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A PRELIMINARY STATEMENT ON A SEDIMENTOLOGICAL STUDY OF THE BEACH AND MARINE AREA AT BELLEDUNE POINT, CHALEUR BAY, NEW BRUNSWICK

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D. E. BUCKLEY
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REPORT B.I.O. 64-12

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THE CANADIAN COMMITTEE ON OCEANOGRAPHY

B E D F O R D   I N S T I T U T E   O F   O C E A N O G R A P H Y

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INTRODUCTION

This report is a preliminary appraisal of a beach and bottom sampling program undertaken by the Marine Geology Group at the Bedford Institute of Oceanography, and carried out from June 21 to June 29, 1964 at Belledune Point on the south shore of Chaleur Bay, New Brunswick (Figure 1). This project was undertaken upon the request of the Canadian Hydrographic Service who, at that time, were conducting a tidal current survey in the area for the Department of Public Works. This latter department, in conjunction with the Atlantic Development Board, is examining the feasibility of establishing a major deep sea port at Belledune Point. Therefore, it was appropriate to make a study on the stability of the beach, and determine the amount of sedimentary transport on the beaches as well as on the adjoining sea floor.

To carry out these objectives the following program was organized. The Hydrographic Service supplied a suite of topographic profiles of the beach surveyed over the three-week period immediately following the sampling program. Sediments on the beach and adjacent marine areas were sampled concurrently with observation on wind direction and velocity, as well as with observation on wave characteristics. In the laboratory, mechanical analyses were made on all samples for the purpose of

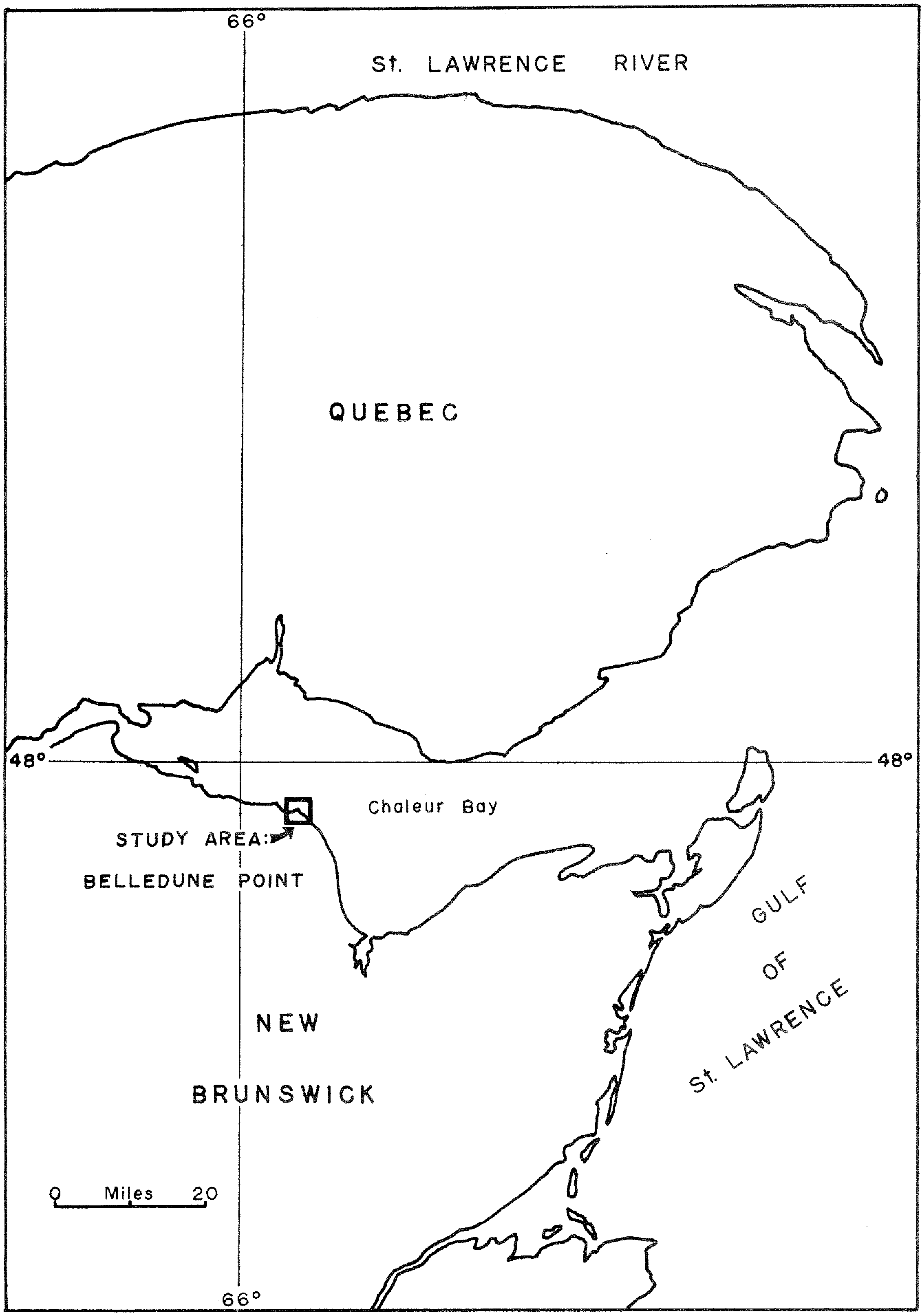


Figure 1. Map of eastern Quebec and New Brunswick showing location of study area on south shore of Chaleur Bay.

classifying the material on the basis of size. The sand and gravel fraction of the sample (material greater than .062 mm in diameter) was sized by seiving, while the finer clay and silt fraction was analyzed by the pipette method (Krumbein and Pettijohn, 1933). Statistical analyses were then carried out on the data relating to the distribution of particle sizes for each sample. These data are based on quartile measurements which are obtained graphically from cumulative frequency curves of the distribution of the particle sizes (Milner, 1962).

