the michigan demonstration erosion control program in 1976

michigan sea grant program

technical report no. 55

michu-sg-77-200 february 1977


A.S. Dorr

THE MICHIGAN DEMONSTRATION EROSION CONTROL PROGRAM IN 1976

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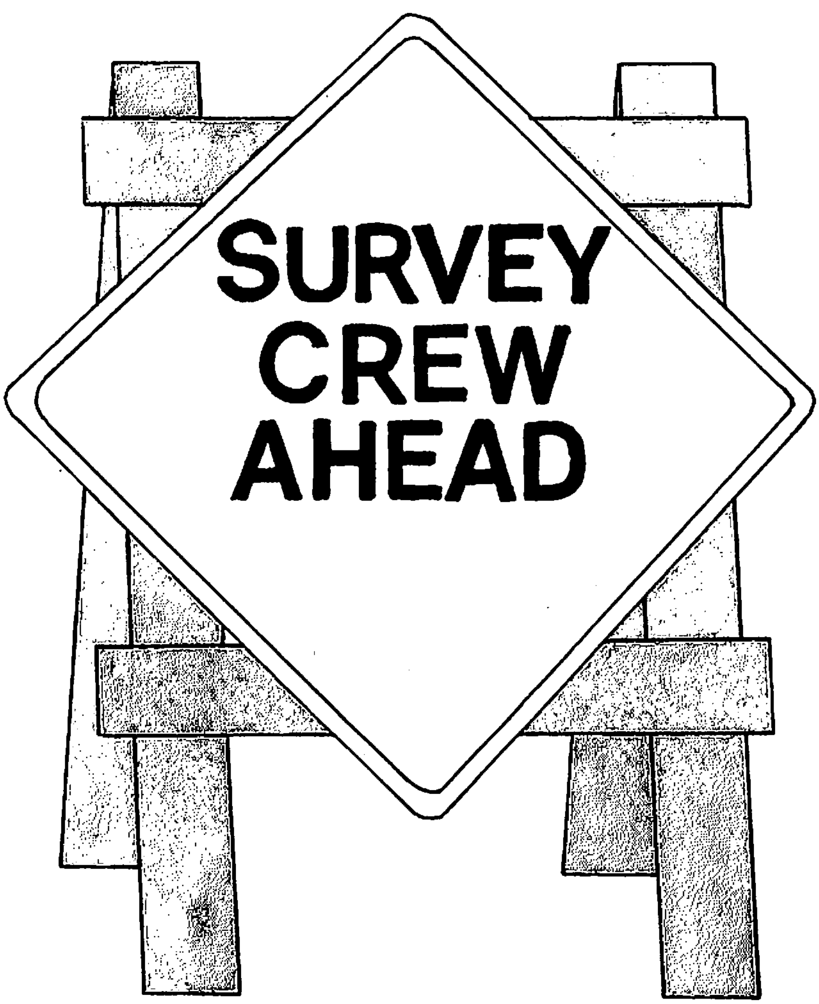

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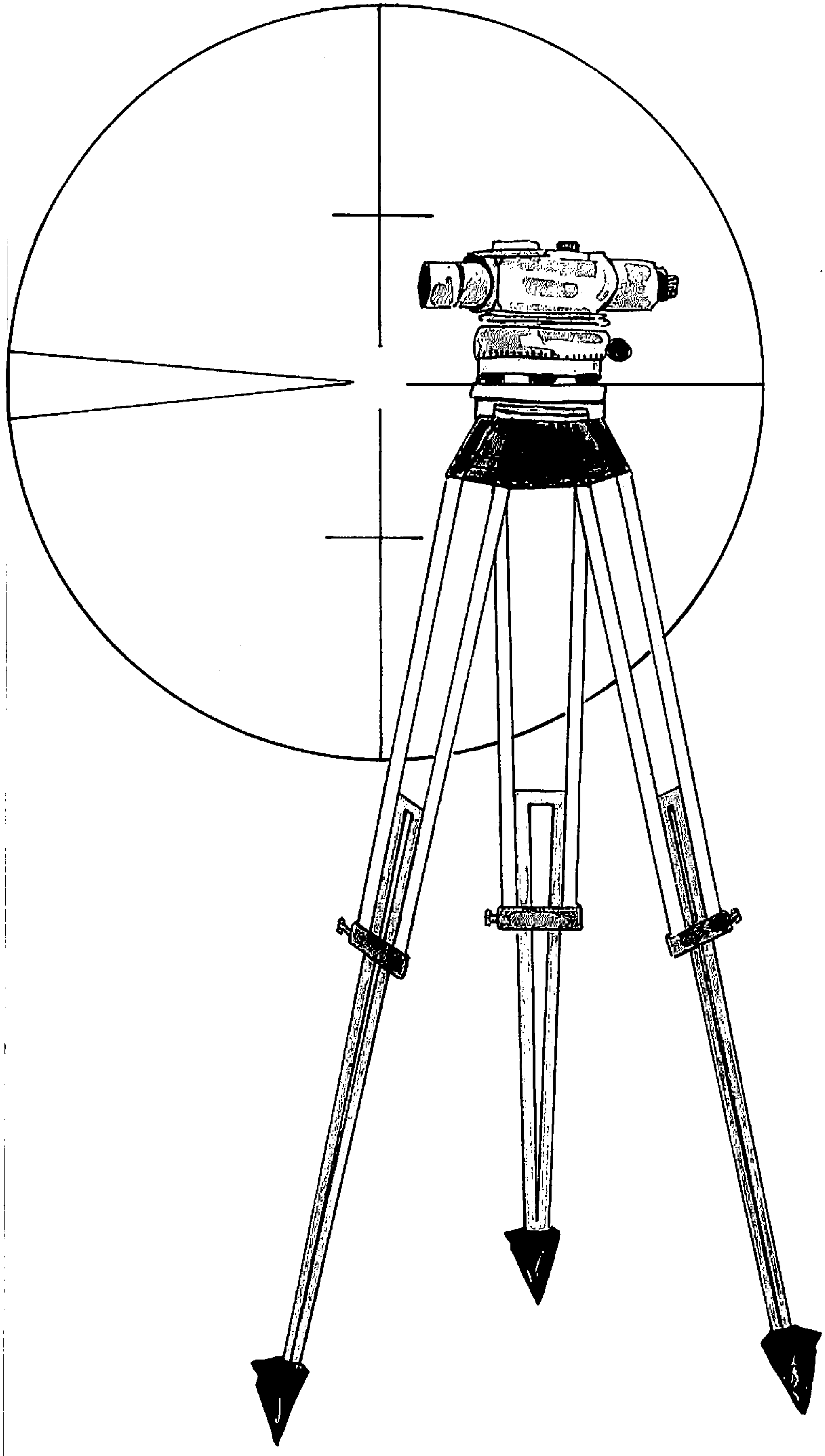


Introduction

The long-range objective of this program is to provide assistance in the selection and design of economically feasible low-cost shore protection procedures. Immediate benefits consist of the demonstration of procedures which have a reasonable chance of success and avoidance of losses which occur with the use of procedures which have little chance of providing benefit. It is estimated that about 600 miles (966 km) of the 3000 miles (4828 km) of Michigan shoreline are having serious erosion problems. In some areas the average bluff recession rates for the last 30 years are more than 5 feet (1.5 m) per year and the annual property loss is many millions of dollars. Part of this loss is due to the use of poorly conceived and improperly constructed shore protection structures.

The information needed to achieve this objective is being obtained from observations of 19 shore protection demonstration projects, from a concurrent laboratory investigation and from an historical study of erosion conditions during the period of records. The distribution of information from the program to the public and to the state agencies which are concerned with coastal zone planning and shore protection has been accomplished by means of published reports, brochures, educational work sessions, radio, and television. The programs for bringing information to those who need help on shore problems have been greatly assisted by the cooperation of the Michigan Sea Grant Advisory Services staff and the Michigan Department of Natural Resources. In addition to the technical reports and papers described later in this report, two self-help brochures have been made available. These are "Low-Cost Shore Protection for the Great Lakes" and "Shore Erosion - Why - What To Do About It." Both of these provide information on how to install well-established types of low-cost shore protection.

This program was initiated in 1973. Nineteen test sites were selected around the State of Michigan on public land for the demonstration of various shore protection schemes. The site locations are shown in Figure 1. These sites are being reviewed in an ongoing program which utilizes topographic/hydrographic surveys and/or photographic records. Storm activity has been recorded for many of the sites. Brief descriptions of the installations at each site are given in Appendices I, II, and III.

This report provides new data gathered during 1975-76. Only a brief description of each project is presented because three previous reports have been issued which provide detailed information about the projects. The first report, Shore Erosion Engineering Demonstration Project Post-Construction--Season Progress Interim Report, was issued in February 1974. This report describes the sites and methods to be tested during the program. It is basically a background document with baseline information.

The second report, Michigan's Demonstration Erosion Control

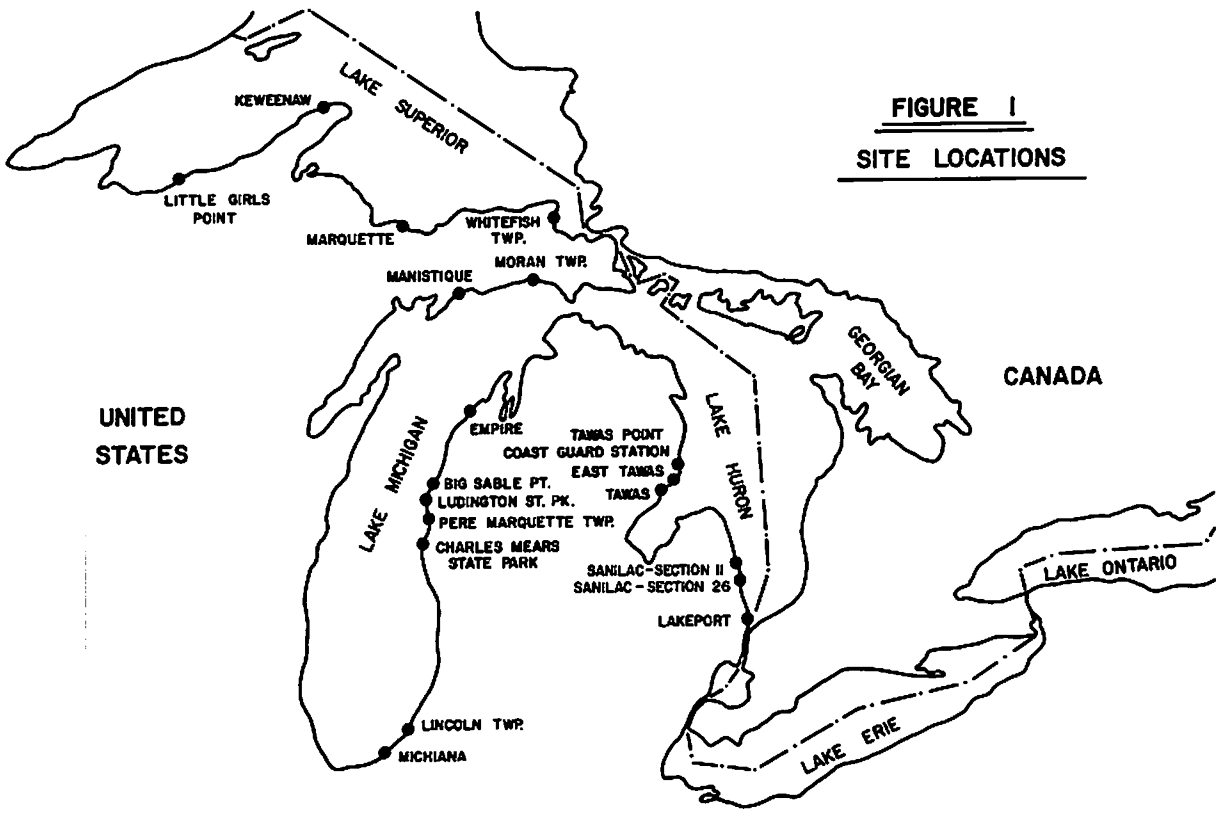
Program, Evaluation Report, was issued in November 1974. This report repeats much of the information given in the first report and describes the study programs.

The third report, Michigan's Demonstration Erosion Control Program, Update Evaluation Report, provides information regarding the analysis of the various structures, including maintenance requirements and suggested design modification. This report also includes an extensive set of conclusions and observations. Information regarding asphalt-mastic design is also included in this report.

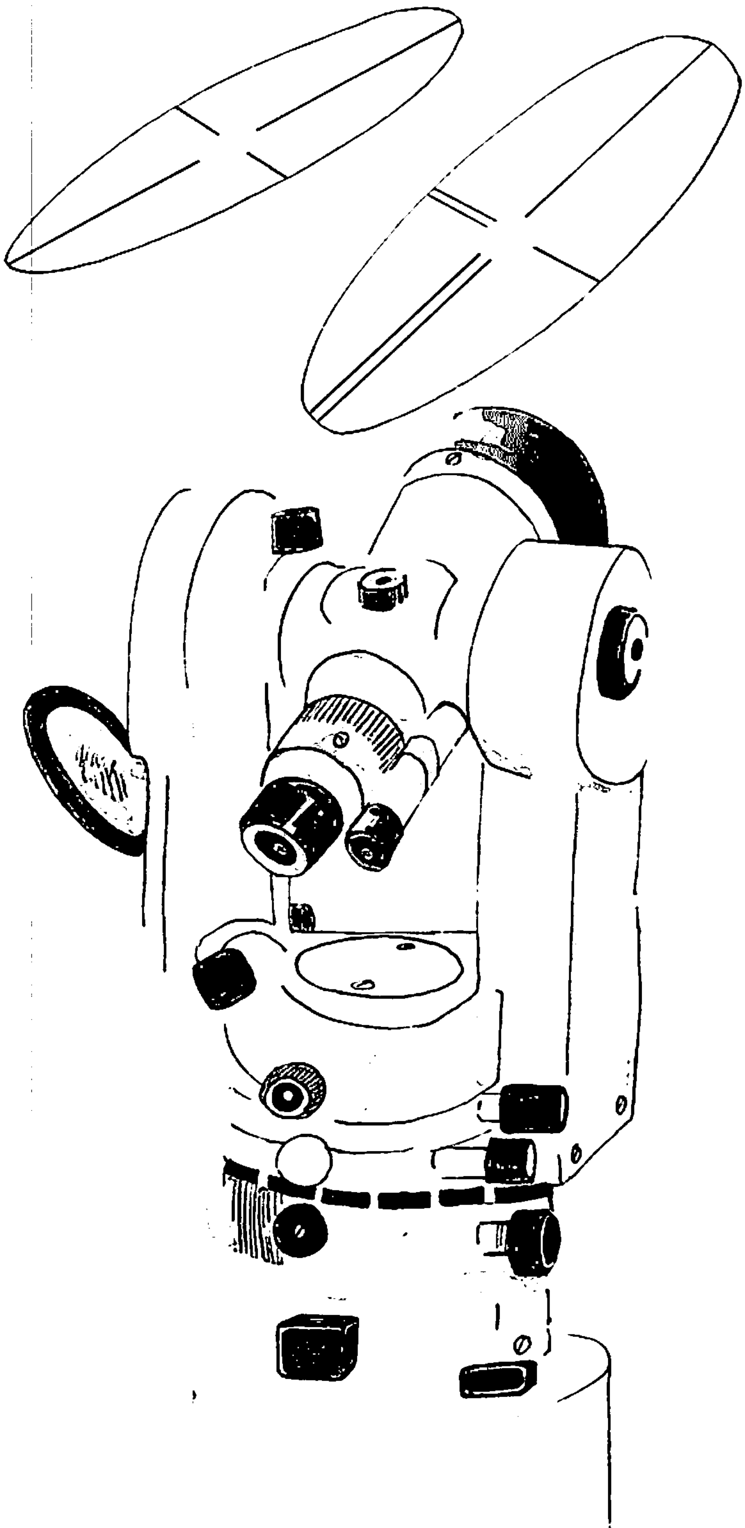
All three reports include a section on laboratory studies with a wave tank which complements the field work. Concurrent with this program an historic report was issued, Beach Erosion in Michigan, An Historical Review, which reviews the problem in a longer time perspective. These reports should be consulted if further detail is desired concerning this program.

FIGURE I

SITE LOCATIONS



Revetments and Sea Walls



Revetments and Sea Walls

Michiana

This site in the Village of Michiana is a 400-foot (122 m) long open coast with sand bluffs approximately 30 feet (9.1 m) high. North and south of the project area there are existing seawalls. A narrow beach exists in this area; see Figures 2 and 3. This shoreline is exposed to long fetches from the west and northwest and has been undergoing severe erosion for many years. A new concept in revetment construction on the Great Lakes was chosen for testing at this site. An inexpensive European technique[1,2,3] using rock and asphalt-mastic (a mixture of sand, mineral filler, and asphalt) was adapted for constructing the revetment. The structure was built in the fall of 1973; see Figure 4. The structure was installed at an expense of $70 per foot ($230 per meter); the Village of Michiana shared in this cost by providing some of the labor needed during construction.

Observations have been made on this installation each spring and fall and after a number of major storms; see Appendix I. During the first year of study the structure performed very effectively and withstood four major storms. A storm in the spring of 1975 which produced breaking waves of approximately 7 feet (2.1 m) for a duration of 24 hours caused most of the structure to collapse. The damage can be seen in Figure 5. This combination of wave height and long duration produced very severe conditions at the bluff.

Conditions were so severe that the steel seawall at the north edge of the site was destroyed and the road at the top of the bluff was threatened. Damage to the revetment resulted in a change of its slope from 2 to 1 to 4 to 1. Figure 6 presents a typical profile of this site. The backside of the revetment was 3 feet (.9 m) lower after the storm. The underwater region immediately offshore had been severely eroded. Therefore, depths near the toe of the structure were greater than those before and during construction. This factor made the toe of the structure more vulnerable to erosion and probably increased the run-up. It is believed that the undermining was caused by the combination of scour at the toe and the backwash from the run-up. The rock mastic revetment was more effective than the adjacent seawall as it was able to provide protection for the bluff (and the road) even in its damaged condition.

It appears that the rock mastic revetment performs quite well during most storm activity. The damage to the revetment from the

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[1] Proceedings of The Association of Asphalt Paving Technologists, Technical sessions held at Philadelphia, Pennsylvania, February 15, 16, and 17, 1975, Vol. 34.

[2] Baran W. F. Van Asbeck, Bitumen in Hydraulic Engineering, Vol. I, Shell Petroleum Co., Ltd., London, 1955.

[3] Ibid., Vol. II, Elsevier Publishing Company, New York, 1964.

Figures 2 (left) & 3 (right). Michiana, August 1, 1973

These photographs show the Michiana site prior to construction. The seawalls evident at the ends of the beach mark the limits of the project area. The Village's major utilities and road are located at the top of the sand bluff.

Figure 4. Michiana, September 23, 1973.

The revetment can be seen one week after construction. The stakes mark the lower edge of the structure.

Figure 5. Michiana, September 16, 1975.

This photograph shows the condition of the revetment after collapse. Some sections, however, have remained relatively unchanged. Notice the exposed foundation of the concrete seawall in the background; evidence of the higher lake level in this vicinity and the lowered beach profile.

