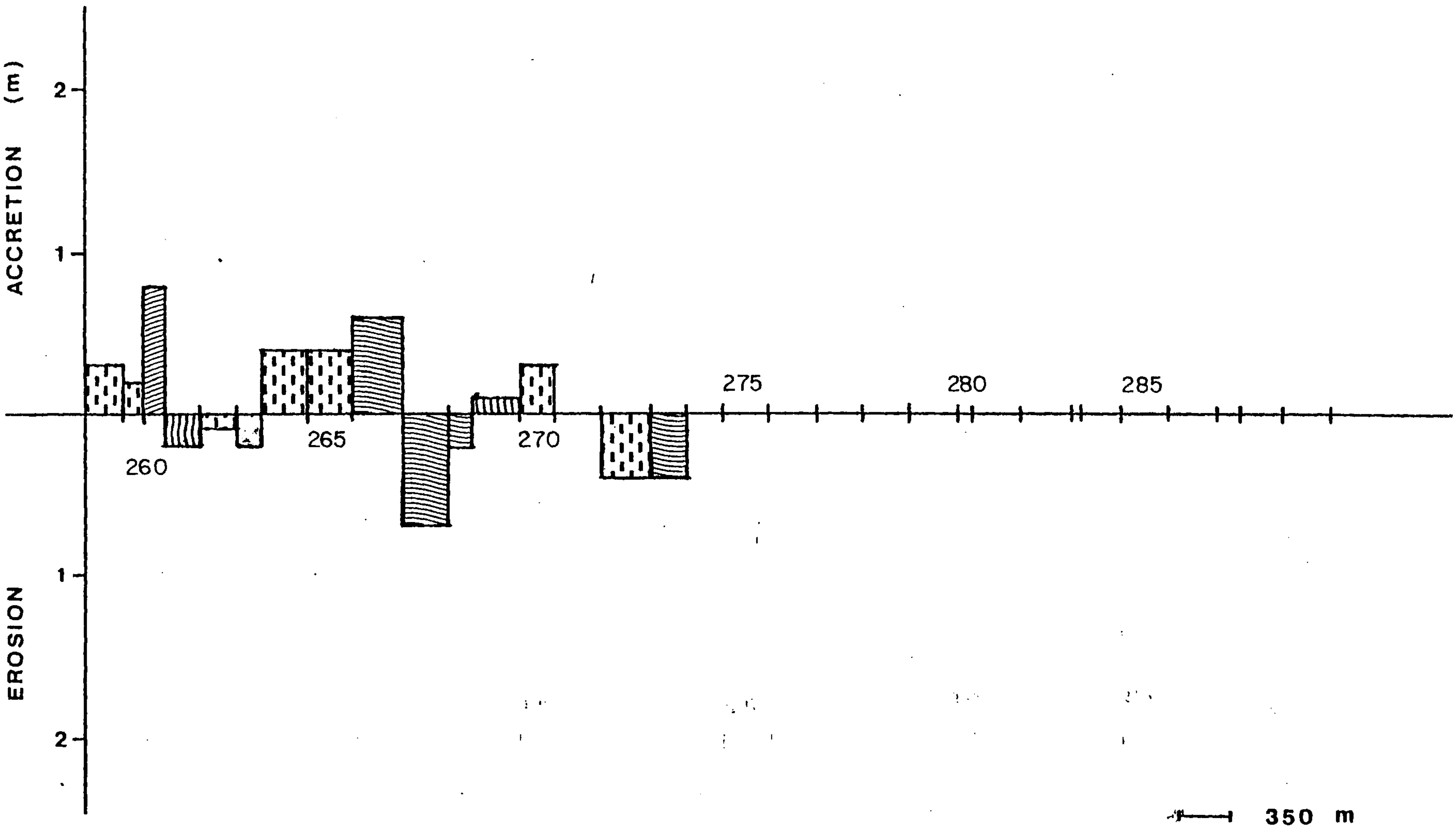

SABIN POINT
BULLOCK POINT
260
BARRINGTON BEACH
270
NYATT POINT
ADAMS PT.
280
290
RUMSTICK NECK
300
JACOB'S PT.
BRISTOL
MA/RI BORDER
TOUISSET
370
310
NORTH PT.
MILL POND
POPASQUASH NECK
330
360
320
BRISTOL HARBOR
350
340
POPASQUASH POINT
BRISTOL POINT

BULLOCK POINT — RUMSTICK POINT



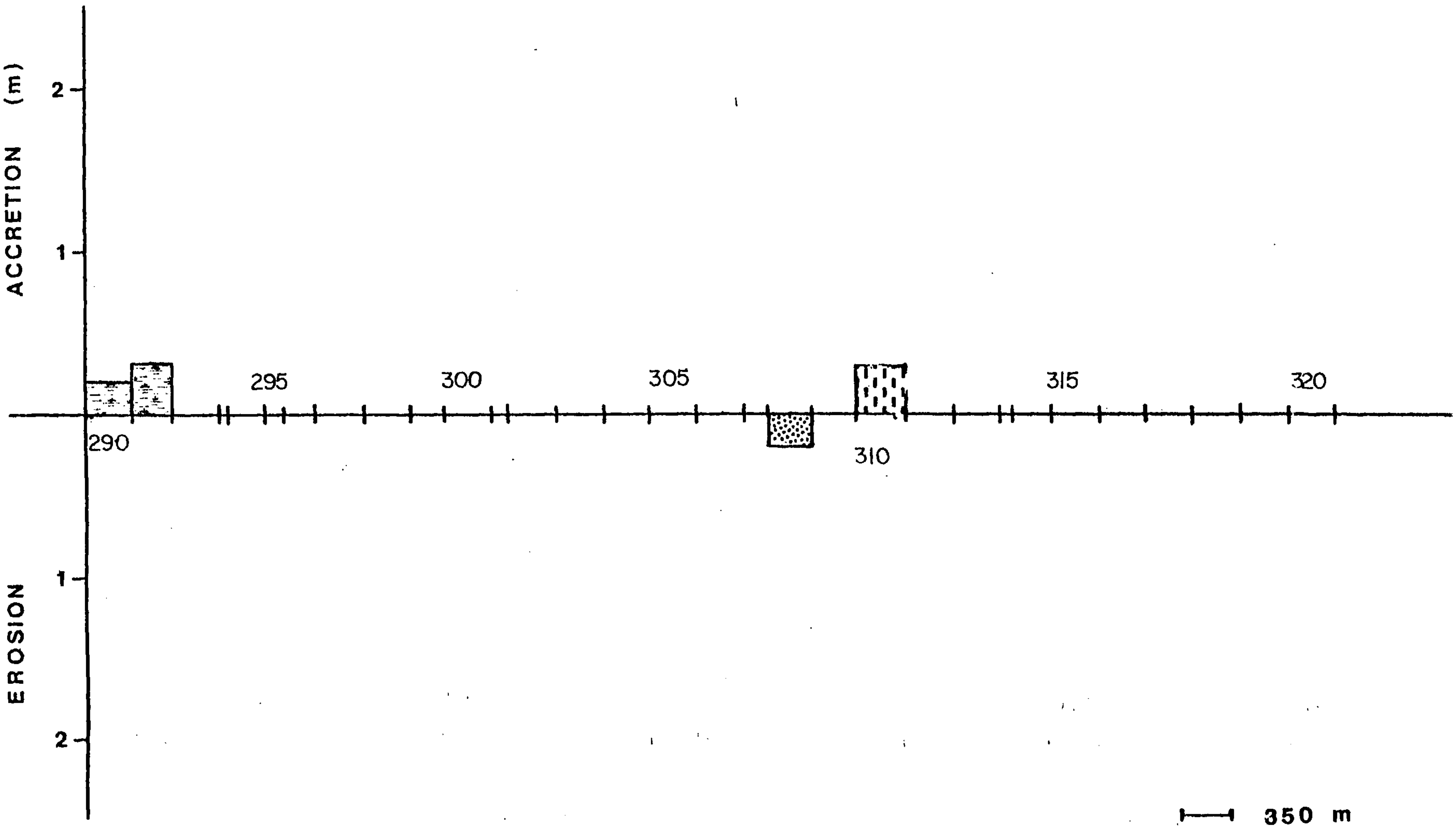
AVERAGE HIGH TIDE LINE CHANGE

BULLOCK POINT — RUMSTICK POINT

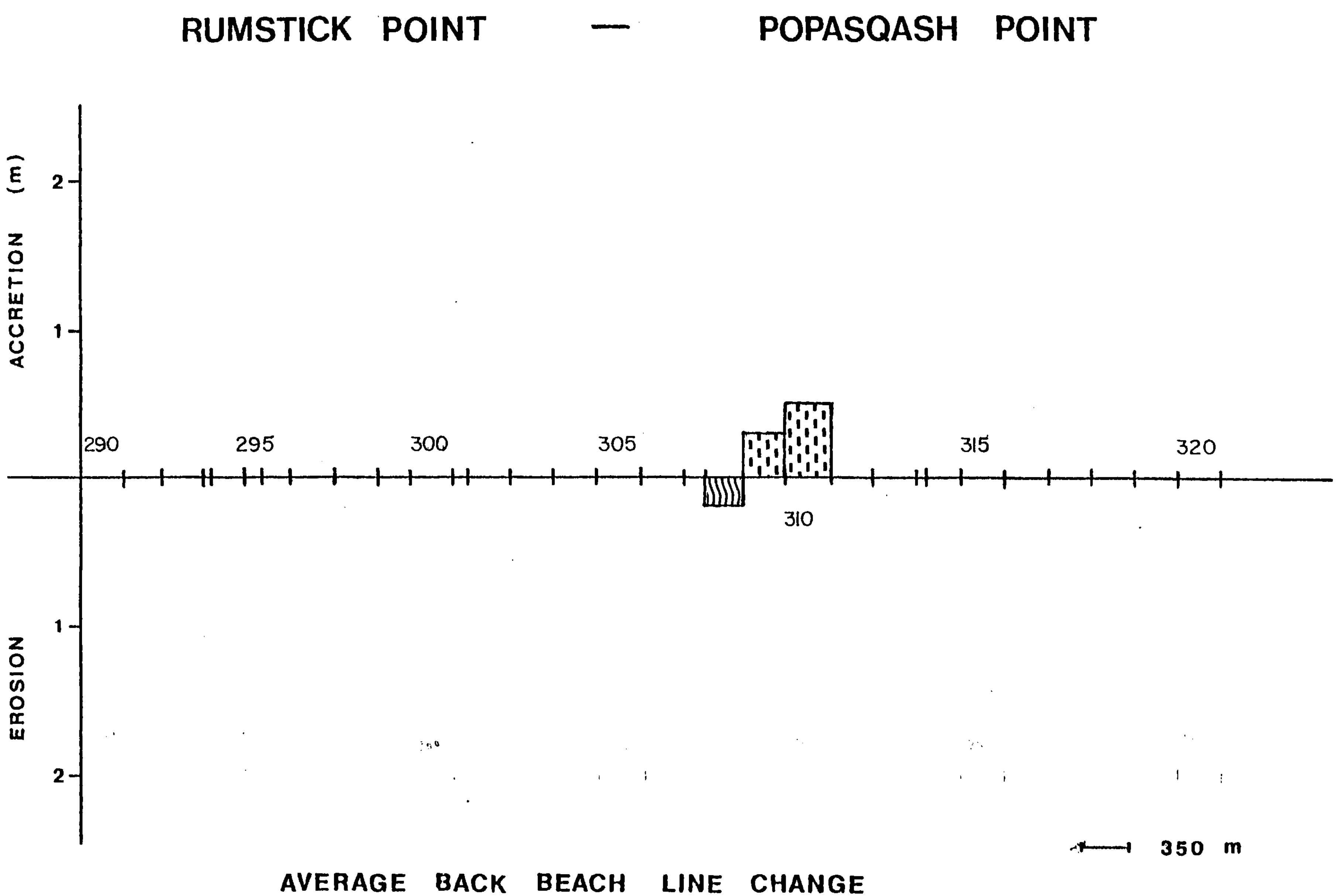


AVERAGE BACK BEACH LINE CHANGE

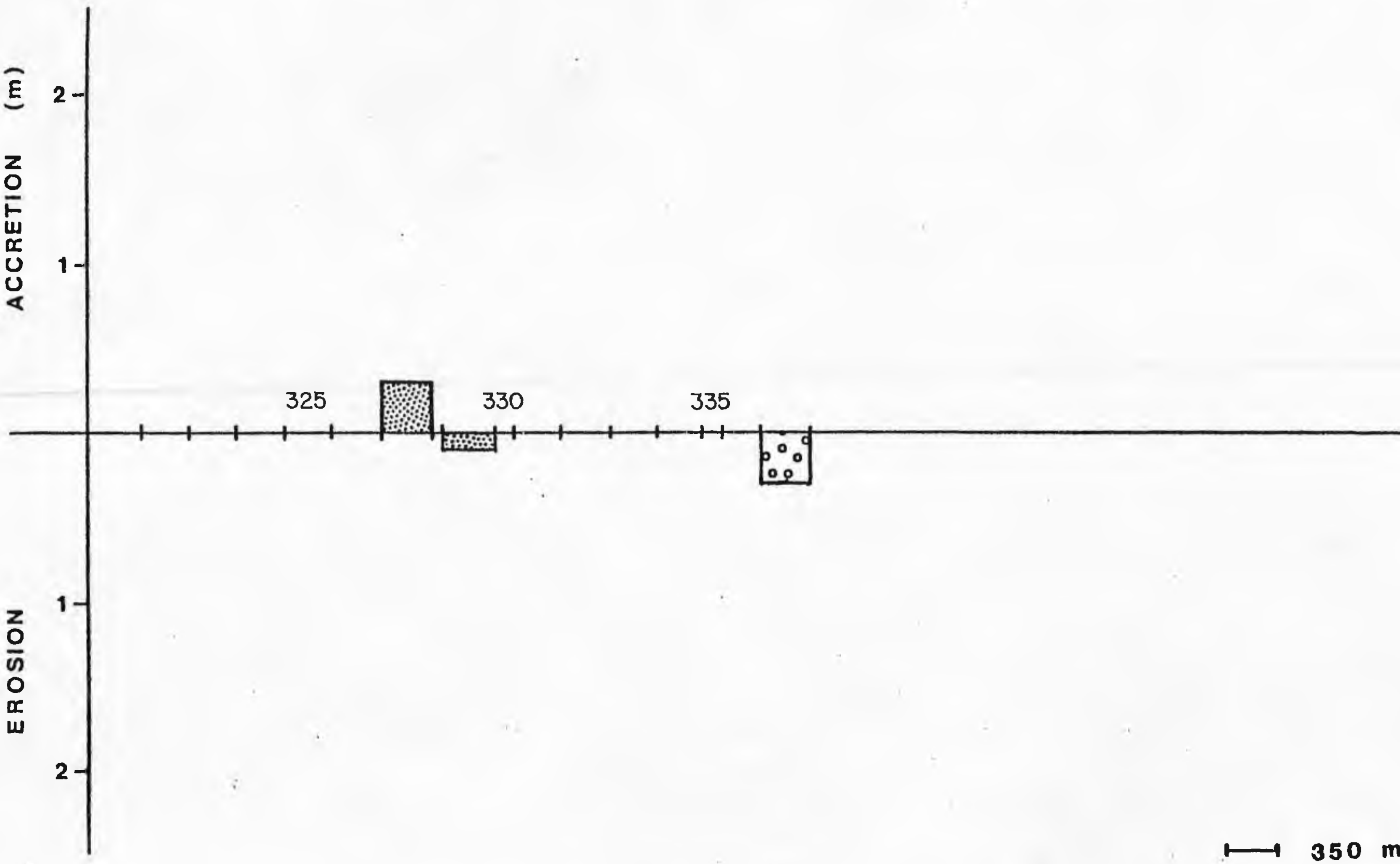
RUMSTICK POINT — POPASQUASH POINT



AVERAGE HIGH TIDE LINE CHANGE

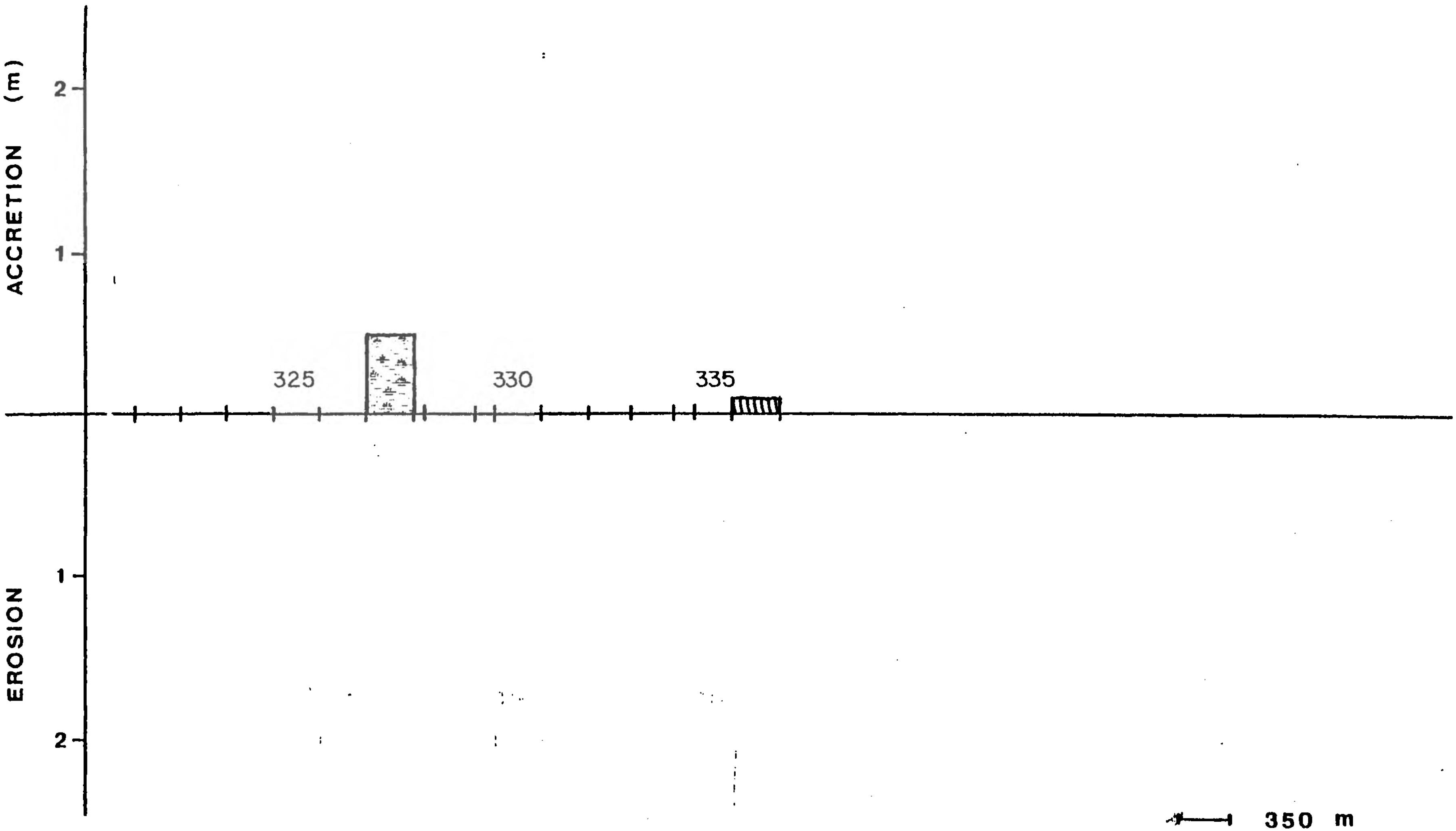

RUMSTICK POINT — POPASQASH POINT
ACCRETION (m)
EROSION
2
1
1
2
290
295
300
305
310
315
320
350 m
AVERAGE BACK BEACH LINE CHANGE

POPASQUASH POINT — MILL POND

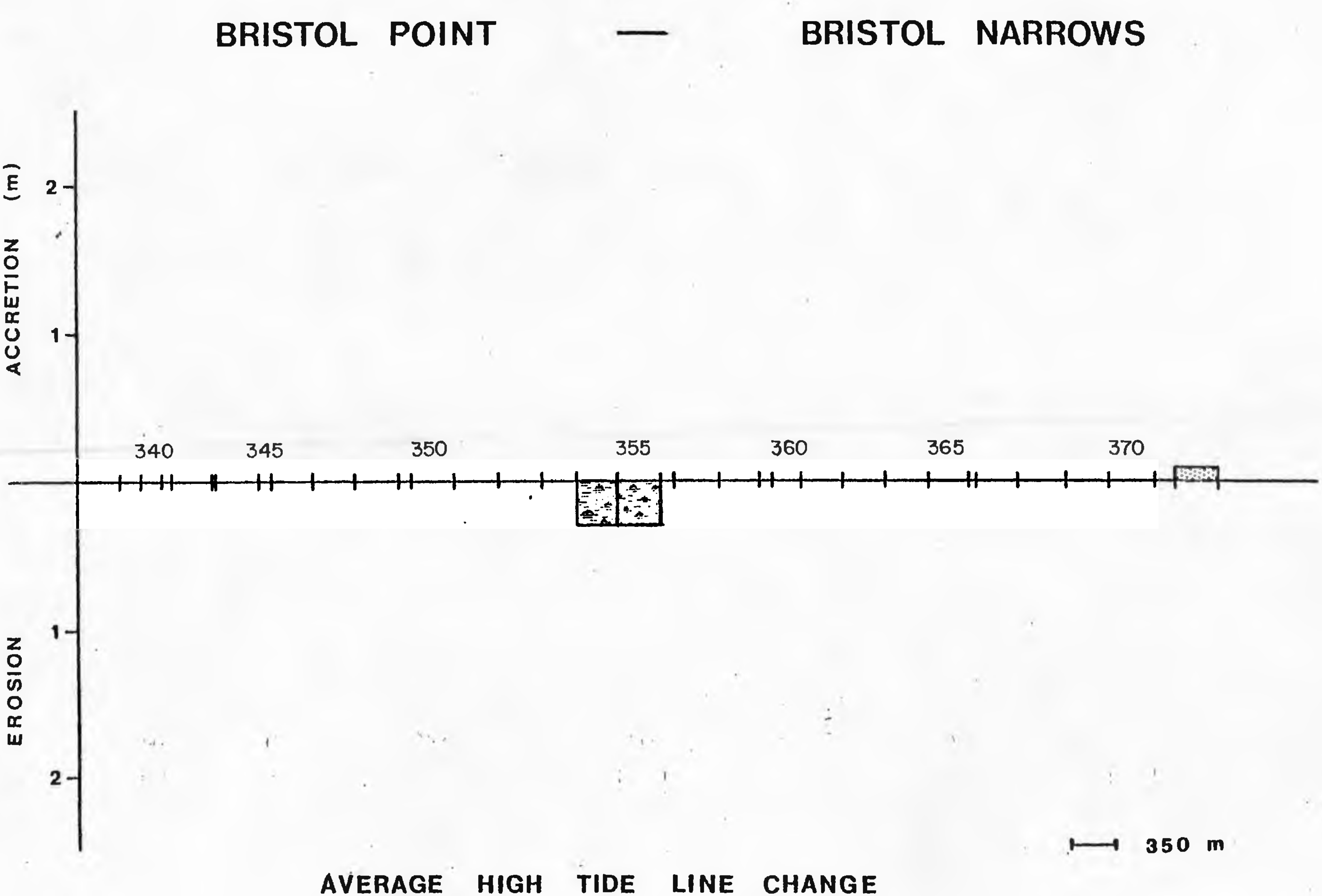


AVERAGE HIGH TIDE LINE CHANGE

POPASQUASH POINT — MILL POND

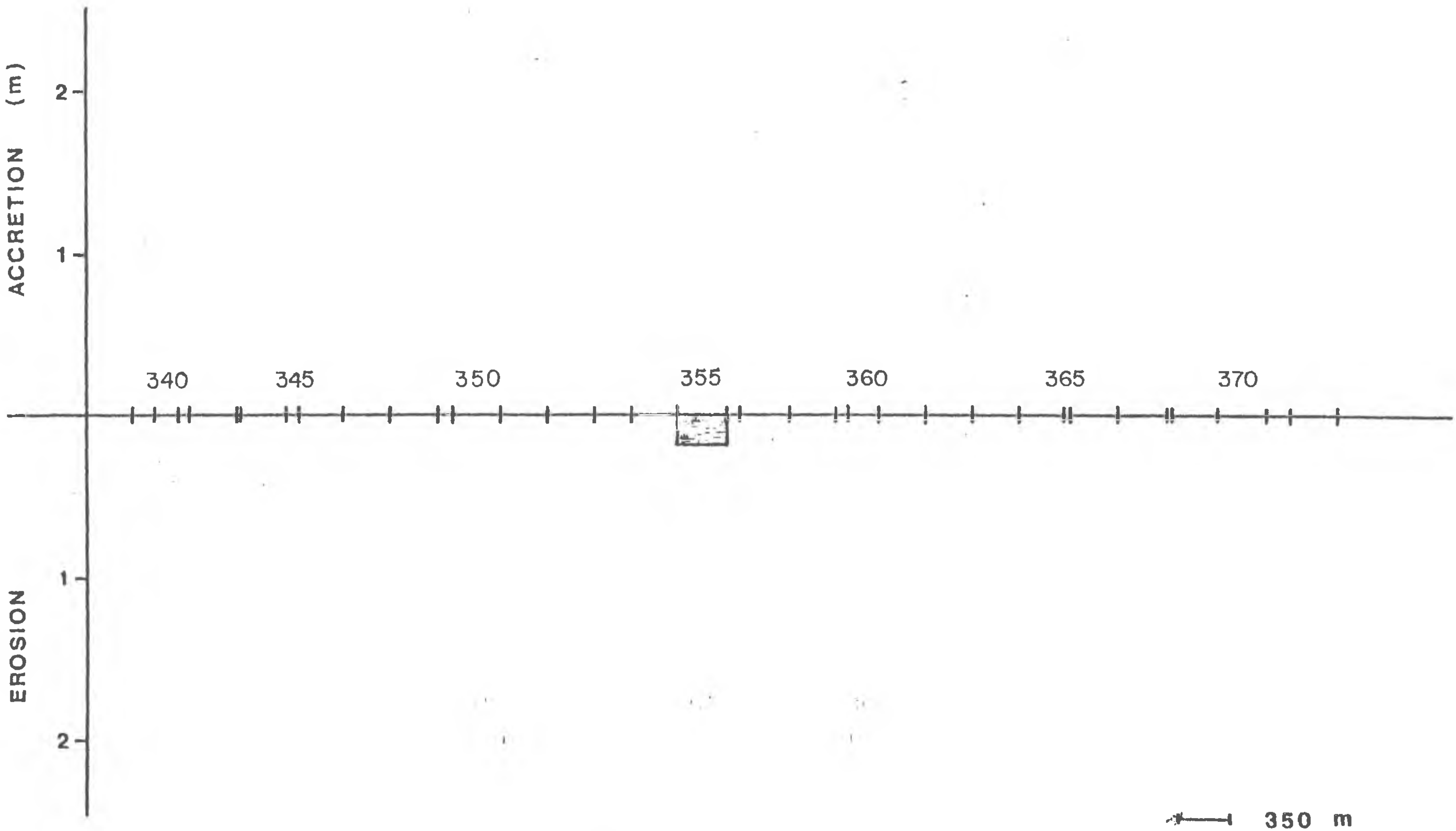


AVERAGE BACK BEACH LINE CHANGE



BRISTOL POINT — BRISTOL NARROWS
ACCRETION (m)
EROSION
2
1
1
2
340
345
350
355
360
365
370
350 m
AVERAGE HIGH TIDE LINE CHANGE

BRISTOL POINT — BRISTOL NARROWS



AVERAGE BACK BEACH LINE CHANGE

This northern border of Narragansett Bay (Fig. D); (Fig. A_{17}, A_{18}, segments 259-289),(Fig. A_{19}, A_{20}, segments 290-320),(Fig. A_{21}, A_{22}, segments 321-337), (Fig. A_{23}, A_{24}, segments 338-372), is dominated geomorphically by the glacial headlands of Bristol and Poppasquash and Rumstick Necks. Barrington Beach is another important feature. It is a barrier beach and is exposed to a long fetch. This section of shoreline consists of a glacial moraine, glacial outwash, and kame delta deposits (Smith, 1955).

The Bullock Point area (segments 258-260) is dominated by accretion, most notably at the mouth of Bullock Cove, where dunes and sand beach have developed seaward of the 1938 location. Segments 261-263, between Bullock Cove and the East shore of Brown Cove, show erosion of up to 0.3 m/yr. The back beach areas of segments 264 and 265 have been built out by man, but the net accretion at segment 266 is at the mouth of the Amawomscutt River, where natural outbuilding of the dune and sand beach have occurred since 1938. Erosion dominates past Nyatt Point to segment 274 on Barrington Beach. Segments 275-280, the East end of Barrington Beach, show no change.
No additional shoreline change is measured until Rumstick Neck is reached (segments 282-286), where there is erosion of the high tide line from 0.0-0.6 m/yr. Segment 289,

a marshy area just to the northeast of Rumstick Point, eroded at 0.1 m/yr. Segments 290-291 gained material at 0.2 and 0.3 m/yr. respectively.

No measurable change occurs along the Barrington, Palmer, or Warren Rivers, which are north and west of Adams Point at segment 310, just north of Colt State Park. At Mill Gut in Bristol, there has been accretion. Between North Point, past Poppasquash Point to the area of Usher Point there is no measured change; but in segment 327, just west of Usher Point, accretion occurred at an average rate of 0.3 and 0.5 m/yr at the high tide line and back beach line, respectively. Changes from segment 337 at Bristol Harbor to segment 338 just northwest of Bristol Point could not be mapped or measured due to lack of availability of 1975 vertical aerial photograph coverage at the time of the study. No change was observed from segment 338 to 353. At segments 354 and 355 at Church Cove, 0.2-0.3 m/yr. of erosion occurred. From Church Cove, past Mount Hope Point, and north to Bristol Narrows, no change was measured. At segment 372, at the mouth of the Kickamuit River, accretion of 0.1 m/yr. was observed. No change was measured from Coggeshall Point to the Massachusetts-Rhode Island border.

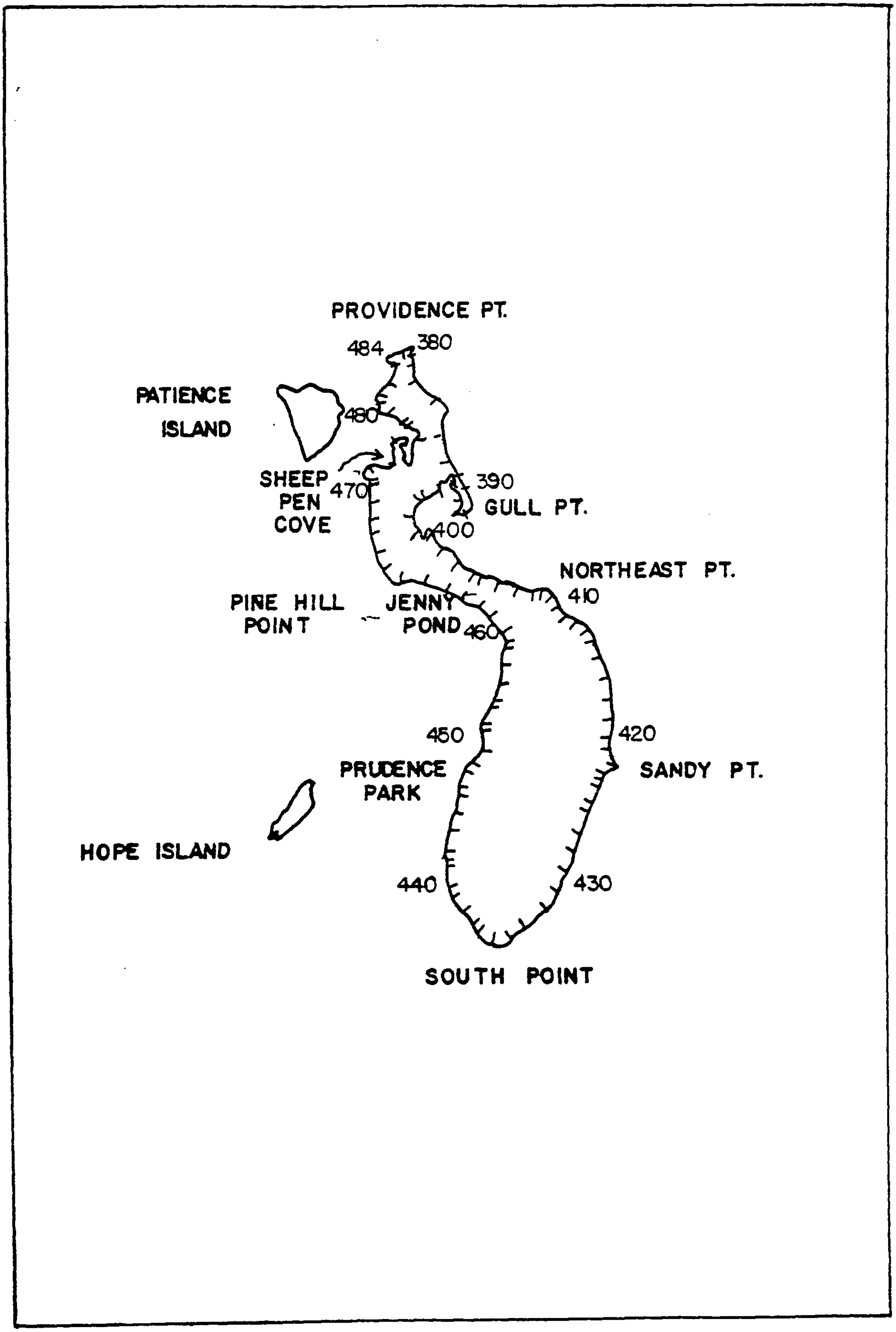
SHORELINE CHANGES, PRUDENCE ISLAND

Of the three major islands in the bay, Aquidneck, Conanicut, and Prudence Islands, (Fig. E); (Fig. A_{25}, A_{26}, segments 414-445),(Fig. A_{27}, A_{28}, segments 448-480), Prudence Island is by far the least populated; it is accessible from the mainland only by sea or by air. The glacial till-dominated shoreline is little influenced by man-made structures. Marsh deposits of Recent age have developed along the island's narrow neck.

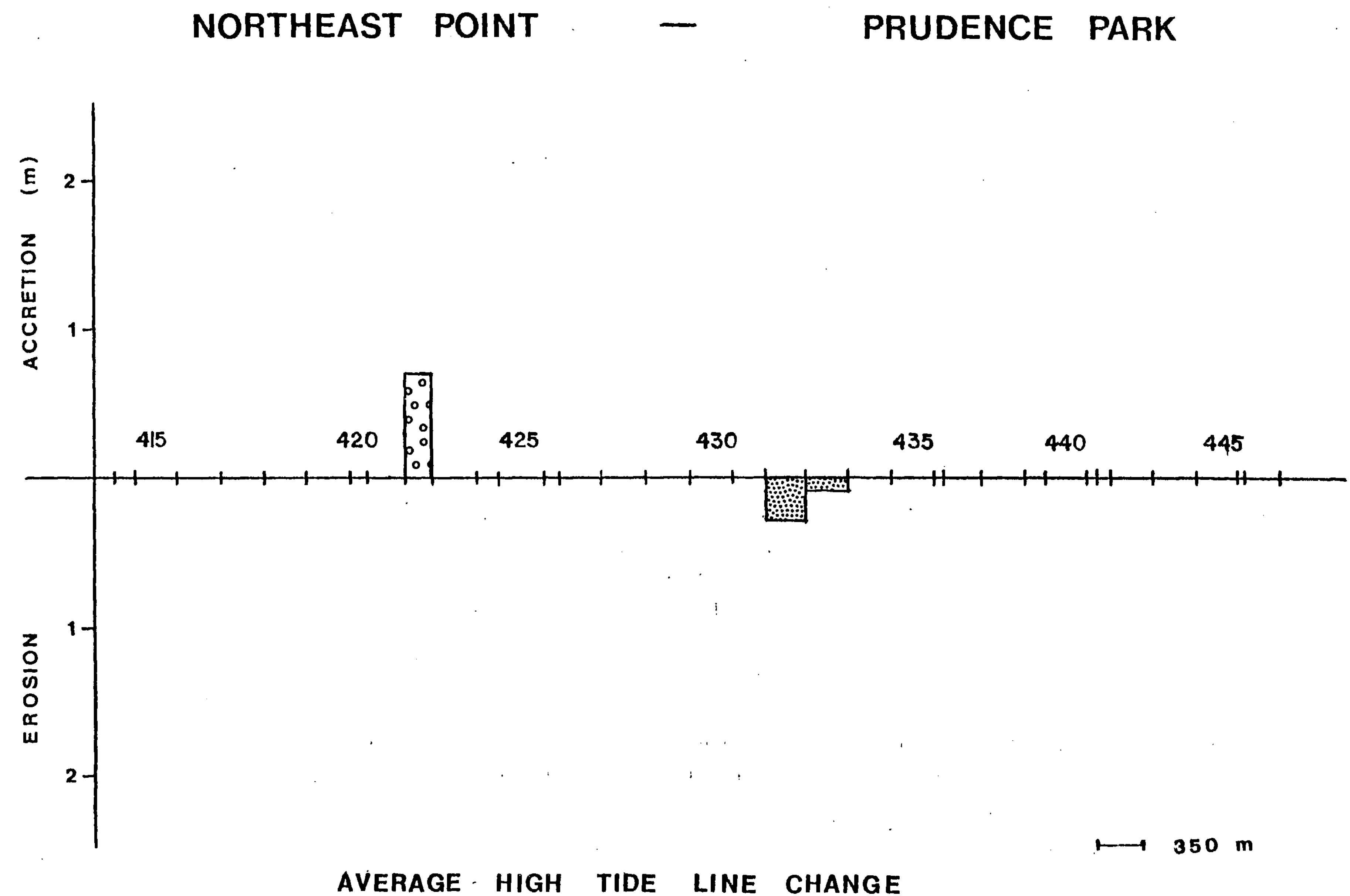
No shoreline change occurred between Providence Point (segment 380) and segment 382, just to the southwest of Providence Point. At segment 382, erosion of 0.5 m/yr occurred at the back beach line, and 0.2 m/yr of erosion took place at the high tide line of the cobble beach. No change was observed until segment 398 was reached, where 0.5 m/yr of accretion occurred in the marsh deposits. Segment 398 is not represented on a graph because of its isolation from other areas of change.

