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COASTAL
STUDIES

EFFECTS OF GREAT LAKES HARBOR ON THE LAKE MICHIGAN SHORE IN ILLINOIS

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EFFECTS OF GREAT LAKES HARBOR ON THE LAKE MICHIGAN SHORE IN ILLINOIS

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ABSTRACT

Review of previous studies and the incorporation of newly acquired data reinforces the interpretation (Tetratech, 1980) that the harbor at the Great Lakes Naval Training Center, since 1923, has been impounding sediment in its fillets and harbor as well as diverting littoral sediment lakeward beyond recovery. The result is that downdrift shores are denied normal littoral sediment and are more than ordinarily exposed to wave effects from the lake.

It also is demonstrated that littoral drift available to the Great Lakes Naval Training Center harbor is meagre because of sediment capture and diversion effects of Waukegan Harbor. Furthermore, there is evidence that a long-term general trend toward reduction of the littoral drift south of Waukegan will allow increased wave effects on the shore in future years.

INTRODUCTION

The harbor at the Great Lakes Naval Training Center (fig. 1) in Lake County, Illinois is one of the most important prominences on the Illinois shore. Knowledge of its effects on the dynamics of the shore is important to the formulation of any shorewide coastal management effort. Its long and short term effects on the adjacent shores, in addition, are of paramount importance to riparian owners and municipal agencies for day to day management of their properties on the shore. For these reasons, the harbor has been the subject of numerous studies of its effect on littoral sediment transport, sediment distribution, shore recession and lake bottom changes. The earliest important work was a beach erosion study published in 1949 as a U.S. Congressional Document for the Chicago District, U.S. Corps of Engineers, wherein recession lines and profiles were recorded for the period 1872 to 1946. In 1958, the Illinois Division of Waterways completed a comprehensive study of erosion on the Illinois shore. It presented a review of shore recession and profile changes up to 1955, as well as an inventory of shore protective structures that summarized basic data from the forties and fifties. The Illinois Division of Waterways (now the Division of Water Resources) has provided an additional invaluable resource in sets of aerial photos taken irregularly in the thirties and forties but annually each spring from the early fifties to the present.

In 1973, with the institution of the Illinois Coastal Zone Management Program (sponsored by the U.S. Coastal Office), a number of new studies that involved the GLNTC harbor were begun by the Illinois State Geological Survey under the auspices of the Illinois Division of Water Resources. The first year products of the program include a report on bluff erosion on the Illinois shore by Berg and Collinson (1975), an inventory of shore

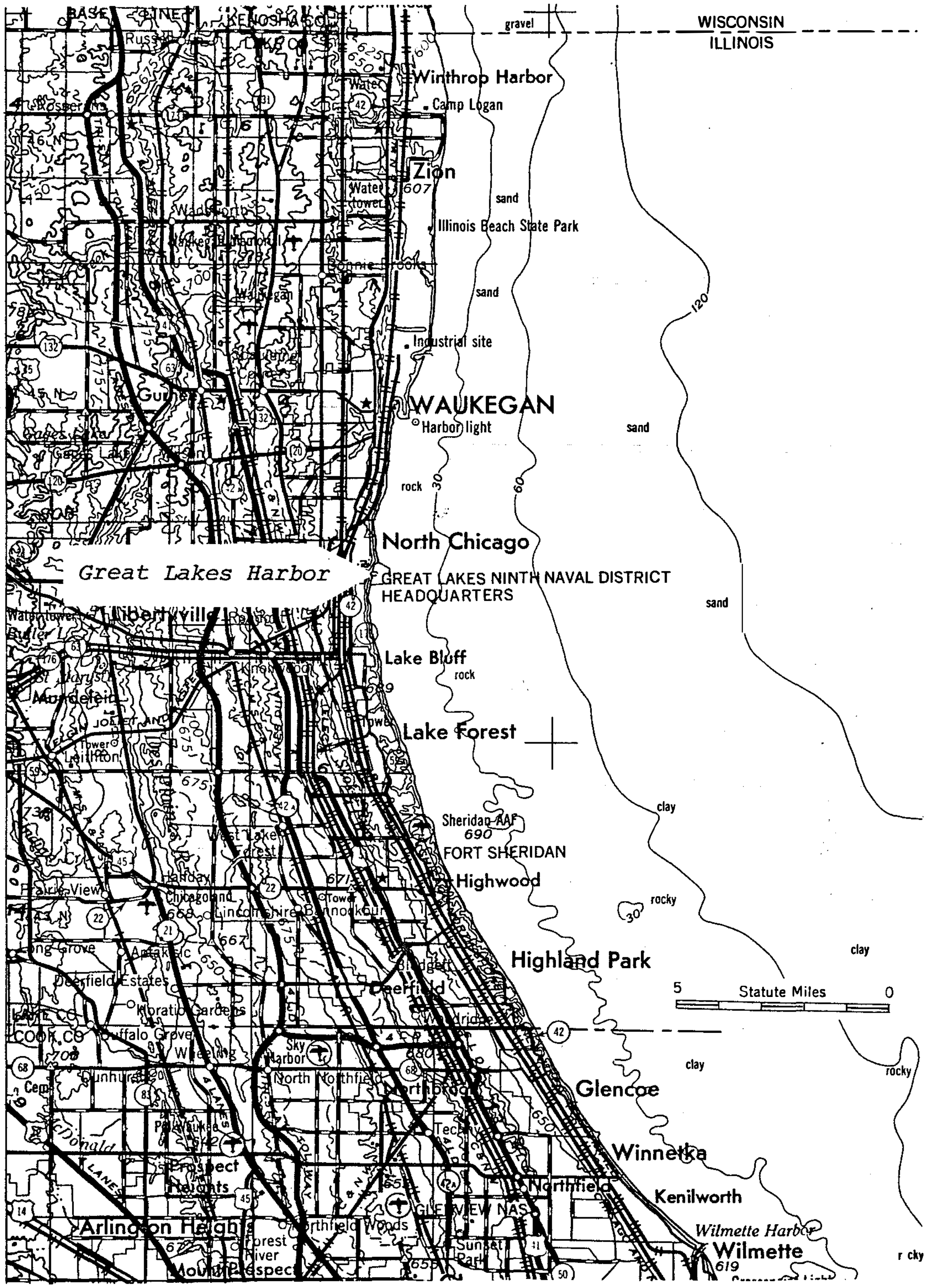


Fig. 1 - Map showing the location of Great Lakes Naval Training Center harbor, Lake County, Illinois.

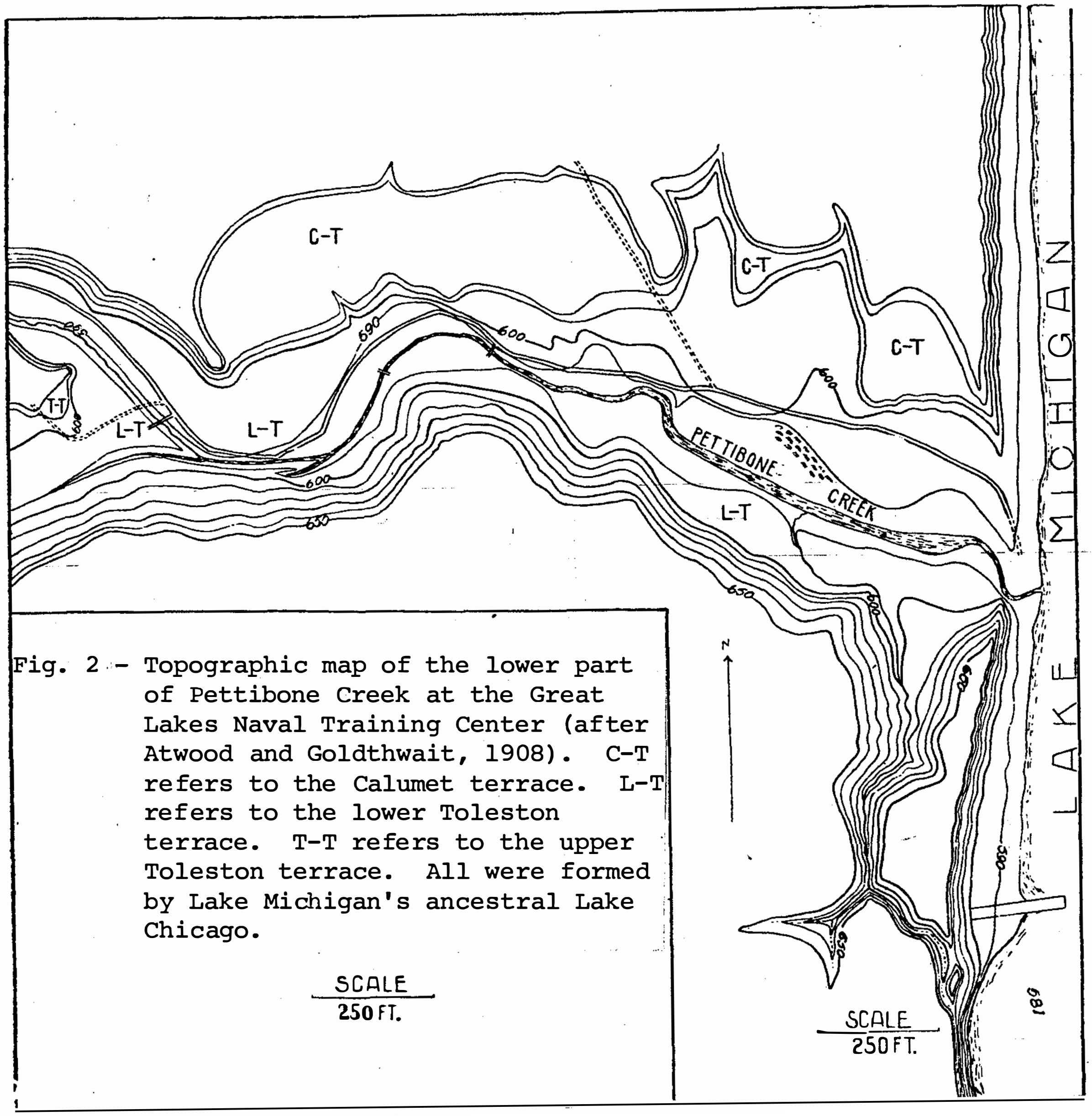


Fig. 2 - Topographic map of the lower part of Pettibone Creek at the Great Lakes Naval Training Center (after Atwood and Goldthwait, 1908). C-T refers to the Calumet terrace. L-T refers to the lower Toleston terrace. T-T refers to the upper Toleston terrace. All were formed by Lake Michigan's ancestral Lake Chicago.

