Geol Survey

Erosion and Accretion Trends Along the Lake Michigan Shore at North Point Marina and Illinois Beach State Park

Year-2 (1996) Report of a Four-Year Study of Coastal Geology and Coastal Geologic Processes

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EXECUTIVE SUMMARY

In 1996, the Illinois State Geological Survey (ISGS) began Year-2 of a four-year study to examine erosion and accretion trends along the Lake Michigan shore at North Point Marina (NPM) and the North and South Units of Illinois Beach State Park (IBSP). This study is funded by the Illinois Department of Natural Resources (DNR) which is responsible for coastal management at these facilities. The goal of the study is to develop a sediment budget for the coastal reach which extends between the WI-IL state line and Waukegan Harbor (the SL/WH coastal reach). This will provide input for planning and implementing long-term strategies for coastal management. An immediate objective is to provide information on erosion and accretion trends relevant to ongoing coastal management.

Comparison of 1872-1996 data on lake-bottom (nearshore) change indicates that the northern part of the SL/WH coastal reach has become increasingly important as a source area for sediment supply to areas further south. Between 1974 and 1996, all accretion along the southern segment of the coastal reach could be accounted for by erosion along the northern segment of the reach. Most of the erosion occurred along present-day DNR lakeshore while most of the accretion occurred in areas to the south of DNR property. The 124-year record also suggests that the greatest beach and nearshore erosion will likely continue to be focused in the area between the WI-IL state line and Camp Logan.

Net erosion has characterized the beaches and nearshore along the 7700-ft stretch of shore between the WI-IL state line and Camp Logan both prior to, and subsequent to, marina construction (1987-1989). During 1995-1996, net nearshore erosion along this shore totaled 139,300 cu yds. This was almost a six-fold increase in the annual net erosion rate when compared with the 1992-1995 interval. The area of most extensive lake-bottom erosion occurred between the marina / state park boundary and Camp Logan. For the shore along the marina property, the most severe erosion continued to occur lakeward of the south parking area, undermining the existing line of shore defense and causing loss of backfill.

The nearshore on the updrift (north) side of NPM was net accretional between 1987 and 1995 due to sediment entrapment on the updrift side of the north breakwater. During 1995-1996, this nearshore became net erosional, losing 21,100 cu yds of sand. This may be a one-year erosional anomaly or it may indicate the start of a new erosional trend. It does indicate, however, that accretion does not necessarily occur on the updrift side of this facility on an annual basis. An erosional trough has been located about 90 ft offshore of the NPM north breakwater since 1988. During 1995-1996, this trough deepened by 7 ft to its greatest recorded depth of 18.6 ft Low Water Datum (LWD) and was up to 5 ft deeper than the design base elevation of the north breakwater. Sediment lost from this part of the nearshore moved downdrift causing accretion in the shallow nearshore along the south breakwater.

As of June 1996, the marina entrance had experienced a net loss of sediment during 1995-1996 (-3,300 cu yds). It had been net accretional during 1992-1995 (+3,100 cu yds/yr). The net loss of sediment is primarily attributed to 1995-1996 dredging which was completed in August 1996. In the recreational and commercial basins, average water depths in 1996 generally remained at or greater than the design depth of 8.1 ft LWD. A 19-ft deep erosional trough, located 50 ft east of the north inner breakwater near the marina entrance, was 7 ft deeper than the design depth for the base of the north inner breakwater.

The northern part of the IBSP North Unit, between the marina / state park boundary and the Camp Logan headland, underwent severe lake-bottom erosion during 1995-1996. However, the 1996 beach area remained similar to that of 1995 (8 acres). This can be attributed to reduced shoreline recession caused by the input of beach nourishment at the updrift end. While beach nourishment in 1995-1996 slowed the rate of shoreline recession, it was not sufficient to counteract the net loss of 65,200 cu yds of sand, silt, and gravel from the nearshore. The Year-2 interim littoral sediment budget suggests that a nourishment rate of at least 82,600 cu yds/yr would be required annually at the North Unit nourishment site to initiate a balanced sediment budget and to halt net erosion.

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PART 1: STUDY DESCRIPTION

INTRODUCTION

Background

The historical record of coastal change along the Illinois shore of Lake Michigan indicates that the most dynamic coastal area in the state is located between the Wisconsin-Illinois (WI-IL) state line and Waukegan Harbor (Fig. 1-1). Along this reach, severe erosion and pronounced accretion have resulted in some of the most rapid rates of coastal change documented along the entire shore of southern Lake Michigan.

In subsequent sections of this report, the 9.7-mile shore between the state line and Waukegan Harbor is referred to as the WI-IL state line / Waukegan Harbor coastal reach (SL/WH coastal reach). 6.5 miles, or 67 percent, of the coastal reach is state-owned (Fig. 1-2), consisting of the coastal zone at North Point Marina (NPM) near the state line, and the North and South Units of Illinois Beach State Park (IBSP/NU and IBSP/SU). Both the marina and state park are managed by the Illinois Department of Natural Resources (Illinois DNR) and are among the most heavily used DNR recreation and conservation areas in the state. NPM is a state investment of nearly 42 million dollars that incorporates state-of-the-art marina design for 1500 boat slips, making this the largest marina in the Great Lakes Region. IBSP not only provides lakeshore recreation, but also preserves the last remaining stretch of natural lakeshore and concentration of coastal wetlands and dunes in Illinois.

Purpose and Scope

In 1995, the Illinois State Geological Survey (ISGS) began a four-year study of coastal geology and coastal geologic processes along the northernmost segment of the Illinois shore of Lake Michigan. This study focuses on NPM and IBSP, but also examines erosion and accretion trends on a regional scale between the WI-IL state line and Waukegan Harbor. The ultimate goal is to develop a sediment budget for the coastal zone identifying sediment sources and sinks, sediment transport pathways, and average annual rates of lake-bottom change. This information is needed for ongoing and future management of coastal sand resources.

This report is the second in a series of four annual reports that summarizes yearly findings during the course of this four-year study and provides information relevant to ongoing coastal management at NPM and IBSP. The report generally follows the format of the Year-1 Report (Chrzastowski *et al.*, 1996). Appendix A contains the executive summary from the Year-1 Report. Because the collection, processing, and interpretation of field data are continuing as this report is submitted, some of the findings presented here are interim in nature. As additional annual data are collected and evaluated, these interim findings may be modified or expanded upon in subsequent annual reports.

Project Funding

The primary funding for this study is a contract with the Illinois Department of Natural Resources (Illinois DNR), Office of Capital Development. Additional funding on a cost-share basis was provided by the ISGS from general revenue funds for ISGS studies of Lake Michigan coastal geology. This report is a contract deliverable for Illinois DNR Contract No. 9643E.

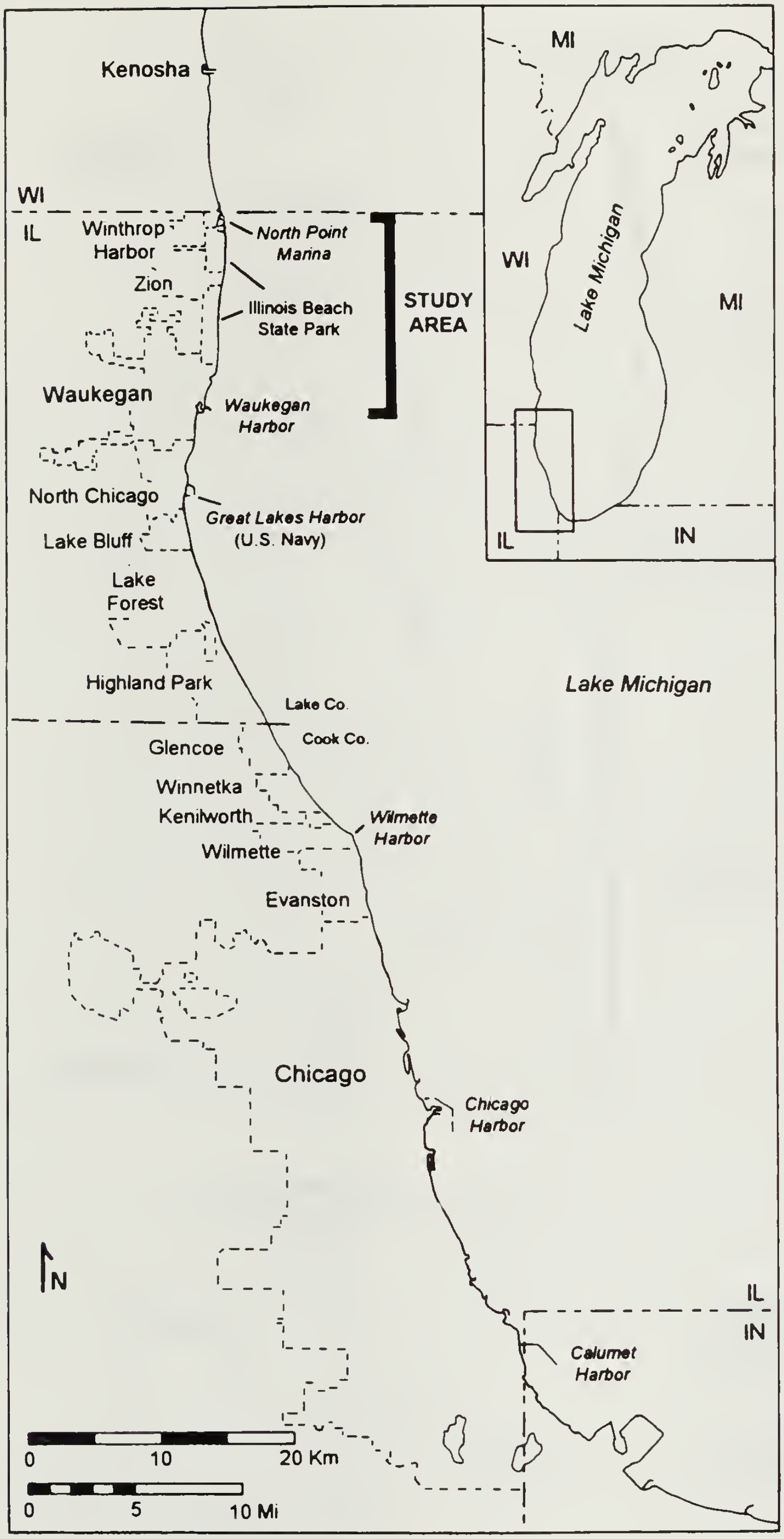

Figure 1-1 Map of the Illinois coast of Lake Michigan showing location of the study area.