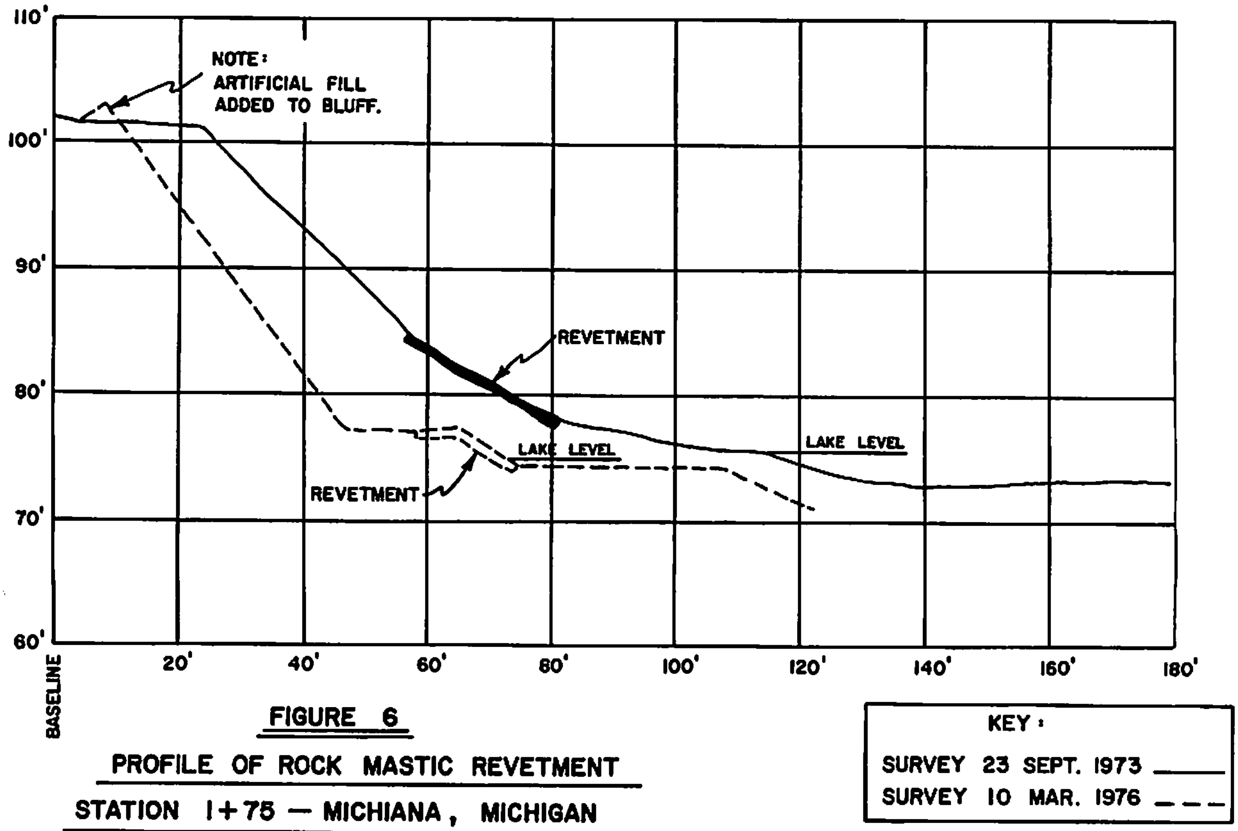


FIGURE 6

PROFILE OF ROCK MASTIC REVETMENT

STATION 1+75 — MICHIANA, MICHIGAN

unusually long storm also may have been caused by wave reflection off the steel wall at the north end. This is supported by the fact that 75 feet (22.9 m) of revetment closest to the wall suffered severe slumping whereas the next 75 feet (22.9 m) was hardly damaged. Even in its collapsed position, the revetment continues to provide some protection from minor storms.

Big Sable Point

This project site is located at the lighthouse station at Big Sable Point. An existing 200-foot (61 m) seawall, which extended 4 feet (1.2 m) above the lake surface, had been built many years earlier to protect the lighthouse. This seawall had been flanked and fill behind the wall was eroded. The plan view of the seawall is a curve with the concave side toward the shore. It was decided, at a later date, to include this in the Demonstration Program in an attempt to repair and to stop further damage behind the seawall.

Since this project was included in the program at a late date, funds were limited and use was made of materials left over from another project. During the fall of 1974, tie-backs were installed to strengthen the wall, three groins were constructed between the wall and the existing bluff, and the area between the wall and the bluff was backfilled. The groins were constructed from gabions lined with filter cloth (to help prevent sand movement); see Figure 7. Since some of the materials used for construction of this project were left over from other projects, it is not possible to determine the costs for this installation.

This site has been visited each spring and fall to obtain photographic records. Periodically, additional visits have been made to obtain supplemental information. Appendix I gives the dates of visits to this site.

The south groin was poorly constructed and failed shortly after construction; see Figure 8. The center groin, also poorly constructed, was too short to be functional and heavy erosion of the backfill/bluff has occurred. This erosion exposed the tie-back system and revealed that these had not been completed properly. The seawall, in spite of its curved shape, has now begun to lean forward because of the deep water in front of it.

The methods selected for testing here would have been more effective if they had been properly constructed. This project demonstrates the weakness of inadequate construction and the need for constant inspections when construction is in progress. Constant inspection of construction was not possible at this site. This project also provides a demonstration of the vulnerability of a vertical wall without tie-backs or toe protection.

Empire

Rapid recession rates have been experienced at the Village Park in Empire. This open coast with 3-foot (.9 m) sand bluffs (see

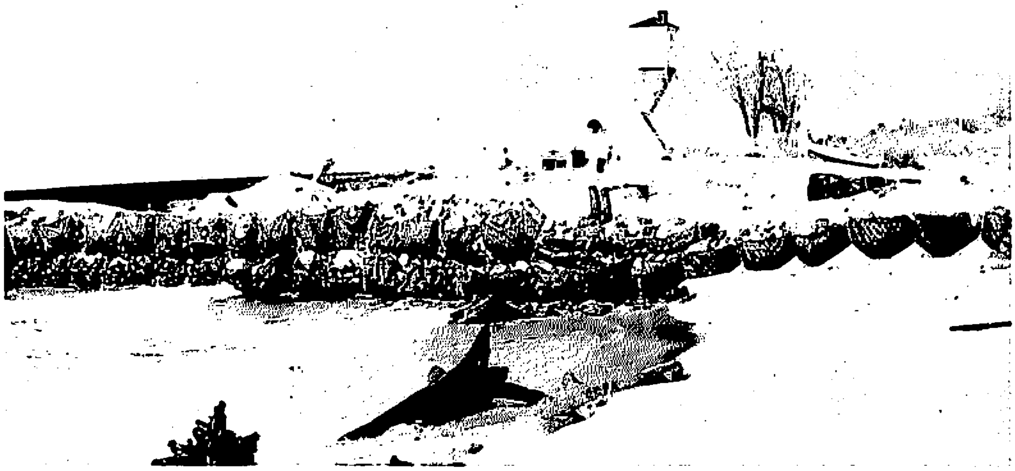


Figure 7. Big Sable Point, October 19, 1974.

The gabion return wall can be seen at the southern limit of the project site. The filter cloth used to line the baskets is evident. The existing seawall can be seen in the left center of this picture.

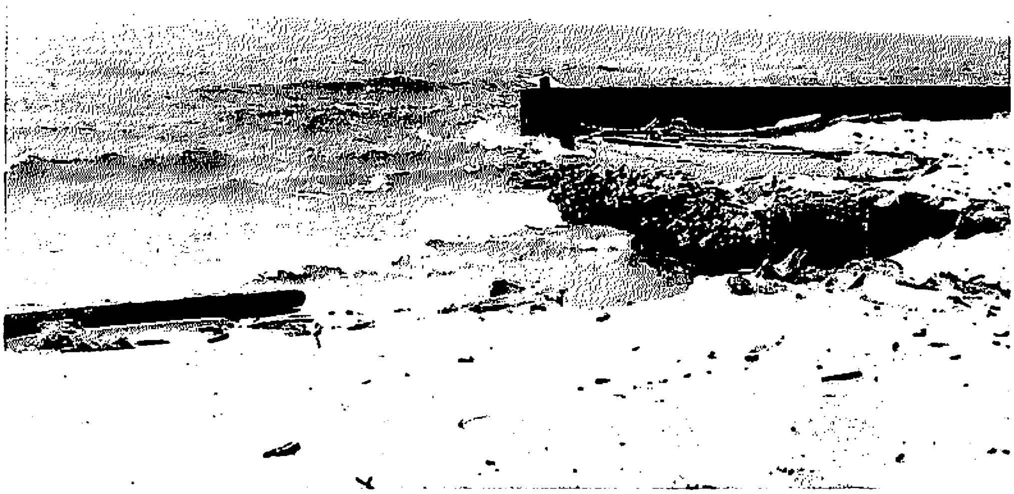


Figure 8. Big Sable Point, May 19, 1975.

The failed return wall can be seen in this view of the site at Big Sable Point.

Figure 9) was selected for testing a 40-inch (101.6 cm) diameter Longard tube used as a seawall. The 300-foot (91.4 meter) tube was laid during the fall of 1973 on a filter cloth foundation parallel to shore at a cost of $30 per foot ($98 per meter) of shoreline. The tube can be seen immediately after it was installed in Figure 10. Shortly after construction the tube was attacked by 5-foot (1.5 m) breaking waves for a 14-hour period. Probable maximum wave height was 11 feet (3.4 m). Due to the shoreline configuration, waves pounded directly against the structure. The single tube was unable to withstand this wave attack and was severely damaged and undermined, as illustrated in Figure 11. By the spring of 1974 the remaining exposed south end of the tube began to rip open; see Figure 12. Erosion of the bluff and beach at this site and at adjacent areas has continued at about the same rate. Enough beach had eroded by the spring of 1976 to expose portions of the settled north end of the tube; see Figure 13. Figures 14 and 15 provide plan and profile details of this site.

This method of shore protection has proven ineffective at this exposed location. Modifications, such as tying the ends of the tube into the bluff or providing a foundation, may be expected to increase the effectiveness of a single 40-inch (101.6 cm) diameter Longard tube used as a seawall. At the Moran Township site a similar installation consisting of three tubes has been quite successful. At Sanilac-Section 11, a single 69-inch (175.3 cm) diameter Longard tube has been somewhat more effective.

Moran Township

This site is located along U.S. 2 in Moran Township, Mackinac County. The 30-foot (9.1 m) sand bluffs found here have been severely eroded. Two styles of seawalls were selected for testing. Three 40-inch (101.6 cm) diameter Longard tubes were installed in a pyramid configuration (one on top of two) on filter cloth parallel to the shoreline near the waterline in the fall of 1973. The tubes extended for 300 feet (91.4 m). The second structure consisted of giant* sandbags placed in four different stacking patterns at the toe of the bluff, parallel to the shoreline, for 250 feet (76.2 m). Construction of the sandbags began in the fall of 1973 and was completed in the spring of 1974. The different stacking sequences were incorporated to test their relative effectiveness. A view of this site during the late fall of 1973 can be seen in Figure 16. The cost of construction per foot (meter) of shoreline for each seawall was $60 ($197). This site has been surveyed each spring and fall and after a number of major storms; see Appendix I for the dates of each visit.

During the first year of study the top Longard tube shifted out of position due to back pressure from the slumping bluff and had to be shimmed up. The western 50 feet (15.2 m) moved lakeward about 3 feet (.9 m). The lower tube is now covered with sand, apparently from sand washed in and around it or from the slumping bluff. The top of the bluff behind the structures has continued to recede and slump.

*Giant sandbags refers to the large size of these particular sandbags ranging from 2 x 5 x 10 feet or 1.5 x 6 x 20 feet (.6 x 1.5 x 3.0 meters or .4 x 1.8 x 6.1 meters).

Figure 9. Empire, August, 1973.

This photo shows the condition of the Empire site immediately prior to construction. The narrow, low bluff makes this area particularly susceptible to erosion.

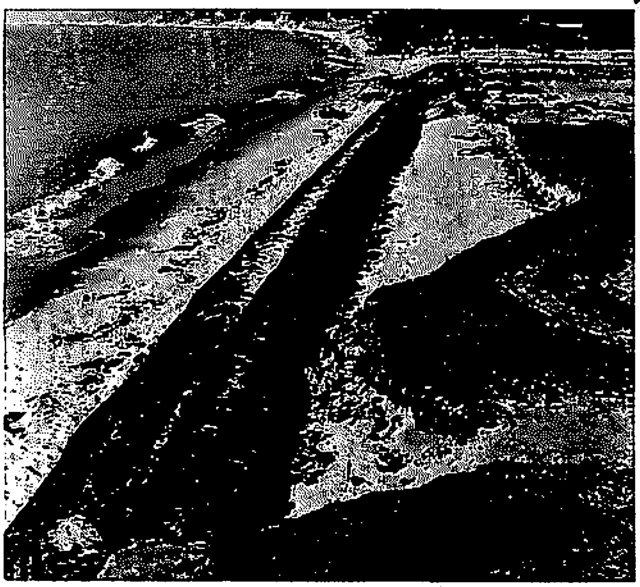
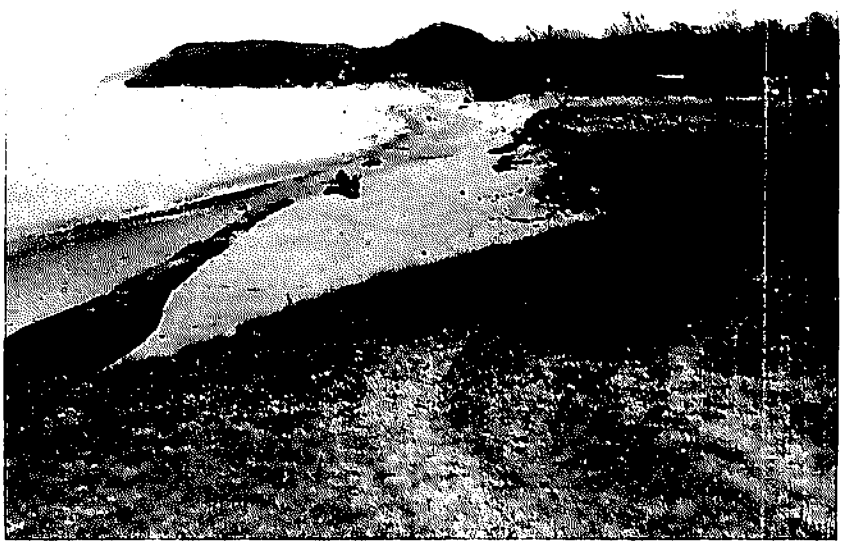


Figure 10. Empire, October 23, 1973.

The condition of the site immediately after construction was completed is shown. The 40-inch (101.6 cm) diameter tube has been placed on a layer of filter cloth. The low sand bluff is particularly evident in this photograph.

Figure 11. Empire, December 1, 1973.

The north end of the tube moved considerably lakeward (about 20 feet [6.1 m]) and settled about 3 feet (.9 m). The south end of the tube remained relatively stable. This is probably because of large rocks buried in the beach under the tube which helped prevent settling.



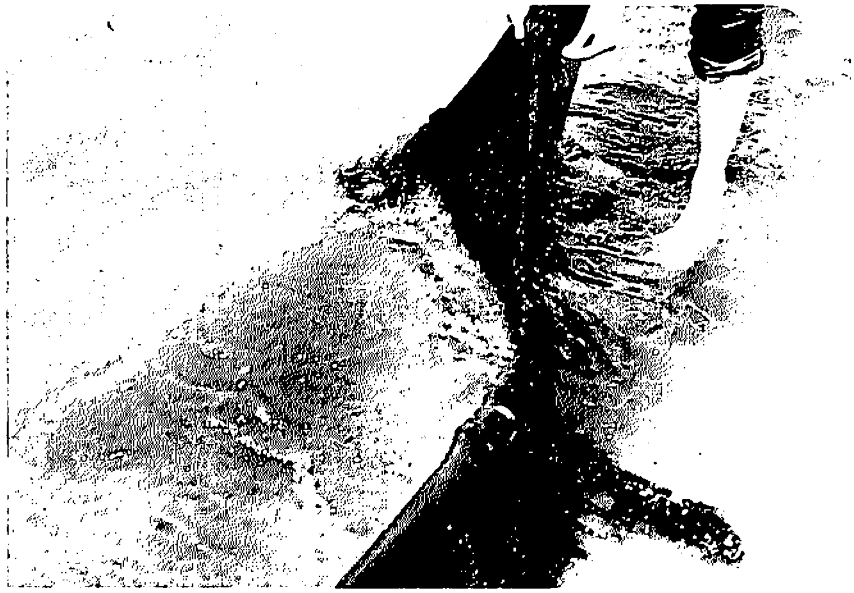


Figure 12. Empire, June 15, 1974.

This photograph shows a portion of the tube which was ripped after the initial damage experienced in the fall.

Figure 13. Empire, April 28, 1976.

The portion of tube which was exposed after substantial beach area was eroded can be seen. Some of the filter cloth foundation is also evident in the photograph. Most of the tube, which had begun to rip in 1974, was completely ripped and shredded at the time of this photograph.

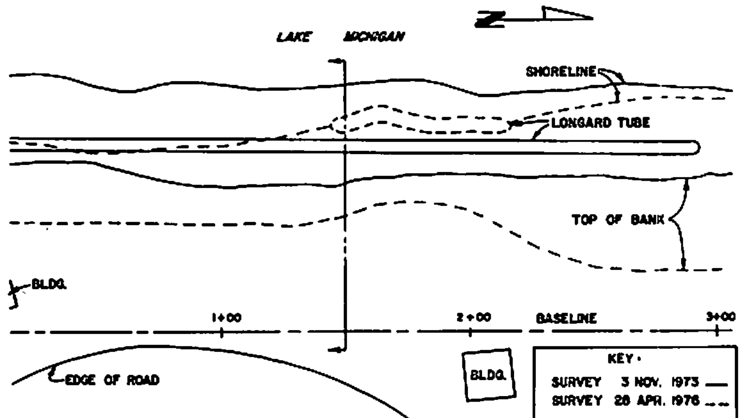


FIGURE 14
PLAN VIEW OF EMPIRE, MI.

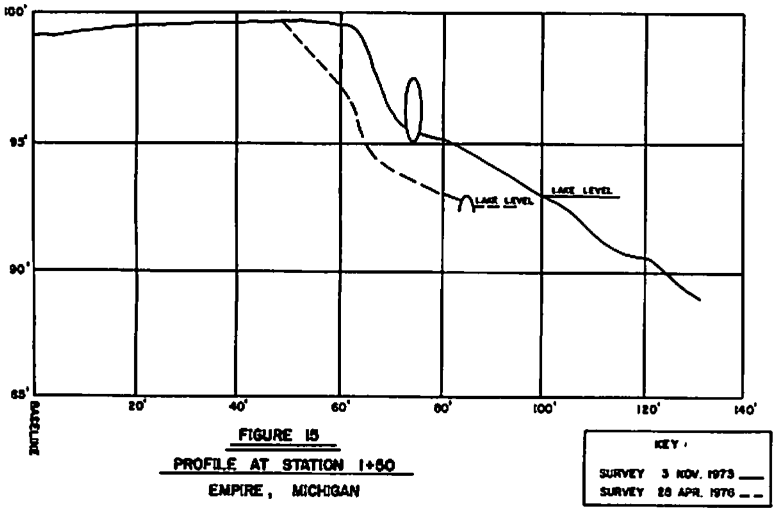


FIGURE 15
PROFILE AT STATION 1+50
EMPIRE, MICHIGAN

Figure 16. Moran Township, November 4, 1973.

This view of the project area shows the initial configuration of the Longard tubes and the sandbags which are still under construction. Note the steep high sand bluffs which are directly exposed to wave attack.

This occurred because the sand bluff was not at a stable slope. Some bluff loss due to lake activity has occurred behind the sandbags and between the two structures. The sandbag structure has suffered some bag loss due to vandalism or floating logs and fallen trees. However, it has remained quite stable and performs effectively; see Figures 17, 18, and 19. There has been no major wave erosion behind these installations. However, the shoreline adjacent to the structures has also experienced only minor recession. The width of beach in front of the Longard tubes is greater than in front of the sandbags. This appears to be more of a natural phenomenon than an indication of relative structure effectiveness. Figure 20 shows the site's condition in the spring of 1976.

Tawas Point Coast Guard Station

The shoreline at the Tawas Point Coast Guard Station is exposed to direct wave attack and has 10-foot (3.0 meters) sand bluffs; see Figure 1 for the location of this site. A rock revetment was selected for testing at this site and was constructed in the summer of 1974. To install the 400-foot (121.9 m) revetment, a foundation layer of 4 to 10 inch (10.6 to 24.4 cm) rock was graded to a 3:1 slope 30 feet (9.1 m) wide. At the top of the revetment a 3 by 5 foot (.9 by 1.5 m) trench was dug and filled with smaller size (1 to 3 inch [2.5 to 7.6 cm]) rock. This prevents erosion in back of the revetment caused by wave overtopping. The north half of the structure was capped with medium size (11 to 16 inches [27.9 to 40.6 cm]) armor stone. Total cost of construction was $50 per foot($164 per meter) of shoreline. The U.S. Coast Guard Station contributed one-fifth of the construction costs.

Appendix I shows the specific dates when this site was surveyed. Generally surveys were conducted in the spring and fall and after major storms. Prior to installing this revetment the Coast Guard Station had considerable bluff recession. There has been little recession since the revetment has been completed. Although only minor storm activity has been experienced, slight slumping and shifting of the rock is evident; see Figures 21 and 22. Further rock movement may occur if major storms are experienced. This structure is very effective in protecting the shoreline.