SCALE
250 FT.

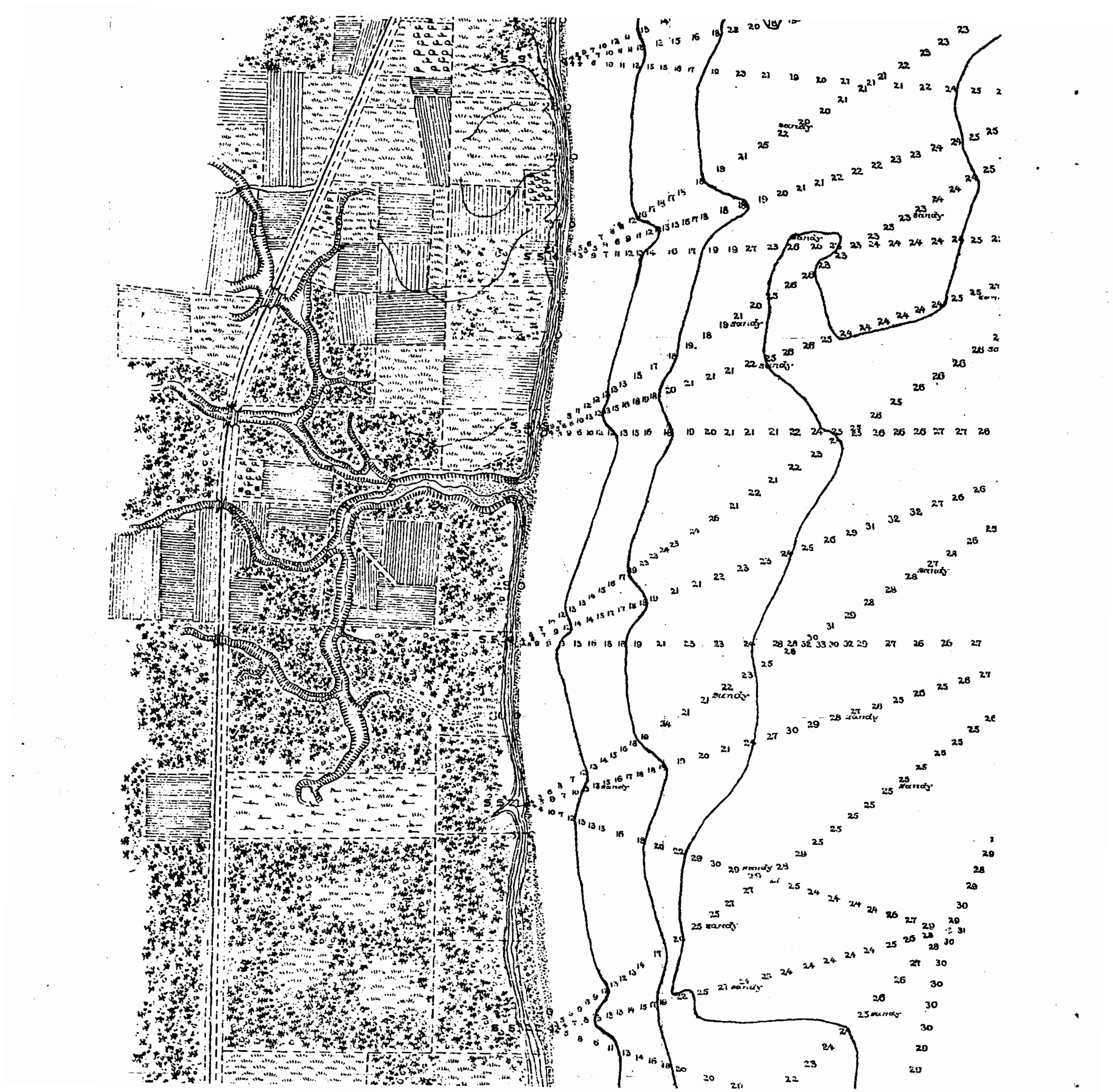


Fig. 3 - The site of Great Lakes harbor, Pettibone Creek ravine, in 1873. After National Lake Survey Map No. 1-553 (scale 1:20,000).

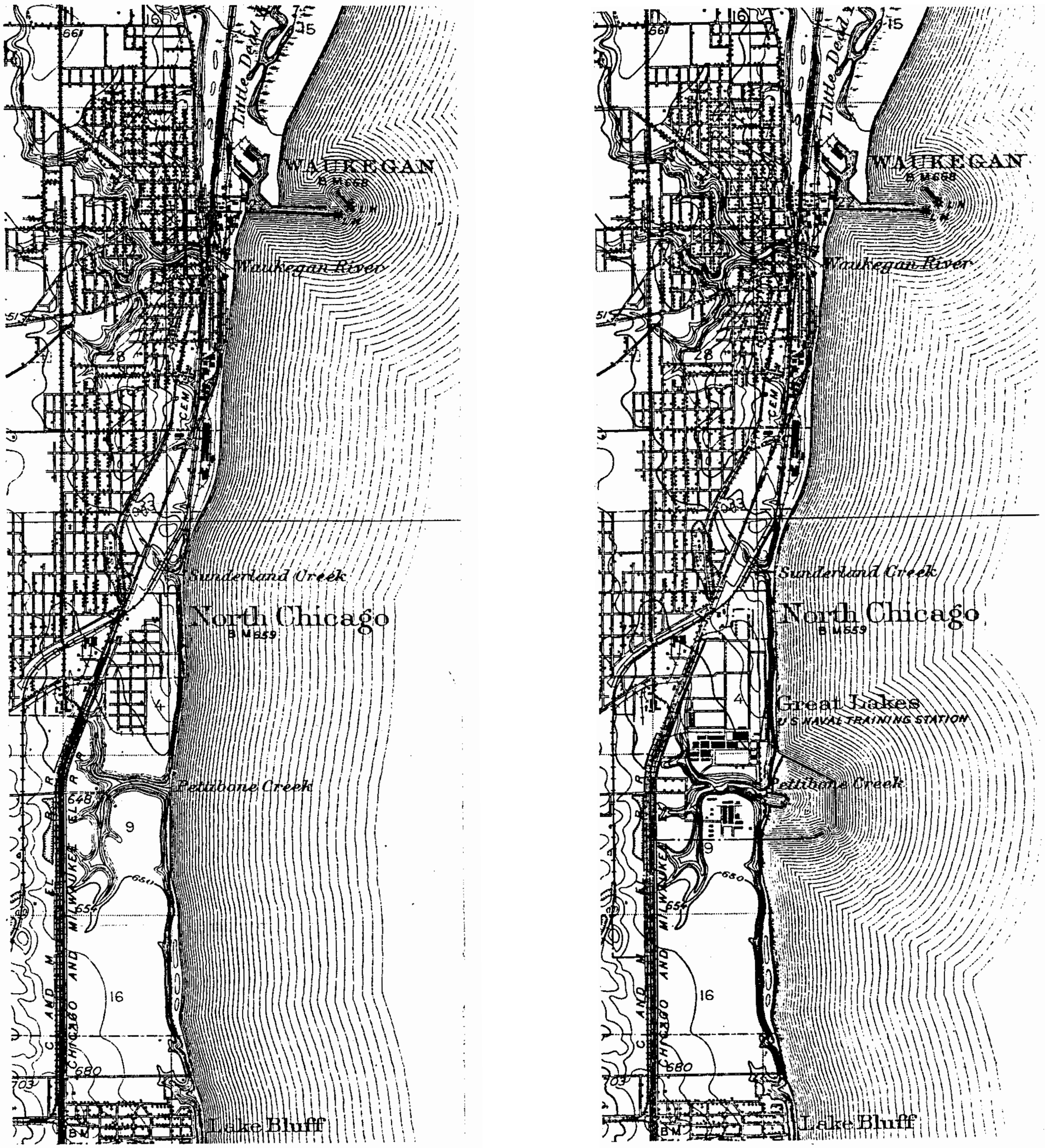


Fig. 4 - The Waukegan-Lake Bluff shore as shown by U.S. Geological Survey, 1908 (left) and 1929 (right) editors of the Waukegan Quadrangle (15-minute series).

conditions (Collinson, Drake, and Anchor, 1975) and hydrographic maps of the nearshore between the Wisconsin line and Wilmette (Collinson et al., 1975). In the first report, erosion of the bluff in the general vicinity of the Great Lakes Naval Training Center harbor was discussed and illustrated in detail (figures 12, 13 of this report). The second report, the inventory, identified unstable reaches of the shore as well as protective structures and beach conditions. Hydrographic maps, from the third report, covered the nearshore lake floor just south of the harbor but did not include the harbor itself nor the armored shore north of it.

The 1975 hydrographic maps were succeeded by a new generation of maps which included the Great Lakes Naval Training Center harbor (Collinson, et al., 1977). These were published in a coastal atlas as a second year product of the ICZM program. The hydrography was compiled from maps published by Norby and Collinson (1977) as part of a report on sedimentary characteristics of the shore. The hydrography, combined with results of a drilling program, provided estimates on sediment distribution and thickness.

In addition to the foregoing, Berg (1977) authored an ICZM report on the effect of coastal processes on the Waukegan and Great Lakes Naval Training Center harbors in which he concluded that the overall effect of Great Lakes Naval Training Center harbor on the shore has been "moderately beneficial" through protection of the downdrift shore from severe northeasterly storms despite interception of littoral drift sediments.