Between Northeast Point and Prudence Park, only two areas of change were present. Sandy Point is located at segments 421 and 422. Segment 421, the northern side of the cuspate shoreform, experienced erosion at a rate of 0.1 m/yr at the back beach line. The south side (segment 422) accreted at a rate of 0.6-0.7 m/yr at the back beach line and high tide line, respectively. Just northwest of South Point, at segments 432 and 433, erosion of

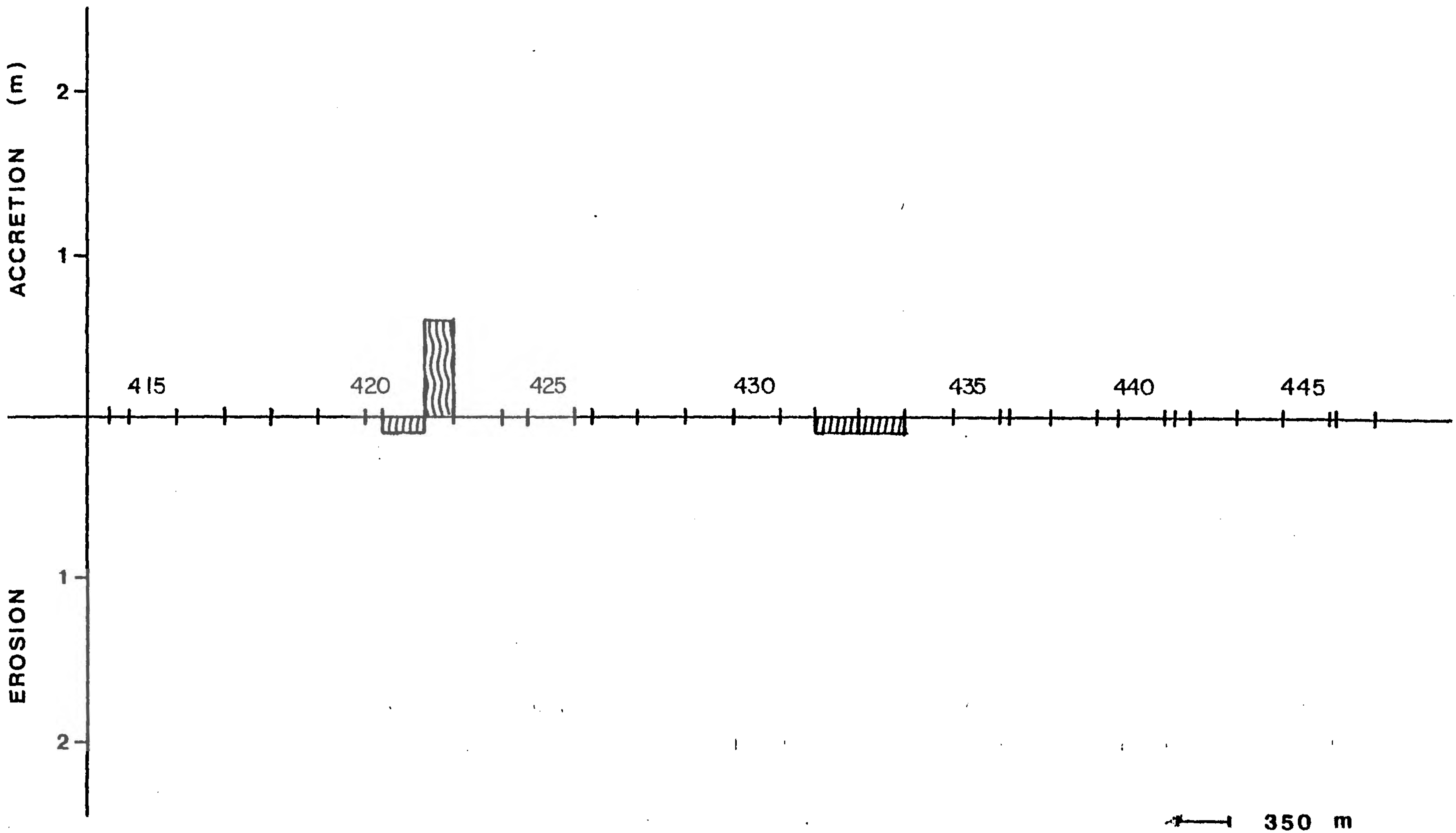
Figure 37. Shoreline Segment Location Map: Prudence Island.



PROVIDENCE PT.
484
380
PATIENCE
ISLAND
480
SHEEP
PEN
COVE
470
390
GULL PT.
400
NORTHEAST PT.
410
PINE HILL
POINT
JENNY
POND
460
450
420
PRUDENCE
PARK
SANDY PT.
HOPE ISLAND
440
430
SOUTH POINT

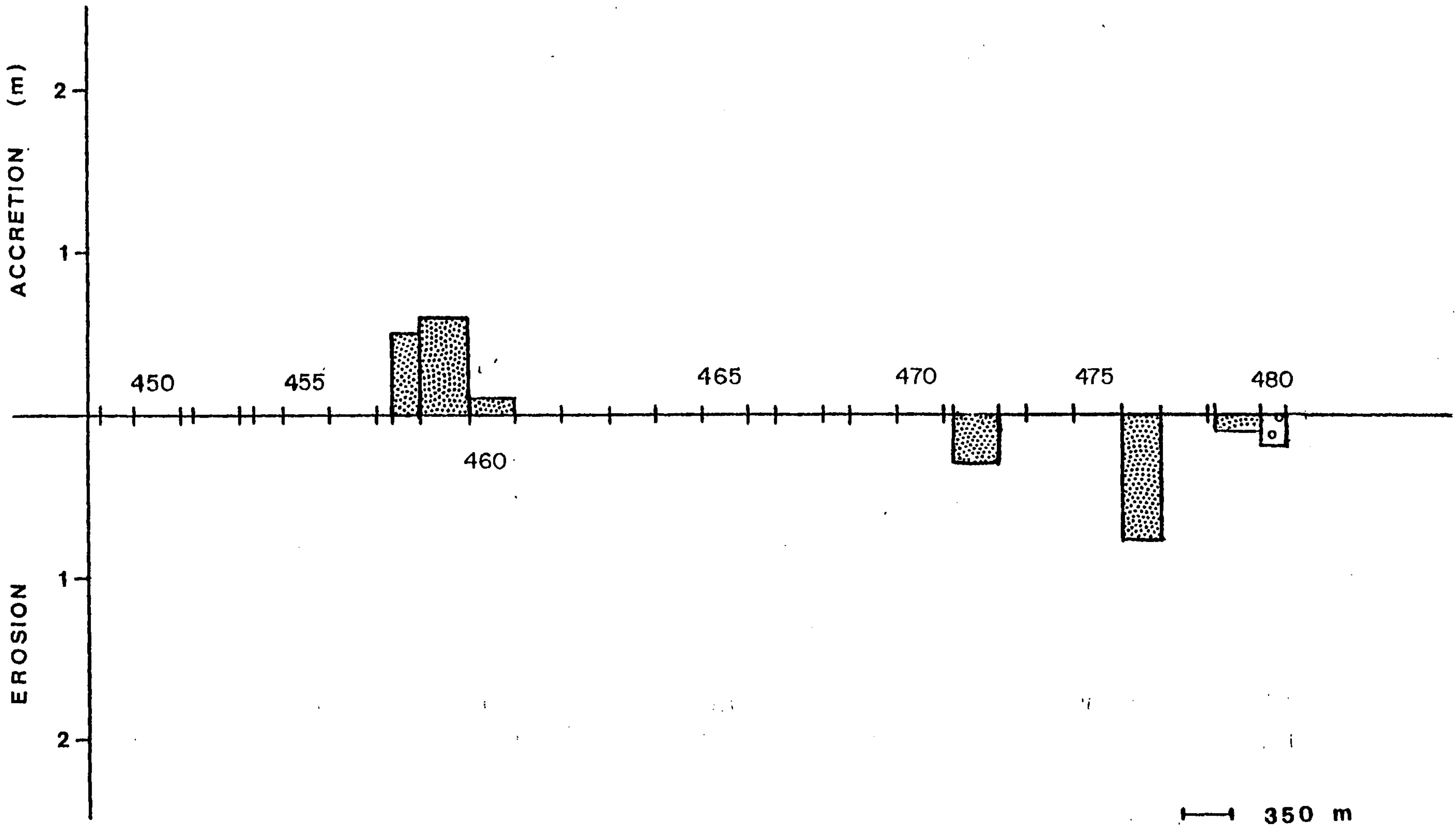

NORTHEAST POINT — PRUDENCE PARK
ACCRETION (m)
EROSION
2
1
1
2
415
420
425
430
435
440
445
350 m
AVERAGE HIGH TIDE LINE CHANGE

NORTHEAST POINT — PRUDENCE PARK



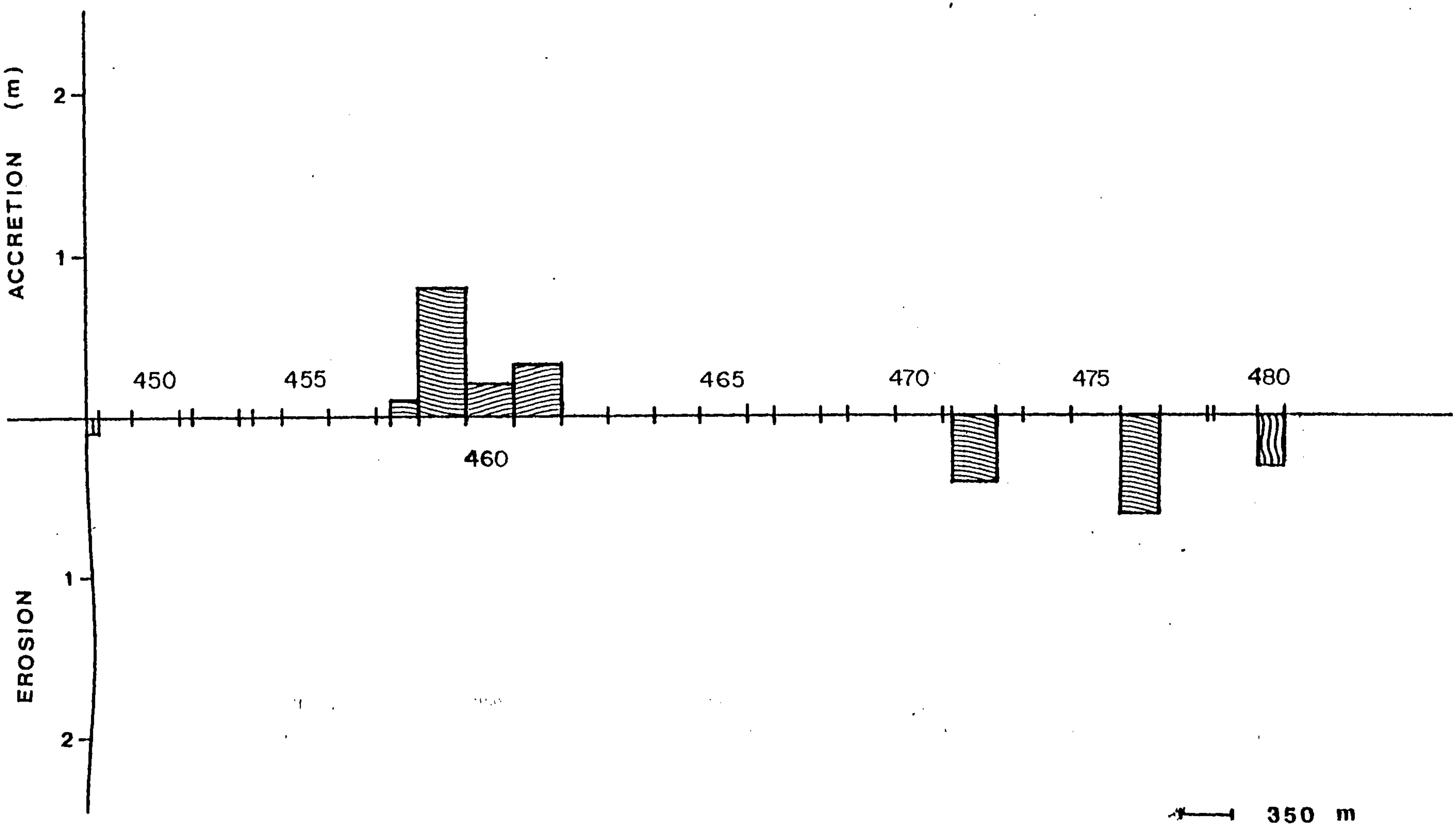
AVERAGE BACK BEACH LINE CHANGE

PRUDENCE PARK — PROVIDENCE POINT



AVERAGE HIGH TIDE LINE CHANGE

PRUDENCE PARK — PROVIDENCE POINT



AVERAGE BACK BEACH LINE CHANGE

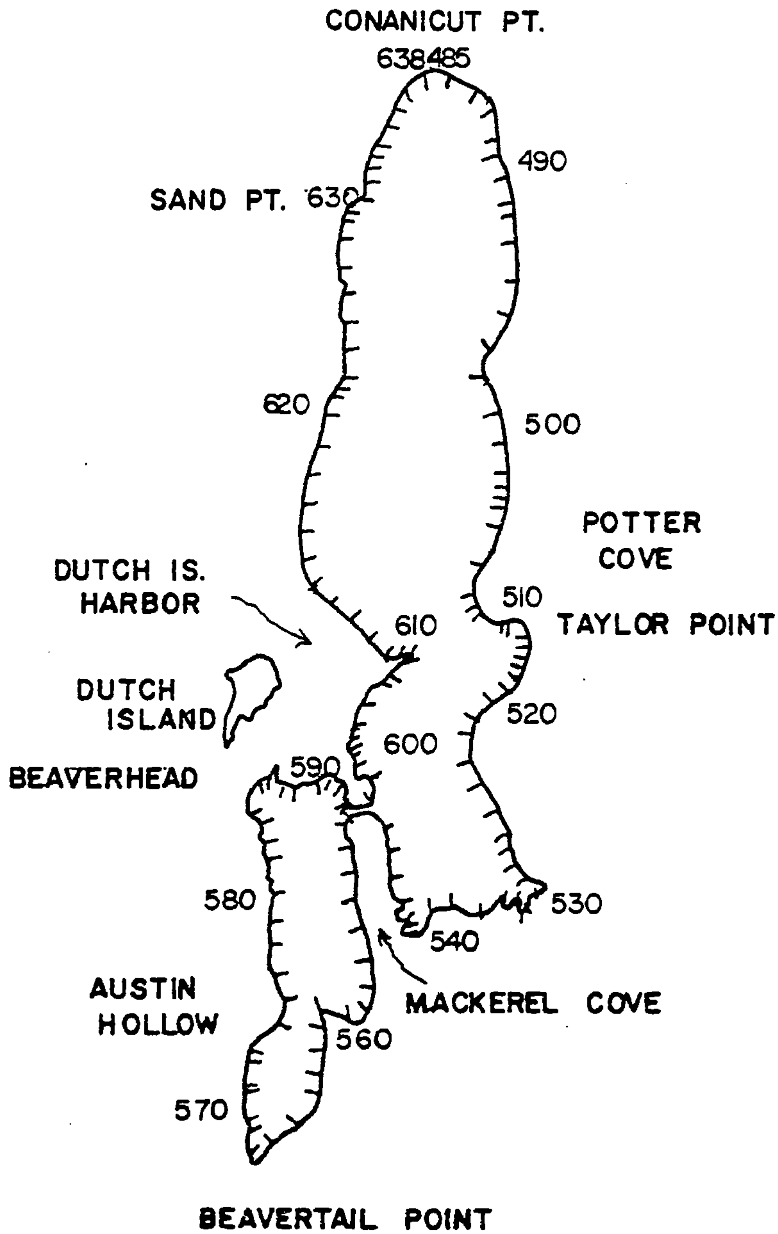
0.1-0.3 m/yr occurred.

From segment 433, at the southern side of Prudence Island to the Jenny Pond area (segment 461), no change is observed. From segments 458-461, however, accretion of 0.1-0.8 m/yr was measured. Sheep Pen Swamp (segment 472) experienced erosion of 0.4 m/yr at the back beach line and 0.8 m/yr at the high tide line. On the north flank of Coggeshall Cove (segments 479-480), erosion occurred at 0.1-0.3 m/yr.

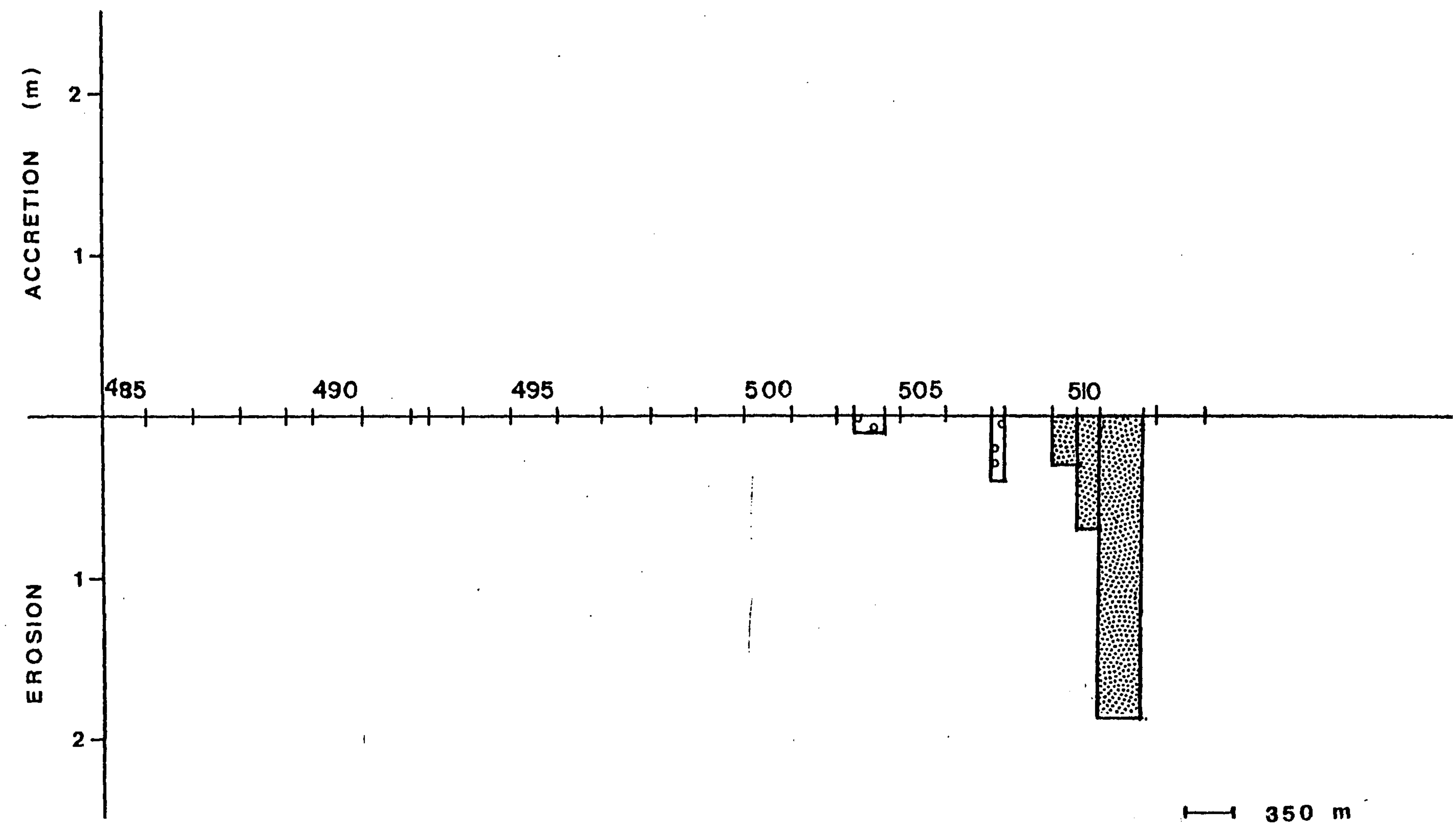
SHORELINE CHANGES: CONANICUT ISLAND

Conanicut Island (Fig. F), (Fig. A_{29}, A_{30}, segments 485-513),(Fig. A_{31}, A_{32}, segments 574-612), commonly known as Jamestown, consists of two islands connected at Mackerel Cove Beach by a riprapped causeway. Beavertail, the smaller island on the southwest, contains exposures of the oldest (Cambrian and PreCambrian) rocks in the Narragansett Basin. In the vicinity of segment 565, Cambrian trilobites are represented in the rocks (Skehan, et al. 1981). Beavertail's shoreline is mostly resistant bedrock, except for the portion at Beaverhead where a Recent sand spit is migrating inland. A bedrock shoreline is also characteristic of the southern portion of the main island of Jamestown. The coves and pocket beaches are similar to those found along the southernmost margin of Aquidneck Island. The remainder of the Conanicut Island shoreline consists largely of glacial drift deposits.

Figure 42. Shoreline Segment Location Map: Conanicut Island.

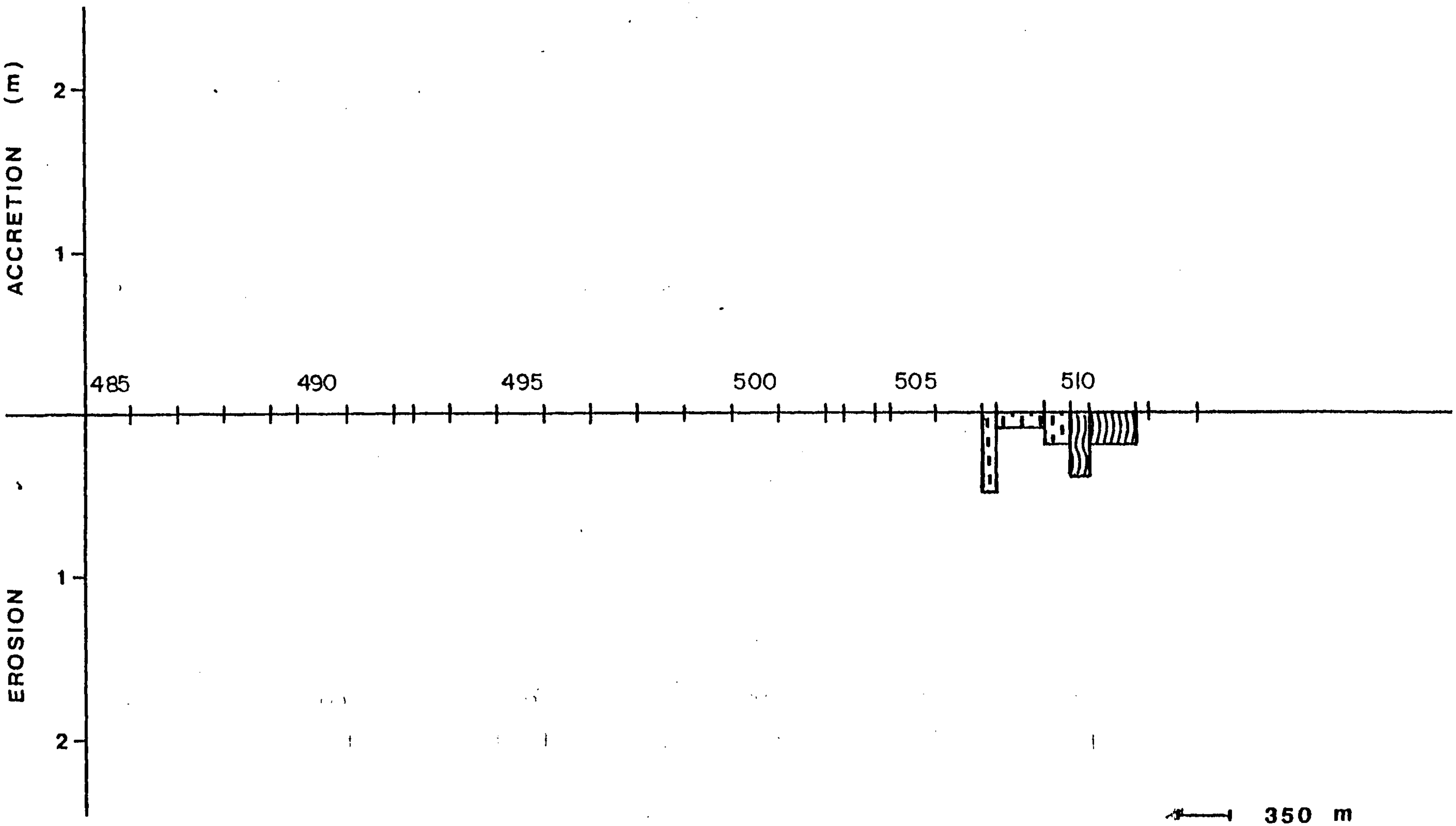

CONANICUT PT.
638485
490
SAND PT. 630
620
500
POTTER
COVE
DUTCH IS.
HARBOR
510
TAYLOR POINT
610
DUTCH
ISLAND
520
600
BEAVERHEAD
590
580
530
540
AUSTIN
HOLLOW
MACKEREL COVE
560
570
BEAVERTAIL POINT

CONANICUT POINT — TAYLOR POINT

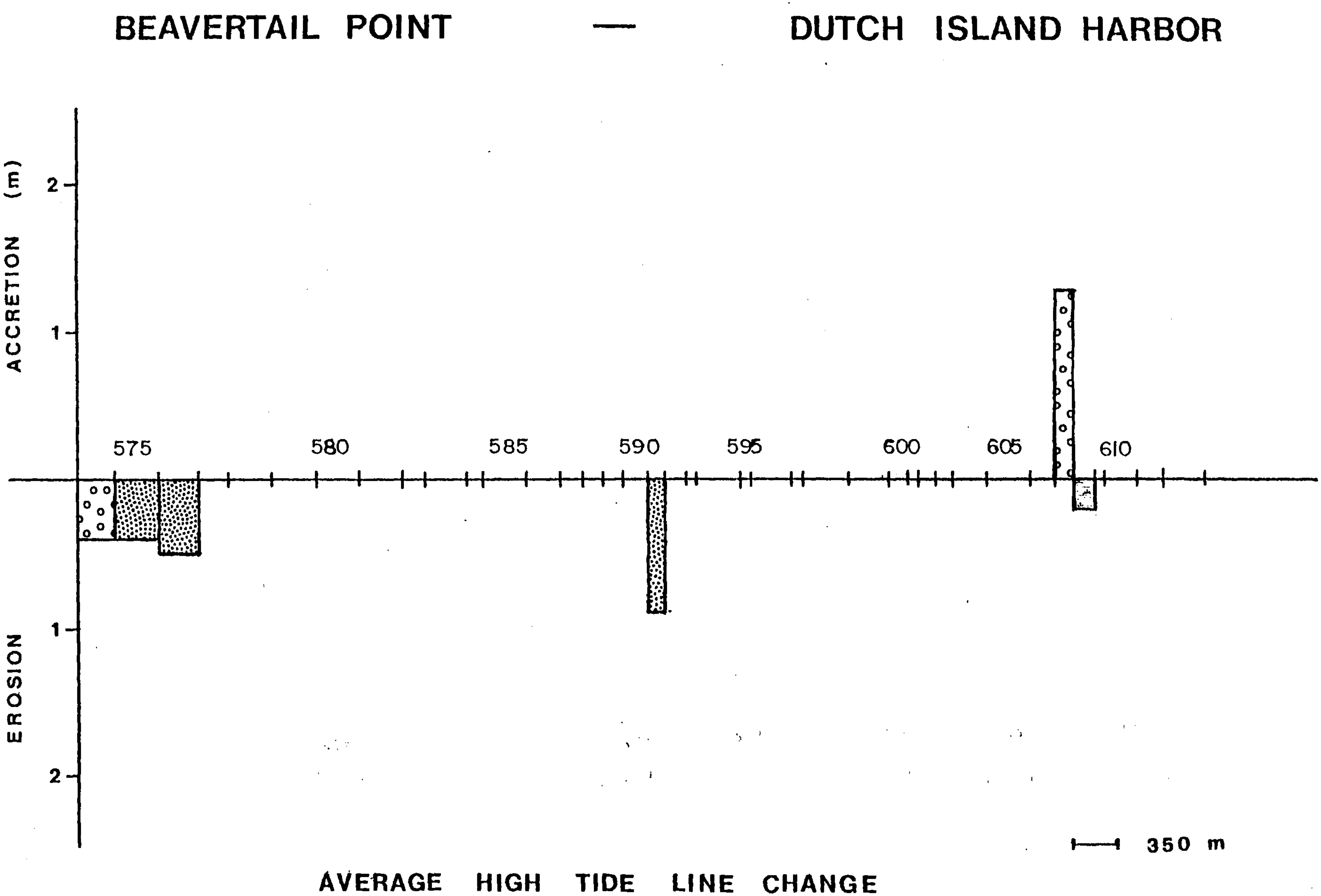


AVERAGE HIGH TIDE LINE CHANGE

CONANICUT POINT — TAYLOR POINT

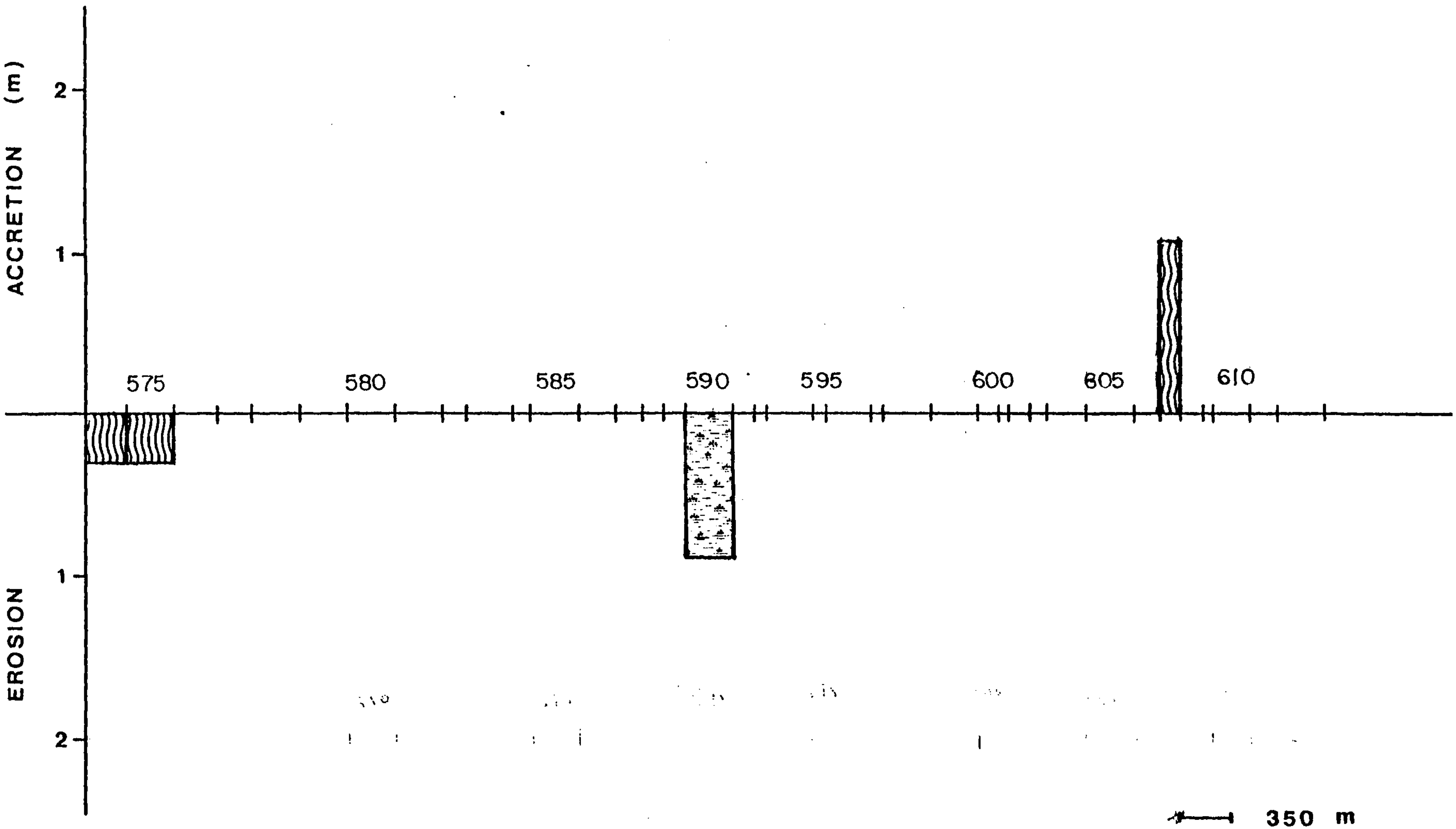


AVERAGE BACK BEACH LINE CHANGE



BEAVERTAIL POINT — DUTCH ISLAND HARBOR
ACCRETION (m)
EROSION
2
1
1
2
575
580
585
590
595
600
605
610
350 m
AVERAGE HIGH TIDE LINE CHANGE

BEAVERTAIL POINT — DUTCH ISLAND HARBOR



AVERAGE BACK BEACH LINE CHANGE

Between Conanicut Point and Potter Cove there was no measurable shoreline change. Between segment 507 and 511, however, much erosion occurred, ranging from 0.1-0.5 m/yr at the back beach line and from 0.3 to 1.9 m/yr at the high tide line.

No additional change was observed along the rocky shoreline of southern Jamestown. Segment 549, the southern shore of Mackerel Cove Beach, lost 0.5 m/yr of material from the high tide line. Segments 574-577 were measured at Austin Hollow, North of Beavertail Point, but are not represented on graphs, since they are adjacent to long stretches of no change. Here erosion of 0.3 m/yr occurred at the back beach line and 0.4-0.5 m/yr occurred at the high tide line. Change from Austin Hollow to the Pond at Beaverhead was not evident, but segment 590 shows erosion of 0.9 m/yr. Change was not in evidence between segment 590 and Dutch Island Harbor, where at segment 607 there was accretion of 1.1 m/yr. at the back beach line and 1.3 m/yr at the high tide line. Segment 608 experienced 0.2 m/yr of erosion. Isolated points of shoreline change were found between Dutch Island Harbor and Conanicut Point, (segment 609-638), but are not graphed. At segment 623, erosion of 0.1 m/yr occurred in both the gentle slope and on the sandy beach high tide line. At Sand Point (segment 631) erosion of 0.3 m/yr was measured in the marsh at the back of the beach, and 0.5 m/yr of erosion was displayed at the high tide line of the sandy beach.

SHORELINE CHANGES: AQUIDNECK ISLAND

The shoreline of Aquidneck Island (Fig. G), (Fig. A_{33}, A_{34}, segments 658-684),(Fig. A_{35}, A_{36}, segments 707-732), (Fig. A_{37}, A_{38}, segments 795-828),(Fig. A_{39}, A_{40}, segments 829-863),(Fig. A_{41}, A_{42}, segments 864-894), (Fig. A_{43}, A_{44}, segments 895-923) consists primarily of glacial drift, on the east and west shores, and of bedrock, on the southern shore. Notable exceptions include the extensive use of engineering structures on the west shore of Newport and at the Naval Reservation in Middletown. Barrier beaches; Easton Beach, Second Beach, and Third Beach, are present in the South, and there is accretion of cobble-sized material on the beach at Common Fence Point at the northern tip of the island. Here marsh grass grows seaward of the cobble beach, which was added by the Town of Portsmouth shortly after World War Two.

To the immediate southwest of Mount Hope Bridge, at Musselbed Shoals in segment 639, there is erosion of the back beach line of 0.2 m/yr and erosion of the high tide line at 0.1 m/yr, due to the migration of the mouth of a stream. This is not graphed. From this point south to Coggeshall Point (segment 657), change was observed but not measured. The addition of material to

Figure 47a. Shoreline Segment Location Map: Aquidneck Island.