Sanilac-Section 11

This site is located at a roadside park about three miles south of Port Sanilac in Sanilac County. Two 69-inch (175.3 cm) diameter Longard tubes were installed here as a seawall by the Michigan Department of State Highways and Transportation. The tubes were placed end-to-end at the toe of the bluff, parallel to the shoreline, for a distance of 400 feet (121.9 m). For experimental purposes these tubes were installed without any foundation. The "solid" clay lake bottom did not appear to warrant such measures. Cost of construction was $65 per foot ($213 per meter) of shoreline at the time of installation in the early fall of 1974. Figure 23 shows the condition of the site in the

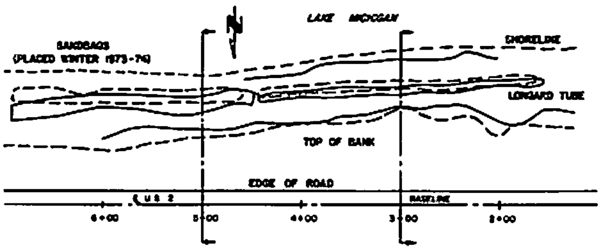


FIGURE 17
PLAN VIEW OF MORAN TWP., MICHIGAN

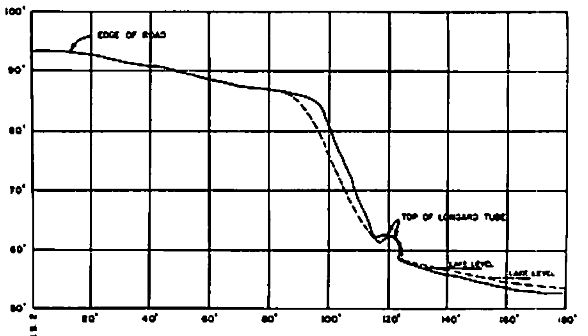


FIGURE 18
PROFILE AT STATION 3+00
MORAN TWP., MICHIGAN

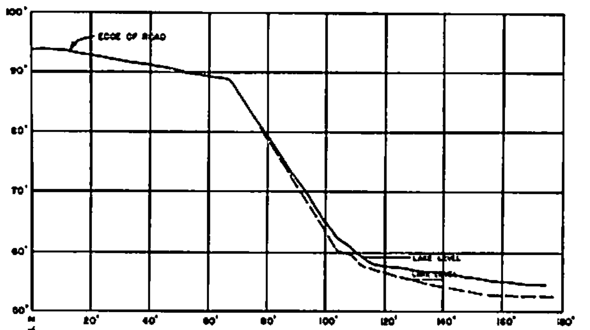


FIGURE 19
PROFILE AT STATION 5+00
MORAN TWP., MICHIGAN

Figure 20. Moran Township, April 28, 1976.

The Moran Township site is seen in the spring of 1976. The Longard tubes are still in place after being shimmed up. Although a number of the shims (wedges) have been lost, many are still evident in this photo. It can be seen that the lower front tube is still a different color. This is because an experimental protective coating was applied to this tube during the first year of study. The sandbag structure is evident in the background. Many of the sandbags have been lost (largely, it is believed, due to vandalism). A number of trees have fallen immediately behind these structures as the top of the bluff has receded.

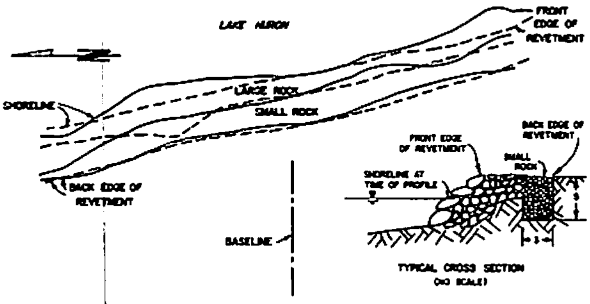


FIGURE 21
PLAN VIEW OF
TAWAS POINT COAST GUARD STATION

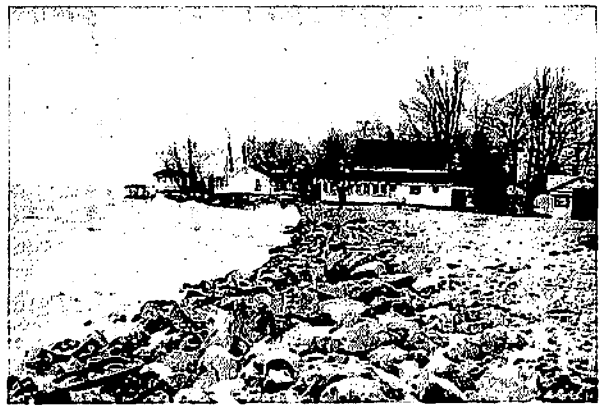


Figure 22. Tawas Point Coast Guard Station, April 25, 1976.

Taken in the spring of this year, this photo shows the rock revetment at Tawas Point Coast Guard Station. There has been some very minor shifting of rocks used to construct this revetment but on the whole this structure has performed very well.

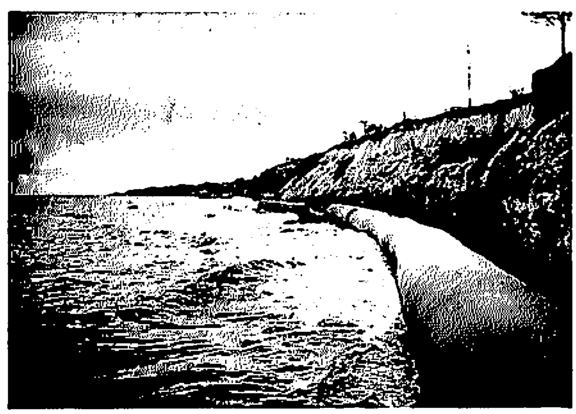


Figure 23. Sanilac-Section 11, October 20, 1974.

This photo was taken during the first survey of this site. At that time the filling operation of the tube was still underway. The hopper which is used to fill the tubes is evident in the background of the picture. The background tube is yet to be filled completely. The very steep, actively eroding, clay bluffs typical of this area can also be seen.

fall of 1974. This site has been reviewed each spring and fall.

The tubes performed well at this location through the fall of 1975. There was minor shifting and damage. Some sand had been lost at the center of the structure where the two tubes meet, and the north end had moved lakeward about 5 feet (1.5 m); see Figure 24.

The survey made in the spring of 1976 revealed that this structure had been severely damaged; see Figure 25. This damage probably occurred during a critical storm experienced in late April 1976. Portions of the tube have collapsed and the entire structure has rolled toward the lake. Photographic records show that during the past two years the bluff recession rates to the north and south have been greater than at the site of this installation. It appears that these tubes have reduced the erosion rate to the land area behind them. Figures 26 and 27 show the movement of the tube.

At this point it appears that simply placing a single Longard tube, of any size, parallel to the shoreline in an open coast area is not a suitable long-term method of shore protection.

Whitefish Township

The Whitefish Township site is located at a Michigan Department of Natural Resources roadside park. This park is located on the west side of Whitefish Bay. This relatively sheltered coast has a low bluff composed of sandy loam which is easily eroded (see Figure 28). The protection system constructed here in the summer of 1974 consisted of filling lakeward with sand (to regain eroded park area) and protecting the fill sand with a series of timber groins and a rock revetment (see Figure 29). The cost of this system was $30 per foot ($98 per meter) of shoreline protected.

This site has been observed yearly during the summer and intermittently at other times. Photographic records show the installation at Paradise has provided complete protection through the spring of 1976. The rock revetment, groins and backfill have suffered no noticeable damage. However, there may be some settling in one portion of the structure. Erosion at both ends of the installation and along the highway about 300 feet (91.4 m) south has continued during the past two years. Recent erosion is also evident in the Village at the library. To date, this installation has been a very satisfactory solution to an erosion problem in a low bluff area with a fetch limited to 25 miles (15 km).

Manistique

The Manistique site is located on the north shore of Lake Michigan at a Michigan Department of Highways and Transportation roadside park. This is an open coast with a low, sandy bluff and a narrow sand beach. A series of gabions were installed as a revetment/seawall during the summer of 1974 at a cost of $20 per foot ($66 per meter) of shoreline.

Figure 24 (above). Sanilac-Section 11, November 1, 1975.

At the time of this photograph the bluff had slumped (naturally) to some extent and portions of the tube were being pushed lakeward by the back pressure of the slumping bluff. One small portion in the center of the structure had lost sand. Generally, it can be seen that the tube withstood the forces of the environment to that point.

Figure 25 (right). Sanilac-Section 11, May 20, 1976.

The damage to the tubes is evident in this photograph. The tubes have rolled toward the lake and sections of the tube have lost their sand. Bluff recession has been recorded behind the tubes.

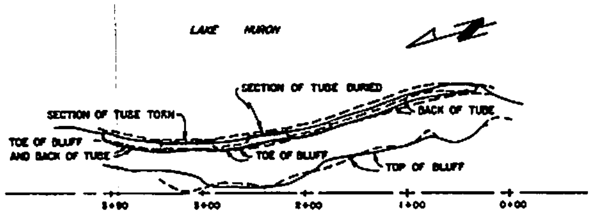


FIGURE 26

PLAN VIEW OF 69" DIA. LONGARD TUBE

SECTION 11 - SANILAC TWP., MICHIGAN

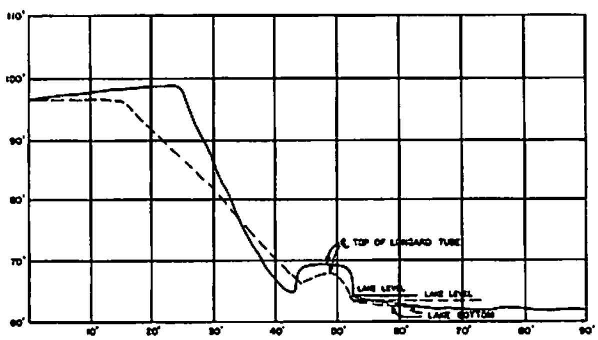


FIGURE 27

PROFILE AT STATION 3+60

SECTION 11 - SANILAC TWP., MICHIGAN

Figure 28. Whitefish Township, Summer, 1973.

This photo was taken in the summer before construction of the shore protection system was completed. As is readily apparent, erosion damage was active at this site and many trees and other valuable park land were being lost.

Figure 29. Whitefish Township, May 18, 1975.

There are no obvious changes after the revetment's first year in place.

Shortly after construction of the gabions, this site was filled and paved over to construct a parking area. Although the gabion system is probably still offering protection to the area, it is impossible to record changes in the structure because of the parking construction.

Keweenaw Peninsula

The site is located in Sand Bay on the northwest shoreline of the Keweenaw Peninsula. The bluffs are 15 feet (4.5 m) high and composed mostly of sand. Wave erosion had been causing the bluff to recede and a highway was being threatened. The county engineer also reported that there had been some wind erosion in the bluff area. Waste rock from mines was available at a low cost. A revetment was constructed using this rock, which varied in size from 3 inches to 2 feet (.1 to .6 m); see Figure 30. These sizes are much smaller than would normally be used. Furthermore, some of the revetment has a slope of 1 to 1 which is steeper than would usually be specified. However, a good toe foundation was constructed by trenching and filling with the same rock. The revetment reaches the top of the bluff in most locations. It is high enough at all locations to prevent substantial overtopping. The cost of the revetment was $20 per foot ($66 per meter) when installed in 1974. In November of 1975 a severe storm occurred along this portion of Lake Superior. This storm did not damage the revetment and no damage was done to the bluff (see Figure 31). This site is slightly sheltered compared with most of the Superior shoreline because the water in the bay is shallower than general for Lake Superior. Furthermore, since the site is located in a bay, some wave energy is refracted toward the points on either end of the bay. Nevertheless, the county engineer reported that the wave action during the November storm must have been very severe. The county engineer also reported that wave spray was rising higher than the tall trees on an island at Copper Harbor. Considering the erosion previously experienced at that site, the revetment probably prevented considerable damage.

Little Girls Point

This site is located near the western end of Michigan's Lake Superior shoreline. The site is fully exposed to waves approaching from the north. During the period of observation the beach had a width of about 30 feet (9 m) and a slope of about 1 to 10. The basic composition is sand but it contains rock varying in size from 2 to 4 inches (5 to 10 cm). The bluff, which is about 30 feet (9.1 m) high, is composed primarily of clay till. Large storms had been eroding the toe of the bluff and there had been considerable bluff recession.

The installation selected for this site was a revetment consisting of Nami rings. These are concrete rings 2 1/2 feet (.7 m) in diameter, 1 foot (.3 m) high and weighing 240 pounds (120 kg). Some of the rings were installed on filter cloth and some on a rock

Figure 30. Keweenaw Peninsula, June 30, 1976.

The highway which was being threatened by severe erosion can be seen at the top of the bluff. Note the varying sizes of rock used in the revetment.

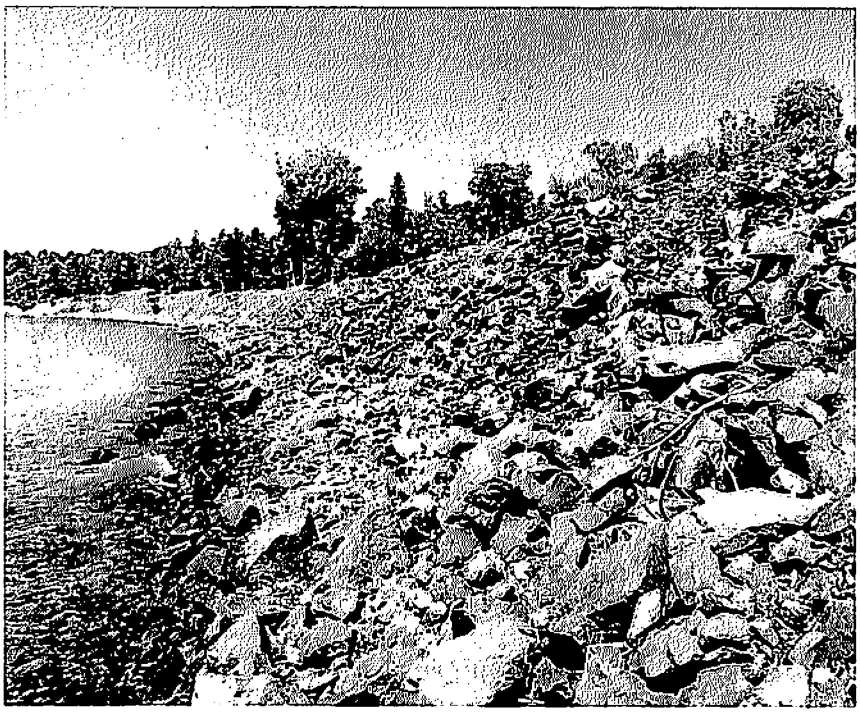


Figure 31. Keweenaw Peninsula, June 30, 1976.

This photograph of the revetment in the spring after the major storms illustrates the stable condition of the revetment.

foundation. Some of the rings were tied together with steel rods. It had been planned to grade the bluff to a slope of 1 to 1 1/2 and install the revetment at the base of the bluff. Instead, the bluff was not graded and the revetment was installed along the upper portion of the beach next to the base of the bluff in the fall of 1974. Therefore, the slope of the revetment was about 10 to 1; see Figure 32.

This site was attacked by a severe storm in November 1975. The park supervisor reported that the spray from the waves striking the bluff was carried above the top of the bluff. The storm eroded the toe of the bluff and considerable slumping has been occurring. It appears that except for one short reach the bluff recession behind the revetment was slightly less than in the adjacent areas. Most of the rings are still in place but some have settled, others have been moved and a number have been broken. The filter cloth has been torn and is exposed in some locations and one of the reinforcing bars has been displaced and bent. The condition of the revetment in June, 1976, is shown in Figures 33, 34, and 35.

Figure 32 (left). Little Girls Point, May 21, 1975.

The Nami rings can be seen after the first year of service. For the most part the rings have remained stable except for some shifting due to the slumping bluff. Many of the rings had filled with sand by the time of this photograph.

Figure 33 (right). Little Girls Point, June 30, 1976.

Many of the Nami rings have settled and/or been broken since installation. This view shows the ongoing recession of the bluff behind the revetment.

Figure 34. Little Girls Point, June 30, 1976.

The broken Nami rings and torn filter cloth foundation are clearly evident in this photo.

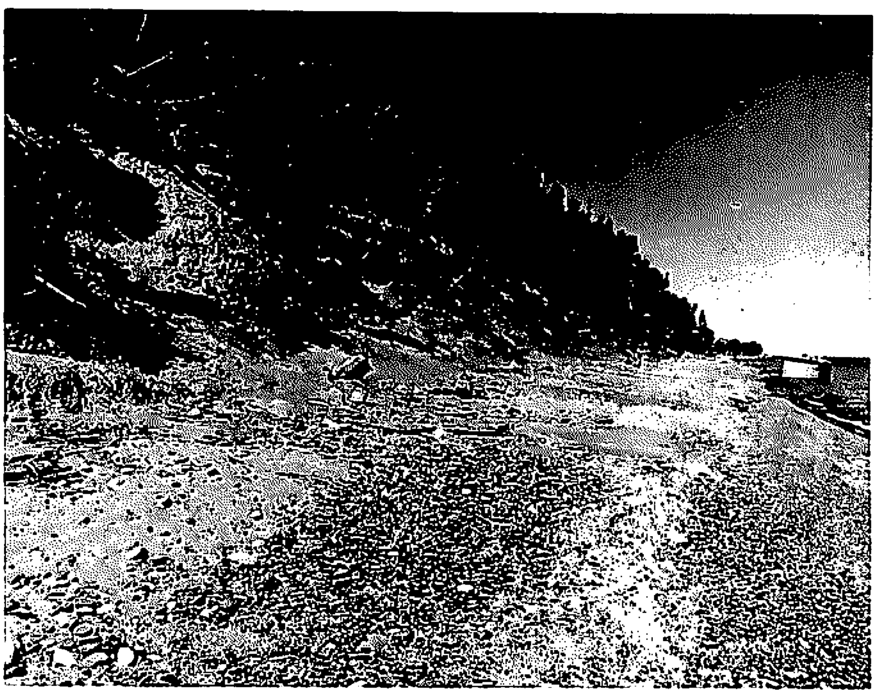
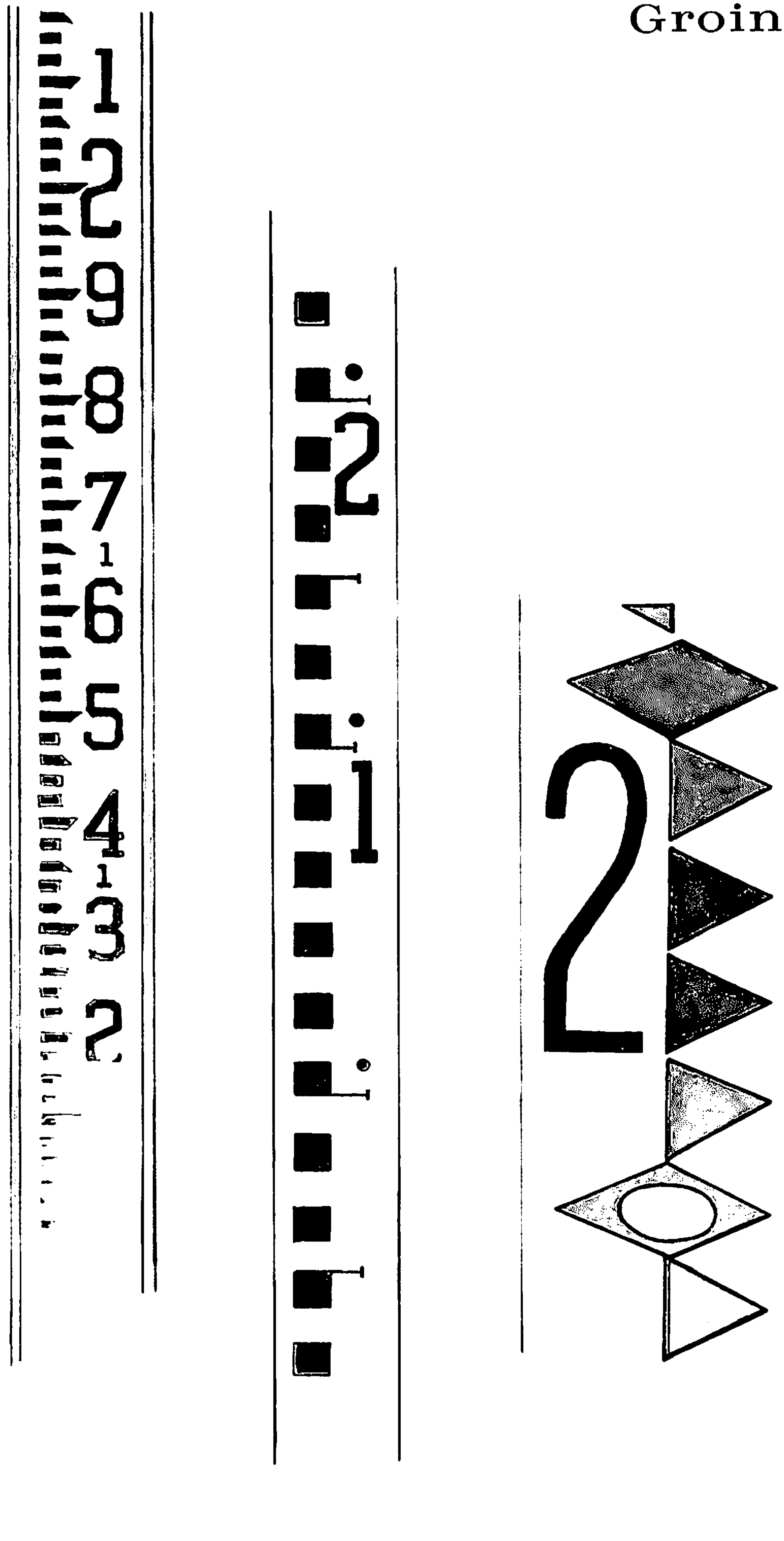


Figure 35. Little Girls Point, June 30, 1976.