Stability of the beach was determined from an analysis of the beach profiles, and by observation of the shift of pebbles over the surveyed areas of the beach. Areas of relatively strong and correspondingly weak hydrodynamic activity were delineated on the basis of sedimentary maps drawn from a partial sedimentological analysis of the bottom deposits. From these beach and offshore studies, recommendations were made on the feasibility of constructing a pier at Belledune Point.

The authors express their thanks to Dr. B. R. Pelletier for his continued guidance and helpful criticism throughout the course of the project. We are especially grateful to Mr. Colin J. Langford and his staff of hydrographers for their cooperation in surveying the study area, their assistance in the collection of samples, and their generous support in providing the launch "ANDERSON" and her crew. Mr. Paul Cant of the Fisheries Research Board also gave much valuable assistance in the field. Rock Cormier also assisted in the field, and directed the laboratory analyses to completion. He joins the authors in expressing appreciation to our summer assistants - Nick Fowler, Sonia Pitcher, Eric Smith, Patricia Sirdevan and Penny Wyse. Thanks are also due the Canadian Hydrographic Service for supplying advance field sheets of the study area. Karl Mihoff of the Naval Research Establishment deserves special thanks for his kind cooperation, time and assistance in processing tape data. Charles Quon of the Bedford Institute of Oceanography generously advised in the discussion of wave phenomena in the Bay of Chaleur.

Physical Setting

Belledune Point is located on the southern shore of Chaleur Bay approximately 70 miles inland from the Gulf of St. Lawrence. It consists essentially of a series of beach ridges near the shore, a light forest growth and smaller vegetation in a central area, and a lagoonal area toward the land. On the land, several areas of outcrop occur peripherally to the Point. Bedrock is exposed both at Chapel Point, which is situated about 3,000 feet west of Belledune Point, and on the landward side of the lagoon. Bedrock was reached by a drill operating offshore north of Belledune Point after penetrating about 40 feet of unconsolidated sediments. East of Chapel Point the beach material consists of very coarse sand and gravel, and the whole of Belledune Point north and east of the lagoon appears to be of similar composition.

The topographic contours in Figure 2 indicate the pronounced beach ridge encompassing Belledune Point, and also the series of elongate ridges landward on the west side of the Point. The area enclosed by the encompassing beach ridges has a general cover of grass, and supports alders and evergreens in the central portion. A thin layer of mud covers the bottom of the lagoon, and maximum depth of this bottom is approximately at sea level. Water level in the lagoon fluctuates with the tides, thus indicating the porous nature of the material at Belledune Point. Seepage through the beach occasionally results in a break through the beach ridge thereby permitting rapid drainage of the lagoonal water.

Offshore the depth contours between Chapel and Belledune Points are fairly regular in outline and somewhat uniformly spaced. Near shore the spacing is closer than offshore areas but, in general, the floor of Chaleur Bay in this area is without marked local relief. In contrast, the area due east of the beaches south of Belledune Point shows more marked irregularity in the depth contours, as