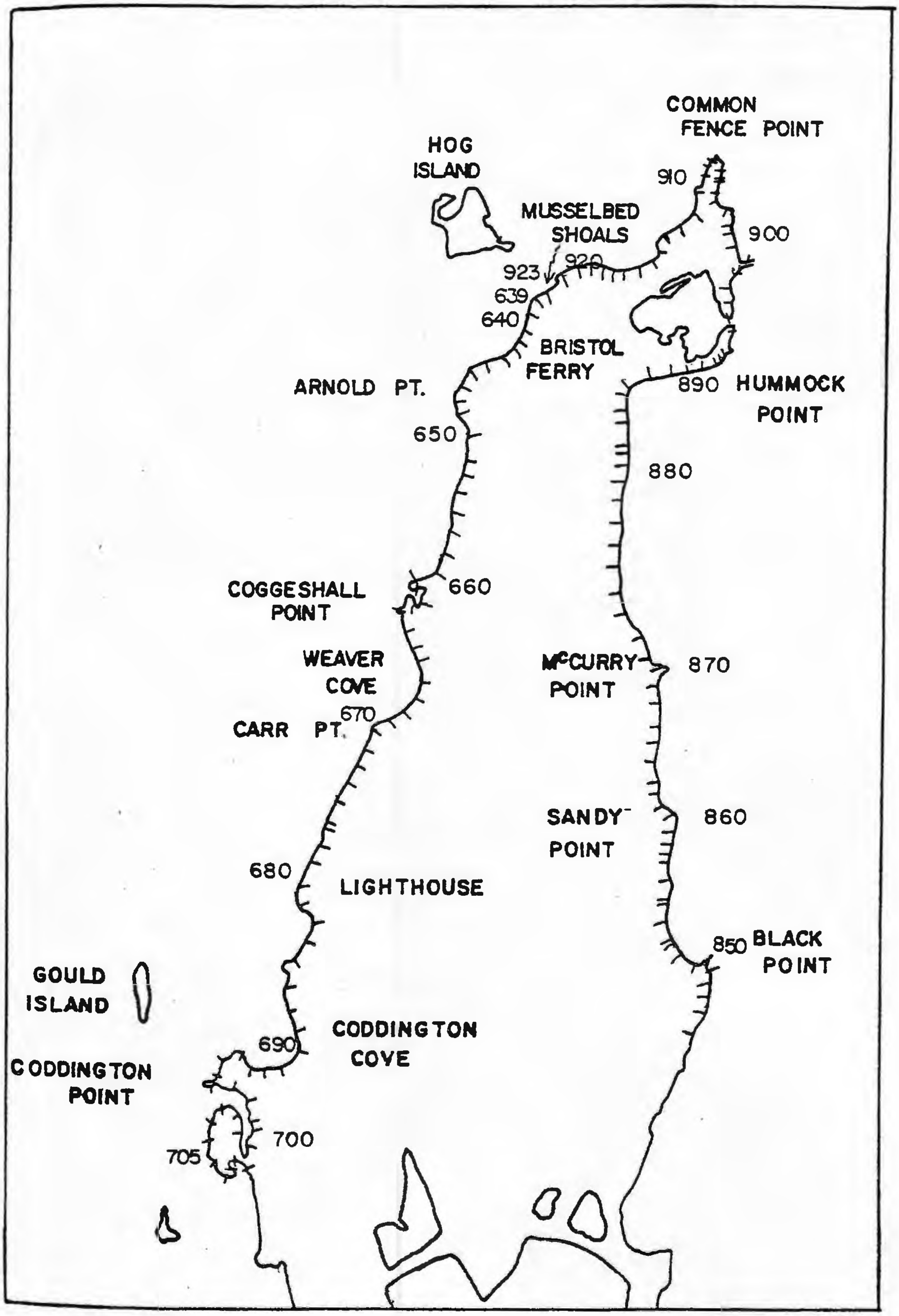
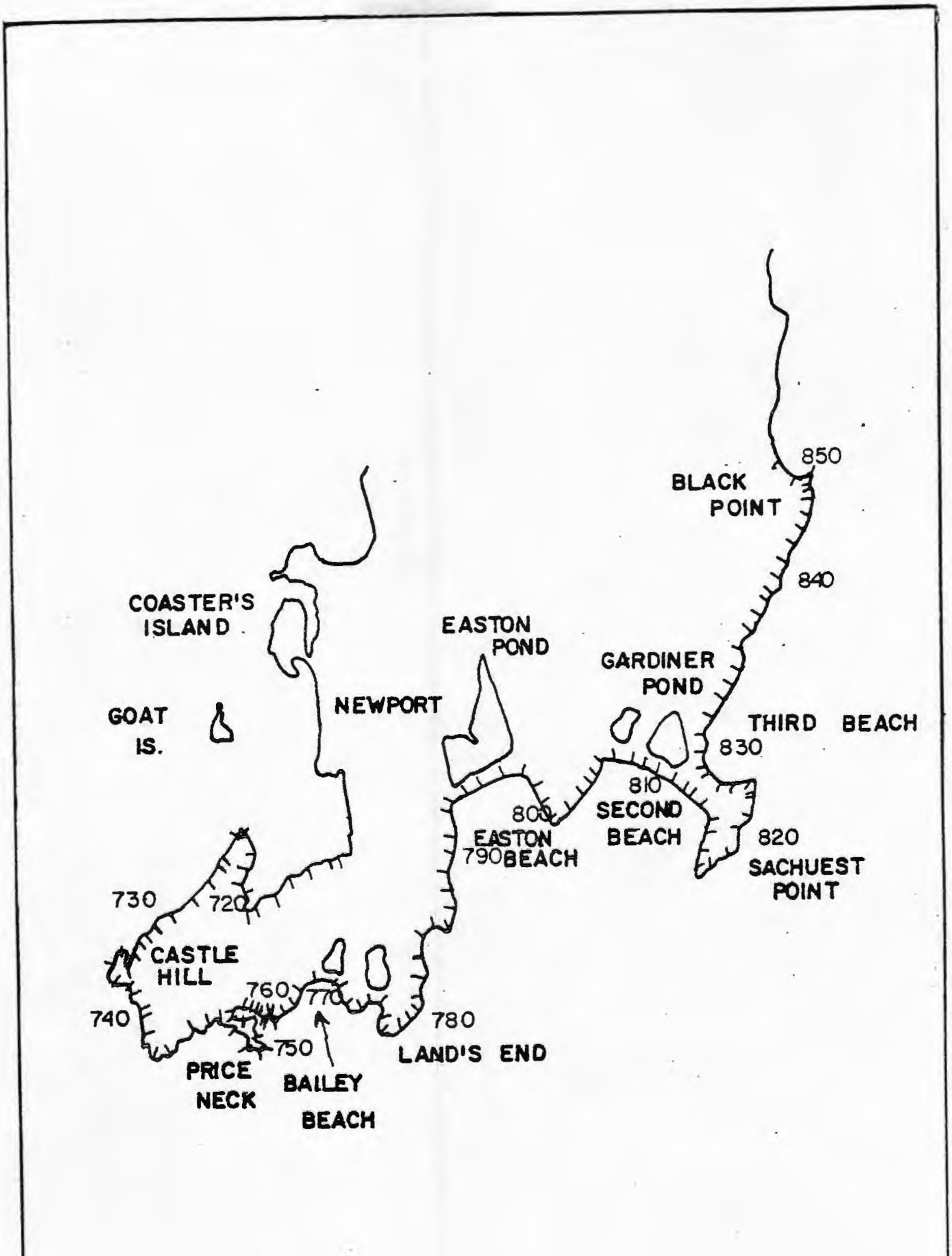
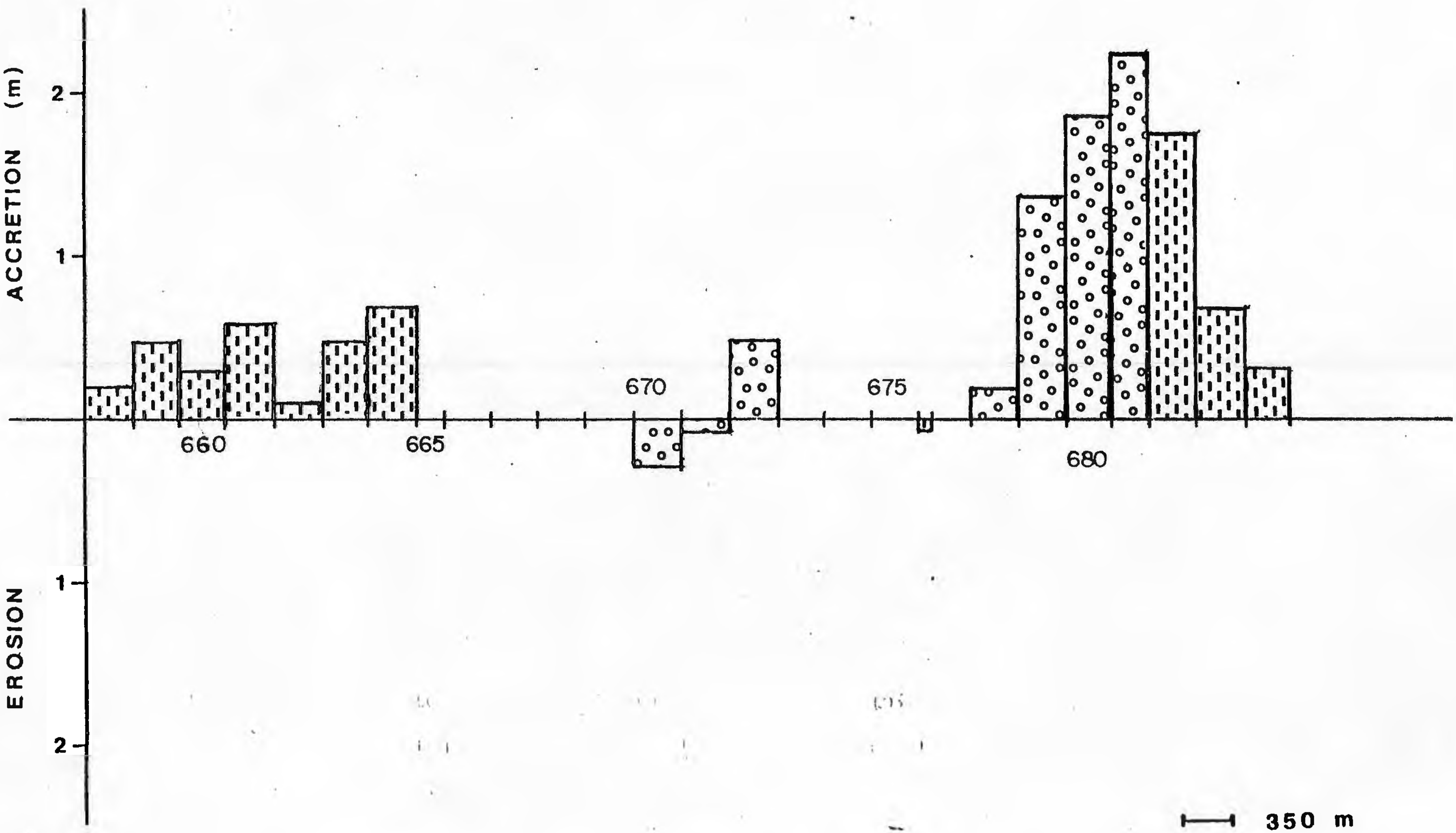

COMMON FENCE POINT
HOG ISLAND
910
MUSSELBED SHOALS
900
923
920
639
640
BRISTOL FERRY
ARNOLD PT.
890
HUMMOCK POINT
650
880
COGGESHALL POINT
660
WEAVER COVE
McCURRY POINT
870
670
CARR PT.
SANDY POINT
860
680
LIGHTHOUSE
850
BLACK POINT
GOULD ISLAND
CODDINGTON COVE
690
CODDINGTON POINT
700
705

Figure 47b. Shoreline Segment Location Map: Aquidneck Island.

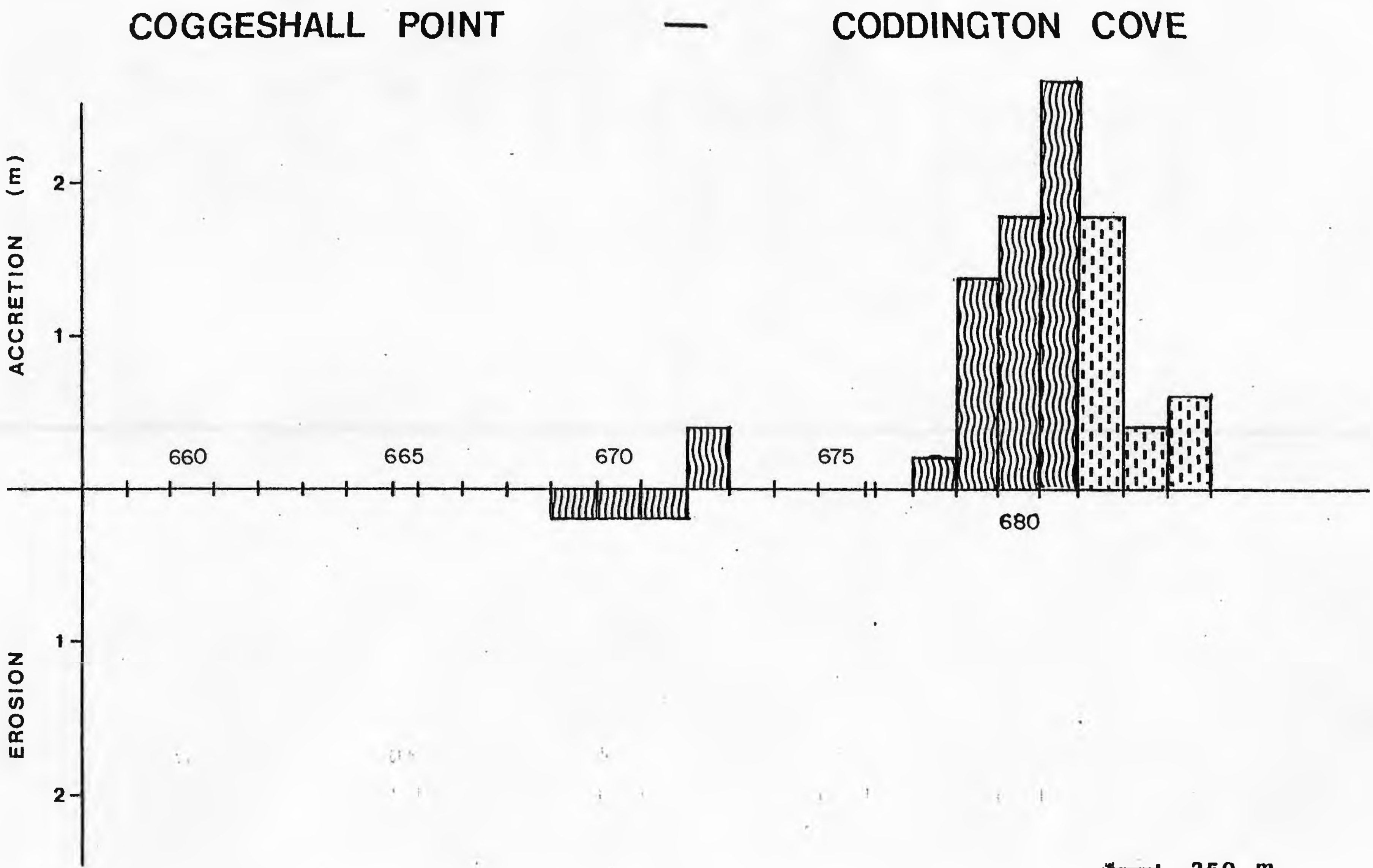


850
BLACK POINT
840
COASTER'S ISLAND
EASTON POND
GARDINER POND
GOAT IS.
NEWPORT
THIRD BEACH
830
810
800
SECOND BEACH
820
EASTON BEACH
790
SACHUEST POINT
730
720
CASTLE HILL
760
770
740
780
750
LAND'S END
PRICE NECK
BAILEY BEACH

COGGESHALL POINT — CODDINGTON COVE

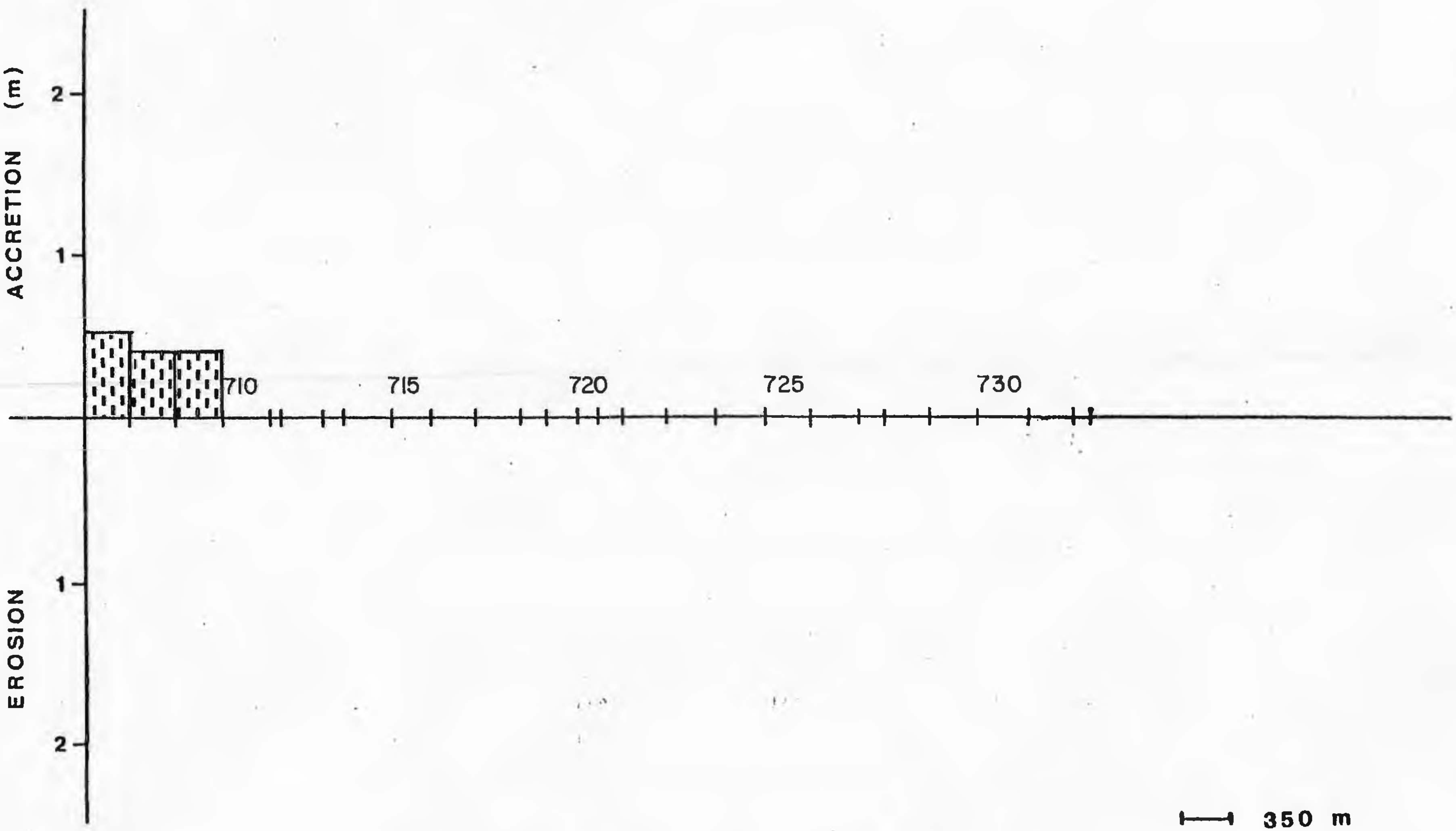


AVERAGE HIGH TIDE LINE CHANGE

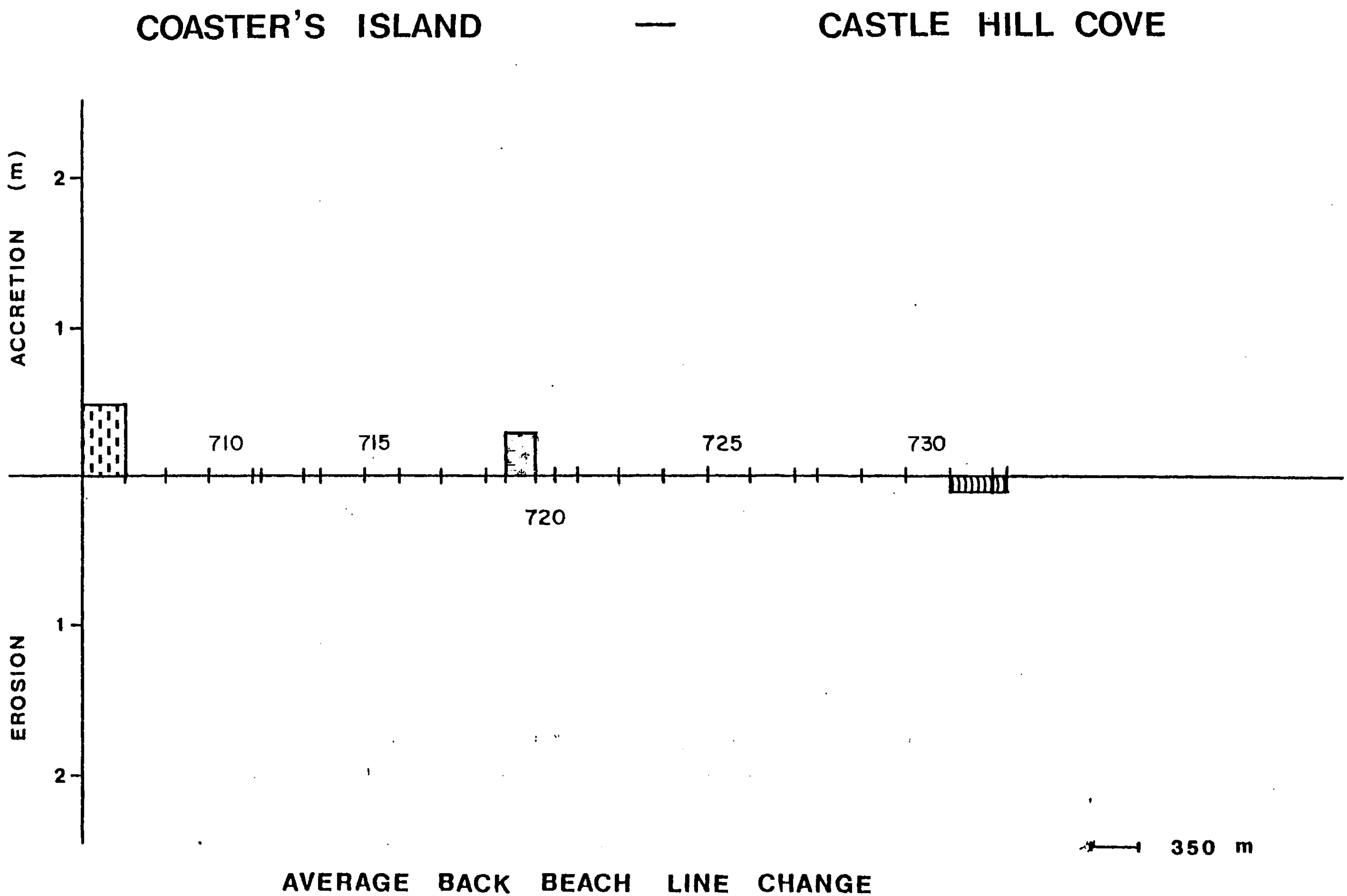


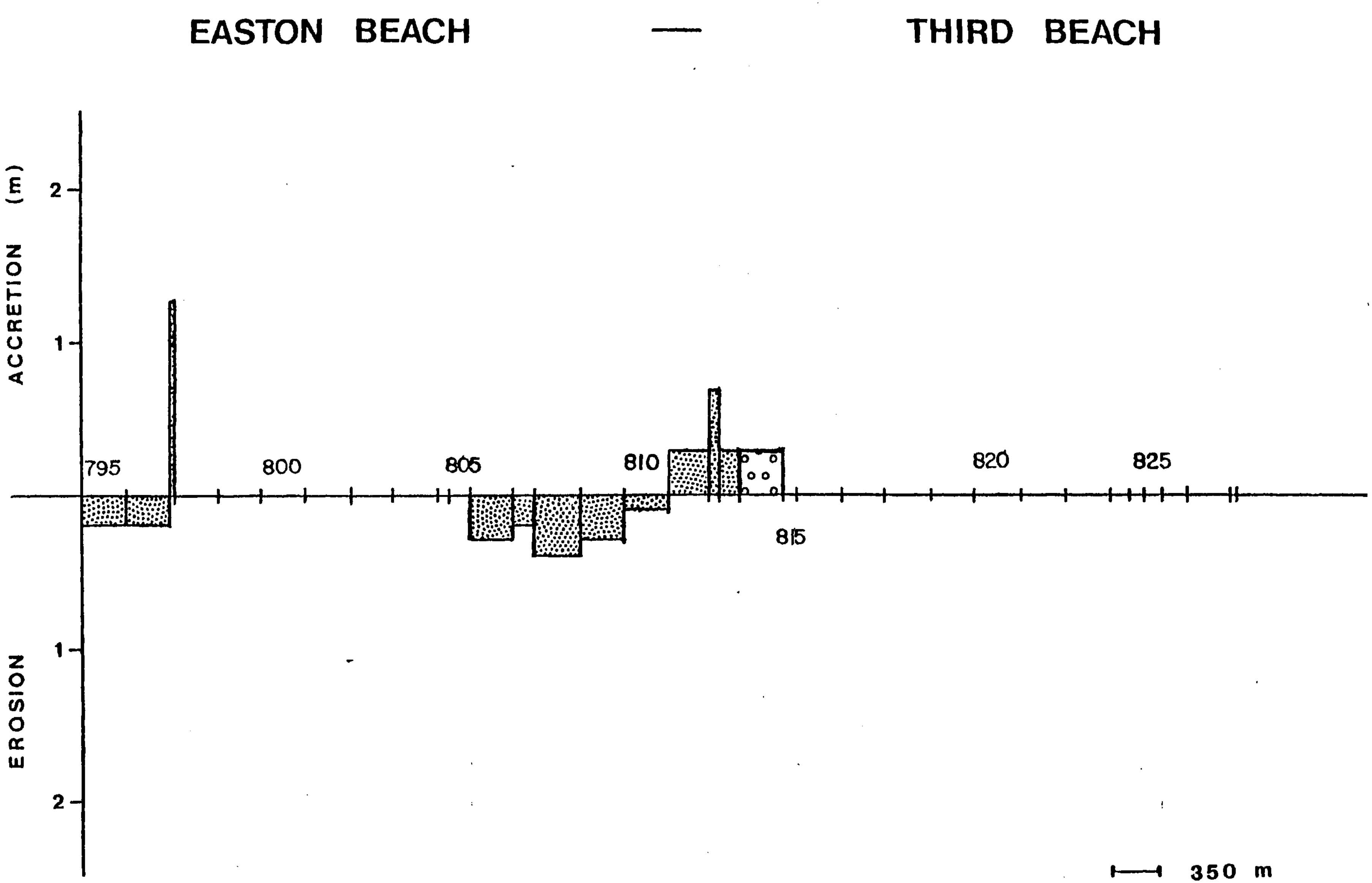
AVERAGE BACK BEACH LINE CHANGE

COASTER'S ISLAND — CASTLE HILL COVE

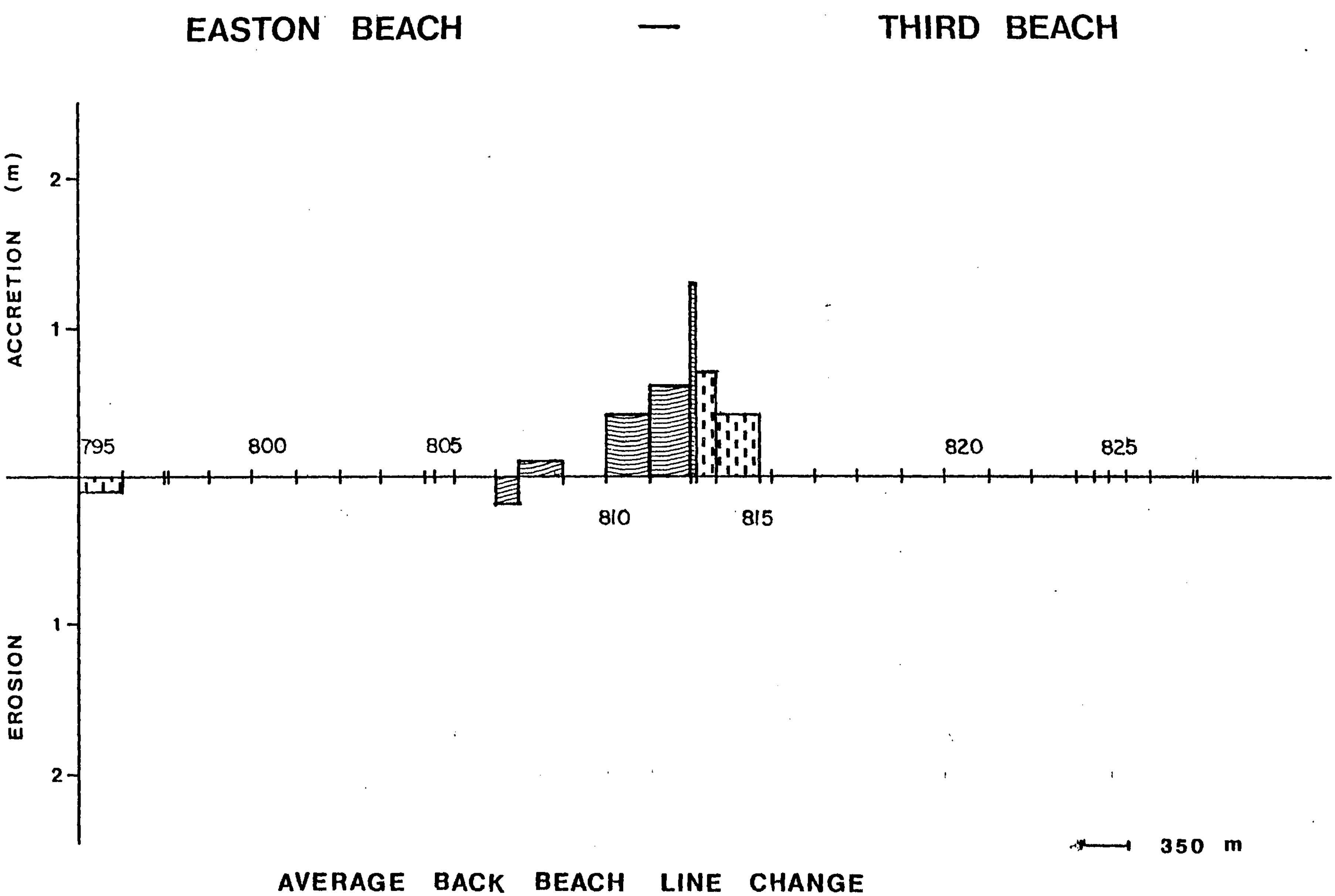


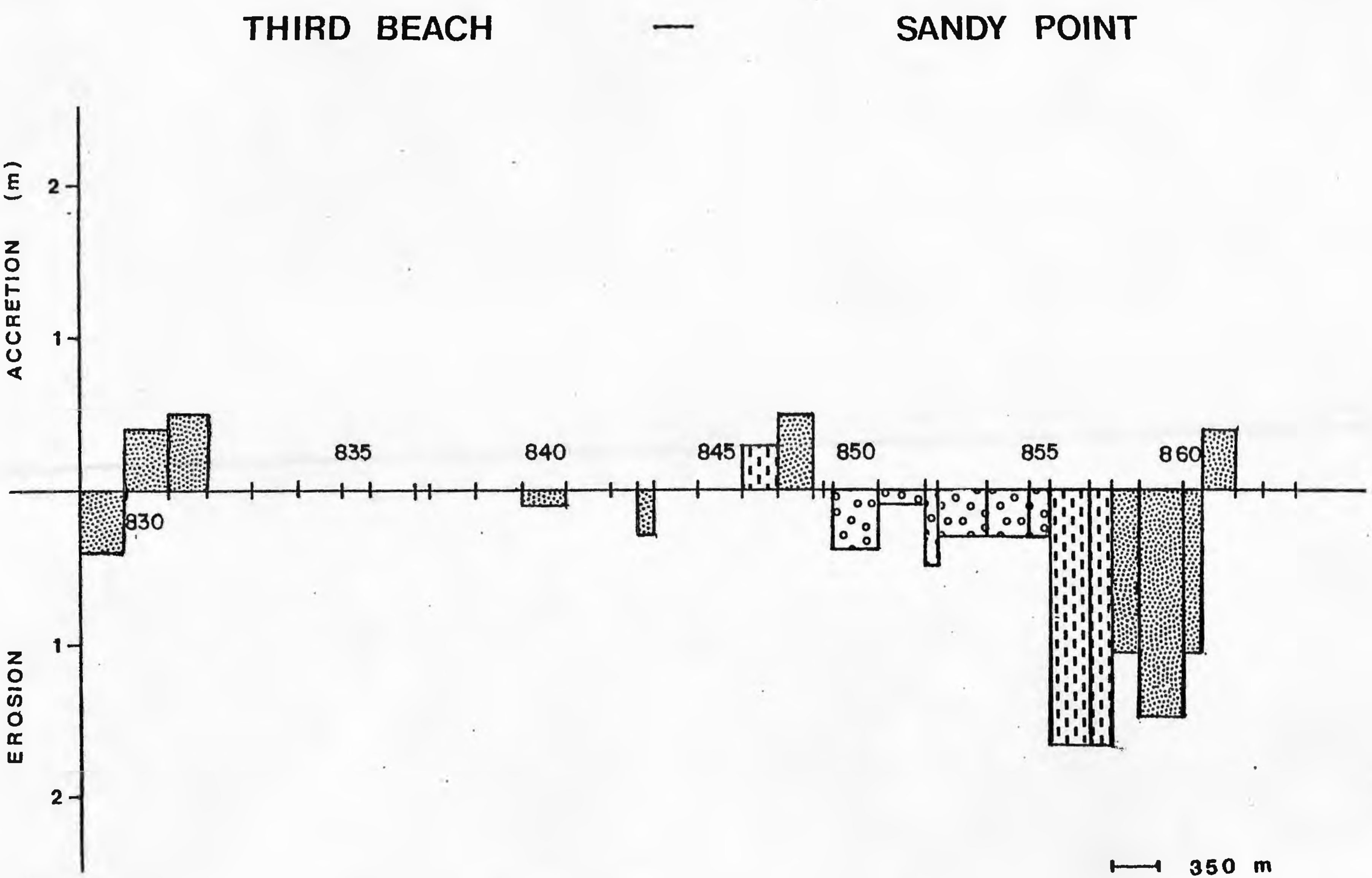
AVERAGE HIGH TIDE LINE CHANGE


COASTER'S ISLAND — CASTLE HILL COVE
ACCRETION (m)
EROSION
2
1
1
2
710
715
720
725
730
350 m
AVERAGE BACK BEACH LINE CHANGE