This is the same view of the project site as Figure 32, only one year later. The large amount of damage to the revetment is readily apparent. Bluff recession behind the revetment is also obvious.

Groins



Groins

Lincoln Township

Lincoln Township Park is located near Stevensville on the southeast coast of Lake Michigan. The shoreline is unprotected with a narrow beach backed by 20-foot (6 m) sand dunes. An existing steel seawall marks the southern border of the site and a concrete wall forms the northern border (see Figure 36).

The shore protection structures installed at this site consist of two groins 240 feet (73.2 m) apart. Two types of groins were used: a 40-inch (101.6 cm) diameter Longard tube, 120 feet (36.6 m) long, and a 90-foot (27.4 m) long timber pile groin; see Figures 37, 38, and 39. This site has been reviewed each spring and fall and after most major storms.

The Longard tube was the first structure installed at this site in the fall of 1973 at a cost of $30 per foot ($98 per meter). This tube was also installed without a foundation to test the effectiveness of setting such a structure on a sand lake bottom. The Longard tube has suffered moderate damage. Approximately 30 feet (9.1 m) of the lake end of the tube has been lost and the whole structure has settled about 3 feet (.9 m) along the centerline (see Figure 38). The rate of settlement increased again in the fall of 1975 after remaining relatively stable for about a year. It has not been determined if this is due to sand washing out of the tube from the lakeward end or by sinking. The tube still acts successfully as a groin in trapping sand which helps to protect the bluff though some bluff recession has been recorded near this structure. However, after less than three years its effectiveness has been greatly reduced.

The timber pile groin was completed while working through the ice in the late fall/winter of 1973 at a cost of $50 per foot ($164 per meter). This structure has performed well and shows no sign of deterioration (see Figure 39), thus providing additional evidence that wood is an excellent material for groin construction. An impervious timber pile groin is an old and proven means of shore protection in areas where there is adequate littoral drift.

The wide spacing between groins has proven quite successful and the entire system has worked very effectively in protecting the site by trapping sand and raising the beach profile. Both structures are still stabilizing the bluff although there has been minor slumping (see Figure 40). This slumping is probably due to factors other than simply wave attack, such as wind erosion or heavy human traffic on the bluff.

Figure 36. Lincoln Township, August 11, 1973.

The narrow beach and the vulnerable sand bluffs at this site can be seen. The steel seawall marks the southern limit of the project area.

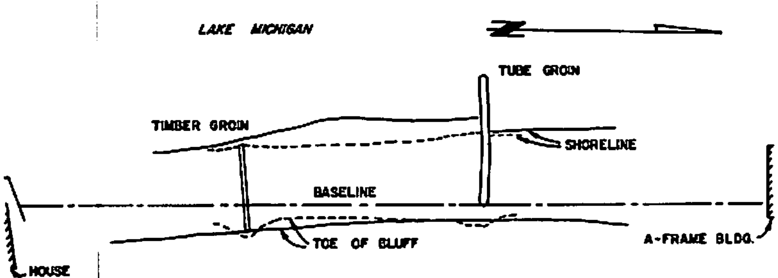


FIGURE 37

PLAN VIEW OF LINCOLN TWP., MICHIGAN

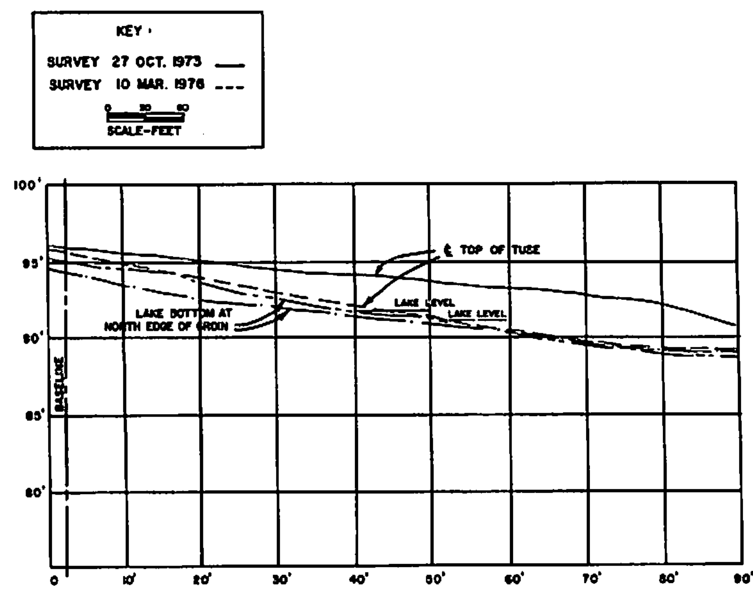


FIGURE 38

PROFILE OF LONGARD TUBE

LINCOLN TWP., MICHIGAN

KEY:
SURVEY 27 OCT. 1973
SURVEY 10 MAR. 1976

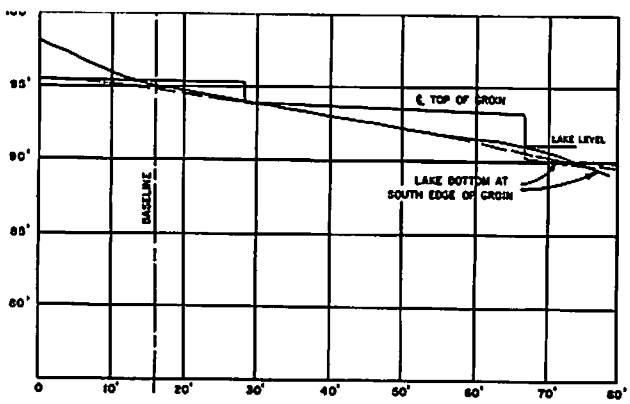


FIGURE 39

PROFILE OF TIMBER GROIN

LINCOLN TWP, MICHIGAN

KEY:
SURVEY 26 JAN. 1974 ——
SURVEY 10 MAR. 1976 - - -

Figure 40. Lincoln Township, May 1, 1976.

This is a view of the site in the spring of 1976 looking to the north. The wood pile groin is evident in the foreground and close observation will reveal the 40-inch (101.6 cm) diameter Longard tube in the background. Some bluff recession/stabilization is evident as documented by the flattened slopes on the bluff.

Charles Mears State Park

The Charles Mears State Park site is located on the east shore of Lake Michigan in an open coast area immediately north of the Pentwater inlet. This site has a wide sandy beach in front of high sand dunes. The erosion control system installed here was designed to protect a park center located near the water's edge.

During the fall of 1973 three gabion groins were installed. During the spring of 1974 it was decided to remove the lakeward gabions and replace them with sandbags (see Figure 41). The park's maintenance program periodically nourishes these groins with sand which has drifted onto a nearby parking area behind the system. This site is surveyed twice a year and usually after major storms. Park personnel also record major changes in the structures.

To date there have been only moderate changes in these structures (see Figures 42, 43, 44, 45, and 46). All the groins have been lowered, particularly at their lakeward end. This lowered profile is partly due to settling of the structures and partly due to bag loss. Because of periodic nourishment, it is difficult to evaluate their effectiveness.

Ludington State Park

This park is located just south of Big Sable Point on the east coast of Lake Michigan. This site is exposed to severe wave action and there appears to be very little near shore littoral drift. Two steel groins were installed 125 feet (38.1 m) apart to stabilize the beach and protect a parking area. The north groin is 100 feet (30.5 m) long and the south groin is 70 feet (21.3 m) long. Work was completed in late fall of 1973. It is not possible to determine the exact cost of construction as some materials and labor were provided at no charge by park personnel. This site has been visited in the spring and fall and after most major storms. Park personnel also assist in observation.

Improper tie-back into the bluff prevented the north groin from performing well. This groin was flanked shortly after construction and deep holes scoured in the lake bottom. This scour caused some shifting of the groin and the breaking of the wales. The lake portion of the groin had to be pulled out, straightened, and redriven. After the original construction-related problems, the groins have remained stable. With periodic filling the groins have successfully prevented beach erosion and protected the adjacent parking area. This procedure has provided protection while preserving the area as a bathing beach.

Sanilac - Section 26

A roadside park four miles (6.4 km) south of Port Sanilac in Sanilac Township on Lake Huron was selected for testing six types of groin construction. This site has a 30-foot (9.1 m) clay till

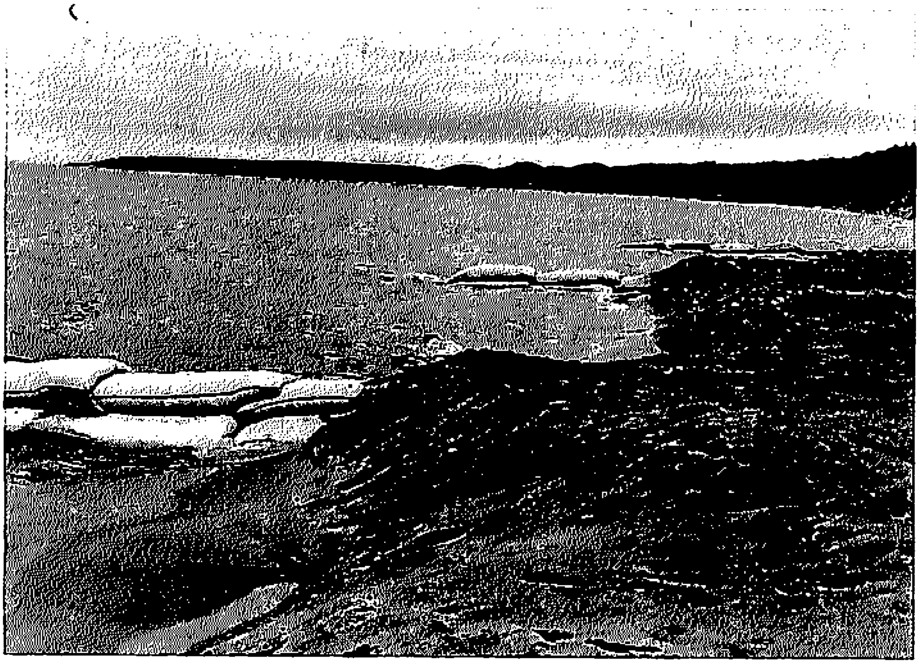


Figure 41. Charles Mears State Park, April 27, 1976.

This photo was taken shortly after sandbags were used to replace the lakeward end of each groin. Buried under the piled sand is the remaining original gabion system.

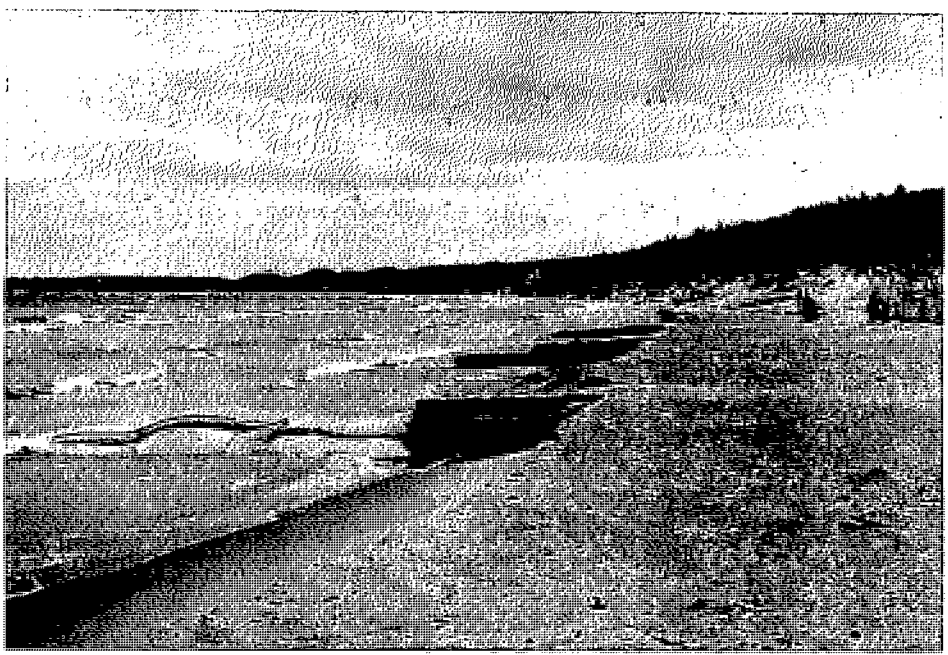


Figure 42. Charles Mears State Park, June 15, 1974.

It is evident that some of the sandbags were either lost or displaced at the extreme lakeward end of the groins. Some of the beach sand has been eroded to expose parts of the original gabions.

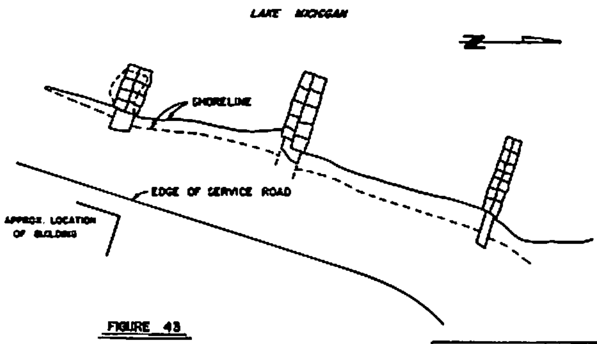


FIGURE 43
PLAN VIEW OF CHARLES MEARS STATE PARK
PENTWATER, MICHIGAN

KEY:
SURVEY 15 JUNE 1974
SURVEY 27 APR. 1976
0 20 40
SCALE-FEET

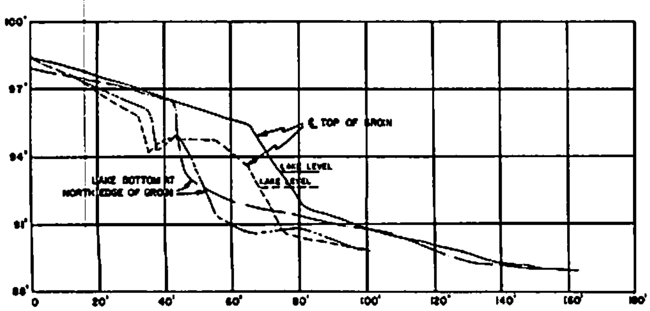


FIGURE 44
PROFILE OF SOUTH GROIN
CHARLES MEARS STATE PARK

KEY:
SURVEY 15 JUNE 1974
SURVEY 27 APR. 1976

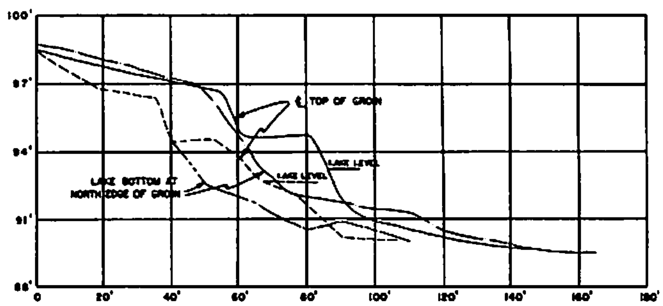


FIGURE 45
PROFILE OF CENTER GROIN
CHARLES MEARS STATE PARK

KEY:
SURVEY 15 JUNE 1974
SURVEY 27 APR. 1976

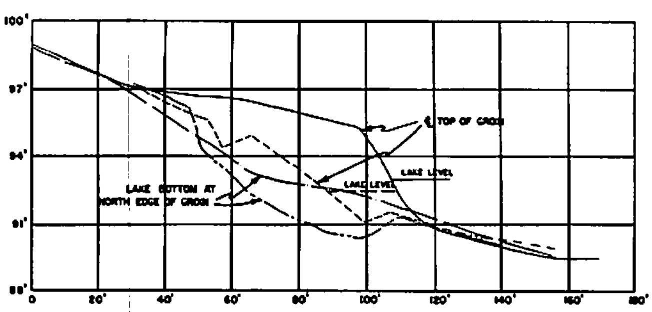


FIGURE 46
PROFILE OF NORTH GROIN
CHARLES MEARS STATE PARK

KEY:
SURVEY 15 JUNE 1974
SURVEY 27 APR. 1976

bluff and no beach with hard clay lake bottom.

Erosion had been occurring at this site for many years. The bluffs had reached a very steep and potentially unstable slope. It had been planned that the Highway Department would provide fill material at the shoreline ends of the groins. This has not yet been done.

The clay lake bottom makes the driving of any type of piles difficult. Thus, the groins selected for this site were designed to rest on the lake bottom. Figure 47 shows the locations of the various types of groins. An important aspect of this project was the 200-foot (61 m) spacing between each of the groins, which is two to three times their length. Groins are often spaced closer together than this. These structures have been reviewed each spring and fall and at other times, particularly after major storms.

Two 40-Inch (101.6 cm) Diameter Longard Tubes. Two 40-inch (101.6 cm) diameter Longard tubes were installed side-by-side in the fall of 1973. The tubes are 100 feet (30.5 m) long and were installed at a cost of $30 per foot ($98 per meter) of shoreline. It was planned to stack a third tube on those two in pyramid style. A storm occurred during construction which prevented placement of the third tube (see Figures 48, 49, and 50). This groin appears to be working well; although some settlement has occurred along both tubes, particularly the southern tube. The groin is still trapping sand. The tubes have helped to build up the beach and thus resist wave attack. Recession at the top of the bluff has been about 10 feet (3 m) since installation in the immediate vicinity, and some slumping has occurred due to rain and frost action.

One 69-Inch (175.3 cm) Diameter Longard Tube. The 69-inch (175.3 cm) diameter Longard tube was installed in the spring of 1974. This tube is 50 feet (15.2 m) long and cost $25 per foot of shoreline ($82 per meter) to install. It was expected to trap sand more effectively than the 40-inch (101.6 cm) diameter tubes because it has more freeboard. However, as of the last survey, both groins have performed equally well. Only minor settlement was experienced with this tube (see Figures 51 and 52). The lack of settlement indicates that a structure of this type can be placed directly on the lake bottom (without a supporting foundation) in areas where the soil is clay. This tube has effectively trapped sand and prevented direct wave attack on the bluff, although minor recession of the bluff has been recorded in the immediate area.