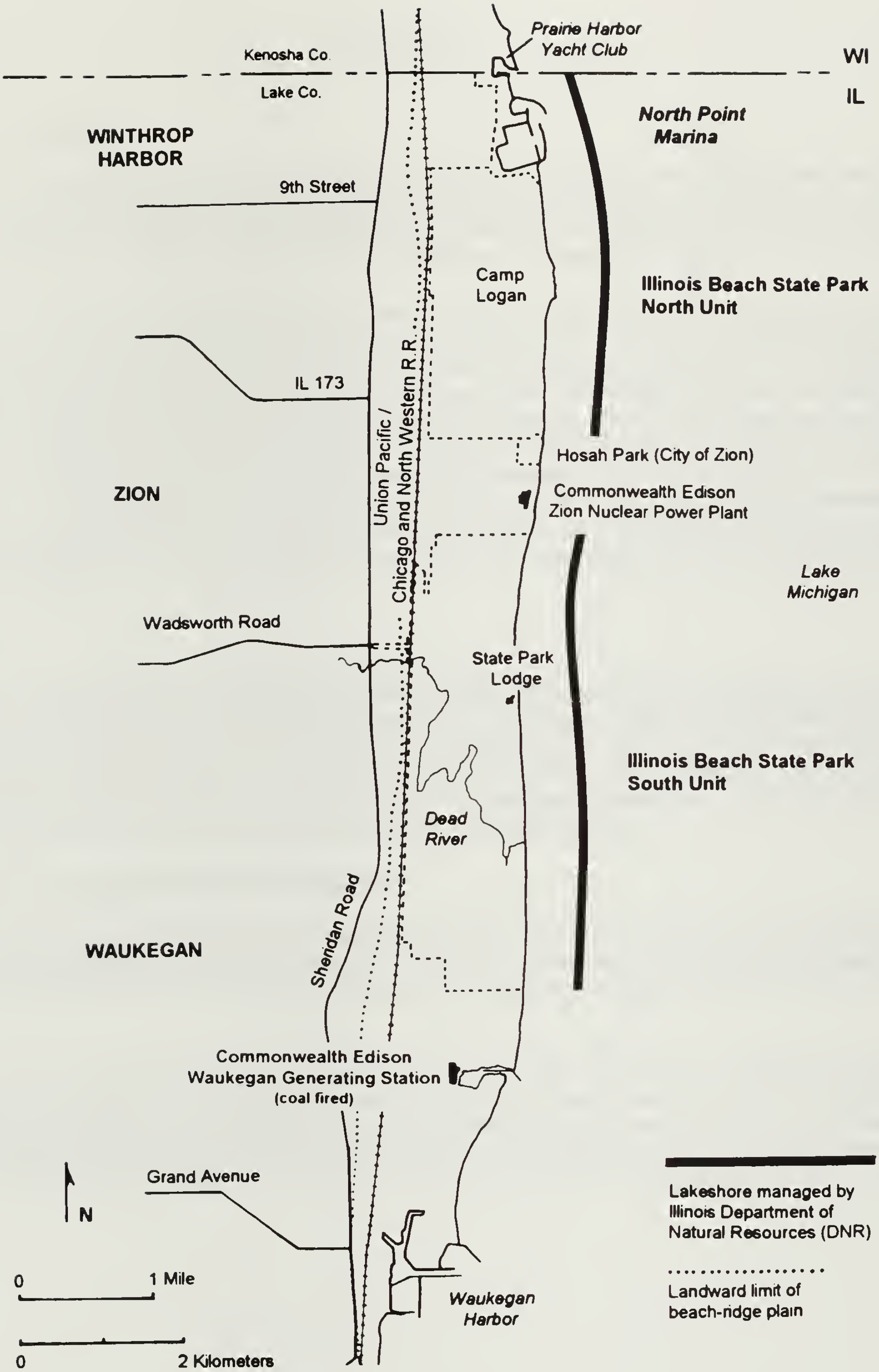

Figure 1-2 Map of the study area, the WI-IL state line / Waukegan Harbor (SL/WH) coastal reach, showing major place names and geographic features.

SETTING

Geologic Framework

The study area is located along the coast of the Zion beach-ridge plain, a low-lying coastal sand and gravel plain that extends 18 miles from Kenosha, WI, to North Chicago, IL (Fig. 1-1). In Illinois, the western border of the plain is marked by a north-south trending bluff line, which is approximated by the north-south right-of-way of the Union Pacific / Chicago and North Western Railroad (Fig. 1-2).

The Zion beach-ridge plain is the above-water part of a coastal sand body that extends up to 8000 ft lakeward of the modern shoreline (Fraser and Hester, 1974). In cross section, the sand body is lens-shaped and attains its maximum thickness of 30 to 35 ft near the modern shoreline (Fig. 1-3). Curvilinear beach ridges and dunes mark the approximate locations of former shorelines (Fig. 1-4) and formed as the sand plain migrated southward by the accretion of sand and gravel. Radiocarbon dating indicates that the plain first migrated southward across the WI-IL state line about 4000 years ago (Larsen, 1985). Construction of Waukegan Harbor between 1883 and 1906 interrupted southward migration of the sand plain because the harbor jetties formed a partial to near-total barrier to littoral transport (Chrzastowski and Trask, 1995). As a result, the construction of Waukegan Harbor has contributed towards the accretion of approximately 500 acres of new land along the north side of the harbor since the late 1880s (Foyle and Chrzastowski, 1996).

Lake Level

Lake Michigan water levels during 1996 were consistently above the long-term (1918-1995) average (U.S. Army Corps of Engineers, 1996). Lake level ranged from 0.06 ft above average in January, to 0.75 ft above average in August, to 1.15 ft above average in November (Fig. 1-5). High lake levels generally cause shoreline recession and loss of land as the shoreline is forced to move landward. High lake levels also permit higher wave energies to be imparted across the shallow nearshore and at the shoreline. These latter effects can induce increased lake-bottom and beach erosion.

Wave Climate and Littoral Sediment Transport

The wave climate between the WI-IL state line and Waukegan Harbor is such that 90 percent of the waves in the nearshore are less than 3 ft in height (Booth, 1994). The highest waves are typically associated with storms occurring between autumn and spring. During severe storms, nearshore wave heights may reach 8 or 9 ft.

The Illinois coast is exposed to waves approaching from either the northeast or southeast quadrants. Northeasterly waves tend to be highest since winds from the northeast quadrant have the longest fetch (*i.e.*, distance over water). The predominance of northeasterly waves is responsible for a net southerly transport of sediment along the beaches and nearshore. Southeasterly waves occasionally cause brief reversals in the littoral transport direction by moving sediment northward, but <u>net</u> littoral transport is to the south.

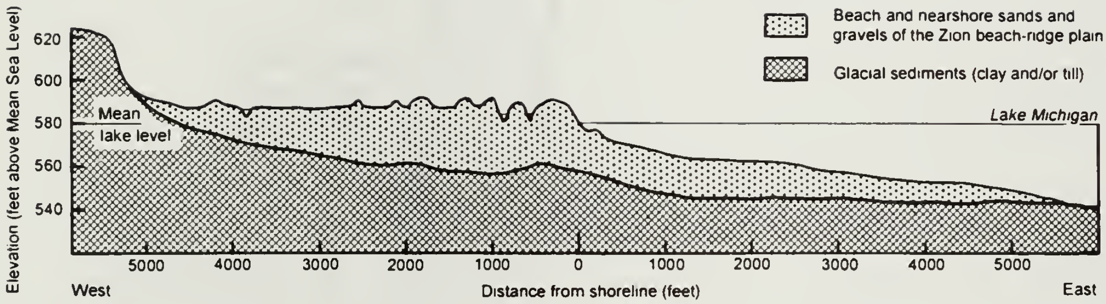

Figure 1-3 East-west cross section of the Zion beach-ridge plain in the vicinity of Dead River. The maximum sand thickness of 30 to 35 ft occurs near the present shoreline (modified from Fraser and Hester, 1974).