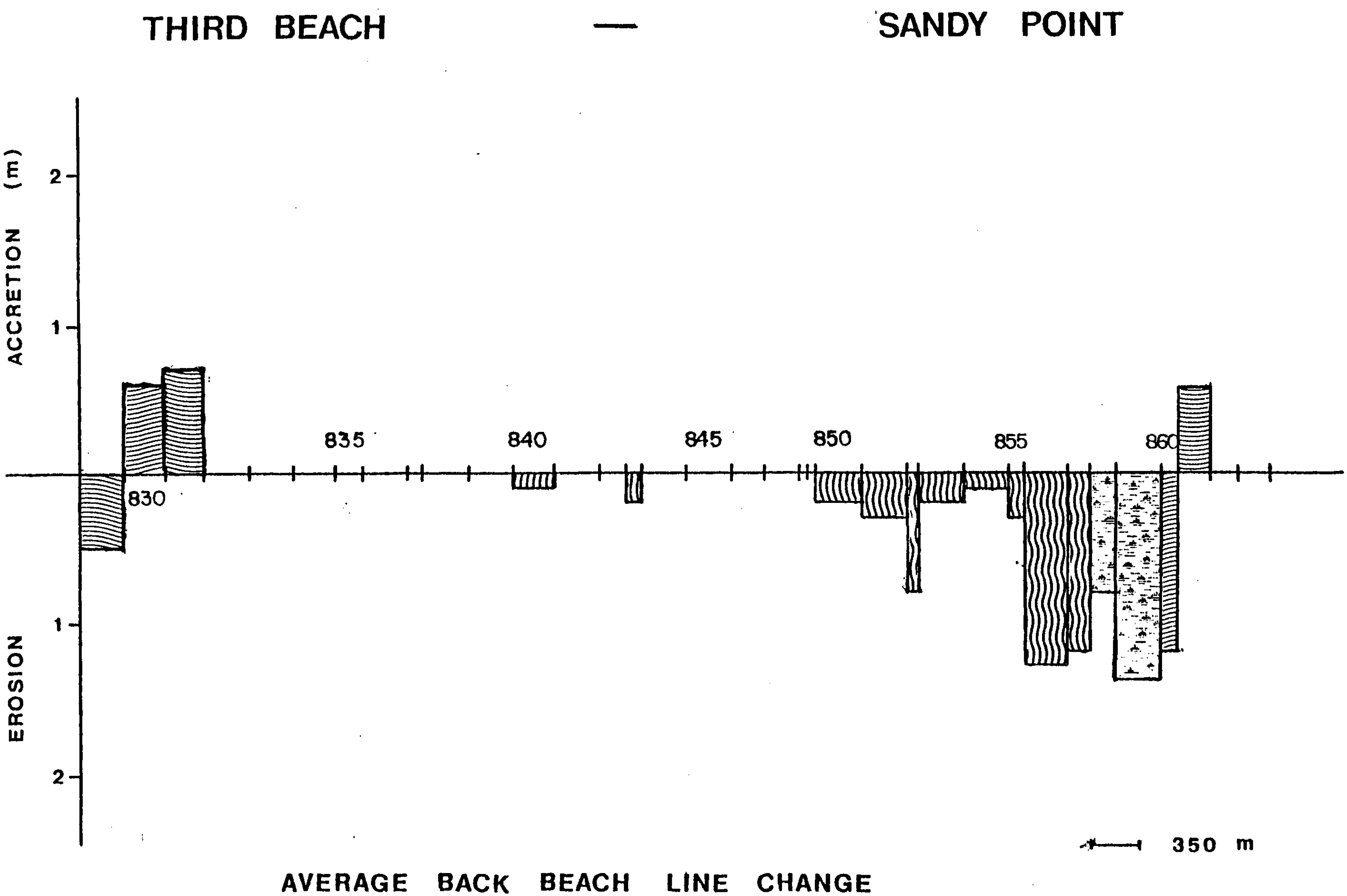


AVERAGE HIGH TIDE LINE CHANGE

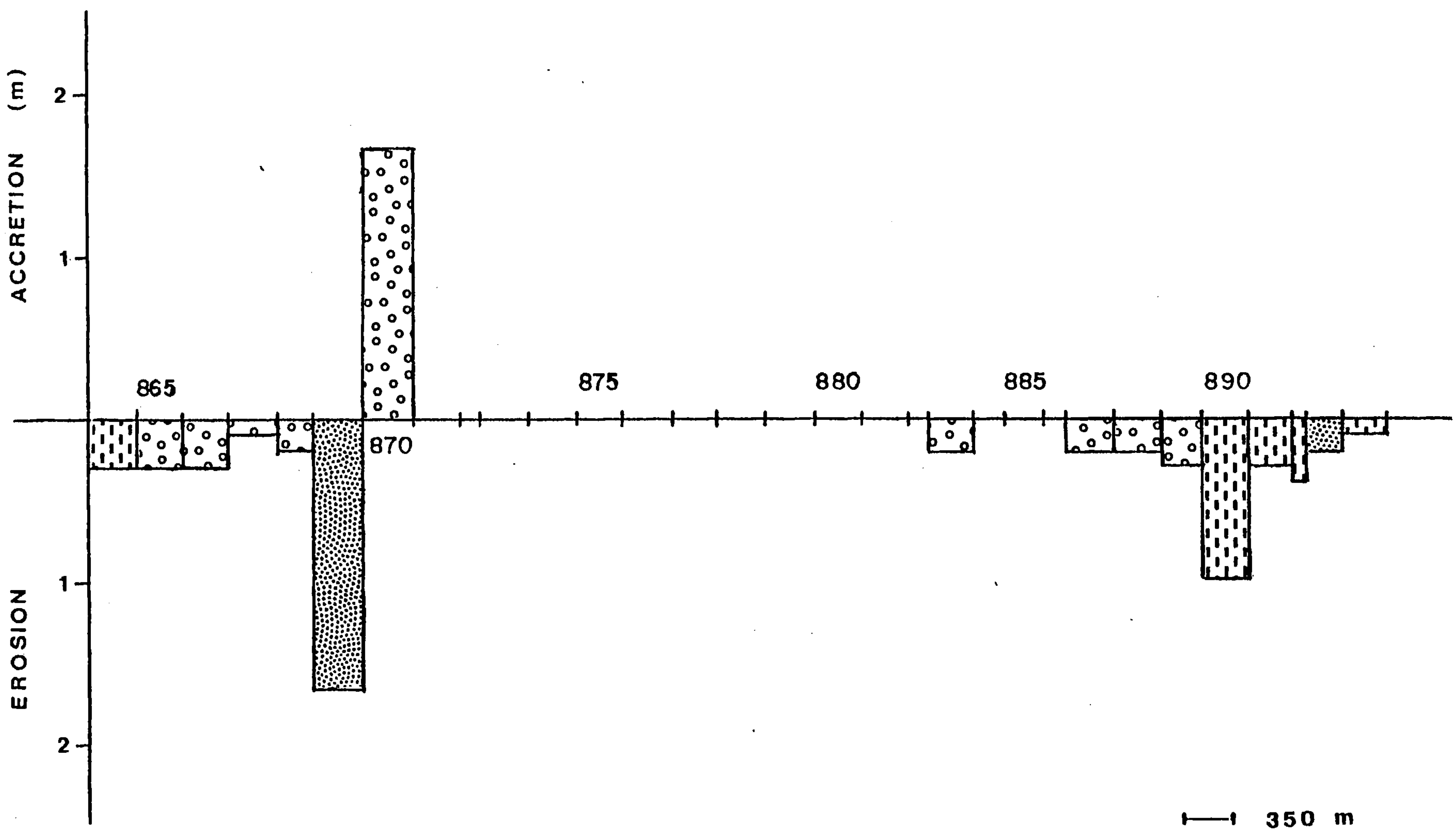

EASTON BEACH — THIRD BEACH
ACCRETION (m)
EROSION
2
1
1
2
795
800
805
810
815
820
825
350 m
AVERAGE BACK BEACH LINE CHANGE



AVERAGE HIGH TIDE LINE CHANGE

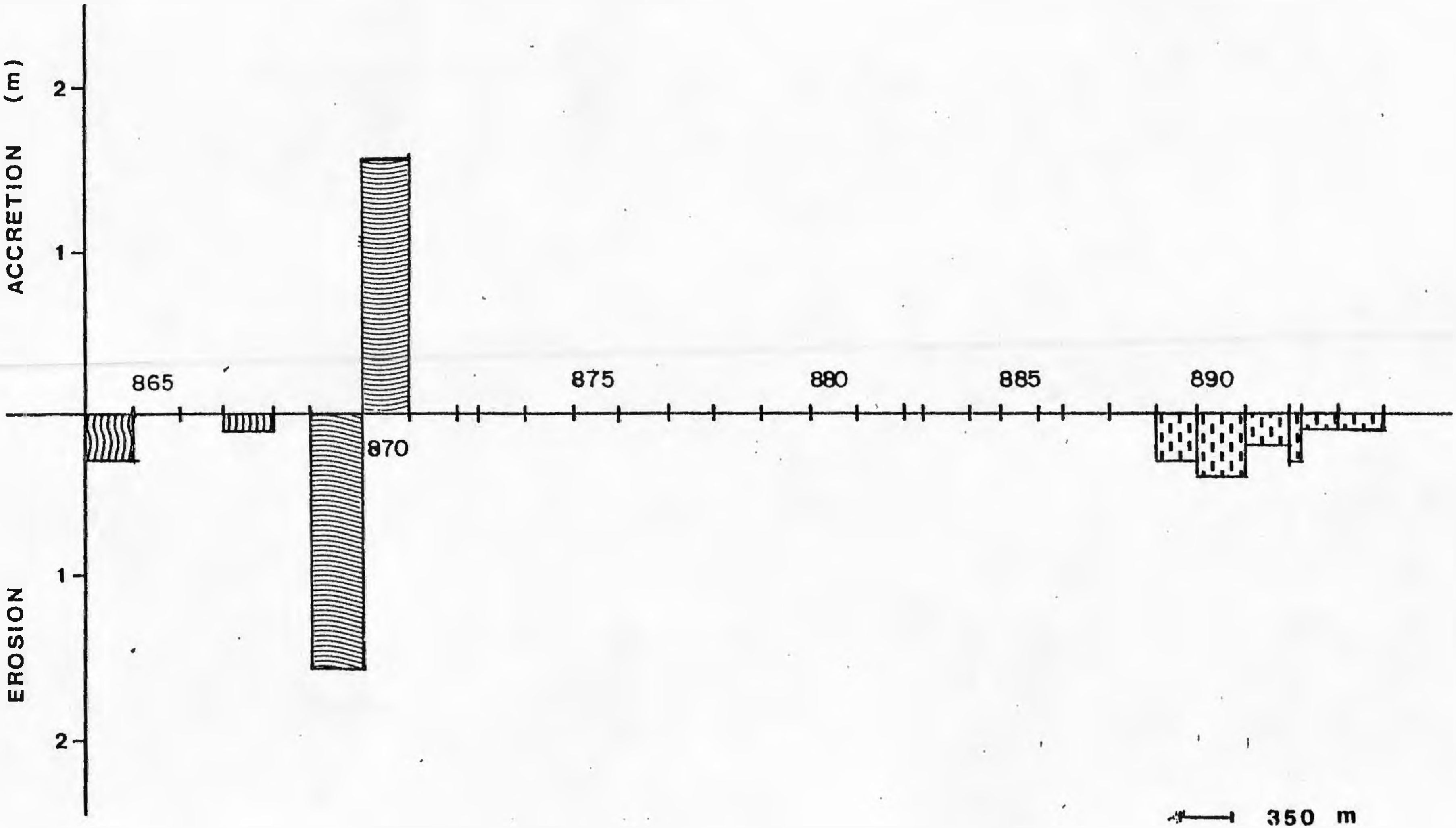

THIRD BEACH — SANDY POINT
ACCRETION (m)
EROSION
2
1
1
2
830
835
840
845
850
855
860
350 m
AVERAGE BACK BEACH LINE CHANGE

SANDY POINT — ALMY POINT



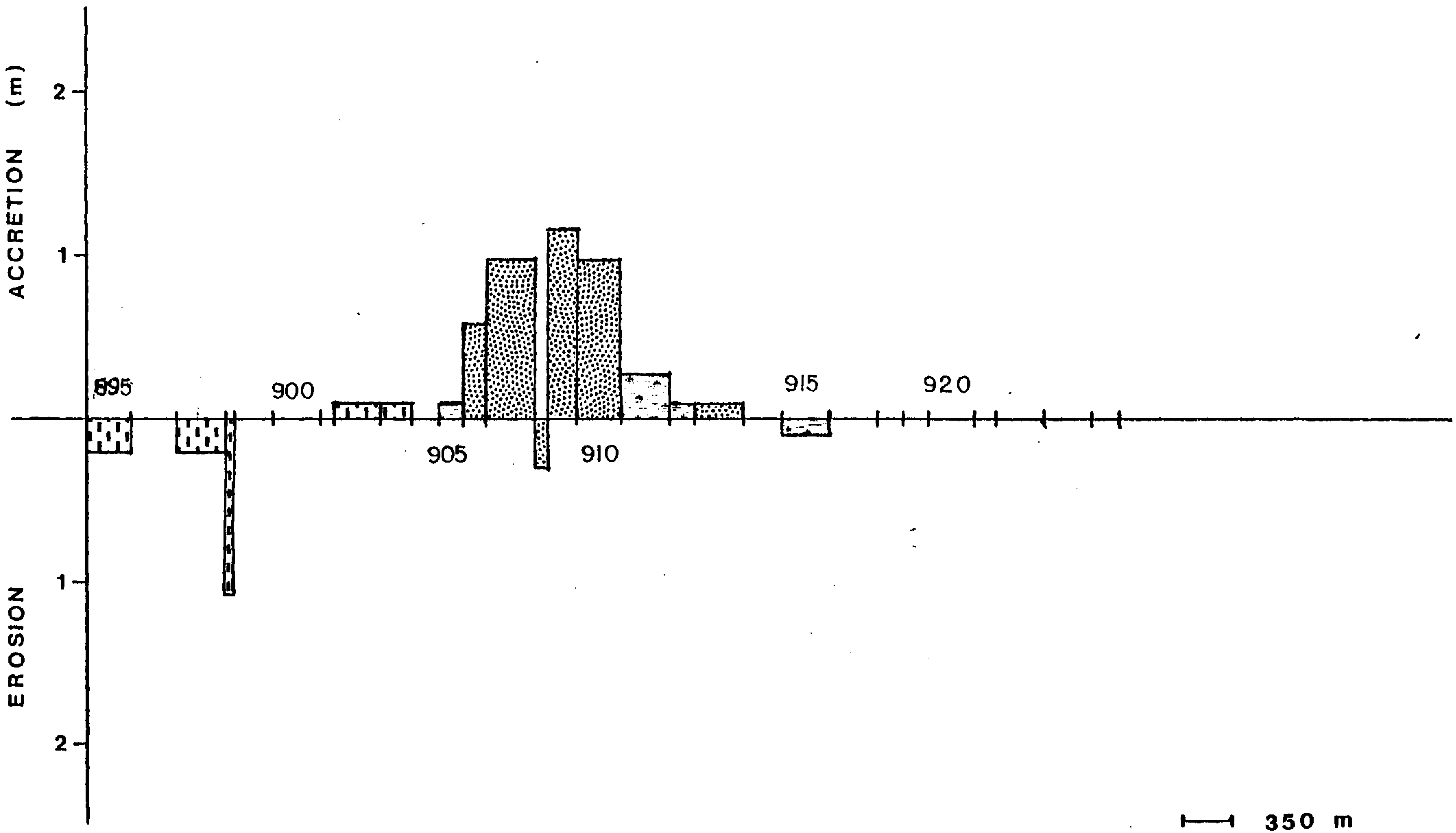
AVERAGE HIGH TIDE LINE CHANGE

SANDY POINT — ALMY POINT



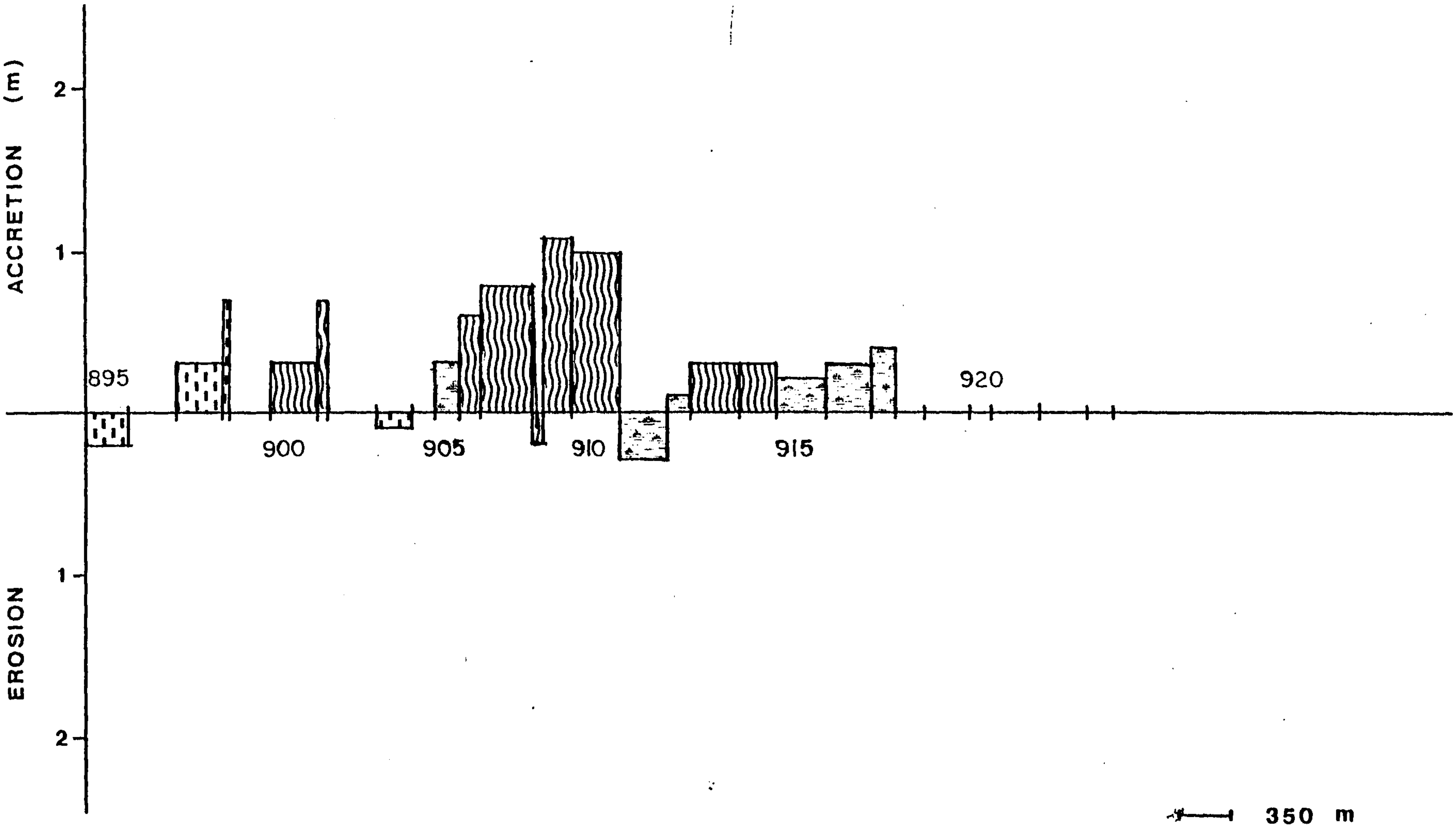
AVERAGE BACK BEACH LINE CHANGE

HUMMOCK POINT — BRISTOL FERRY



AVERAGE HIGH TIDE LINE CHANGE

HUMMOCK POINT — BRISTOL FERRY



AVERAGE BACK BEACH LINE CHANGE

the high tide line in the area of Coggeshall Point (segments 658-665) is due directly to man-made changes imposed on the area during the course of the study period. A back beach line was not identifiable for most of the 1975 shore at this site.

The next measurable change that occurs is in the area of Carr Point, segments 669-672. Segments 669-671 show erosion of 0.0-0.3 m/yr, whereas segment 672 exhibits accretion of 0.4-0.5 m/yr. Segments 678-684 show considerable addition of shoreline material: 0.2-2.3 m/yr at the high tide line, and 0.2-2.7 m/yr at the back beach line. This area, between Carr Point and Coddington Cove, (segment 689) has been artifically built out. Segments 685-689 display accretion attributable to the building of the naval base at Newport. While Coddington Point and vicinity made no measurable net gain or loss, segments 707-709 on Coaster's Harbor Island displayed accretion of 0.4-0.5 m/yr, probably due to landfill development for the Naval War College.

There was no change for Breton Cove or Fort Adams, but segments 731 and 732, just north of Castle Hill, experienced erosion of 0.1-0.2 m/yr. No change occurred on the rock beaches and cliffs from Castle Hill through Breton Point, Land's End and Ochre Point. Even Bailey Beach, consisting of sandy barrier beach and dunes west of Land's End, experienced no change. The cliff walk, which extends from segment 676 (the East end of Bailey Beach) to segment 792 (the west end of Easton Beach) exhibited no change. This is a bedrock shoreline. At Easton Beach the change that occurred was limited to the central and eastern portions of the beach. At segments 795 and 796, erosion of 0.1-0.2 m/yr was shown. At the Newport/Middletown City Boundary (segment 797) a very short length of beach (12.1 m) shows enormous accretion of 1.3 m/yr.

Easton Point experienced no change, but at Second Beach there was net erosion displayed at the western end and net accretion at the eastern end. Sachuest Point and Flint Point remained stable, but at Third Beach there occurred erosion at the southern end and net accretion at the northern end. Erosion for segments 827-829 was 0.4 m/yr, and accretion for segments 830-831 ranged from 0.4-0.7 m/yr.

The only measurable change that occurred between Wood's Castle and Black Point was at pocket beaches, where erosion ranged from 0.1-0.3 m/yr (segments 840 and 843). North of Black Point are shown patches of moderate erosion and accretion rates, but from segment 850 north to the tip of Sandy Point at segment 860 is erosion of 0.1-0.7 m/yr. Erosion at segments 856 and 857 has occurred where bulkheads and seawalls have been erected unsuccessfully to halt erosion. Segment 861 on the north side of Sandy Point accreted at a rate of 0.6 m/yr at the dune line and 0.4 m/yr at the high tide line.

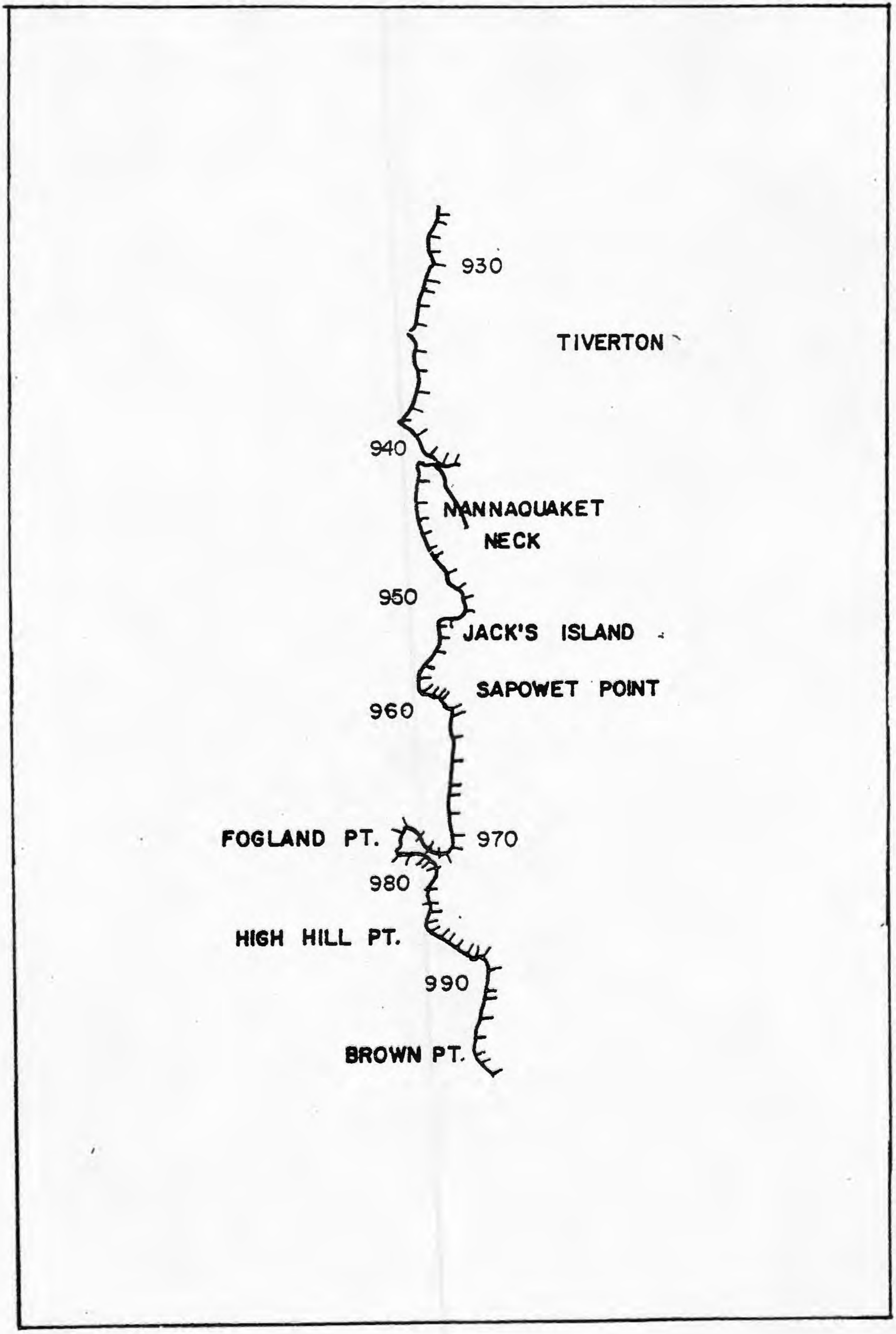
Between the cuspate shoreforms of Sandy Point and McCurry Point (segments 862-868) there is moderate erosion, but at McCurry Point, erosion of the south side and accretion of the north side both took place at 1.6 m/yr for the dune line and 1.7 m/yr at the high tide line. Both cuspate shoreforms on Aquidneck Island are migrating northward. There is virtually no change between McCurry Point and Almy Point, (segments 871-894), where erosion ranges from 0.1-1.0 m/yr. Hummock Point north to the Common Fence Point tombolo (segments 895-904) generally shows net accretion of the back beach line (0.3-0.7 m/yr) and net erosion of the high tide line (0.1-1.1 m/yr).

Common Fence Point (segments 905-910) displays a tremendous amount of accretion, both of the back beach line and of the high tide line, during the study period. Segment 908 alone showed erosion; at 0.2-0.3 m/yr. Artificial filling has occurred at the site. Segments 911-918 were largely accretionary at the back beach line, but from segment 919 to Bristol Ferry at segment 923 there was no measured change.

SHORELINE CHANGES: SAKONNET RIVER AND SOUTH SHORE

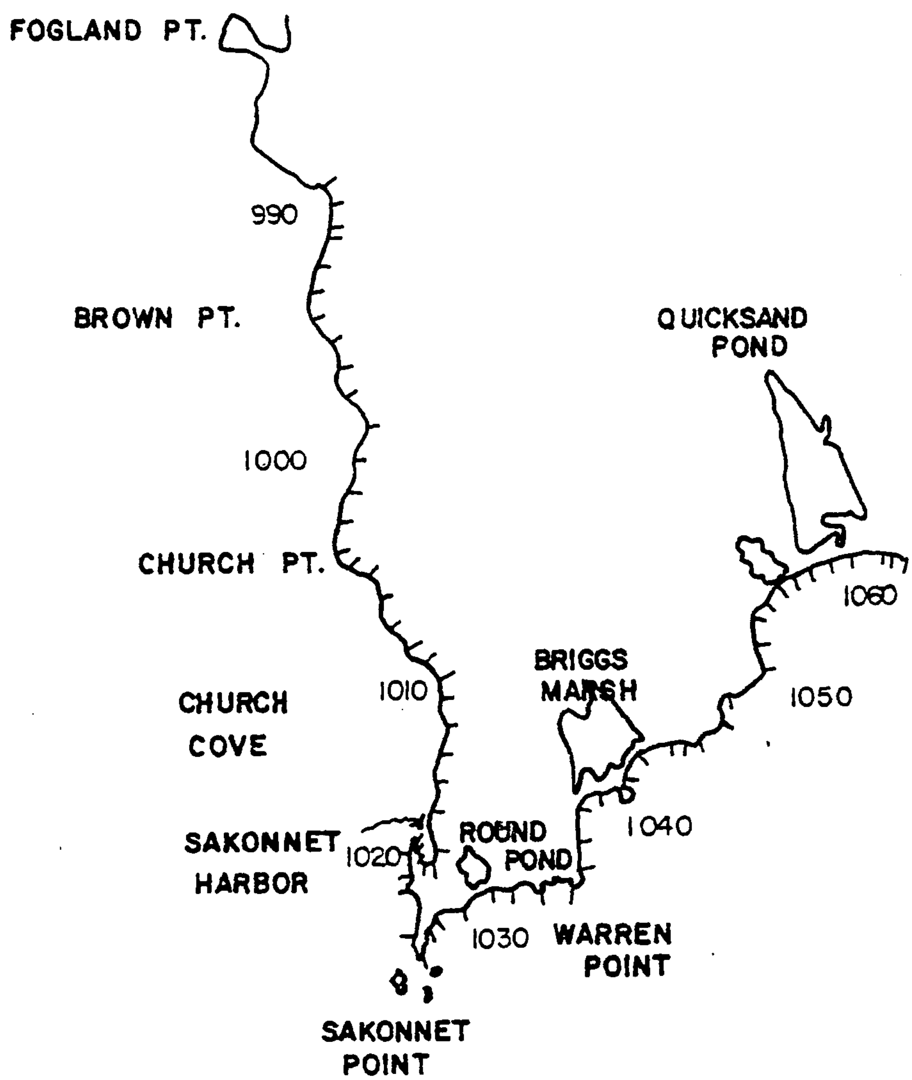
See Fig. H, (Fig. A_{45}, A_{46}, segments 924-954),

Figure 60a. Shoreline Segment Location Map:
Sakonnet River and South Shore.

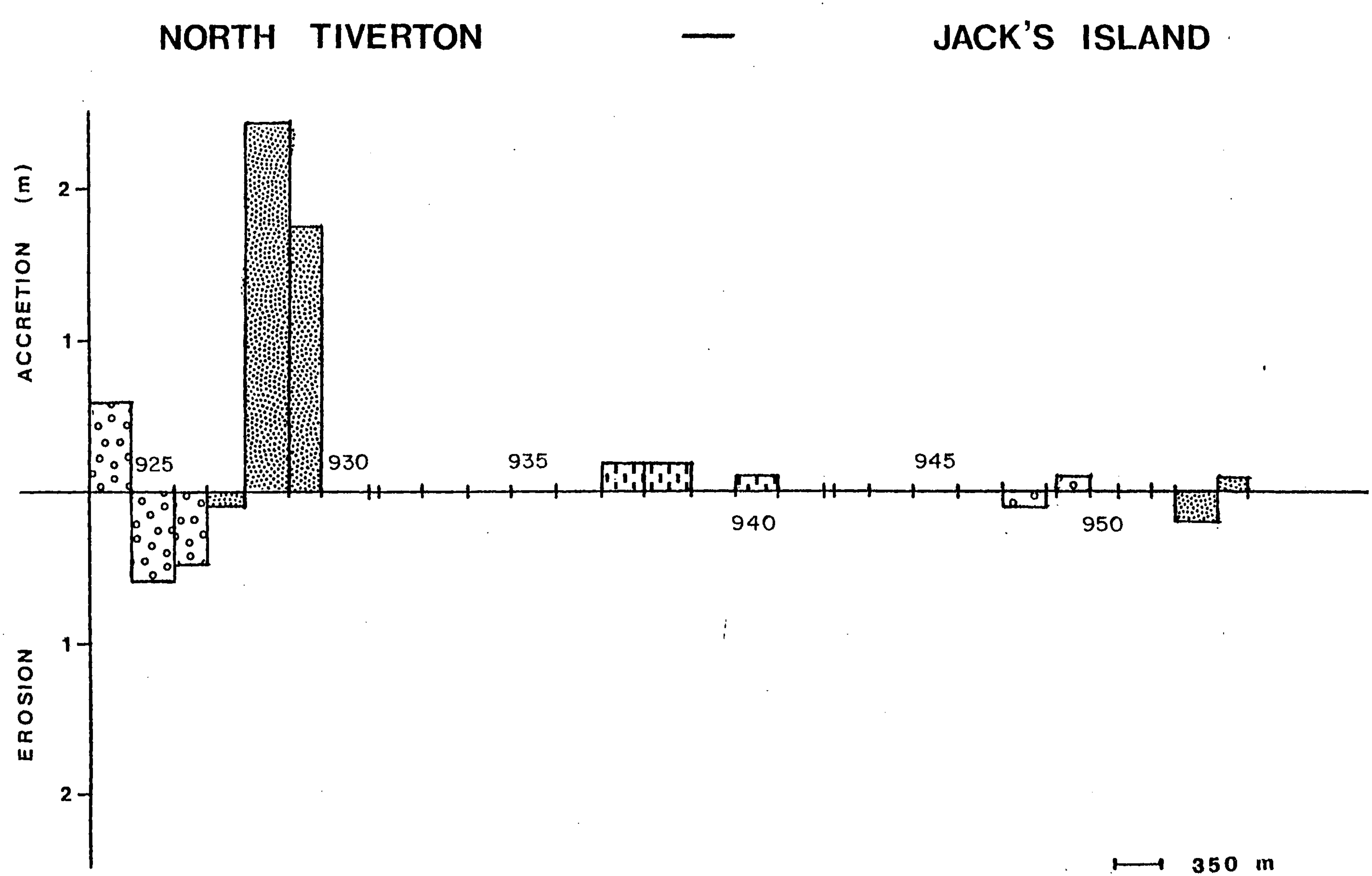


930
TIVERTON
940
NANNAQUAKET
NECK
950
JACK'S ISLAND
SAPOWET POINT
960
FOGLAND PT.
970
980
HIGH HILL PT.
990
BROWN PT.

Figure 60b. Shoreline Segment Location Map:
Sakonnet River and South Shore.

