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SEDIMENTATION OFF THE KEWAUNEE NUCLEAR POWER PLANT

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THE UNIVERSITY OF WISCONSIN

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Preface

At the end of 1973 forty-two nuclear reactors were reported to be in operation in the continental U.S. The combined capacity of these 42 plants represents about 5.6% of the nation's total electrical generating capability. The advent of nuclear powered generating stations, therefore, has been lifted out of the experimental-feasibility stage into the realm of practical reality, an advance which has been prompted by the need to meet the growing demands of modern American society. Clearly then, this means that nuclear fueled power plants are intended to supply an increasing proportion of the total U.S. electrical requirements in the near future.

The present state-of-the-art in nuclear energy conversion and technology requires that existing and planned nuclear power plants be placed in locations where adequate supplies of cooling water are available. This has made the siting of power plants a matter of vital concern, particularly if many of these facilities are to be located within the nation's coastal zones.

The purpose of this investigation is primarily one of capitalizing on the opportunity to examine a coastal environment before a nuclear power plant becomes operational and then to monitor whatever physical changes might arise as a consequence of its operation. This ideal circumstance provides a sound scientific base from which comparative assesements can be made of the environmental responses in the nearshore zone at the plant site. Such an approach should prove to be a valuable asset in the discriminatory process of selecting suitable power plant sites in other locales.

ACKNOWLEDGMENTS

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I wish to express my gratitude to those students at the University of Wisconsin-Green Bay who so willingly and capably rendered the necessary field and laboratory support which made this project a success. Special thanks are extended to Susan Nelson who assumed the responsibility of maintaining the efficiency of the sedimentology laboratory as well as for the many analytical tasks performed; to Vicky Garsow for her prompt attention to data assimilation and the drafting of numerous displays of graphical information; and to Linda Hoffman for the compilation of map data and the preparation of line drawings.

My sincerest gratitude is also expressed to Mr. E. R. Matthews, Assistant Vice President, Power Generation and Engineering, Wisconsin Public Service Corporation, who so generously made himself available for consultation and for supplying a copy of the 1967 nearshore bathymetric map. In the field Mr. Don Frisque's congenial advice and direction with regard to matters of civil engineering related to the plant site are gratefully acknowledged.

To Messrs. Howard Zar, Project Officer, Environmental Protection Agency, Region V, and Barton Hoglund, President of Environmental Technology Assessment, Inc., Oak Brook, Illinois, I wish to express my appreciation for granting permission to reproduce Figure 3 of ANL Contract Report 72-1.

ABSTRACT

A comparative two-year study of the nearshore sedimentary environment of Lake Michigan was undertaken to provide basic information on the physical characteristics of the lake bottom and beach zone in the vicinity of the condenser cooling water discharge flume of the Kewaunee Nuclear Power Plant located near Two Creeks, Wisconsin. The pre-operational data have indicated that the sedimentary processes operative along this segment of the lakeshore are controlled largely by a shallow, hard, clay-covered, dolomitic bedrock promontory which forms an extension of the point of land upon which the plant has been constructed. Wave action and wind-driven currents are the principal mechanisms by which the sediments are redistributed along the littoral zone in a general southerly direction.

Broad irregular patches of silt-sized sediments which are found distributed along the northern and southern flanks of the rocky platform may arise from lateral (i.e., lakeward) deflection of the predominantly southerly-directed currents. Dissipation of these lateral currents, perhaps through the development of eddies on the lee sides of the platform, may permit the deposition of finer clastics in these lower energy environments. Under these conditions the silt-sized sediments tend to be enveloped by north-south trending sheets of sand - one along the inshore zone parallel to the beach line and the other in the offshore waters along the lakeward side of the platform. During periods of intense wave and current activity which accompany severe storms the lateral currents may be strong enough to induce the migration of sand-sized sediments across the flanks of the platform into the deeper parts of the lake.

Sediments are derived principally from the adjacent shoreline bluffs of glacial drift through the action of storm waves which sweep across the

backshore zone of the beach and undermine the foot of the bluffs. The impingement of wind-driven ice masses on the beach and banks may constitute an important aspect of shoreline erosional processes. The high clay content of these glacial deposits promotes a steep, blocky type of bank failure, which in turn induces slumping or cascading of higher sections of the bluff face directly onto the beach. Reworking of the collapsed material then takes place through the swash action of waves.

Monitoring of the sediment field and adjacent shoreline after the plant is in operation should indicate whether the jet flow of discharged cooling water will adversely affect the natural sedimentary processes operative in the nearshore environment.

INTRODUCTION

Current national demand for electrical energy has increased to the point where power generating utilities must seek to augment their existing capacities by at least eight-fold by the year 2000 with as much as half the total anticipated electrical output being supplied by nuclear power plants.

Within the Great Lakes region alone the power consumption demands of a projected 70 million people for the year 2000 (Heindl, 1970) cannot be met by fossil fuel plants alone. Furthermore, the stricter operational requirements of any power generating station in terms of national and state air quality standards, as well as depleting resources of a suitable low-sulfur grade of coal, make the coal fueled plants economically and environmentally less attractive than the more efficient nuclear plants. To meet the expected industrial and domestic power requirements of the Great Lakes region over the next decade, at least 17 nuclear power plants have been planned and of these several are already in operation while a number are nearing completion (Arnold, 1970). Within the Lake Michigan basin, seven of the present 27 electric power generating stations are nuclear fueled (Figure 1), five of which use through flow of lake water as the principal mode of condenser cooling. The output of these seven plants ranges from 75 MWe at the Big Rock plant near Charlevoix, Michigan to the 2200 MWe Donald C. Cook plant near Bridgman, Michigan.

Along the Wisconsin shoreline of Lake Michigan two nuclear power plants have been constructed near the community of Two Creeks, Wisconsin (Figure 2). The Point Beach Plant, operated jointly by the Wisconsin Electric Power

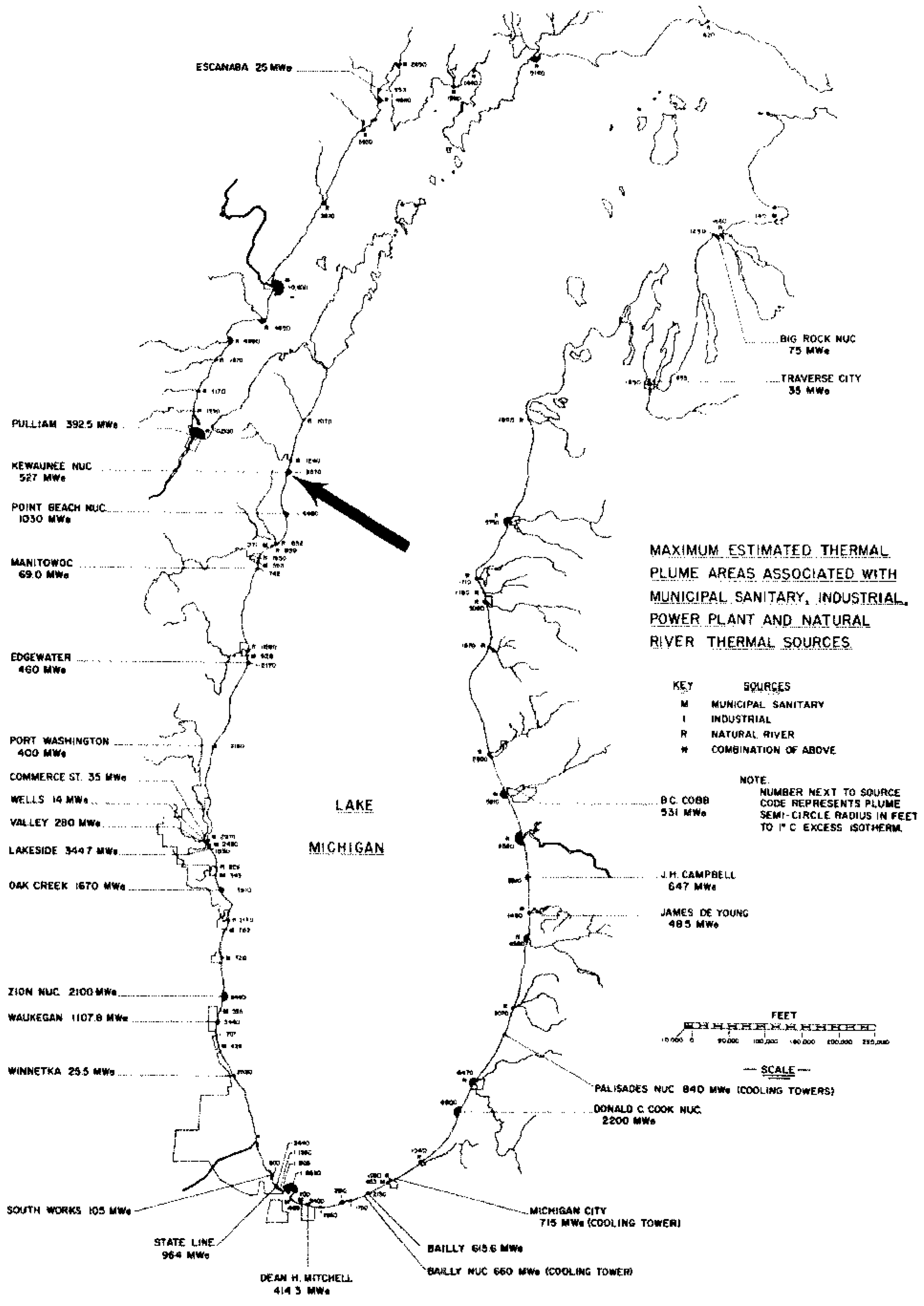

Fig. 1. Maximum Estimated Thermal-plume Areas Associated with Municipal, Sanitary, Industrial, Power-plant, and Natural River Thermal Sources.

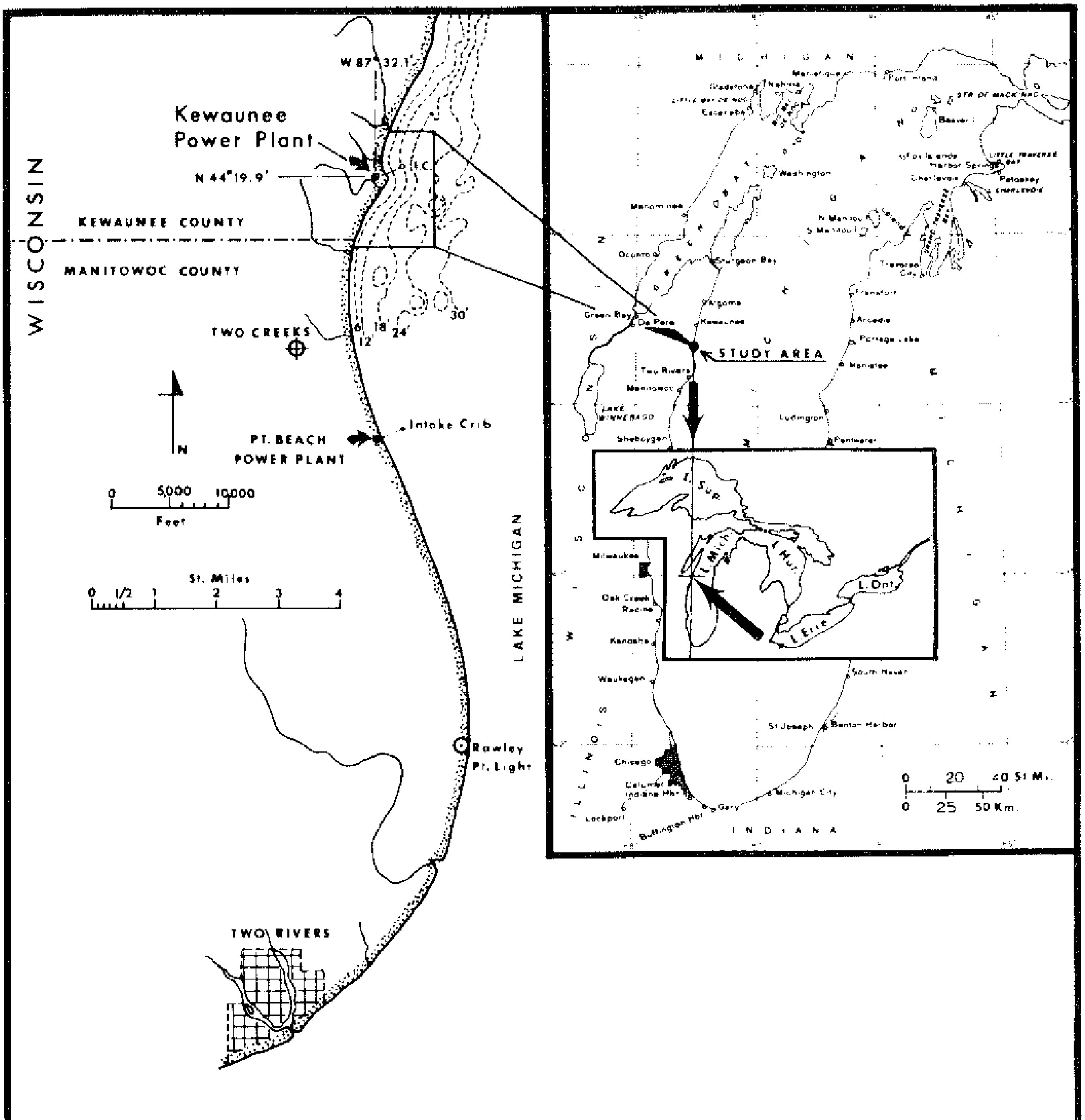

FIG. 2. LOCATION MAP SHOWING STUDY AREA

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Company and the Wisconsin-Michigan Power Company, is currently operating at close to its full capacity of 1030 MWe. The Kewaunee Nuclear Power Plant, where the present study has been undertaken, is nearing completion and is expected to be in operation by the spring of 1974, with a planned output of 540 MWe. Ownership in the latter is vested in the Wisconsin Public Service Corporation (the operators), Wisconsin Power and Light Company and Madison Gas and Electric Company.

While each of these plants has a different cooling structural design, both use lake water in a once through cycle for cooling the condensors. The Kewaunee power plant cooling system consists of an intake structure located 1570 feet offshore in 15 feet of water and a discharge structure constructed in a small basin at the shoreline (Argonne National Laboratory, 1972).

The intake is comprised of a triangular arrangement of three steel inlet ports protected by steel trash grills and connected to a common intake pipe having an inside diameter of 10 feet. A cylindrical bubble screen generated by a perforated air line located on the bottom around the periphery of the intake structure serves to ward off fish.

The inlet ports and pipeline are buried beneath the floor of Lake Michigan with the pipe sloping toward a forebay within the plant complex. Gravity flow produces an intake velocity at the grills of 0.9 fps (27.4 cm/sec) while the maximum pipe flow velocity is 11 fps (335.3 cm/sec). The maximum intake flow into the forebay is 413,000 gpm (26.1 cu. m/sec).

From the forebay the water is withdrawn by pumps and circulated through the condensers. During winter operations the intake flow is reduced to 287,000 gpm (18.1 cu. m/sec) and a small volume of discharge water is recirculated to the intake structure to prevent icing.

The discharge system consists of a 40-foot wide embayment at the shoreline protected by steel sheet piling. Under normal operating conditions the discharge velocity is 2 fps (61 cm/sec) with a rise in temperature of the cooling water of about 20°F (10°C) above ambient. In the winter the temperature rise is about 29°F (16°C) due to the lower circulation rate.

PURPOSE AND OBJECTIVES

The Kewaunee power plant site offers a unique opportunity to critically examine the immediate inshore zone of the Lake Michigan shoreline, both before and after the facility goes on stream. One of the principal objectives of this study is to determine the physical effects of the discharged cooling water on the sediment dispersal patterns along the shoreline, both north and south of the plant. It is not within the scope of this investigation to raise or explore the biological effects of heated water or radiation hazards stemming from the operation of the plant; rather the basic purpose is to monitor those physical responses of the nearshore water, the shoreline, and the contiguous upland and drainage basin which have bearing on the sedimentary processes in the vicinity of the plant.

Specific long-range objectives which have been identified within this study are as follows: (1) the baseline data will serve to establish the preoperational physical characteristics of the coastal zone within the vicinity of the plant, particularly in terms of the nearshore sediment properties, the bathymetric changes arising from the redistribution of sediments by littoral processes, the beach geometry and the rate of shoreline recession due to wave action and ice erosion; (2)parametric data of the above nature can provide a basis for developing a capability for predicting possible changes in sediment distribution and beach geometry which might be attributable to the direct or indirect influence of the discharge plume.

ENVIRONMENTAL SETTING

One of the basic operational requirements of any conventional steam-powered electric generating plant, whether fossil fueled or nuclear powered, is an adequate supply of cooling water for the condenser systems (Meredith, 1972). However, the siting of such power plants has become of such great environmental concern -- and at times quite disproportionate to the benefits that would accrue -- that serious ecological and economic issues face the owners and operators of such facilities. The most desirable plant sites, therefore, would be those localities where an economically attractive and readily accessible source of water is to be found such as the coastal zones of the Great Lakes and marine shorelands. Nonetheless, economy and accessibility in themselves do not mitigate the need for due environmental concern, particularly in terms of those particular effects arising from the emission of large quantities of cooling water, and due care must be exercised in site selection so that any environmental impact would be reduced to an acceptable level.

1. Geography

The reactor silo of the Kewaunee Nuclear Power Plant, as well as the associated administrative, public relations and utility buildings, are located near a small point of land along the western shore of Lake Michigan about 3 miles northeast of the village of Two Creeks, Wisconsin (Figure 2). The plant property occupies parts of Sections 25 and 26 of Township 22 North, Range 24 East of southeastern Kewaunee County. The power plant is set back about 660 feet from the shoreline and is located about 20 feet above mean lake level on a relatively smooth terrace-like platform whose surface dips very gently towards the lake. The topographic relief in the immediate environs is remarkably subdued with local drainage channels transecting the grounds along the southern edge of the site. Northward, the topography rises to form a prominent bluff with an elevation of approximately 50 feet above the mean level of the lake. This steep abrupt shoreline, classified as a high erodible bluff (U.S. Corps of Engineers, 1971) continues for several miles to the north and south of the plant site.

Aside from small groves of trees along the bluff crests, most of the land surrounding the power plant serves the agricultural needs of the local farming communities, particularly in terms of harvesting crops such as hay, silage corn and some oats.

The local watershed contiguous to the plant site comprises a drainage basin of approximately 8 square miles through which three streams flow and discharge into the lake ('A', 'B', 'C' in Figure 3). The largest of these streams, 'A', has its headwaters about seven miles north of the plant. The other two are shorter, intermittent and usually dry or nearly so by midsummer.

2. Precipitation and Ice Cover

Annual precipitation in this region of the Midwest is approximately 26 to 34 inches (U.S. Dept. of Agriculture, 1941) with 60% falling between May and September. In the summer, winds blow from the south to southwest about 40% of the time (Industrial-Biotest, Inc., 1972).