The latest generation of reports, of which this is an appendix, was prepared by the coastal engineering firm, Tetratech, under the main guidance of Dr. Choule Sonu. The Tetratech reports are part of the final ICZM Summary Plan for Lake Michigan Shore Erosion Protection (1980), which treats the coastal dynamics, the sedimentational history, and the erosion history in great detail and concludes that the Great Lakes Naval Training Center harbor both impounds sediment in its fillets and harbor as well as deflects it beyond recovery offshore, thereby depriving the downdrift shore of littoral sediments necessary for natural shore protection.

The present report is a general overview based on the foregoing as well as the result of new and increasingly detailed remapping of GLNTC harbor and its vicinity in 1979 (fig. 6). In the same year, new drilling, including three drill holes within the harbor (Norby, 1980), was completed along with size analyses of sediments and new mapping of sediment distribution. Norby states that the fillet and harbor-fill sediments have a general average size of .12 mm (3.0Ø) or finer (very fine sand).

Additional information was derived from frequent field examinations and from low altitude aerial photos taken by the Illinois State Geological Survey.

The conclusion of the present summary study is that Great Lakes Naval Training Center harbor itself is largely deprived of sediment by Waukegan Harbor but that Great Lakes harbor in turn virtually precludes littoral flow to the Lake Bluff shore through impoundment of the sediments in fillets and deflection of sediments offshore.

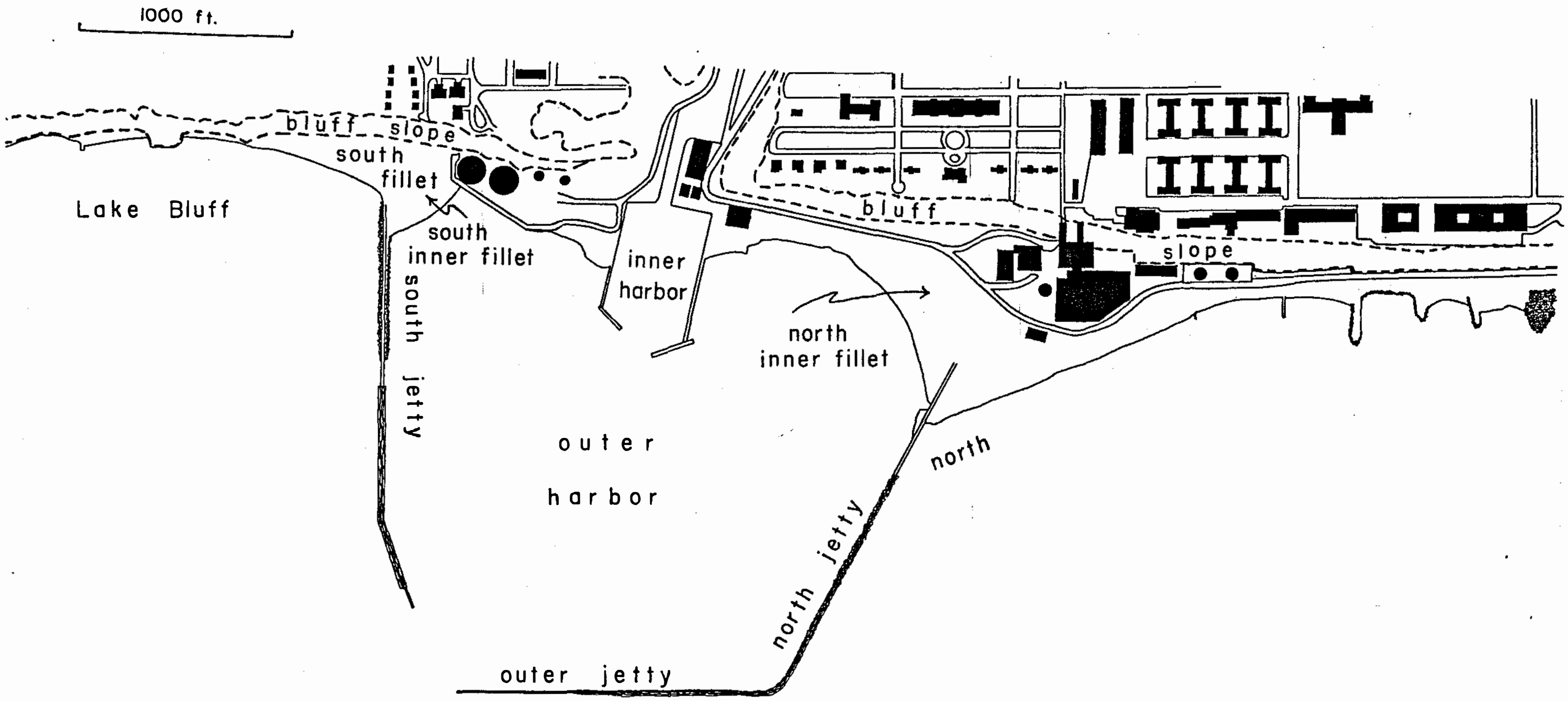


Fig. 5 - Details of harbor and shore structures at Great Lakes Naval Training Center, 1979.

HISTORY OF RECESSION AND PROGRADATION OF THE SHORE AND NEARSHORE

Construction of Great Lakes Naval Training Center harbor was begun prior to 1910 with the building of a small inner harbor at Pettibone Creek (figs. 2-4). In 1923, the large outer shelter harbor, which projects some 2000 feet into the lake, was completed (fig. 5). Since that time the structure has been one of four large installations (fig. 1): Waukegan Harbor, Great Lakes Naval Training Center harbor, Gross Pointe-Wilmette Harbor and the Northwestern University landfill, that compartmentalize littoral drift movement and supply on the Illinois shore.

The largest and most effective impedment to littoral flow, Waukegan Harbor, was constructed prior to 1908 (fig. 4). It has greatly affected the role the Great Lakes harbor has played in Illinois coastal dynamics.

Maps of the 1908 and 1910-11 shore (figs. 4, 8) show the presence of the main Waukegan Harbor jetties along with a short offshore breakwater to the northeast of the harbor mouth. This latter structure was connected to the shore in stages between 1928 and 1931 to become the northernmost jetty of the present-day harbor. Comparison of 1873 and 1910 shorelines south of Waukegan (fig. 8) reveals severe shore erosion before Waukegan Harbor was built. An area south of the U.S. Steel plant in North Chicago, left unprotected until about 1910, showed more than 200 feet of shore recession in the preceeding 37 years. Because of such conditions most of the shore a mile and a half south of Waukegan was already protected when the Waukegan Harbor jetties were built. The shore, southward from there to Blodgett Avenue in Lake Bluff, which was unprotected, averaged about 4 feet of recession per year. Berg and Collinson give an overall average recession figure of 157 feet for the 37 year-period. Recession was greatly slowed thereafter by the periodic addition of groins and bulkheads on the reach southward from GLNTC.

There is evidence that littoral sediments were bypassing Waukegan before the harbor was built. The 6-, 12-, and 18-foot depth contours for 1873 and 1910-11 (fig. 8) are relatively widely spaced north of the site of the future harbor. The spacing narrows sharply south of the harbor site, but the 1910-11 contours nevertheless show lakeward advance to a point a mile and a half south of the site. Littoral sediments were getting at least that far south before Waukegan Harbor was built. On southward to Lake Bluff, there is no convincing evidence for deposition of more than small quantities of littoral sediment before 1911. Relatively wide spacing of the 18-foot depth contours, however, suggests that fine sediment suspended in that water column was transported some distance south of Wuakegan in offshore plumes.

The Waukegan Harbor complex was built in stages. The main east-west harbor entrance jetties were built prior to 1908 as was the outermost 900 feet of the north breakwater (fig. 5) which tended NW-SE and served to protect the entrance of the harbor from northeasterly waves. This configuration greatly affected southward littoral flow inasmuch as the structure projected 1600 feet due east into the lake when it was built. By 1911, its fillet had grown eastward 250 feet suggesting capture of virtually the entire