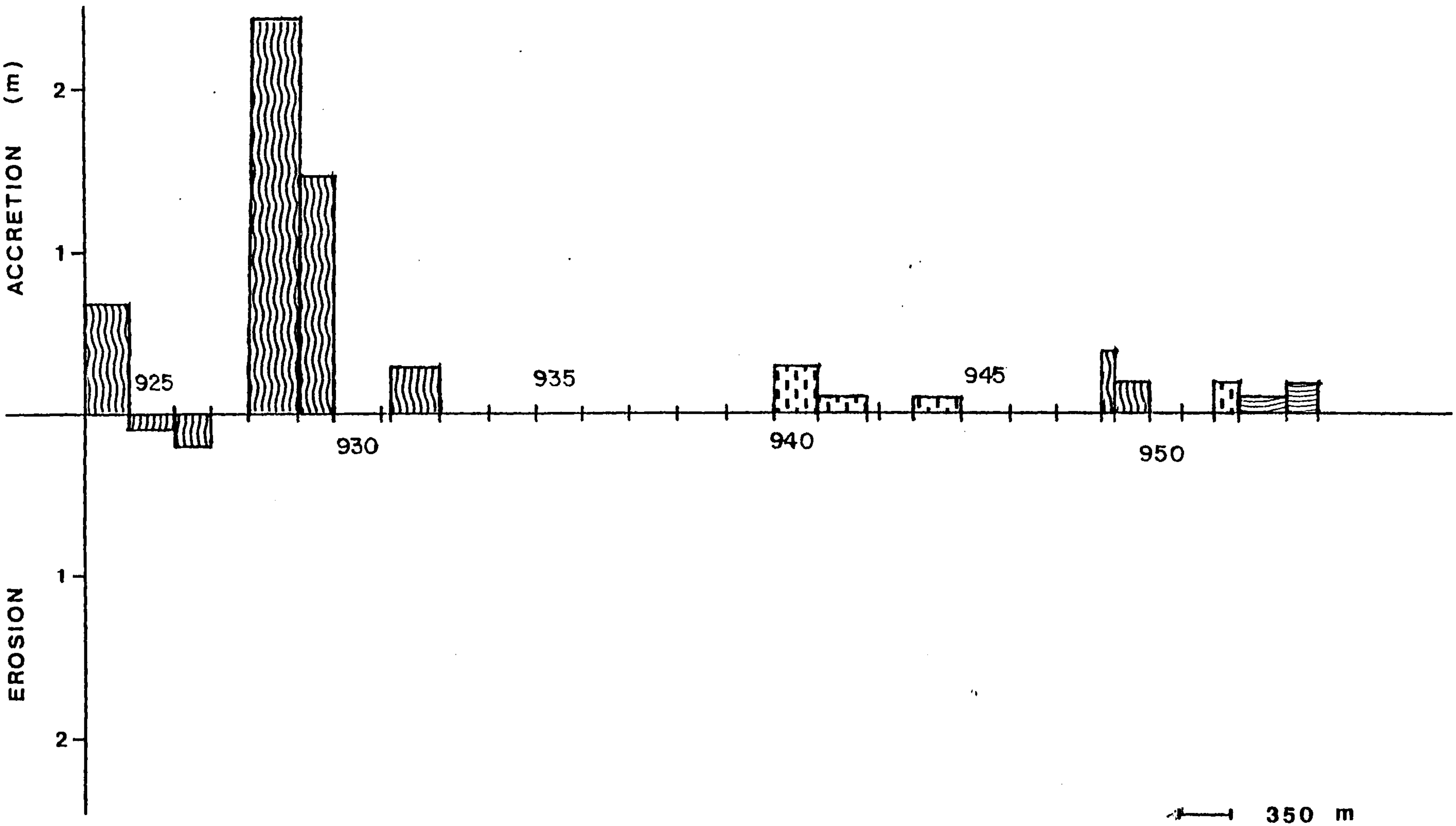


FOGLAND PT.
990
BROWN PT.
1000
CHURCH PT.
CHURCH
COVE
1010
SAKONNET
HARBOR
1020
ROUND
POND
1030
WARREN
POINT
SAKONNET
POINT
BRIGGS
MARSH
1040
1050
QUICKSAND
POND
1060



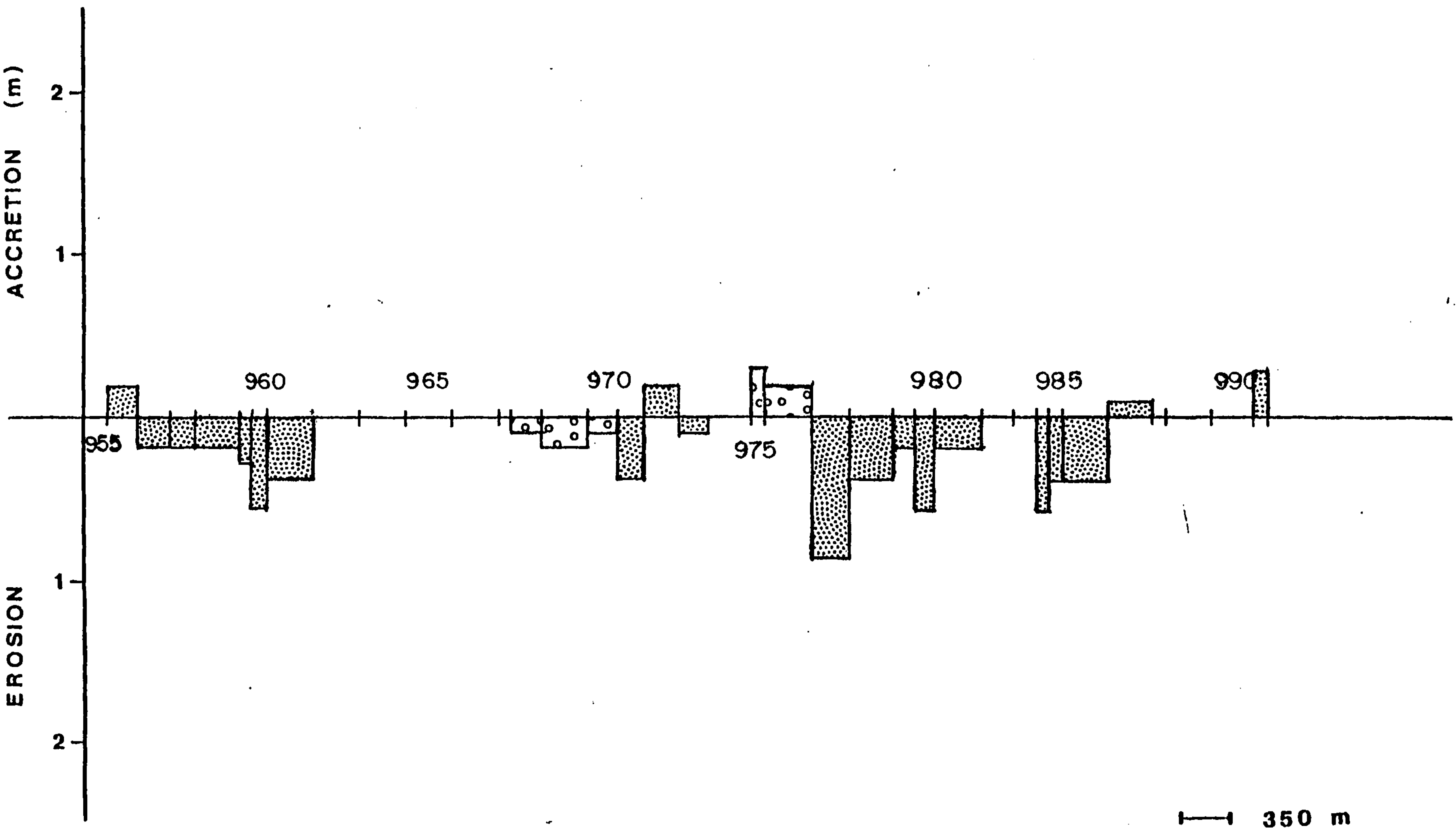
AVERAGE HIGH TIDE LINE CHANGE

NORTH TIVERTON — JACK'S ISLAND

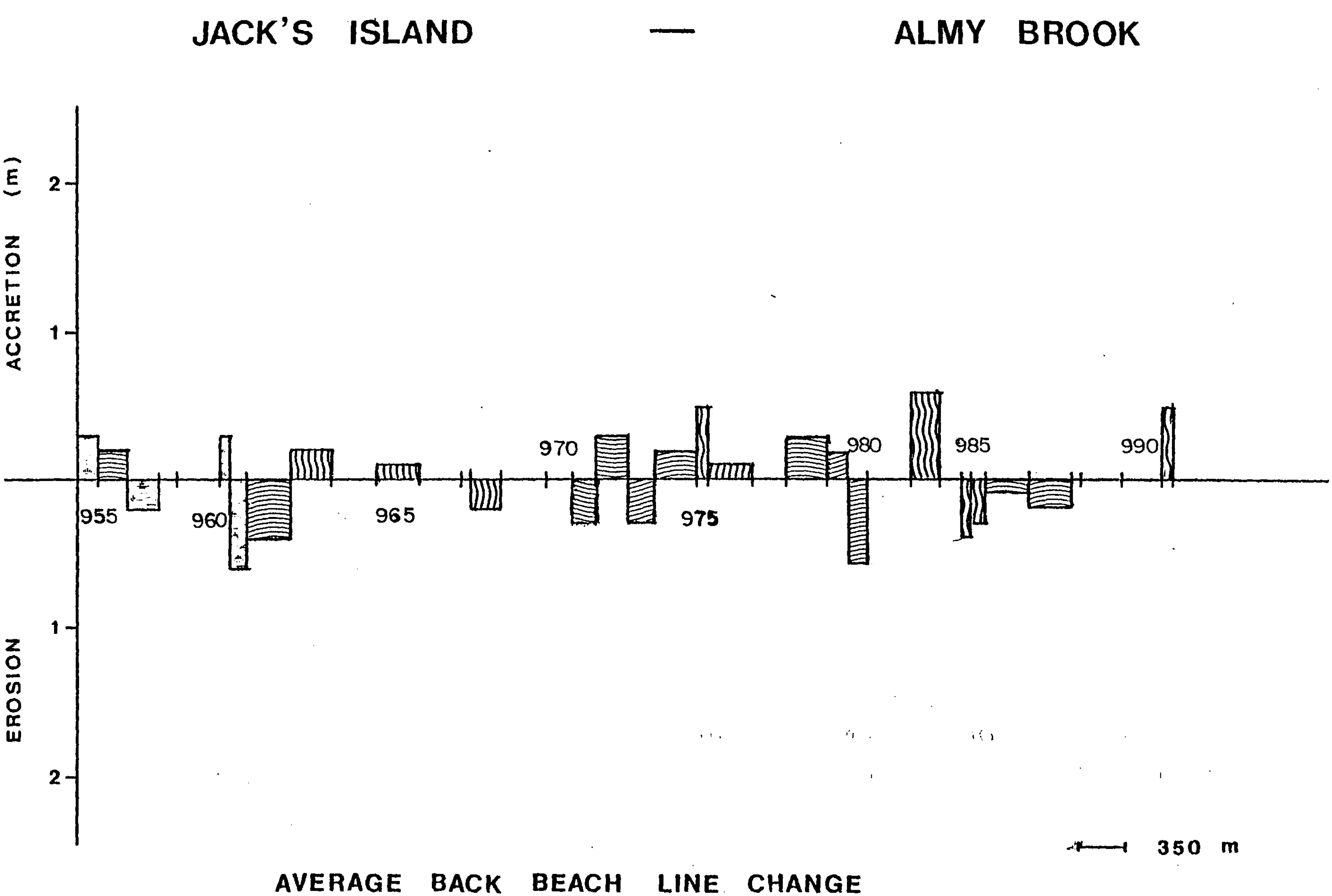


AVERAGE BACK BEACH LINE CHANGE

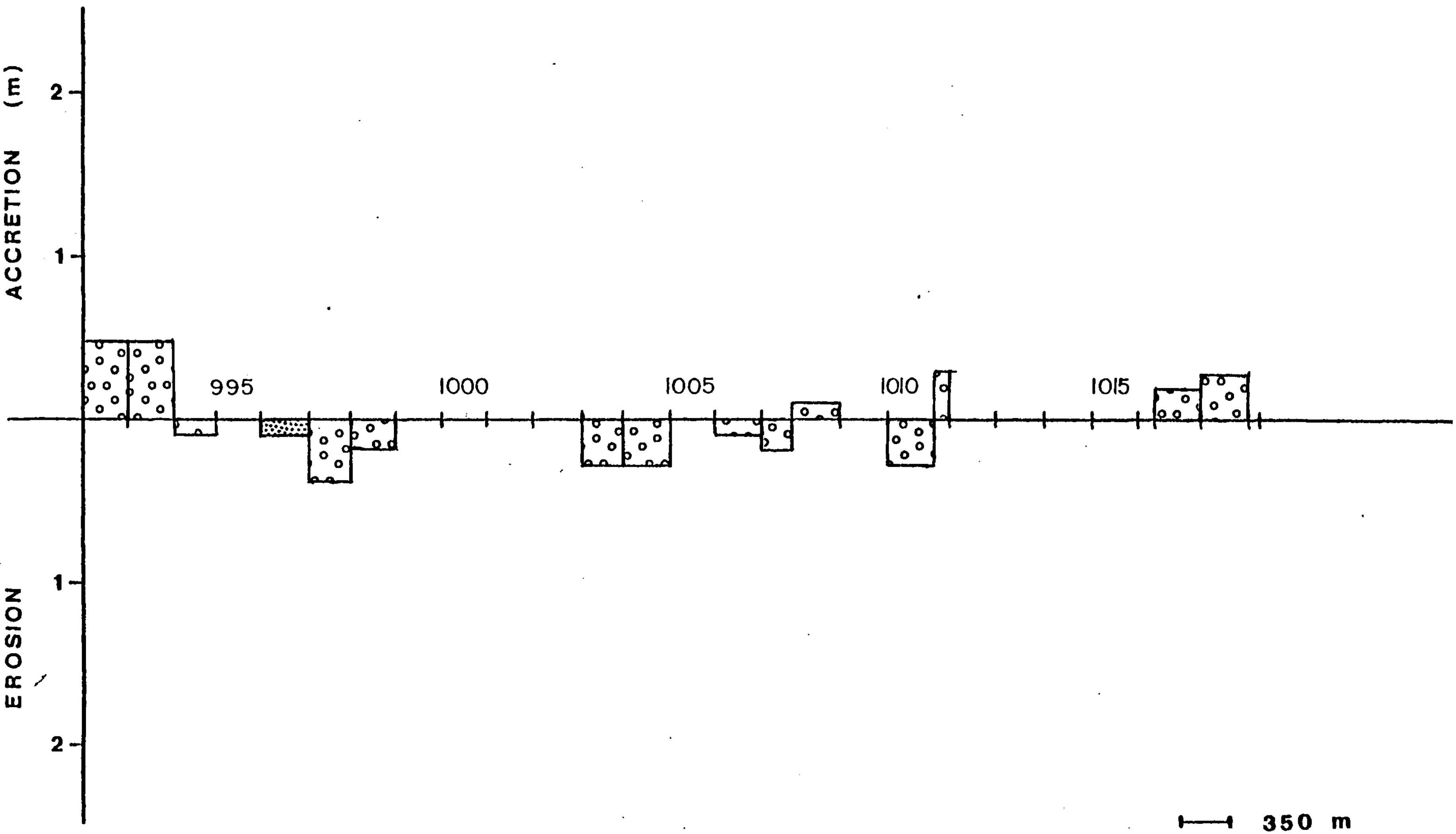
JACK'S ISLAND — ALMY BROOK



AVERAGE HIGH TIDE LINE CHANGE

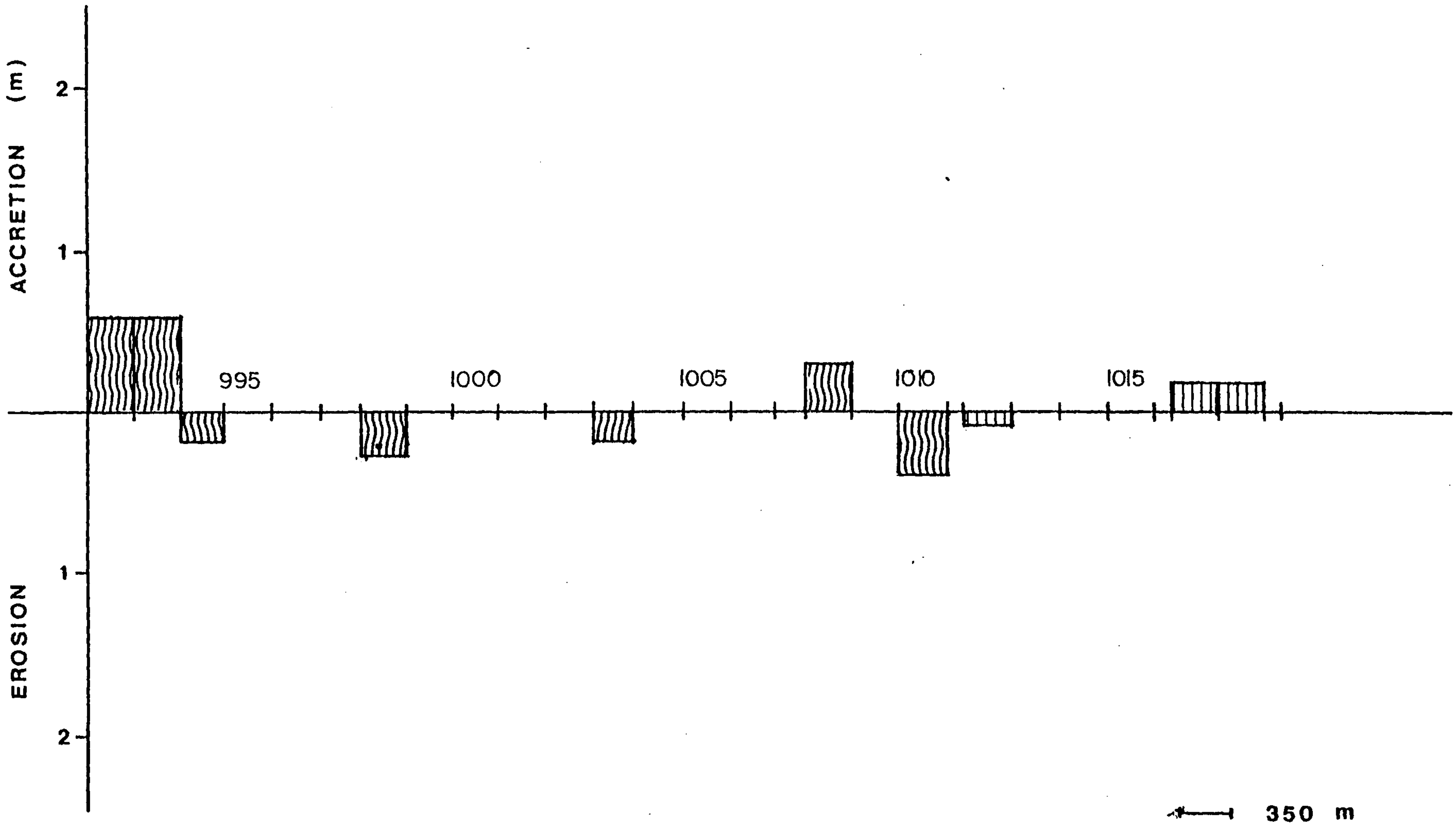

JACK'S ISLAND — ALMY BROOK
ACCRETION (m)
EROSION
2
1
1
2
955
960
965
970
975
980
985
990
350 m
AVERAGE BACK BEACH LINE CHANGE

ALMY BROOK — SAKONNET RIVER

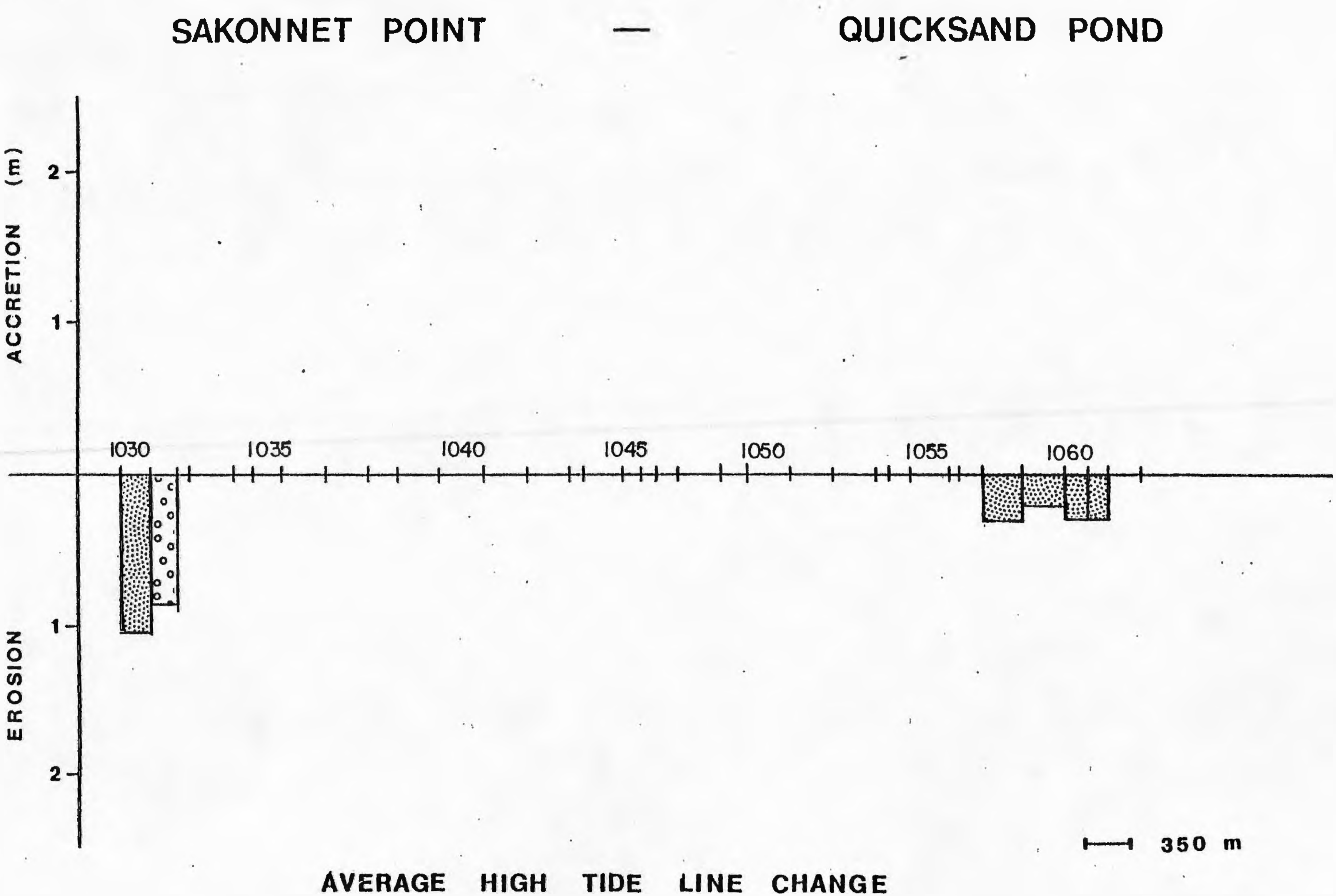


AVERAGE HIGH TIDE LINE CHANGE

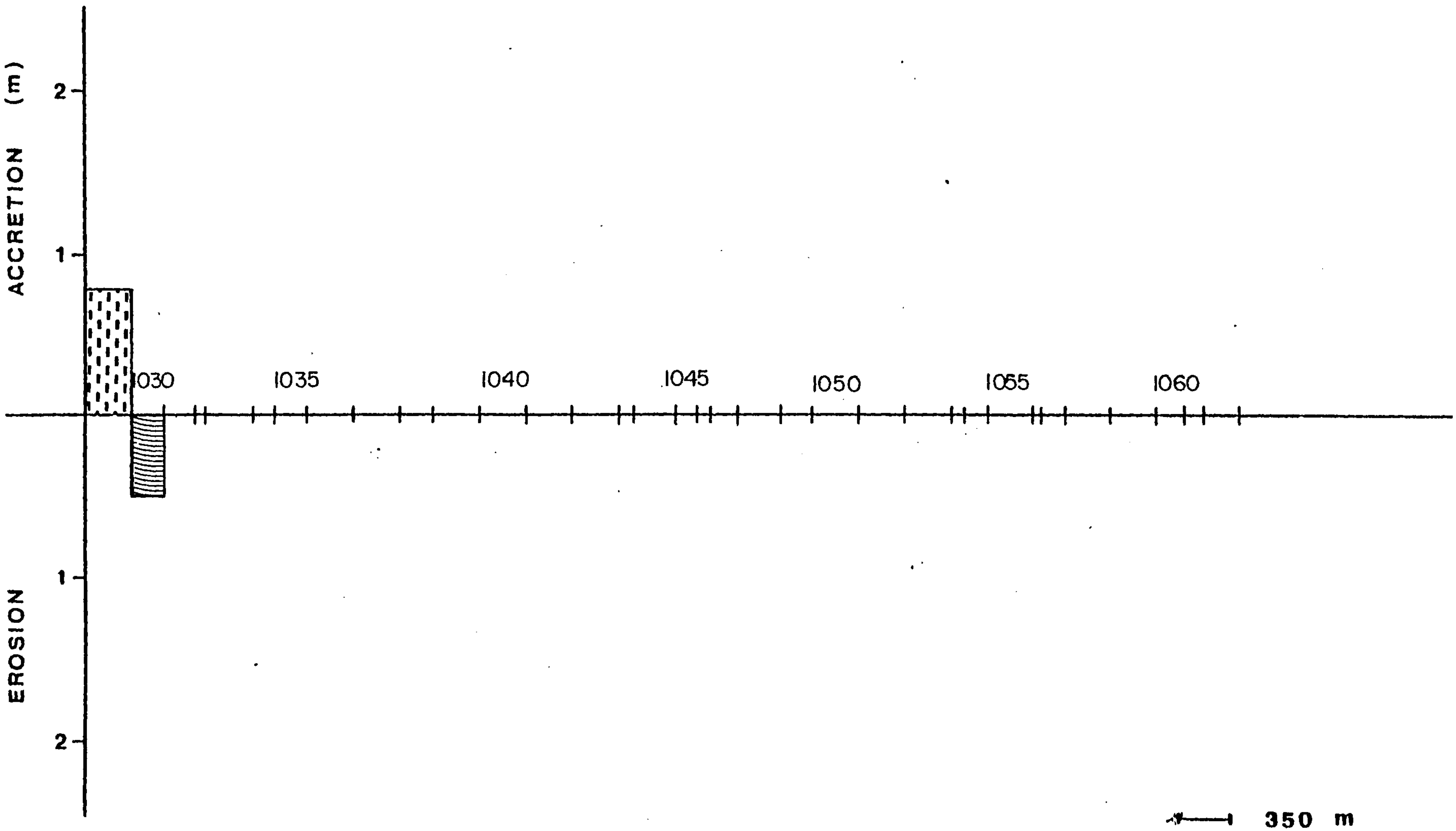
ALMY BROOK — SAKONNET RIVER



AVERAGE BACK BEACH LINE CHANGE


SAKONNET POINT — QUICKSAND POND
ACCRETION (m)
EROSION
2
1
1
2
1030
1035
1040
1045
1050
1055
1060
350 m
AVERAGE HIGH TIDE LINE CHANGE

SAKONNET POINT — QUICKSAND POND



AVERAGE BACK BEACH LINE CHANGE

(Fig. A_{47}, A_{48}, segments 955-991),(Fig. A_{49}, A_{50}, segments 992-1019),(Fig. A_{51}, A_{52}, segments 1029-1062). The eastern shoreline of the Sakonnet River consists largely of steep slopes of glacial drift and bedrock material. A tombolo exists at Fogland Point. Additional headlands and coves line the shore south to Sakonnet Point. The Sakonnet Point shoreline area is heavily protected by man-made structures. The south shore consists alternately of glacially dominated shoreline and barrier beach systems.

Segment 924 in North Tiverton exhibits accretion of 0.6-0.7 m/yr, while segments 925-927 are primarily erosional. Segments 928 and 929 show accretion of 1.5-2.6 m/yr. These segments are located on a U.S. Military Reservation and may be due to landfill.

Moderate erosion and accretion interfinger with areas of no change from North Tiverton to Sakonnet Point. Generally, neither erosion or accretion predominates, although erosion on the south side of Fogland Point (segments 977-978) reaches 0.9 m/yr at the high tide line. Stereo photo coverage for 1975 photographs was not available for segment 973 at High Hill Point.

Erosion of 0.1-0.9 m/yr predominated from segments 979-1007, although accretion of 0.3-0.6 m/yr occurred at Almy Brook (segments 991-993). Accretion of 0.2-0.3 m/yr occurred at segments 1016 and 1017, just north of Sakonnet Harbor.

At Sakonnet Point there was no measurable change, but at Round Pond, where there is a sandy barrier beach and dune system (segments 1030-1031) erosion of 0.9-1.1 m/yr occurred at the high tide line and of 0.5 m/yr occurred at the dune line. At segment 1029, addition of riprap to the scarp caused accretion.

No change was measured between Round Pond and Quicksand Pond. At Quicksand Pond, (segments 1051-1062), barrier beach erosion of the high tide line measured 0.3-0.4 m/yr. Dune line erosion was impossible to measure, because overexposure of the dune area on both sets of photographs made unsuccessful the attempts to identify the top-of-dune line.

DISCUSSION OF SHORELINE CHANGES

INTRODUCTION

For the purpose of the discussion of shoreline changes, the shoreline has been divided into categories in order of decreasing resistance to wave erosion, as follows: recent beach and barrier spit, glacial outwash and till, and metasedimentary and crystalline bedrock. Resistance to erosion is only one of several factors determining the amount of actual erosion or accretion along any given stretch of shoreline. Another factor is wave energy, which is a factor of dominant and prevailing wind speed, duration, and direction, wave fetch, tidal current velocities, and local river discharge. Bathymetry, salinity and temperature gradients, other chemical and biologic activity, and the Coriolis acceleration are additional, less significant factors.

The amount of mapped change for selected areas of the shoreline for 1938-1975 is analyzed in relationship to wind, fetch, tidal, river discharge, and bathymetric factors. Immediate source areas of accreted sediment and the immediate locus of deposition of eroded sediment are discussed. Sites were chosen for discussion on the basis of large, unusual, or unexpected shoreline change.

RECENT BEACH, BARRIER SPIT, OR CUSPATE SHOREFORM

The maximum erosion of the barrier beaches (including cuspate shoreforms) was 1.7 m/yr, while the average was 0.3 m/yr. Other beaches had rates of 1.1 m/yr and 0.2 m/yr for the maximum and average values, respectively.

Scarborough Beach (seg. 12-17) has an unlimited fetch to the South and East, which allows wave heights to develop sufficient to cause the 0.3-0.7 m/yr of erosion. This conclusion is based on the approximately 1 m/yr of erosion along the R.I. south shore (Regan, 1976). Sed-ment movement is to the north. This northward movement of sediment is evidenced by accumulation of sediment on the south side of a groin located at the southern end of the beach, the decrease in the erosion rate northward along the beach toward the headland at Black Point, and the southerly direction of the fetch.

At Narragansett Beach (segments 33-38), there is an unlimited fetch (southeasterly) causing the 0.4-0.7 m/yr of erosion. There is also the Pettaquamscutt River constantly changing the morphology of the north end of the beach, as can be observed both from the vertical aerial photos (Figures 71 and 72) and from observation of the beach itself. Maximum normal tidal current velocites at Narragansett Beach at the time of the mean Newport tidal range are 40.8 cm/sec (U.S. Coast and Geodetic Survey, 1963). Sediment moves to

Figure 69. 1938 Vertical Aerial Photograph:
Narragansett Beach.

Figure 70. 1975 Vertical Aerial Photograph: Narragansett Beach.

the north and into the Pettaquamscutt River, as evidenced by the extended spit at the northern end of the beach, a well-developed flood tidal delta, and offshore, subtidal sedimentary structures observed on vertical aerial photographs.

Bonnet Shore barrier beach (segments 56-60) has an unlimited fetch to the south-southwest and yearly erosion of 0.0-0.6 m. Ebb tidal currents at Bonnet Shores normally peak at 35.7 cm/sec during the mean tidal range at Newport. Corresponding flood tidal currents peak at 25.5 cm/sec. Sediment washes over the barrier during storms. This overwash can be viewed on vertical aerial photographs as lagoonal deposits and in vegetation changes similar to those observed by Simpson (1977) on the Rhode Island south shore to be the washover boundaries of the 1938 hurricane. Source sediment for the Scarborough, Narragansett, and Bonnet Shores beach faces comes from the dunes, a natural process of every beach backed by dunes, and from the south. Meade (1969) made the well-documented observation that in estuaries of the Atlantic Coastal Plain, bottom sediments are transported landward toward the head of the estuary. In Narragansett Bay, bottom sediments migrated North.

The south side of the South Ferry cuspate shoreform (segment 71), exposed to an unlimited fetch to the sea and a fetch of 2.7 km to the southeast, experienced 0.2 m/yr of erosion. Maximum ebb tidal velocities at the conditions described above (as are all of the following tidal velocities) are 45.9 cm/sec. Corresponding flood tidal velocities are 25.5 cm/sec. (U.S. Coast and Geodetic Survey, 1963). Although the north side of the shoreform (segment 72) is exposed to the dominant winter wind direction, which is from the northeast, and has a fetch of 18 km to the north-northeast, it experiences accretion of 0.1 m/yr. This is because sediment is moving to the north (Meade, 1969) either by washing over the top of the shoreform, migrating around its tip, or both. (Boothroyd, J.C., 1981, personal. commun.).

Casey Point (segments 80-81), which has an unlimited fetch to the south and a 1.3 km fetch to the southeast, shows 0.5 m/yr of erosion on its south side. No change occurred on its north side. Maximum ebb and flood tidal current velocities are 56.1 cm/sec and 25.5 cm/sec respectively, higher than at the beaches to the south because of the narrowing of West Passage and the presence of Dutch Island. Fetch to the north-northeast is 16 km, and winter storms from the northeast may counteract the tendency for northward moving sediment to accumulate on the north side of the shoreform. In addition, some of the sediment that may wash over the south side during storms would be deposited in the lagoon which covers the surface of the shoreform.

Plum Beach Point (segments 89-90), which has a fetch of 13.8 km to the north-northeast, has eroded at a rate of

0.8 m/yr on its north side. Ebb and flood tidal current velocities are 45.9 and 20.4 cm/sec in this shallow section of West Passage. Such erosion on the north side of the shoreform may be due to acquisition of till material for the piers of the Jamestown Bridge, which passes directly over Plum Beach Point. Greene Point (segments 91-92) is protected by numerous offshore rocks, so although it has a fetch of 13 km to the north-northeast, a fetch of 2.8 to the southeast and moderate tidal current velocities of 45.9 cm/sec (ebb) and 20.4 cm/sec (flood), it exhibits 0.1 m/yr of erosion or less.

Although Cold Spring Beach (segments 122-123) is a sandy beach, it shows no shoreline change, since it has only a moderate fetch of 4.8 km to the north-northeast and is protected by Rome Point. Pojac Point (segments 150-151) has a fetch of 8.4 km to the southeast and 0.6 km to the northeast and is situated at the mouth of the Potowomut River. It serves as a barrier trapping sediment being carried out of the Potowomut River during ebb flow and as river runoff and is accreting at a rate of 0.5 m/yr on its west side.

Sandy Point (segments 155-156) is located at the south-east entrance to Greenwich Bay, and has a fetch of 8.8 km to the southeast and a fetch across Greenwich Bay to the north, north-northwest, and north-northeast of 2.4, 3.2, and 2.6 km, respectively. It has lost sediment at 0.5 m/yr on its

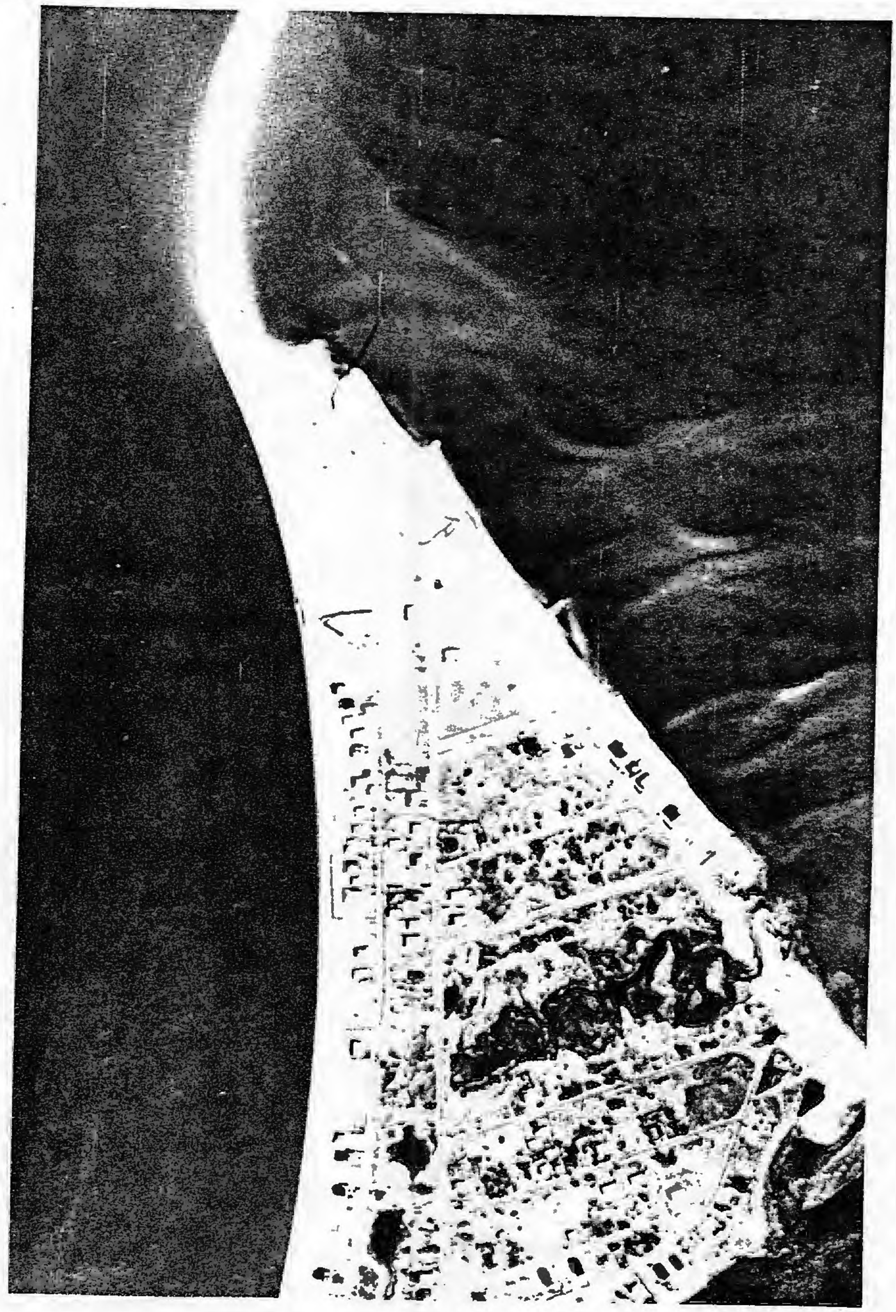
Figure 71. 1938 Vertical Aerial Photograph: Conimicut Point

south side and 0.3 m/yr on its north side, while its tip is building out into Greenwich Bay. It can be seen from vertical aerial photographs that sediment is moving east from Sally Rock Point to the tip of Sandy Point, where a groin has been built. Sediment at the farthest extent of the groin and on the south shore of Sandy Point can be seen from the photographs to be moving south along the shoreline, while some suspended sediments are visible extending into Narragansett Bay.

Conimicut Point (segments 234-240) has a fetch of 14.6 km to the south-southeast. It has lost material at 0.9 m/yr from the south side, where it can be seen from groins on the photographs that sediment is moving east to accumulate along the extensive intertidal spit. The Providence River, discharging through a channel at 30.6 cm/sec during normal tidal outflow at the end of this spit, leaves material behind at the northern side of Conimicut Point at a rate of 0.2-0.4 m/yr. A subtidal platform and suspended sediment are evident to the immediate north of Conimicut Point on the photos.

Gaspee Point (segments 254-257), which is in close proximity to a Providence River channel that is narrower and farther upriver than at Conimicut Point, loses sediment at 0.8 m/yr from its north side. There is a 9.2 km fetch to the south and a loss from the south side of 0.8-10.1 m/yr at the high tide line.

Figure 72. 1975 Vertical Aerial Photograph: Conimicut Point.



Barrington Beach, located at the top of the bay and adjacent to the outlet of the Providence River, has lost sediment at 0.5 m/yr from its western end, which is immediately adjacent to a dredged channel. At the eastern end of the beach, there has been no net erosion, although it is located in shallow water with a fetch of 10.4 km to the south and 12.4 km to the south-southwest. Any erosion from the eastern end of the beach is counterracted by accretion due to the eastward movement of sediment from the direction of Nyatt Point. This can be seen in accumulation on the western sides of groins as seen in photographs.

The east side of Rumstick Neck (segments 286-292) is a low-energy shoreline, as indicated by its marshy deposits and low erosion rate (0.0-0.3 m/yr). Its fetch, the width of the Warren River, is small, and it is not exposed to a dominant wind direction. Adams Point (segments 293-294) and Jacob's Point (segments 298-299), under circumstances similar to those on the east side of Rumstick Point, show no shoreline change.

The Jenny Pond area of the Prudence Island shoreline (segments 458-464), has evidenced no shoreline change on its western end and accretion of 0.8 m/yr on its eastern end, where sediment is accumulating at the mouth of a stream. Although there is a fetch to the southwest of 11.2 km and to the south of 16.4 km, the Jenny Pond area has experienced no net erosion because of sediment deposition at the outlets of Jenny Pond and other areas surrounding the marsh.