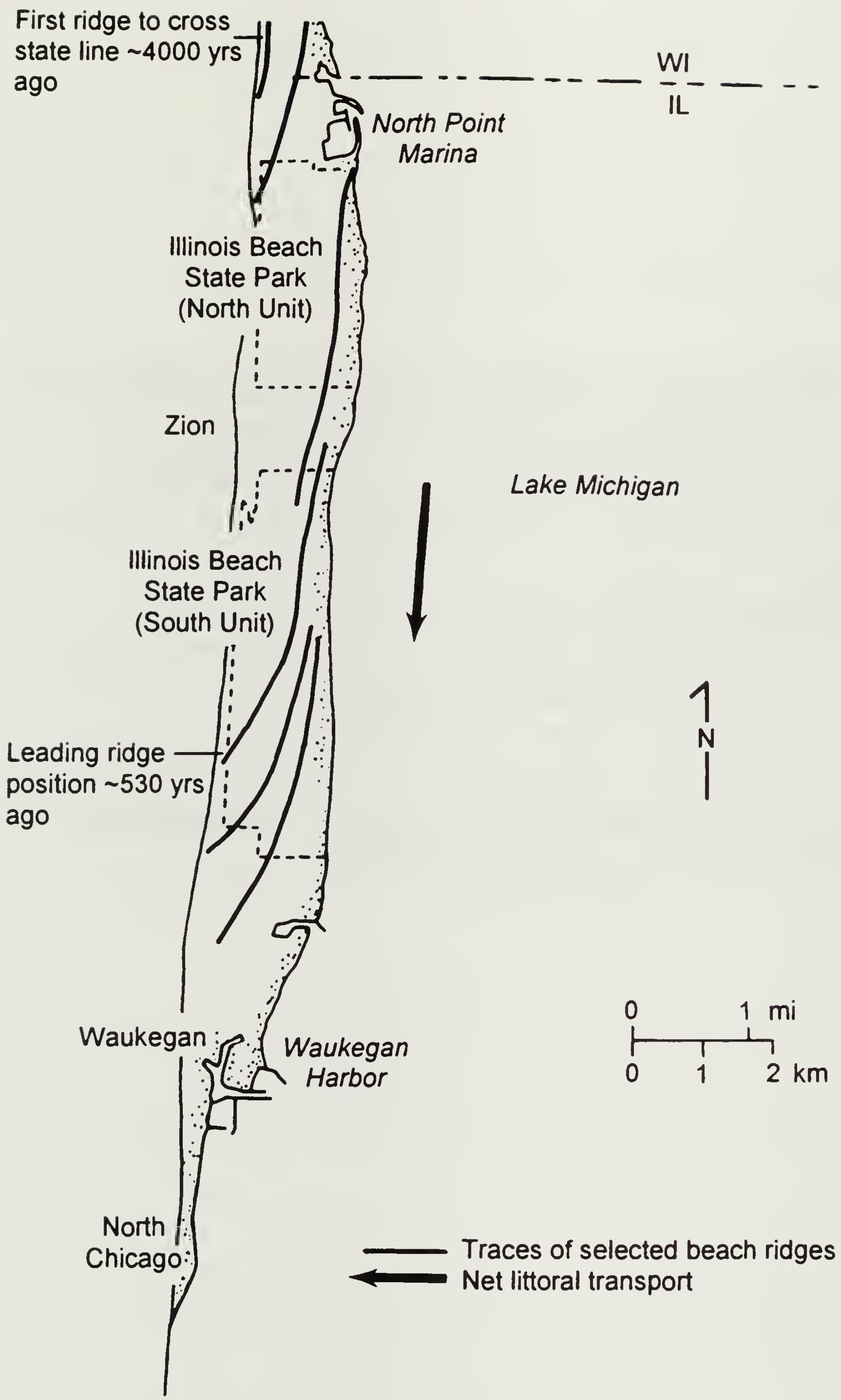

Figure 1-4 Schematic illustration of the Zion beach ridge plain in Illinois showing selected curvilinear beach ridges. Approximate beach-ridge ages are shown in calendar years (modified from Larsen, 1985).

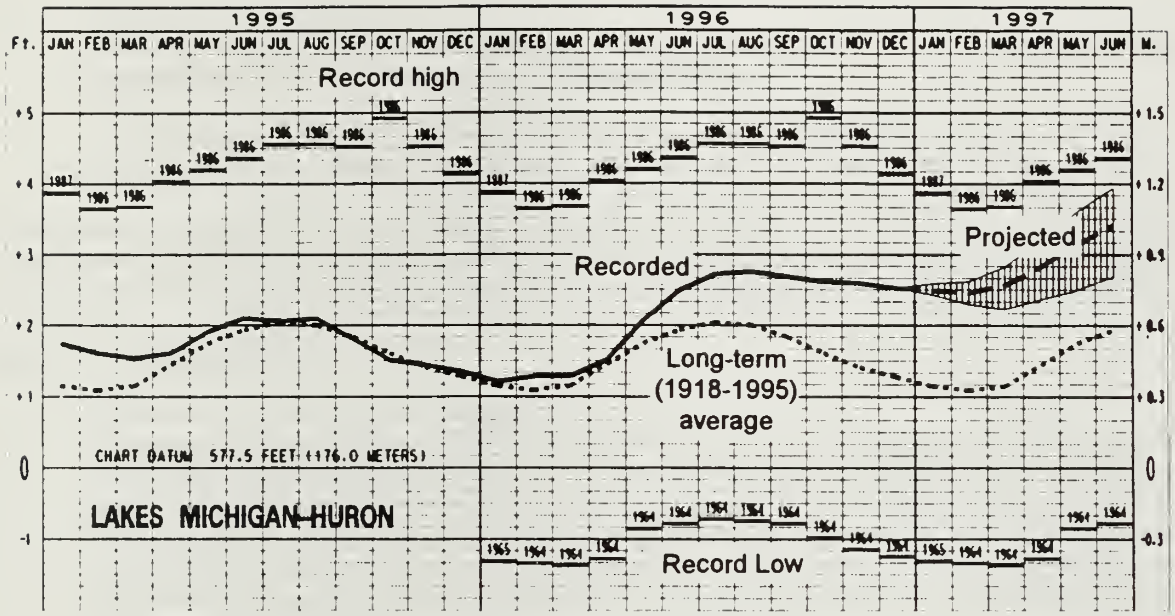

Figure 1-5 1995-1996 lake-level record for Lakes Michigan and Huron. Projected 1997 lake levels are also shown (from U.S. Army Corps of Engineers, Monthly Bulletin of Lake Levels for the Great Lakes, December 1996).

OVERVIEW OF 1996 DATA COLLECTION

General Statement

Data collection during 1996 consisted of three principal components:

- *Site-specific collection of bathymetric-profile data*
  Coverage of areas surveyed in 1995 to document magnitudes and rates of single-year (1995-1996) coastal change at North Point Marina and at beach nourishment sites in Illinois Beach State Park.

- *Regional data collection*
  Shoreline mapping, bathymetric profiling, and subsurface geophysical mapping to cover the entire coast between the WI-IL state line and Waukegan Harbor.

- *Compilation of data from previous studies along the northern Illinois shore*
  Expansion of the bathymetric-profile data base to cover time periods from 1872 to present.

The following paragraphs provide an overview of 1996 data collection and compilation as of the end of November 1996. Results from the 1996 data are discussed in Part 2 and Part 3 of this report. Procedures used in data collection and processing, and a glossary of principal terms, are outlined in Appendix B.

North Point Marina (NPM)

- *Bathymetric and topographic surveys*
  To repeat 1995 data coverage, 49 bathymetric profile lines were run between the WI-IL state line and the marina / state park boundary. This number included an additional nine lines collected along the south breakwater that were not collected during 1995. Thirteen lines were run in the marina entrance, a four-line increase in coverage over 1995. Sixty-three new profile lines were used to map the marina's commercial and recreational boat basins and approaches. These latter data were collected to document 1996 bathymetry and lake-bottom change since construction of the basin in 1987-1988.

- *South parking area monitoring*
  In winter 1995, an estimated 7,000 cu yds of sand were placed along an 1100-ft stretch of riprap-defended shoreline at the south parking area. In summer 1996, an additional 13,000 cu yds of sand were placed at the site. The winter sand application occurred at the same time that beach nourishment was being applied at the IBSP/NU site (see below). The sand was applied for reasons of public safety and to help mitigate erosion along the shore. The area was monitored to document erosion along the lakefront between the NPM south breakwater and the marina / state park boundary.

Illinois Beach State Park (IBSP) / North Unit

- *Bathymetric and topographic surveys*
  A total of 17 bathymetric profile lines were run between the marina / state park boundary and the Camp Logan headland to document 1996 bathymetry and calculate 1995-1996 lake-bottom change.

- *Beach nourishment monitoring*
  Between December 1995 and January 1996, an estimated 26,000 cu yds of beach nourishment were placed at the northern end of the North Unit. The 26,000 cu yds were an addition to 20,000

cu yds placed at this location in July 1995. The topographic and wading survey scheme initiated in Year-1 prior to placement of the July 1995 nourishment was continued through 1996 to document erosion at this site.

Illinois Beach State Park (IBSP) / South Unit

- *Beach nourishment monitoring*
  Although the north end of the South Unit did not receive beach nourishment during 1996, the 24,000 cu yds of nourishment it did receive during June and July 1995 continued to be depleted. The topographic and wading survey scheme initiated in July 1995 (during Year-1) was continued on a bimonthly basis through 1996 to document shoreline and nearshore change at this nourishment site.

Regional Data Collection

- *Compilation of historical bathymetric records from 1872 through 1974*
  Bathymetric data sets from 1872, 1910, and 1974 (see Appendix C) were compiled to assist in evaluation of long-term changes in shoreline position, historical lake-bottom changes, and the distribution of long-term erosional and accretional zones within the SL/WH coastal reach.

- *Horizontal and vertical control for shoreline, bathymetric, and topographic surveys*
  Survey traverses were extended from benchmarks in IBSP South Unit northward to Camp Logan and southward to Waukegan Harbor to provide new horizontal and vertical control along the shore. The origins for nine primary range lines, first established in 1946 by the Illinois Division of Waterways, were reestablished and X-Y-Z coordinates were determined. Origins for 14 new intermediate, or secondary, range lines were also established.

- *Bathymetric and topographic surveys*
  Bathymetric and topographic profiles were collected along the 9 primary and 14 intermediate east-west range lines, spaced at 1700 to 1900 ft intervals along the SL/WH coastal reach (Appendix J). All 23 lines have pre-existing bathymetric data available for the years 1872, 1910, and 1974. These data sets allow for long-term comparisons of lake-bottom change.

- *Shoreline survey*
  The 1996 shoreline was surveyed at 200-ft intervals between the WI-IL state line and Waukegan Harbor. Comparison of the 1996 shoreline with those from 1872, 1910, and 1974 allows evaluation of long-term rates of shoreline recession or progradation.

- *Nearshore seismic reflection survey*
  High-resolution seismic reflection data were collected along the nearshore between the WI-IL state line and Waukegan Harbor. North-south and east-west intersecting profile lines were spaced at 0.75-mile intervals. Data coverage extended from near the shoreline up to 1.75 miles offshore. This data set allows mapping of the submerged part of the Zion beach-ridge plain to calculate sand thickness and identify potential sand reserves. These data also allow determination of the depth to the sand / glacial sediment interface.

- *Dredge records from the Waukegan area*
  Dredge records, compiled initially for the Year-1 report, were updated to incorporate volumes from dredging carried out during 1995-1996. Dredge data were available for the Commonwealth Edison Waukegan Generating Station and for Waukegan Harbor. These data allow estimation of the approximate rates of littoral sediment transport at the downdrift end of Illinois Beach State Park.

PART 2: STUDY APPLICATIONS AND SUMMARY

SUMMARY OF YEAR-2 KEY FINDINGS

The following sections summarize the principal results and recommendations of Year-2 (1996) monitoring at North Point Marina (NPM) and Illinois Beach State Park (IBSP). Geographically-keyed sections in Part 3 of this report address these and other topics in more detail.