According to the Great Lakes Ice Atlas (Rondy, 1971), during a normal winter the maximum ice cover occurs in Lake Michigan about mid-March. At this time, some open pack ice has been observed north of Rawley Point (see Figure 2 for location), while close pack ice has been noted south of the point. During a mild winter, this part of the lakeshore is characterized by a narrow band

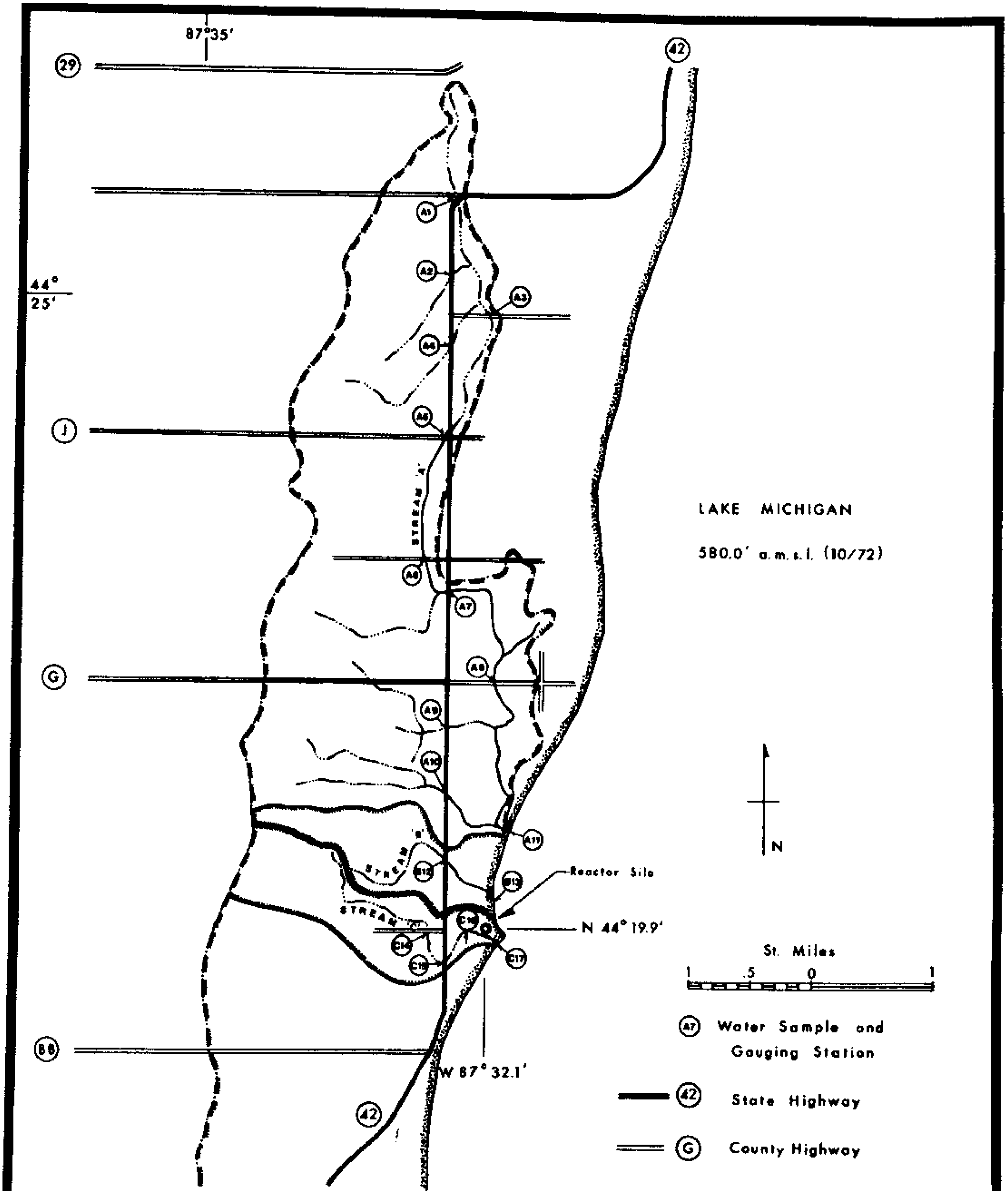


Figure 3

STREAM DRAINAGE – VICINITY KEWAUNEE NUCLEAR POWER PLANT of close pack ice along the shoreline both north and south of the point. The presence of ice within these shallow embayments is probably due to accumulation processes arising from wave refraction about the headland, an effect which tends to result in a net transport into the innermost part of the bay (cf. Strahler, 1971, pp. 278-279, 682). This condition is manifest within most of the embayments along the Lake Michigan coastline, particularly during mild winters (Rondy, 1971, plate 13). A severe winter, on the other hand, is accompanied by an extensive ice cover over a large part of the lake. North of Rawley Point, close pack ice tends to form just offshore, while a narrow inshore zone remains ice free beginning just south of the Point and extending southward along the length of the coastline approximately to Milwaukee. During spring breakup, the impingement of onshore driven ice rafts by strong winds may have pronounced effects on the erosional and depositional characteristics of this part of the shoreline.

3. Geology

(a) Bedrocks

According to engineering information provided through the courtesy of the Wisconsin Public Service Corporation and its subcontractor, Pioneer Service and Engineering Company, the foundation of the reactor chamber is located within a hard, compact, reddish brown to grayish brown clay base. Based on test borings, the bedrock which underlies this glacial deposit at an average depth of about 80 feet consists of pure to cherty, buff-colored dolomite of Niagaran or Mid-Silurian age (some 415 to 420 million years old).

The structural attitude of these bedded rocks is such that they dip very gently eastward into Lake Michigan at about one degree. Figure 4 is a reconstruction of a cross-section of the upper part of the earth's crust from Green Bay to Kewaunee and eastward into Lake Michigan, as adapted from the work of Thwaites and Bertrand (1957, p. 892, Figure 5). The eastward dipping beds are a consequence of the fact that the bedrocks along the western shore of the lake constitute the upturned and truncated western rim of a major ancient sedimentary basin in the Midwest, known as the Michigan Basin (Hough, 1958, p. 14, Figure 8). The center of this basin lies in lower Michigan, just west of Saginaw Bay, where a total section of about 14,000 feet of sedimentary rocks overlie the depressed crystalline rocks of the Precambrian Shield (Dorr and Eschman, 1970, Ch. V).

(b) Surficial Deposits

Overlying the bedrocks at the power plant site is a moderately thick deposit of glacial, interglacial and postglacial sediments derived from the Wisconsin stage of glaciation and recent sedimentary processes. According to Prest (1970, p. 718), the ice front of the Michigan and Green Bay lobes occupied this particular area some 11,800 years ago. The alternate advance and recession of glacial ice in this region resulted in the development of a number of ancient shorelines whose terraces are still visible in places along the lakeshore. Within the immediate vicinity of the plant location, a barely perceptible higher abandoned shoreline is to be found (Thwaites and Bertrand, 1957, Plate 8). This particular terrace developed when the surface of Lake Michigan stood at an elevation of about 605 feet above mean sea level, or 25 feet

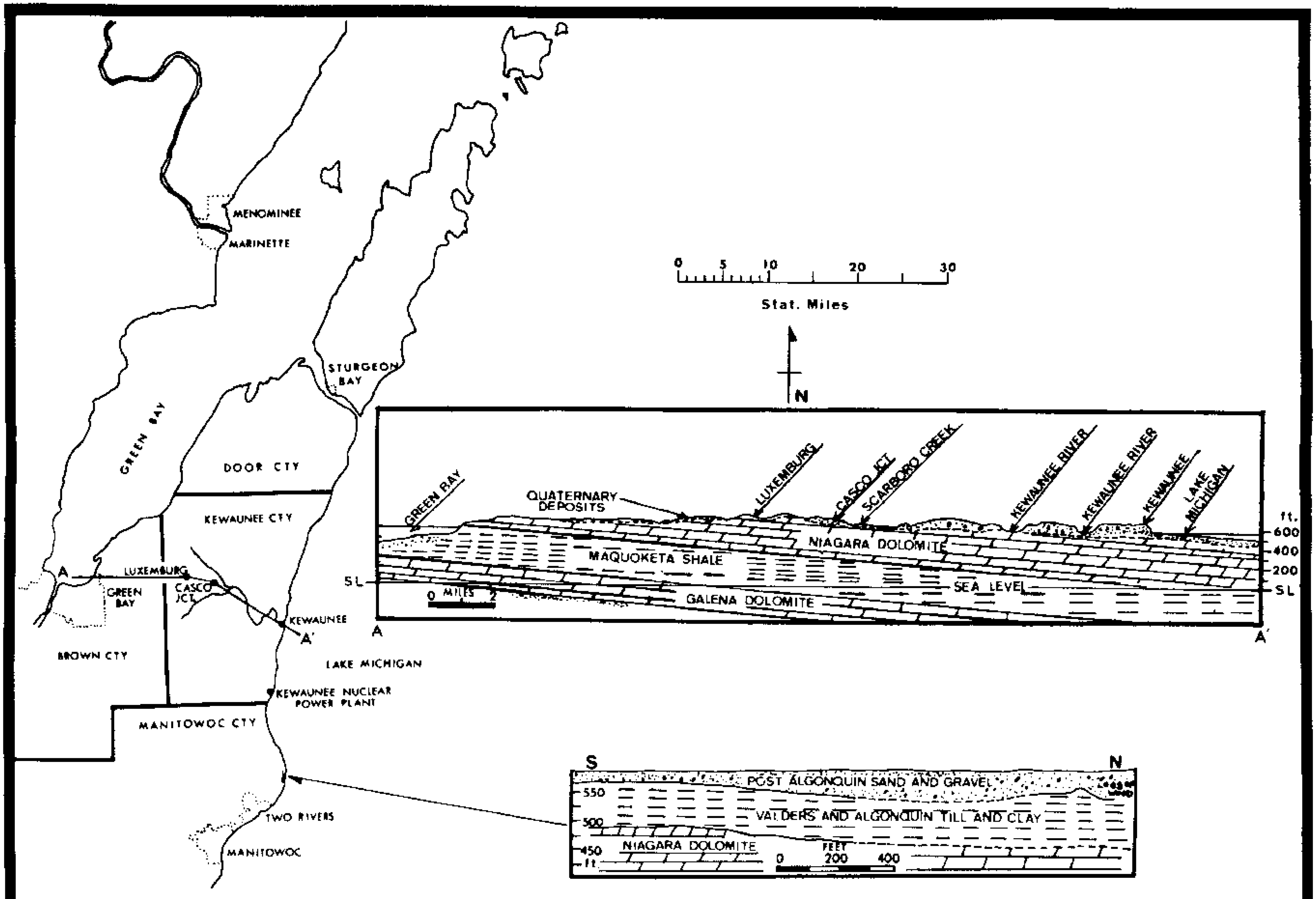


FIG. 4. STRATIGRAPHIC CROSS SECTIONS VICINITY KEWAUNEE POWER PLANT

above the present elevation of the lake surface. This higher level was attained at least twice in the late glacial history of Wisconsin, the earlier event being known as the main Algonquin stage (10,500 years before present) while the most recent is referred to as the Nipissing stage (3,000-4,000 years before present (cf. Wayne and Zumberge, 1965).

These surficial deposits appear to be the principal source of present day sediments which form the beaches and the inshore bottom deposits of the lake. The following stratigraphic sequence of Quaternary deposits is based on the interpretations of Thwaites and Bertrand (1957) with the time-rock units (sub-stages of the Wisconsin) derived from the correlations of Leighton (1960) and Leighton and Willman (1950).

(i) Postglacial (Recent)

The modern beach and lacustrine deposits comprise essentially gravels, sands and clays originating principally from the somewhat indurated tills and boulder clays of the lakeshore bluffs which are being actively eroded through strong wave action.

At the tops of the bluffs a well-developed soil horizon is clearly evident, particularly where large sections of the shoreline have slumped or collapsed into the lake. The most extensive soil type found in this area is a clay loam which supports general farming and dairying (Whitsun, et al., 1914). To a much lesser extent, fine sandy loam has developed on the glacial drift, particularly along the course of Sandy Creek (Stream 'A', Figure 3).

(ii) Glacial (Pleistocene)

The section of glacial drift exposed in the study area consists of Valders, Two Creeks and Cary substage deposits. In stratigraphic order from the top, the section comprises the following units:

Valders substage (ground moraine):

(i) red till, high in silt and clay

(ii) Pro-Valders gravel, sand, silt and clay deposited in glacial lakes which formed in front of the advancing ice

Two Creeks substage:

The classical Forest Bed consists of organic debris such as tree stumps and logs, some beach type sands and varied clays, all of which appear to be associated with an interglacial event. Lignin and cellulose separated from wood samples obtained from exposures along the Lake Michigan shoreline near Two Creeks, Wisconsin have been dated at approximately 11,850 years B.P. (Broecker and Farrand, 1963).

Cary substage: (end moraine)

(i) grey till, high in silt and clay and containing rounded boulders, cobbles and fragments of Niagaran dolomite and other rock types

(ii) glaciolacustrine deposits of varved clays

These glacial and interglacial deposits appear to be the principal sources of sedimentary materials which are being dispersed along the inshore zone of the lake in this region.

THE STUDY AREA

1. Sample Design

The area under study comprises approximately two square miles of the inshore waters of Lake Michigan with the northern and southern limits located about 1 mile north and south of the point of land on which the plant is located (Figure 5). Bottom sediment samples were collected during the summers of 1971, 1972 and 1973. Since it was felt that the most significant movement and redistribution of sediments would occur close to shore, the lakeward limit

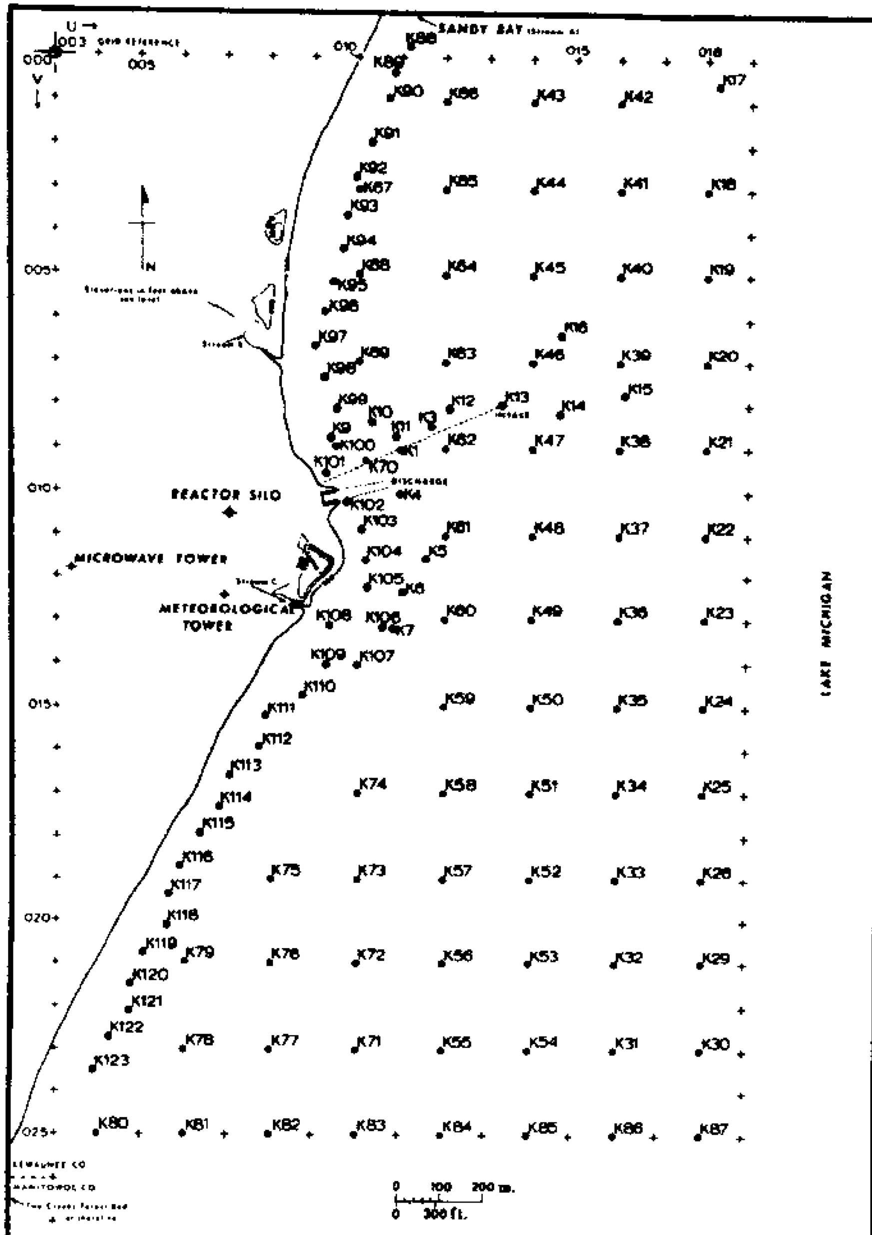
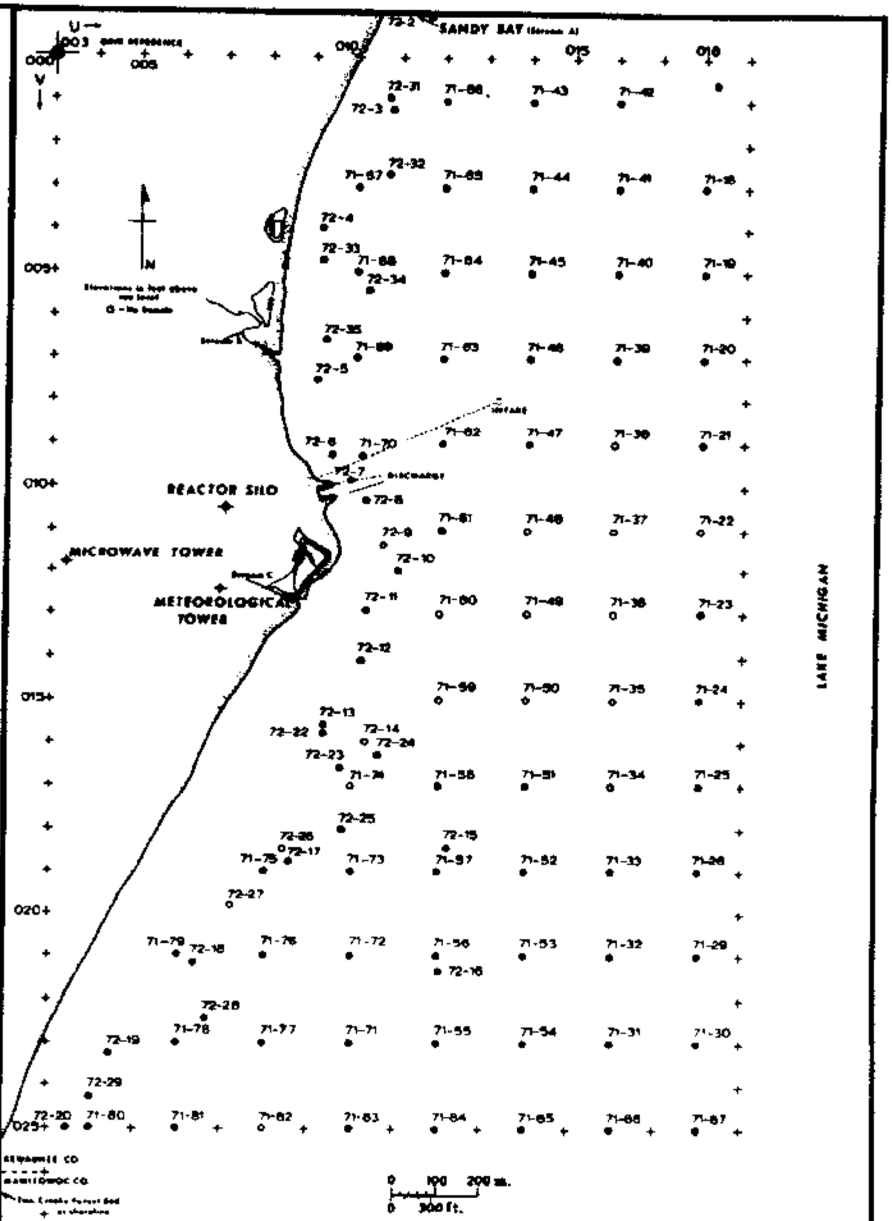


Figure 5 **SEDIMENT SAMPLING STATIONS-1971**



SEDIMENT SAMPLING STATIONS -1972

of the sampling area was set at approximately one mile offshore where water depths reach approximately 30 to 32 feet. The grid patterns for the 1971 and 1972 surveys were approximately similar in that most of the stations were located in a rectangular network, particularly where lake depths were greater than about 10 feet. Reaching these predetermined stations was facilitated through the use of the University of Wisconsin research vessel R/V AQUARIUS, using radar as the principal mode of navigation. Close to the shoreline a 19-foot outboard powered runabout was used to collect the samples but due to the difficulty encountered in attempting to reach the predesignated sites, no particular sampling pattern was adopted in the very nearshore zone. Such stations were located by compass fixes after the samples had been retrieved.