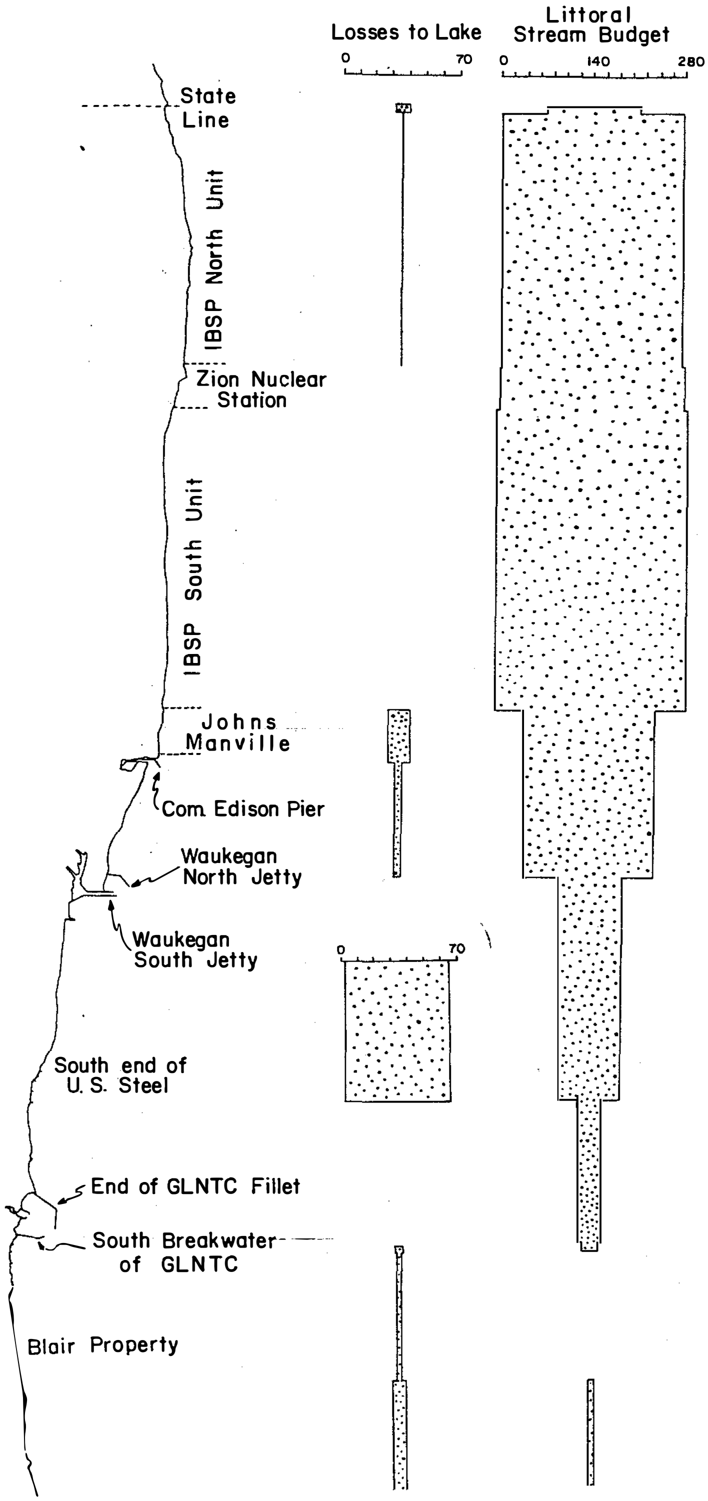


Fig. 7 - Graph showing the littoral budget in thousands of cubic yards (right column) for the Wisconsin boundary to Lake Bluff reach of shore. The left column indicates amount of sediment diverted to deep water in thousands of cubic yards. After Tetratech, 1980, table 5.2.1.

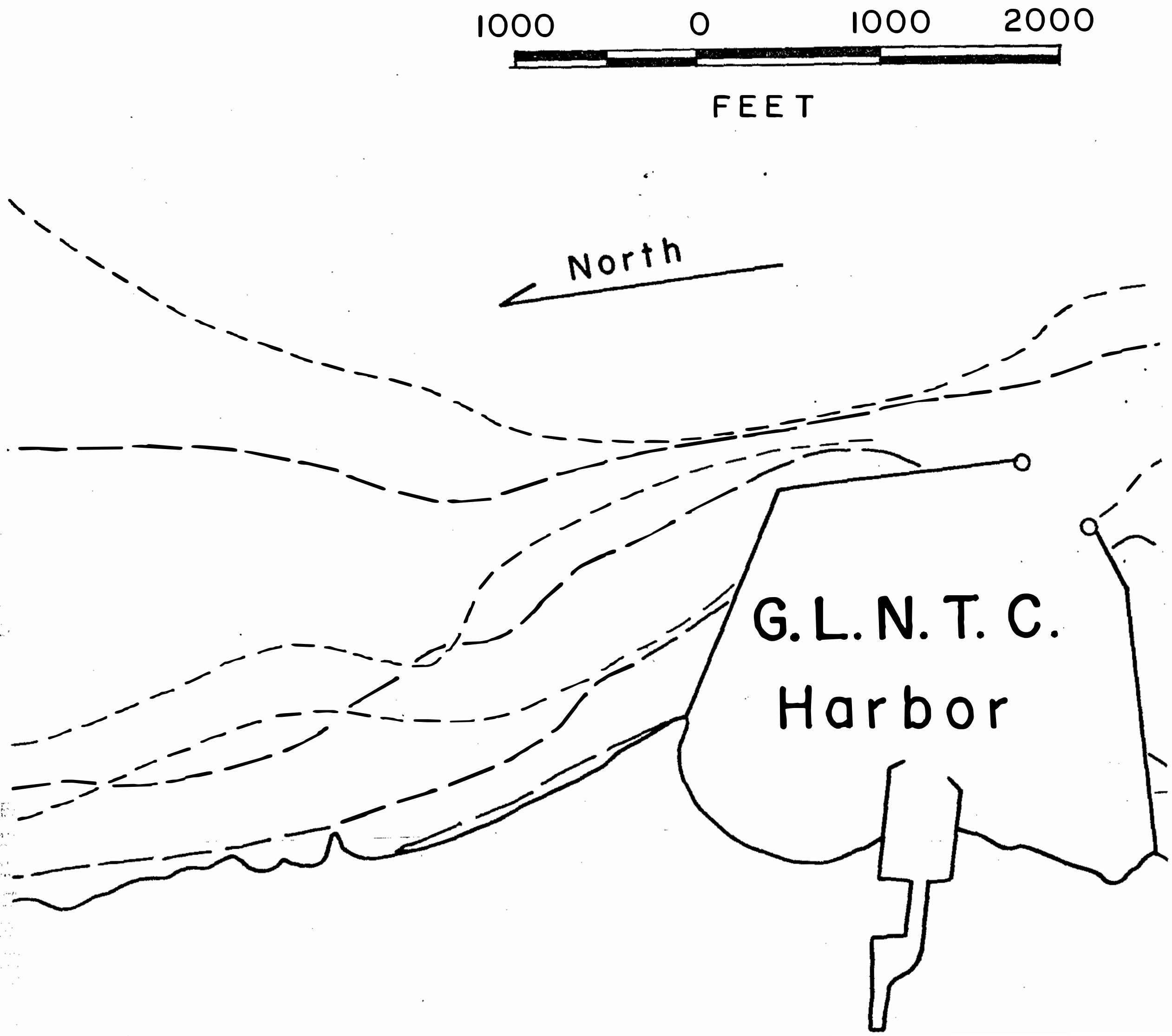
southward littoral drift. Maps and aerial photos indicate that the fillet grew an additional 400 to 450 feet eastward during the next 20 years before the northeast breakwater was connected to the shore. That construction created an entirely new sediment catchment configuration. The new structure was angled southward 15° on its inner leg while the outer half retained its 45° south direction. This remodeled structure (fig. 6) extended more than 1500 feet lakeward from the shore north of it and more than 3500 feet east of the shore south of it. Its design nevertheless improved general conditions for bypassing once a fillet was built and stablized. When first completed in 1931, however, it represented a new empty groin-like structure. Records suggest that it did not attain a stable bypassing condition until the forties. Consequently, the Great Lakes Naval Training Center harbor, built in 1923, was largely deprived of sediments from the beginning and did not reach a stable filled state until the early forties when it reached its approximately 400,000 cubic yard capacity (Tetratech, 1980). From the middle forties to the present, both Waukegan Harbor and the GLNTC harbor have been bypassing and diverting sediment into deeper water (figs. 7-11, 14). Tetratech estimates that GLNTC intercepts approximately 34,000 cubic yards annually (fig. 7), small amounts being added or lost from the fillet but most captured within the harbor by overwash of the jetties or diverted into the open lake.

The 1980 depth contours (fig. 8) indicate that sediments continued southward from Waukegan to within a mile of GLNTC and in the immediate vicinity of the north fillet of GLNTC harbor as well as south and southeast of the GLNTC harbor for a half mile (figs. 8, 10, 11). After the record low water levels of 1964, (fig. 14) and the return to increasingly deep waters of the early seventies (fig. 16) there was a change in the trend toward offshore accretion and there began a trend toward general loss of sediment in the fillets of GLNTC (fig. 9) as well as from offshore profiles. Both 1976 (not shown) and 1979 contours show a significant landward retreat of the 18-foot contour. The 1979 contour is 300 to 800 feet shoreward of the 1960 contour, both north and south adjacent to GLNTC harbor. The 1979 12-foot contour shifted landward 250 to 800 feet in the same areas.

It is difficult to interpret such shifts and to attribute causes. There is a general long term trend toward offshore net loss of sediment along most of the shore north of Chicago. General reduction in the amount of sediment available from the Wisconsin shore appears to be partly responsible, although an overall attrition, resulting from offshore diversions by the major structures on the lake, may be the fundamental cause. The very fine nature of the littoral sediments provides a basis for such offshore diversions. Since 1938, the Waukegan generation station in North Waukegan (fig. 1) has been causing some diversion. In addition, the Zion Nuclear Generation Station, which has been operational since the mid-seventies, is now known to divert some sediment offshore. A most important element, however, must be the consistent dredging of the outer parts of Waukegan Harbor during the decade of the sixties (Tetratech, 1980, table 5.1.12) which displaced almost 300,000 cubic yars of polluted sediment offshore. Further dredging during the seventies probably displaced an additional 100,000 cubic yards. All of these losses occurred at or north of Waukegan Harbor, however, so their effect on GLNTC fillets is questionable. More important has been the effect of high lake levels that arrived in 1969, reached a record high in 1974, and have continued to the present day. Conventional wisdom calls for removal of material from shallow areas during high water levels and deposition below wave base causing accretion in offshore areas. Such a process may have been operative at GLNTC but, because of the nature of the local system, sediment was washed over the jetties into the harbor with the result that there was a general removal of sediment from the fillets but no accretion offshore. Sediment removal from the lower depths can be attributed to lack of normal sediment load in lakeward currents and surges that normally would sustain equilibrium or contribute sediment.