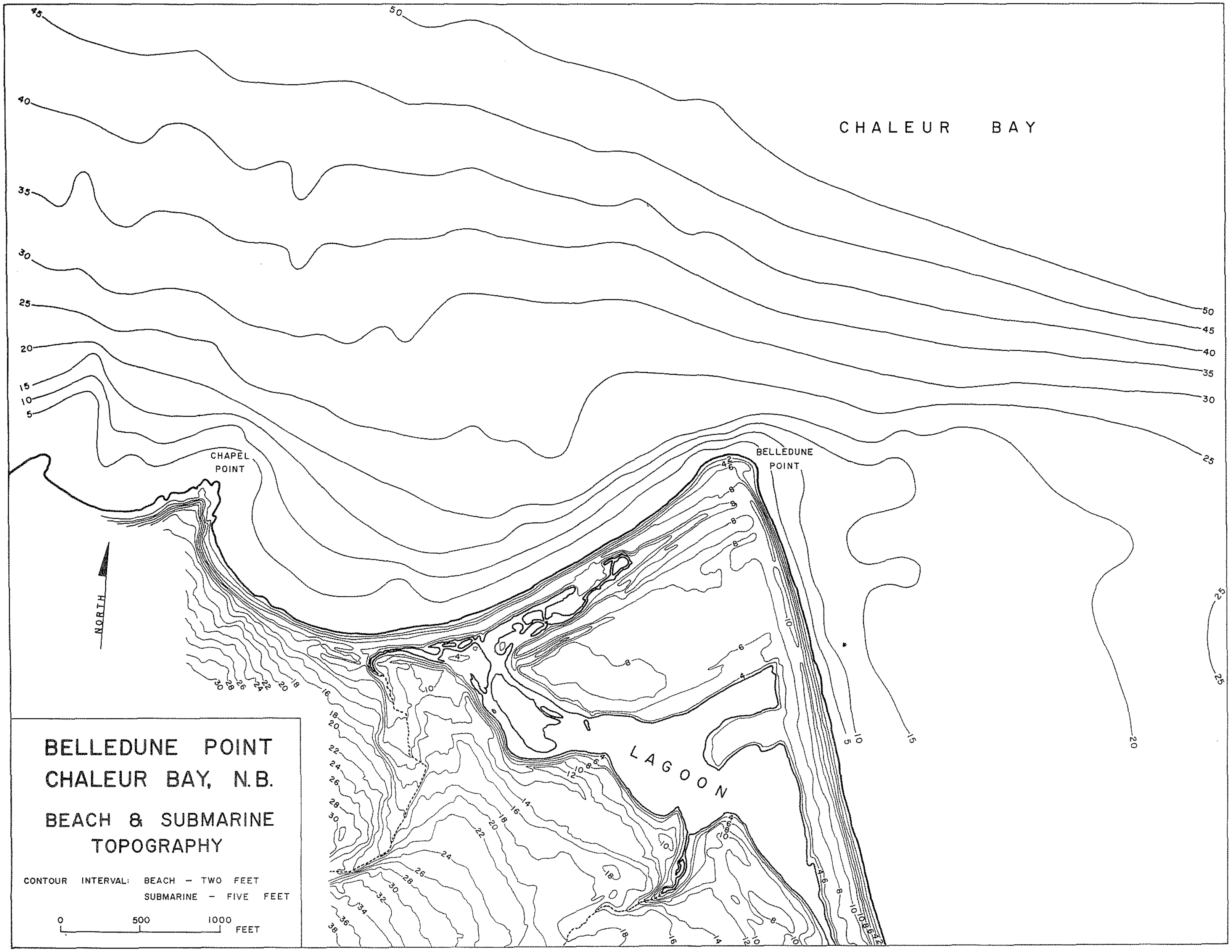


Figure 2. Topography of study area showing the parallelism of both land and submarine contours to the shoreline.

well as uneven spacing and lack of parallelism with each other. This area consists of a short, steep, inshore zone within 100 feet of shore, and a relatively broad shallow area extending at least 3,000 feet seaward of the eastern beaches, where water depth is 25 feet. This same depth is reached about 1,000 feet from shore in the western area. This overall bottom configuration is one of the fundamental controls upon sedimentation in the marine areas around Belledune Point, as well as upon the construction and erosion of the beaches, the transportation of sediments around Belledune Point and the ultimate stability of Belledune Point itself.

The Beach Profile

The locations of the beach profiles surveyed by the Hydrographic Service are shown in Figure 3. These profiles record the contour of the beach from the low-water mark to a point about 120 feet onshore. Each profile was surveyed an average of four times over the three-week period immediately following the sediment study and although these profiles were not surveyed concurrently with the sampling program, they reflect a condition which generally applies to the range of beach surveyed.

While the particular configuration of the beach face shows appreciable variation with time for any one profile, the average slope of the beach face remains fairly constant.

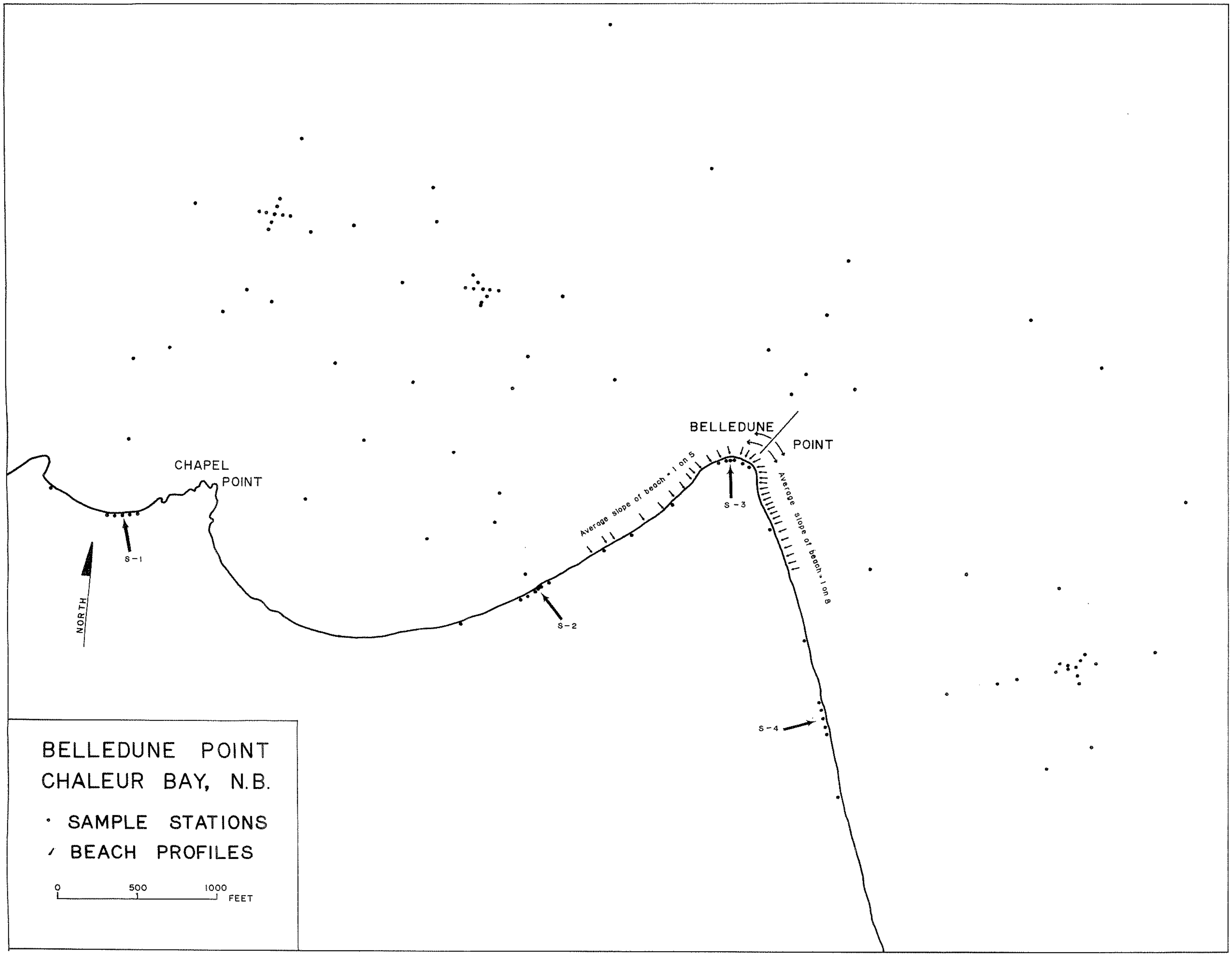


Figure 3. Sampling stations and areas designated for study on beach stability (S-165-4). Note line at Belledune Point which separates areas containing beaches with different profiles. Beaches to west of line are steeper than those to east and south.