Sandy Point, on the eastern side of Prudence Island (segments 421-422), which has shown 0.1 m/yr of erosion on the north and 0.7 m/yr of accretion on its south side, is situated adjacent to a dredged shipping channel. The accretion may consist of dredge spoil. It has a small fetch of 2.0 km to the southeast and a relatively long fetch of 14.4 km to the south-southwest with a narrow fetch width. No tidal current velocities are available. The accreted material may be dredge spoil, or it may have been carried north along the shore. Sediment is accumulating on the south side of a pier located near the southern end of Sandy Point.

Potter Cove in Jamestown (segment 511) has shown erosion at an average annual rate of 1.9 m/yr, the greatest in the bay, a rate too high to be attributed to a 6.4 km northeast fetch or 20.4 cm/sec egg tidal velocity, material was dredged from the beach (anonymous, 1981, personal commun.), during construction of the Newport Bridge whose eastern piers are located to the immediate south of Taylor Point, which is adjacent to Potter Cove. Some sand was returned (anonymous, 1981, personal commun.), to the beach during recent construction of a sewage treatment plant at Taylor Point. This returned material does not cause net accretion because its volume is much smaller than the volume removed for bridge construction.

The mussel bed shoals area of the Portsmouth shore

Figure 73. 1938 Vertical Aerial Photograph:
Potter Cove.

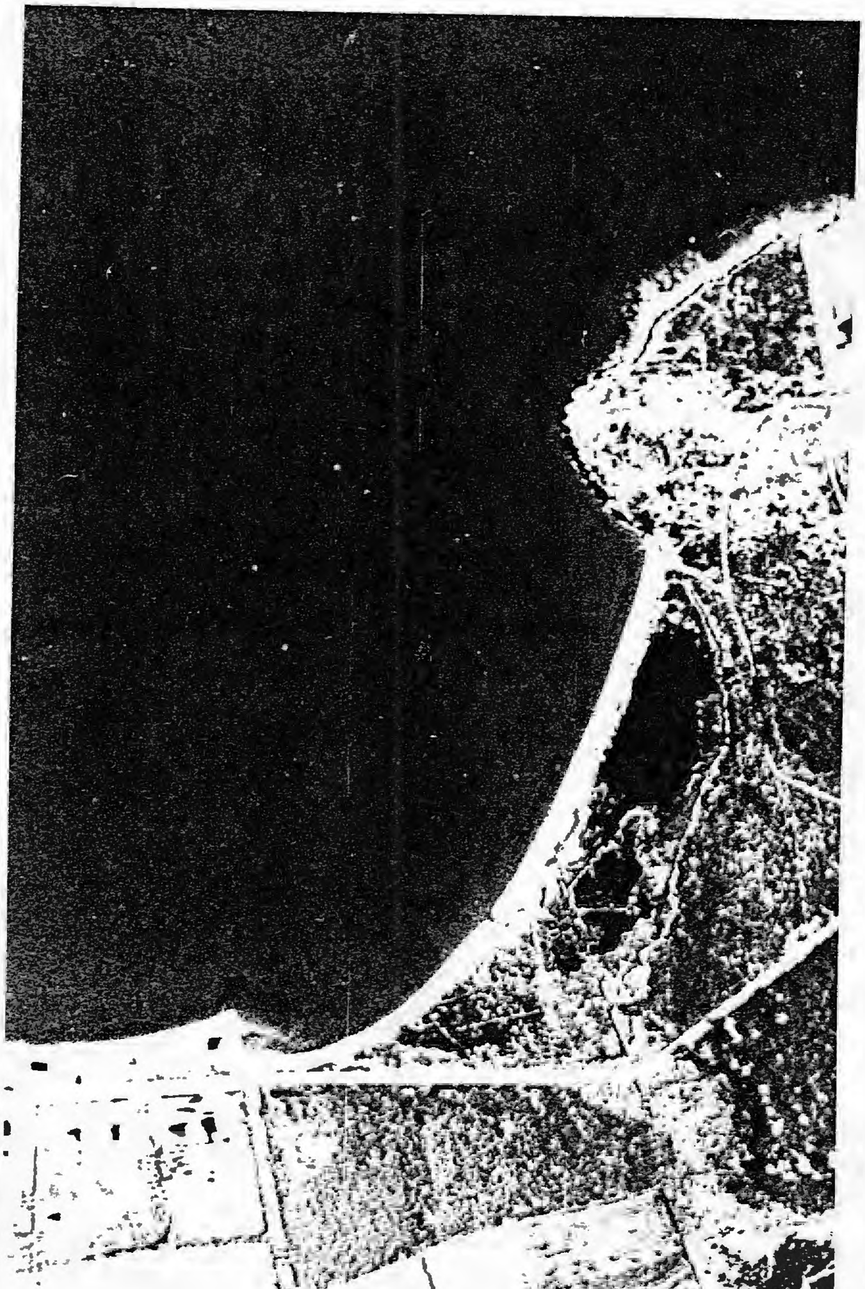
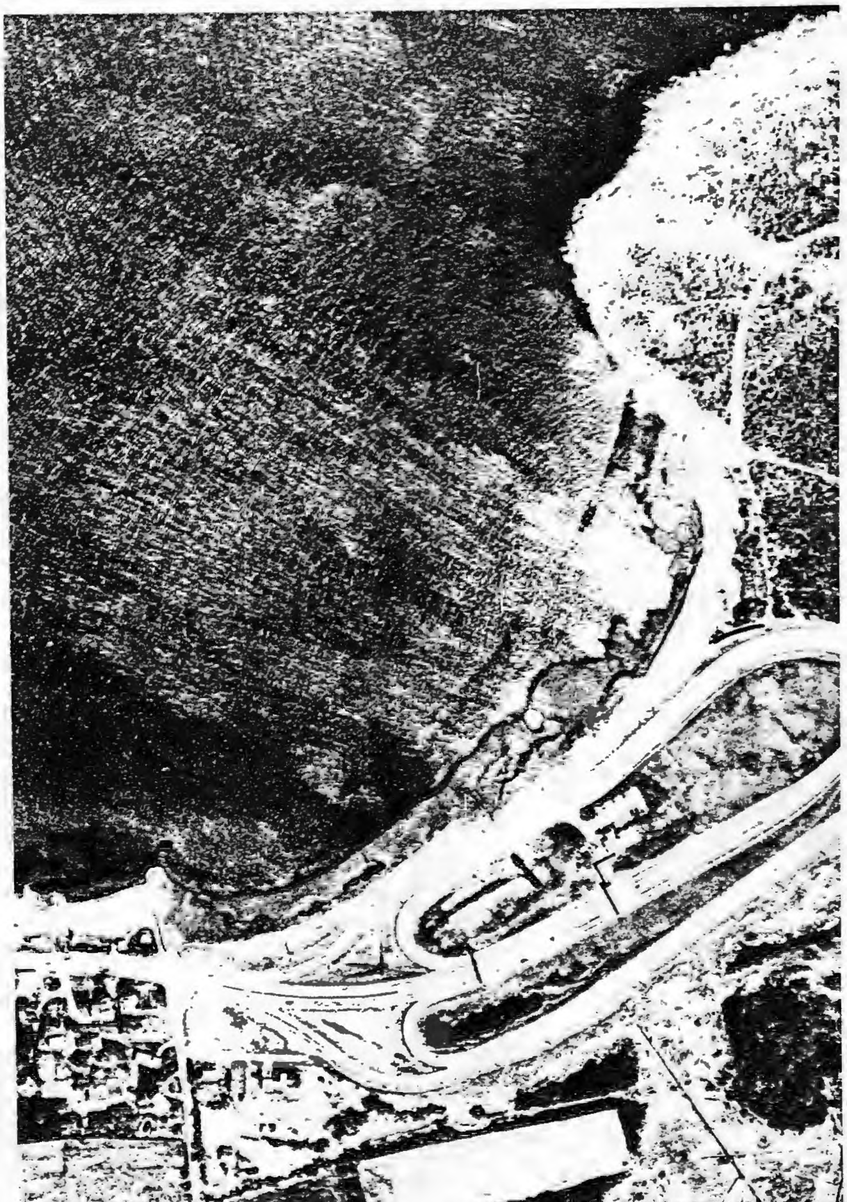


Figure 74. 1975 Vertical Aerial Photograph: Potter Cove.



segments (639-641) has experienced no net erosion or accretion except, those observable but unmeasurable amounts attributable to the discharge of a small stream. It is sediment discharged from this stream that can be viewed on vertical aerial photographs, and which supplies sediment to stabilize the shoreline.

The pocket beaches of Castle Hill, Price Neck, Cherry Neck, and Bailey Beach on the south shore of Newport (segments 738, 753-762, 768-770, and 774-775) have experienced no change because of their protection by the adjoining headlands. Easton Beach (segments 793-797), although it has an unlimited south and southeast fetch, has experienced very little erosion. This can be only partially attributed to adjacent headlands, which diffract oncoming waves, and wave energy around themselves (May and Tanner, 1973). Sand entering the beach from around the perimeter of Easton Pond replenishes the beach, as evidenced by the 1.3 m/yr rate of accretion where it flows across the beach face. Second Beach (segments 806-815) has an unlimited fetch to the south. It shows net erosion on the western end (0.2 - 0.4 m/yr) and net accretion on the eastern end (0.3-0.7 m/yr), and is protected somewhat by the headlands at Easton and Sacuest Points by diffraction of waves.

Third Beach (segments 829-831) exhibits sediment movement from south (0.4-0.5 m/yr of erosion) to north (0.4-0.7 m/yr of accretion). This can be seen on aerial photos where effluent from around the perimeter of Gardiner Pond not only accumulates, but visibly moves toward the north. Migration of material to the north is exhibited also at Sandy Point (segments 859-861) and McCurr Pt. (segments 869-870) in Portsmouth. Sandy Point has eroded 1.2-1.4 m/yr on its south side and accreted 0.4-0.6 m/yr on the north where there are located groins that show sediment accumulation on their south sides. At McCurry Point, erosion on the south side and accretion on the north side are 1.6-1.7 m/yr. Common Fence Point, the northern tip of Aquidneck Island, exhibits 0.1-0.2 m/yr of accretion of a cobble beach, which is present in conjunction with occasional marshy deposits seaward of the cobble beach. The presence of a cobble beach at an apparent low energy shoreline is due to deposition of material in the area during dredging of a nearby shipping channel shortly after World War Two (Pierce, 1981, personal commun.).

On the east side of the Sakonnet River, Sapowet Point (segments 958-962) has experienced erosion of up to 0.6 m/yr. There is a small 3.2 km northwest fetch and a 2.0 km southwest fetch. Flood and ebb tidal current velocities are a moderate 20.4 cm/sec. Sediment is moving north, as can be seen from the accretion of sediment on the south sides of groins. Most of the erosion measured probably occurs under

Figure 75. 1938 Vertical Aerial Photograph: Common Fench Point.

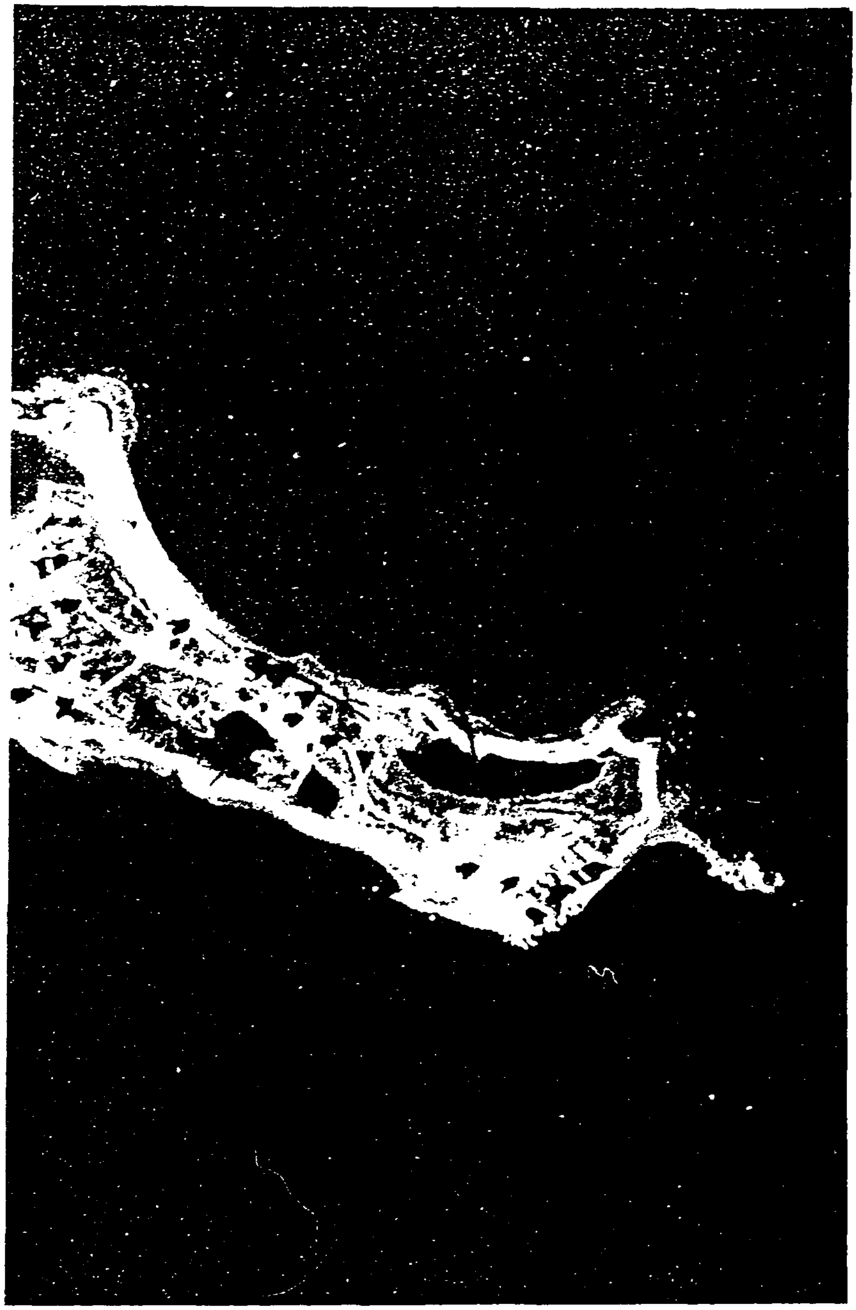
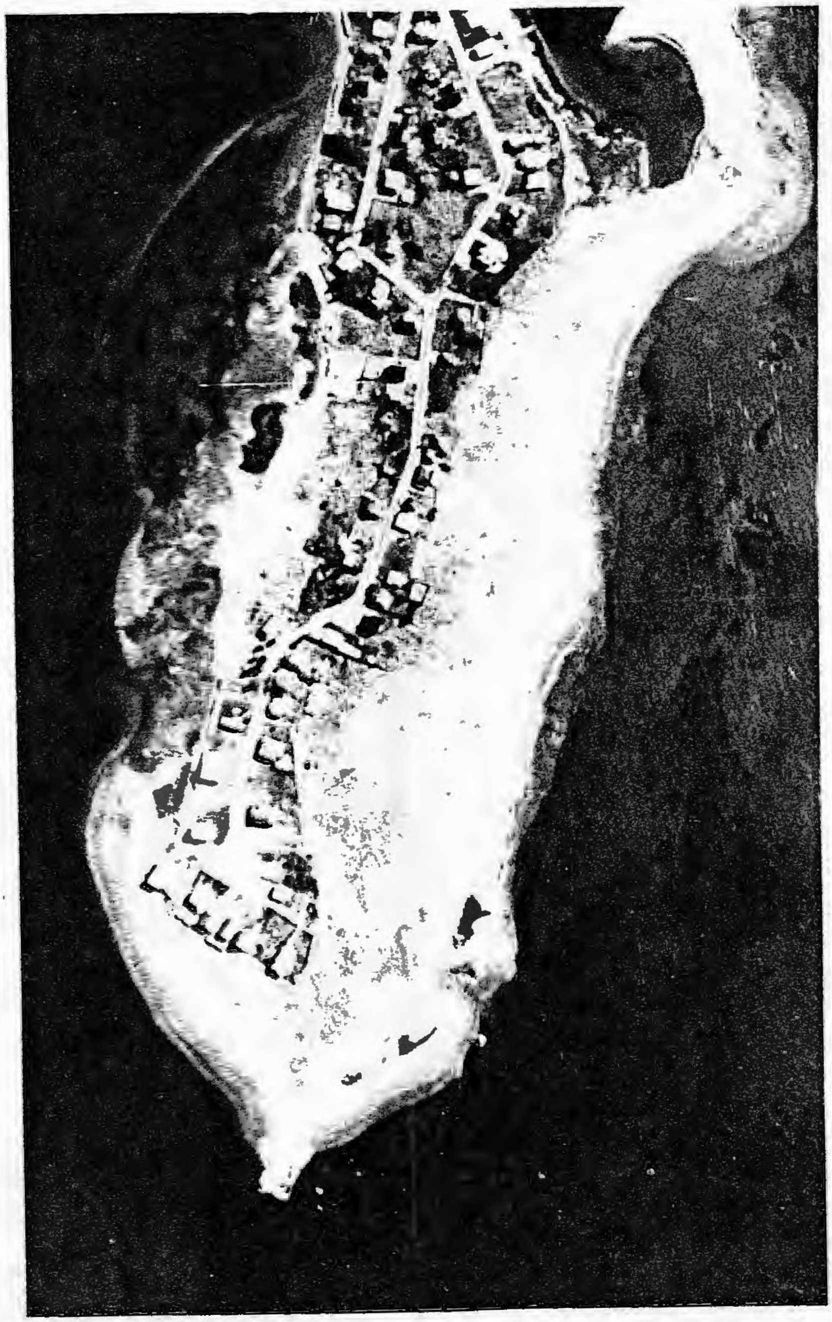


Figure 76. 1975 Vertical Aerial Photograph: Common Fench Point.



atypical conditions such as storm events. The north and south sides of Fogland Point, with an unlimited fetch to the south and a 6.8 km fetch to the north, has eroded at up to 0.9 m/yr. Material is eroded from the glacial bluff and beach face and transported partly to the adjacent channel and partly to the shore north of this tombolo, where suspended sediment is visible on aerial photos.

The barrier beach at Round Pond (segment 1029) on the south shore east of Sakonnet Point has an unlimited fetch and an erosion rate of 1.1 m/yr. There is much overwash activity at this beach (readily apparent on photos and in the field) as well as at the beaches at Briggs Marsh and Quicksand Pond (segments 1058-1061).

GLACIAL TILL AND OUTWASH

Glacial outwash beaches eroded at an average rate of 0.2 m/yr and a maximum rate of 1.5 m/yr. Till shoreline erosion averaged at 0.1 m/yr, and reached its maximum at 1.0 m/yr. Glacial outwash shorelines often eroded at rates similar to those at beach or barrier spit shorelines. Glacial till shorelines, however, were much more resistant to erosion, even under circumstances of large fetch in the dominant wind direction with strong tidal current velocities.

The outwash beach south of Pojac Point at segments 146 and 147 has eroded at a rate of 1.1 m/yr. It has a fetch of 8.4 km to the southeast and 12.0 km to the northeast. Tibbets Creek discharges on the south, and the Potowomut

River discharges to the north. Material moves from south to north, as evidenced by the northward-extending sand spit on the south side of the Tibbets Creek outlet into the bay.

Oakland Beach (segments 200-202), has an unlimited fetch to the south. It is an outwash beach whose erosion is as low as 0.4-0.8 m/yr even with the use of groins and raprap to curtail erosion.

Highland Beach (segments 225-226) although a till shoreline, has eroded at a rate of 0.5 m/yr because of a 6.8 km fetch to the southeast and a 3.6 km northeast fetch.

Most of Popasquash Neck in Bristol (segments 315-333) has experienced almost no change. This till beach is protected by a modest fetch (3.2 km from the southeast; 5.6 km from the northwest, and 2.0 km from the southeast) and low tidal currents. Bristol Neck (segments 338-371) has a till shoreline and shows almost no change, due partly to the proximity of Hog Island.

On Prudence Island, the till shoreline from Sheep Pen Swamp to Pine Hill Point (segments 465-470) shows no change in spite of a 6.4 km fetch to the southwest and northwest. Tidal currents are less than 25.5 cm/sec, and West Passage is at one of its widest extents at this locality. South Point on Prudence Island, a till shoreline, (segments 434-441) evidenced no change despite an 11.2 km fetch to the south.

Water depth in the area is less than 13 m, and ebb tidal currents are only 15.3 cm/sec.

Most of the till shore from Jamestown's Conanicut Point to Taylor Point (segments 485-510) experienced no change. Tidal currents are moderate and fetches are 8.0 km to the northeast and 4.0 km to the southeast. Auston Hollow (segments 574-576), with an unlimited south-southwest fetch and tidal currents of 35.7 cm/sec shows erosion of 0.3-0.5 m/yr.

On the west side of Aquidneck Island, Arnold Point (segments 645-647), near Mussel bed shoals, had little or no change in its till shore in spite of tidal currents of 45.9 cm/sec and a 10.4 km northwest fetch. Weaver Cove (666-688) is a till shoreline and showed little or no change. Fetch is 8.0 km to the southwest, but tidal currents are low (15.3 cm/sec). The till beach at the lighthouse at segments 679-680 accreted at 1.4-1.9 m/yr, explained only by artificial fill, which is observable on aerial photos.

On the till shoreline on the east side of Aquidneck Island sediment moved from south to north, which is visible at Sandy and McCurry Points, South of Sandy Point (segments 840-858) change ranged from 0.6 m/yr of accretion to 1.5 m/yr of erosion. Sandy Point to McCurry Point (segments 862-868) experienced erosion of up to 0.3 m/yr, and there was no change north of McCurry Point (segments 872-886). This pattern of decreasing shoreline erosion with distance up the Sakonnet River is a result of a corresponding general decrease in tidal current velocities and an extensive area of shallow water depths north of McCurry Point.

Segment 1004, a till beach south of Church Point on the east side of the Sakonnet River, has an unlimited south and southwest fetch and corresponding average erosion of 0.3 m/yr. Church Cove, segments 1010-1011, exhibits change that ranges from 0.4 m/yr of erosion to 0.3 m/yr of accretion. It has an unlimited fetch to the south and moderate tidal currents (25.5 cm/sec), as does segment 1004. At Warren Point, a till beach on the south shore (segments 1036-1038), there was no net erosion in spite of an unlimited fetch.

BEDROCK

In terms of erosion susceptibility, there is an important distinction to be made between the metasedimentary Pennsylvanian rocks, which often crumble in the hand when weathered and plutonic rocks, which, over the whole bay, showed no visible erosion over 37 years. Even the less resistant rocks, however, usually had erosion rates observable but too small to be measured.

SEDIMENT BUDGET ANALYSIS

INTRODUCTION

Many studies have been done on erosion and accretion, but relatively few have made volumetric determinations or sediment budget analyses. A sediment budget analysis is a method of addressing the questions of what happens to the sediment eroded from an area, and what the sources are of sediment in areas that are building out. A sediment budget is useful in identifying relevant coastal processes or estimating volume rates for an engineering design (U.S. Army Coastal Engineering Research Center, 1973). Much of the Narragansett Bay shoreline is erosional; only a relatively few localities are accretional. When sediment is eroded from a cliff or beach, it may stay in the immediately vicinity, as is often the case with boulders and cobbles, except during storm events. Sand-sized particles most often are carried along the shore and redeposited in a continuous cycle. Silt- and clay-sized particles may be transported away from the shore, lost in a sediment sink, and deposited at the bottom of the water body or in shoals, on mudflats or flood or ebb tidal deltas, and not redeposited along the shoreline. Sometimes sand is lost in sediment sink,s as in the case where a river mouth cuts off the continuity of longshore transport. Sometimes silt is redeposited, instead of being lost from the system.

PREVIOUS STUDIES

Pierce (1969) conducted a sediment budget analysis along a segment of the North Carolina Outer Banks from Hatteras Inlet to Cape Lookhout. Historical records, short-term mapped shoreline changes, and volume estimates were used to determine relative amounts of accreted and eroded material and their areas of source and deposition. Simpson (1977) compared volumes of washover accretion, tidal delta accretion, and beach erosion for the southern Rhode Island coast to determine percentages of accretion resulting from beach erosion. Riegler (1980) conducted a sediment budget analysis for the Boston Harbor Islands, Massachusetts, for which it was calculated how much sediment eroded from the shoreline was redeposited along the shoreline.

PURPOSE

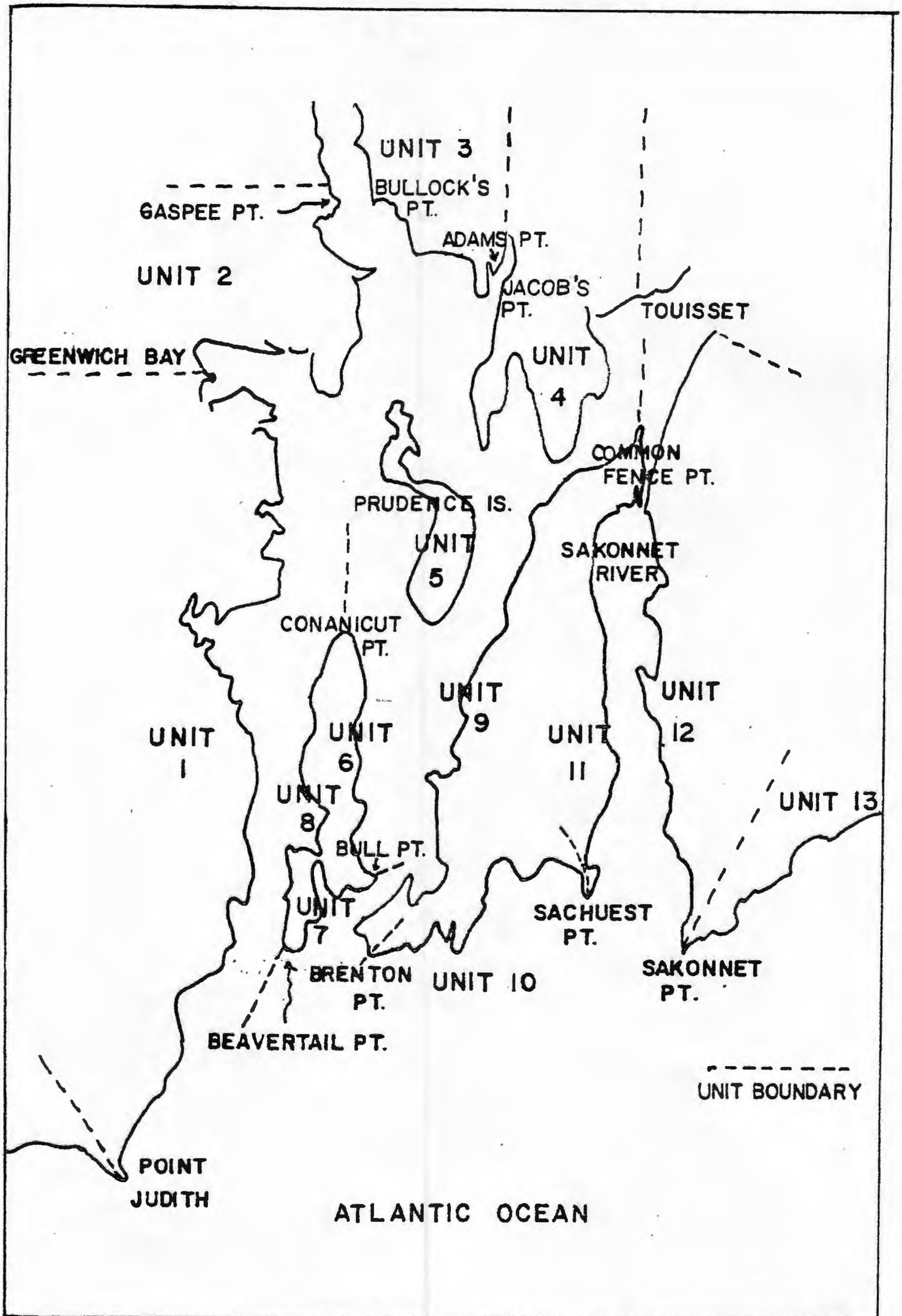
A sediment budget analysis was performed on the Narragansett Bay shoreline for two purposes. One determination involved a comparison of the total volume of sediment eroded from the beaches, cliffs and dunes with the total amount of sediment accreted elsewhere along the shoreline. In this way was determined the total amount of sediment lost from the shoreline system. In addition to this volumetric analysis of materials, a determination was made of percentages of cobbles and pebbles, gravel, sand and silt/clay eroded, redeposited, and lost from selected shoreline sediment budget units. Cobbles, pebbles, and gravel may remain at the base of a till cliff or on the beach as lag deposits, or may during periods of relatively high wave energy be transported and redeposited. Sand is the dominant sediment size transported and redeposited alongshore. Its source area as well as its destination may be a dune, a beach face, an offshore bottom deposit, a lagoonal deposit, or suspended sediment.

PROCEDURE

For purposes of the sediment budget analysis, the bay shoreline is divided into thirteen areas representing sediment transport units. Transport of sediment along the shoreline within each unit is considered to be continuous. Units are separated from one another by sediment sinks, or barriers such as bays, large rivers, inlets or large headlands, across which sediment is not transported. Areas of extensive man-made structures, such as the Providence Harbor facilities, are not included in the sediment budget units, and do not enter into budget calculations.

The units are 1) Point Judith - Greenwich Bay (segments 1-169); 2) Greenwich Bay - Gaspee Point (segments 180-257); 3) Bullock Point - Adams Point (segments 258-296); 4) Jacob's Point - Touisset (R.I. - Massachusetts border) (segments 297-379); 5) Prudence Island (segments 380-484); 6) Conanicut Point - Bull's Point on Conanicut Island (segments 485-530); 7) Bull's Point - Beavertail Point

Figure 77. Sediment Budget Analysis Index Map.


UNIT 3
BULLOCK'S PT.
GASPEE PT.
ADAMS PT.
UNIT 2
JACOB'S PT.
TOUISSET
GREENWICH BAY
UNIT 4
COMMON FENCE PT.
PRUDENCE IS.
UNIT 5
SAKONNET RIVER
CONANICUT PT.
UNIT 9
UNIT 12
UNIT 1
UNIT 6
UNIT 11
UNIT 13
UNIT 8
BULL PT.
UNIT 7
SACHUEST PT.
BRENTON PT.
UNIT 10
SAKONNET PT.
BEAVERTAIL PT.
UNIT BOUNDARY
POINT JUDITH
ATLANTIC OCEAN

on Conanicut Island (segments 531-567); 8) Beavertail Point - Conanicut Point on Conanicut Island (segments 568-638); 9) Common Fence Point - Brenton Point on Aquidneck Island (segments 907-923, 639-743); 10) Brenton Point - Sachuest Point on Aquidneck Island (segments 744-818); 11) Sachuest Point - Common Fence Point (segments 819-906); 12) The East side of the Sakonnet River (segments 9240 1026); and 13) Little Compton's South Shore (segments 1027-1062).

Major sediment sinks and barriers occur at Greenwich Bay, the Providence River, the major passages of Narragansett Bay, and Sakonnet Point.

VOLUMETRIC ANALYSIS OF THE SEDIMENT BUDGET

For each segment exhibiting change, the volume of sediment eroded from the back beach line and high tide line is compared to the net volume of sediment added to the high tide line shoreline in that unit. The resulting quotient x 100 is the percentage of sediment remaining in the system, and redeposited elsewhere along the shoreline. Back beach line accretion was not considered in the sediment budget, because in the rare instances when it occurred, it was a result of landfill or other managerial activity and not a natural process of sediment movement.

Volume values for sediment eroded from the back beach line were obtained by multiplying the area measured by the planimeter with the height of the cliff, dune, or slope. The

Table 1. Volumetric Analysis of Sediment Budget

Sediment Budget Units	Erosion EBL (m^3)	Erosion HTL (m^3)	Volume Loss (m^3)	Accretion HTL (m^3)	% Lost now Accretion
Unit 1: Pt. Judith to Greenwich Bay	16.8	272.6	289.4	41.4	14
Unit 2: Greenwich Bay to Gaspee Pt.	13.8	165.4	179.2	31.2	17
Unit 3: Bullock Pt. to Adams Pt.	1.3	44.7	46.0	21.1	46
Unit 4: Jacob's Pt. to Touisset	0.1	15.2	15.3	15.2	99
Unit 5: Prudence Island	2.5	16.9	19.4	20.2	104
Unit 6: Conanicut Pt. to Bull Pt.	0.8	28.7	29.5	0.0	0
Unit 7: Bull Pt. - Beavertail Pt.	0	0	0	0	0
Unit 8: Beavertail Pt. to Conanicut Pt.	0.4	50.6	51.0	21.9	43
Unit 9: Common Fence Pt. to Brenton Pt.	4.7	18.6	23.3	112.2	481
Unit 10: Brenton Pt. to Sachuest Pt.	0.1	14.3	14.4	24.5	170
Unit 11: Sachuest Pt. to Common Fence Pt.	55.9	140.9	196.8	40.5	20
Unit 12: North Tiverton to Sakonnet Pt.	10.5	86.9	97.4	74.3	76
Unit 13: Sakonnet Pt. to Quicksand Pond	0.1	34.6	34.7	0.0	0

height of the back beach line was acquired from U.S.G.S. topographic maps, whose contour interval is 10 feet. Hence there is an error inherent in the volume figures of ± 5 cu. ft. (±1.52 m^3) per unit beach length. The size of the study area made it unfeasible to take direct measurements of heights in the field. Measurement of heights from the aerial photographs carries an inherent error of ±10 feet (J. Fisher, personal commun., 1981) twice that for the topographic maps.

In determining volume values for the high tide line, area change measurements were multiplied by 8.44 m (Pierce, 1969) which is derived from an estimate of 0.76 m^3 per 0.09 m^2 (1 yard per cubic foot) of beach loss (CERC, 1973; Pierce, 1969). Since each change in slope of 1^o causes a corresponding change in beach volume of 0.9 $units^3$, the factor 8.44 must be considered an average rather than an exact figure when applied to Narragansett Bay beaches.

The results of the calculation for each unit are presented on Table 1. The values for the entire study area are as follows:

Total Back Beach Line Erosion	107 m^3/yr
Total High Tide Line Erosion:	889 m^3/yr
Total Volume Loss:	996 m^3/yr.

Of this nearly 1000 m^3/yr of volume loss, approximately 10% has been eroded from the back beach, approximately 90% from the high tide line.

TABLE 2: SEDIMENT BUDGET ANALYSIS PROCEDURAL OUTLINE

I VOLUMETRIC ANALYSIS OF THE SEDIMENT BUDGET

A. DETERMINATION OF SEDIMENT BUDGET UNITS: STRETCHES OF SHORE ALONG WHICH THERE IS CONTINOUS TRANSPORT OF SEDIMENTS.

B. AREAL MEASUREMENT OF BACK BEACH LINE AND HIGH TIDE LINE EROSION AND ACCRETION.

C. DETERMINATION OF VOLUME ERODED AT BACK BEACH LINE BY TAKING HEIGHT READINGS FROM USGS TOPO SHEETS.

D. DETERMINATION OF VOLUME ERODED AND ACCRETED AT THE HIGH TIDE LINE BY MULTIPLYING AREA MEASUREMENTS BY 8.44. (PIERCE, 1973)

E. CALCULATION OF PERCENT OF SEDIMENT REDEPOSITED ALONG THE SHORELINE AFTER EROSION:

$$\frac{\text{TOTAL HIGH TIDE LINE ACCRETION}}{\text{TOTAL VOLUME LOSS}} \times 100 = \%\ \text{REDEPOSITED}$$

II GRAIN SIZE ANALYSIS OF THE SEDIMENT BUDGET

A. COLLECTION OF SEDIMENT SAMPLES FROM EROSIONAL BACK BEACH LINES AND ACCRETIONAL HIGH TIDE LINES FROM BEACHES IN AREAS OF GLACIAL TILL AND AREAS OF GLACIAL OUTWASH AROUND THE BAY.

B. GRAIN SIZE ANALYSIS OF EACH SAMPLE.

C. SELECTION OF SAMPLES TYPICAL OF TILL AND OUTWASH SHORELINES, EROSIONAL BACK BEACH LINES, AND ACCRETIONAL HIGH TIDE LINES.

D. MEASUREMENT FROM DATA OF HOW MUCH OF TOTAL SHORELINE IS OUTWASH, HOW MUCH TILL.

E. CALCULATION, USING GRAIN SIZE DISTRIBUTION OF TYPICAL OUTWASH AND TILL SAMPLES, OF THE PERCENT OF EACH GRAIN SIZE ERODED FROM AND ACCRETED TO THE OUTWASH AND TILL SHORELINES.

F. CALCULATION OF THE PERCENTAGE OF EACH GRAIN SIZE LOST FROM THE OUTWASH AND TILL SHORELINES THAT IS REDEPOSITED ALONG THE SHORELINE.

Total High Tide Line Accretion: $402\ m^3/yr$.