WI-IL State Line to Camp Logan

Figure 2-1 shows 1995-1996 lake-bottom change along the 7700 ft of shore between the WI-IL state line and Camp Logan. Table 2-1 summarizes data on lake-bottom changes across the same area over the periods 1992-1995 (Year-1 Report) and 1995-1996. During 1995-1996, net nearshore erosion along the state line - Camp Logan nearshore, including the NPM entrance area, totaled 139,300 cu yds (Table 2-1). This is almost a six-fold increase in the rate of net annual erosion compared to the 1992-1995 interval.

Overall, net erosion has characterized this 7700-ft stretch of shore both prior to and subsequent to marina construction. Comparison of 1974, 1987, and 1996 bathymetric data indicates, however, that the nearshore on the updrift side of NPM became net accretional in 1987. This accretion has mitigated historical shoreline recession and land loss that occurred at North Beach prior to 1987. In the interval between marina construction (1987-1989) and 1996, a broad accretional lobe extended southward from the WI-IL state line past the marina entrance to midway along the NPM south breakwater. The accretional lobe indicates that the marina is not a total barrier to southward littoral sediment transport and that natural bypass of sediment to downdrift nearshore areas began to occur soon after breakwater construction.

North Beach / north breakwater

- Net erosion of 21,100 cu yds occurred in the North Beach / north breakwater nearshore on the updrift side of NPM during 1995-1996. This was a major reversal in this area's net-accretional trend between 1987 and 1995 when the average rate of net change was +10,800 cu yds/yr. It was also the first year of net erosion documented in this nearshore since the beginning of marina construction in 1987. The 21,100 cu yds of erosion during 1995-1996 may be a one-year erosional anomaly among eight previous years of net accretion, or it may indicate the start of a new erosional trend.

- In mid September 1996, a beach washover occurred at the north end of North Beach adjacent to Prairie Harbor Yacht Club. This resulted in sand being washed into the south side of Prairie Harbor's boat basin and the formation of a sand delta. Without emplacement of an improved barrier to sand transport, this process will likely recur in the future, particularly during easterly and southeasterly wave events.

- An erosional trough has been located adjacent to the lakeward side of the NPM north breakwater since 1988. During 1995-1996, this trough deepened by 7 ft to its greatest recorded depth (18.6 ft LWD) since 1988 (Fig. 2-1). Sediment lost from this part of the nearshore moved downdrift causing accretion along the south breakwater nearshore. The trough, centered about 90 ft offshore from the breakwater's waterline, also lengthened by about 100 ft during 1995-1996. The 18.6 ft LWD maximum axial depth in 1996 means that the lake bottom within 90 ft of the breakwater was 3.6 to 5.0 ft deeper than the breakwater's design base elevation.

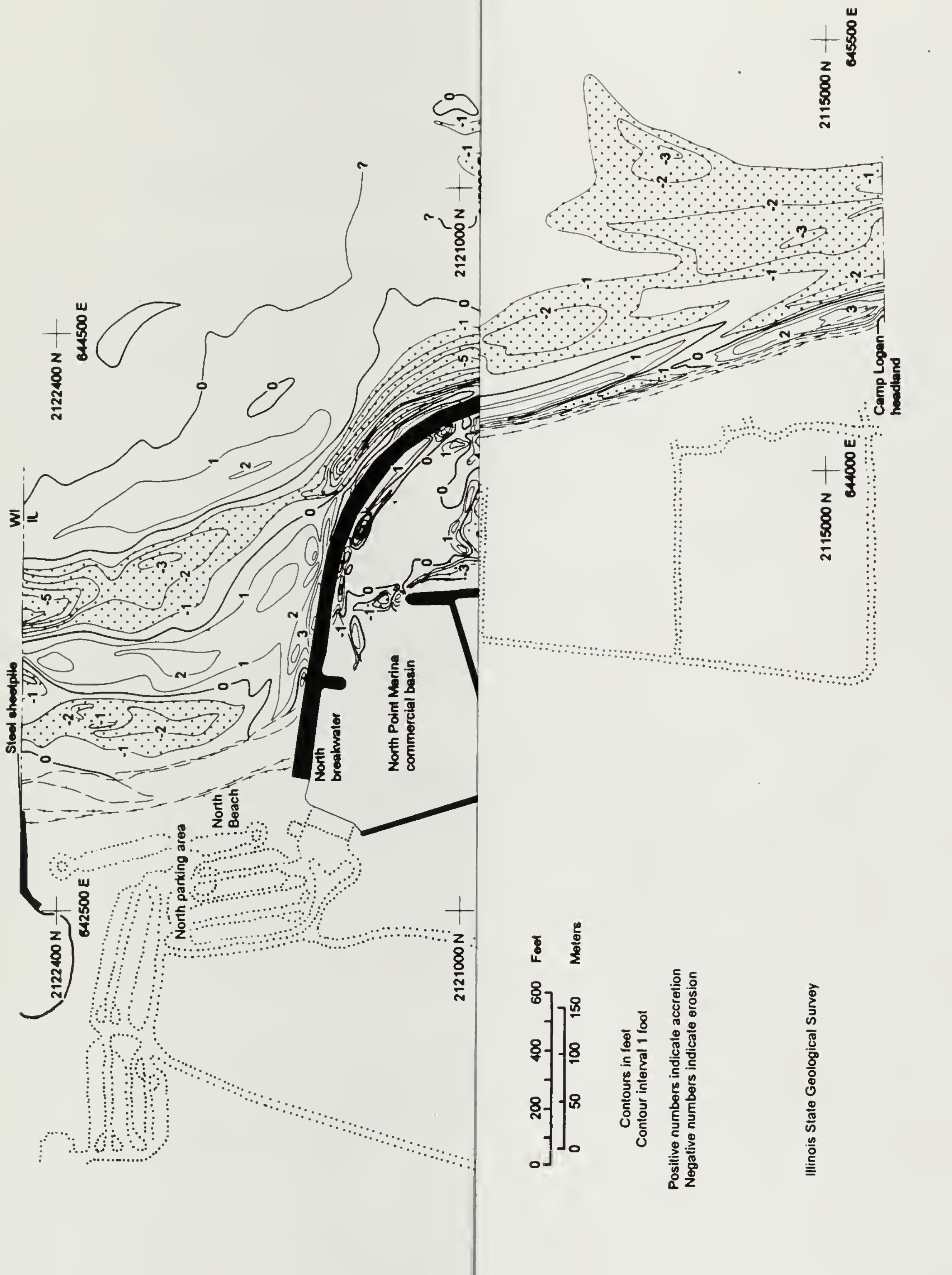

Figure 2-1 Summary map of 1995-1996 lak
Camp Logan headland.

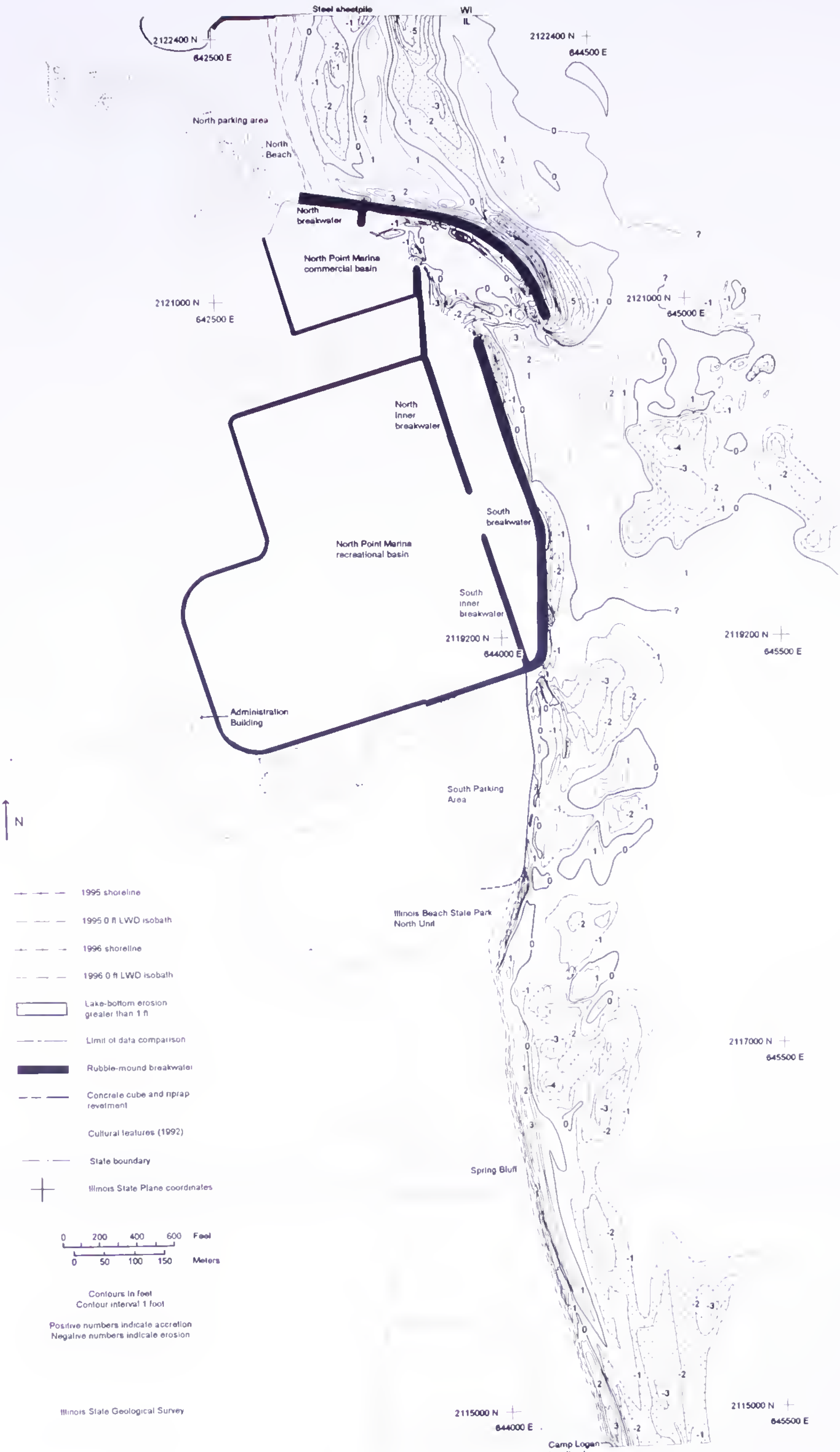

Figure 2-1 Summary map of 1995-1996 lake-bottom change between the WI-IL state line and the Camp Logan headland

- Looking at the longer-term picture for the north breakwater area, the 1987-1996 record of lake-bottom change between the WI-IL state line and Camp Logan indicates that the site of the erosional trough along the northeast side of the north breakwater is an "erosional hotspot" where the lake-bottom lay 3 ft deeper in 1996 than it did in 1987. Most of the erosion occurred during 1995-1996. Of all the erosional areas between the state line and Camp Logan, this is the most severe erosion in proximity to any infrastructure.