2. Field Methods

Sediment samples were collected with a Ponar grab sampler which proved to be quite satisfactory for the quantity of sediment required for grain-size analysis. While the Shipek sampler has demonstrated a high degree of efficiency in retrieving undisturbed bottom samples (Sly, 1969), the sheer weight of this sampler precludes its use aboard small watercraft where adequate winch capabilities are not normally available. The Ponar sampler, however, is readily handled by means of a small, hand-operated winch.

Upon retrieval, a brief visual description of the sample was made and then a representative fraction of the homogenized bulk sample was placed in a water-tight plastic bag with a small quantity of lake water. Water depths were obtained by means of a direct reading fathometer or a lead line. The surface temperature of the water was recorded along with the wind speed and direction and the general weather conditions were noted at the time of sampling.

During early September of 1973, 53 beach slope measurements and the same number of beach face sediment samples were taken in the swash zone along the entire shoreline at 200-foot intervals beginning at the mouth of Sandy Creek and ending approximately at the Kewaunee-Manitowoc county line (Figure 6). These data will form the basis for gauging the degree to which the shoreline is being undermined and receding as a consequence of strong wave action impinging on the clay bluffs.

A hydrological and water quality survey of the drainage basin contiguous to the plant site was initiated in the fall of 1972 and continued in the spring of 1973. At each of 17 sample stations selected along the courses of the three streams which drain the subbasin, the discharge was measured and a water sample taken (see Figure 3). The concentration of suspended particulate matter in each sample was determined according to the procedures described in Part 200 of Standard Methods (1971).

3. Laboratory Methods and Data Reduction

A representative subsample of each field sediment sample was subdivided into two fractions by wet sieving the sediment through a No. 230 (63μ) screen. The fraction finer than 4 phi was analyzed for particle size distribution by means of the falling-drop technique (Pezzetta, 1973), while the material coarser than 4 phi was dried and sieved through a nest of 3-inch diameter screens using a Sonic Sifter. The class interval for both the fine and coarse fractions was 0.5 phi, and the total spectrum of sizes generally ranged from about -1.0 phi to 9.0 or 10.0 phi. Since the most mobile grade of sediments transported in the littoral zone is to be found within this range, the very coarse particles such as pebbles, cobbles and boulders were

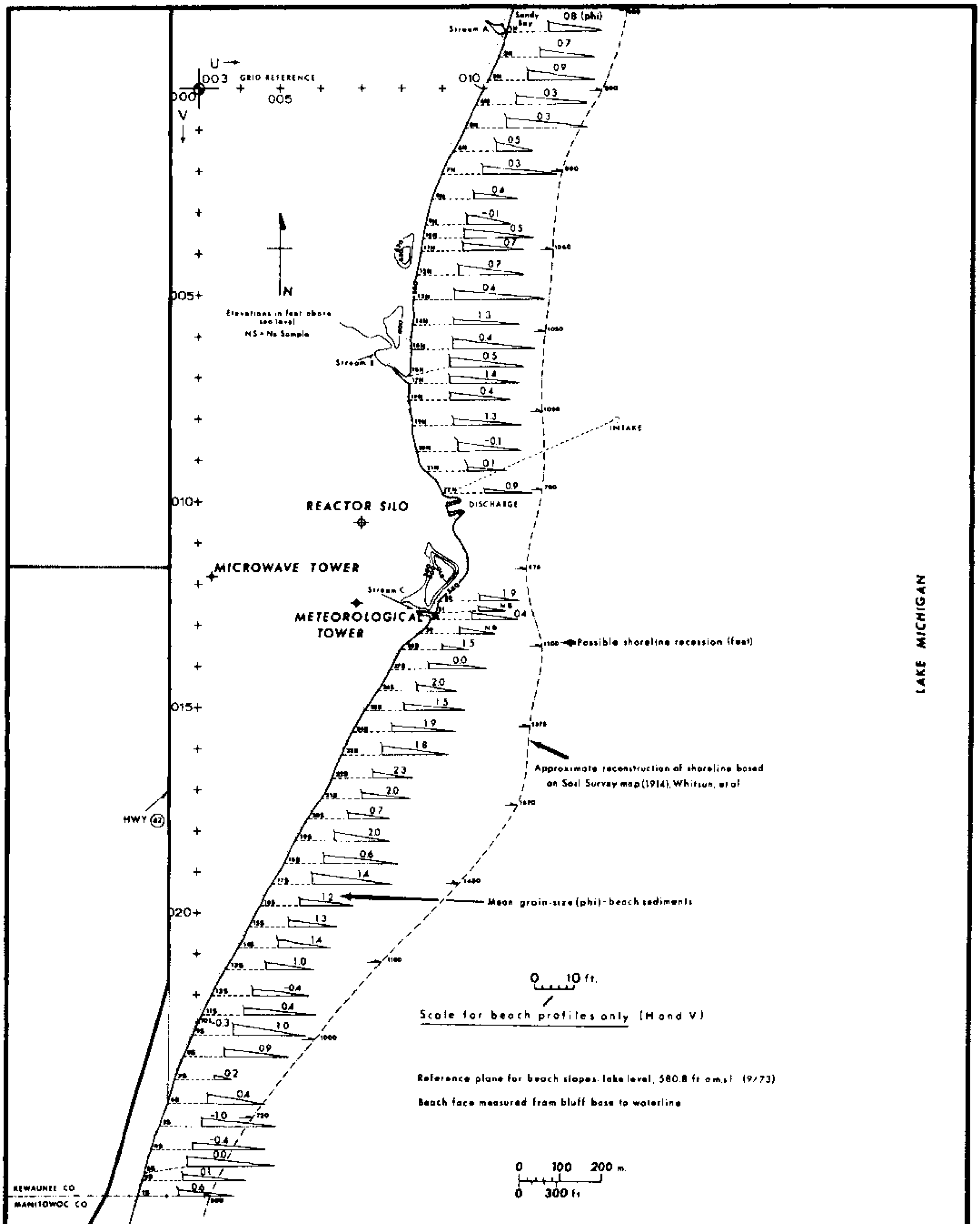


Figure 6 **BEACH PROFILES AND TEXTURES, 1973**

not included in the size distributions; however, the presence of these very large particles has been noted in the data records (see Appendix A-1 and A-2) as well as on the sediment distribution maps.

Standard statistical textural parameters derived from the weight percentage data were obtained by means of the method of moments using a computer program developed by the writer in 1968. The display of grain-size measures was in printed, graphical and punched modes which facilitated the tabulation and interpretation of the results.

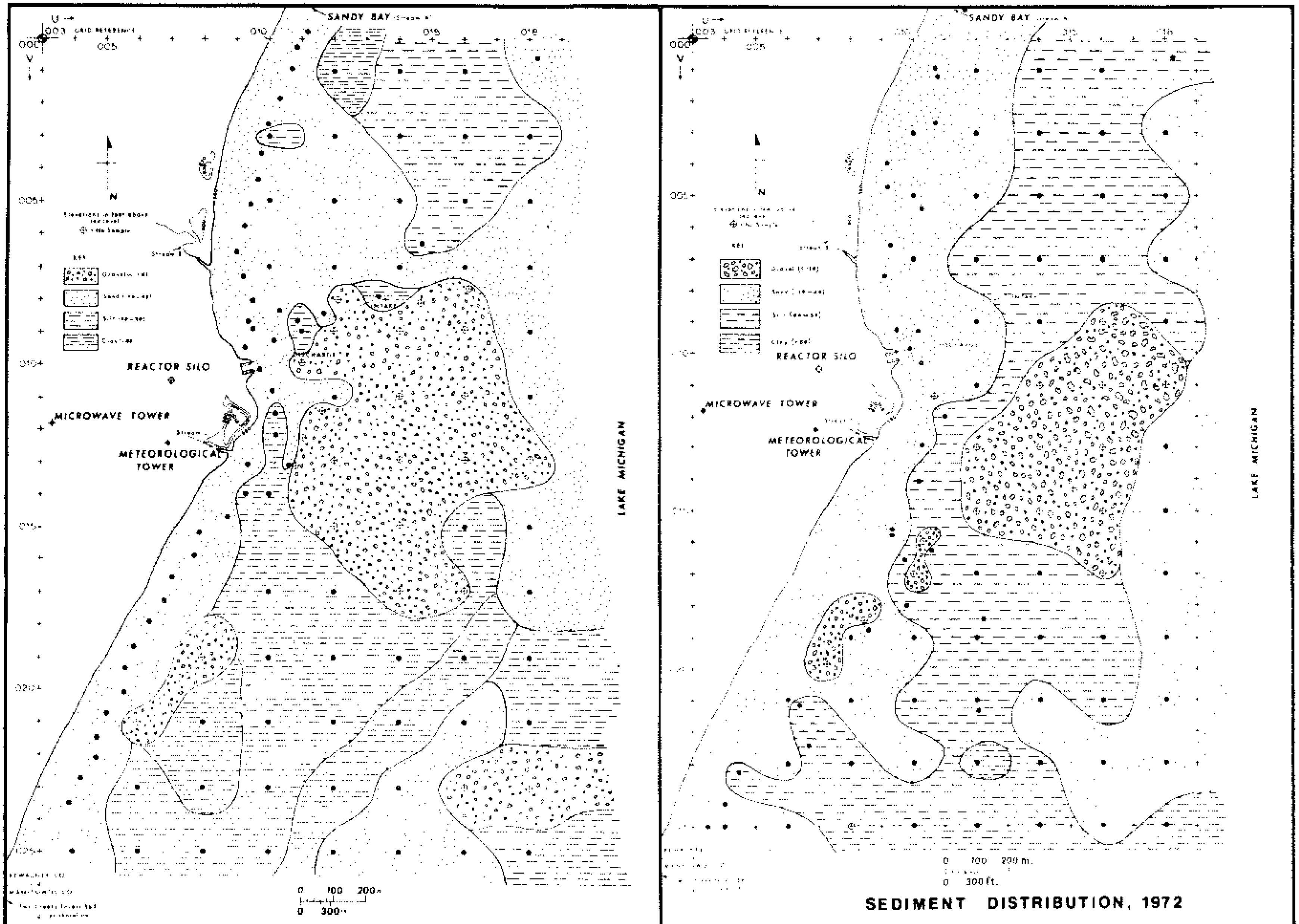
Heavy mineral components were separated from the 2Ø to 3Ø class interval (Carver, 1971) by standard sink-float techniques using bromoform as the heavy liquid (Krumbein and Pettijohn, 1938; Mueller, 1967). After the determination of the percentage distribution of the heavy minerals in each sample, a glass mount was made of a representative portion of the heavies for later identification.

The grain-size parameters and heavy minerals percentages were displayed as isopleth maps which provide a good approximation to the regional trends identified within the sampled area.

SEDIMENT CHARACTERISTICS

1. Distribution

The areal distribution of the principal sediment types (gravel, sand, silt and clay) is shown in Figure 7. These comparative maps (1971 and 1972) provide a convenient means for determining the temporal and spatial variations of the several sediment facies which characterize this area. The complex interrelationships between the sediment types in turn are a reflection of the



SEDIMENT DISTRIBUTION, 1971

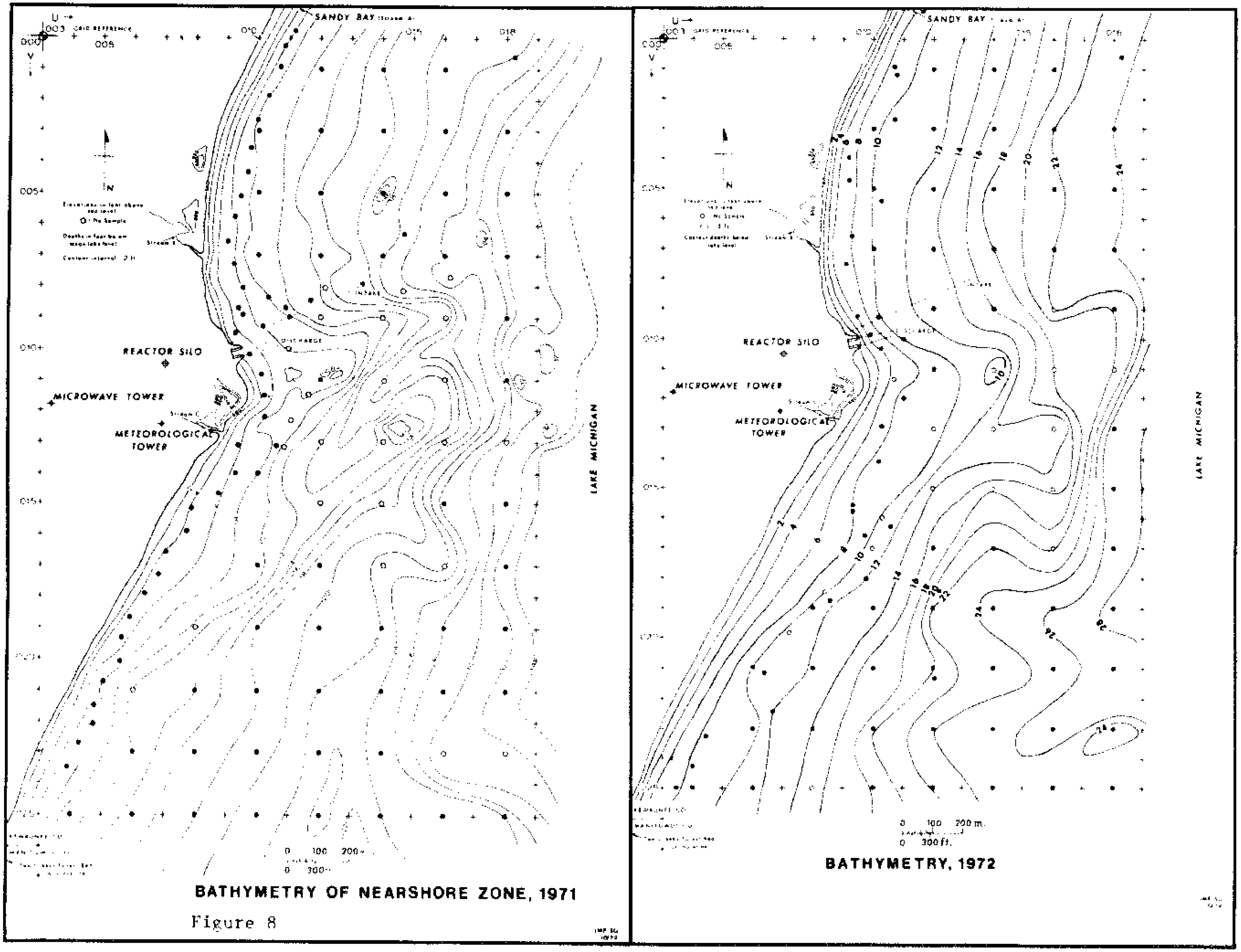
SEDIMENT DISTRIBUTION, 1972

Figure 7

delicate balance maintained between the intensity of the distributive processes operative in the nearshore zone and the influence of the bottom topography in modifying the modes and directions of sediment transport.

The bathymetric map of the study area is shown in Figure . The 1971 bottom topography in the immediate vicinity of the discharge flume is based in part on a detailed hydrographic survey conducted in 1967 by C. W. Rolland & Associates, Green Bay, for the Wisconsin Public Service Corporation. The remaining portion was interpreted on the basis of soundings obtained during the present investigation.

The most prominent topographic feature of the lake bottom in this area is the platform-like promontory which juts eastward from the plant site to about the 26-foot isobath where the bottom then assumes a more regular configuration as the water deepens. The geometry of this underwater feature suggests that this part of the nearshore zone is an extension of the point of land upon which the power plant is located. Indeed, the difficulty encountered in obtaining sediment samples from the platform appears to substantiate this observation; the area delineated by the dashed line in the distribution maps (Figures 11,12,13,14,15) and labelled "hard bottom" has yielded thus far either pebbles and cobbles, or small chunks of hard, red clay. Several attempts were made to take core samples from this area, but due to insufficient water depth, the maximum penetration attained with a Phleger gravity corer was about 1" of hard clay. Generally, the core cutting head sustained severe damage,which suggests that the cobbles strewn over this surface seriously interfere with the coring action by deflecting the tube and preventing penetration of the substrate. Barring a more intensive investigation using scuba gear, it has been concluded that this section of the nearshore zone of Lake Michigan is comprised of a hard glaciolacustrine clay surface, or perhaps an exposed area



BATHYMETRY OF NEARSHORE ZONE, 1971

BATHYMETRY, 1972

Figure 8

of dolomitic bedrock upon which are scattered numerous cobbles derived from the reworking of the Pleistocene drift deposits of boulder clay found in the adjacent bluffs. Since the major littoral transport of finer clastic debris such as sand and silt is in a north to south direction (Kohler and Moore, 1972) in a zone which tends to hug the shoreline (Figure 7), the hard bottom area is apparently kept free of all but the coarsest components. Therefore, in this highly agitated zone the strong wave action as well as the alongshore currents will preclude the deposition of the finer clastics so that the textural character of the surface of this platform tends to remain fairly uniform in spite of temporal sedimentary changes elsewhere. Indeed, the dynamic characteristics which prevail on this promontory may allow only short residence times, thereupon for all but the largest sedimentary materials.