Further, a rather pronounced change to steeper average slopes on the west side occurs just southeast of the tip of Belledune Point (Figure 3). East of this location, the slopes average about 1 on 8, but to the west the slopes steepen to 1 on 5. This may be due to exposure to different conditions of wave energy, in fact, Bascom (1948, p. 874) in relating slope of the beach face to wave energy concluded: "The amount of energy is a function of the refraction conditions; consequently, beaches that are protected are steeper for any given sand size than exposed beaches." This principle is demonstrated at Belledune Point in the following discussion.

In purely qualitative terms, the size of wind-generated waves depends upon three factors: 1) the velocity of the wind, 2) the duration of the wind, and 3) the fetch or extent of open water over which the wind blows. From Belledune Point, the maximum fetch to the west in Chaleur Bay is about 25 miles. The apparent eastward fetch is more than twice this distance although it is not necessarily true that waves from the east are twice the size as those from the west. The eastern fetch, however, is effectively many times greater than the west, due to the fact that very large waves can enter Chaleur Bay from the Gulf of St. Lawrence. Attenuation of these latter waves in travelling up Chaleur Bay is considerable and complex, but their energy contribution in the study area is important.

In any case, the west side of Belledune Point is the more protected, and on this basis exhibits the more steeply sloping beach.

The depth to which wave action is effective in disturbing bottom sediment is proportioned to the wave length, and maximum wave length is limited by the fetch. Also, in water less than half the wave length in depth, waves are refracted according to the configuration of the bottom topography. The refractive properties of Belledune Point appear to be those of classical illustration (see Krumbein, 1950), where wave energy is concentrated on the headland and widely dissipated in the bay beyond. In terms of fetch, therefore, the protected situation of the beach west of Belledune Point applies likewise to the bottom in that area, and the refractive effects of Belledune Point constitute a barrier to wave energy from the east.

Beach Sampling

The beach sampling program was designed to trace the movement of "tagged" beach sediments (i.e. pebbles coated with a mixture of alcohol and red ochre) with reference to four particular stations. These stations were located at Chapel Point, the tip of Belledune Point, and the beach on both sides of the Point (Figure 3). At low tide on June 23 at noon hour, about 400 pounds of painted beach gravel was deposited in the intertidal zone at each of these stations. The painted gravel was evenly distributed over a circle 10 feet in diameter. Samples of sediment were taken from the intertidal zone for a period of 56 hours thereafter. Samples were also gathered from an area of one square foot at various sites 5, 10, 25, 50, 100 and 500 feet east and west from each station. The gravel that was coloured for this purpose was selected from dry material above the high-water mark, and as nearly as possible it was representative of material in the intertidal zones. Approximately 200 beach samples were collected during this phase of the program which ended on June 25 at 8:00 p.m.

In advance of the beach sampling program, the Hydrographic Service staked out the sample sites at the four main stations shown on Figure 3. At Station 3, on the tip of Belledune Point, the sample stakes were installed in the intertidal zone on June 18. During the period June 18 to June 21, a series of storms occurred with wind direction predominantly from the west. On June 21, when weather conditions had returned to normal, loose gravel covered all sample stakes at Station 3 except those at 100 and 500 feet east. The tip of Belledune Point had been extended seaward a distance of 60 feet. Prior to this stormy period of June 18 to June 21, the lagoon on Belledune Point filled and drained through a wide gap in the beach at its northwest end. On June 21, the beach ridge was completely restored at that point.

These events at Belledune Point may be explained as follows. Waves arriving from the west encountered the beach at some low angle to the shore. The energy expended by the breaking waves was sufficient to rebuild the beach ridge, and also effect a littoral drift - or net transport of sediment - toward the Point. The transported gravel accumulated at the tip and on the eastern side of the Point where refraction of the waves in the shallow water around the Point dissipated their energy.

On June 23 and June 24 at beach stations 2 and 3, eastward movement of the painted gravel under the action of 10-inch waves from the northwest was obvious. During the same period at Stations 1 and 4, the beach gravel remained essentially undisturbed. These brief observations demonstrate the role of littoral transport as a function of beach exposure to wave action, and indicate the order of wave energy required to initiate movement of beach material.

The severe overnight storm of June 24 removed all trace of the coloured beach gravels from all stations. At 9:00 a.m. on June 25, a three- to four-foot swell was striking the Point from the northeast, causing rapid movement of beach material westward around the Point. The tip of Belledune Point had receded a distance of 60 feet, and was slightly "hooked" to the west. Seven of the sample stakes, which had been buried by the storms of June 18 to June 21, were again visible. Judging from the changes which had occurred with reference to these stakes, it was estimated that 3,000 to 6,000 cubic yards of beach material had been transported around the Point during the previous night.

On the west side of the Point, slightly east of Station 2, water from the lagoon was again escaping to the sea through a large break in the beach ridge. At 2:45 p.m. on June 25, the eastern beach was still receiving a swell about two feet in height from the northeast. Wave height at Station 2 was at this time in the order of six to eight inches. An abnormally high tide overnight had accompanied the storm; in fact, the beach about Station 2 was littered with fresh kelp on the following morning.

The foregoing summary indicates the rapid manner in which the general outline of the Point can change, and hints at the approximate amount of material involved in the process. It again appears that sediment transport is partly dependent on exposure of the beach to wave action, and that the Point acts to impede wave energy.