Percent Eroded From Back Beach Line and High Tide Line Present Now as Accretion of the High Tide Line:

$$\frac{\text{Total High Tide Line Accretion}}{\text{Total Volume Loss}} \times 100 = \frac{402\ m^3/yr}{996\ m^3/yr} \times 100 = 40\%$$

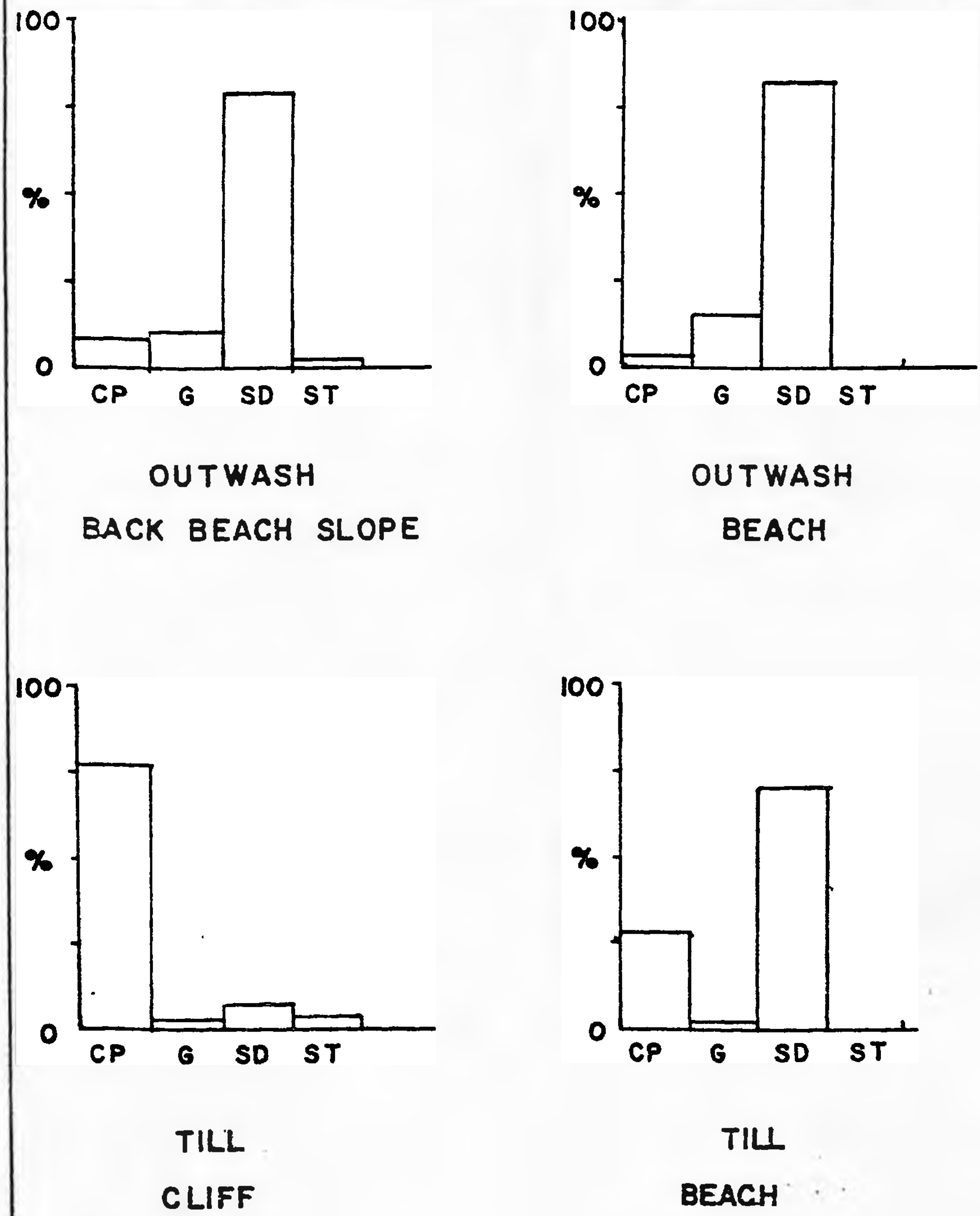
This indicates that of the nearly 1000 m^3/yr of volume loss, less than half was redeposited as high tide line accretion. This assumes homogenous material.

GRAIN SIZE ANALYSIS OF THE SEDIMENT BUDGET

The volumetric analysis of the sediment budget uses measurements of deposits that contain all sediment sizes. Since the deposits are not homogeneous, and since some grain sizes within each deposit have a greater tendency than others to be redeposited, a grain size analysis of the sediment budget is performed. In this way it can be determined what percentages of which grain sizes remain the system following erosion.

The glacial till- and glacial outwash- controlled shorelines of Narragansett Bay contribute to the sediment budget over a 37-year period; comparatively resistant bedrock shorelines do not erode sufficiently. Samples of glacial till and outwash back beach line material were collected with corresponding beach face deposits. Samples used for the sediment budget analysis were those which grain size analysis

Figure 78. Sediment Budget Grain Size Analysis.



KEY

CP	COBBLES & PEBBLES	SD	SAND
G	GRAVEL	ST	SILT

showed to be representative of an erosional till cliff, an accretional till-fed beach face, an erosional outwash back beach slope, or accretional sandy beach. With these representative samples, percentages of grain sizes remaining in the system after erosion could be calculated and presented as values representative of all the till or all the outwash deposits along the shoreline of Narragansett Bay.

Two samples were taken at each of seven back beach line locations where net erosion occurred over the study period. Samples were collected from the following four sediment transport units: Point Judith - Greenwich Bay, Sachuest Point - Common Fence Point, the East side of the Sakonnet River, and the Little Compton south shore. Each cliff sample consisted of material taken from top to bottom of the cliff to give an average grain size configuration. Stratigraphic units were sampled in proportion to their thickness in the cliff. Grain size analysis values for the two samples taken at each locality were averaged. Each beach sample consisted of material taken from the water line to the back beach line. Samples were dry-sieved in the laboratory. The -2 sieve was used (4 mm screen), separating gravel from pebbles and cobbles. The -1 sieve (2 mm screen) separated gravel from sand, and the 4 sieve (0.0625 mm screen) separated sand from silt and clay. (Folk, 1974).

There were two sample localities at erosional cliffs of two different types of glacial till in the Point Judith -

Greenwich Bay sediment transport unit (sediment unit 1): one to the immediate South of Scarborough Beach, in the Point Judith End Moraine, and one to the immediate South of the South Ferry cuspate shoreform, in a ground moraine. (Schafer, 1961). The accretion sample locality for this unit was the north side of the South Ferry cuspate shoreform beach. At Goddard State Park, to the west of Sally Rock Point on the south shore of Greenwich Bay, samples of outwash were collected from the back beach slope and from the beach. For the unit from Sachuest Point - Common Fence Point (sediment unit 11), samples were collected from an eroding till cliff approximately 200 m north of Black Point, and from the accretional localities at the north sides of Sandy Point and McCurry Point. The Unit encompassing the east side of the Sakonnet River in Tiverton and Little Compton (sediment unit 12) was sampled at an erosional till area on the south shore of Fogland Point and at an accretional area just north of Sakonnet Point and Sakonnet Harbor. The unit represented by the south shore of Little Compton (sediment unit 13) was sampled at a till cliff to the immediate east of the Round Pond barrier beach and another erosional area to the west of the barrier.

The grain size analyses for the representative samples, shown on Figure 70, are as follows. The South Ferry till cliff contained 76.2% cobbles and pebbles, 3.3% gravel, 7.1%

sand, and 4.3% silt. The South Ferry cuspate beach contained 27.6% cobbles and pebbles, 2.3% gravel, 70.1% sand, and 0% silt. The Goddard Park outwash back beach slope contained 8.2% cobbles and pebbles, 10.2% gravel, 79.8% sand, and 1.8% silt. The Goddard Park outwash beach contained 2.3% cobbles and pebbles, 14.9% gravel, 82.8% sand, and 0% silt.

Based on the Lang et al. (1960) map showing till and outwash deposits, 69 km of the 360 km-long Narragansett Bay shoreline consists of outwash deposits. Of the 889 m^3/yr of material eroded from back beach lines and high tide lines, 69 m^3/yr or 19% is from outwash material, and 231 m^3/yr or 81% is from till deposits.

Based on the grain size analysis of the representative outwash back beach slope sample, of the total 69 m^3/yr of outwash material eroded from the shoreline, 5.6 m^3/yr (8.2%) was cobbles and pebbles, 7.0 m^3/yr (10.2%) was gravel, 55 m^3/yr (79.8%) was sand, and 1.2 m^3/yr or 1.8% was silt. Based on the grain size analysis of the representative accretional outwash beach sample, 28.0% (or 1.6 m^3/yr) of the cobbles and pebbles eroded were subsequently redeposited. Of the gravel, 146.1%, or 10.2 m^3/yr was redeposited, along with some additional material. Of the sand, 103.7% or 57 m^3/yr was redeposited. No silt-sized material was redeposited.

Based on the grain size analysis of the representative till cliff sample, of the 231 m^3/yr of till material eroded from the shoreline, 176.0 (76.2%) was cobbles and pebbles, 7.6 m^3/yr (3.3%) was gravel, 16.4 m^3/yr (7.1%) was sand, and 9.9 m^3/yr or 4.3% was silt. Based on the grain size analysis of the representative till beach sample, 36.2% or 83.6 m^3/yr of the cobbles and pebbles was redeposited, 70.0% of the gravel, or 161.7 m^3/yr, was redeposited, 987.3%, or 2280.0 m^3/yr of the sand was redeposited along with additional material, and no silt-sized particles were redeposited.

Conclusions

Between 1938 and 1975, total erosion for the Narragansett Bay shoreline, including back-beach line (cliff, dune and man/made structure line) and high tide line was 141 m/yr (996 m^3/yr $\pm$ 30 m/yr. Of this, 15.1 m/yr (107 m^3/yr) was from the back beach line, and 125.8 m/yr (889 m^3/yr) was from the high tide line. Approximately 30% of the high tide line shoreline of the bay showed no erosion or unmeasurable amounts from 1938-1975. Average erosion rates for those areas exhibiting changes was 0.3 cm/yr.

Of the material eroded from the high tide line, 40% was redeposited along the shoreline. The highest percentage of particles redeposited along the shoreline after erosion was for sand-sized particles. All eroded silt was lost from the shoreline. This was true for both till and outwash shorelines, despite differences in grain size composition for the two types of deposits. Till cliff deposits representative of the entire shoreline included much higher percentages of cobbles and pebbles and much lower percentages of sand than the outwash beach slope deposits. Beach samples representative of both outwash and till-fed beaches contained high percentages of sand and no silt.

The most significant factor contributing to the tendency toward erosion was shoreline geomorphic type. Recent beaches

TABLE 3: AVERAGE AND MAXIMUM HTL EROSION VALUES*

BARRIER BEACHES:	MEAN: 0.2 M/YR STANDARD DEVIATION: 0.2 MAXIMUM: 1.1 M/YR AT ROUND POND, LITTLE COMPTON.
CUSPATE SHOREFORMS:	MEAN: 0.4 M/YR STANDARD DEVIATION: 0.4 MAXIMUM: 1.7 M/YR AT McCURRY POINT, PORTSMOUTH.
OTHER SANDY BEACHES:	MEAN: 0.2 M/YR STANDARD DEVIATION: 0.3 MAXIMUM: 1.1 M/YR BETWEEN BLACK POINT AND SANDY POINT, PORTSMOUTH.
GLACIAL OUTWASH BEACHES:	MEAN: 0.2 M/YR STANDARD DEVIATION: 17.7 MAXIMUM: 1.5 M/YR NORTH OF TIBBETS CREEK, NORTH KINGSTOWN.
GLACIAL TILL BEACHES:	MEAN: 0.01 M/YR STANDARD DEVIATION: 10.1 MAXIMUM: 1.0 M/YR NORTH OF POINT JUDITH.

*Includes areas of erosion and no change.

and barrier spits, including cuspate shoreforms, were the most susceptible. The average erosion rate for barrier beach high tide lines was 0.2 m/yr, with a maximum of 1.1 m/yr at Round Pond, Little Compton. Standard deviation was 0.2. For cuspate shoreforms, the average high tide line erosion rate was 0.4 m/yr, the maximum being 1.7 m/yr. at McCurry Point. Standard deviation was 0.4. Sandy beaches other than barrier beaches or those at cuspate shoreforms eroded at an average rate of 0.2 m/yr, with a maximum of 1.1 m/yr between Black Point and Sandy Point in Portsmouth. Standard deviation was 0.3. Glacial outwash beaches, high in sand content, were also highly susceptible to erosion. Outwash beaches eroded at an average rate of 0.2 m/yr and a maximum of 1.5 m/yr, near Tibbers Creek in North Kingstown. Standard deviation was 17.7. Glacial till was moderately susceptible. The average erosion rate for till shorelines was 0.01 m/yr., with a maximum of 1.0 m/yr near Point Judith. Stnadard deviation was 10.1. Bedrock beaches were resistant to erosion over the course of the study period.

Regan (1976) measured an area of 0.2 m/yr of erosion at the Rhode Island south shore beach high tide lines. This is the same value as that found for the barrier beaches and other sandy beaches in Narragansett Bay, but half the average rate as that found for the cuspate shoreforms in the bay.

The Boston Harbor Island (Riegler, 1980) are drumlins with exposed till cliffs and till-fed beaches. The high tide line of the Boston Harbor Islands retreated at an average rate of 0.2 m/yr between 1938 and 1977. This is twenty times the average rate for till-fed beaches in Narragansett Bay. This may be due to a greater exposure to the dominant wind direction in Boston Harbor than in Narragansett Bay.

Work by Boothroyd and Abu Al-Sand of the Univ. of R.I. published in Robadue and Lee (1980) assesses erosion susceptibility of the Upper Narragansett Bay shoreline based on shoreline types. (See Appendix II). It is concluded that, although shoreline types are the single most significant factor affecting erosion rates, fetch length and direction are also important factors.

Sediment in Narragansett Bay is moving generally northward toward the head of the bay. The most prominent evidence of this is the migration of the cuspate shoreforms to the north. This is a characteristic of estuarine bottom water flow common to estuaries of the Atlantic Coastal Plain (Meade, 1969).

Because of the shape and orientation of the bay and its islands, there are a number of sandy beaches exposed to long southerly fetches. Many of these beaches, however, including those on the south shore of Little Compton show only moderate rates of erosion. Fetch may be less of a factor than longshore sediment transport in these cases. Material eroded would then be continuously replaced by transport from adjacent areas along the shoreline.

An exception to this is Oakland Beach, which has a long southerly fetch and a relatively high erosion rate. At this locality, bathymetry may be of more than usual importance directing greater wave energy to Oakland Beach.

River discharge appears to be an overriding effect locally, as at the outlets of Tibbets Creek and the Amawomscutt River. The effect of tidal currents on shoreline change was greater at sandy beaches than at shorelines with larger grained sediments.

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APPENDIX 1

SHORELINE CHANGE MEASUREMENTS

Segment Number	Shoreline Type		Segment Length (m)	Average Area Change (m/yr)	
	BBL	HTL		BBL	HTL
1	M	M	350.0	-0.3	-1.0
2	M	M	350.0	-0.2	-0.6
3	S	CB	386.2	-0	-0.1
4	M	M	253.4	-0	-0
5	M	SB	386.2	-0	-0
6	M	M	108.6	-0.2	-0.6
7	M	SB	169.0	-0	-0.5
8	M	M	325.9	-0	-0.7
9	M	CB	350.0	-0.1	-0.8
10	M	CB	253.4	+0.4	-0.6
11	D	SB	350.0	-0.4	-0.5
12	D	SB	72.4	-0.4	-0.4
13	D	SB	193.1	+0	-0.7
14	D	SB	350.0	-0.3	-0.3
15	D	SB	350.0	0.0	-0.2
16	D	SB	48.3	0.0	+0.2
17	D	SB	144.8	0.0	-0.1
18	M	M	350.0	-0	-0.1
19	M	M	350.0	-0.0	-0.0
20	S	RB	350.0	0.0	0.0
21	S	RB	350.0	0.0	0.0
22	S	RB	350.0	0.0	0.0
23	S	RB	350.0	0.0	0.0
24	S	RB	350.0	0.0	0.0
25	S	RB	253.4	0.0	0.0
26	S	RB	72.4	0.0	0.0
27	S	RB	350.0	0.0	0.0
28	S	RB	350.0	0.0	0.0
29	M	RB	350.0	0.0	-0
30	M	RB	229.3	0.0	0.0
31	M	M	350.0	-0	-0.1
32	M	M	144.8	0.0	0.0
33	M	SB	350.0	-0.1	-0.4
34	M	SB	350.0	-0.1	-0.5
35	M	SB	217.2	0.0	-0.7
36	D	SB	350.0	+0.1	-0.7
37	D	SB	350.0	+0	-0.7
38	D	SB	132.7	-	+0.1
39	S	CB	277.6	0	-0.0
40	S	RB	157.0	0.0	0.0
41	S	SB	253.4	0.0	-0.1
42	S	RB	229.3	0.0	0.0
43	S	RB	350.0	0.0	0.0

Segment Number	Shoreline Type BBL	Shoreline Type HTL	Segment Length (m)	Average Area Change (m/yr) BBL	Average Area Change (m/yr) HTL
44	S	RB	350.0	-0	-0
45	S	RB	157.0	0.0	0.0
46	S	CB	181.0	0.0	0.0
47	S	RB	144.8	0.0	0.0
48	S	SB	84.5	0.0	0.0
49	S	RB	350.0	0.0	0.0
50	S	RB	350.0	0.0	0.0
51	S	RB	120.7	0.0	0.0
52	S	CB	274.1	0.0	0.0
53	S	RB	350.0	0.0	0.0
54	S	RB	84.5	0.0	0.0
55	S	RB	289.6	0.0	0.0
56	D	SB	48.3	-0.5	-0.6
57	D	SB	350.0	-0.2	-0.4
58	D	SB	350.0	-0	-0.2
59	D	SB	84.5	0.0	0.0
60	M	M	132.7	0.0	0.0
61	S	RB	350.0	0.0	0.0
62	S	RB	350.0	0.0	0.0
63	S	RB	84.5	0.0	0.0
64	S	RB	350.0	0.0	0.0
65	S	RB	350.0	0.0	0.0
66	S	RB	132.7	0.0	0.0
67	M	SB	337.9	0.0	0.0
68	S	SB	350.0	0.0	-0.2
69	S	SB	72.4	0.0	-0
70	M	CB	229.3	0.0	0.0
71	S	CB	169.0	0.0	+0.1
72	S	SB	157.0	-0.2	-0.1
73	S	CB	350.0	+0.1	+0.1
74	S	CB	289.6	0.0	0.0
75	S	CB	350.0	-0	-0.2
76	S	CB	253.4	-0	-0.2
77	S	CB	229.3	-0.4	-0.4
78	S	SB	350.0	-0.3	-0.3
79	S	CB	277.6	-0	-0.4
80	S	CB	252.2	-0.3	-0.4
81	S	CB	178.6	0.0	-0
82	M	SB	265.5	0.0	0.0
83	S	CB	229.3	0.0	-0
84	M	SB	205.2	0.0	0.0
85	M	M	265.5	0.0	0.0
86	M	SB	132.7	+0.2	-0.2
87	S	CB	350.0	-0	-0.3
88	D	SB	144.8	-0	-0.3
89	D	SB	177.4	-0.0	-0.1
90	D	SB	350.0	-0.3	-0.8

Segment Number	Shoreline Type BBL	HTL	Segment Length (m)	Average Area Change (m/yr) BBL	HTL
91	D	SB	96.5	-0.0	-0.1
92	SH	SH	205.2	-0	-0.1
93	D	SB	350.0	-0.1	-0.1
94	D	SB	350.0	0.0	0.0
95	D	SB	313.8	0.0	-0
96	SH	SH	217.2	0.0	0.0
97	S	SB	350.0	-0	-0
98	S	SB	132.7	+0.3	+0.4
99	S	CB	350.0	-0.1	-0.2
100	S	CB	96.5	-0	-0.1
101	S	SB	277.6	-0.2	-0.5
102	S	SB	120.7	0.0	-0.1
103	SH	SH	289.6	-0.2	-0.3
104	S	SB	277.6	-0.0	-0.0
105	S	CB	350.0	+0.1	-0.1
106	S	CB	60.3	+0	-0.2
107	M	CB	229.3	+0	-0
108	M	RB	72.4	0.0	0.0
109	M	SH	72.4	0.0	0.0
110	M	SB	193.1	0.0	0.0
111	M	SH	350.0	0.0	0.0
112	M	SB	84.5	+0.5	+0
113	SH	SB	96.5	0.0	0.0
114	M	SB	157.0	0.0	-0
115	M	RB	84.5	0.0	0.0
116	M	RB	193.1	0.0	0.0
117	SH	SH	193.1	0.0	0.0
118	S	CB	84.5	0.0	0.0
119	S	RB	24.1	0.0	0.0
120	S	SB	72.4	0.0	0.0
121	M	M	289.6	0.0	0.0
122	M	SB	350.0	-0	-0
123	M	SB	72.4	0.0	-0.1
124	SH	SH	84.5	-0	-0.4
125	S	CB	181.0	-0	-0.4
126	M	M	314.0	0.0	0.0
127	M	M	350.0	+0.2	-0.1
128	M	M	350.0	0.0	-0.1
129	M	M	350.0	-0	+0.1
130	M	M	350.0	+0.2	-0.3
131	M	SB	362.1	+0.1	+0.3
132	M	SB	205.2	-0.5	-0.2
133	M	SB	350.0	+1.0	+0.7
134	M	SB	277.6	-0.2	0.0
135	S	SB	350.0	+0.5	+0.5
136	S	SB	350.0	-0.2	-0.4
137	S	SB	289.6	+1.2	+1.5

Segment Number	Shoreline Type BBL	Shoreline Type HTL	Segment Length (m)	Average Area Change (m/yr) BBL	Average Area Change (m/yr) HTL
138	S	SB	350.0	+0.8	+0.5
139	S	SB	121.0	+0.2	0.0
140	S	SB	121.0	-0.3	0.0
141	M	SB	350.0	-0	-0.1
142	M	SB	96.5	0.0	-0.4
143	M	SB	132.7	-0	-0.5
144	SH	SH	217.2	-0.4	-1.1
145	S	SB	277.6	-0.2	-0.9
146	M	SB	108.6	-0.6	-1.1
147	S	SB	350.0	-0.9	-1.1
148	M	M	169.0	-0.9	-1.1
149	SH	SH	60.3	-0.7	-0.5
150	S	SB	229.3	-0.9	-1.5
151	S	SB	189.5	+0.3	+0.5
152	SH	SH	350.0	-0	-0
153	SH	SH	350.0	-0	-0
154	M	M	350.0	-0.4	-0.6
155	M	M	217.2	-0.5	-0.5
156	M	SB	350.0	-0.1	-0.3
157	M	SB	350.0	-0.3	-0.4
158	M	SB	350.0	-0	-0.3
159	M	SB	241.4	-0.4	-0.4
160	M	SB	229.3	+0.3	-0.2
161	M	SB	108.6	0.0	-0
162	S	SB	144.8	-0	0.0
163	SH	SH	84.5	-0.4	-0.6
164	S	SB	350.0	-0.3	-0.3
165	S	SB	301.7	-0.2	-0.3
166	M	SB	277.6	-0.2	-0.3
167	M	SB	205.2	-0.3	-0.2
168	S	SB	289.6	-0.2	-0.2
169	SH	SH	169.0	-0.2	-0.2
170	SH	-	350.0	-0	-
171	SH	SH	350.0	+0.2	0.0
172	SH	-	181.0	-0.1	-
173	M	CB	181.0	+0.1	+0.0
174	M	-	132.7	+0.3	-
175	SH	-	289.6	-0.1	-
176	S	SB	181.0	-0	-0.1
177	SH	SH	120.7	+0.2	-0.2
178	M	SB	205.2	-0.2	-0.1
179	SH	SH	120.7	+0.2	-0
180	M	SB	144.8	+0.3	+0
181	SH	SH	144.8	+0.2	+0
182	M	SB	72.4	+0.2	-0.4
183	SH	SH	96.5	+0.2	-0.1
184	M	M	350.0	+0.8	-0.3

Segment Number	Shoreline Type		Segment Length (m)	Average Area Change (m/yr)	
	BBL	HTL		BBL	HTL
185	M	M	84.5	+1.5	+1.0
186	SH	SH	350.0	+0.1	-0.2
187	SH	SH	265.5	0.0	-0.3
188	SH	SH	144.8	0.0	0.0
189	O	SB	337.9	-0.2	-0.4
190	M	SB	229.3	0.0	-0.8
191	SH	SH	181.0	+0.1	-0.1
192	S	SB	350.0	+0.2	0.0
193	S	SB	350.0	+0.4	-0.1
194	S	SB	350.0	0.0	-0
195	S	SB	181.0	0.0	0.0
196	M	SB	350.0	+0.3	-0.1
197	M	SB	325.9	+0.8	+0.2
198	M	M	350.0	+0.6	+0.1
199	M	M	313.8	+0.6	+0.1
200	M	SB	148.4	-0.8	-0.8
201	M	SB	350.0	-0.5	-0.4
202	M	SB	350.0	-0.5	-0.7
203	M	M	337.9	-0	-0.2
204	M	M	265.5	0.0	-0
205	M	M	289.6	0.0	-0
206	S	M	60.3	-0	-0.5
207	S	M	350.0	0.0	-0.3
208	S	M	217.2	-0.2	-0.4
209	S	SB	337.9	0.0	+0.2
210	M	SB	313.8	0.0	-0.1
211	S	SB	144.8	-0	+0.1
212	S	SB	350.0	0.0	-0
213	M	SB	241.4	0.0	-0.3
214	M	SB	350.0	-0.1	-0.3
215	M	SB	60.3	0.0	-0.3
216	M	SB	350.0	+0.1	+0
217	S	SB	193.1	-0	0.0
218	S	SB	205.2	-0.3	-0.6
219	M	SB	217.2	-0.2	-0.3
220	M	SB	350.0	-0.0	-0.1
221	M	SB	350.0	-0.2	-0.1
222	M	SB	350.0	-0.2	-0.4
223	M	M	350.0	0.0	0.0
224	M	M	169.0	+0.7	+0.8
225	S	CB	386.2	-0.5	-0.4
226	S	SB	301.7	-0.2	-0.1
227	M	M	386.2	-0.1	+0.3
228	SH	SH	181.0	-0.2	+0
229	D	SB	301.7	-0.9	-1.2
230	SH	SH	156.9	-0.6	-0.8

Segment Number	Shoreline Type BBL	Shoreline Type HTL	Segment Length (m)	Average Area Change (m/yr) BBL	Average Area Change (m/yr) HTL
231	D	SB	350.0	-1.0	-1.0
232	D	SB	350.0	-0.6	-0.5
233	D	SB	84.5	+1.3	+1.4
234	D	SB	313.8	-0.5	-0.6
235	D	SB	350.0	-0.2	-0.2
236	D	SB	169.0	-0.4	0.0
237	D	SB	241.4	-0.8	-0.9
238	D	SB	241.4	+0.2	+0.4
239	D	SB	350.0	0.0	-0
240	D	SB	181.0	0.0	-0
241	M	SB	350.0	+0	0.0
242	M	SB	350.0	+0.2	0.0
243	M	SB	350.0	-0	0.0
244	M	SB	350.0	+0.8	-0
245	M	SB	350.0	+0	-0.6
246	M	SB	350.0	-0.3	-0.3
247	M	SB	350.0	-0.2	-0.3
248	SH	SH	350.0	0.0	0.0
249	SH	SH	350.0	-0	-0
250	SH	SH	350.0	-0.2	-0.2
251	SH	SH	350.0	+0	-0
252	SH	SH	84.5	0.0	0.0
253	S	SB	350.0	-0.3	-1.1
254	S	SB	120.7	-0.3	-0.9
255	D	SB	350.0	0.0	-0.8
256	D	SB	350.0	+0.2	-0.2
257	D	SB	350.0	-0.3	-0.5
258	M	SB	301.7	+0.7	+0.4
259	M	M	169.0	+0.2	-0.2
260	D	SB	193.1	+0.8	+1.4
261	S	SB	265.5	-0.2	-0.3
262	M	SB	313.8	-0.1	-0.3
263	SH	SB	181.1	-0.2	-0.3
264	M	M	350.0	+0.4	+0
265	M	M	350.0	+0.4	0.0
266	D	SB	350.0	+0.6	+0.2
267	D	SB	350.0	-0.7	-0.5
268	D	SB	169.0	-0.2	-0.1
269	S	SB	350.0	+0.1	+0
270	M	SB	265.5	+0.3	-0.2
271	M	SB	350.0	0.0	0.0
272	M	SB	350.0	-0.4	-0.4
273	D	SB	259.5	-0.4	-0.5
274	D	SB	265.5	-0	-0.3
275	D	SB	350.0	0.0	0.0
276	D	SB	350.0	0.0	0.0

Segment Number	Shoreline Type BBL	Shoreline Type HTL	Segment Length (m)	Average Area Change (m/yr) BBL	Average Area Change (m/yr) HTL
277	D	SB	350.0	0.0	0.0
278	D	SB	350.0	0.0	0.0
279	D	SB	350.0	0.0	0.0
280	D	SB	96.6	0.0	0.0
281	S	CB	350.0	-0	0.0
282	S	CB	350.0	0.0	-0.5
283	S	CB	60.4	0.0	-0.6
284	M	CB	313.8	0.0	-0.4
285	D	SB	350.0	0.0	-0.3
286	D	SB	350.0	0.0	-0.3
287	D	SB	229.3	0.0	0.0
288	SH	SB	313.8	+0	+0
289	-	SH	350.0	-	-0.1
290	-	SH	350.0	-	+0.2
291	-	SH	313.8	-	+0.3
292	SH	SB	326.0	0.0	0.0
293	M	M	48.3	0.0	0.0
294	M	SB	290.0	0.0	0.0
295	SH	SH	144.8	0.0	0.0
296	SH	SB	229.3	0.0	0.0
297	SH	SB	350.0	0.0	0.0
298	SH	SB	350.0	0.0	0.0
299	SH	SB	241.4	0.0	0.0
300	S	CB	350.0	0.0	0.0
301	S	CB	120.7	0.0	0.0
302	S	CB	350.0	0.0	0.0
303	S	CB	350.0	0.0	0.0
304	S	CB	350.0	0.0	0.0
305	M	SB	350.0	0.0	0.0
306	M	SB	350.0	0.0	0.0
307	M	SB	169.0	0.0	0.0
308	S	SB	325.9	-0.2	-0.2
309	M	CB	350.0	+0.3	0.0
310	M	CB	350.0	+0.5	+0.3
311	M	CB	350.0	0.0	0.0
312	M	CB	350.0	0.0	0.0
313	M	CB	84.5	0.0	0.0
314	M	CB	265.5	0.0	0.0
315	S	CB	350.0	0.0	0.0
316	S	CB	350.0	0.0	0.0
317	S	CB	350.0	0.0	0.0
318	S	CB	350.0	0.0	0.0
319	S	CB	350.0	0.0	0.0
320	S	CB	350.0	0.0	0.0
321	S	CB	350.0	0.0	0.0
322	S	CB	350.0	0.0	0.0

Segment Number	Shoreline Type		Segment Length (m)	Average Area Change (m/yr)	
	BBL	HTL		BBL	HTL
323	S	CB	350.0	0.0	0.0
324	S	CB	350.0	0.0	0.0
325	S	CB	350.0	0.0	0.0
326	S	CB	350.0	0.0	0.0
327	SH	SB	350.0	+0.5	+0.3
328	S	SB	72.4	0.0	0.0
329	S	SB	350.0	0.0	-0.1
330	S	SB	132.8	0.0	0.0
331	S	CB	350.00	0.0	0.0
332	S	CB	350.0	0.0	0.0
333	S	CB	301.7	0.0	0.0
334	S	M	301.7	0.0	0.0
335	S	M	156.9	0.0	0.0
336	SH	M	253.5	0.0	-0
337	S	CB	350.0	+0.1	-0.3
338	S	CB	350.0	0.0	0.0
339	S	CB	181.1	0.0	0.0
340	SH	CB	181.1	0.0	0.0
341	SH	CB	84.5	0.0	0.0
342	S	CB	350.00	0.0	0.0
343	S	CB	24.1	0.0	0.0
344	M	CB	350.0	0.0	0.0
345	M	CB	84.5	0.0	0.0
346	S	CB	313.8	0.0	0.0
347	S	CB	350.0	0.0	0.0
348	S	CB	350.0	0.0	0.0
349	S	CB	120.7	0.0	0.0
350	S	CB	350.0	0.0	0.0
351	S	CB	350.0	0.0	0.0
352	S	CB	350.0	0.0	0.0
353	S	CB	265.5	0.0	0.0
354	SH	SH	350.0	0.0	-0.3
355	SH	SH	350.0	-0.2	-0.3
356	SH	SH	60.4	-0	-0
357	S	RB	350.0	0.0	0.0
358	S	RB	350.0	0.0	0.0
359	S	RB	84.5	0.0	0.0
360	S	RB	229.3	-0	-0
361	S	SB	350.0	0.0	0.0
362	S	SB	350.0	0.0	0.0
363	S	SB	350.0	0.0	0.0
364	S	SB	347.6	0.0	0.0
365	M	SB	48.3	0.0	0.0
366	S	SB	350.0	0.0	0.0
367	S	SB	350.0	0.0	0.0
368	S	SB	24.1	0.0	0.0
369	M	SB	350.0	0.0	0.0
370	M	SB	350.0	0.0	0.0

Segment Number	Shoreline Type		Segment Length (m)	Average Area Change (m/yr)	
	BBL	HTL		BBL	HTL
371	M	SB	205.2	0.0	0.0
372	-	SB	350.0	-	+0.1
373	-	SB	290.00	-	-0.6
374	M	SB	350.0	+0	0.0
375	M	SB	350.0	0.0	0.0
376	M	SB	265.5	0.0	0.0
377	SH	SB	301.7	0.0	0.0
378	M	SB	350.0	0.0	0.0
379	M	SB	350.0	0.0	0.0
380	D	SB	84.5	0.0	0.0
381	S	SB	193.1	0.0	0.0
382	S	CB	253.5	-0.5	-0.2
383	S	CB	350.0	0.0	0.0
384	S	CB	350.00	0.0	0.0
385	S	CB	24.1	0.0	0.0
386	S	SB	350.00	0.0	0.0
387	S	SB	350.00	0.0	0.0
388	S	SB	350.00	0.0	0.0
389	S	SB	350.00	0.0	0.0
390	S	SB	350.00	0.0	0.0
391	S	SB	277.6	0.0	0.0
392	SH	SH	350.00	0.0	0.0
393	SH	SH	350.0	0.0	0.0
394	SH	SH	350.0	0.0	0.0
395	SH	SH	350.0	0.0	0.0
396	SH	SH	350.0	0.0	0.0
397	SH	SH	108.6	0.0	0.0
398	SH	SH	301.7	0.0	+0.5
399	SH	SH	253.5	0.0	0.0
400	SH	SH	350.0	0.0	0.0
401	S	SB	350.0	0.0	0.0
402	S	SB	350.0	0.0	0.0
403	S	SB	350.0	0.0	0.0
404	S	SB	350.0	0.0	0.0
405	S	SB	96.6	0.0	0.0
406	SH	SB	241.4	0.0	0.0
407	SH	SB	338.0	0.0	0.0
408	SH	SB	132.8	0.0	0.0
409	S	SB	241.4	0.0	0.0
410	S	CB	132.8	0.0	0.0
411	S	SB	350.0	0.0	0.0
412	S	SB	265.5	0.0	0.0
413	S	SB	169.0	0.0	0.0
414	S	SB	169.0	0.0	0.0
415	S	CB	350.0	0.0	0.0
416	S	CB	350.0	0.0	0.0
417	S	CB	350.0	0.0	0.0

Segment Number	Shoreline Type BBL	HTL	Segment Length (m)	Average Area Change (m/yr) BBL	HTL
418	S	CB	350.0	0.0	0.0
419	S	CB	350.0	0.0	0.0
420	S	CB	132.8	0.0	0.0
421	S	CB	304.1	-0.1	-0
422	S	CB	217.2	+0.6	+0.7
423	S	RB	350.0	0.0	0.0
424	S	RB	205.2	0.0	0.0
425	S	CB	350.0	0.0	0.0
426	S	CB	144.8	0.0	0.0
427	S	CB	350.0	0.0	0.0
428	S	CB	350.0	0.0	0.0
429	S	CB	350.0	0.0	0.0
430	S	CB	350.0	0.0	0.0
431	S	CB	265.5	0.0	0.0
432	S	SB	350.0	-0.1	-0.3
433	S	SB	350.0	-0.1	-0.1
434	S	CB	350.0	0.0	0.0
435	S	CB	350.0	0.0	0.0
436	SH	SB	96.6	0.0	0.0
437	S	CB	290.0	0.0	0.0
438	S	CB	350.0	0.0	0.0
439	S	CB	156.9	0.0	0.0
440	S	CB	350.0	0.0	0.0
441	S	CB	60.4	0.0	0.0
442	S	CB	120.7	0.0	0.0
443	RC	RB	350.0	0.0	0.0
444	RC	RB	350.0	0.0	0.0
445	RC	RB	350.0	0.0	0.0
446	RC	RB	36.0	0.0	0.0
447	S	CB	277.6	0.0	0.0
448	S	M	108.6	-0.1	0.0
449	S	CB	241.4	0.0	0.0
450	S	SB	350.0	0.0	0.0
451	S	SB	108.6	0.0	0.0
452	S	RB	350.0	0.0	0.0
453	S	RB	96.6	0.0	0.0
454	S	CB	217.3	0.0	0.0
455	S	CB	350.0	0.0	0.0
456	S	CB	350.0	0.0	0.0
457	S	CB	108.6	0.0	0.0
458	D	SB	193.1	+1.0	+0.5
459	D	SB	350.0	+0.8	+0.6
460	D	SB	350.0	+0.2	+0.1
461	D	SB	350.0	+0.3	+0
462	D	SB	350.0	0.0	0.0
463	S	SB	350.0	0.0	0.0