In general, the several sediment types are irregularly distributed in this area and do not follow a gradational sequence from coarse to very fine in a lakeward direction. Instead, two prominent sheets of sand trending in a north-south direction, one close to shore and the other in the deeper offshore waters, tend to envelop a central zone which includes the gravel surfaced (rocky) platform and its two adjacent silty areas lying immediately to the north and south of the platform. The 1971 distribution map reveals that a narrow belt of sand developed in an east-west direction along the northern edge of the platform and connected the two major sand bodies. The 1972 pattern, however, shows that while this northern connective link was breached, a similar east-west trend was almost completely established south of the platform. The presence of the rocky, gravelly platform, however, remained dominant during both surveys and serves to indicate the major influence which it exerts in the distributive pattern of the more movable sedimentary components.

2. Sediment Source and Shoreline Erosion

The sediments found in the littoral zone of the study area (as well as along most of the western shore of Lake Michigan) are derived principally from the onshore glacial tills which form a veneer of variable thickness overlying the Paleozoic bedrocks. The mechanical composition of these tills varies quite widely in this part of Wisconsin. In Kewaunee county the Valders till consists of 5% gravel (>2mm), 27% sand (2 mm to 1/8 mm) and 68% very fine sand, silt and clay (<1/8 mm). At the Two Creeks Forest Bed site, the Cary till comprises 4 to 5% gravel, 27 to 39% sand and 57 to 68% fine sand, silt and clay (Bertrand and Thwaites, 1957). Offshore the lake bottom is characterized by a hard glaciolacustrine clay substrate, perhaps interrupted occasionally by exposures of dolomitic bedrocks and scattered irregular patches of boulders. The latter are derived in part from the reworking of the onshore tills during higher stands of lake level and in part through ice rafting and subsequent melting of the ice which occupied the Lake Michigan basin during late Pleistocene time. The intermediate textured, highly mobile sedimentary materials, such as sand and silt, are transported over this substrate through the action of alongshore currents.

Topographic profiles constructed for the onshore area immediately adjacent to the power plant site (Figure 9) show that the shoreline is characterized by steep bluffs which form the most prominent physiographic feature in this part of the landscape. Inland, away from the bluffs, the relief is subdued with a broadly rolling type of topography occasionally dissected by several streams which drain the area. Where the lower reaches of some of these streams transect the bluffs, the banks have a similar type of steepness as found in the lakeward facing clay cliffs.

Shoreline recession appears to result from the combined effects of percolating rainwater which prompts slope failure and oversteepening through

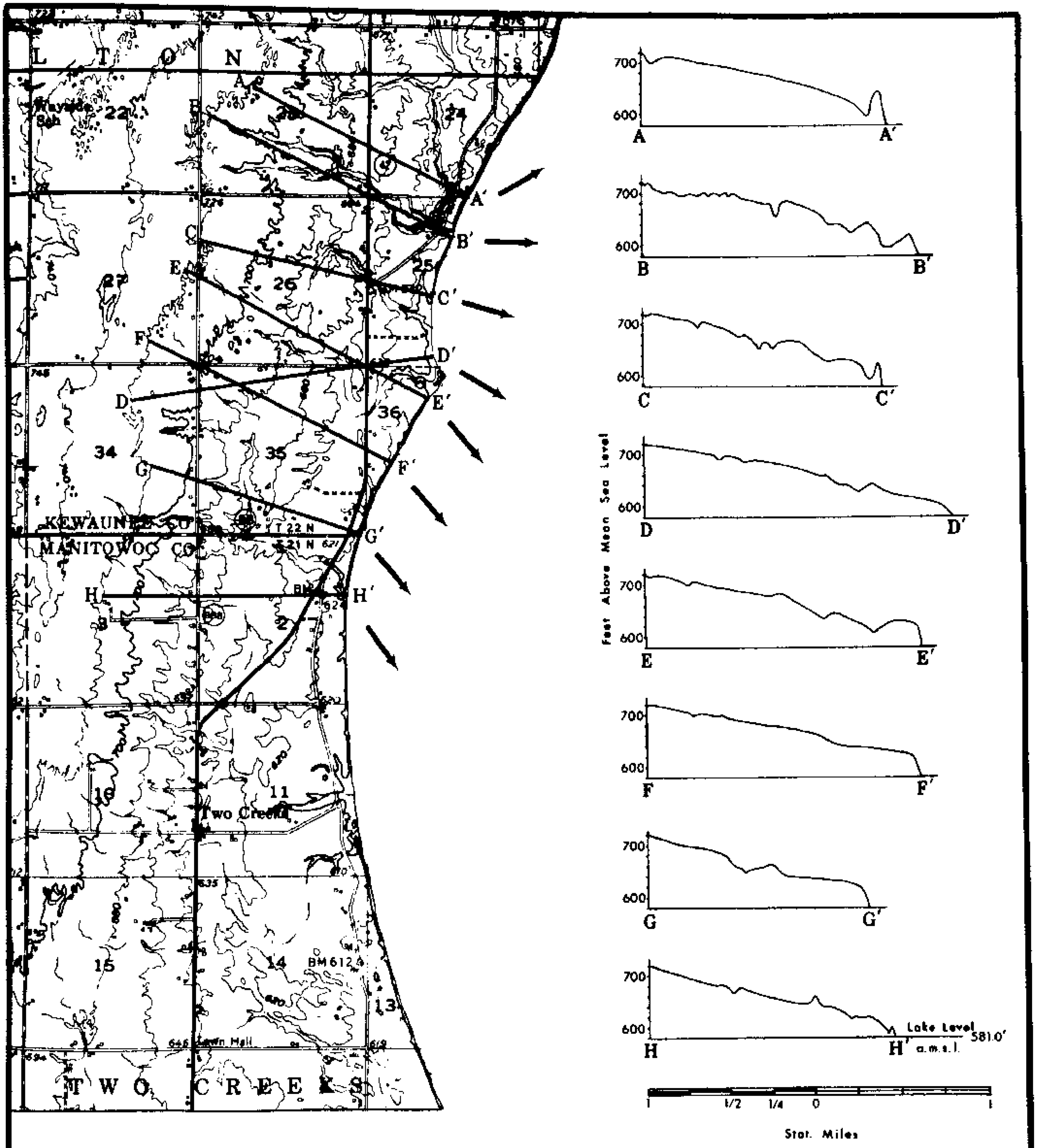


Figure 9. TOPOGRAPHIC PROFILES – VICINITY KEWAUNEE NUCLEAR PLANT

the undermining action of storm waves and wind-driven ice masses impinging on the base of the bluffs. Pincus (1964) has presented a qualitative evaluation of a number of factors which influence bluff development and shoreline retreat; these include, in addition to the above cited effects, frost action, surface wash, vegetation, as well as the competency of the sedimentary materials. The combined effect of these processes causes large sections of the bluffs to slump directly onto the beach, where reworking of the dislodged debris is effected by wave action. In recent years unusually high lake levels have accelerated the processes of shoreline erosion and recession. The narrow beaches (Figure 9) which arise from higher lake levels offer little protection to the shoreline because under these conditions the zone of intense wave activity is brought closer to the base of the bluffs. On the other hand, the development of wider beaches during lower lake levels does not necessarily prevent shoreline recession but, rather, may serve only to decrease the erosional rate. Oversteepening of the shore bluffs may still continue because of the competency of the clayey drift deposits. The cohesiveness of the glacial clays coupled with a certain degree of induration results in a somewhat blocky type of failure (Plate I), rather than normal slope angle development. In spite of the unconsolidated nature of the till deposits, the shoreline bluffs at many locations are almost vertical walls which seldom develop into natural angles of repose.

The degree to which the shoreline can be damaged by ice effects depends on several factors: the presence or absence of an ice foot (fast ice), the strength and direction of the wind and the competency of the shoreline materials. Since an ice foot is mechanically fastened (frozen) to the shoreline, it serves to protect the beach zone and the foot of the bluffs from further

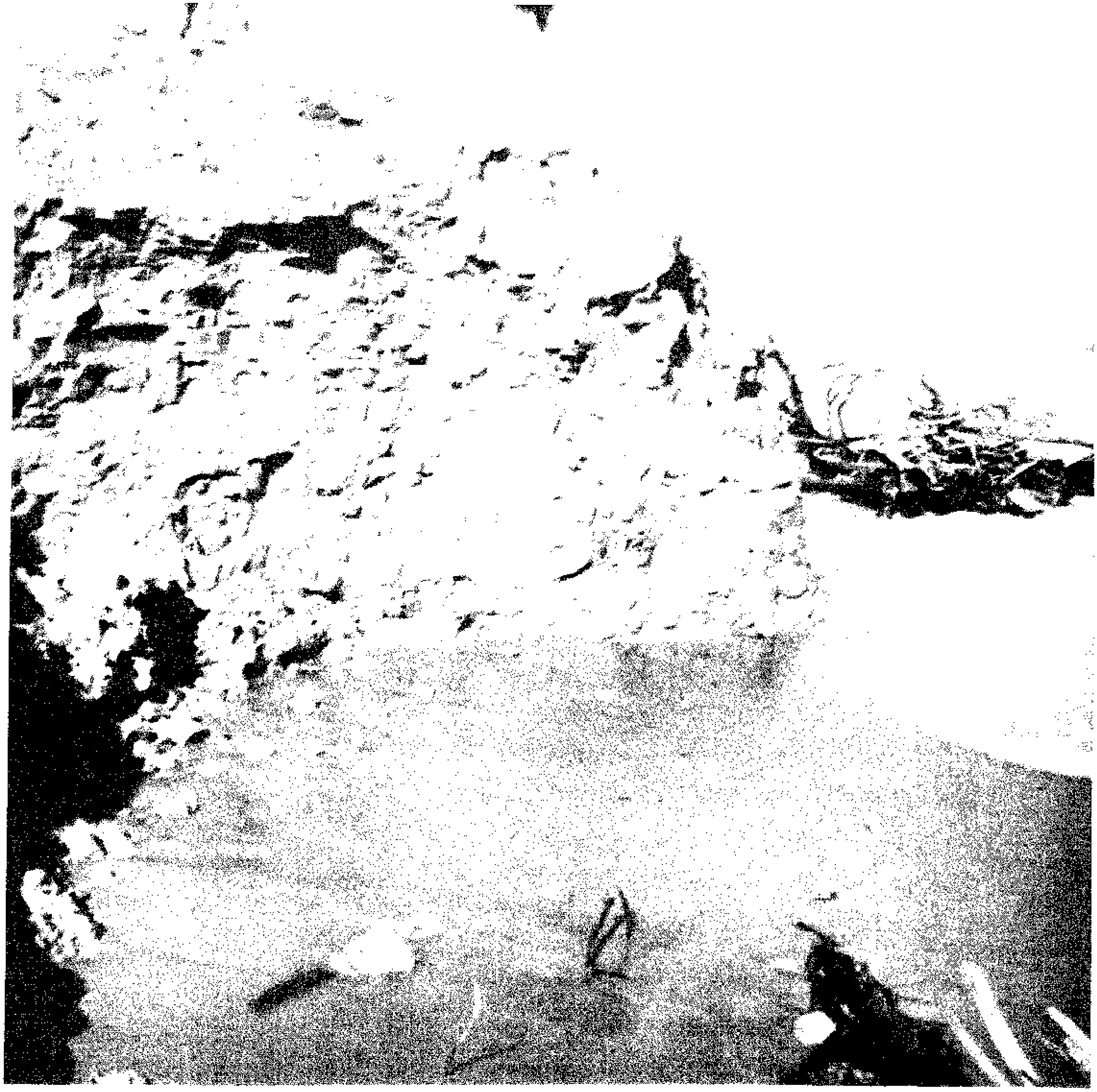


Plate 1. Blocky erosion at foot of clay bluffs.

erosion. However, this is only a temporary condition that is readily disrupted by strong onshore winds which dislodge and break up the ice foot and drive the ice masses ashore. Offshore winds, on the other hand, tend to keep the inshore zone swept free of ice by blowing the ice blocks into the open lake; however, this condition exposes the beach area to attack, either by storm waves alone or by onshore driven ice masses.

The effectiveness of these processes, whether due to ice or waves, depends, in turn, on the nature of the shoreline materials — bedrock surfaces will not be as severely affected as weakly-bedded or unconsolidated sediments. Since most of the shoreline in the area of study consists of glacial tills of varying composition, considerable damage can result from winter ice erosion, particularly during periods of high lake levels.

In Figure 6 the dashed line running approximately parallel to the present shoreline is a reconstruction of the possible position of the lakeshore in this area as it might have appeared some 60 years ago. The earlier location is based essentially on a soil survey map of Kewaunee County compiled by Whitsun, et al. (1914) and, hence, due caution is advised in interpreting the degree of shoreline recession as inferred from the superposition of the older shoreline on the present map. While the figures given probably represent the maximum possible degree of recession, due allowance must be provided for inaccuracies stemming from cartographic errors inherent in the older survey map.

Agricultural practices employed in this region also may have an important bearing on the rate of shoreline recession along this part of the coastline. During a photographic survey conducted in October 1973, it was noted that the land surface along the bluffs was tilled in such a manner that the furrows were oriented parallel to the bluff edge. This not only hastens the percolation of surface water into the lower horizons but also permits the furrows to act as troughs where excess moisture can collect. This effect is especially pronounced along the perimeter of the field near the bluff crest because there the outermost furrow tends to be somewhat deeper and wider than the others. Water channelled and concentrated in this furrow would quickly saturate the soil zone near the edge of the bluff. Hence, deep, V-shaped cracks which were noted along the bluff crest (Plate II) probably developed through frost action wedging out slices of the bluff face. This zone appears to be especially vulnerable to frost action because the outer face of the bluff offers no resistance to the expansive force of the freezing water. Consequently, the wedging action would induce the separation of large slices of clayey till from the upper face of the bluff and this process in turn would cause slumping or collapsing of the loosened masses of glacial debris (Plate III).

Surface runoff within the drainage basins of the three streams 'A,' 'B,' and 'C' does not appear to be a major source of sediments reaching the lakeshore in this area. The suspended sediment loadings, as well as other hydrologic characteristics of each stream, are given in Table A-3 of the Appendix. The highest concentration of suspended sediments was observed at the mouth of stream 'A' (Station A-11) during the fall of 1972. Much lower values were noted at the mouths of streams 'B' and 'C' (Stations B-13 and C-17, respectively). However, these figures may not necessarily represent the seasonal amount of sediment contributed to the lakeshore by these streams because the discharge rates at the stream mouths are largely a function of the presence or absence there of a transverse wave-built gravel bar. It has been observed that the gravel bars choke off the stream mouths for a large part of the year and under these conditions

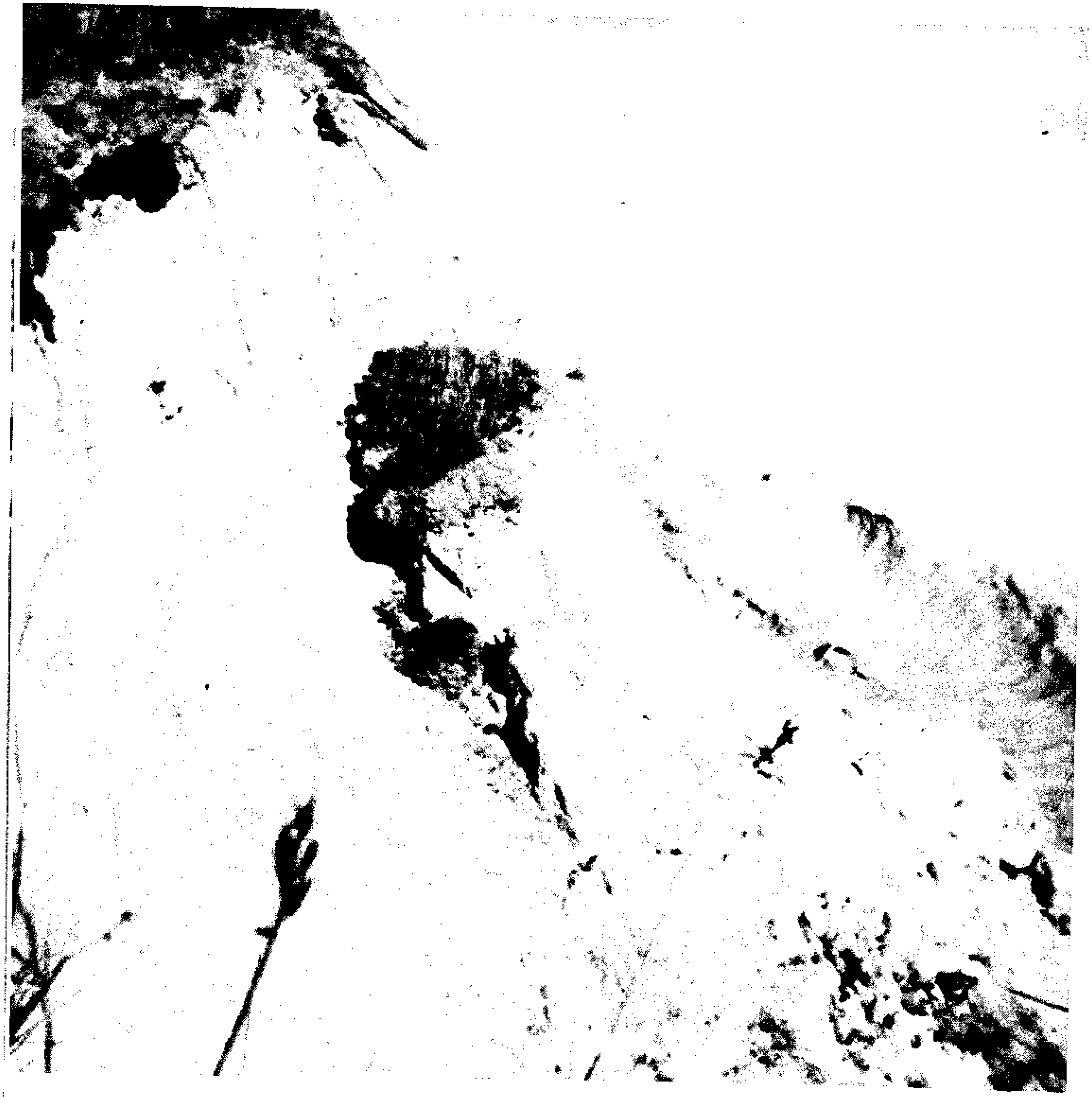


Plate III. Slumping along face of clay bluffs.

drainage to the lake is effected principally by seepage through the bars. Hence, sediment carried into the lower reaches of the stream would tend to settle out in the pool that develops on the inside of the bar. However, higher discharge rates, particularly those which may accompany spring thaws, serve to breach the gravel bars and provide direct access to the lake. This periodic flushing action probably contributes the bulk of stream-borne sediments to the inshore zone after which storm waves quickly re-establish the gravel bar which again obstructs the stream discharge.