Offshore Sampling

The purpose of the offshore sampling program was to examine the bottom sediments, and to map the general distribution of sediment types offshore from Belledune

Point. On June 25 and June 26, bottom grab samples were taken by means of a Van Veen sampler at 5, 10, 50, 100 and 500 foot intervals outward from surveyed buoys on bearings approximately north, south, east and west (Figure 3). A suitably labelled 500 foot rope was used to measure distance from the marker buoys. Bottom sampling on the above dates was conducted from a Hydrographic Service speed boat. Both the speed boat and the launch "ANDERSON" were employed to collect samples on June 27 and June 28 at scattered locations offshore from Belledune Point. The positions of these samples were fixed by sextant angles to markers on shore. This offshore sampling was completed by the Marine Geology Group on June 28, at which time about 100 samples had been recovered. Several additional samples were collected by Mr. Colin J. Langford during the first two weeks of July.

On the basis of the mechanical analyses in the laboratory, size-frequency cumulative curves of each sample were drawn, from which various statistics and objective statements on the nature of the material could be given (Figures 4 to 7). A graphic description of the offshore samples is presented in Figure 4. The description is based upon the dominant texture of each sample according to the frequency distribution of that class of material in the whole sample. Clearly there exists an area east of the Point in which the dominant texture is gravel, and an area west of the Point in which the dominant texture

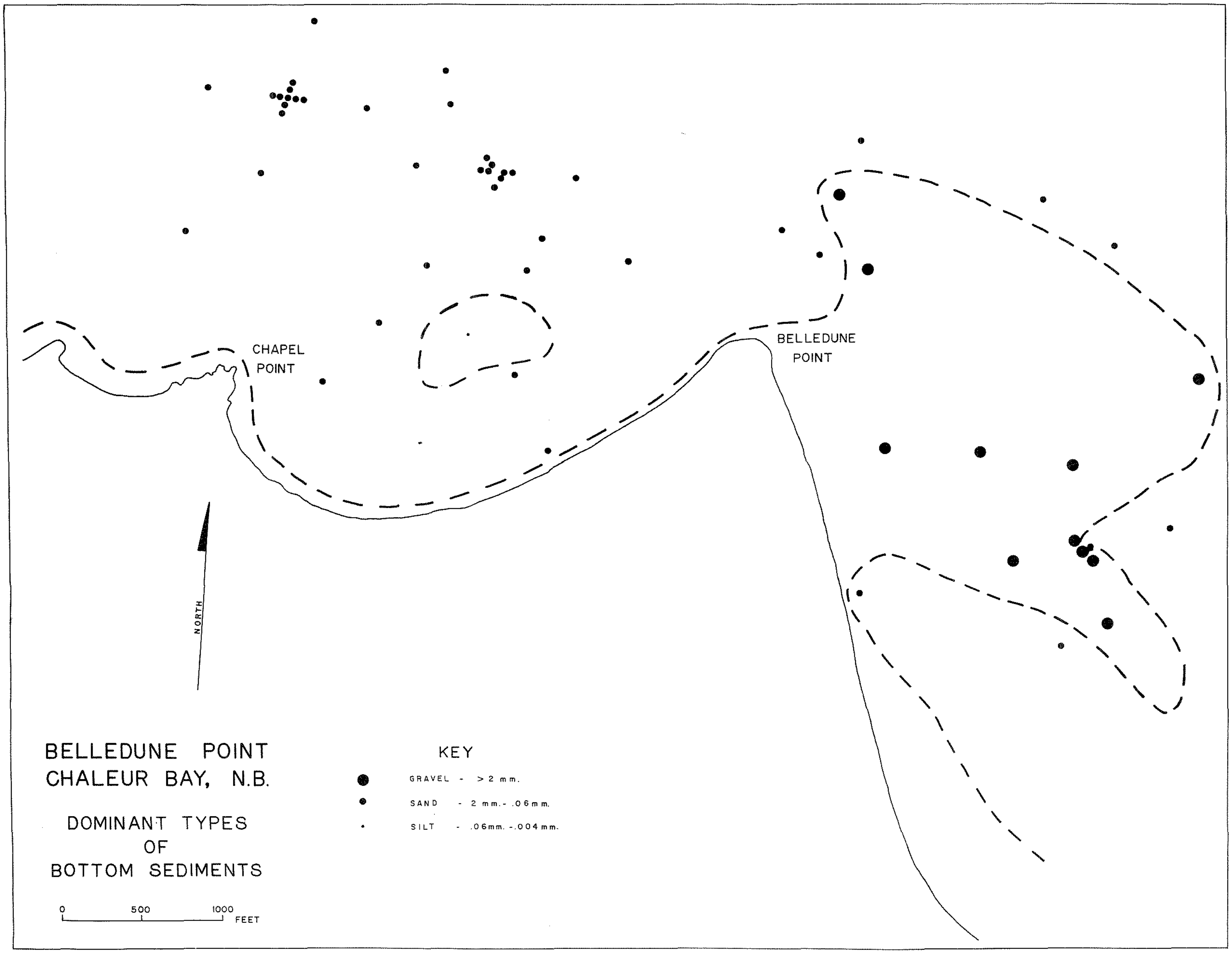


Figure 4. Chief textural types of sediments. Gravels occur in the east and close to shore, and sands occur to the west and further offshore.