Gabion Groin. The gabion groin installed at this site in the late fall of 1974 is 70 feet (21.3 m) long and cost $30 per foot ($98 per meter) to construct. It is in good condition and has trapped sand as expected. The groin has settled a little, particularly at the lake end where some scour is evident (see Figure 53). Despite the beach build-up, slumping of the bluff has occurred (see Figures 54 and 55). This is due primarily to the

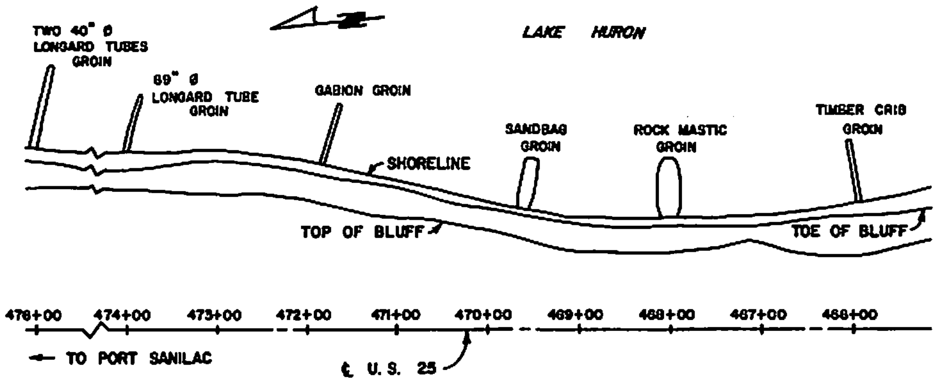


FIGURE 47

PLAN VIEW OF M.D.S.H.T. ROADSIDE PARK

SECTION 26 – SANILAC TWP., MICHIGAN

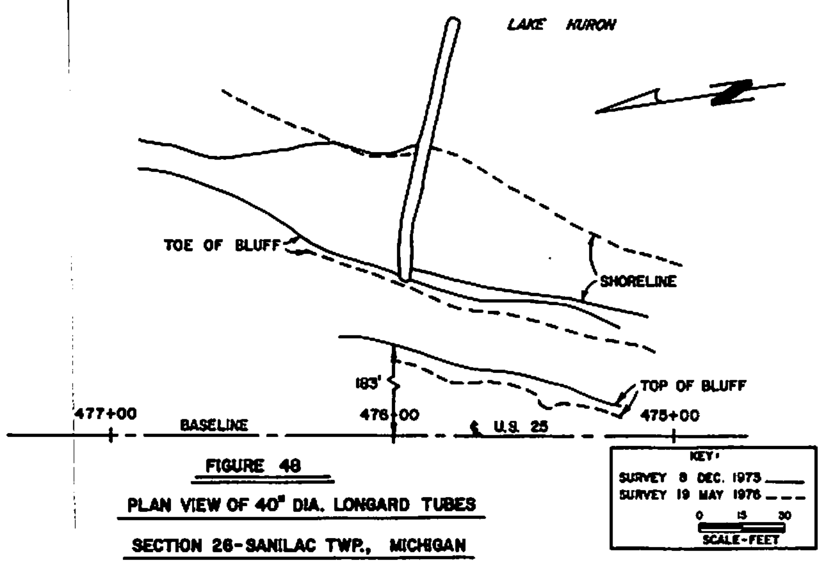


FIGURE 48

PLAN VIEW OF 40" DIA. LONGARD TUBES

SECTION 26-SANILAC TWP., MICHIGAN

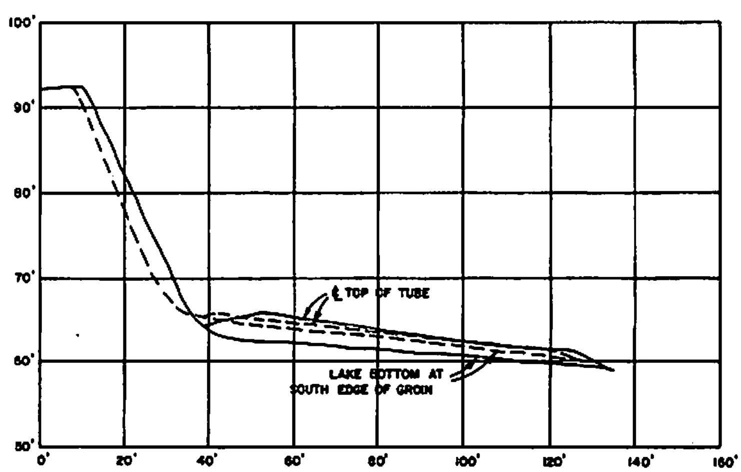


FIGURE 49

PROFILE OF SOUTHERN 40" DIA. TUBE

SECTION 26 – SANILAC TWP., MICHIGAN

KEY:
SURVEY 8 DEC. 1973 ——
SURVEY 19 MAY 1976 - - -

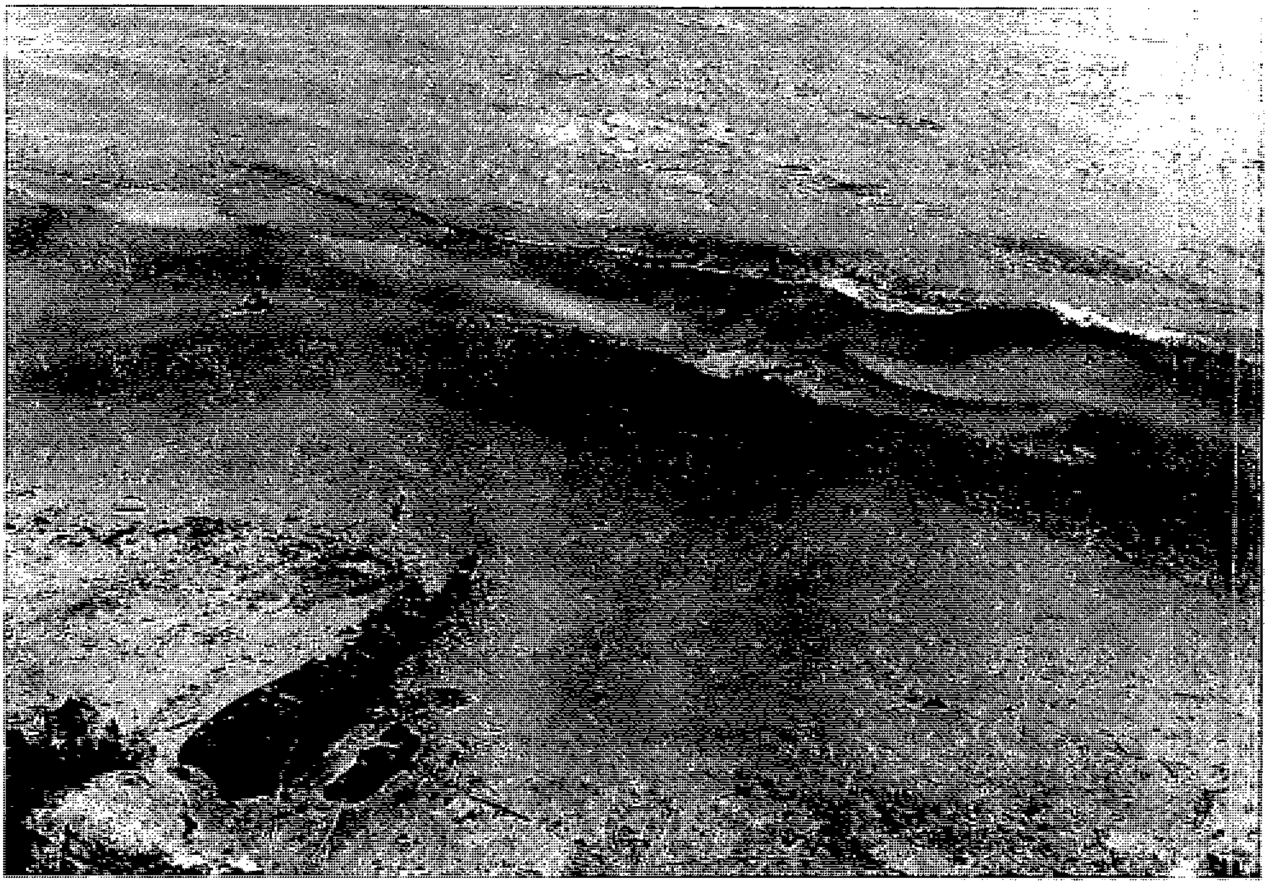


Figure 50. Sanilac-Section 26, May 19, 1976.

The two 40-inch (101.6 cm) diameter Longard tubes can be seen used as a groin. It is evident that a large amount of beach has been trapped as the tubes are buried. The south tube which can barely be seen is lower than the north tube. It has settled about 1 foot (.3 m).

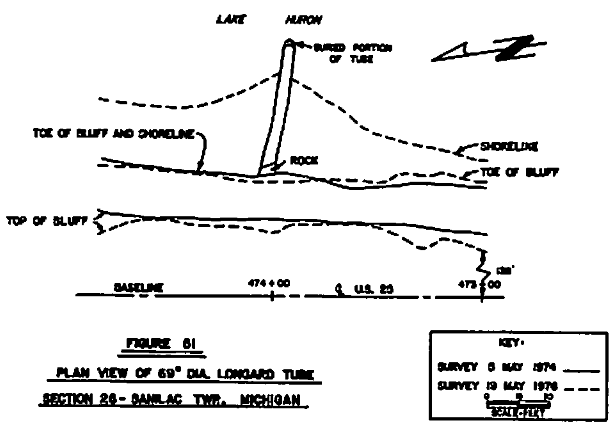


FIGURE 51
PLAN VIEW OF 69" DIA. LONGARD TUBE
SECTION 26 - SANILAC TWP., MICHIGAN

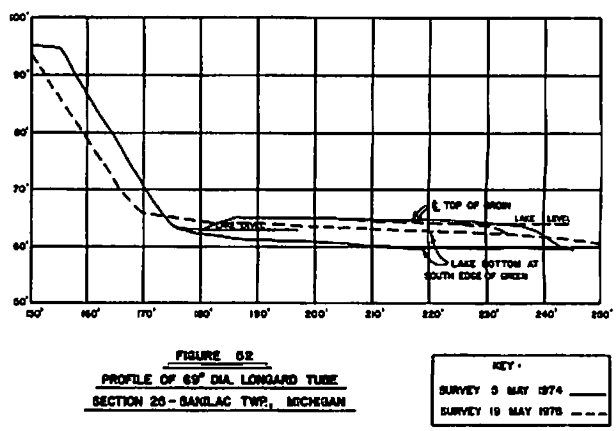


FIGURE 52
PROFILE OF 69" DIA. LONGARD TUBE
SECTION 26 - SANILAC TWP., MICHIGAN

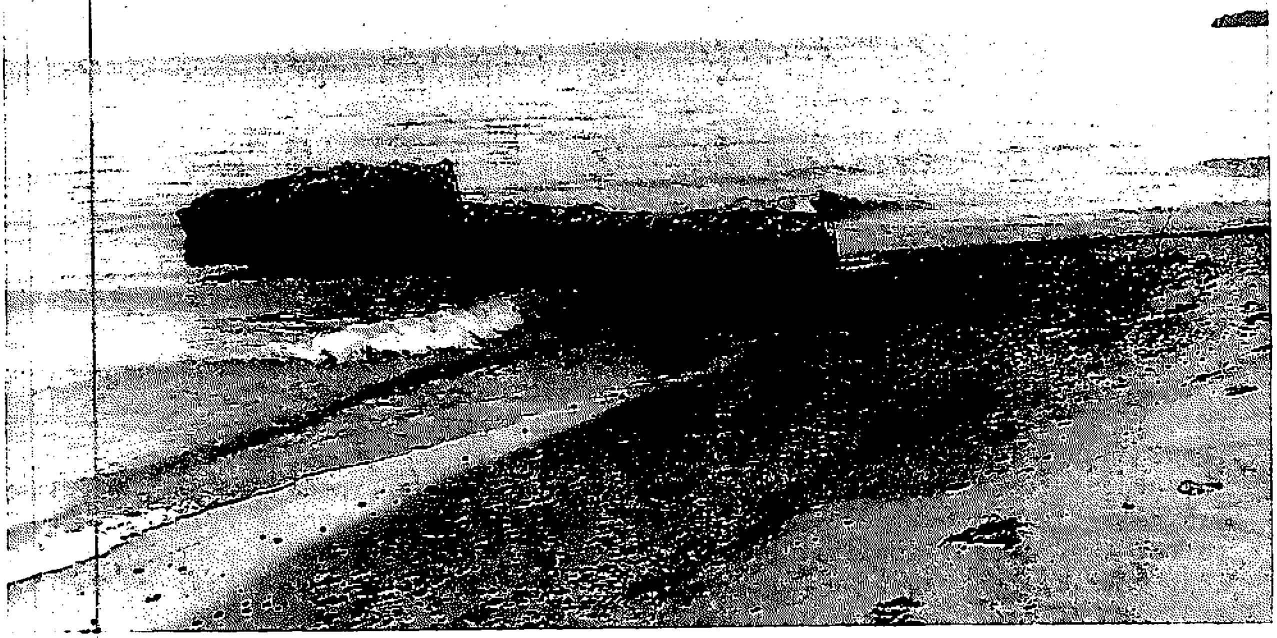


Figure 53. Sanilac-Section 26, May 19, 1976.

This view of the gabion groin, after one and a half years of service shows beach build-up and settling at the lake end of the groin.

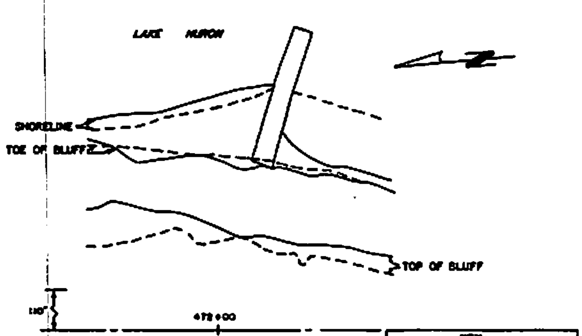


FIGURE 54
PLAN VIEW OF GABION GROIN
SECTION 26 - SANILAC TWP., MICHIGAN

KEY:
SURVEY 27 APR. 1975 ———
SURVEY 19 MAY 1976 - - -

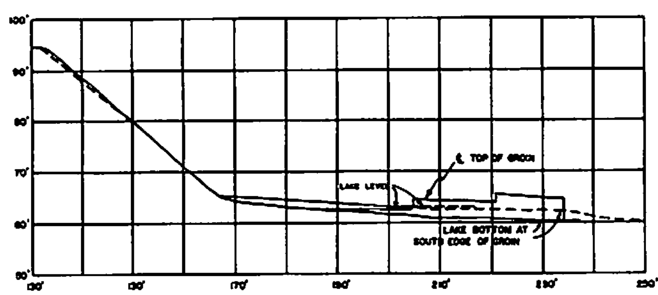


FIGURE 55
PROFILE OF GABION GROIN
SECTION 26 - SANILAC TWP., MICHIGAN

KEY:
SURVEY 27 APR. 1975 ———
SURVEY 19 MAY 1976 - - -

tendency of the steep bluff to adjust to a more stable slope.

Giant Sandbag Groin. The giant sandbag groin was installed in the late fall of 1973 and suffered major damage in the first year. The length of the groin is 60 feet (18.2 m) and it cost $30 per foot ($98 per meter) to install. Nearly 15 feet (4.6 m) of sandbags were lost at the lake end of the groin. Vandalism is probably not the cause since the missing bags were from the lakeward end of the structure which is submerged. Bags are continuing to deteriorate, rip open, and become lost; other bags are being displaced from their original positions; see Figures 56 and 57 for changes. The structure appears to be trapping some sand despite the damage (see Figures 58 and 59). Preliminary conclusions as to effectiveness and durability indicated that sandbag groins offer temporary protection. They do not seem as durable as other structures and should not be considered permanent protection. With annual replacement of damaged bags and protection against tearing, sandbag groins could function effectively for several years.

Rock Mastic Groin. The rock mastic groin was completed in the fall of 1973. Design and construction supervision of this groin was provided by The University of Michigan's Coastal Zone Laboratory. The successful installation of this structure demonstrated that it was possible to pour mastic through 7 feet (2.1 m) of water. Prior to this successful application, the existing literature had reported that mastic should not be poured through water of more than 1 foot (.3 m). The rock mastic groin is 60 feet long (18.3 m) and was installed at a cost of $45 per foot ($146 per meter) of shoreline. Large amounts of sand have been trapped providing a protective beach. No movement of the groin has been visible. However, there has been minor damage to the north edge (see Figures 60 and 61). A section of the mastic and underlying rock was broken off at the lake edge. Minor recession and slumping of the bluff has occurred, probably due to slope adjustment. This type of structure has proven stable and effective although it lacks the aesthetic qualities of other methods. The lack of maintenance requirements indicates that only an initial expense for building will be incurred. This structure has performed well thus far and is a good example of successful low-cost shore protection.

Timber Crib Groin. Very few data are available for the timber crib groin installed at the extreme south end of the site in the fall of 1975. It extends 50 feet (15.2 m) and cost $30 per foot ($98 per meter) to install. To date, it has remained in good condition (see Figures 62, 63, and 64).

Sanilac-Section 26 Summary. In general, the wider spacing between the different groins has proven effective. Minor bank recession has been recorded for small stretches of the shoreline. However, as stated earlier, this could be completely due to adjustment of the bluff slope to a more stable condition. Of the six groins studied at Sanilac-Section 26, the sandbag groin has suffered the most damage. The Longard tube and rock mastic groins are performing adequately. Both the gabion and the timber crib groins are in good condition.

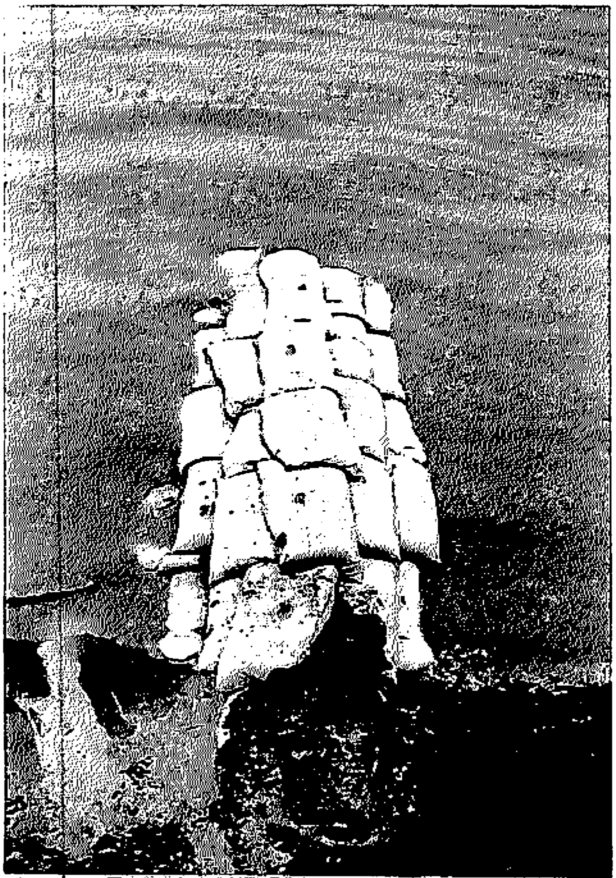


Figure 56. Sanilac-Section 26, March 9, 1974.

This photo was taken in the spring after construction was completed the previous fall. The sandbags withstood the effects of the winter ice. Some of the clay till bluff has slumped onto the end of the groin.

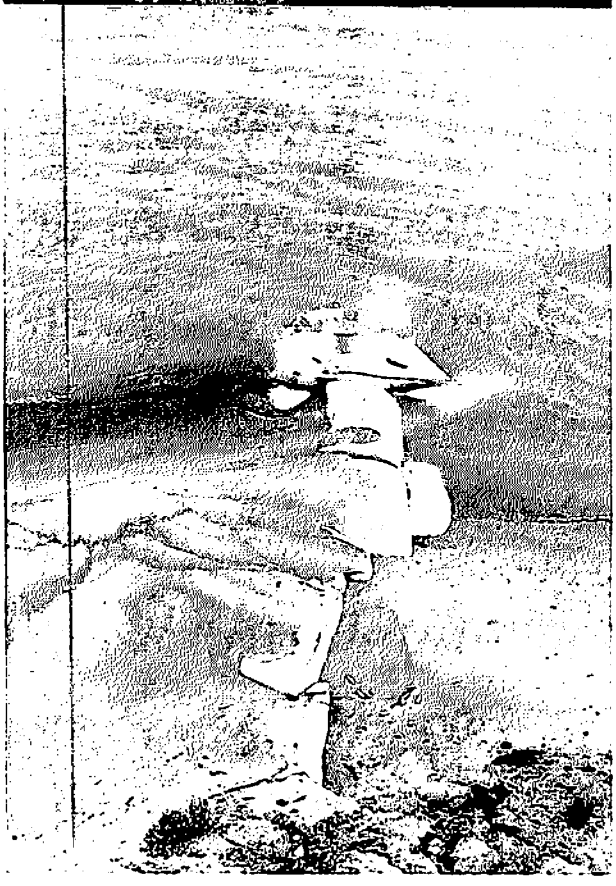


Figure 57. Sanilac-Section 26, May 19, 1976.

The condition of the groin is shown two years later (than Figure 56). Sand has been trapped by the groin but a large number of bags have been lost or have shifted. As is apparent, sandbags are not a permanent means of shore protection.