Table 2-1 Annualized nearshore change volumes between the WI-IL state line and Camp Logan from 1992 through 1996.[1]

	1992-1995[2]	1995-1996
North Beach/north breakwater (cu yds/yr)[3]	10,300	-21,100
Marina entrance (cu yds/yr)	3,100	-3,300[4]
South breakwater (cu yds/yr)	-6,600	-20,000
South parking area (cu yds/yr)	-10,600	-29,700
Spring Bluff (cu yds/yr)	-20,600	-65,200
Total (cu yds/yr)	-24,400	-139,300

[1] All volumes are computed for lake-bottom elevation changes in excess of 1 ft occurring below Low Water Datum (LWD) and exclude beach nourishment volumes. Volumes are rounded to the nearest 100 cu yds.
[2] These are annualized net volume changes derived from a three-year comparison of Year-1 (1995) data and data available from 1992.
[3] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[4] Net erosion is due to basin dredging performed in the interval between collection of the 1995 and 1996 bathymetric data sets.

Marina entrance area and boat basins

- As of June 1996, the marina entrance area had a net loss of sediment (-3,300 cu yds/yr). It had been net accretional during 1992-1995 (+3,100 cu yds/yr). The change is attributed primarily to 1995-1996 dredging in the marina entrance and in the approach channel to the recreational boat basin. A total of 24,000 cu yds of sand were dredged during 1995-1996.

- An erosional zone at the tip of the north breakwater is a southward continuation of the North Beach / north breakwater nearshore trough. The trough was probably caused by currents flowing around the tip of the north breakwater. More than 6 ft of erosion during 1995-1996 is significant and may be of immediate concern with regard to its potential future impact on the breakwater.

- Up to 3.5 ft of accretion occurred within a NW-SE trending accretional zone on the lakeward (south) side of the marina entrance. The sediment was probably supplied from erosion of the North Beach / north breakwater nearshore trough. Some of the accreted sand may also have been supplied during southeasterly wave events by the accretional lobe located just to the east. Accretion at the marina entrance is part of a general trend of sediment entrapment that has been documented since 1989.

- Comparisons of 1994 and 1996 bathymetric data from the recreational and commercial boat basins indicate that, in general, there was no significant lake-bottom shallowing or deepening during this two-year period. As of 1996, average water depths in both basins generally remained at or greater than the design depth of 8.1 ft LWD.

- Localized areas of the approach channel to the recreational basin had significant bathymetric change between 1994/1995 and 1996. This was likely due to a combination of current scouring and 1995-1996 dredging. An erosional trough located 50 ft east of the north inner breakwater deepened by 2 to 4 ft to just over 19 ft LWD. This trough is the deepest feature within the entire marina.

- The base of the 19-ft deep erosional trough along the north inner breakwater lies about 7 ft below both the design depth for this part of the marina basin floor and the design depth for the base of the adjacent north inner breakwater.

South breakwater

- The south breakwater nearshore was net erosional during 1995-1996 but appears to have trapped the sediment lost from the North Beach / north breakwater nearshore. The trapped sediment built an accretional lobe containing 23,200 cu yds of sand. The location and orientation of the lobe suggest that most of its contained sediment was derived from the erosional trough in the North Beach / north breakwater nearshore.

South parking area

- During 1995-1996, approximately 20,000 cu yds of sand were added to fill erosional embayments that developed on the lakeward side of the NPM south parking area. All of this back-fill had been eroded and transferred to the nearshore by late autumn 1996. 24,000 cu yds of sand dredged from the marina entrance and the approaches to the recreational boat basin were deposited in the nearshore at the north end of the south parking area.

- In the south parking area nearshore, a line of submerged riprap contributed to a slowing of lake-bottom erosion rates. The crest of the submerged riprap continued to subside at an average rate of 0.5 to 1 ft/yr during 1995-1996, a rate similar to that documented between 1991 and 1995 in the Year-1 Report. A trough on the landward side of the submerged riprap also deepened by about 0.5 to 1 ft. At the site of a proposed offshore submerged breakwater, the lake bottom generally deepened by an average of 1 to 1.5 ft during 1995-1996. This exceeded the Year-1 rate-estimate of 0.25 ft/yr that was based on data from 1992-1995 lake-bottom change.

Illinois Beach State Park / North Unit (IBSP/NU) north of Camp Logan (Spring Bluff)

- Approximately 26,000 cu yds of beach nourishment were added to the IBSP/NU nourishment site between December 1995 and January 1996. Almost all of this had been eroded and transferred into the nearshore and onto downdrift beaches by autumn 1996. By autumn 1996, the scarp crest along the lakeward side of the nourishment stockpile had moved landward of its summer 1995 position, which preceded an earlier, summer 1995, addition of 20,000 cu yds of nourishment. This indicates that 46,000 cu yds of beach nourishment were transferred to the nearshore during 1995-1996.

- Net erosion (65,200 cu yds) was pervasive across the Spring Bluff nearshore despite continued littoral sediment input from the IBSP/NU nourishment stockpile and from nearshore areas further updrift. Sediment derived from the nourishment stockpile contributed to a reduction in the rates of shoreline recession and lake-bottom erosion. However, the positive effect of sediment input from updrift was felt primarily along a narrow zone between the shoreline and the nearshore bar.

- As was documented in the Year-1 report, the Spring Bluff nearshore remains the area of most extensive lake-bottom erosion between the WI-IL state line and Camp Logan. Despite a relatively stable shoreline facilitated by beach nourishment, the normalized nearshore net change rate of

-25 cu yds/yr/shoreline ft exceeds that of all nearshore erosion between the state line and the southern limit of the south parking area.

- The 1996 shoreline along the Spring Bluff shore lay 40 to 115 ft lakeward of the pre-construction (1987) shoreline. This can be attributed primarily to accretion of sediment supplied from the IBSP/NU beach-nourishment site since construction of the marina.

- Nearshore erosion during 1995-1996 resulted in up to 30 ft of shoreline recession along the central parts of the Spring Bluff shore. Sand supplied from the IBSP/NU beach-nourishment site, and entrapment against the Camp Logan headland, allowed for a stable to progradational shoreline along the north and south ends of the Spring Bluff shore.

- The 1996 beach along the Spring Bluff shore remained 5 acres larger than it was in 1987 despite ongoing nearshore erosion. Typically, the Spring Bluff beach has been decreasing in area at an average rate of 1.3 acres/yr (1989-1995 data). Beach stability in 1996 can be attributed primarily to continued sediment supply from the updrift beach nourishment site at IBSP/NU.

<u>Illinois Beach State Park / North Unit (IBSP/NU) South of Camp Logan</u>

- Comparison of 1974 and 1996 data indicate that, during this 22-year interval, shoreline recession occurred along most undefended parts of the IBSP/NU shore south of the Camp Logan headland.

- The 0.6 mile of shore immediately south of the Camp Logan headland had up to 350 ft of shoreline recession between 1974 and 1996. This yields an average annual recession rate of almost 16 ft/yr, one of the highest rates along the entire WI-IL state line / Waukegan Harbor (SL/WH) coastal reach during the 1974-1996 interval.

- Between 1974 and 1996, nearshore erosion was pervasive along this stretch of shore.

<u>Illinois Beach State Park / South Unit (IBSP/SU)</u>

- The beach-nourishment site at the north end of IBSP/SU showed no significant change during 1996. Most of the 24,000 cu yds of 1995 beach nourishment had been transferred into the nearshore by late 1995. The shoreline has returned to its pre-nourishment position along a line of pre-existing riprap and concrete-cube shore defense.

- Since the erosion of the 1995 beach nourishment, however, a scarp (2 to 4 ft high) has existed between the access road and the adjacent line of riprap along the southernmost 200 ft of this shore.

- Comparison of 1974 and 1996 shoreline-position data indicates that, during this 22-year interval, shoreline recession occurred along most undefended parts of the IBSP/SU shore in areas to the north of the State Park Lodge. In the vicinity of Dead River, the shoreline maintained a relatively stable position. Along the remainder of the IBSP/SU shore south of Dead River, the shoreline generally shifted lakeward due to accretion along the beach and in the shallow nearshore.

- Comparison of 1974 and 1996 bathymetric data indicates that the nearshore north of Dead River was generally erosional during those 22 years while the nearshore south of Dead River was generally accretional.

Regional Coastal Monitoring

Shoreline and lake-bottom change

Data for shoreline position and bathymetry for the years spanning the 1872-1996 interval were compiled to document long-term trends within the SL/WH coastal reach. Comparisons of bathymetric data for the intervals 1872-1910, 1910-1974, and 1974-1996 yield the following observations:

Overview:

- Historically, nearshore erosion and shoreline recession have characterized the northern segment of the SL/WH coastal reach, shoreline stability has typified the shore centered on the mouth of Dead River, and nearshore accretion and shoreline progradation have characterized the shore from just south of Dead River to Waukegan Harbor.

- Between 1872 and 1996, the SL/WH coastal reach had a persistent general trend of increasing erosion and decreasing accretion. The result was that the entire reach switched from being net accretional during 1872-1974 to being net erosional during 1974-1996. The long-term trend, and the switch to net erosional conditions, suggests that net erosion will persist within the SL/WH coastal reach.

1872-1910:

- Between 1872 and 1910, net accretion of 68,400 cu yds/yr occurred. Most of the accretion took place in the nearshore zone between the south end of IBSP/SU and Waukegan Harbor. The greatest accretion occurred on the north (updrift) side of Waukegan Harbor. In nearshore areas between the state line and Camp Logan, net lake-bottom erosion was pervasive. The greatest amount of nearshore erosion occurred in the vicinity of present-day North Point Marina.