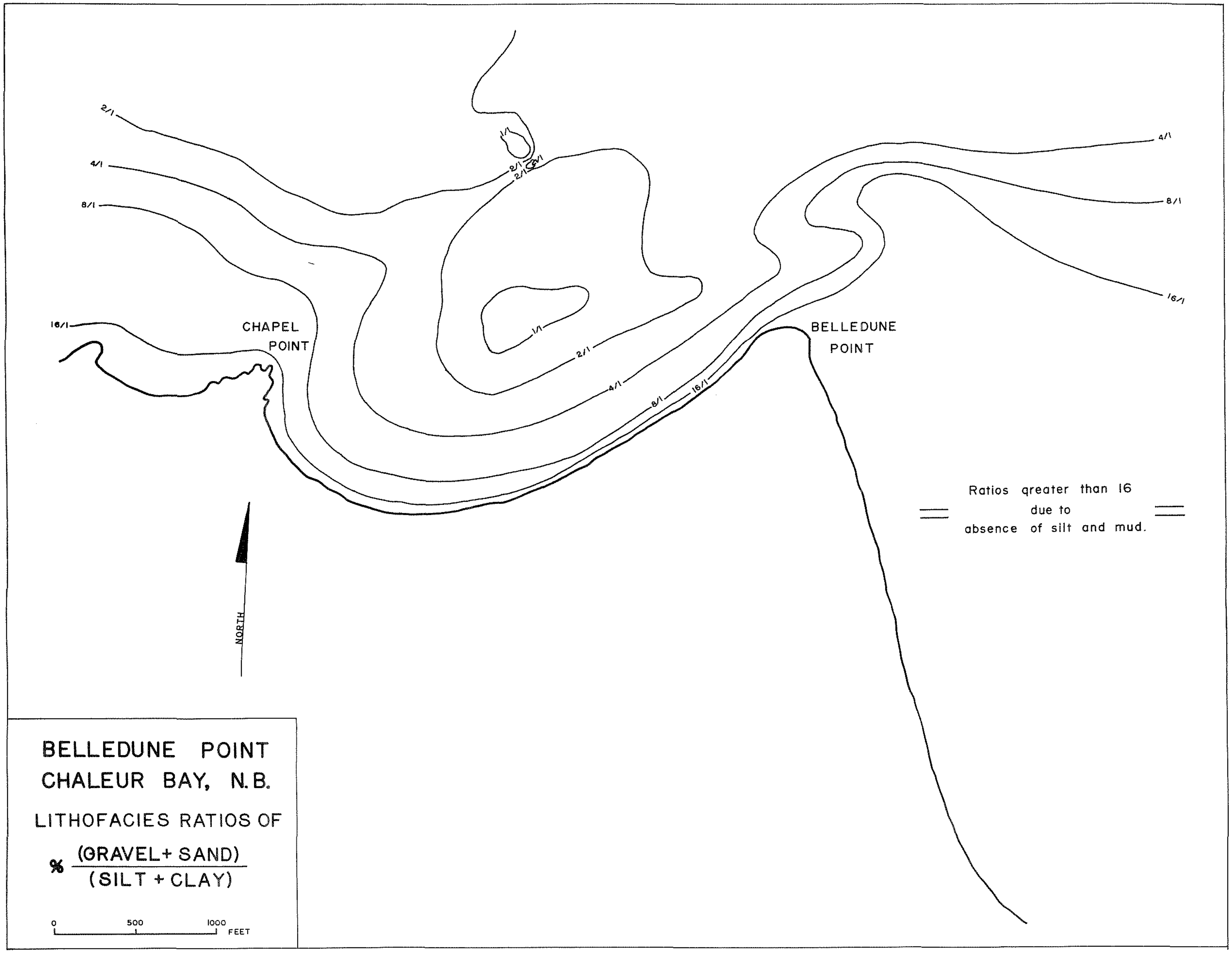


Figure 5. Lithofacies map indicating abundance of coarse material in the east and near shore in the west. Finer material occurs seaward of these areas.