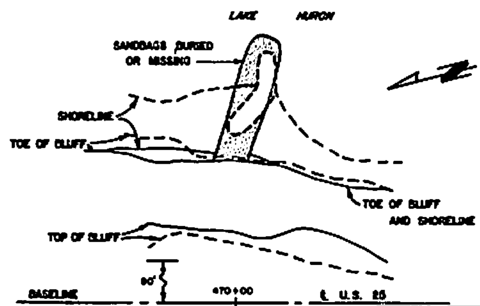


FIGURE 58

PLAN VIEW OF SANDBAG GROIN

SECTION 26 - SANILAC TWP., MICHIGAN

KEY:
SURVEY 9 MAR. 1974 ——
SURVEY 19 MAY 1976 - - -
0 10 30
SCALE-FEET

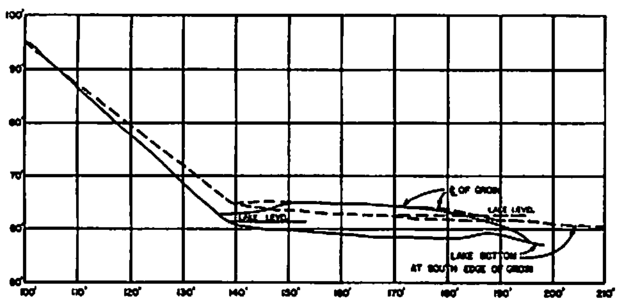


FIGURE 59

PROFILE OF SANDBAG GROIN

SECTION 26 - SANILAC TWP., MICHIGAN

KEY:
SURVEY 9 MAR. 1974 ——
SURVEY 19 MAY 1976 - - -

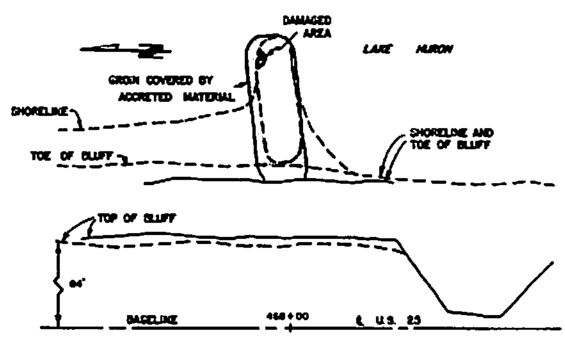


FIGURE 60

PLAN VIEW OF ROCK MASTIC GROIN

SECTION 26 - SANILAC TWP., MICHIGAN

KEY:
SURVEY 23 NOV. 1973 ——
SURVEY 19 MAY 1976 - - -
0 10 30
SCALE-FEET

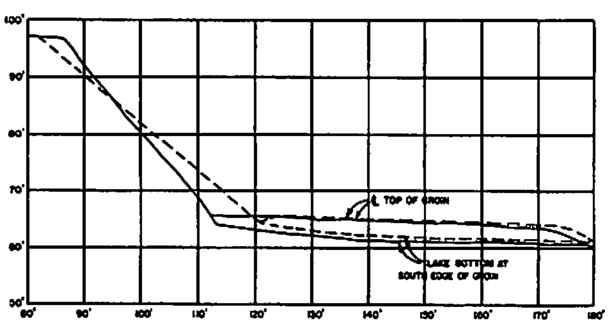


FIGURE 61

PROFILE OF ROCK MASTIC GROIN

SECTION 26 - SANILAC TWP., MICHIGAN

KEY:
SURVEY 23 NOV. 1973 ——
SURVEY 19 MAY 1976 - - -

Figure 62. Sanilac-Section 26, May 19, 1976.

Shown here is the timber crib groin. It had been installed the previous fall. Some beach build-up can be seen in this photo.

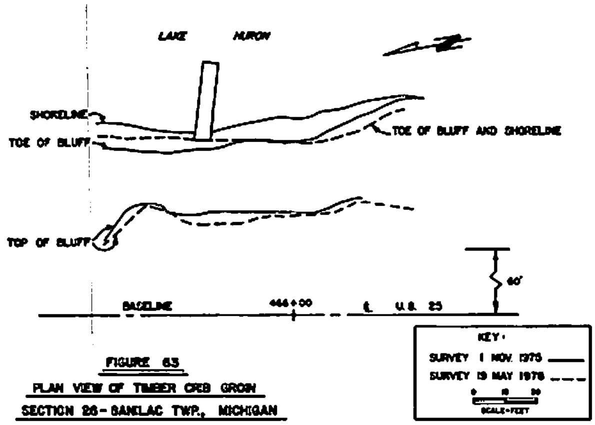


FIGURE 63
PLAN VIEW OF TIMBER CRIB GROIN
SECTION 26 - SANILAC TWP., MICHIGAN

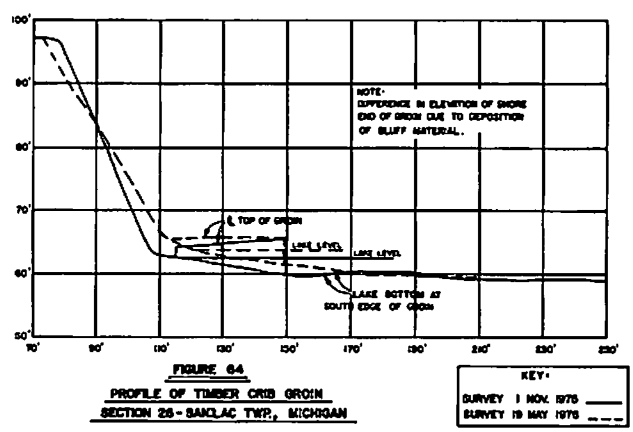
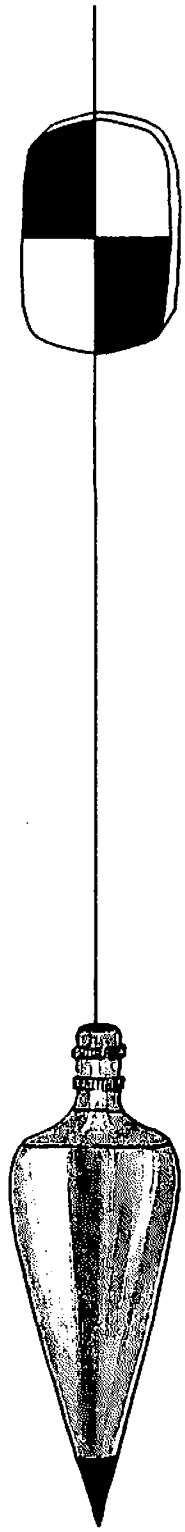


FIGURE 64
PROFILE OF TIMBER CRIB GROIN
SECTION 26 - SANILAC TWP., MICHIGAN

Breakwaters



Breakwaters

Pere Marquette Township

This site is located 1 mile (1.6 km) south of the Ludington Harbor entrance. The shoreline consists of 20-foot (6.1 m) sand bluffs and a narrow beach in an open coast. A bathhouse at the top of the bluff was threatened by the severe erosion occuring at this site.

A new concept in breakwater design consists of precast, reinforced concrete panels bolted together to form zig-zag walls. These walls were originally designed for installation onshore. Two 70-foot (21.3 m) walls and one 56-foot (17.0 m) wall were constructed. The zig-zag walls were placed offshore parallel to the shoreline with 50-foot (15.2 m) spacings between structures and with a 1-foot freeboard. The structures were located approximately 50 feet (15 m) from shore. Cost per foot of shoreline protected was $70 ($230 per meter) when installed in the fall of 1973 and the spring of 1974. The township contributed $3,000 of this cost of construction. This site has been visited each spring and fall and many other times during the year, generally after major storms.

The breakwater system performed quite effectively in building up a beach and preventing bluff recession for the first year. A major storm with 6- to 10-foot (1.8 to 3.0 m) waves during the winter of 1975 caused extensive damage to this protection system and the bluff. Walls 2 and 3 have been damaged by settlement and panel breakage (see Figures 65, 66, 67, and 68). Wall 3 lost two entire panels and settled about 3 feet (.9 m). It is now completely submerged. One panel was lost off wall 2 which also settled and tilted radically. The remaining panels in walls 2 and 3 are chipped and cracked and have tilted toward shore. Wall 1 has remained largely unchanged except for some tilting. Major bluff recession has continued, up to 30 feet (9.1 m) in some locations during the past three years. The bathhouse has been completely destroyed.

The experimental percast zig-zag walls were originally intended for onshore use. Their performance in this offshore location was not satisfactory. Design modifications to include a foundation and toe protection would eliminate this system from the low-cost category. The private homeowner could not install this structure himself because heavy construction equipment is required. This is not a recommended method of shoreline protection as used in this program.

Lakeport State Park

This state park is located in an open coast area on the southwest end of Lake Huron. The shore area is composed of high sand dunes, low

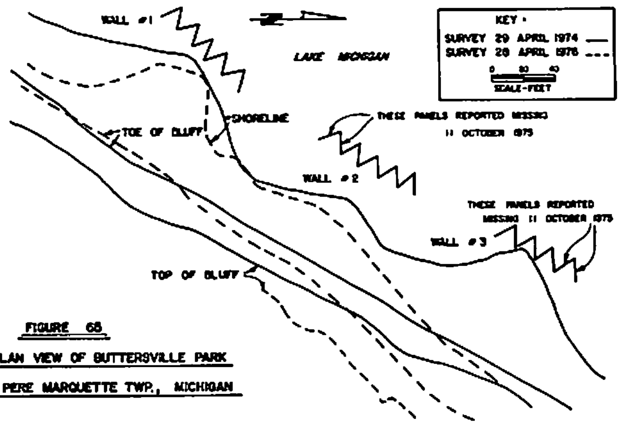


FIGURE 65

PLAN VIEW OF BUTTERSVILLE PARK

PERE MARQUETTE TWP., MICHIGAN

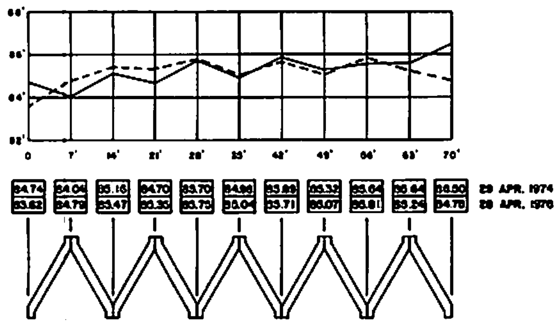


FIGURE 66

PLAN VIEW AND LONGITUDINAL PROFILE OF WALL #1

BUTTERSVILLE PARK-PERE MARQUETTE TWP., MICHIGAN

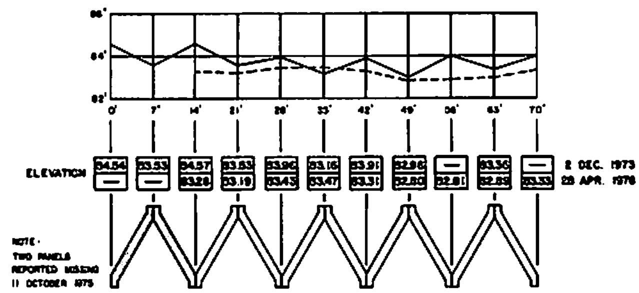


FIGURE 67

PLAN VIEW AND LONGITUDINAL PROFILE OF WALL #2

BUTTERSVILLE PARK-PERE MARQUETTE TWP., MICHIGAN

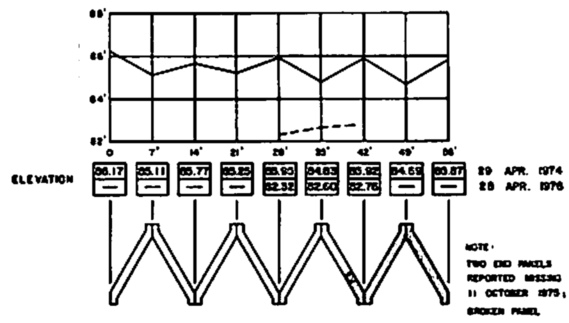


FIGURE 68

PLAN VIEW AND LONGITUDINAL PROFILE OF WALL #3

BUTTERSVILLE PARK - PERE MARQUETTE TWP., MICHIGAN foredunes, and a beach area. In the spring of 1974 a 40-inch (101.6 cm) Longard tube was placed on a partly submerged sandbar to form an offshore breakwater. For some unexplained reason unrelated to the installation of this structure, sand began to accrete in this general area. This tube is now well back from the shoreline (see Figure 69). This site is not now being actively monitored. This site is visited several times a year to determine if conditions have changed. Should this accreted sand erode, the project will again be included in the monitoring program.

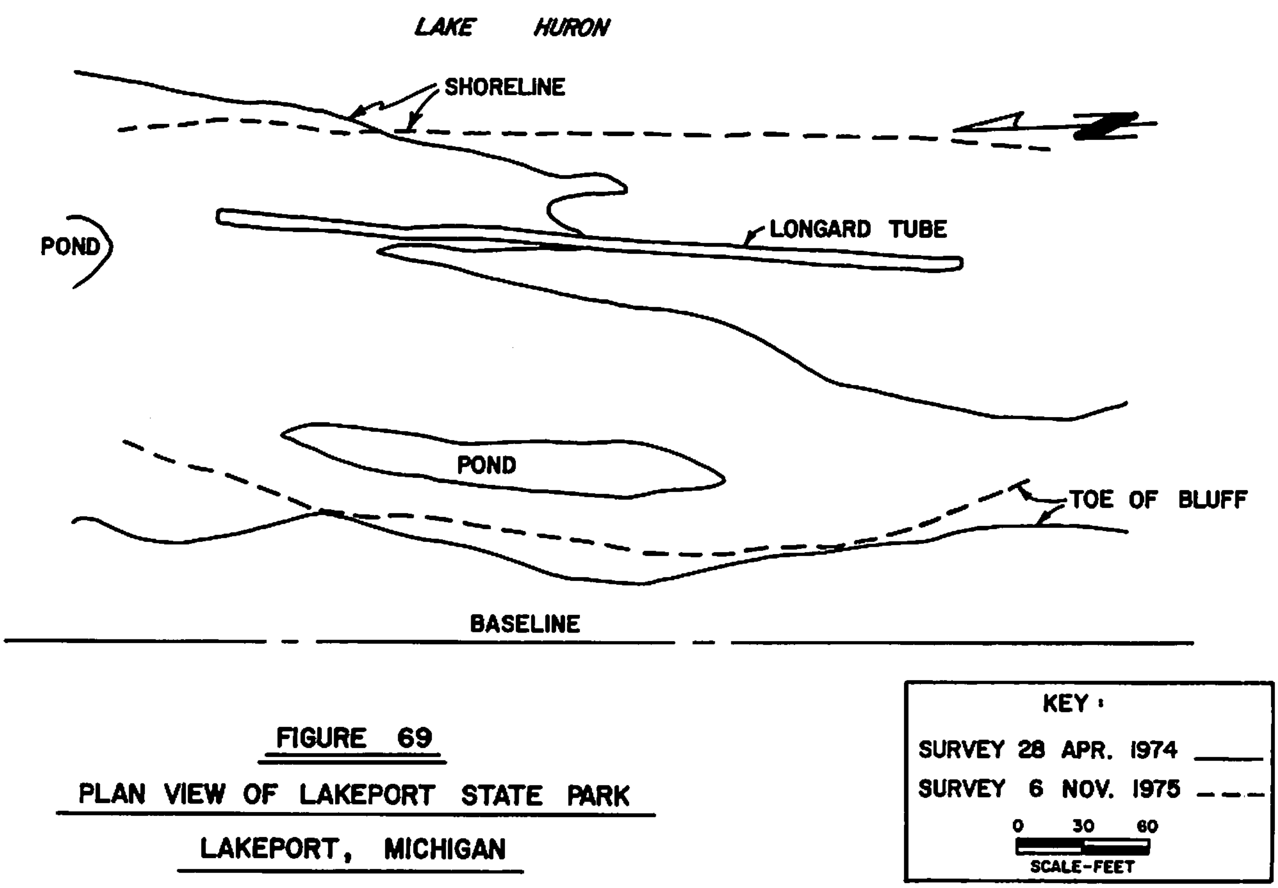
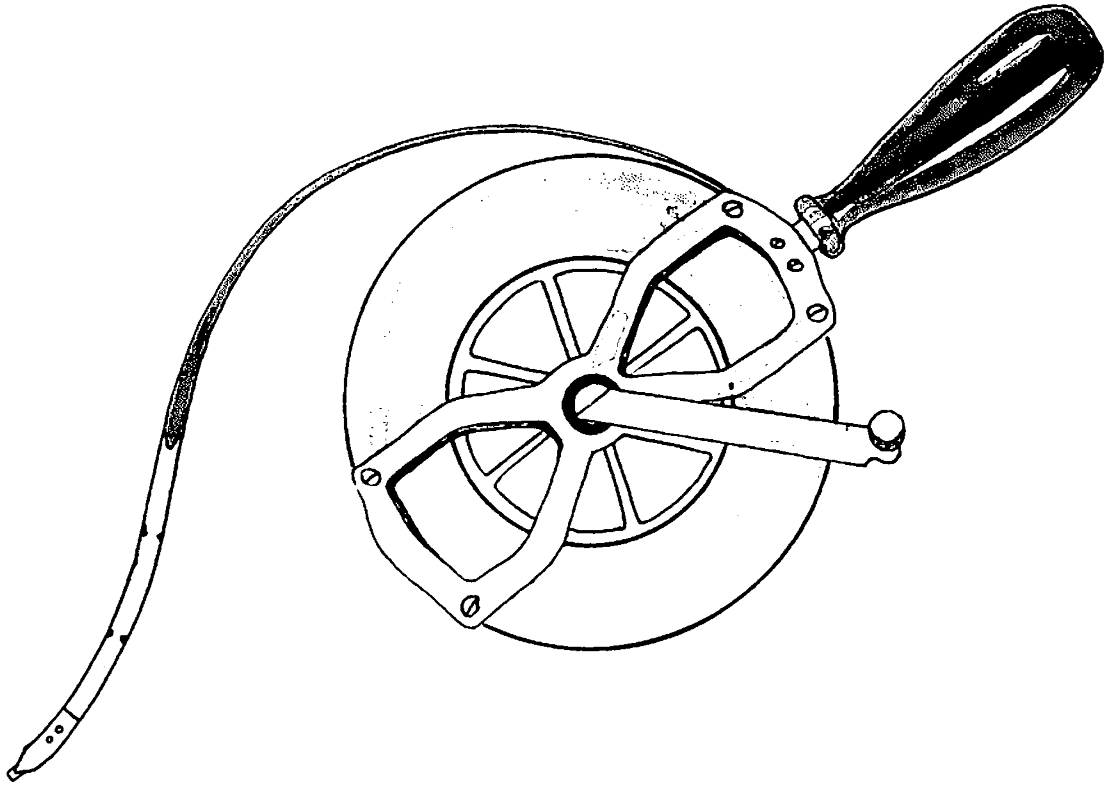


FIGURE 69

PLAN VIEW OF LAKEPORT STATE PARK

LAKEPORT, MICHIGAN

Nourishment



Nourishment

Tawas City

Tawas City Park was selected for the examination of a nourishment project. The site is sheltered by Tawas Bay and has a sand shoreline with no bluff. Sand nourishment was the selected method of shore protection in order to maintain the site as a bathing beach and because of the site's sheltered location. There is an existing pier (jetty) at the southwest end of the project area. Tawas City installed a timber crib groin at the northeastern limit of the site. Installation of the sand fill began in the fall of 1973 and was completed by the spring of 1974. Four hundred linear feet (122 m) of shoreline (between the groin and jetty) was protected with 4,350 cubic yards (3,328 m^3) of sand fill. The fill sand used had a size distribution similar to the natural beach sand. The nourishment project cost \$20 per foot (\$66 per meter)*. After some initial shifting the sand remained relatively stable through the spring of 1975. Minor shifting was again detected through this year. See Figure 70 for further details. The timber crib groin and pier have helped to hold the fill sand in place as well as trap additional sand. However, only minor storm activity has been experienced, so further evaluation of this project is required to determine overall effectiveness. To date, this nourishment project has been very successful and inexpensive.

East Tawas

East Tawas City Park in Tawas Bay was selected as another test site. This site is similar to the one at Tawas City as it is in a bay and is heavily used as a bathing beach. Sand nourishment was used, but without any groins or jetties for protection, at a cost of \$15 per foot (\$48 per meter). Three thousand cubic yards (2,295 m^3) of sand fill were placed along 400 feet (121.9 m) of shoreline in the spring of 1974. For nearly a year the sand nourishment remained stable. During the winter of 1974-75 much of the sand was dispersed. By the fall survey of 1975, some sand had shifted back into the area of the original nourishment. See Figure 71 for current conditions. This site experienced the same storm activity as Tawas City, yet had much sand movement. This helps confirm the observation that stabilization of sand nourishment by a groin system will maintain the initial fill over a longer period of time.

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*As some sand would probably have been lost without the addition of the timber groin, total cost including the groin is \$26 per foot (\$85 per meter) of shore.