1910-1974:

- Between 1910 and 1974, the SL/WH coastal reach had annual net accretion of 25,200 cu yds/yr which is approximately 40% of that calculated for the 1872-1910 interval. The nearshore accretion zone lengthened so that it extended from the mouth of Dead River to Waukegan Harbor. Greatest accretion occurred in the vicinity of the newly constructed jetty at the Commonwealth Edison Waukegan Generating Station. The erosional nearshore along the northern part of the coastal reach extended southward to the present-day location of the Commonwealth Edison Zion Nuclear Power Plant. However, the greatest nearshore erosion continued to occur in the vicinity of present-day North Point Marina.

1974-1996

- Between 1974 and 1996, a major change occurred within the SL/WH coastal reach. The nearshore switched from being net accretional (1872-1974) to net erosional, losing 64,900 cu yds/yr of littoral sediment. Most accretion again occurred in nearshore areas to the south of Dead River and was greatest at the updrift side of Waukegan Harbor and updrift of the jetty at Waukegan Generating Station. However, annualized accretion rates were only about 50% of those documented between 1872 and 1974. This may be related to the entrapment areas at Waukegan Generating Station and Waukegan Harbor approaching an equilibrium state.

- A significant change occurred adjacent to the WI-IL state line during the 1974-1996 interval. Net accretion occurred in the North Beach nearshore on the updrift side of the NPM north breakwater, reversing long-term (1872-1974) erosional trends at this site.

- To the south, erosion continued to dominate in nearshore areas adjacent to DNR property between the entrance to NPM and the mouth of Dead River. The greatest amount of lake-bottom erosion during the 1974-1996 interval was documented in the Spring Bluff nearshore.

Summary:

- The 124-year record indicates that the northern part of the SL/WH coastal reach has become increasingly important as a source area for littoral sediment supply to areas further south. Between 1974 and 1996, all of the accretion along the southern segment of the coastal reach could be accounted for through erosion along the northern segment of the reach. Most of the erosion occurred along present-day DNR lakeshore; most of the accretion occurred in areas to the south of DNR property.

- The 124-year record indicates that the greatest beach and nearshore erosion has been, and will probably continue to be, focussed in the area between the WI-IL state line and the Camp Logan headland.

Littoral sediment budget

The primary goal of this study is to develop a littoral sediment budget for the Lake Michigan shore at NPM and IBSP. Part 3 of this report includes a littoral sediment budget that averages trends in coastal change for the four years 1992 to 1996. A comprehensive understanding of the littoral sediment budget will provide input for planning and implementing long-term coastal management strategies along the DNR-managed lakeshore. The following listing summarizes the key components of the Year-2 littoral sediment budget.

- Although some volume of sediment crossed the WI-IL state line during 1995-1996, the North Beach / north breakwater nearshore became net erosional, losing 21,100 cu yds of lake-bottom sand. This is the first year since marina construction that this nearshore was net erosional.

- It is not known what volume of sediment bypassed the marina without being trapped in the marina entrance or in the accretional lobe in the south breakwater nearshore.

- Between 1992 and 1995, net nearshore erosion occurred between the marina entrance and the Camp Logan headland. Between 1995 and 1996, net nearshore erosion occurred between the state line and the Camp Logan headland. Overall, between 1992 and 1996, the entire nearshore lost at least 62,400 cu yds/yr of sand to areas downdrift of Camp Logan. 62,400 cu yds/yr is a minimum estimate of this area's average erosion rate between 1992 and 1996 considering only lake-bottom changes.

- Between 1992 and 1996, beach nourishment at IBSP/NU, sand dredged from NPM, and erosion at the NPM south parking area, contributed an average 20,200 cu yds/yr to the nearshore updrift of the Camp Logan headland. When combined with the nearshore erosion rate (62,400 cu yds/yr), this yields an average total erosion rate of at least 82,600 cu yds/yr. This is a minimum estimate of the average volume of littoral sediment that moved southward past Camp Logan on an annual basis during the four-year interval.

- At least 78,700 cu yds/yr of littoral sediment moved southward out of the IBSP/SU nearshore between 1992 and 1996. This estimate was obtained by combining the volume of material dredged from Commonwealth Edison Waukegan Generating Station and Waukegan Harbor between 1992 and 1996.

- The minimum volume of littoral sediment reaching the southern end of the SL/WH coastal reach between 1992 and 1996 is estimated at 32,900 cu yds/yr. This estimate is based on the volume of material dredged from Waukegan Harbor between 1992 and 1996. It is not known how much sediment naturally bypassed the harbor to areas further downdrift.

RECOMMENDATIONS

North Point Marina

1) During 1995-1996, the North Beach / north breakwater nearshore on the updrift side of NPM became net erosional for the first time since 1987, losing 21,100 cu yds of sand. This indicates that accretion does not necessarily occur in this nearshore on an annual basis. This creates uncertainties concerning: (1) whether or not there will be continued accretion in the North Beach nearshore; and (2) the suitability of the site for future dredging and sand bypassing to areas south of the marina. Based on the net erosion that occurred in the North Beach / north breakwater nearshore during 1995-1996, it would be advisable to delay any plans to dredge this nearshore area until future monitoring can determine whether sand entrapment will resume or whether natural erosional processes will continue to remove entrapped sand. Decisions about dredging this nearshore should await the collection and processing of 1997 bathymetric data.

2) The beach washover event at the north end of North Beach adjacent to Prairie Harbor Yacht Club in autumn 1996 will likely recur unless a barrier is constructed. The planned construction of a sand barrier by Prairie Harbor Yacht Club at the north end of North Beach will be of definite benefit in mitigating transfer of sand from North Beach into Prairie Harbor's boat basin in the future.

3) During 1995-1996, the erosional trough on the lakeward side of the north breakwater deepened by 7 ft to its greatest recorded depth (18.6 ft LWD) since 1988. This is of concern if a cause-and-effect relationship can be established between this erosional trough and a sag in the north breakwater that was documented in the Year-1 Report. Continued monitoring of this erosional trough is warranted.

4) During 1995-1996, accretion of 1 to 3.5 ft occurred in a NW-SE trending accretional zone on the lakeward (south) side of the marina entrance. This accretional area may currently, and will likely in the future, supply sediment to the dredged marina-entrance area and possibly cause increased rates of infilling. Any planned future dredging of the marina entrance should consider extending the limits of dredging further lakeward (southward) to remove sediment accumulated at the approach to the marina entrance.

5) The 19-ft deep erosional trough along the north inner breakwater lies about 7 ft below design depth for the base of the adjacent north inner breakwater. Up to 4 ft of deepening in the center of this trough between 1994 and 1996 indicates that continued monitoring of this erosional trough is warranted. Diver or ROV inspection would be prudent to determine if this trough is adversely affecting the stability of the adjacent revetment.

6) Planned shore defense along the south parking area nearshore, currently under review by state and federal agencies, must account for ongoing and annually variable lake-bottom erosion in this area. At the site of the proposed offshore submerged breakwater, the rate of lake-bottom deepening during 1995-1996 was four to six times greater than that documented during 1992-1995. Based on ongoing lake-bottom erosion at this site, and the increased rate of lake-bottom erosion during 1995-1996, post-construction monitoring at this site is recommended.

Illinois Beach State Park / North Unit

1) The Spring Bluff nearshore remains the area of most extensive lake-bottom erosion between the WI-IL state line and Camp Logan. The normalized 1995-1996 net change rate of -25 cu yds/yr/shoreline ft exceeded that of all nearshore erosion between the state line and the southern limit of the south parking area. To maintain beach width and reduce the rates of shoreline recession, this area will benefit from continued application of beach nourishment at the IBSP/NU beach-nourishment site.

2) The data for 1974-1996 lake-bottom change indicate continued erosion along most of the nearshore between the marina entrance and the State Park Lodge. Future beach nourishment would be most beneficial if focussed at the North Unit beach-nourishment site rather than the South Unit site. This would benefit the greatest length of DNR-managed lakeshore. Concentrating nourishment at the North Unit would help mitigate the high rates of nearshore erosion in the Spring Bluff area, the high rates of shoreline recession just south of the Camp Logan headland, and would ultimately benefit the remaining erosional nearshore along the northern half of the South Unit.

3) This study's Year-1 report concluded that, at a minimum, the volume of sand nourishment needed to prevent any net loss of lake-bottom sand between the marina and the Camp Logan headland would need to be 68,400 cu yds/yr. Comparisons of 1992-1996 data for lake-bottom change in this area, documented in Part 3 of this report, suggest that this estimate be upgraded to a minimum of 82,600 cu yds/yr to mitigate lake-bottom erosion and shoreline recession.

4) Long-term (1872-1996) shoreline and bathymetric-profile data indicate the high probability of continued beach and lake-bottom erosion between the NPM entrance and just north of Dead River. The greatest erosion has been, and will probably continue to be, focussed in the area between the WI-IL state line and the Camp Logan headland. Lake-bottom erosion may become more severe in this area, particularly along the shoreline and shallow nearshore of the Spring Bluff area.

5) The four preceding recommendations highlight the need for a regional and long-term coastal-management plan to mitigate erosion along DNR lakeshore between the WI-IL state line and Dead River. Such a coastal-management plan should incorporate provisions for continued and increased beach nourishment. Other options need to be evaluated such as constructed headlands that would ultimately allow the shoreline to erode into a series of arcuate embayments, or offshore structures that would reduce wave energy impacting the shore. Ideally, this regional and long-term coastal-management plan would address the needs of all lakeshore property managers within the SL-WH coastal reach. For example, the erosional issues along the DNR property need to be addressed in conjunction with the accretional issues at Waukegan Generating Station and Waukegan Harbor.

Illinois Beach State Park / South Unit

1) A scarp (2 to 4 ft high) exists between the shore-access road and the adjacent line of riprap along the southernmost 200 ft of the IBSP/SU beach-nourishment site. Additional riprap may need to be placed at this site to establish a lower-gradient riprap slope between the edge of the access road and the beach. This will provide erosion protection for the road bed during extreme wave events and assure continued public safety along the road edge.

PART 3: 1996 STUDY FINDINGS

NORTH POINT MARINA

General Statement

Two maintenance operations occurred at North Point Marina (NPM) during 1996 that were designed to mitigate ongoing coastal accretion and erosion. Hydraulic dredging to mitigate sediment accretion, begun initially in summer 1995 in the approaches to the recreational basin, continued during summer 1996 at the marina entrance. Lakefront maintenance involving the placement of sand back-fill occurred at the south parking area to mitigate 1995-1996 erosion on the landward side of the concrete-cube and riprap revetment (Fig. 3-1).