WAVE STORM EFFECTS

Littoral sediments on the shore north of GLNTC harbor are mobilized mainly by wave storms from the north and from the northeast (fig. 15) which cover the maximum fetch and present the most effective angles of incidence for southward movement. South of the harbor, some sediment is moved northward by southeasterly storms which present an effective angle to the shore. The storms, however, occur over a relatively short fetch so their effect on the shore is minor. When northeasterly wave fronts occur, sediment in the littoral zone is moved southward along the shore onto the northern fillet (fig. 15). Sediment in the breakwater zone moves southward along the fillet but little sediment is newly incorporated into the fillet which has been in a state of relative equilibrium (figs. 4, 15) for decades. During this movement some sediment reaches the north jetty where large waves that top the jetty wall wash it over into the harbor (fig. 15) where virtually all is impounded. Once in the harbor, some sediment moves eastward and southward along the northern and eastern jetties. Much is deposited before it reaches the harbor mouth but a fraction arrives at the mouth where a channel is maintained by dredging. The sediment that does not go over the jetty into the harbor moves lakeward along the outside and passes out into the lake beyond the jetty wall (fig. 15). Water and sediment are then diverted and accelerated southward along the east jetty. As it moves southward along the wall, the stream of sediment approaches the harbor mouth where reflected waves help to spread the relatively narrow stream of sediment, some of which is shifted shoreward by direct wave action and falls into the wave shadow south of the south jetty. The remainder of the littoral sediment flow spreads southward onto the lake floor some 2000 to 3000 feet from the shore in 15 to 30 feet of water (fig. 17). There the sediment continues to be spread lakeward, shoreward and southward by deep waves, surges and bottom currents. The material is so fine that once suspended it may remain in the water column for hours.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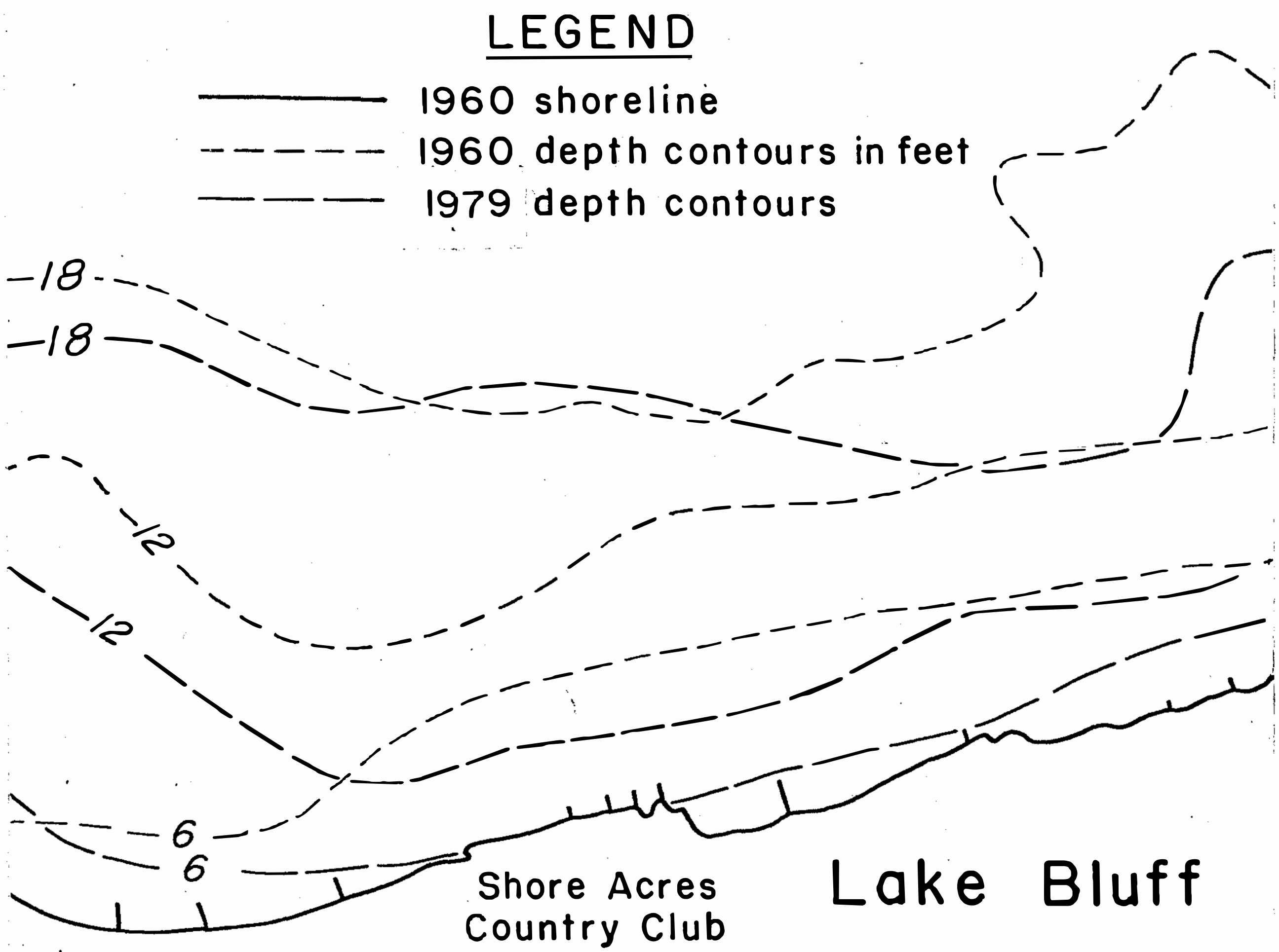

Fig. 9 - Depth contours covering the vicinity of Great Lakes Naval Training Center harbor for the years 1960 and 1979. The contours illustrate the history of deposition and recession of the nearshore areas to a depth of 18 feet.

SEDIMENT BYPASS AT GLNTC HARBOR

Many factors control the flow of sediment around and into the Great Lakes Naval Training Center harbor:

1. Most important is the design of the jetties which facilitate the passing of littoral sediment. The northern jetty is angled 30° south of east, and the eastern jetty runs north-south. In addition, the harbor mouth is inset at the south end of the eastern jetty so that sediments tend to bypass it. The south jetty, which extends 2000 feet into the lake, is angled northward at its distal end, a design that should facilitiate return of sediment to the shore. Unfortunately, the south end of the east jetty stands 2400 feet out from the shore while the rapidly receding bluff south of it continuously increases the distance thereby reducing the possibility of sediment return to the beaches and shallows. The pattern of sediment distribution immediately south of the harbor (figs. 6, 8, 9), suggests that some sediment bypasses the harbor mouth southward and is carried by eddies toward the shore adjacent to the south breakwater. There it is impounded because of protection from northeasterly storms. On the other hand, it is in a pocket wherein southeasterly storm waves overtop the jetty, washing sediment over the small south fillet into the harbor.

2. Lake floor slope characteristics are somewhat less than favorable at GLNTC harbor. North of the harbor the lakeward slope is approximately 10 feet per mile. Due east it is 80 feet per mile, whereas south of the harbor it is about 50 feet per mile. Such relatively steep slopes permit high wave energies to reach the shore, they permit very fine sediments to stay suspended for relatively long periods of time and they bring below-wave-base depths close to shore.

3. Norby (1980) has analysed the size characteristics of the sediment surrounding the harbor. He has shown it to range from fine to very fine sand--none of which is satisfactory for beach use. Such sand is easily mobilized and transported so that most that bypasses the harbor is easily diverted lakeward. The notable exception is the harbor fill, most of which is retained within the harbor. Because of its polluted nature (Norby, 1980) the harbor fill is not acceptable for beach or shore replenishment and cannot be bypassed artificially.

4. The most severe wave storms encountered on the Illinois shore have north to northeasterly wave fronts which represent the directions most effective for mobilizing littoral sediments on a north-south shore. Such conditions should promote sediment bypass around the harbor. Unfortunately, northeasterly wave fronts also generate strong southward currents that run against the north jetty and are diverted lakeward then around the corner southward so that much sediment is carried southward beyond the harbor into relatively deep-water. Wave storms in addition temporarily raise water levels through wind set-up and increased wave heights and run-up. All increase the frequency of jetty overtopping as well as increase the lakeward currents that set up along jetty walls. In many systems such factors would increase the passing of sediment to the downdrift shore. At GLNTC, however, impoundment and offshore diversion are increased more than bypassing to the downdrift shore.

DISTRIBUTION OF SEDIMENT AT GLNTC HARBOR

Distribution of sediment is illustrated by figure 17 which is based on detailed hydrography done in 1979 (fig. 6) and drilling done in 1976 and 1979 (Norby, 1980). The diagram shows thickness of sediment over the glacial till bottom as interpreted from 16 boreholes, detailed fathometer profiles and bottom grab samples. Three main features distinguish sediment distribution around the harbor:

1. There is a thick fillet north of the harbor (figs. 5, 6, 17, 18A) which extends only a short distance lakeward beyond the east jetty but also extends southward along the jetty. The profiles of the fillet, measured just north of the north jetty (fig. 18A), show that large quantities of sediment have accumulated onto the 1873 sediment levels in the fillet. Tetratech (1980) estimates the amount to be 207,900 cubic yards of material.

Beyond the toe of the fillet, backwash and longshore currents have reduced the 1979 surface below the 1873 level producing a profile that is consistent with those recorded in 1946, 1954, and 1974 (fig. 10) verifying the stable state of the fillet over the past 30 years. Sediment in the submerged part of the fillet ranges from fine sand (mean of 2Ø) in its shoreward parts to very fine sand (mean of 3.25Ø) near its toe.

2. There is a thick harbor-fill that lies along the inner side of the north and east jetties. The profile in figure 18B, taken just north of the inner harbor (fig. 17), shows that the harbor bottom in general conforms to that of pre-construction times except for the portion of harbor-fill attributed to wave over-topping. Because of the stability of the north fillet, this sediment ridge (figs. 6, 14) represents the only significant growing sediment accumulation in the harbor area. In 1964, 100,000 cubic yards of material (Tetratech, 1980) were dredged from the harbor to maintain a 21-foot channel. Since then Tetratech estimates that fill growth has brought the harbor total back up to at least 174,000 cubic yards. Of this amount most is contained in the sediment ridge which appears to have grown virtually uninterrupted since 1923. Aerial photos (Berg, 1977, fig. 3) show that some of the over-top sediment travels to and exits from the harbor mouth.

More than 80 percent of the material in the harbor-fill represents very fine sand, silt and clay. It, therefore, would be of exceedingly poor quality for use as fill of replenishment material. Norby (1980) indicates that virtually all is polluted.