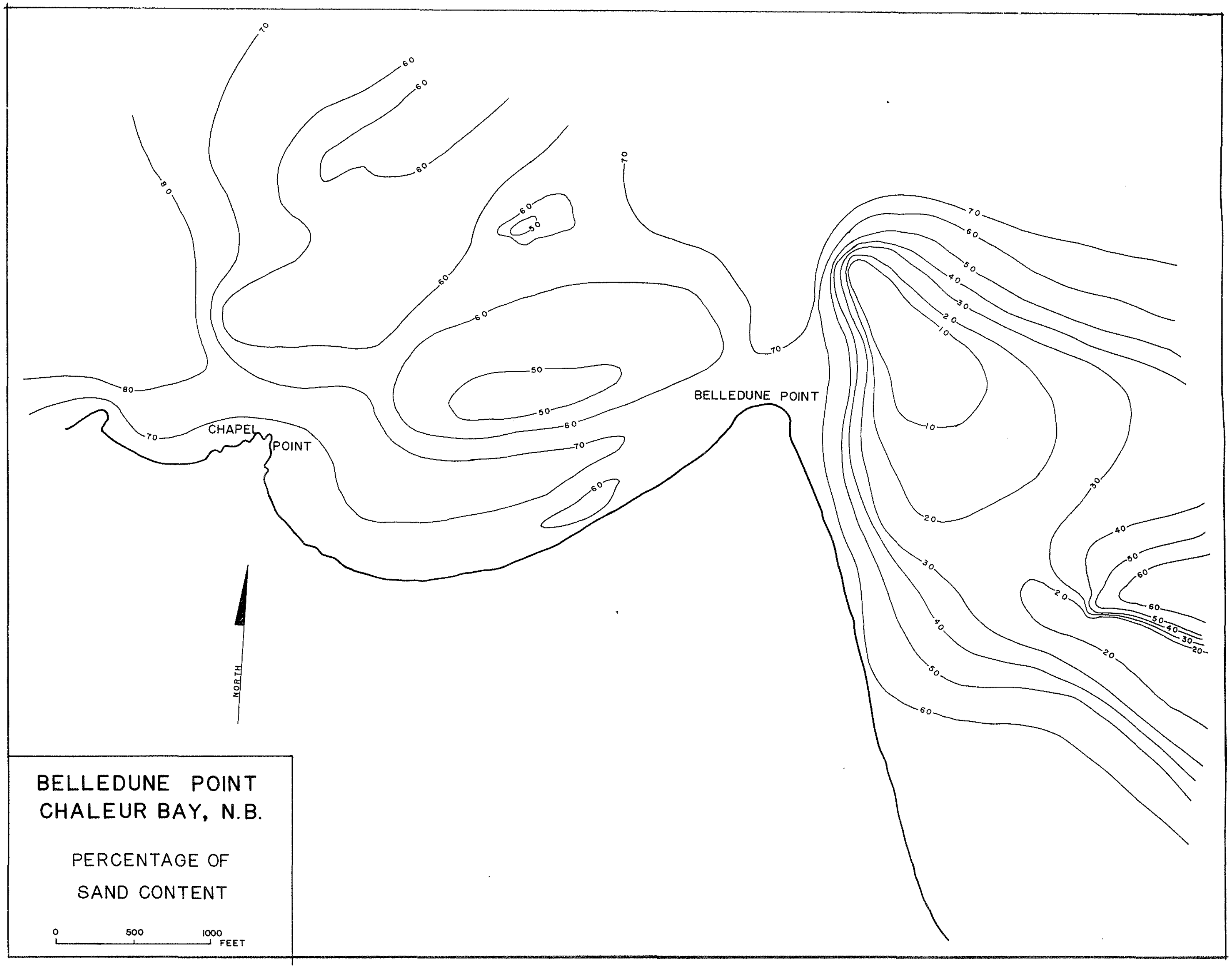
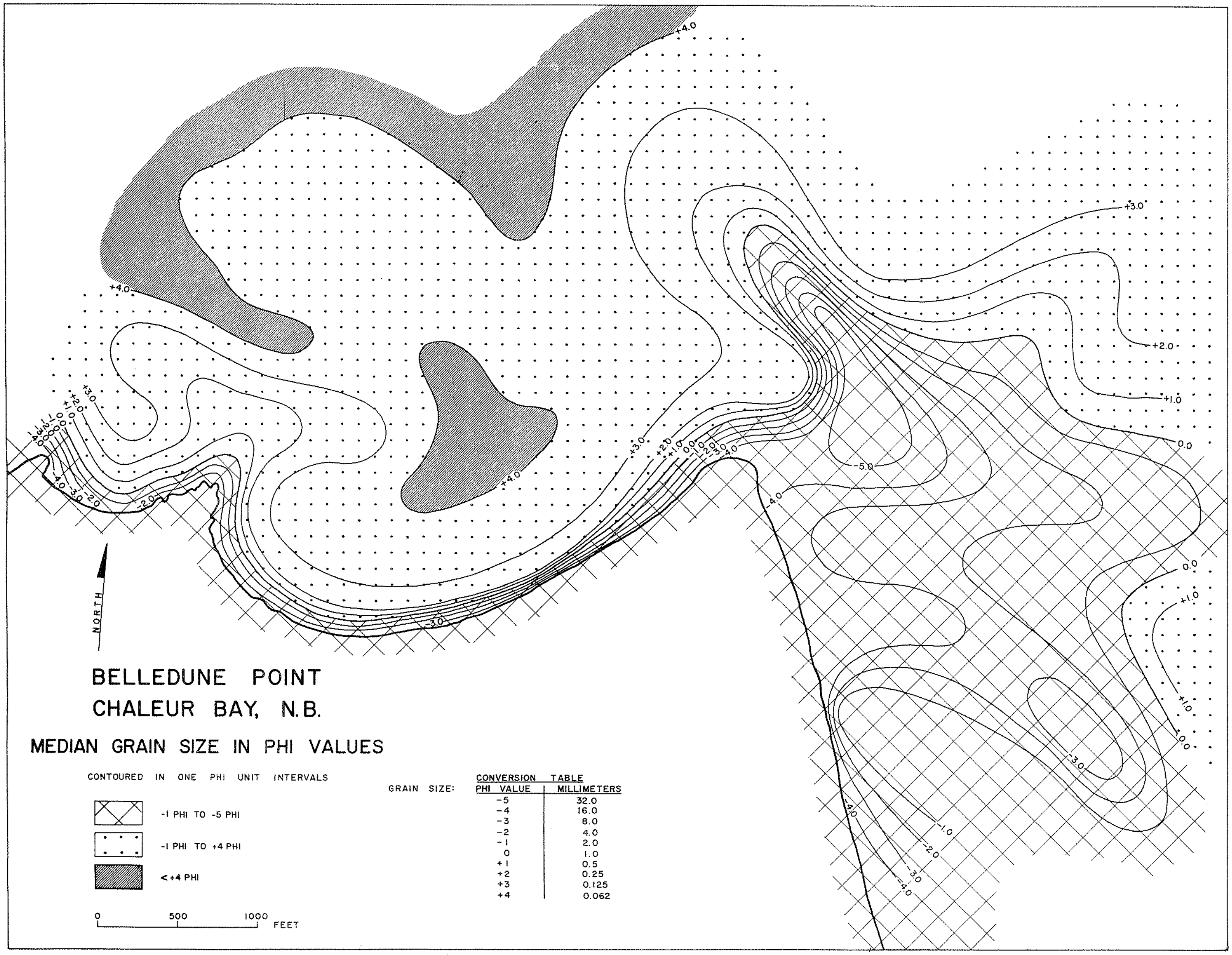


Figure 6. Details on the distribution of the percentage of sand in over the study area. Generally sand, as a major constituent, occurs mostly in the west and in the offshore areas to the east.