1996 marina dredging occurred between April and August and was focussed primarily around the north tip of the south outer breakwater (Fig. 3-1). The area dredged has experienced shoaling over the past several years, and dredging was necessary to maintain design depths. Approximately 24,000 cu yds were dredged between summer 1995 and summer 1996 (J. LaBelle, NPM General Manager, pers. comm.). As was the case for similar dredging in 1995, the sediment slurry was transported through dredge pipes placed along the crest of the south breakwater and was discharged on the lakeward side of the breakwater where it joins the riprap-defended south parking area. The sediment discharge formed a small and short-lived beach and shoal at the discharge site.

On the south side of the marina, 13,000 cu yds of sand back-fill were supplied to an 1100-ft length of riprap-defended shore at the south parking area between May and July, 1996. This material was obtained from dredging at Prairie Harbor Yacht Club, WI, and supplemented a similar volume of material placed at the site between December 1995 and January 1996. Both sand additions were used to fill large, arcuate, erosional embayments that developed during storms in autumn 1995 and spring 1996. During 1996, planning continued for building a submerged breakwater ("reef") and shoreline revetment along the shore of the south parking area to mitigate further erosion. No construction occurred in 1996.

On the north side of the marina, rain-induced flooding in early May 1996 caused a localized loss of parking lot and a dune breach that resulted in the loss of 375 cu yds of dune sand to the shallow nearshore. During a storm in mid-September, a beach washover occurred at North Beach adjacent to Prairie Harbor Yacht Club and resulted in sand being washed northward from North Beach into the south side of the Prairie Harbor boat basin. By mid-October, North Beach had essentially recovered to pre-storm conditions, but a shoal area persisted in the Prairie Harbor boat basin.

1996 data and observations from the vicinity of North Point Marina are discussed under the following headings:

- North Beach / North Breakwater Nearshore
- North Beach Bar
- Lake-Bottom Erosion at the NPM North Breakwater
- Marina Entrance
- Recreational and Commercial Boat Basins
- South Breakwater Nearshore
- South Parking Area Nearshore
- South Parking Area Monitoring
- Submerged Riprap at the North End of the South Parking Area

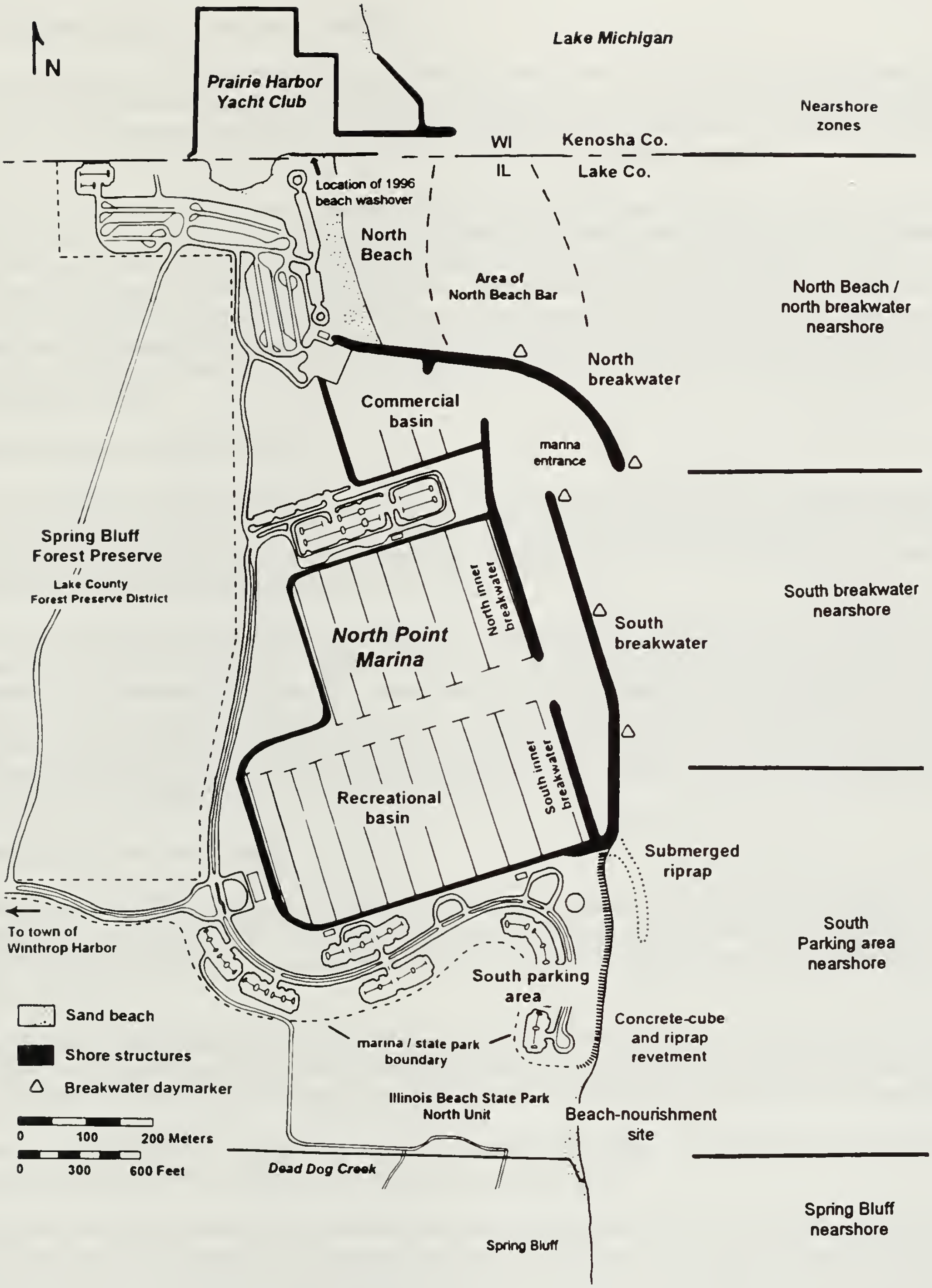

Figure 3-1 Index map of place names in the North Point Marina vicinity.

<u>North Beach / North Breakwater Nearshore</u>

The North Beach / north breakwater nearshore area is located lakeward of North Beach, between the WI-IL state line and the southern tip of the NPM north breakwater (Fig. 3-1). Topographic and bathymetric data from this area are particularly valuable for calculating the minimum volume of littoral sediment coming across the WI-IL state line which marks the updrift end of the study area.

North Beach has had a net gain of sand and consequent beach expansion since marina construction in 1987. Long-term erosional trends in this area (see Part 3: Regional Coastal Monitoring) have been reversed since 1987. As a result of beach accretion, all post-1987 annual shorelines occur lakeward of the 1987 shoreline. Figure 3-2 illustrates comparative positions of the North Beach shoreline in 1987, 1992, 1995 and 1996. Most of the sand involved in the accretion at North Beach is derived from updrift areas along the Wisconsin nearshore. A probable secondary source of sand along the south end of North Beach was the placement of sand on the beach adjacent to the north breakwater during marina construction in 1987.

1996 bathymetry (Figure 3-3)

The North Beach / north breakwater nearshore generally has a smooth lake bottom between the shoreline and depths of 20 ft LWD. At greater depths, an irregular contour pattern suggests a lake bottom consisting of exposed glacial clay or till. Within 100 ft of the shoreline, the lake bottom is generally a low-gradient surface lying at depths less than 0 ft LWD.

Three prominent bathymetric features are evident and are discussed in detail below. The elongate North Beach bar, defined by the 5 and 4 ft LWD closed contours, is centered about 500 ft lakeward of the shoreline. On its lakeward side, a second, newly developed bar is defined by the 8-ft LWD closed contour. Between the two bars, an elongate lake-bottom trough is defined by the 10 and 12 ft LWD closed contours. This trough deepens towards the south-southeast where it joins a deeper erosional trough that has been present since 1988. This latter trough is defined by the 17 and 18 ft LWD closed contours along the lakeward side of the north breakwater (Fig. 3-3).

1995-1996 lake-bottom change (Figure 3-4)

Between 1995 and 1996, the North Beach / north breakwater nearshore underwent net erosion of 21,100 cu yds (Fig. 3-4, Table 3-1). The erosion volume (-41,500 cu yds) exceeded the accretion volume (+20,400 cu yds) by a factor of 2.0 (Table 3-1). Most lake-bottom change occurred in water depths less than 15 ft LWD.

The two most significant bathymetric changes between autumn 1995 and summer 1996 were: (1) the evolution of the North Beach bar into a paired-bar system; and (2) the severe (up to 7 ft) deepening and the southward extension of the erosional trough that lies on the lakeward side of the north breakwater.

There was no significant change in beach area during 1995-1996. The 1996 shoreline occurred in approximately the same location as the 1995 shoreline (Fig. 3-4).

Accretion Accretion in excess of 1 ft occurred primarily along two distinct NNW-SSE trending bands lying about 550 and 1100 ft offshore, respectively (Fig. 3-4). The inner accretional band formed as the 1995 North Beach bar moved landward between autumn 1995 and summer 1996 (see Part 3: North Beach Bar). Up to 2.5 ft of accretion occurred (Fig. 3-4). The outer accretional band is associated with development of a new bar 400 to 600 ft lakeward of the North Beach bar. This areally less-extensive band has maximum accretion values of just over 2 ft. The accreted sand was supplied by sediment moving south across the state line and by a redistribution of sand from shallower parts of the nearshore. Both elongate accretional bands terminate about 1000 ft south of the WI-IL state line; the inner band terminates against the north breakwater.