3. Sediment Textural Characteristics

a) Mean grain-size and standard deviation (sorting or dispersion):

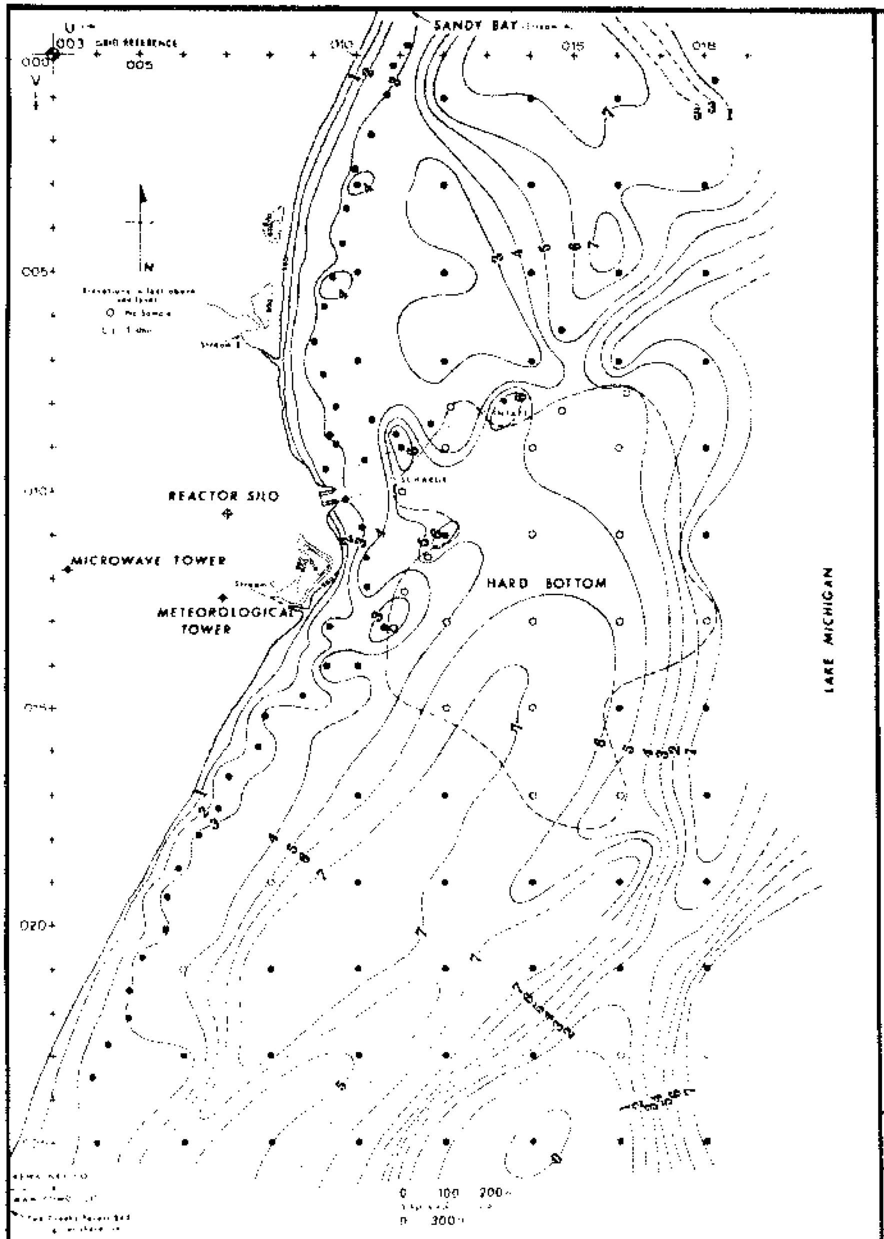
Spencer (1963) has shown that distinctive relationships (summarized in Table 1) exist between the mean grain-size of naturally occurring sediments and their degree of sorting. Using the dispersion scale proposed by Folk and Ward (1957), it was found that the medium to very fine sand components tend to be well-sorted while the fine-grained end members, such as very fine silt and coarse clay, generally are very poorly sorted. Coarse to fine silt fractions, on the other hand, exhibit the poorest degree of sorting with coefficients sometimes exceeding values of 4.0 phi.

Comparison of the regional trends for these two parameters (mean and standard deviation (Figures 10 and 11) indicates that Spencer's model is in fairly good agreement with the sedimentary environment as identified during the 1972 survey, but only partially so for the 1971 distribution.

Deviation from the proposed model is most pronounced for the 1971 survey in the offshore zone southeast of the rocky platform where coarse to fine silt fractions exhibit a higher degree of sorting than that implied from the interpretations of Table 2. This suggests that the 1971 survey may have followed a period of intense and vigorous wave and current dispersion, during which there may have existed a closer correspondence between the

Textural Category	Mean Size ϕ	Standard Deviation ϕ	Degree of Sorting Folk and Ward Scale (1957)
Very coarse and coarse sand	<1.0	>1.0	Poorly sorted
Medium to very fine sand	1.5 to 4.0	0.4 to 1.0	Well sorted to moderately sorted
Coarse to fine silt	4.0 to 7.0	2.0 to >4.0	Very poorly sorted to extremely poorly sorted
Very fine silt and coarse clay	7.0 to 9.0	2.0 to 3.0	Very poorly sorted

Table 1. Relationship between texture and sorting of sediments (based on Spencer, 1963).



MEAN GRAIN SIZE (PHI), 1971

Figure 10

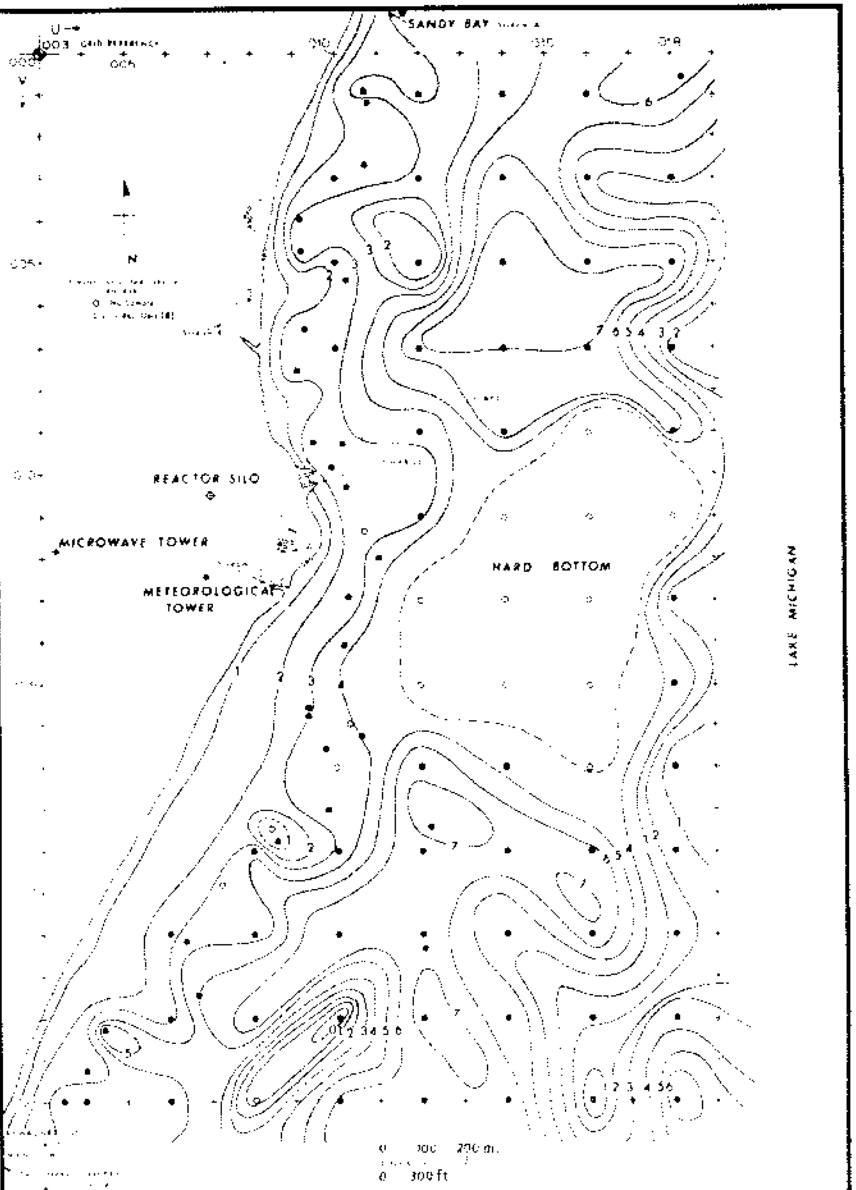
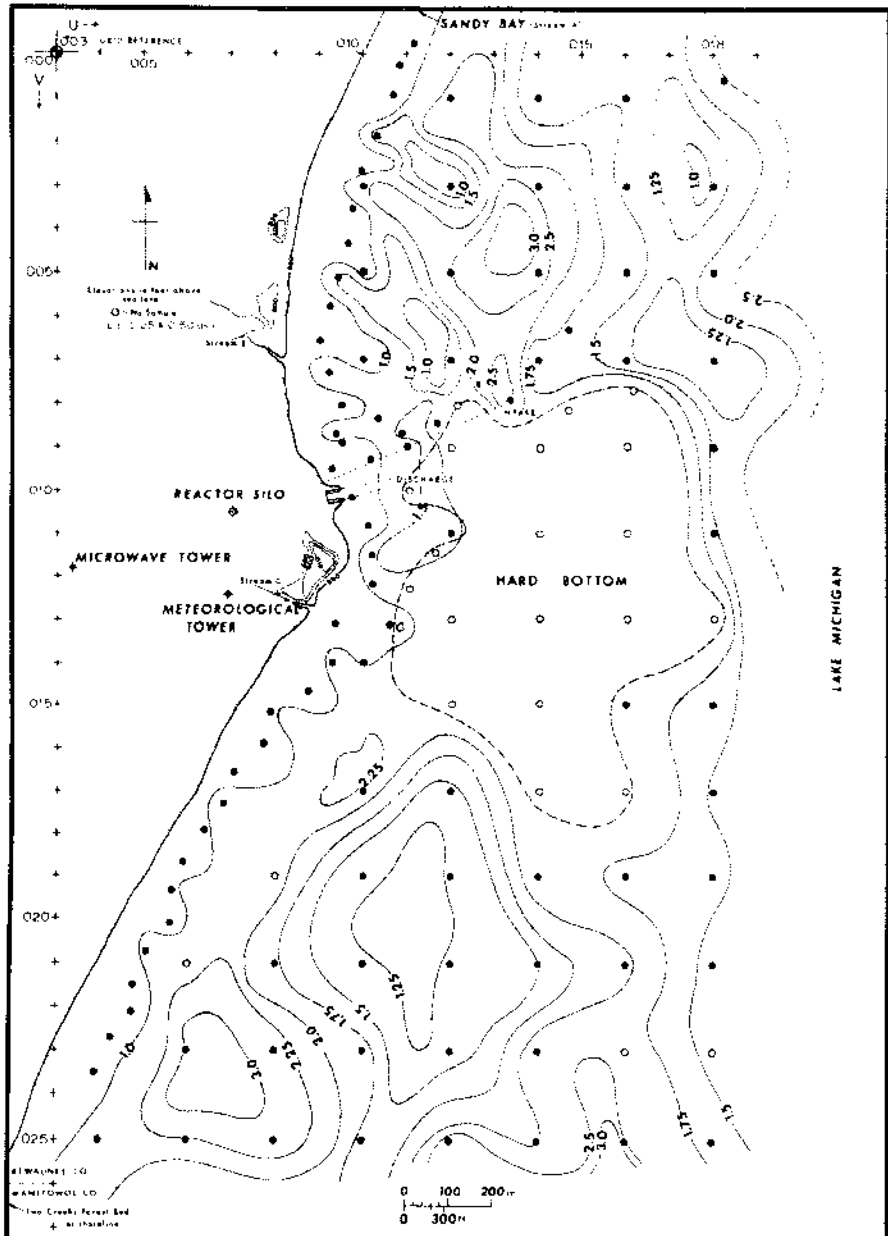
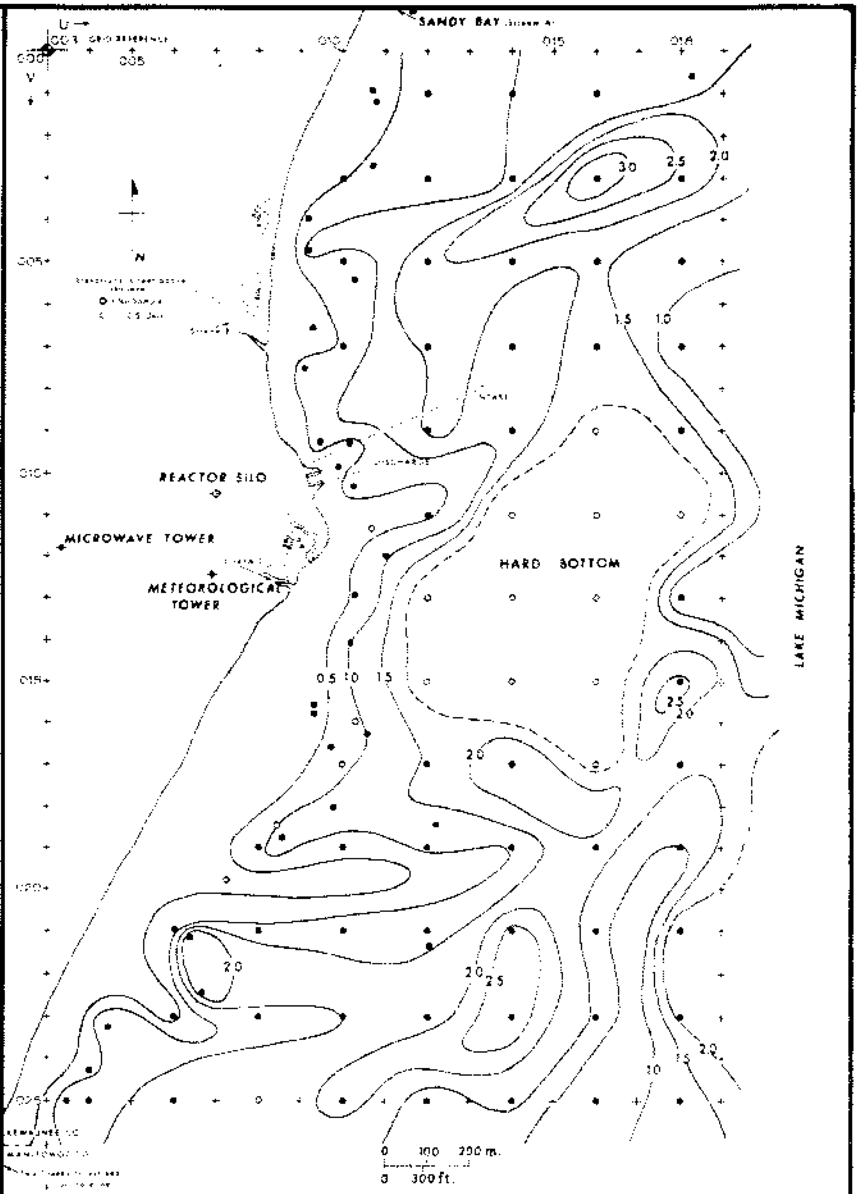


FIG. MEAN GRAIN SIZE (ø), 1972



STANDARD DEVIATION (SORTING COEFF.), 1971

Figure 11



STANDARD DEVIATION, 1972

size of the sediments and the energy required to move the components in that area.

The high mobility of the fine to medium sand fractions is attested to by the low entrainment velocities (16 to 45 cm/sec) required to maintain the movement of this grade of sediment (Sundorg, 1956, p. 177). Current speeds on this order have been observed in the study area in July 1971 by Grunewald (1972, p. A-17). However, lower values ranging from 5.1 to 10 cm/sec were noted by Industrial Bio-Test, Inc. during August 1972. The latter study also revealed that directional components of the currents were to the south and southwest during 40% of the observational period. Aside from the discrepancies noted in the current speeds, differences which may be due either to real changes or perhaps to instrumental variations, the dynamic conditions in the nearshore zone substantiate the suggested dispersal of clastic sediments in a general southerly direction. In particular, the inshore belt of fine to medium sand appears to be the most active zone of littoral transport. It is of interest to note here that the cuspate pattern of the 1-, 2-, and 4-phi mean grain size isopleths and the 1-phi standard deviation contour for the 1971 survey may be indicative of the dominance at that time of obliquely impinging wave trains at the shoreline. This, in turn, may be an indirect measure of the average wind field associated with the development of nearshore sand ridges.

The average texture of the beach sediments is that of coarse sand (0.77 phi). However, a slight textural difference was observed between the mean grain size of the northern beach sediments (0.57 phi) and that of the southern section (0.98 phi). The slightly finer texture of the latter may be attributed to the availability of larger quantities of fine grained clastics or to the influx of finer components winnowed out of the northern beach area and transported into the southern beach environment.