A small south inner fillet lies in the southwest corner of the harbor. It too owes its existence to over-topping.

3. Sediment south of the harbor (figs. 17, 18C) is both thin and widely dispersed. It probably does not greatly differ in volume from that of 1873 but differs in distribution in that, instead of a uniform wedge-shaped

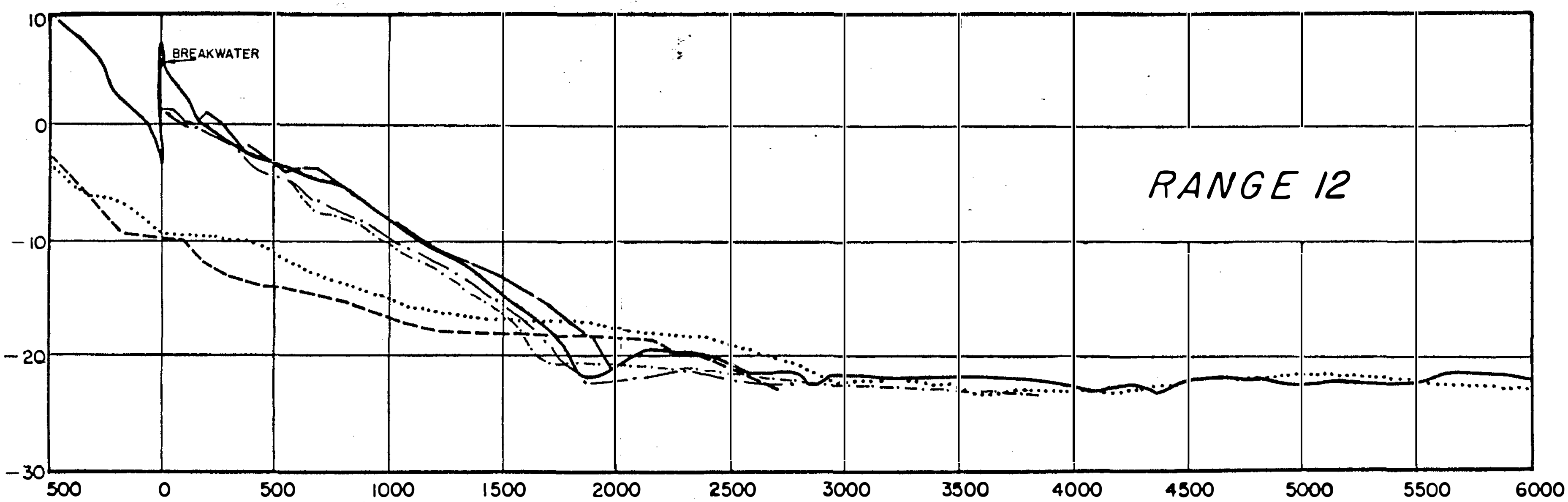

Fig. 10 - 1872-1980 profiles taken at U.S. Corps of Engineers Range 12 at the north side of the north jetty, Great Lakes Naval Training Center harbor. The 1872 and 1909-11 profiles were measured before harbor construction. Measurements are in feet. Zero is the low water datum, 578.5 I.G.L.D. Note that the 1946 and 1954 profiles show a stable condition for the north fillet. A maximum development was attained during the sixties whereas 1974 and 1980 saw a slight reduction in size. In the stable state there is a slope area between 5 and 10 feet above which erosion predominates and below which deposition generally prevails.

LEGEND

———	1946	BOTTOM PROFILE
- - - - -	1872	BOTTOM PROFILE
·········	1909-11	BOTTOM PROFILE
—— ——	1954	BOTTOM PROFILE
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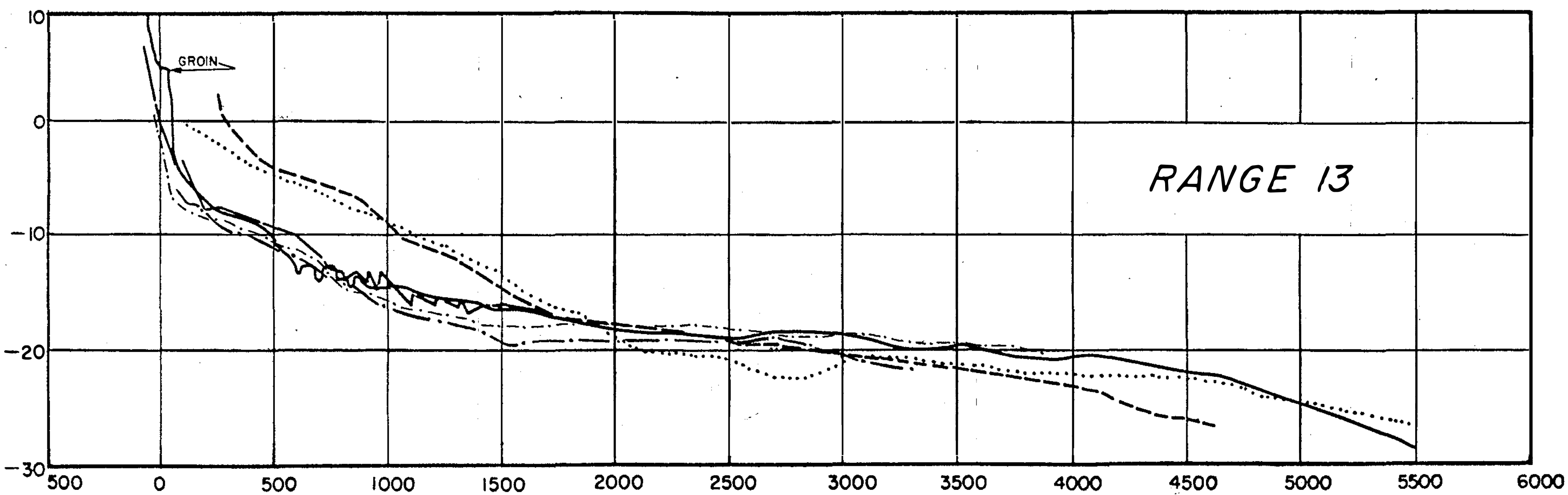


Fig. 11 - 1872-1980 profiles taken at U.S. Corps of Engineers Range 13, .9 miles south of the Great Lakes Naval Training Center harbor south jetty. This is a relatively stable area protected by a groin. It is characterized by a slope between 10 and 20 feet that has been relatively stable since the groin was installed. Sand is relatively thin or absent below 10 feet.

LEGEND

1946 BOTTOM PROFILE
1872 BOTTOM PROFILE
1909-11 BOTTOM PROFILE
1954 BOTTOM PROFILE
1974 BOTTOM PROFILE
1979 BOTTOM PROFILE

(AFTER ILL. DIV. WATER RESOURCES 1958, EXHIBIT NO. 12)

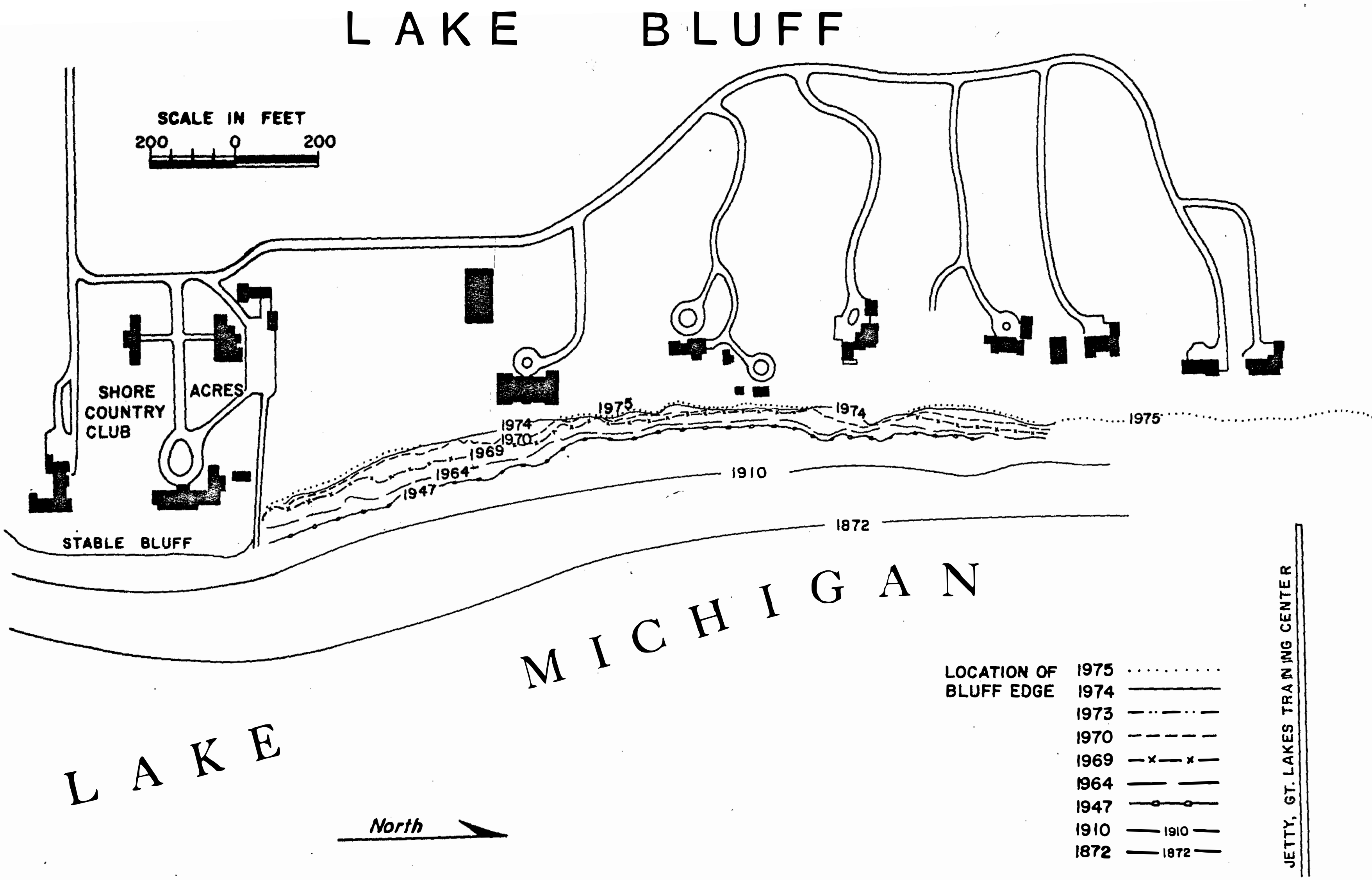


Fig. 12 - Bluff recession lines, 1872-1975, extending one half mile south from the Great Lakes Naval Training Center harbor south jetty.