Marquette

This site is located at Shiras Park in a partially sheltered coast area with low sand bluffs and little to no beach. Broken concrete had been previously placed here in an attempt to protect the shoreline. In the fall of 1973 sand was placed over the concrete and out into the lake as a nourishment project. This sand was donated by a local power company from a dredging operation. The sand contained a large amount of fine material which was not expected to stay in place for very long (see Figure 72). However, since the sand was free, it was of interest to determine how much protection this kind of sand would provide. A steel sheet pile groin was installed in the fall to help stabilize the sand. This groin was added because the city had the steel available.

This site is visited on a yearly basis. More detailed observations are being made by members of the staff of Northern Michigan University.

Much of the sand has been lost. The groin which had originally been covered with sand is now exposed. However, the removal of the sand has not yet exposed the original rubble which was buried by the sand fill. Therefore, the fill is still providing protection. The rate of erosion will be determined when surveys which have been made by associates in Marquette become available. A view of the area is shown in Figure 73.

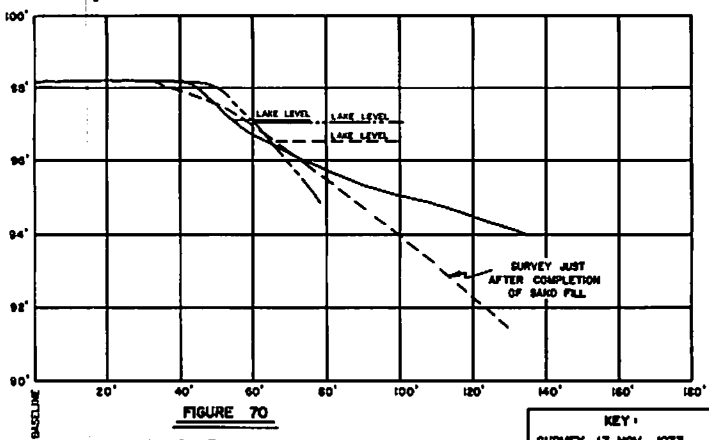


FIGURE 70

PROFILE AT STATION 3+00

TAWAS CITY, MICHIGAN

KEY:
SURVEY 17 NOV. 1973
SURVEY 11 MAY 1974
SURVEY 25 APR. 1976

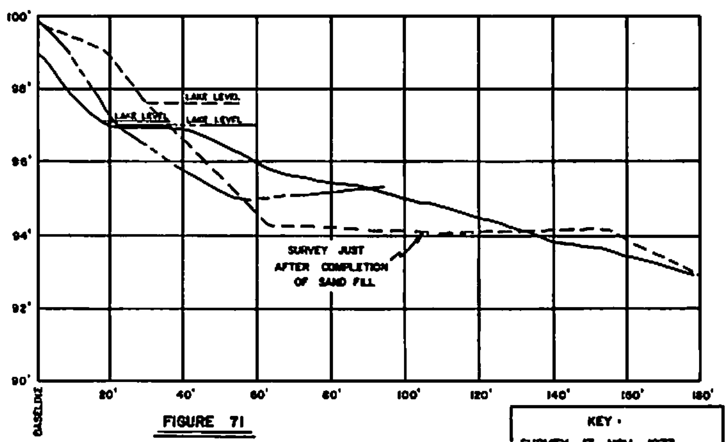


FIGURE 71

PROFILE AT STATION 3+00

EAST TAWAS, MICHIGAN

KEY:
SURVEY 17 NOV. 1973
SURVEY 11 MAY 1974
SURVEY 25 APR. 1976

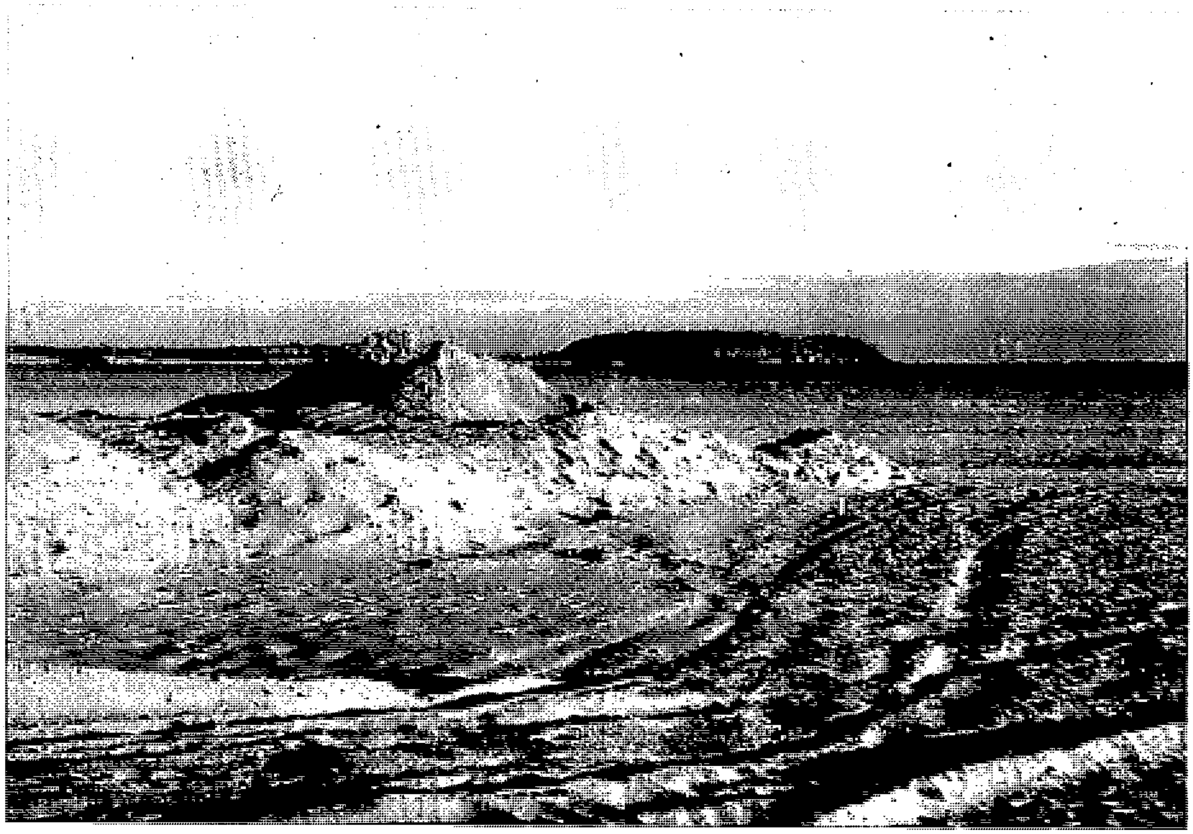


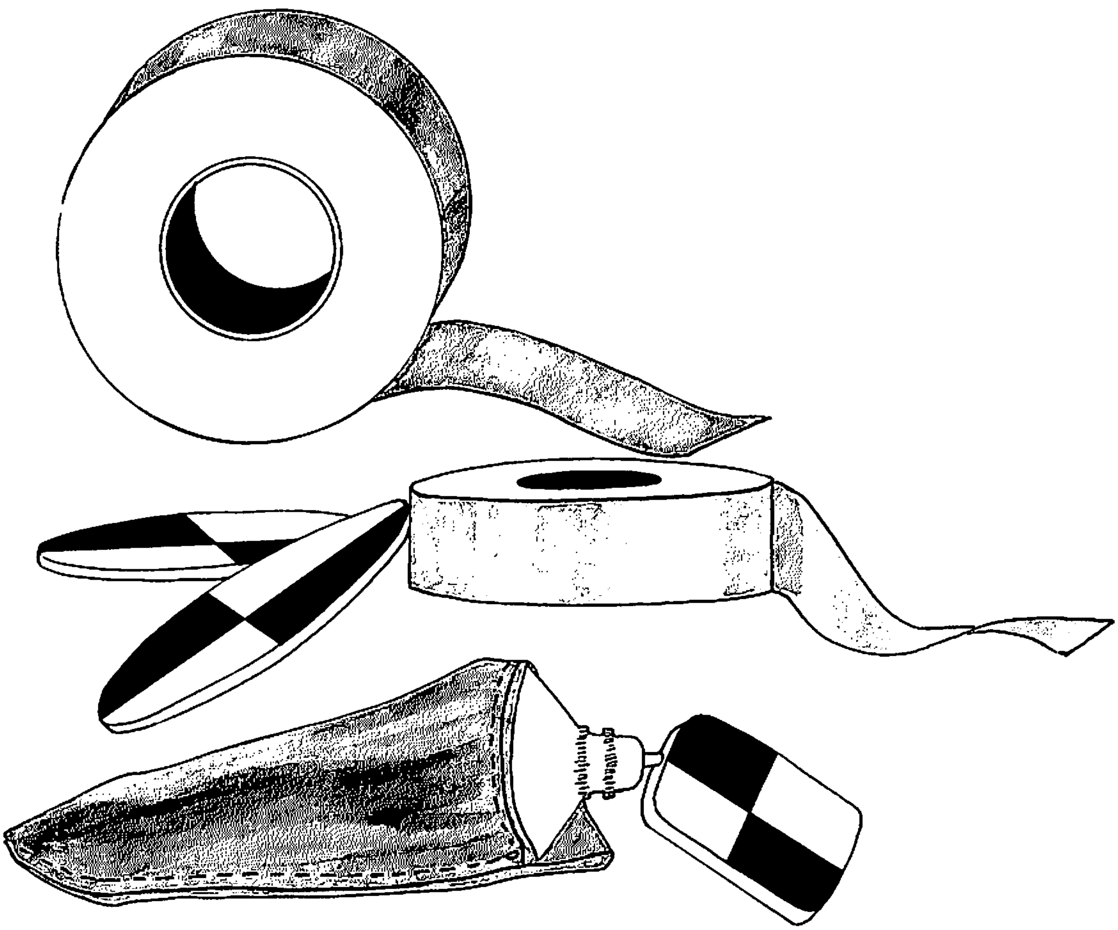
Figure 72. Marquette, Summer 1973.

Fill sand dumped over broken concrete and rubble is evident at this site. This method of shore protection maintained the use of the beach for bathing.

Figure 73. Marquette, June 30, 1976.

This aerial view shows the project site at the point in the center of the picture. There appears to be a substantial amount of fill sand remaining in place.

Laboratory Investigations



Laboratory Investigations[1]

The laboratory program was developed to supplement information gathered from the monitoring of the field installations. A wider range of variables and procedures not included in the field program have been tested. The laboratory program has also proven to be useful in the demonstration of shore erosion processes to groups concerned with shore problems. Although erosion rates determined in the model cannot be converted quantitatively to nature, it was reasoned that if repeatable erosion rates could be produced in the model the results would help to evaluate the relative effectiveness of many protective methods. The advantages of using a model are the much lower cost compared with field installations, the control over such variables as wave height, and water level and the speed with which results can be obtained.

The tests were conducted in The University of Michigan's Lake Hydraulics Laboratory. Waves were formed by a wave machine and projected toward a model sand bluff at an angle of 35° to the shoreline. The model consisted of a sand bottom with a slope of 1 to 20 and a sand bluff having a slope of 60° with the horizontal. The bluff was 6 feet (1.8 m) long. After 30 minutes and again after 60 minutes of exposure to the waves, profiles were determined at six locations along the model and the amount of littoral drift passing the downdrift end of the model was measured in 12 sand traps which extended 6 feet (1.8 m) out from the shoreline.

The first testing involved the development of a procedure for constructing the model bluff which would produce the same amount of erosion for repeated tests. In judging the repeatability of test results it was necessary to take into account the fact that it was impossible to reproduce identical test conditions. This was because there was no control over the water temperature in the wave tank and because the actual average wave height was not known until it was determined from the oscillograph charts. The effect of these variables was taken into account by plotting bluff recession against a parameter (N); N represented the ratio of the wave energy to the energy dissipation multiplied by the duration of the test runs, either 30 or 60 minutes. The parameter used to represent bluff recession is the shoreward movement of the toe of the bluff (r_b). This method of presenting the data is illustrated in Figure 74 by two sets of test results for a particular section through the model bluff. The upper set shows bluff recession for a free shoreline and the lower set shows the corresponding recessions after installing a set of groins having a length to spacing ratio (g/s) equal to 1.0. Statistical tests indicate that the points in Figure 74 provide a significant relationship between the variables r_b and N. Considering the random nature of the sand slumping process, it was concluded that these correlations provided satisfactory evidence that repeatable results were being obtained.

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[1]Prepared by Professor E.F. Brater and David Ponce-Campos.

Another criterion as to whether or not the model could be used to test actual protective procedures was the degree to which the model simulated natural shore processes. Among the indications that the model did simulate natural processes were the typical manner in which bluff erosion occurred, the formation of sandbars and the creation of littoral drift. It was also observed that the rate of bluff recession increased with water depth in a manner similar to that observed on the Great Lakes. Probably the most interesting simulation of natural processes was the occurrence of more rapid bluff recession in the starved area of the shoreline as compared with the portion of the model which was being supplied with littoral drift.

After the preliminary testing described above, a number of protective procedures were investigated and the erosion rates were compared with those which occurred with an unprotected shore. The procedures studied were groin systems, groins with artificial sand nourishment, groins with a permeable wall, sand nourishment without groins, a permeable wall without groins and a submerged barrier.

1. A number of groin systems were tested. The variables were the length (g), spacing (s), and height of the groins. The groins extended above the water surface a distance of 0.02 feet (.01 meters) which corresponds to about 1 foot (0.3 meters) in nature. All of the groin systems reduced the bluff recession rates. This is illustrated in Figures 74 and 75. Figure 75 shows bluff recessions at two locations on the model (x = 1.5 and x = 2.5) for shoreline conditions and for various protective procedures. The lines in Figure 75 are best fit lines like those in Figure 74 but for clarity of presentation the individual test points were omitted. The groins for which results are shown in Figure 75 have a length-to-spacing ratio (g/s) of 0.8 and it will be noted that this system provides less protection than those with g/s = 1.0 for which results were shown in Figure 75. Two sets of groins with different lengths but with the same length-to-spacing ratio showed about the same degree of effectiveness. Sets of groins with a higher free board were less effective because the groins reflected more wave energy into the shore.

2. The measurements of littoral drift showed that the sand movement was predominantly in two zones, the uprush zone near shore and the breaker zone. This condition also existed when structures built parallel to the shore were tested but when groin systems were tested they captured the near-shore portion of the littoral drift. However, when groin systems were artificially nourished at the beginning of a test, the littoral drift passed over the groins and continued on in the downdrift direction at about the same rate as with a free shoreline. The groins with artificial sand nourishment provided very good protection against bluff erosion as shown in Figure 75. Artificial nourishment placed without groins was rapidly carried away and provided little continuous protection.

3. Tests were made with pervious walls placed parallel to shore and located a distance out from the shoreline which would correspond to 20 feet (6.1 m) in nature. These walls simulated structures which have been extensively used by property owners. The area of the openings was about 35 percent of the area of the wall. It may be seen in Figure 75 that these

walls provided considerable protection. When the pervious walls were combined with sand fill, the bluff recession was reduced to a very small amount. It will be seen in Figure 75 that this combination of groins with a pervious wall ranked with groins plus sand fill in effectiveness. It should be noted, however, that both of these combinations are expensive compared with groins alone.

4. One set of tests was made using a submerged barrier placed parallel to shore in the breaker zone. The height of the barrier was about 0.4 of the depth of the water. As shown in Figure 75, this barrier provided no measureable protection.

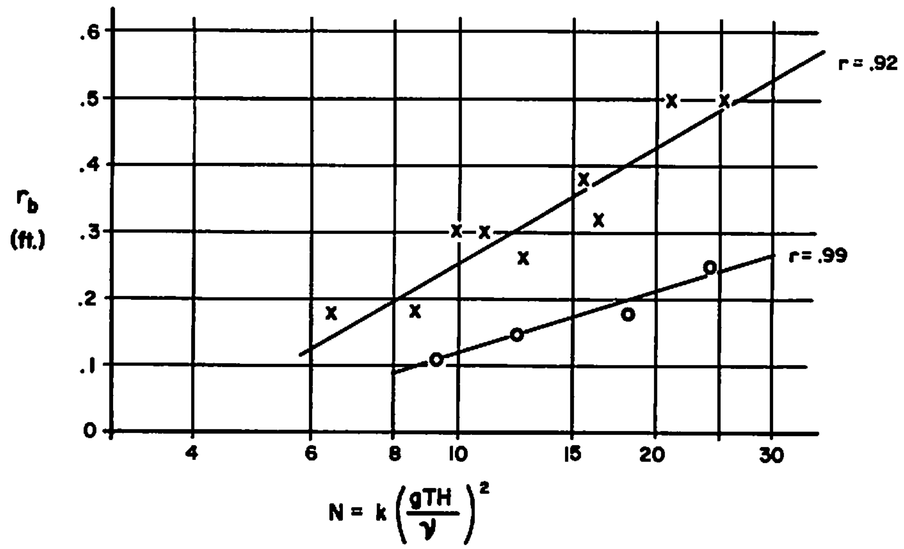


FIG. 74

PROFILE AT X = 1.5

X : FREE SHORELINE ; H/L = .039

O : GROINS ; H/L = .039 ; g/s = 1.0

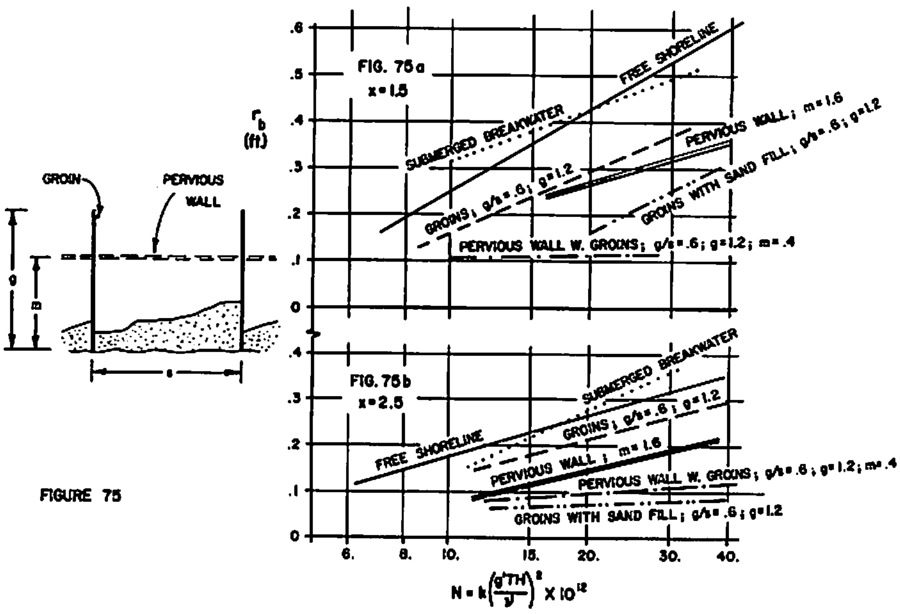
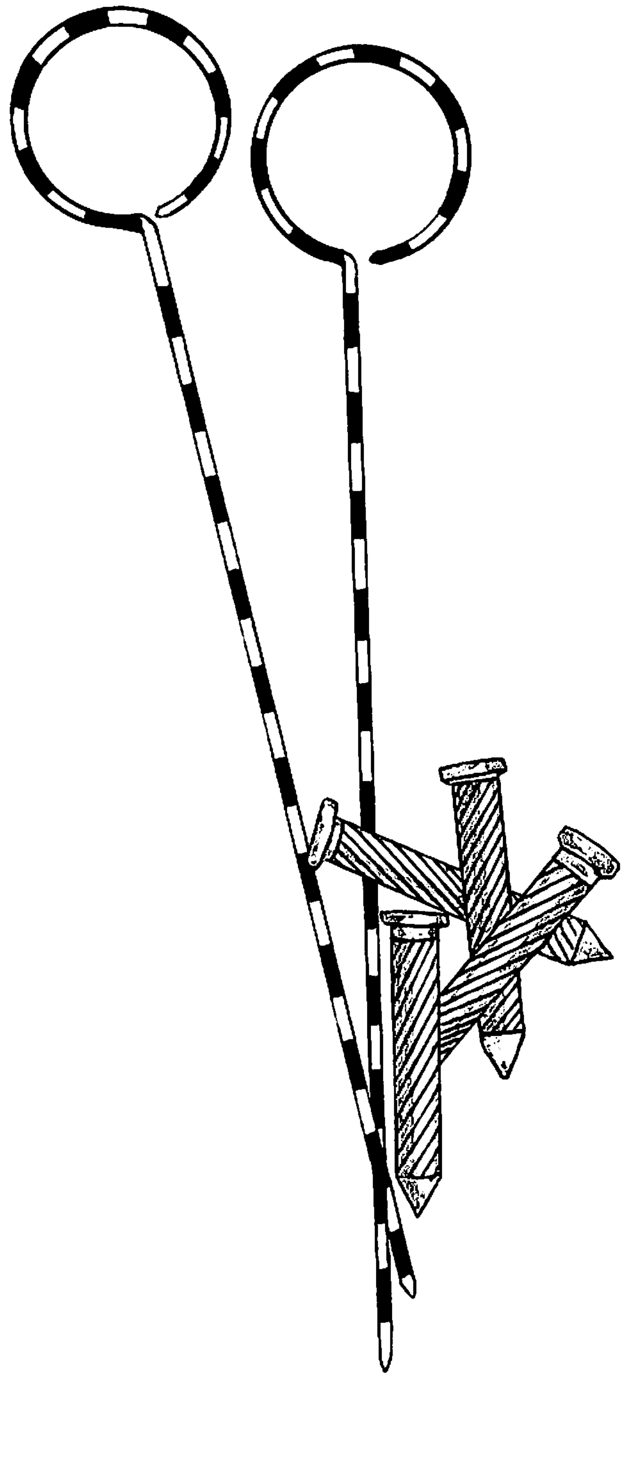


FIGURE 75

g' = GRAVITATIONAL ACCELERATION CONSTANT

Summary



Summary

Shore protection procedures can be evaluated only after the installations have been exposed to one or more onshore storms. The frequency of occurrence of major storms is variable. Sometimes several large storms occur within a few months and at other times there may be periods of years without a major onshore storm. Therefore, unless there is early failure, the effectiveness and durability of the shore installations cannot be fully evaluated until observations have been continued for a number of years. Each year of study gives more useful information; it is hoped that enough data will be available for storm protection analysis after five years. Sufficient data for a detailed engineering-economic evaluation will become available later. This report has supplied the data available at the end of 1975-76 which brings the period of observations to three years for most of the projects. Even though more time is needed for ultimate evaluation of the projects, a number of useful results have been observed which can be reported at this stage.