At the time of this survey, the mean width of the northern and southern beaches, as measured along the slope face from the waterline to the base of the clay bluffs, was approximately 15.6 feet and 13.4 feet, respectively.(Fig.6) The corresponding mean slope angles for each portion of the beach were determined to be 7.5° and 7.4°, respectively. Wherever a distinct berm was present, the slope changed slightly from a steeper beach face to a flatter backshore zone; however, this is not apparent from the scale of the profiles shown in Figure 6. Berm deposits generally were composed of well-rounded gravel deposited above the waterline by storm waves. These gravel ridges tend to offer some degree of protection to the finer-textured sediments of the backshore from the scouring effects induced by normal wave action associated with average weather conditions.

b) Skewness:

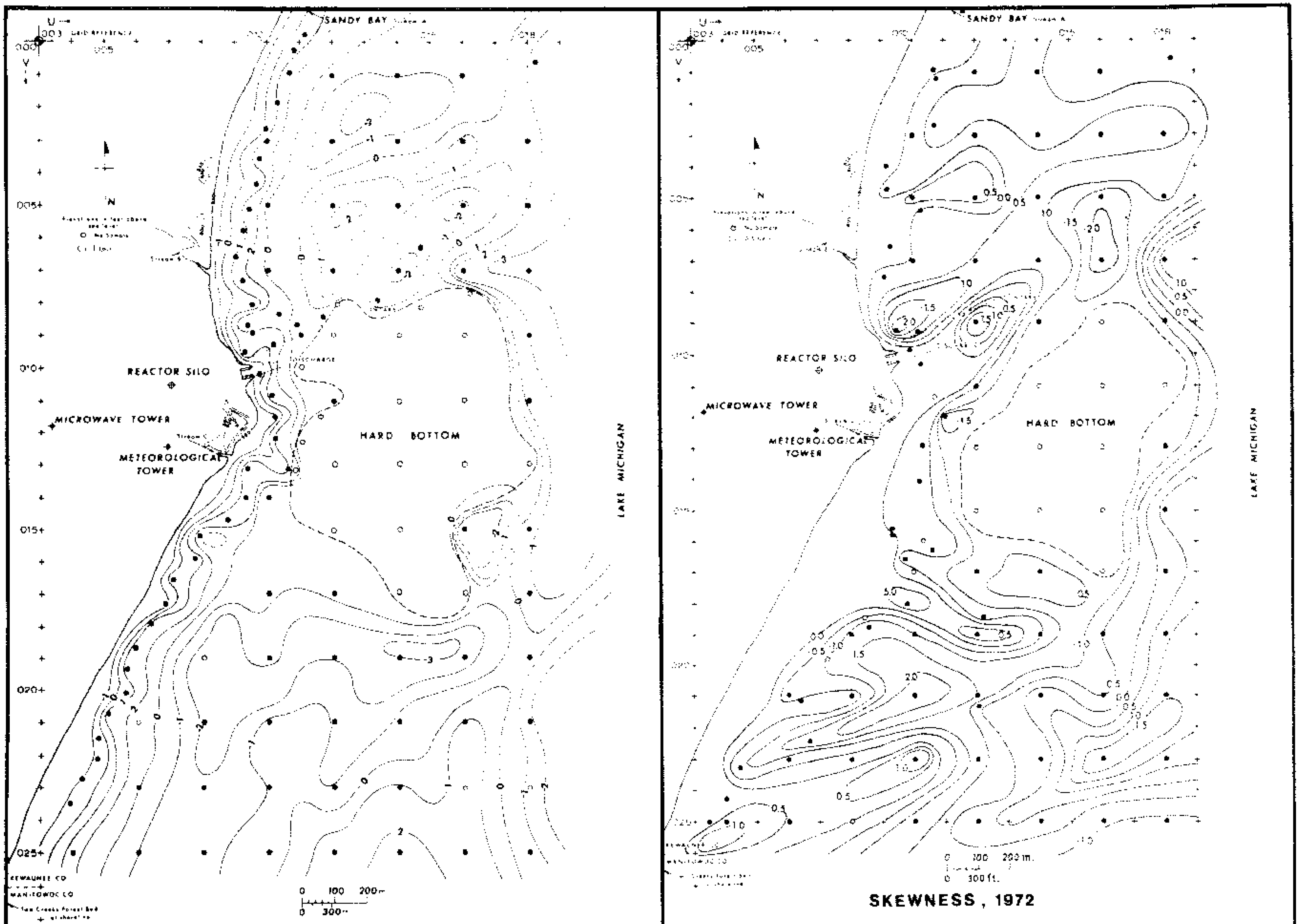
Skewness is a measure of the non-normality or asymmetry of a grain-size distribution. Geologically, it is interpreted to be an indication of the degree of mixing of two log-normal populations of grain sizes (Folk and Ward, 1957; Spencer, 1963) with the sign of the skewness identifying the subordinate modal class. For example, a sediment sample having a preponderance of fine-grained particles and a subordinate coarse-grained population would give a negative skewness value. On the other hand, if the coarse fraction is dominant, positive skewness would result. Bimodality of grain-size distributions, therefore, is related to dynamic processes in the sedimentary domain, which either bring together genetically unrelated sediments or which selectively remove size fractions which are compatible with the prevailing energy drives (Friedman, 1961; Duane, 1964; Martins, 1965; Fox et al., 1966).

Negatively skewed distributions generally have been associated with high energy systems such as those obtained in beach and littoral zones where the influx of small quantities of coarser-grained sediments occurs (Mason and Folk, 1958). The regional distribution of the skewness values for the 1971 and 1972 surveys as shown in Figure 12 bears out this interpretation. The narrow belt of highly mobile sediments which hugs the shoreline is also identified by a similar narrow zone of negative skewness for the grain-size distributions. The environmental sensitivity of this parameter is further manifest just south of the rocky platform where a highly negatively skewed distribution trends in an east-west direction. The interpretation attached to this is that a transverse component of the southerly currents is directed eastward towards the deeper part of the lake.

c) Kurtosis:

The kurtosis parameter serves as a test for the degree of normalcy of the grain-size frequency distribution. As a dimensionless measure it is expressed as the ratio between the dispersion (sorting) in the central part of the distribution and that in the tails. The coefficient of sorting, however, is understood to be a measure of the degree to which a sediment has been subjected to sorting processes. The geometric significance of kurtosis can be recognized by examining the shape of the frequency distribution curves in terms of the amount of flatness or peakedness of the curves. Flat distributions are termed 'platykurtic' curves, while sharply peaked curves are called 'leptokurtic;' normal distributions are 'mesokurtic.'

The sedimentological interpretation of this statistical measure is that leptokurtic distributions of sediments tend to be unimodal and, hence, reflect good sorting processes. Platykurtic distributions, on the other hand, are indicative of mixing processes which bring together non-genetically related sediments. Mason and Folk (1958), Fox, et al. (1966) and Pezzetta (1973) have demonstrated the use of this parameter as an environmental discriminator in terms of energy drives.



SKEWNESS, 1971

SKEWNESS, 1972

Figure 12

The close correspondence between leptokurtic grain-size distributions and generally low values for the standard deviation (hence, good sorting processes) is shown in Figure 13. This is particularly evident in the 1971 survey where local zones of high kurtosis values, such as along the northern and southern flanks of the platform, are also characterized by the lowest values of dispersion. For the 1972 survey, a similar relationship of relatively high inverse correlation was noted to exist between the distributions of these two parameters, standard deviation (dispersion) and kurtosis, even though local anomalies (regions of high and low values) showed some displacement with respect to the 1971 survey. Hence, while the integrity of the correlations was fairly well maintained in 1971 and 1972, the positions of the anomalies shifted in response to fluctuations in the intensity and direction of the sedimentary processes.

4. Sediment Composition (Heavy Mineral Distributions)

The areal distribution of heavy mineral components is shown in Figure 14. It is interesting to note that during both surveys the highest concentrations occurred directly north and south of the "hard bottom" area and along the narrow neck in the inshore waters immediately adjacent to the point of land. This again emphasizes the dominant influence which the "hard bottom" platform area exerts on selective transport processes in this nearshore environment. The remarkable correspondence between the distribution patterns of the kurtosis parameter (Figure 13) and the heavy minerals (Figure 14) is clearly exemplified in the 1971 survey. Areas showing high concentrations of accessory (heavy) minerals are closely correlated with leptokurtic grain-size distributions, i.e., high values of kurtosis. Conversely, low concentrations of the heavy fractions correspond with platykurtic (low kurtosis) grain-size distributions. This

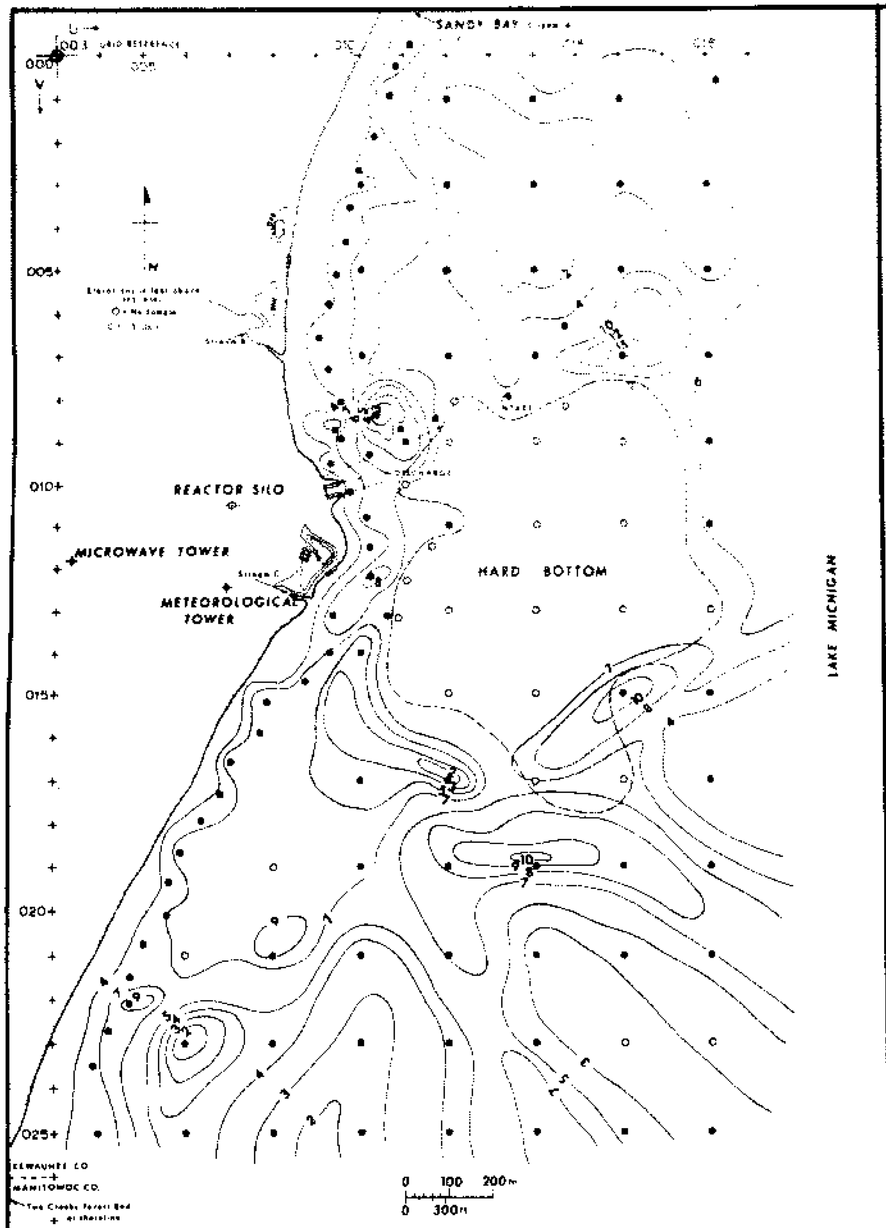
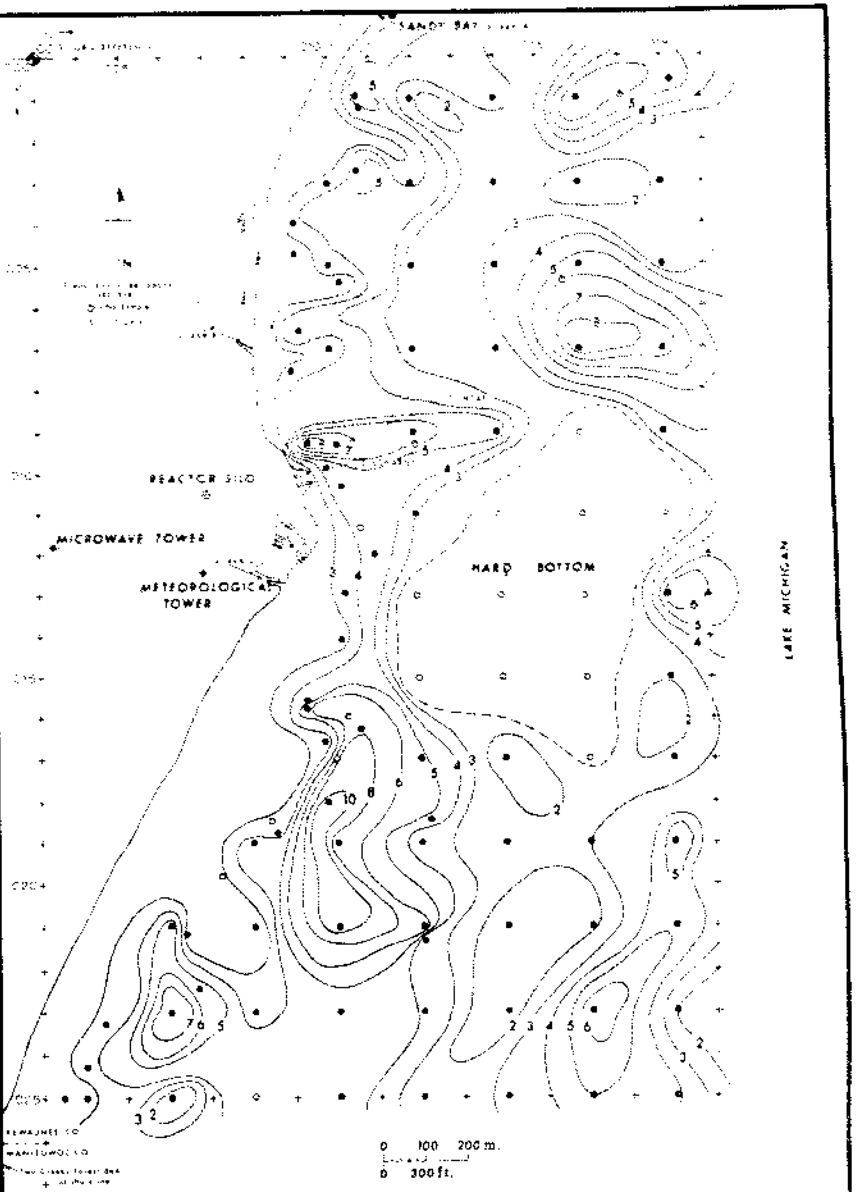
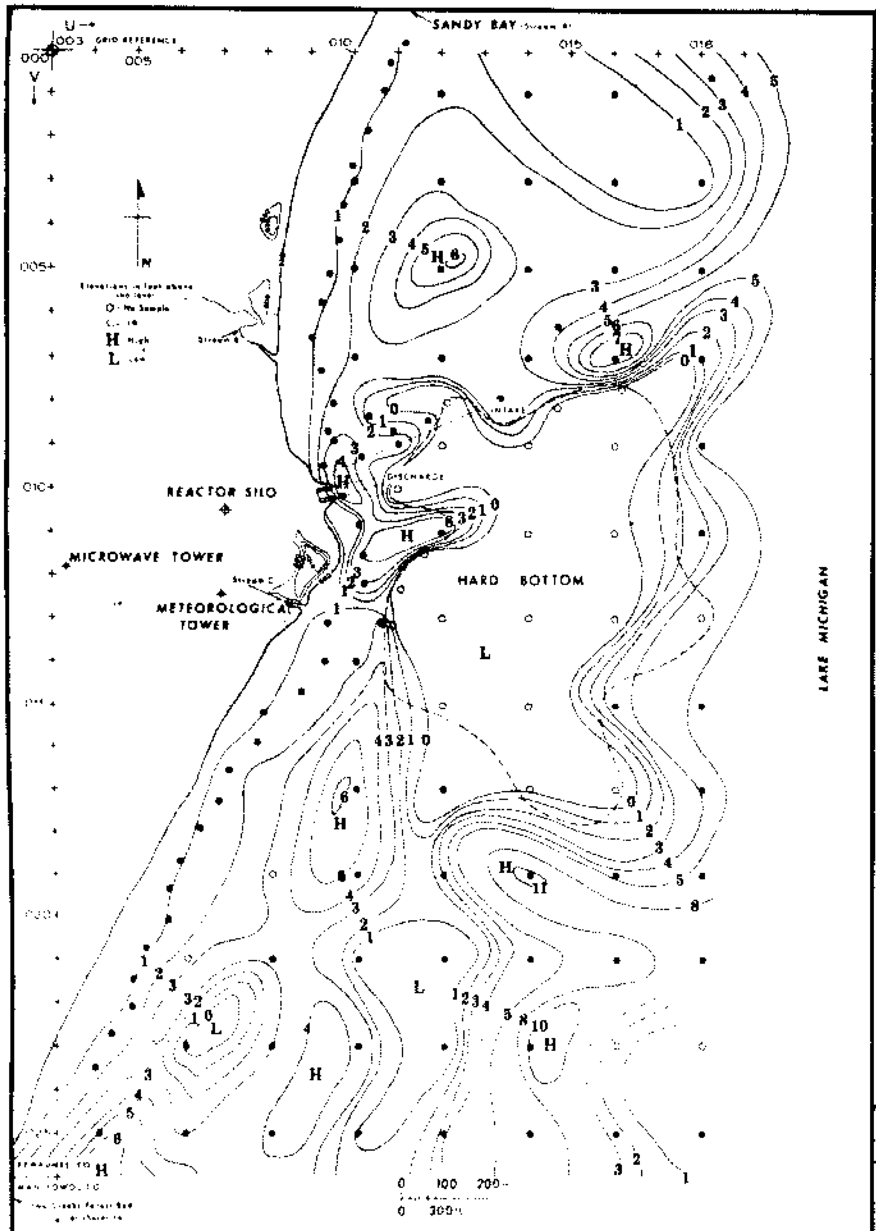


FIG. KURTOSIS, 1971

Figure 13

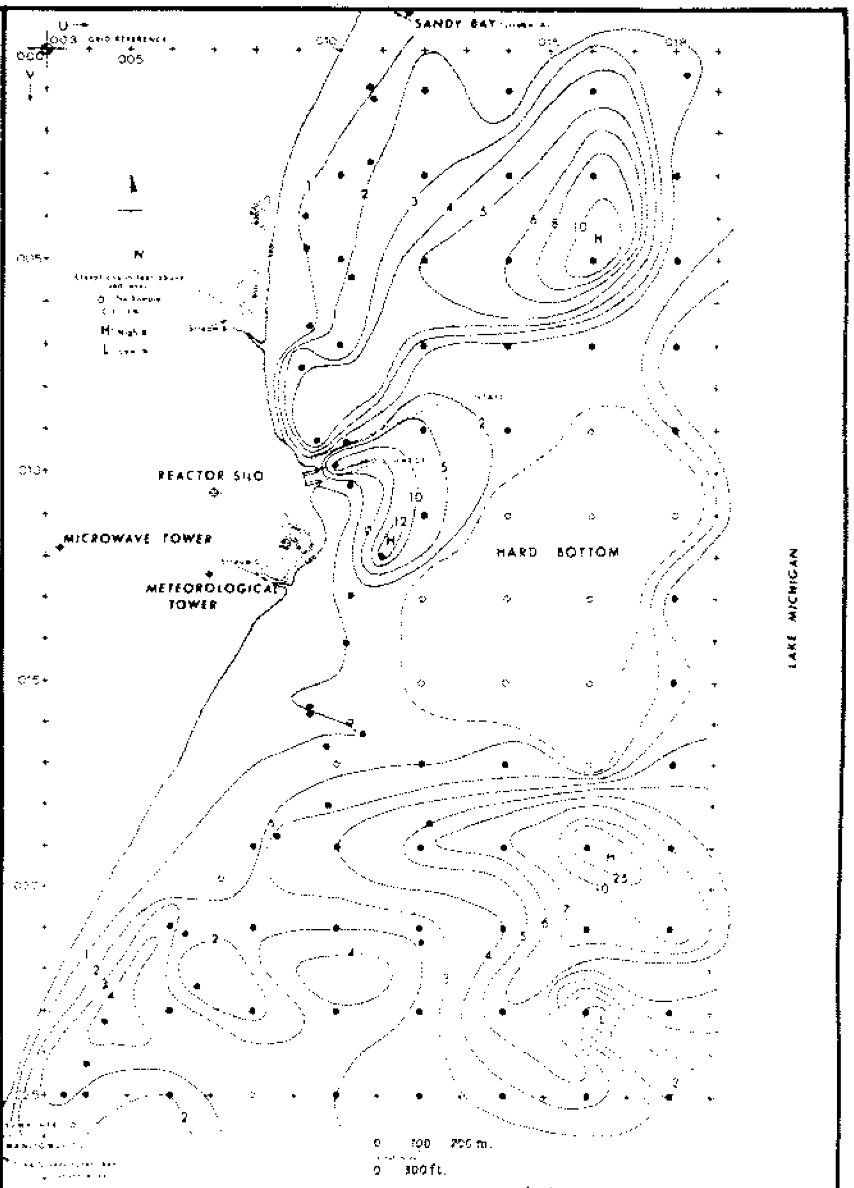


KURTOSIS, 1972



HEAVY MINERAL DISTRIBUTION (%), 1971

Figure 14



HEAVY MINERALS (%), 1972

relationship between the kurtosis of a grain-size distribution and the percentage of heavy minerals is not necessarily fundamental; rather the correspondence alluded to suggests that if heavy minerals are present in substantial quantities, then such sediments may be characterized by leptokurtic grain-size distributions.