sediment blanket, it is arranged into three main sediment distribution areas: (a) The thickest deposit is immediately downdrift from the south jetty (fig. 7) where sediment has been moved from the north into the littoral drift shadow of the harbor. There it is protected from northeasterly storms. (b) The smallest deposit is downdrift along the Lake Bluff shore (fig. 17) where sediment has moved downdrift from the harbor shadow, forming a nearshore wedge. Combined with sediment eroded from the immediate bluffs, it makes up the modern beaches. It consists mainly of medium to very fine sand. (c) The most extensive deposit consists of sediment tailings that have bypassed the harbor but remained in relatively deep water where they form a thin veneer in 20-30 feet of water (fig. 17). Data from six boreholes that penetrate the deposit indicate that the material is relatively finer at the southern end than at the harbor end. In the north, 93 percent belongs in the very fine sand, silt and clay fractions whereas in the south 98 percent belongs there.

BLUFF RECESSION SOUTH OF GREAT LAKES NAVAL TRAINING CENTER

The shore immediately south of Great Lakes Naval Training Center, excluding the small south fillet (fig. 5) and the area protected from northeasterly waves, has receded rapidly since before the keeping of shore recession records. The earliest detailed hydrographic and shore map (fig. 3) published in 1873 shows a shore with oversteepened bluffs and narrow beaches. On that map the area that today is south of Shore Acres Country Club (figs. 3, 8, 13) is shown as a recessed shore with slumped materials at its base (fig. 3, bottom center). That reach, although intermittantly protected during this century, today recedes at an average rate of more than 2 feet per year (Berg and Collinson, 1976). Berg (1977) makes much of the fact that bluff recession rates for the northern Lake Bluff shore (fig. 12, 13) were higher prior to construction of Great Lakes Harbor than during subsequent years. He fails to take into account, however, the fact that after the harbor was built the entire reach was protected from time to time by groins and bulkheads (figs. 6, 8, 13). Unfortunately, in recent years, especially during the high water levels of the mid-seventies, the structures were permitted to disintegrate or be submerged so that high recession rates have returned. A most important factor in rapid recession of the Lake Bluff shore lies in the nature of the materials that constitute the bluff. Over most of the mile reach just south of GLNTC, the lower 30-35 feet of bluff consists of gray silty clay till (Berg and Collinson, 1976, fig. 8) that in places contains significant beds of bedded silt--beds that conduct ground water to the bluff face—whereas the upper 20-25 feet of the bluff generally consists of silt, cross-bedded sand, gravel, and pebbly silty clay till. The materials in the upper bluff are commonly contorted and weak, and generally are saturated with ground water. These weaknesses are accentuated by the fact that the tableland above is flat and poorly drained. In addition, utility drains from homes on the shore in a number of cases empty onto the bluff face. Consequently, the bluff is unusually vulnerable to recession caused by natural forces and any exposure to waves causes exaggerated effects.

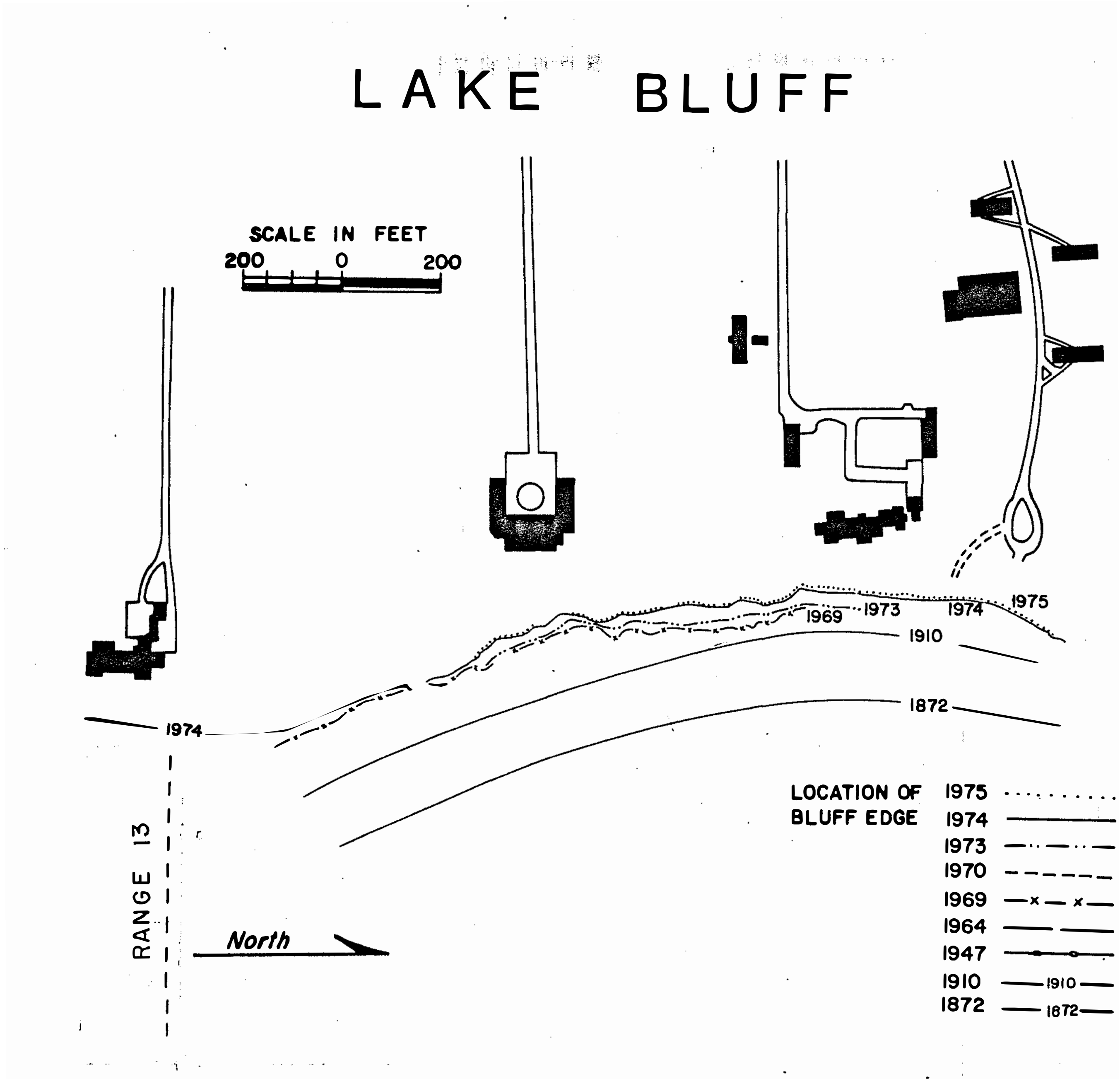


Fig. 13 - Bluff recession lines, 1872-1975, extending from .6 to .9 miles south of the south jetty of the Great Lakes Naval Training Center harbor.

Fig. 14 - Great Lakes Naval Training Center harbor in April 1964 showing emergent north fillet and harbor filling at abnormal low water levels. Waves from the southeast show wave reflection patterns adjacent to the landward end of the south jetty as well as at the distal ends of the south, and east jetties. Refracted wave fronts are seen within the harbor and adjacent to the north fillet.

Fig. 15 - Great Lakes Naval Training Center harbor in April, 1958 showing wave fronts from the northeast. At the south end of the north fillet, waves break over the north jetty depositing sediment within the harbor. Natural flow extends along the inside of the north and east jetties toward the mouth of the harbor. Small wind-induced waves are present over the shallowest part of the harbor fill just inside the east jetty. Reflected wave patterns can be seen in the north fillet area as well as off the distal end of the east jetty. Refracted waves curl around the south side of the harbor.

Fig. 16 - Great Lakes Naval Training Center harbor at near record high water levels in late June 1974. Note the submerged condition of the north and south fillets. Strong winds are from the southeast causing a wind shadow inside the north jetty as well as near the shoreward end of the south jetty. Wind streaks can be seen across the harbor. Waves are reflected from the end of the east jetty whereas waves are refracted into the west side of the harbor mouth and around the south jetty to the southern shore.

CONCLUSIONS

GLNTC harbor, since its construction in 1923, has caused significant changes in the Lake Michigan shore. Northward, extending one-half mile above the harbor, a fillet has been built against the north jetty through interception of southward moving littoral sediment. This fillet, containing more than 200,000 cubic yards today, reached a stable bypassing condition during the late thirties or early forties and has been in a bypassing condition ever since. Almost from the beginning, during periods of high lake levels, wave over-topping of the north jetty has thrown sediment into the harbor, gradually accumulating more than 200,000 cubic yards of material there. This material is effectively removed from the littoral budget and most is permanently impounded. Lakeward from the harbor, fine sediment has been diverted by the north jetty into the open lake, eastward and southward, spreading a thin sheet of very fine sand and silt over the lake floor. Today this material amounts to about a 100,000 cubic yards but in truth it probably represents a reduction since 1872.

Immediately south of the harbor some sediment that bypasses the north and east jetties is diverted by waves into the lee of the south jetty and has formed a significant deposit of nearly 100,000 cubic yards there, probably half of what was there in 1873. A small south fillet, in addition, has been built by over-topping of southeasterly waves.