PHI VALUE	MILLIMETERS
-5	32.0
-4	16.0
-3	8.0
-2	4.0
-1	2.0
0	1.0
+1	0.5
+2	0.25
+3	0.125
+4	0.062

Figure 7. Map of the distribution of median grain sizes of bottom sediments in the study area. Map gives summary on sediment distribution and reflects other aspects of sedimentary distribution shown in Figures 4, 5 and 6. The coarse material is to the east and fine is to the west and offshore. This correlation with Figures 4-6 is due to the fact that the sediments are generally well sorted.

is sand. This is further illustrated in the lithofacies map (Figure 5) which sharply delineates these respective areas. It is notable that these textural trends conform closely to shoreline trends thus suggesting a progressive sorting of sediments in the direction away from shore. Spacing between the isopleths is fairly uniform but, because the contour interval is logarithmic to the base 2, it further suggests that decrease in texture takes place exponentially according to distance from zones of greatest energy. In the eastern half of the study area, the isopleths are more widely divergent from shore. This divergence is partly due to the fact that most of the area near shore is a zone of very high energy, and sediments deposited in this area would be coarse and hence yield a high ratio of coarse versus fine material.

Such a virtual absence of silt and clay in the zones of high energy has brought about lithofacies ratios that tend toward infinity, consequently, ratios greater than 16:1 were not plotted. In order to visualize the hydrodynamic environment together with the nature of the bottom sediments, the percentage of sand in the samples was plotted and contoured as shown by the isopleths in Figure 6. These contours also conform to shoreline trends, and give wider information on the nature of the bottom in that they indicate the amount and distribution of the actual content of sand. Because of its intermediate range of sizes, the sand texture is a sensitive indicator of average conditions of current direction and velocity. Therefore in areas where the isopleths are somewhat complicated it is suspected that unknown variations of energy conditions exist within the hydrodynamic framework. Such variations will be investigated when the tidal and current analyses have been completed.

Complementing the values on the lithofacies and sand percentage, is the plot of median diameters (Figure 7) which indicates the occurrence of coarse material in the shallow areas of the eastern part of the study area and further explains the high lithofacies ratios in that locality. These contours generally conform to each other as well as to the shoreline thus illustrating the general principle that sediments are coarser near shore than farther out to sea. The regularity of such trends indicates the regular, progressive nature of the agent of deposition.

From Figure 7 it is clear that finer sediments occur much closer inshore on the west side of Belledune Point where the energy level is sufficiently low to allow settling of these fine particles. Here the median sand sizes occur within 100 feet of shore while east of the Point these same sizes occur 2,000 feet from shore. In this latter area, the much broader distribution of gravel offshore reflects the more energetic hydrodynamic environment which is a result of the fetch conditions discussed previously. In fact, the symmetrical nature of the isopleths about the Point also reflects the fetch conditions from both easterly and westerly directions.

Although the common observation that sediments decrease in size seaward is generally true, an apparent anomaly exists in the area due west of Belledune Point (Figure 7). In this area the median diameters decrease in value progressively from -4 phi, at the shoreline, to +4 phi in the seaward direction about 3,000 feet offshore. However, a small area occupied by material in the silt sizes with a median diameter of +4 phi occurs only 1,000 feet offshore and is surrounded by coarser sediments. This area of finer material indicates the occurrence of weaker currents, in fact, it may be the central part of an eddy. This has been partly corroborated by preliminary current observations according to Mr. C. Langford. These sedimentary data will be correlated with the current data in the next phase of the Belledune Point study when all available data are processed for the final environmental analysis.

Summary, Conclusions and Recommendations

Sedimentary transport in a coastal environment is extremely complicated, and the study outlined must be recognized as constituting only a cursory observation of processes active in the area. The effects of winter ice conditions, for example, are unknown. The brief comments that follow are based mainly on sedimentological features and as such are regarded as tentative, although certain conclusions on the hydrodynamic environment are clearly seen.

Belledune Point is composed of coarse sand and gravel. It is situated at the apex of a major prominence on the southern side of Chaleur Bay. In terms of fetch, northwesterly and easterly winds are the important wave-builders. The Gulf of St. Lawrence supplies additional wave energy from the east, and this is reflected in the distribution of bottom sediments which is a result of the effectively longer eastward fetch.

The sequence of ridges extending back from the beach indicates seaward growth of the Point by means of accretionary processes, and the cover of vegetation denotes some continued stability of the central area of the Point. While the marginal configuration of the Point adjacent to the sea is subjected to rapid change, its position and general shape suggest beach drift from opposing directions toward a common point of sediment accumulation.

The authors do not presume to attempt a forecast of the long-term effects of pier installation in the Belledune Point area. On the implication of the foregoing paragraph in connection with the general equilibrium condition of the Point, it is perhaps a valid speculation that pier construction will somewhat disturb this balance. A pier extending northward from the tip of Belledune Point, for example, might exercise effects similar to those described by Johnson (1956) for breakwaters extending from shore.

Thus, beach material normally swept westward around the Point could be expected to accumulate along the eastern side of the pier, although the direction of the pier might be of some influence in this regard. Depending upon the length of the pier, greater or lesser deposition of finer materials (sand, silt) may be anticipated west of the seaward extremity. With the wind from the northwest, a similar movement of sediments might take place on the northwest face of a pier extended from Chapel Point.

Belledune Point appears to be the natural centre for sediment accumulation from perhaps a considerable range of coastline. Construction of a pier may alter the distribution of sediment in that locale, but will not likely curtail deposition.

The following is recommended: 1) sedimentological data be reviewed when results are available from the tidal current study and the offshore drilling program; 2) a study be conducted to determine the range of coastline contributing sediment to Belledune Point area, and the approximate amount and size of these materials; 3) wave characteristics be investigated in terms of water depth to which they influence sediment distribution; 4) the effects of winter ice and other seasonal influence be investigated.

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