While the full geologic significance of the kurtosis parameter has yet to be realized, the inference in this case is that since this statistical device is an indirect measure of the intensity of the sedimentary processes, it should also provide a means for assessing the gross composition of the sediments. The principle which obtains herein is that the distribution of residual ('lag') sedimentary components such as the heavy mineral suite (sp. gr. > 2.89) should be a function of selective processes which are sufficiently energetic to maintain through the winnowing of lighter components, unimodal and, hence, leptokurtic grain-size distributions. While this presupposes that most detrital sediments contain at least small proportions of accessory minerals (commonly less than 1%), this assumption is not unreasonable, particularly since this has been clearly demonstrated through the investigations of such workers as Rubey (1933), Rittenhouse (1943), Pettijohn (1955), and Van Andel and Poole (1960).

If sufficient evidence accrues, however, to establish a general correlation between these two properties of clastic sediments, then the fourth moment measure should provide the sedimentologist with a convenient guide for the preliminary assessment of placer deposits having potential economic significance.

Identification of representative portions of the heavy minerals had not been undertaken at the time of writing; however, high proportions of magnetite were noted in many of the heavy mineral suites. Fractionation of this species of the opaque heavy minerals was accomplished by means of a magnetic separator, a rather simple device which readily segregates these particular mineral grains from the rest of the sample. The non-opaque heavies, on the other hand, are to be classified by means of standard petrographic techniques.

While heavy mineral identification serves a useful guide in determining the provenance of the nearshore sediments, the patterns of heavy mineral concentrations, as noted in this survey, provide a means for determining the nature and vigor of nearshore processes. The October 1973 photographic survey of the northern and southern sections of the beach zone provided an opportunity to observe the dynamic conditions along this section of the lakeshore. The shoreline bluffs, 30 to 40 feet above the lake, offered convenient vantage points from which the beach processes could be easily noted. One striking example of this was the pattern of lakeward 'streaking' of irregularly scattered sheets of heavy minerals along the beach face. These streaks were oriented obliquely to the strike of the shoreline and the effect gives clear evidence of the efficacy of swash action or wave runup in redistributing the sediments along the beach. Therefore, lag beach deposits of high specific gravity such as the heavy minerals may be indicative of periods of intense and severe storms during which times the beach environment is most vulnerable to the destructive and erosional effects of high waves.

DISCUSSION AND CONCLUSIONS

This study has provided a comprehensive description of the nearshore sedimentary environment of Lake Michigan in the vicinity of the Kewaunee Nuclear Power Plant during the pre-operational or construction phase of the facility. The background information which has accrued over a period of three years is intended to establish a suitable base of reference from which changes in the sedimentary regime can be adequately assessed after the plant goes on stream. The principal objective in this continuing investigation ultimately is to determine whether the jetting action of the discharged cooling water will significantly alter the natural sedimentary processes operative along this part of the lakeshore. Since the interruption or interception of littoral transport processes may also result in changes to the beach geometry, the study has been extended to include an examination of the hydrology, topography and surface erosion of the contiguous watershed.

The following observations have been noted in the course of this investigation:

a) Offshore zone: Variability in sediment textures and distribution patterns appears to be markedly influenced by the bottom topography in the immediate offshore waters and by the intensity and direction of wind-generated waves and longshore currents.

The promontory-like extension of the point of land upon which the plant has been built is comprised of a very hard glaciolacustrine clay substrate upon which are strewn coarse gravels and boulders. Portions of this area may also consist of exposures of dolomitic bedrock; however, no direct evidence was obtained to support this contention other than the extreme difficulty encountered in attempting to obtain samples from this surface, as well as the frequent and severe damage sustained by the core sampler in most of the "hard bottom" area. This moderately shallow environment is well above the depth of storm wave base so that a powerful scouring action occurs during periods of heavy surf.

Sedimentation patterns in the study area are characterized by well-developed pockets of silt along the northern and southern flanks of the salient; there the generally southerly-moving currents are deflected in a lakeward or eastward direction. Local eddies may develop along these deeper flanks as the maximum wave transport is dissipated through friction along the rough surface of the shallow, rock-strewn platform. Littoral transport, however, persists in a very narrow zone parallel to the beach where coarser but highly mobile sands are carried from the northern beach around the point and into the southern region.

A significant, though nonfundamental, direct correlation was found to exist between the fourth moment measure (kurtosis) and the distribution of lag deposits of heavy mineral concentrates, a relationship which may find wider, practical application in the study of economic mineral resources.

b) Transition (beach) zone: The beach deposits are comprised of coarse sand, the northern sector being characterized by a slightly greater mean grain-size than the southern sector. Predominantly southerly directed longshore currents probably account for this discrepancy by winnowing out the finer components and depositing them in the southern beach environment.

The cuspate pattern of the nearshore grain-size isopleths reflect the effects of obliquely impinging waves along this part of the Lake Michigan shoreline. The swash zone is often characterized by irregular, lakeward-streaking patches of heavy minerals which are derived from the nearby bluffs of glacial drift.

c) Onshore zone: The primary source of sediments deposited within the study area is to be found in the adjacent glacial drift deposits which form steep clay-rich bluffs right at the shoreline. Hence, glacial processes are the primary determinant of sediment type while local secondary processes such as waves and currents are the principal means by which the sediments are redistributed along the inshore zone.

Delivery of these sediments to the beach environment is effected through wave-induced undermining at the base of the clay bluffs and subsequent bank failure through slumping or direct cascading. Bank recession is further accelerated by seasonal processes such as frost wedging along the crests of the shoreline bluffs and long term effects such as excessively high lake levels. Saturation of the soil and subsoil horizons is prompted through agricultural practices in which the tilling of the surface occurs almost to the edge of the bluff and parallel to its strike. The extreme outer furrow acts as an effective drainage ditch and permits rapid percolation of moisture into the lower substrate. High water content in the porous till deposits beneath this soil permits rapid soil and bank failure through frost action. This process in effect wedges out slices of till parallel to the face of the bluff and thereby induces instability in the segments so loosened.

Oversteepening of the shoreline bluffs is attributable to the high clay content of the glacial till which causes a blocky type of erosion. Sandy lenses in the till, however, tend to wash out and develop gentler angles of repose which are characteristic of non-cohesive materials.

The surfaces of the bluffs are gently rolling except in the vicinity of the three drainage streams which transect the area adjacent to the plant site. There the steeply dipping stream banks have erosional characteristics similar to the faces of the shoreline bluffs. The three streams, however, may contribute only minor quantities of sediment to the littoral zone because during most of the year the stream mouths are choked off by gravel bars. Perhaps the greatest contribution of stream-borne sediments to the lake occurs during spring breakup when higher discharge rates may serve to breach the bars and periodically flush out the sediments which have collected in the small lagoons on the upstream sides of the bars.

In 1973 a radial pattern of sampling sites was employed in which the discharge bay was used as the point of departure for each sample transect. This permitted a higher sample density in the area which would be influenced most directly by the discharge plume. Mapping of the textural properties of these sediments is presently in progress so that a third set of comparative data will be available in the near future.

Continuation of the sediment monitoring program, particularly in the immediate vicinity of the discharge zone, should permit some assessment to be made of the effect of the jet-like plume of water on the natural sedimentary processes operative in this nearshore environment.

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APPENDIX

Table A-1 Lake Michigan Nearshore Station Locations and Sedimentological Data

KEWAUNEE PROJECT SAMPLE DATA 1971

SAMPLE NO.	GRID POINT	DEPTH (FT)	MEAN PHI	MEDIAN PHI	STD. DEV.	SKEW-NESS	KUR-TOSIS	PCT. SAND	PCT. SILT	PCT. CLAY	PCT HEAV MIN
K001	11-09	10.0	6.17	5.98	1.14	-0.69	4.58	1.6	96.7	1.7	2.6
K002	10-09C	7.5	3.00	2.29	1.00	2.40	11.23	93.7	5.7	0.6	2.2
K003	12-09D	13.0	3.59	3.00	0.83	1.47	8.22	86.5	13.5	0.0	0.8
K004	11-10	8.0			COBBLES						
K005	12-11C	8.0			COBBLES						
K006	11-12B	9.0			NO SAMPLE						
K007	11-13C	10.5			NO SAMPLE						
K008	SDBAYZ	6.0	2.64	2.07	0.58	2.32	15.07	98.4	1.6	0.0	3.0
K009	09-09A	6.7	3.10	2.42	1.69	3.03	12.09	90.5	4.6	4.9	2.4
K010	10-08B	10.0	3.63	2.98	1.29	0.66	3.04	68.7	31.3	0.0	0.6
K011	11-09D	11.0	6.25	6.13	1.58	-0.71	4.50	7.3	82.0	10.7	1.7
K012	12-08B	15.0			COBBLES						
K013	13-08A	17.0	6.29	6.85	2.68	-1.50	4.65	14.9	44.0	41.1	2.1
K014	15-08C	21.0			COBBLES						
K015	16-08A	25.0			NO SAMPLE						
K016	15-06C	21.0	5.74	4.83	1.70	0.68	4.66	3.0	83.4	13.6	3.7
K017	18-01A	22.0	0.81	-0.13	2.48	1.50	4.90	89.1	8.6	2.3	3.3
K018	18-03	27.0	6.19	5.97	1.03	0.03	3.67	0.9	93.9	5.2	INSD
K019	18-05	22.0	2.22	1.46	2.15	0.99	3.55	80.6	19.4	0.0	4.4
K020	18-07	28.0	2.22	1.87	1.04	3.39	19.22	96.4	2.9	0.7	1.0
CK020	18-07	28.0	7.58	7.71	2.01	-1.63	6.36	6.0	44.8	49.2	1.3
K021	18-09	26.0	2.41	1.84	1.49	1.95	6.51	89.0	11.0	0.0	5.3
K022	18-11	26.0	0.47	0.07	1.49	1.23	6.25	98.2	1.8	0.0	2.5
K023	18-13	29.0			NO SAMPLE						
K024	18-15	30.0	1.04	1.16	1.69	0.53	4.36	96.6	3.4	0.0	5.2
K025	18-17	33.0	0.08	99.99	1.49	0.40	1.46	100.0	0.0	0.0	4.0
K026	18-19	22.0	6.75	6.63	1.13	-0.60	5.43	0.4	90.1	9.5	INSD
K027		30.0	6.24	5.48	2.07	-0.22	2.95	8.7	64.5	26.8	2.6
K028		31.0	1.75	1.16	1.66	2.64	10.49	92.9	3.9	3.2	5.4
K029	18-21	33.0	6.83	6.90	1.13	-1.72	7.00	1.2	93.3	5.5	INSD
K030	18-23	31.0			COBBLES						
K031	16-23	31.0			COBBLES						
K032	16-21	29.0	2.11	1.52	1.93	1.05	4.33	87.0	13.0	0.0	6.2
K033	16-19	28.0	7.94	8.34	1.68	-2.29	8.27	5.4	26.7	67.9	3.2
K034	16-17	22.0		NO SAMPLE							
K035	16-15	27.0	5.89	6.25	1.81	-2.56	10.34	8.0	88.7	3.3	3.7
K036	16-13	11.5			NO SAMPLE						
K037	16-11	16.0			COBBLES						
K038	16-09	17.0			NO SAMPLE						
K039	16-07	22.0	1.82	1.48	1.20	2.67	15.57	96.0	2.7	1.3	7.2
K040	16-05	23.0	6.93	6.89	1.69	-2.08	9.77	5.5	77.6	16.9	2.8
K041	16-03	21.0	6.10	5.55	1.44	0.40	3.42	0.7	89.8	9.5	INSD
K042	16-01	21.0	7.13	7.00	1.42	-0.29	2.64	0.2	67.1	32.7	INSD
K043	14-01	18.0	6.87	6.88	1.02	-0.80	3.93	0.2	94.2	5.6	INSD
K044	14-03	17.0	5.65	5.52	2.41	-0.16	1.58	32.8	41.3	25.9	2.2
K045	14-05	16.0	4.09	3.77	2.80	0.24	1.74	49.8	38.2	12.0	2.6
K046	14-07	20.0	2.74	2.50	1.13	1.50	8.17	94.5	5.5	0.0	3.4
CK046	14-07	20.0	7.04	7.26	1.68	-1.64	5.70	8.0	58.0	34.0	3.3
K047	14-09	12.0			COBBLES						
K048	14-11	17.0			COBBLES						

Table A-1 (cont'd)

KEWAUNEE PROJECT SAMPLE DATA 1971

SAMPLE NO.	GRID POINT	DEPTH (FT)	MEAN PHI	MEDIAN PHI	STD. DEV.	SKEW-NESS	KUR-TOSIS	PCT. SAND	PCT. SILT	PCT. CLAY	PCT. HEAV. MIN.
K049	14-13	15.0			COBBLES						
K050	14-15	18.0			COBBLES						
K051	14-17	23.0			COBBLES						
K052	14-19	22.0	4.66	5.68	2.88	-0.33	1.49	39.2	53.8	7.0	11.5
CK052	14-19	22.0	5.82	5.80	1.83	-2.17	9.80	5.2	85.0	9.8	INSD
K053	14-21	24.0	7.45	7.83	1.50	-0.92	3.59	1.0	43.9	55.1	INSD
K054	14-23	25.0	3.00	1.71	2.34	1.06	3.20	67.7	26.9	5.4	10.6
K055	12-23	23.0	7.66	7.76	1.65	-1.04	4.03	2.0	47.7	50.3	INSD
K056	12-21	22.0	6.75	6.49	1.43	-1.18	7.79	2.6	78.5	18.9	INSD
K057	12-19	21.0	6.83	6.90	1.37	-2.09	8.93	5.6	85.1	9.3	3.2
K058	12-17	19.0	7.28	7.46	1.45	-0.36	1.73	0.2	57.8	42.0	INSD
K059	12-15	13.0			COBBLES						
K060	12-13	14.0			NO SAMPLE						
K061	12-11	10.0	1.80	1.47	2.17	0.47	2.76	90.4	9.6	0.0	8.3
K062	12-09	13.0			COBBLES						
K063	12-07	16.0	2.74	2.40	1.20	2.20	9.80	94.0	6.0	0.0	2.4
K064	12-05	16.0	3.48	2.34	2.45	1.38	3.61	79.4	9.6	11.0	5.9
K065	12-03	14.0	2.74	2.54	0.55	-1.30	6.08	100.0	0.0	0.0	2.9
K066	12-01	13.0	6.61	7.01	2.24	-0.44	1.80	24.0	30.7	45.3	1.8
K067	10-03	11.0	4.81	4.09	1.94	1.02	3.42	42.0	46.9	11.1	1.1
K068	10-05	11.0	3.28	2.95	0.92	-0.51	8.36	87.6	12.4	0.0	2.6
K069	10-07	10.0	3.29	2.99	0.67	-0.16	7.27	89.9	10.1	0.0	2.1
K070	10-09B	10.0	3.31	2.92	0.92	1.35	5.47	87.3	12.7	0.0	1.8
K071	10-23	19.0	5.30	5.38	1.89	-0.76	2.33	23.0	77.0	0.0	3.5
K072	10-21	18.0	7.33	7.32	1.30	-0.99	3.72	1.3	67.0	31.7	INSD
K072A	10-21	21.0	7.54	7.56	1.26	-2.00	11.30	1.5	56.1	42.4	INSD
K073	10-19	18.0	7.57	7.34	1.36	-1.38	7.42	1.5	65.5	33.0	4.4
K074	10-17	9.0	5.60	5.33	2.25	-0.79	3.89	17.5	70.0	12.5	5.3
K075	08-19	10.0			COBBLES						
K076	08-21	14.0	7.52	7.86	1.76	-2.00	8.48	3.8	38.9	57.3	3.1
K077	08-23	17.0	7.49	7.74	2.41	-1.50	4.66	10.2	40.1	49.7	2.9
K078	06-23	12.0	2.84	4.24	3.76	-0.09	1.13	47.2	52.8	0.0	INSD
K079	06-19	12.0			NO SAMPLE						
K080	04-25	11.0	2.61	1.96	1.37	1.79	6.38	87.9	12.1	0.0	5.6
K081	06-25	15.0	5.92	5.72	2.24	-1.05	4.37	14.5	64.3	21.2	3.0
K082	08-25	18.0	4.97	4.12	2.52	0.22	2.43	21.1	60.0	18.9	4.5
K083	10-25	21.0	7.19	7.08	1.67	-0.48	2.85	1.0	59.9	39.1	INSD
K084	12-25	20.0	1.47	0.49	2.57	1.44	4.38	80.7	16.1	3.2	4.0
K085	14-25	24.0	-0.32	99.99	1.98	2.31	7.49	94.2	5.8	0.0	5.7
K086	16-25	25.0	0.75	-1.07	3.07	1.53	3.87	81.8	12.7	5.5	2.3
K087	18-25	26.0	7.39	7.46	1.62	-0.70	2.61	0.5	58.4	41.1	INSD
K088	11-00A	8.0	2.67	2.44	.59	0.52	5.87	97.8	2.2	0.0	1.9
K089	11-00C	8.0	2.77	2.50	0.60	0.22	5.74	97.6	2.4	0.0	0.8
K090	11-01D	9.0	3.01	2.73	0.64	1.69	11.19	96.1	3.9	0.0	0.8
K091	10-02A	10.0	5.19	4.78	1.54	0.96	4.20	10.2	79.9	9.9	1.4
K091A	10-02A	10.0	3.34	2.80	1.26	1.97	6.81	85.0	15.0	0.0	1.1
K092	10-03D	10.0	3.03	2.82	0.52	-0.01	4.25	96.6	3.4	0.0	0.9
K093	10-03C	9.0	3.11	2.74	0.78	1.37	6.74	89.6	10.4	0.0	1.4
K094	10-04C	9.0	3.28	2.92	0.77	0.90	4.87	83.6	16.4	0.0	1.2
K095	09-05B	9.0	4.03	3.34	1.50	1.48	5.68	59.8	35.8	4.4	1.0