In addition to impounding and diverting littoral drift, currents caused by impingement of waves upon the jetties has caused scour zones that are relatively free of sediment (figs. 6, 17, 18). One is present 800 to 1000 feet east of the east jetty where southward currents turn past the northeast corner of the harbor and move southward. The other main area lies 3000 feet south of the south jetty and results from wave and bottom and current scour of a zone starved of sediment because of its location downdrift from the harbor.

Present conditions indicate that as long as high lake levels in Lake Michigan, there will be a general attrition of sediment from the north fillet as well as from other deposits associated with the harbor. If high levels persist along enough, all significant deposits of littoral sediment on the Great Lakes-Lake Bluff reach will be depleted.

Impoundment of sediment within the harbor, which is the most important effect of the harbor on the littoral drift, can be stopped by raising the height of parts of the harbor jetties. Such construction would add significantly to the amount of sediment bypassed naturally to the south of the harbor and would avoid pollution of large quantities of sediment. On the other hand, such action probably would greatly increase silting at the harbor mouth. Periodic movement of the material there to the south side of the harbor by dredge, on the other hand, would effectively remedy some of the conditions caused by the silting and would feed the southern shore. Because of the very fine nature of the littoral sediment, however, and the fact that the drift from Waukegan is meagre, even 100 percent bypassing of sediment at the GLNTC harbor would not solve all of the recession problems of the downdrift shore in north Lake Bluff.

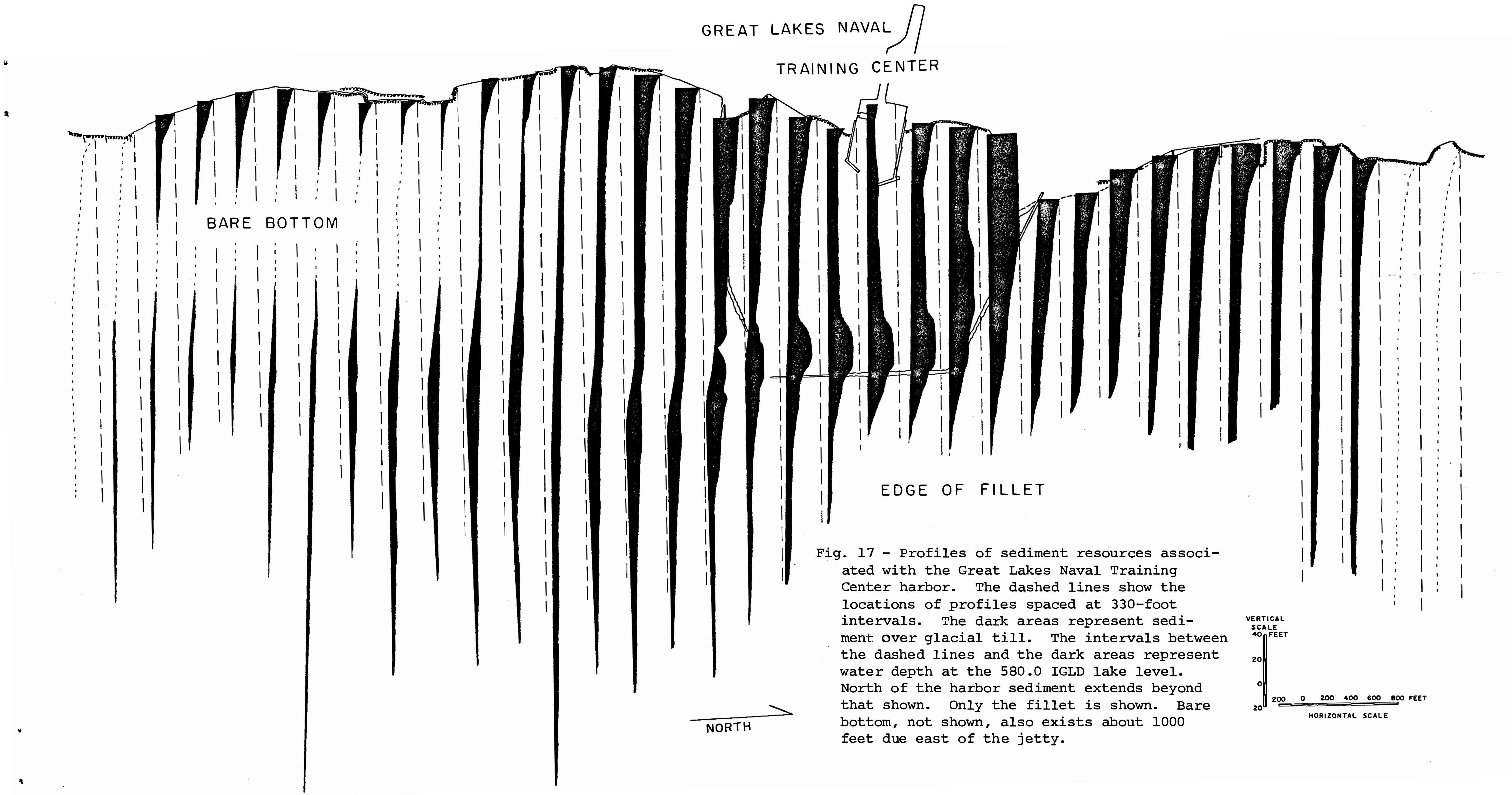
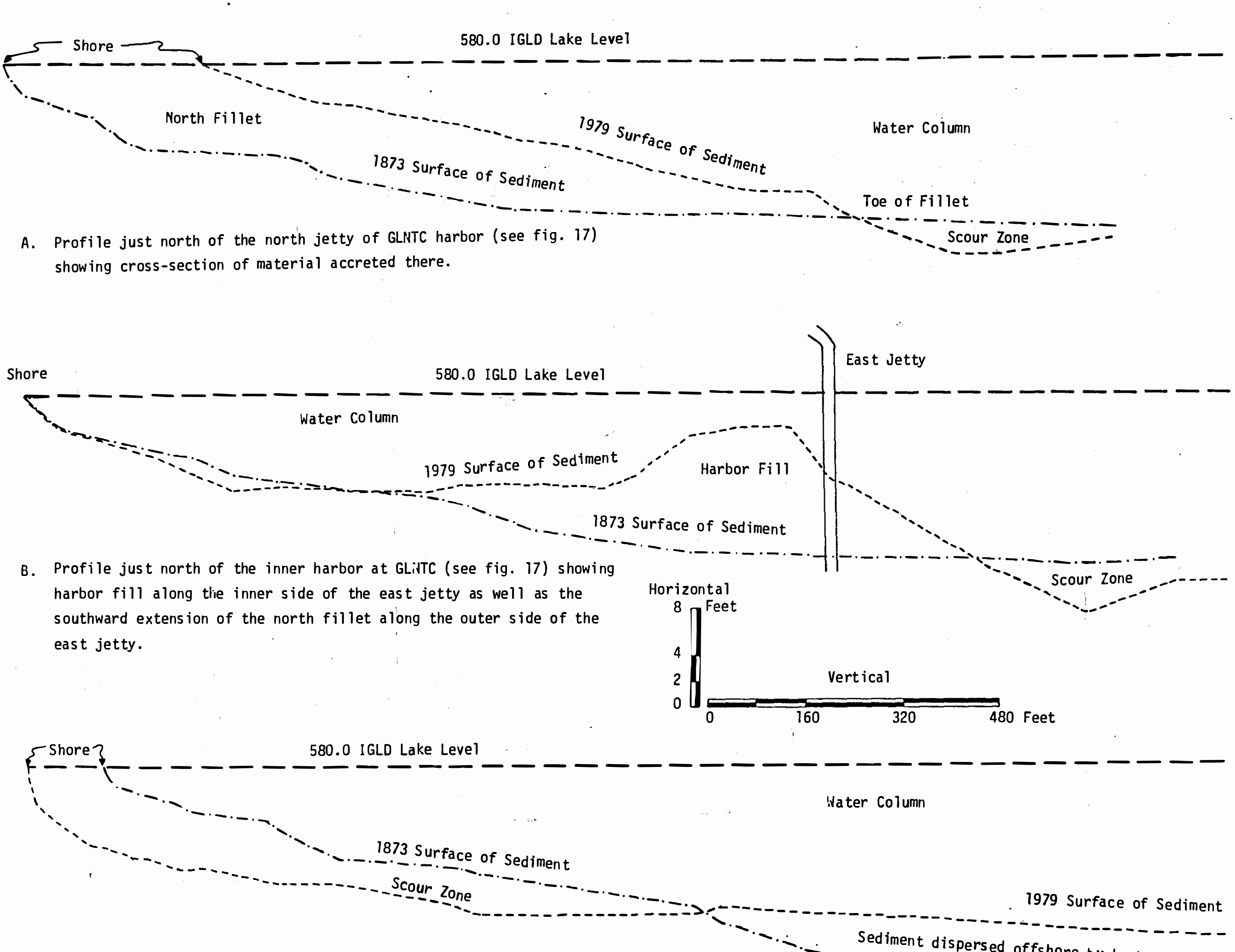


Fig. 17 - Profiles of sediment resources associated with the Great Lakes Naval Training Center harbor. The dashed lines show the locations of profiles spaced at 330-foot intervals. The dark areas represent sediment over glacial till. The intervals between the dashed lines and the dark areas represent water depth at the 580.0 IGLD lake level. North of the harbor sediment extends beyond that shown. Only the fillet is shown. Bare bottom, not shown, also exists about 1000 feet due east of the jetty.



A. Profile just north of the north jetty of GLNTC harbor (see fig. 17) showing cross-section of material accreted there.

B. Profile just north of the inner harbor at GLNTC (see fig. 17) showing harbor fill along the inner side of the east jetty as well as the southward extension of the north fillet along the outer side of the east jetty.

C. Profile located 450 feet south of the south jetty at GLNTC harbor.

FIGURE 18

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