Segment Number	Shoreline Type		Segment Length	Average Area Change (m/yr)	
	BBL	HTL	(m)	BBL	HTL
464	S	SB	350.0	0.0	-0
465	S	SB	350.0	0.0	0.0
466	S	SB	217.3	0.0	0.0
467	S	CB	350.0	0.0	0.0
468	S	CB	193.1	0.0	0.0
469	S	CB	350.0	0.0	0.0
470	S	CB	350.0	0.0	0.0
471	S	CB	48.3	0.0	0.0
472	D	CB	350.0	-0.4	-0.3
473	D	CB	193.1	0.0	0.0
474	SH	SH	350.0	0.0	0.0
475	SH	SH	350.0	0.0	0.0
476	D	SB	277.6	-0.6	-0.8
477	SH	SH	350.0	0.0	0.0
478	SH	SH	48.3	0.0	0.0
479	D	SB	350.0	-0	-0.1
480	S	CB	181.1	-0.3	-0.2
481	S	CB	120.7	0.0	0.0
482	D	SB	350.0	0.0	0.0
483	D	SB	350.0	0.0	0.0
484	D	SB	338.0	0.0	0.0
485	S	CB	350.0	0.0	0.0
486	S	CB	350.0	0.0	0.0
487	S	CB	350.0	0.0	0.0
488	S	CB	350.0	0.0	0.0
489	S	CB	193.1	0.0	0.0
490	S	CB	350.0	0.0	0.0
491	S	CB	350.0	0.0	0.0
492	S	CB	144.8	0.0	0.0
493	S	CB	253.5	0.0	0.0
494	S	CB	350.0	0.0	0.0
495	S	CB	350.0	0.0	0.0
496	S	CB	350.0	0.0	0.0
497	S	CB	350.0	0.0	0.0
498	S	CB	350.0	0.0	0.0
499	S	CB	350.0	0.0	0.0
500	S	CB	350.0	-0	0.0
501	S	CB	350.0	-0	0.0
502	S	CB	169.0	0.0	0.0
503	S	CB	229.3	0.0	-0.1
504	S	CB	120.7	0.0	0.0
505	M	CB	350.0	0.0	0.0
506	M	CB	350.0	0.0	-0
507	M	CB	108.6	-0.5	-0.4
508	M	CB	350.0	-0.1	0.0
509	M	SB	193.1	-0.2	-0.3

Segment Number	Shoreline Type BBL	HTL	Segment Length (m)	Average Area Change (m/yr) BBL	HTL
510	S	SB	132.8	-0.4	-0.7
511	S	SB	350.0	-0.2	-1.9
512	S	SB	84.5	+0	0.0
513	S	RB	350.0	0.0	0.0
514	S	RB	120.7	0.0	0.0
515	M	M	169.0	0.0	0.0
516	S	SB	120.7	0.0	0.0
517	S	SB	84.5	0.0	0.0
518	S	CB	265.5	0.0	0.0
519	M	CB	350.0	0.0	0.0
520	M	CB	350.0	0.0	0.0
521	M	CB	193.1	0.0	0.0
522	M	CB	350.0	0.0	0.0
523	M	CB	350.0	0.0	0.0
524	M	CB	350.0	0.0	0.0
525	M	CB	96.6	0.0	0.0
526	S	CB	156.9	0.0	0.0
527	S	RB	144.8	0.0	0.0
528	S	SB	253.5	0.0	0.0
529	S	RB	350.0	0.0	0.0
530	S	RB	313.8	0.0	0.0
531	S	M	350.0	0.0	0.0
532	S	M	96.6	0.0	0.0
533	S	RB	362.1	0.0	0.0
534	S	SB	181.1	0.0	0.0
535	S	RB	325.9	0.0	0.0
536	S	SB	120.7	0.0	0.0
537	S	SB	350.0	0.0	0.0
538	S	RB	350.0	0.0	0.0
539	S	RB	350.0	0.0	0.0
540	S	RB	350.0	0.0	0.0
541	S	RB	350.0	0.0	0.0
542	S	SB	12.1	0.0	0.0
543	S	RB	48.3	0.0	0.0
544	S	SB	313.8	0.0	0.0
545	S	RB	350.0	0.0	0.0
546	S	RB	350.0	0.0	0.0
547	S	RB	338.0	0.0	0.0
548	S	CB	277.6	0.0	0.0
549	D	SB	350.0	-	-0.5
550	D	SB	48.3	0.0	0.0
551	M	M	169.0	0.0	0.0
552	S	RB	350.0	0.0	0.0
553	S	RB	350.0	0.0	0.0
554	S	RB	350.0	0.0	0.0
555	S	RB	350.0	0.0	0.0
556	S	RB	350.0	0.0	0.0

Segment Number	Shoreline Type		Segment Length (m)	Average Area Change (m/yr)	
	BBL	HTL		BBL	HTL
557	S	RB	338.0	0.0	0.0
558	S	RB	350.0	0.0	0.0
559	S	RB	241.4	0.0	0.0
560	S	SB	350.0	0.0	0.0
561	S	SB	241.4	0.0	0.0
562	S	RB	350.0	0.0	0.0
563	S	RB	350.0	0.0	0.0
564	S	RB	350.00	0.0	0.0
565	S	RB	350.0	0.0	0.0
566	S	RB	350.0	0.0	0.0
567	S	RB	350.0	0.0	0.0
568	S	RB	338.0	0.0	0.0
569	S	SB	132.8	0.0	0.0
570	S	RB	338.0	0.0	0.0
571	S	SB	96.6	0.0	0.0
572	S	RB	350.0	0.0	0.0
573	S	RB	132.8	0.0	0.0
574	S	CB	313.8	-0.3	-0.4
575	S	SB	350.0	-0.3	-0.4
576	S	SB	313.8	+0	-0.5
577	S	SB	277.6	0.0	0.0
578	S	RB	350.0	0.0	0.0
579	S	RB	350.0	0.0	0.0
580	S	RB	350.0	0.0	0.0
581	S	RB	350.0	0.0	0.0
582	S	CB	169.0	0.0	0.0
583	S	SB	350.0	0.0	0.0
584	S	SB	132.8	0.0	0.0
585	RC	CB	350.0	0.0	0.0
586	RC	CB	277.6	0.0	0.0
587	M	M	169.0	-	-
588	S	SB	169.0	-	-
589	SH	SB	144.8	-	-
590	SH	SB	350.0	-0.9	-0.9
591	S	RB	156.9	0.0	0.0
592	S	SB	84.5	0.0	0.0
593	SH	SH	350.0	0.0	0.0
594	SH	SH	84.5	0.0	0.0
595	M	SB	350.00	0.0	0.0
596	M	SB	84.5	0.0	0.0
597	SH	SH	350.0	0.0	0.0
598	SH	SH	350.0	0.0	0.0
599	SH	SH	144.8	0.0	0.0
600	S	SB	72.4	0.0	0.0
601	M	M	156.9	0.0	0.0
602	S	SB	120.7	0.0	0.0
603	RC	CB	289.7	0.0	0.0

Segment Number	Shoreline Type BBL	HTL	Segment Length (m)	Average Area Change (m/yr) BBL	HTL
604	S	RB	338.0	0.0	0.0
605	S	CB	205.2	0.0	0.0
606	S	CB	144.8	+1.1	+1.3
607	SH	SH	156.9	-0	-0.2
608	S	SB	84.5	0.0	0.0
609	S	SB	253.5	0.0	0.0
610	SH	SH	205.2	0.0	0.0
611	S	SB	350.0	0.0	0.0
612	S	SB	350.0	0.0	0.0
613	S	SB	48.3	0.0	0.0
614	S	CB	350.0	0.0	0.0
615	S	CB	350.0	0.0	0.0
616	S	CB	350.0	0.0	0.0
617	S	CB	350.0	0.0	0.0
618	S	CB	350.0	0.0	0.0
619	S	CB	350.0	0.0	0.0
620	S	CB	350.0	0.0	0.0
621	S	CB	96.6	0.0	0.0
622	S	SB	108.6	0.0	0.0
623	S	SB	301.7	-0.1	-0.1
624	S	CB	350.0	0.0	0.0
625	S	CB	313.8	0.0	0.0
626	S	CB	350.0	0.0	0.0
627	S	CB	350.0	0.0	0.0
628	S	CB	350.0	0.0	0.0
629	S	CB	108.6	0.0	0.0
630	S	SB	120.7	0.0	0.0
631	SH	SB	229.5	-0.3	-0.5
632	SH	SB	132.8	0.0	0.0
633	S	CB	205.2	0.0	0.0
634	SH	SH	108.6	0.0	0.0
635	S	CB	350.0	0.0	0.0
636	S	CB	350.0	0.0	0.0
637	S	CB	350.0	0.0	0.0
638	S	CB	265.5	0.0	0.0
639	S	SB	350.0	-0.2	0.1
640	S	SB	350.0	0.0	0.0
641	S	SB	277.6	0.0	0.0
642	M	SB	350.0	0.0	0.0
643	M	SB	181.1	0.0	0.0
644	S	CB	169.0	0.0	0.0
645	S	CB	350.0	-0	-0
646	S	CB	350.0	-0	0.0
647	S	CB	350.0	0.0	0.0
648	S	CB	165.9	0.0	-0
649	M	CB	193.1	-0	0.0
650	S	CB	350.0	-0	0.0

Segment Number	Shoreline Type		Segment Length (m)	Average Area Change (m/yr)	
	BBL	HTL		BBL	HTL
651	S	CB	350.0	0.0	0.0
652	S	CB	253.5	0.0	0.0
653	S	CB	350.0	0.0	0.0
654	S	CB	350.0	0.0	0.0
655	S	CB	350.0	0.0	0.0
656	S	CB	350.0	0.0	0.0
657	S	CB	350.0	0.0	0.0
658	M	-	350.0	+0.2	-
659	M	-	350.0	+0.5	-
660	M	-	350.0	+0.3	-
661	M	-	350.0	+0.6	-
662	M	-	350.0	+0.1	-
663	M	-	350.0	+0.5	-
664	M	-	350.0	+0.7	-
665	M	M	193.1	0.0	0.0
666	S	CB	350.0	0.0	0.0
667	S	CB	350.0	0.0	0.0
668	S	CB	350.0	0.0	+0
669	S	CB	350.0	-0.2	+0
670	S	CB	350.0	-0.2	-0.3
671	S	CB	350.0	-0.2	-0.1
672	S	CB	350.0	+0.4	+0.5
673	S	CB	350.0	0.0	0.0
674	S	CB	350.0	0.0	-0
675	S	CB	350.0	0.0	0.0
676	M	M	60.4	-0.9	-1.0
677	M	M	253.5	0.0	0.0
678	S	CB	350.0	+0.2	+0.2
679	S	CB	350.0	+1.4	+1.4
680	S	CB	350.0	+1.8	+1.9
681	S	CB	253.5	+2.7	+2.3
682	M	M	350.0	+1.8	+1.8
683	M	M	350.0	+0.4	+0.7
684	M	M	350.0	+0.6	+0.3
685	M	M	350.0	-	-
686	M	M	350.0	-	-
687	M	M	277.6	-	-
688	M	M	350.0	-	-
689	M	M	350.0	-	-
690	M	M	350.0	+0.3	+0.1
691	M	M	350.0	0.0	0.0
692	M	M	350.0	0.0	0.0
693	M	M	350.0	0.0	0.0
694	M	M	350.0	0.0	0.0
695	M	M	350.0	0.0	0.0
696	M	M	350.0	0.0	0.0
697	M	M	350.0	0.0	0.0

Segment Number	Shoreline Type BBL	Shoreline Type HTL	Segment Length (m)	Average Area Change (m/yr) BBL	Average Area Change (m/yr) HTL
698	M	M	350.0	0.0	0.0
699	M	M	350.0	0.0	0.0
700	M	M	350.0	0.0	0.0
701	M	M	350.0	0.0	0.0
702	M	M	181.1	0.0	0.0
703	M	M	350.0	0.0	0.0
704	M	M	350.0	+0	0.0
705	M	M	350.0	0.0	0.0
706	M	M	350.0	0.0	0.0
707	M	M	350.0	+0.5	+0.5
708	-	M	350.0	-	+0.5
709	-	M	350.0	-	+0.4
710	M	M	350.0	0.0	0.0
711	M	M	48.3	0.0	0.0
712	M	M	350.0	0.0	0.0
713	M	M	156.9	0.0	0.0
714	M	M	350.0	0.0	0.0
715	S	M	265.5	0.0	0.0
716	S	RB	350.0	0.0	0.0
717	S	RB	350.0	0.0	0.0
718	S	RB	181.1	0.0	0.0
719	SH	-	217.3	+0.3	-
720	S	RB	156.9	0.0	0.0
721	D	SB	169.0	0.0	0.0
722	M	M	350.0	0.0	0.0
723	M	M	350.0	0.0	0.0
724	M	M	350.0	0.0	0.0
725	M	M	350.0	0.0	0.0
726	M	M	350.0	0.0	0.0
727	M	M	181.1	0.0	0.0
728	S	RB	350.0	0.0	0.0
729	S	RB	350.0	0.0	-0
730	S	RB	350.0	0.0	-0
731	S	RB	350.0	-0.1	-0.1
732	S	RB	120.7	-0.1	-0.2
733	S	RB	350.0	0.0	0.0
734	M	M	350.0	0.0	0.0
735	S	RB	350.0	0.0	0.0
736	S	RB	350.0	0.0	0.0
737	S	RB	350.0	0.0	0.0
738	SH	RB	265.5	0.0	0.0
739	S	RB	350.0	0.0	0.0
740	S	RB	96.6	0.0	0.0
741	M	RB	350.0	0.0	0.0
742	M	RB	350.0	0.0	0.0
743	M	RB	350.0	0.0	0.0
744	M	RB	350.0	0.0	0.0

Segment Number	Shoreline Type BBL	Shoreline Type HTL	Segment Length (m)	Average Area Change (m/yr) BBL	Average Area Change (m/yr) HTL
745	M	RB	350.0	0.0	0.0
746	S	SB	229.3	0.0	0.0
747	S	RB	350.0	0.0	0.0
748	S	RB	350.0	0.0	0.0
749	S	RB	350.0	0.0	0.0
750	S	RB	350.0	0.0	0.0
751	S	RB	350.0	0.0	0.0
752	S	RB	217.3	0.0	0.0
753	S	SB	241.4	0.0	0.0
754	S	RB	120.7	0.0	0.0
755	S	SB	229.3	0.0	0.0
756	S	RB	144.8	0.0	0.0
757	S	SB	36.2	0.0	0.0
758	S	RB	24.1	0.0	0.0
759	S	SB	24.1	0.0	0.0
760	S	RB	289.8	0.0	0.0
761	S	SB	132.8	0.0	0.0
762	S	RB	181.1	0.0	0.0
763	M	RB	132.8	0.0	0.0
764	S	RB	289.7	0.0	0.0
765	S	RB	350.0	0.0	0.0
766	S	RB	350.0	0.0	0.0
767	S	RB	350.0	0.0	0.0
768	D	SB	350.0	+0	0.0
769	D	SB	350.0	0.0	-0
770	D	SB	24.1	0.0	0.0
771	S	RB	350.0	0.0	0.0
772	S	RB	350.0	0.0	0.0
773	S	RB	24.1	0.0	0.0
774	D	SB	350.0	0.0	0.0
775	D	SB	144.8	0.0	0.0
776	S	RB	350.0	0.0	0.0
777	S	RB	350.0	0.0	0.0
778	S	RB	350.0	0.0	0.0
779	S	RB	60.3	0.0	0.0
780	RC	RB	350.0	0.0	0.0
781	RC	RB	350.0	0.0	0.0
782	RC	RB	253.5	0.0	0.0
783	RC	RB	350.0	0.0	0.0
784	RC	RB	350.0	0.0	0.0
785	RC	RB	350.0	0.0	0.0
786	RC	RB	350.0	0.0	0.0
787	RC	RB	350.0	0.0	0.0
788	RC	RB	350.0	0.0	0.0
789	RC	RB	350.0	0.0	0.0
790	RC	RB	217.3	0.0	0.0
791	M	RB	350.0	0.0	0.0

Segment Number	Shoreline Type BBL	Shoreline Type HTL	Segment Length (m)	Average Area Change (m/yr) BBL	Average Area Change (m/yr) HTL
792	M	RB	120.7	0.0	0.0
793	M	SB	350.0	0.0	0.0
794	M	SB	277.6	0.0	0.0
795	M	SB	350.0	-0.1	-0.2
796	M	SB	350.0	0.0	-0.2
797	M	SB	12.1	0.0	+1.3
798	S	RB	350.0	0.0	0.0
799	S	RB	350.0	0.0	0.0
800	S	RB	350.0	0.0	0.0
801	S	RB	350.0	0.0	0.0
802	S	RB	350.0	0.0	0.0
803	S	RB	350.0	0.0	0.0
804	S	RB	72.4	0.0	0.0
805	S	RB	144.8	0.0	0.0
806	M	SB	350.0	-0	-0.3
807	D	SB	144.8	-0.2	-0.2
808	D	SB	350.0	+0.1	-0.4
809	D	SB	350.0	+0	-0.3
810	D	SB	350.0	+0.4	-0.1
811	D	SB	350.0	+0.6	+0.3
812	D	SB	24.1	+1.3	+0.7
813	M	SB	169.0	+0.7	+0.3
814	M	CB	350.0	+0.4	+0.3
815	M	CB	84.5	0.0	0.0
816	RC	CB	350.0	0.0	0.0
817	RC	CB	338.0	0.0	0.0
818	S	RB	350.0	0.0	0.0
819	RC	RB	350.0	0.0	0.0
820	RC	RB	350.0	0.0	0.0
821	RC	RB	350.0	0.0	0.0
822	RC	RB	350.0	0.0	0.0
823	RC	RB	144.8	0.0	0.0
824	S	RB	108.6	0.0	0.0
825	S	RB	144.8	0.0	0.0
826	S	RB	229.3	0.0	0.0
827	SH	SB	350.0	-0.5	-0.6
828	SH	SB	36.2	-0.4	-0.4
829	D	SB	350.0	-0.4	-0.4
830	D	SB	350.0	+0.6	+0.4
831	D	SB	301.7	+0.7	+0.5
832	S	RB	350.0	0.0	0.0
833	S	RB	350.0	0.0	0.0
834	S	RB	350.0	0.0	0.0
835	S	RB	217.3	0.0	0.0
836	M	RB	350.0	0.0	0.0
837	M	RB	96.6	0.0	0.0
838	S	SB	350.0	0.0	0.0
839	S	SB	350.0	0.0	0.0

Segment Number	Shoreline Type BBL	Shoreline Type HTL	Segment Length (m)	Average Area Change (m/yr) BBL	Average Area Change (m/yr) HTL
840	S	SB	350.0	-0.1	-0.1
841	S	RB	350.0	0.0	0.0
842	S	RB	144.8	0.0	0.0
843	S	SB	108.6	-0.2	-0.3
844	S	RB	350.0	0.0	0.0
845	S	RB	350.0	0.0	0.0
846	S	M	253.5	+0	+0.3
847	RC	SB	277.6	0.0	+0.5
848	RC	RB	48.3	0.0	0.0
849	S	RB	84.5	0.0	0.0
850	S	CB	350.0	-0.2	-0.4
851	S	CB	350.0	-0.3	-0.1
852	S	CB	96.6	-0.8	-0.5
853	S	CB	350.0	-0.2	-0.3
854	S	CB	350.0	-0.1	-0.3
855	S	CB	120.7	-0.3	-0.3
856	S	M	350.0	-1.3	-1.7
857	S	M	169.0	-1.2	-1.7
858	SH	SB	181.1	-0.8	-1.1
859	SH	SB	350.0	-1.4	-1.5
860	D	SB	162.9	-1.2	-1.1
861	D	SB	265.3	+0.6	+0.4
862	S	RB	217.3	-0	0.0
863	S	M	253.5	0.0	0.0
864	S	M	350.0	-0.3	-0.3
865	S	CB	350.0	-0	-0.3
866	S	CB	350.0	0.0	-0.3
867	S	CB	350.0	-0.1	-0.1
868	S	CB	289.7	-0	-0.2
869	D	SB	333.1	-1.6	-1.7
870	D	CB	350.0	+1.6	+1.7
871	S	CB	350.0	0.0	0.0
872	S	CB	144.8	0.0	0.0
873	S	CB	350.0	0.0	-0
874	S	CB	350.0	0.0	0.0
875	S	CB	350.0	-0	-0
876	S	CB	350.0	0.0	0.0
877	S	CB	350.0	0.0	+0
878	S	CB	350.0	0.0	0.0
879	S	CB	350.0	0.0	+0
880	S	CB	350.0	0.0	+0
881	S	CB	350.0	0.0	0.0
882	S	CB	132.8	+0	0.0
883	S	CB	350.0	-	-0.2
884	S	CB	229.3	0.0	0.0
885	M	CB	277.6	0.0	0.0

Segment Number	Shoreline Type BBL	Shoreline Type HTL	Segment Length (m)	Average Area Change (m/yr) BBL	Average Area Change (m/yr) HTL
886	M	M	144.8	0.0	0.0
887	M	CB	350.0	0.0	-0.2
888	M	CB	350.0	0.0	-0.2
889	M	CB	289.7	-0.3	-0.3
890	M	M	350.0	-0.4	-1.0
891	M	M	350.0	-0.2	-0.3
892	M	M	84.5	-0.3	-0.4
893	M	SB	289.7	-0.1	-0.2
894	M	M	350.0	-0.1	-0.1
895	M	M	350.0	-0.2	-0.2
896	M	M	350.0	-0	0.0
897	M	M	350.0	+0.3	-0.2
898	M	M	12.1	+0.7	-1.1
899	S	SB	350.0	0.0	-0
900	S	SB	350.0	+0.3	+0
901	S	SB	362.	+0.7	0.0
902	-	M	350.0	-	+0.1
903	M	M	240.8	-0.1	+0.1
904	S	SB	169.0	-0	+0
905	SH	SH	181.0	+0.3	+0.1
906	S	CB	169.0	+0.6	+0.6
907	S	SB	372.9	+0.8	+1.0
908	S	SB	62.8	-0.2	-0.3
909	S	SB	195.5	+1.1	+1.2
910	S	SB	350.0	+1.0	+1.0
911	SH	SH	350.0	-0.3	+0.3
912	SH	SH	169.0	+0.1	+0.1
913	S	SB	350.0	+0.3	+0.1
914	S	SB	253.5	+0.3	0.0
915	SH	SH	350.0	+0.2	-0.1
916	SH	SH	350.0	+0.3	0.0
917	SH	SH	181.1	+0.4	0.0
918	D	SB	193.1	0.0	0.0
919	D	SB	350.0	0.0	0.0
920	M	SB	156.9	0.0	0.0
921	M	SB	350.0	0.0	0.0
922	M	M	350.0	0.0	0.0
923	S	SB	193.1	0.0	0.0
924	S	CB	350.0	+0.7	+0.6
925	S	CB	350.0	-0.1	-0.6
926	S	CB	265.5	-0.2	-0.5
927	S	SB	301.7	+0	-0.1
928	S	SB	350.0	+2.6	+2.6
929	S	SB	277.6	+1.5	+1.8
930	M	M	350.0	-	-
931	M	M	72.4	-	-

Segment Number	Shoreline Type BBL	Shoreline Type HTL	Segment Length (m)	Average Area Change (m/yr) BBL	Average Area Change (m/yr) HTL
932	M	M	350.0	+0.3	-0
933	M	M	350.0	-	0.0
934	M	M	350.0	-	0.0
935	M	M	350.0	-	-
936	M	M	350.0	-	-
937	M	M	350.0	-	+0.2
938	M	M	350.0	-	+0.2
939	M	M	350.0	+0	-0
940	M	M	350.0	+0.3	+0.1
941	M	M	350.0	+0.1	0.0
942	M	M	72.4	-	0.0
943	M	SB	265.5	-0	+0
944	M	CB	350.0	+0.1	0.0
945	M	CB	350.0	-0	-0.3
946	M	CB	350.0	+0	+0
947	M	CB	350.0	0.0	-0.1
948	S	CB	72.4	+0.4	+0
949	S	CB	265.5	+0.2	+0.1
950	SH	SB	241.4	0.0	+0
951	S	SB	241.4	-0	0.0
952	M	SB	205.2	+0.2	+0
953	D	SB	350.0	+0.1	-0.2
954	D	SB	265.5	+0.2	+0.1
955	SH	SB	169.0	+0.3	+0
956	D	SB	265.5	+0.2	+0.2
957	SH	SB	277.6	-0.2	-0.2
958	D	SB	217.3	-0	-0.2
959	SH	SB	350.0	0.0	-0.2
960	SH	SB	72.4	+0.3	-0.3
961	SH	CB	132.8	-0.6	-0.6
962	D	CB	350.0	-0.4	-0.4
963	S	CB	350.0	+0.2	0.0
964	S	CB	350.0	0.0	0.0
965	S	CB	350.0	+0.1	+0
966	S	CB	350.0	+0	+0
967	S	CB	60.3	+0	+0
968	S	CB	350.0	-0.2	-0.1
969	S	CB	350.0	0.0	-0.2
970	S	CB	205.2	0.0	-0.1
971	S	CB	169.0	-0.3	-0.4
972	D	SB	265.5	+0.3	+0.2
973	D	SB	230.5	-0.3	-0.1
974	D	SB	350.0	+0.2	-0
975	S	CB	663.8	+0.5	+0.3
976	S	CB	350.0	+0.1	+0.2
977	D	SB	265.5	0.0	-0.9
978	D	SB	350.0	+0.3	-0.4
979	D	SB	169.0	+0.2	-0.2

Segment Number	Shoreline Type BBL	HTL	Segment Length (m)	Average Area Change (m/yr) BBL	HTL
980	D	SB	169.0	-0.6	-0.6
981	S	SB	350.0	+0	-0.2
982	S	SB	241.4	+0.6	+0
983	-	-	181.0	-	-
984	S	SB	48.3	-0.4	-0.6
985	S	SB	132.8	-0.3	-0.4
986	D	SB	350.0	-0.1	-0.4
987	D	SB	350.0	-0.2	+0.1
988	D	CB	60.3	-	-
989	S	SB	350.0	+0	+0
990	S	SB	350.0	-0	-0
991	S	SB	60.3	+0.5	+0.3
992	S	CB	350.0	+0.6	+0.5
993	S	CB	350.0	+0.6	+0.5
994	S	CB	325.5	-0.2	-0.1
995	S	SB	350.0	-0	0.0
996	S	SB	350.0	-0	-0.1
997	S	CB	313.8	-0.3	-0.4
998	S	CB	350.0	-0.3	-0.2
999	S	CB	350.0	+0	+0
1000	S	CB	350.0	0.0	0.0
1001	S	CB	350.0	+0	+0
1002	S	CB	350.0	-0	-0
1003	S	CB	325.9	-0.2	-0.3
1004	S	CB	350.0	-0	-0.3
1005	S	CB	350.0	-0	-0
1006	S	CB	350.0	+0	-0.1
1007	S	CB	229.3	0.0	-0.2
1008	S	CB	350.0	+0.3	+0.1
1009	S	CB	350.0	-0	-0
1010	S	CB	350.0	-0.4	-0.3
1011	S	CB	108.6	0.0	+0.3
1012	M	RB	350.0	-0.1	0.0
1013	RC	RB	350.0	-0	0.0
1014	RC	RB	350.0	0.0	0.0
1015	RC	RB	350.0	0.0	0.0
1016	RC	RB	277.6	0.0	0.0
1017	S	CB	350.0	+0.2	+0.2
1018	S	CB	350.0	+0.2	+0.3
1019	M	M	108.6	0.0	0.0
1020	M	SB	350.0	0.0	0.0
1021	M	M	84.5	0.0	0.0
1022	M	M	181.1	0.0	0.0
1023	RC	RB	350.0	0.0	0.0
1024	RC	RB	132.8	0.0	0.0
1025	S	CB	350.0	0.0	0.0
1026	S	CB	350.0	0.0	0.0

Segment Number	Shoreline Type		Segment Length (m)	Average Area Change (m/yr)	
	BBL	HTL		BBL	HTL
1027	S	CB	350.0	0.0	0.0
1028	S	SB	181.1	0.0	0.0
1029	M	CB	350.0	+0.8	0.0
1030	D	SB	265.5	-0.5	-1.1
1031	S	CB	265.5	0.0	-0.9
1032	S	CB	108.6	0.0	0.0
1033	S	SB	350.0	0.0	0.0
1034	S	SB	181.0	0.0	0.0
1035	S	RB	253.5	0.0	0.0
1036	S	RB	350.0	0.0	0.0
1037	S	CB	350.0	0.0	0.0
1038	S	CB	265.5	0.0	0.0
1039	D	SB	350.0	0.0	0.0
1040	D	SB	350.0	0.0	0.0
1041	D	SB	350.0	0.0	0.0
1042	D	SB	350.0	0.0	0.0
1043	D	SB	108.6	0.0	0.0
1044	S	CB	325.9	0.0	0.0
1045	S	CB	169.0	0.0	0.0
1046	S	SB	108.6	0.0	0.0
1047	S	CB	229.3	0.0	0.0
1048	D	CB	350.0	0.0	0.0
1049	D	CB	241.4	0.0	0.0
1050	S	CB	350.0	0.0	0.0
1051	S	CB	350.0	0.0	0.0
1052	S	CB	350.0	0.0	0.0
1053	S	CB	108.6	0.0	0.0
1054	M	M	181.0	0.0	0.0
1055	D	CB	350.0	0.0	0.0
1056	D	CB	84.5	0.0	0.0
1057	S	CB	169.0	0.0	0.0
1058	D	SB	350.0	-	-0.3
1059	D	SB	350.0	-	-0.2
1060	D	SB	241.4	-	-0.3
1061	D	SB	156.9	-	-0.3
1062	S	CB	301.7	0.0	0.0

APPENDIX II

Robadue and Lee (1980) includes an assessment of
shoreline susceptibili ... for Upper Narragansett
Bay (p. 112-125) by D ... ah
Abu Al-Saud of the Ur ... vere
organized in order o ... sion:
1) Recent beach and ... wash
gravel and sand; 3) ... ;
5) hard bedrock.

It was recogni ... ie type was
only one of sever ... rates of
erosion. Areas most exposed to ... re considered
to be those with an eastern-facing exposure and a long
fetch.

An example of the most erodable category in the Boothroyd and Al-Saud study, was the south shore of the Conimicut Pt. cuspate shoreform (segs. 234-237), which eroded at rates of up to 0.9 m/yr. The north side of Conimicut Pt. (segs. 238-241), also in the most erodable category, showed a combination of accretion and no change.

The Gaspee Pt. cuspate shoreform (segs. 254-257), placed in the beach and barrier spit category, exhibited erosion of 0.2 - 0.9 m/yr. Bullock Pt. (seg. 258), actually accreted at a rate of 0.4 m/yr, in spite of being in the most susceptible to erosion category. Barrington Beach, a barrier spit, experienced moderate erosion of

0.0 to 0.5 m/yr at the western end, but no change at the eastern end.

Rumstick Pt. (segs. 285-286) and the east side of Rumstick Neck (segs. 287-291), were designated highly susceptible to erosion. However, Rumstick Pt. eroded at the moderate rate of 0.3 m/yr, and the east side of the neck showed accretion and no change. Adams Pt. (segs. 292-294) showed no change, as did Jacob's Pt. (segs. 298-299), Prudence Island, Providence Pt. and Sheep Pen Swamp, although all were placed in the high susceptibility category.

On Prudence Island, the area north of Bear Pt. at segs. 383-384, was placed in the glacial outwash category and exhibited no shoreline change.

The south shore of Bear Pt. (segs. 386-387) was designated glacial till, and correspondingly showed no change. The west side of Rumstick Neck (segs. 281-284), a glacial till shoreline, nevertheless exhibited 0.3-0.6 m/yr of erosion. Similarly, Warwick Pt. (segs. 211-216), a glacial till shoreline eroded at 0.0-0.3 m/yr. The average measured erosion for Narragansett Bay barrier beaches was 0.2 m/yr. Oakland Beach, with a long fetch, eroded at 0.2-0.8 m/yr although it was designated a till shoreline.

Rocky Pt. (segs. 224-225) was placed in the soft bedrock category. It showed no measured erosion.

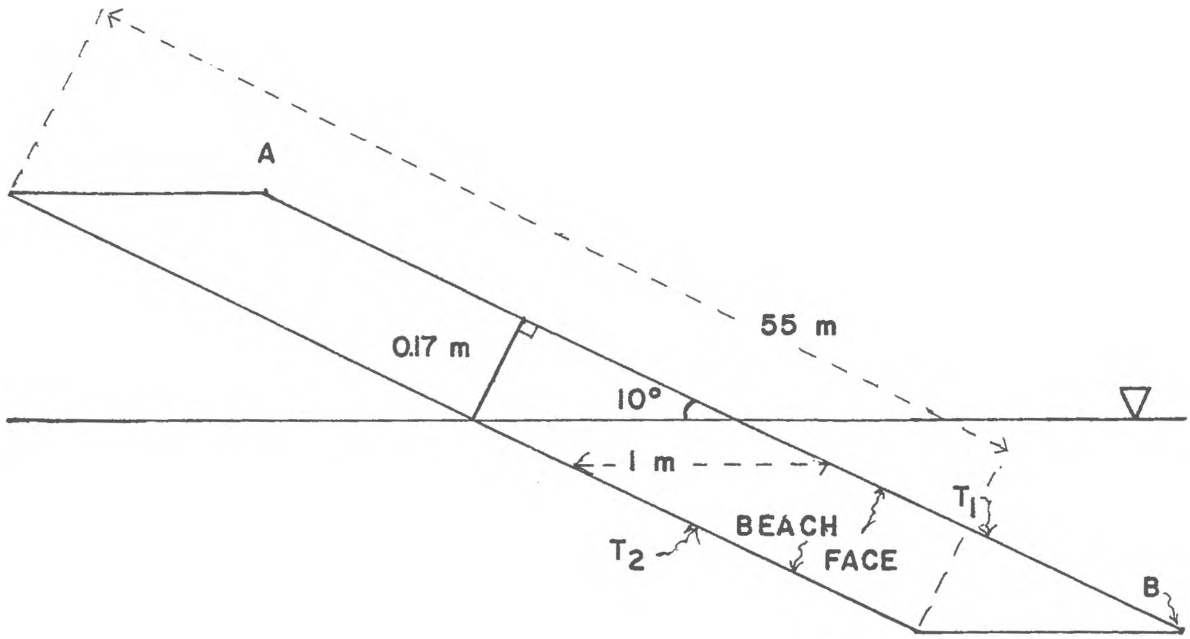
Measured erosion rates for Recent beaches and barrier spits were in agreement with the shoreline type erosion susceptibility predictions for approximately 60% of the Upper Narragansett Bay shoreline length. Glacial till shorelines were in agreement for approximately 40% of the shoreline length.

APPENDIX III

For the sediment budget analysis, sediment volumes were compared. Shoreline change measurements from the aerial photographs were measurements of area loss or gain. In order to make an estimation of volumetric changes at the high tide line for use in the sediment budget analysis, one average figure of 8.44 m^3/m^2 was used. This value is equivalent to that presented in the U.S. Army Corps of Engineers Shore Protection Manual (1973), where it was stated that 1 yd^3 of beach material is eroded for every ft^3 of beach lost (page 4-116).

The use of this figure necessitates certain assumptions that, when applied to the Narragansett Bay shoreline, cause any conclusions based on this single value to be general. One such assumption is that beach slope is a straight line and that it remains at the same angle after erosion or accretion. It is also assumed that the water line (or high tide line) remains at the same level.

As illustrated in the following diagram, the use of the figure 8.44 m means that a swath of approximately 55 meters of beach face one meter wide and 0.17 meters thick is affected for a beach slope of 10° (line AB). For a beach slope of 5°, an approximately 110 meter swath of beach face one meter wide and 0.09 meters thick is affected.



Cross Section of Beach Face

not to scale

Individual beach slopes were not measured for the present study, but slopes of two cuspate shoreforms, Greene Pt. and Casey Pt., were measured by Zarillo (1975 unpub. thesis). At Greene Pt. the upper foreshore dipped 6°-8° toward the water, the lower foreshore dipped at 2°. At Casey Pt., the beach slope was 8°-12°. The length of the Greene Pt. beach face perpendicular to the water line was measured by Zarillo to be 244 m. The length of the Casey Pt. beach face was measured by Zarillo to be 274 m.