Table A-1 (cont'd)

KEWAUNEE PROJECT SAMPLE DATA 1971

SAMPLE NO.	GRID POINT	DEPTH (FT)	MEAN PHI	MEDIAN PHI	STD. DEV.	SKEW-NESS	KUR-TOSIS	PCT. SAND	PCT. SILT	PCT. CLAY	PCT. HEAV. MIN.
K096	09-06A	8.0	3.16	2.73	.74	0.89	3.53	85.2	14.8	0.0	0.9
K097	09-07A	7.0	3.11	2.81	0.67	0.99	5.72	90.6	9.4	0.0	1.0
K098	09-07B	8.0	3.60	3.01	1.33	1.73	6.72	75.9	21.9	2.2	1.2
K099	09-08B	8.0	3.30	2.88	0.79	0.79	4.11	75.0	25.0	0.0	2.3
K100	09-09A	8.0	2.74	2.44	0.72	1.35	8.29	94.6	5.4	0.0	3.7
K101	09-10A	5.0	2.46	2.12	0.68	1.11	6.39	96.3	3.7	0.0	3.0
K102	10-10C	5.0	2.91	2.59	0.76	0.80	5.71	91.7	8.3	0.0	4.6
K103	10-11A	5.0	2.66	2.35	.68	1.76	8.92	94.8	5.2	0.0	1.9
K104	10-11B	5.0	4.34	4.16	1.57	-0.51	5.80	21.5	75.3	3.2	7.9
K104A	10-11B	5.0	3.71	3.94	1.43	-1.57	4.73	32.9	67.1	0.0	2.7
K105	10-12B	8.0	4.32	4.04	1.05	1.09	8.64	16.6	81.9	1.5	3.0
K106	11-13C	9.0	2.73	2.45	0.69	0.88	5.90	94.7	5.3	0.0	2.7
K107	10-14	8.0	4.34	4.26	.90	-0.69	3.11	27.3	72.7	0.0	1.7
K108	09-13B	5.5	3.08	2.72	0.62	1.51	7.52	91.8	8.2	0.0	1.6
K109	09-14A	6.5	4.70	4.38	1.19	1.06	6.99	12.2	85.2	2.6	1.2
K110	09-15D	5.5	2.58	2.26	0.54	1.40	7.57	98.0	2.0	0.0	1.5
K111	08-15C	4.5	2.97	2.58	0.85	2.45	14.08	92.2	7.5	0.3	1.0
K112	08-16D	4.5	2.75	2.49	0.42	0.68	9.77	98.2	1.8	0.0	1.3
K113	07-17A	4.5	2.78	2.51	0.51	0.27	9.09	97.9	2.1	0.0	1.8
K114	07-17C	5.0	2.10	2.33	1.42	-1.68	4.49	99.0	1.0	0.0	1.3
K115	06-18A	4.5	3.10	2.68	0.92	1.05	6.21	86.3	13.7	0.0	1.2
K116	06-19D	5.0	2.78	2.50	0.46	1.45	9.29	97.6	2.4	0.0	1.0
K117	06-19C	5.5	3.24	2.72	0.90	1.33	5.04	80.8	19.2	0.0	1.0
K118	06-20C	7.5	2.79	2.54	0.64	0.67	7.02	96.6	3.4	0.0	1.1
K119	05-21A	8.5	3.60	3.07	1.16	1.19	5.39	67.4	32.3	0.3	1.0
K120	05-21C	6.5	2.92	2.65	0.42	-0.32	5.82	99.2	0.8	0.0	1.1
K121	05-22C	8.5	3.05	2.78	0.46	-0.56	9.44	96.8	3.2	0.0	1.1
K122	04-23A	7.0	2.82	2.58	0.49	-0.76	7.84	99.0	1.0	0.0	1.4
K123	04-23C	7.0	2.94	2.71	0.53	-0.69	6.78	97.5	2.5	0.0	1.8

NOTES:
CK000 INDICATES A CORE SAMPLE.
K000A INDICATES A SECOND SAMPLE TAKEN AT THE SAME STATION.
INSD MEANS INSUFFICIENT DATA; TOO LITTLE SAND TO CALCULATE HEAVY MINERALS.

Table A-2 Lake Michigan Nearshore Station Locations and Sedimentological Data

KEWAUNEE PROJECT SAMPLE DATA 1972

SAMPLE NO.	GRID POINT	DEPTH (FT)	MEAN PHI	MEDIAN PHI	STD. DEV.	SKEW-NESS	KUR-TOSIS	PCT. SAND	PCT. SILT	PCT. CLAY	PCT HEAV MIN
K017	18-001	23.0	6.15	6.33	1.28	-1.42	5.48	3.5	96.5	0.0	2.4
K018	18-003	24.0	3.20	3.57	2.44	-.30	2.11	50.2	49.8	0.0	1.2
K019	18-005	23.0	6.92	7.22	1.36	-.91	2.60	0.2	75.3	24.5	INSD
K020	18-007	24.0	1.70	1.39	.75	1.47	7.51	95.9	4.1	0.0	3.4
K021	18-009	20.0	6.05	6.31	1.41	-.99	3.65	3.8	96.2	0.0	INSD
K022	18-011	20.0			NO SAMPLE						
K023	18-013	27.0	1.88	1.74	.73	-1.25	6.66	99.8	0.2	0.0	3.3
K024	18-015	29.0	3.67	2.26	2.50	.73	2.17	66.9	27.7	5.4	2.5
K025	18-017	27.0	.51	.65	1.45	.19	2.31	98.2	1.8	0.0	4.6
K026	18-019	29.0	1.33	1.00	.99	.84	5.62	96.8	3.2	0.0	7.0
K029	18-021	27.0	2.36	1.54	2.32	1.47	4.87	83.6	9.8	6.6	11.1
K030	18-023	23.0	3.71	2.00	2.62	.79	2.00	64.5	23.4	12.1	4.7
K031	16-023	28.0	2.42	1.80	1.46	1.98	6.56	87.6	12.4	0.0	1.1
K032	16-021	25.0	6.82	7.13	1.21	-.53	1.91	0.1	86.5	13.4	INSD
K033	16-019	26.0	6.10	6.06	1.89	-.54	3.00	9.9	75.1	15.0	52.3
K034	16-017	20.0			NO SAMPLE						
K035	16-015	15.0			NO SAMPLE						
K036	16-013	13.0			NO SAMPLE						
K037	16-011	18.0			COBBLES						
K038	16-009	22.0			COBBLES						
K039	16-007	22.0	6.98	7.47	1.99	-2.16	8.97	3.8	53.7	42.5	INSD
K040	16-005	21.0	6.76	7.08	1.59	-1.67	5.88	4.6	80.3	15.1	16.2
K041	16-003	22.0	3.25	4.90	3.77	-.25	1.22	42.0	58.0	0.0	7.4
K042	16-001	-	5.75	5.59	1.22	-1.35	6.59	3.7	96.2	0.0	4.7
K043	14-001	15.0	4.29	4.29	1.00	-.96	3.59	27.4	72.6	0.0	1.1
K044	14-003	17.0	6.49	6.50	1.06	-.62	2.26	0.0	100.0	0.0	INSD
K045	14-005	19.0	7.30	7.47	1.54	-.84	3.17	1.0	53.6	45.4	INSD
K046	14-007	18.0	7.00	7.05	1.33	-.60	2.42	0.3	67.7	32.0	INSD
K047	14-009	16.0	6.10	6.29	1.18	-1.35	5.20	5.2	94.6	0.2	1.6
K048	14-011	9.0			COBBLES						
K049	14-013	14.0			NO SAMPLE						
K050	14-015	18.0			COBBLES						
K051	14-017	22.0	4.83	5.01	2.16	-.23	1.53	38.4	61.3	0.3	2.5
K052	14-019	25.0	6.47	6.41	1.06	-.45	2.33	0.3	97.4	2.3	INSD
K053	14-021	22.0	3.55	2.14	2.55	.27	1.52	56.5	43.2	0.3	4.1
K054	14-023	25.0	5.49	5.97	2.81	-.23	1.45	36.3	35.0	28.7	5.7
K055	12-023	24.0	7.27	7.79	1.79	-1.18	3.90	4.0	44.4	51.6	2.8
K056	12-021	19.0	6.80	6.87	1.10	-1.49	6.72	1.2	93.5	5.4	INSD
K57A	12-019	22.0	6.51	6.07	1.19	.60	3.48	0.3	85.5	14.2	INSD
K57B	12-019	22.0	2.36	1.44	2.56	.31	2.01	63.9	35.9	0.2	5.8
K058	12-017	17.0	6.43	6.58	1.52	-1.38	5.22	6.5	86.9	6.6	2.0
K059	12-015	14.0			NO SAMPLE						
K060	12-013	9.0			ALGAL MATS						
K061	12-011	10.0	2.93	2.71	.47	-.05	2.99	98.7	1.3	0.0	7.0
K062	12-008	13.0	3.15	2.58	1.58	1.97	6.34	88.6	9.2	2.2	5.4
K063	12-007	13.0	6.94	6.69	1.54	-.57	2.79	1.4	62.7	35.8	INSD
K064	12-005	13.0	1.19	.57	1.97	.55	2.38	87.9	12.1	0.0	5.0
K065	12-003	11.0	3.10	2.87	.66	-.11	3.86	90.1	9.9	0.0	2.9
K066	12-001	10.0	2.66	2.57	.74	-.29	2.08	98.1	1.9	0.0	3.0
K067	10-003				NO SAMPLE ATTEMPTED						

Table A-2 (cont'd)

KEWAUNEE PROJECT SAMPLE DATA 1972

SAMPLE NO.	GRID POINT	DEPTH (FT)	MEAN PHI	MEDIAN PHI	STD. DEV.	SKEW-NESS	KUR-TOSIS	PCT. SAND	PCT. SILT	PCT. CLAY	PCT. HEAV. MIN.
K068	10-005	10.0	2.68	2.22	.60	.58	3.86	96.2	3.8	0.0	1.3
K069	10-007	10.0	2.92	2.68	.52	-.05	3.50	97.5	2.5	0.0	2.5
K070	10-009	10.0	2.97	2.74	.41	-1.12	7.29	99.7	0.3	0.0	1.5
K071	10-023	20.0	-.14	-1.17	1.53	1.48	4.57	96.2	3.8	0.0	3.7
K072	10-021	17.0	6.53	6.54	1.10	-2.21	10.28	2.4	97.6	0.0	INSD
K073	10-019	13.0	3.05	2.86	.54	-1.01	7.41	94.6	5.4	0.0	4.1
K074	10-017	11.0			COBBLES AND ALGAE						
K075	8-019	11.0	3.74	3.66	.87	-1.21	4.38	53.9	46.1	0.0	1.4
K076	8-021	12.0	3.85	3.40	1.05	-.18	2.33	58.9	41.1	0.0	2.6
K077	8-023	14.0	6.29	5.89	1.35	-.33	3.17	2.8	82.3	14.9	1.8
K078	6-023	9.0	2.92	2.64	.38	-.59	7.89	99.5	0.5	0.0	3.2
K079	6-019	10.0	2.62	2.42	.83	-.68	5.77	92.7	7.3	0.0	3.8
K080	4-025	8.0	3.54	2.97	1.08	.64	2.60	65.9	34.1	0.0	2.3
K081	6-025	11.0	3.63	2.77	1.88	.46	1.93	58.2	41.1	0.7	2.0
K082	08-025	15.0			NO SAMPLE						
K083	10-025	18.0	6.05	6.36	2.38	-1.46	4.66	16.0	64.6	19.4	3.0
K084	12-025	22.0	6.30	6.08	1.27	-.10	2.23	0.6	91.6	7.9	INSD
K085	14-025	25.0	6.67	6.36	1.61	-.33	3.57	2.8	76.1	21.1	INSD
K086	16-025	25.0	1.42	1.22	.57	-.83	5.02	100.0	0.0	0.0	4.6
K087	18-025	25.0	6.57	6.82	1.40	-1.12	4.18	2.6	83.9	13.5	2.2
72-1	11- Z	8.0			ALGAL MATS						
72-2	12- Z	9.0	3.22	2.92	.58	.37	3.62	87.4	12.6	0.0	0.3
72-3	11-001C	10.0	2.96	2.70	.44	-.33	4.91	98.9	1.1	0.0	1.5
72-4	9-004	7.5	3.04	2.75	.55	.40	3.95	92.1	7.9	0.0	1.4
72-5	9-008A	7.5	2.58	2.33	.55	-.27	3.84	99.8	0.2	0.0	3.9
72-6	9-009B	6.0	2.57	2.46	.87	-2.35	9.87	99.7	0.3	0.0	4.2
72-7	10-010D	6.3	2.40	2.11	.47	.06	4.55	93.9	0.1	0.0	10.2
72-8	10-010B	6.0	2.60	2.33	.66	.09	4.82	94.8	5.2	0.0	1.7
72-9	11-011C	6.5			ALGAL MATS ON BEDROCK						
7210	11-012	10.5	3.72	3.88	.90	-1.61	4.34	33.2	66.8	0.0	12.2
7211	10-013C	7.0	2.42	2.16	.58	-.30	3.52	99.8	0.2	0.0	1.7
7212	10-014B	9.0	3.93	3.89	1.03	-.32	2.16	45.5	54.5	0.0	1.0
7213	9-016A	8.0	2.72	2.49	.42	-.43	4.22	99.9	0.1	0.0	1.7
7214	10-016A	10.5			COBBLES AND ALGAE						
7215	12-018B	21.0	7.30	7.12	1.25	-.79	4.85	1.1	74.8	24.1	INSD
7216	12-021B	22.5	6.58	6.38	1.40	-.59	3.28	2.5	79.4	18.1	2.8
7217	9-019D	12.0	.47	.11	1.30	.70	3.19	98.8	1.2	0.0	3.7
7218	6-021B	11.0	3.72	4.31	2.92	-.47	2.04	45.4	52.2	2.4	2.3
7219	4-023B	8.5	5.63	5.66	1.53	-.85	3.36	11.2	88.8	0.0	4.3
7220	3-0251	8.0	3.49	2.90	1.15	.44	2.25	65.0	35.0	0.0	3.2
7221	3-027A	9.0	4.20	4.14	1.24	-.22	2.63	36.4	63.6	0.0	2.0
7222	9-016A	8.0	3.01	2.71	.45	.76	5.79	96.6	3.4	0.0	4.6
7223	10-017D	9.0	3.98	3.86	.63	-.62	3.51	41.3	58.7	0.0	1.6
7224	11-016C	11.0	4.04	3.91	1.01	-.36	7.81	36.8	62.9	0.3	1.1
7225	10-018C	12.0	3.84	3.91	1.20	-2.54	10.49	33.6	66.4	0.0	2.7
7226	08-018B	10.0			ALGAL MATS						
7227	07-020A	11.5			ALGAL MATS						
7228	7-022C	12.0	5.00	5.64	2.21	-1.86	5.41	20.8	79.2	0.0	1.7
7229	4-024B	9.0	2.79	2.58	.60	-.29	3.66	98.0	2.0	0.0	3.4
7230	3-026A	8.5	2.91	2.50	.88	1.04	3.79	85.6	14.4	0.0	2.6

Table A-2 (cont'd)

KEWAUNEE PROJECT SAMPLE DATA 1972

SAMPLE NO.	GRID POINT	DEPTH (FT)	MEAN PHI	MEDIAN PHI	STD. DEV.	SKEW-NESS	KUR-TOSIS	PCT. SAND	PCT. SILT	PCT. CLAY	PCT. HEAV. MIN.
7231	11-001D	8.5	3.08	2.82	.42	.24	5.43	96.4	3.6	0.0	0.9
7232	11-003D	11.5	2.84	2.62	.57	-.76	4.88	99.3	0.7	0.0	1.9
7233	9-005A	7.5	3.97	4.01	1.05	-.32	2.19	39.9	60.1	0.0	1.0
7234	10-005B	11.0	2.45	2.31	.62	-.06	2.54	99.6	0.4	0.0	2.4
7235	9-007A	8.0	2.95	2.66	.40	.16	4.84	98.9	1.1	0.0	0.9

NOTES:
CK000 INDICATES A CORE SAMPLE.
K000A INDICATES A SECOND SAMPLE TAKEN AT THE SAME STATION.
INSD MEANS INSUFFICIENT DATA; TOO LITTLE SAND TO CALCULATE HEAVY MINERALS.

Table A-3. Hydrological Characteristics and Suspended Sediment Concentrations of Streams 'A,' 'B,' 'C ' (See Figure 3)

	Stream Flow (ft/sec)			Discharge Rates (cfs)			Suspended Sediments (ppm)		
Sample Station	Fall[1]	Spring[2]	Summer[3]	Fall[1]	Spring[2]	Summer[3]	Fall[1]	Spring[2]	Summer[3]
A-01	N.S.			N.S.	2.38		60.0	17.0	
A-02	N.S.			N.S.	6.11		60.0	11.0	
A-03	0.86		0.10	1.35	15.17	0.26	54.0	45.5	25.1
A-04	0.20	2.52		0.41	4.64		28.0	38.5	
A-05	0.52			1.57	17.66		16.0	24.0	
A-06	1.09			2.03	22.81	0.39	80.0	31.0	8.8
A-07	0.47	2.63		2.39	26.88		88.0	65.0	
A-08	0.40	2.17		2.96	33.28	0.57	150.0	62.5	1.8
A-09	0.58	1.92		0.36	4.07		126.0	40.0	
A-10	0.32	1.61		0.55	6.17		136.0	42.5	
A-11	0.41			4.25	47.82	0.82	336.0	122.0	27.9
B-12	0.72	1.28		0.36	4.07		70.0	44.5	
B-13	1.52			0.50	5.66	0.10	0.0	30.5	27.6
C-14	0.33	2.00	0.10	0.47	5.32	0.09	38.0	27.0	8.4
C-15	0.19	1.85		0.70	7.87		46.0	44.0	
C-16	0.63	1.78		0.76	8.55		58.0	40.0	
C-17	N.S.			N.S.	9.23	0.16	102.0	50.0	23.9

[1] Oct. 23, 27, 1972

[2] April 7, 1973

[3] July 23, 1973

N.S. No Sample