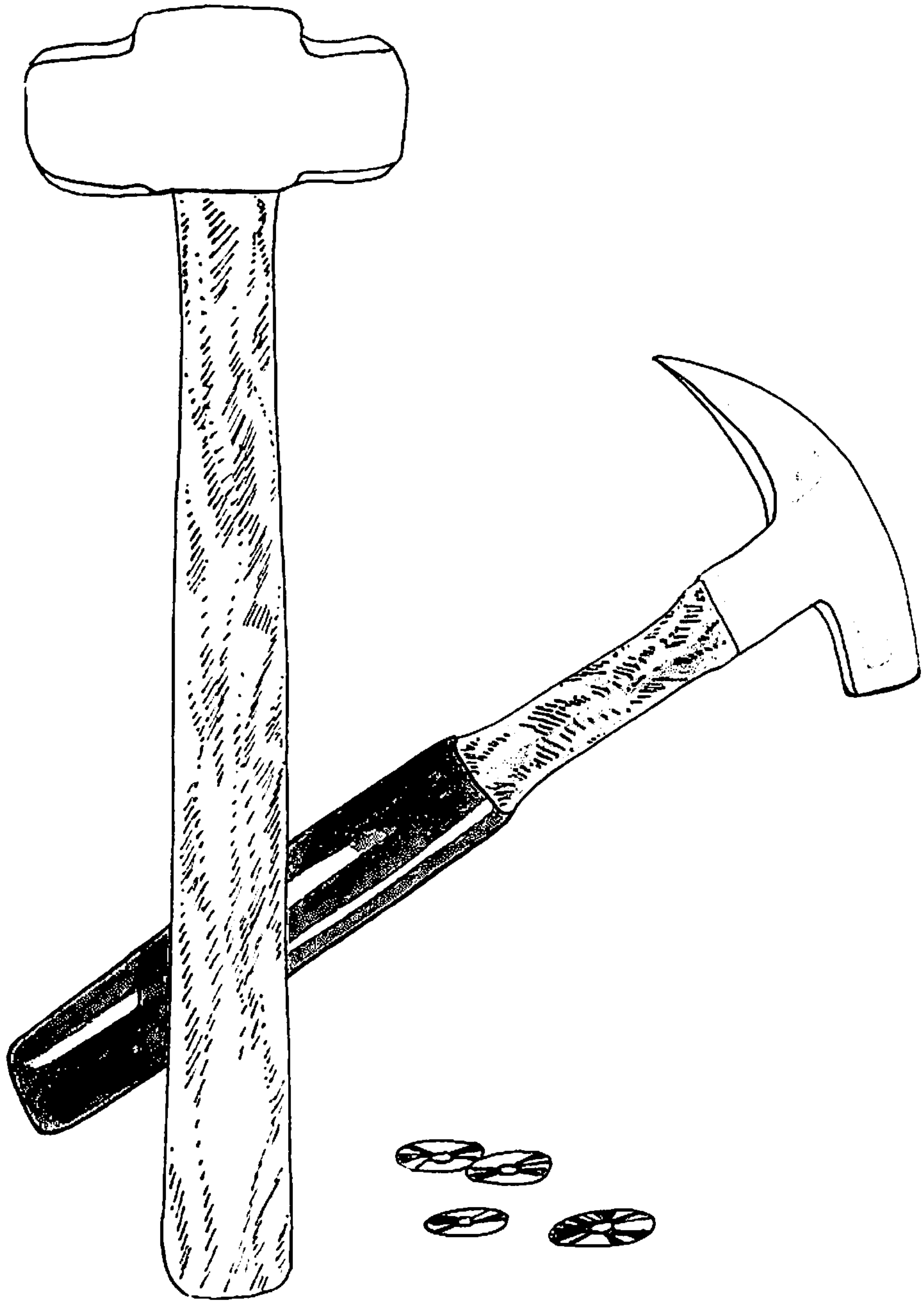
In order to keep the costs of installations within the low-cost range, one offshore breakwater and a number of structures used for bluff toe protection or for groins were placed directly on the lake bottom. Basic coastal design procedures would have provided a rubble foundation and a rubble layer at the toe of the structure to prevent scour. The observations on such installations show that undermining of such structures may be very serious when the structures are placed on sand but that similar structures placed on a clay bottom have not settled enough to destroy their effectiveness up to this time. Examples of settling due to undermining are the offshore zig-zag wall in Pere Marquette Township, the 40-inch (101.6 cm) diameter Longard tube at Empire and a Longard tube groin at Stevensville. The rock mastic revetment at Michiana was also placed on sand and was undermined by a severe storm. On the other hand, the 40-inch (101.6 cm) diameter Longard tubes, stacked one on two, in Moran Township are also placed on sand but have settled only a small amount. The Longard tube used for toe protection at Sanilac Section 11 and those used as groins at Sanilac Section 26 are on a clay bottom and undermining has been minor though the structure at Sanilac 11 has been displaced by other action.

The three rock revetments included in the project, two on Lake Superior and one at Tawas Point Coast Guard Station on Lake Huron, have functioned well and suffered little damage. Those on Lake Superior (Keweenaw Peninsula and Whitefish Township) are in bays which provide some shelter; however, they have been subjected to one major storm.

A number of the field installations have made use of sand-filled bags and sand-filled tubes. This type of structure is vulnerable to vandalism as well as to damage by floating logs and timbers. Such damage has been observed at several of the installations. While a final economic evaluation cannot be made at this stage, it is clear that the sand-filled bags used in the project are failing at a rate which would require a considerable replacement cost to maintain their original condition.

The groin systems in the projects have all collected some sand and appear to be providing beneficial results. A sand nourishment project at Tawas City in Tawas Bay has been effective. This sand is protected by adjacent groins. On the other hand at East Tawas which is also in Tawas Bay and where there are no groins, the sand used for nourishment has been moved away from its original location and is no longer providing complete protection at the demonstration site.

References



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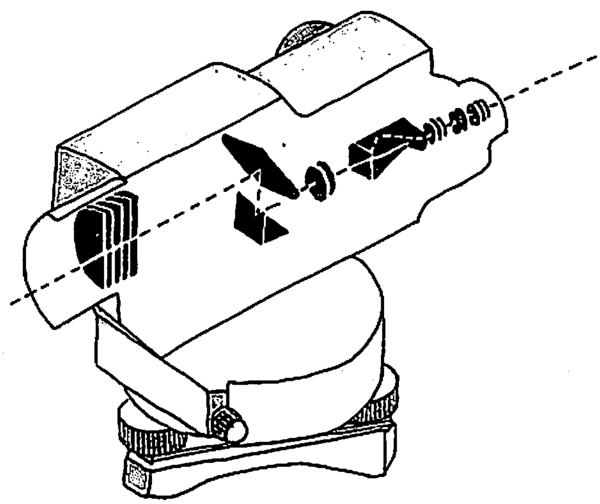
Appendices



APPENDIX I

PROJECT DESCRIPTION

Project Location	Site Description	Method of Protection	Test Construction Cost[1] ($/foot)	Test Construction Cost[1] ($/meter)
Michiana	Open coast area with 30 foot (9.1 m) sand bluff. Shoreline immediately north and south of project area has seawall construction and narrow beach.	Revetment composed of rock and asphalt mastic (a European technique new to the Great Lakes).	70	230
Big Sable Point	Open coast area with 10 foot (3.0 m) sand dunes and an existing damaged seawall; no beach.	Tie backs installed on existing seawall; cutoff gabion groins constructed from existing seawall landward. Land area behind the seawall and between cutoff walls sand filled.	*	*
Empire	Open coast area with 5 foot (1.5 m) sand bluff and little to no beach. This area has been experiencing extremely high (30 feet/yr [9.1 meters/yr]) recession rates.	40-inch (101.6 cm) diameter Longard tube placed on filter cloth parallel to the shoreline near the waterline.	30	98
Moran Township	Open coast area with 30 foot (9.1 m.) sand bluff and narrow beach.	Three 40-inch (101.6 cm) diameter Longard tubes placed (1 on top of 2) on filter cloth parallel to the shoreline near the waterline. Sandbags placed in 4 different stacking patterns parallel to the shoreline along the waterline.	60	197

APPENDIX I--continued

Project Location	Site Description	Method of Protection	Test Construction Cost[1] ($/foot)	($/meter)
Tawas Point Coast Guard Station	Open coast area with 10 foot (3.0 m) sandy soil bluff, no beach.	Layered rock revetment, half "capped" with medium size (11 to 16 inches [27.5 to 40 cm]) armor stone.	50	164
Sanilac-Section 11	Open coast area with 35 foot (10.6 m) clay bluffs and no beach.	Seawall of 69-inch (175.2 cm) diameter Longard tube.	65	213
Whitefish Township	Sheltered coast area with a 3 foot (.9 m) sandy loam bluff, no beach.	Rock revetment with groins "tying" the revetment to the land area behind. Area behind revetment is earth filled.	45	148
Manistique	Open coast area with 5 foot (1.5 m) sand bluff and narrow beach.	Gabion mats placed over bluff face in revetment fashion.	20	66
Keweenaw Peninsula	Open coast area with 15 foot (4.5 m) sand bluff with narrow beach.	Revetment using waste mine rock in a size smaller than normally accepted for a revetment of this type.	20	66

APPENDIX I--continued

Project Location	Site Description	Method of Protection	Test Construction Cost[1] ($/foot)	Test Construction Cost[1] ($/meter)
Little Girls Point	Open coast area with 20 foot (6.1 m) high, predominantly clay bluffs with some beach.	"Nami Rings" (2 1/2 feet by 1 foot [7.6 m by .30 m] concrete rings weighing 265 lbs. [120.2 kg]). Part of this structure was placed on filter cloth, part on a rock foundation. Some of the rings were fastened together.	35	114
Lincoln Township	Open coast area with a 20 foot (6.1 m) sand dune and a narrow beach.	Two groins 240 feet (73.1 m) composed of:		
		(1) 40-inch (101.6 cm) diameter Longard tube, 120 feet (36.5 m) long	30	98
		(2) Timber piling 90 feet (27.4 m) long.	50	164
Charles Mears State Park	Open coast area with low sandy beach in front of high dunes. Study area is immediately north of Pentwater inlet structure.	Groin system with 3 groins about 150 feet (45.7 m) on center. Each groin is composed of gabions in beach area and giant sandbags in the water area.	*	*
Ludington State Park	Open coast area with low, wide sand beach in front of high sand dunes.	Two steel pile groins, 125 feet (38.1 m) on center to stabilize beach. Groins are periodically filled with sand removed from an adjacent parking area.	*	*

APPENDIX I--continued

Project Location	Site Description	Method of Protection	Test Construction Cost[1] ($/foot)	($/meter)
Sanilac - Section 26	Open coast area with 30 foot (9.1 m) clay bluffs and no beach.	An experimental groin system with a spacing between groins of about 200 feet (60.9 meters) consisting of the following groins:		
		(1) 2 40-inch (101.6 cm) diameter Longard tubes, 100 feet (30.4 m) long	30	98
		(2) 69-inch (175.2 cm) diameter Longard tube 50 feet (15.2 m) long	25	82
		(3) Gabion baskets, 70 feet (21.3 m) long	30	98
		(4) Giant sandbags, 60 feet (18.2 m) long	30	98
		(5) Asphalt mastic, 60 feet (18.2 m) long	45	148
		(6) Timber crib, 50 feet (15.2 m) long	30	98
Marquette	Partially sheltered coast area with a low sand bluff, partially "protected" with broken concrete rubble, little to no beach.	Artificial nourishment composed of dredge sand with a large percentage of fines and a steel sheet pile groin was placed in the fill.	*	*
Pere Marquette Township	Open coast area with 20 foot (6.1 m) sand bluff and narrow beach. The Ludington inlet jetty is 1 mile (1.6 km) north of the site.	3 precast reinforced concrete, zig-zag breakwaters about 70 feet (21.3 m) long with 50 foot (15.2 m) gaps between structures. Placed 50 feet off shore.	70	230

Project Location	Site Description	Method of Protection	Test Construction Cost[1] ($/foot)	($/meter)
Lakeport State Park	Open coast area with high sand bluff, low foredunes and some beach.	40-inch (101.6 cm) diameter Longard tube installed on bar to form an offshore breakwater.	25	82
Tawas City	Sheltered sandy area with no bluff and an existing jetty at the southwest end of the project area and a newly constructed timber pile groin at the northeast limit of the project area.	Nourishment between a jetty and wood groin. Fill sand has a size distribution similar to the natural beach sand.	20	66
East Tawas	Sheltered sand coast area with no bluff.	Nourishment project using fill sand which has a size distribution similar to the natural beach sand.	15	49

[1]Cost figures given are determined over the length of shoreline the structure was designed to protect.

*Exact cost figures are not available.

APPENDIX II

PROJECT RESULTS THROUGH SPRING, 1976 FOR SITES UTILIZING SURVEYS

Project	Number of Storms (breaking wave of 6 feet [1.8 m.] or greater) at the Site Since Time of Construction (includes all months)	Structure Condition	Nearshore Environment Condition
Michiana			
Asphalt mastic revetment	5	Revetment collapsed on beach after 5th critical storm. The sand behind the revetment's slope has been flattened. Small portions of the revetment are completely destroyed.	Bluff erosion has continued. Remaining revetment is an inconvenience to bathers at this beach. Other emergency protective actions have been required.
Empire			
40-inch (101.6 cm) diameter Longard tube	**	Destroyed within 1 month.	Rapid bluff recession has continued.
Moran Township			
40-inch (101.6 cm) diameter Longard tubes	8	Some minor differential settlement. The top tube had to be wedged in place to avoid being pushed off due to back pressure from sliding sand.	Sand bluff has flattened some, mostly due to adjustment of bluff to a more stable slope.
Sandbags	8	A number of sandbags have been lost, partly due to vandalism. Some differential settlement has been detected.	Sand bluff has flattened some, mostly due to adjustment of bluff to a more stable slope.

**Storm conditions were not known at the time of destruction of the tube.

Project	Number of Storms (breaking wave of 6 feet [1.8 m] or greater) at the Site Since Time of Construction (includes all months)	Structure Condition	Nearshore Environment Condition
Sanilac-Section 11			
69-inch (175.2 cm) diameter Longard tube	2	The center section of the structure has lost sand and collapsed. The structure has moved lakeward.	Some bluff recession.
Lincoln Township			
40-inch (101.6 cm) diameter Longard tube	18	Outer portion (1/3 of the tube) has been lost. The remainder of the tube has settled from 0-2 feet (0-.61 m).	Tube has trapped and held sand. Slope on dune near tube has flattened to some extent.
Timber pile	18	Unchanged	The groin has trapped and held sand. Slope on dune near this groin has flattened to some extent.
General			Structures have protected site by trapping sand and raising the beach profile.
Charles Mears State Park			
Gabion and sandbag groins	13	Some settlement detected in all groins. One or 2 sandbags lost from each structure, some settlement and shifting.	System has helped stabilize beach area with artificial nourishment added each spring.

APPENDIX II--continued

Project	Number of Storms (breaking wave of 6 feet [1.8 m] or greater) at the Site Since Time of Construction (includes all months)	Structure Condition	Nearshore Environment Condition
Ludington State Park			
Steel pile groins	14	North groin had to be repaired once (lake portion pulled, straightened, and redriven).	Deep holes have been scoured in the lake bottom around the outer edge of the groin. System has required periodic sand nourishment.
Sanilac 26			
2 40-inch (101.6 cm) diameter Longard tubes placed side by side.	2	Minor differential settlement in tubes.	Sand has been trapped by the groin. Recession at top of bluff is about 10 feet (3.0 m) in the immediate vicinity of this groin. This recession could be caused by factors other than wave attack.
69-inch (175.2 cm) diameter Longard tube	2	Minor settlement	This groin has been effectively trapping sand, particularly to the north. Top of bluff recession has been minimal.
Gabion	1	Minor settlement at lake end.	Sand is being trapped, especially on north side of groin.

Project	Number of Storms (breaking wave of 6 feet [1.8 m] or greater) at the Site Since Time of Construction (in - cludes all months)	Structure Condition	Nearshore Environment Condition
(Sanilac-Section 26 continued)			
Sandbags	2	Approximately the outer 20 feet (9.1 m) of this structure have been lost through bag destruction and other bags have been lost and shifted.	Sand has been trapped by this structure. Top of bluff recession has been minimal.
Asphalt mastic	2	Small section about 3 by 3 feet (.9 by .9 m) of groin has broken off at outer end.	Sand has been trapped by structure. Minimal top of bank recession has been recorded.
Timber crib	1	Unchanged (installed late summer 1975).	Generally stable.
General		Spacing between groins has been effective to date.	Some areas of localized top of bluff recession, probably due primarily to adjustment of bluff to a more stable slope.

APPENDIX II--continued

Project	Number of Storms (breaking wave of 6 feet [1.8 m] or greater) at the Site Since Time of Construction (in - cludes all months)	Structure Condition	Nearshore Environment Condition
Pere Marquette Township			
Precast concrete breakwater	18	Walls 1 and 2 have settled. Wall 3 has only tilted. Two panels have been lost off the north end of wall 1 and one panel has been lost off the south end of wall 2.	Bluff recession has continued. Bathhouse that this installation was meant to protect has been destroyed during a major storm.
Lakeport			
40-inch (101.6 cm) diameter Longard tube on bar	3	Unchanged.	Beach area has increased greatly in the vicinity of the tube (unrelated to the tube's performance) to such an extent that the tube is no longer a break-water. This site is no longer part of the extended field program since the tube has been covered with sand.
Tawas City			
Sand nourish-ment	1	Minor shifting of the sand nourishment.	No change.

Project	Number of Storms (breaking wave of 6 feet [1.8 m] or greater) at the Site Since Time of Construction (includes all months)	Structure Condition	Nearshore Environment Condition
East Tawas			
Sand nourishment	2	Totally dispersed.	No apparent effect from sand.

APPENDIX III

PROJECT RESULTS THROUGH SPRING, 1976 FOR SITES UTILIZING PHOTOGRAPHIC MONITORING ONLY

Project Location	Structure Condition	Nearshore Environment Condition
Big Sable Point	Construction problems were experienced at this site which hampered the study. All the sand fill behind the wall has been washed out, exposing improperly installed tie backs. The south cutoff wall which was poorly installed has failed.	Original seawall is leaning forward. Bluff recession has continued at a very low rate.
Tawas Point Coast Guard Station	Some shifting in the rocks is evident.	Unchanged.
Whitefish Township	Unchanged.	Stable.
Manistique	Structure has been paved over and area is now a parking lot.	No longer applicable.
Keweenaw Peninsula	Unchanged.	Unchanged.
Little Girls Point	Some change in revetment position due to sliding clay. Rings have filled with sand and small rock.	Some sliding of clay bluff.
Marquette	Groin has remained unchanged. A large amount of sand has shifted as expected.	The sand is being lost but the original bluff has been protected.