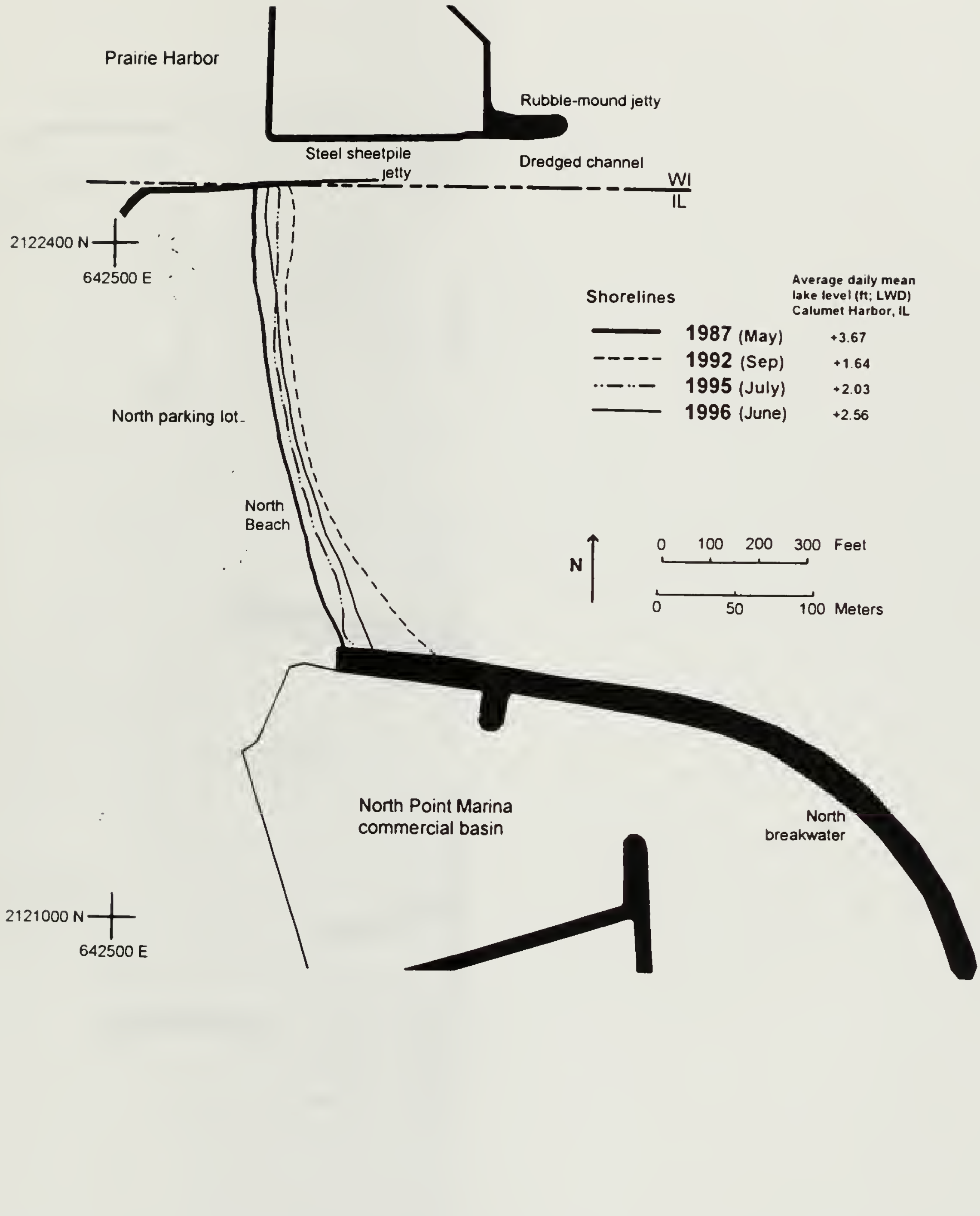

Figure 3-2 North Beach shoreline positions (1987-1996). Selected shorelines are shown for 1987 (prior to marina construction), 1992 (used in the Year-1 Report bathymetric comparisons and remains the most lakeward post-construction shoreline position at North Beach), 1995 and 1996. Shorelines are for the lake level at the time of survey.

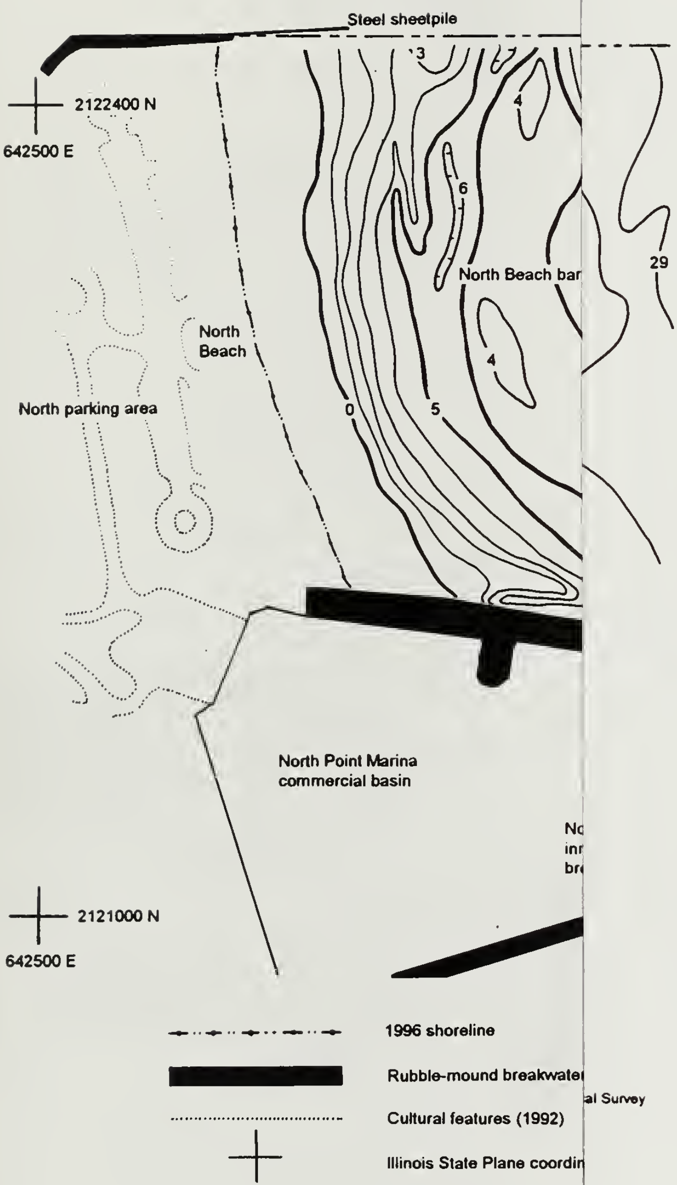

Figure 3-3 1996 bathymetry in the North Be

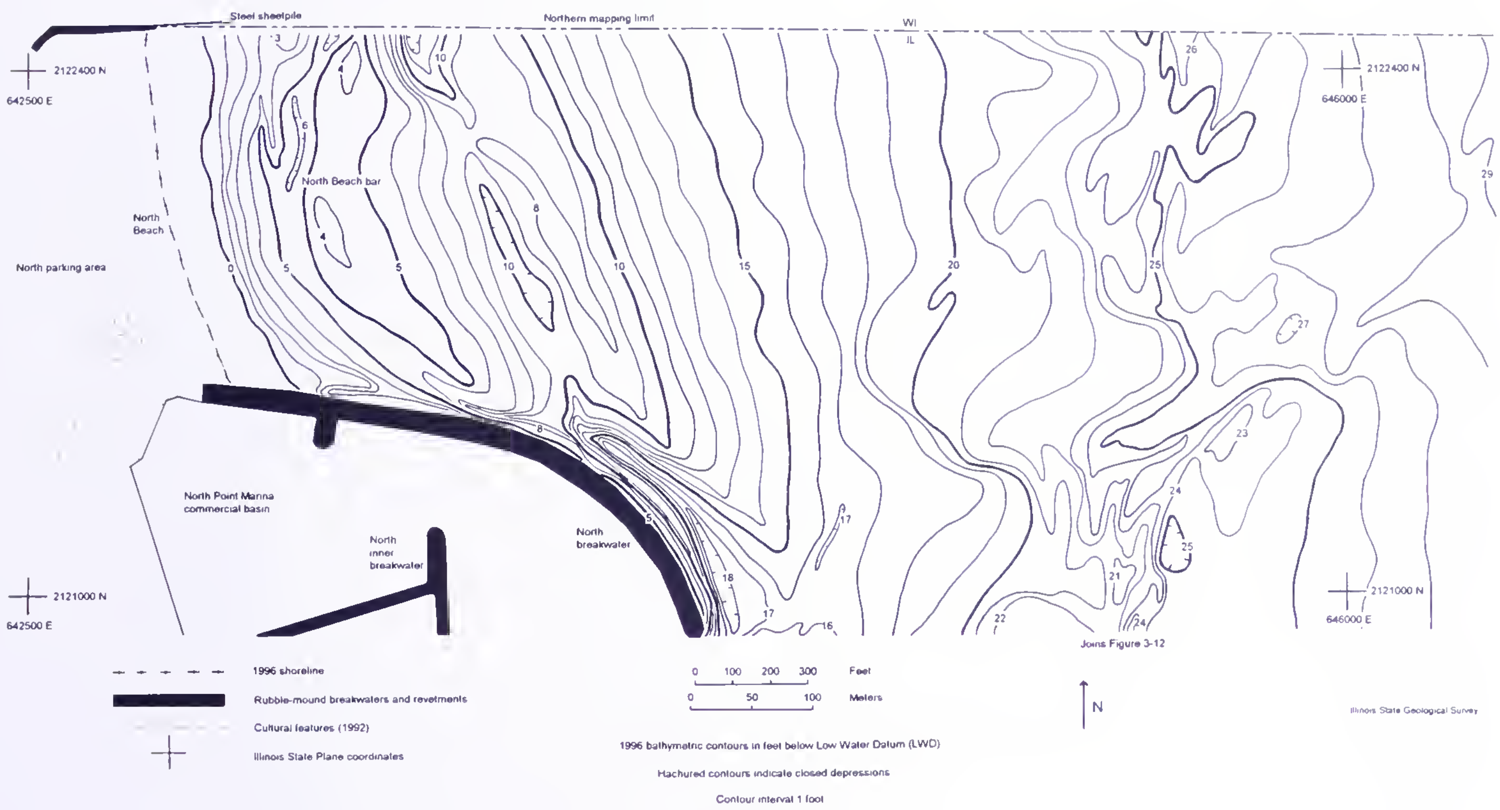

Figure 3-3 1996 bathymetry in the North Beach / north breakwater nearshore.

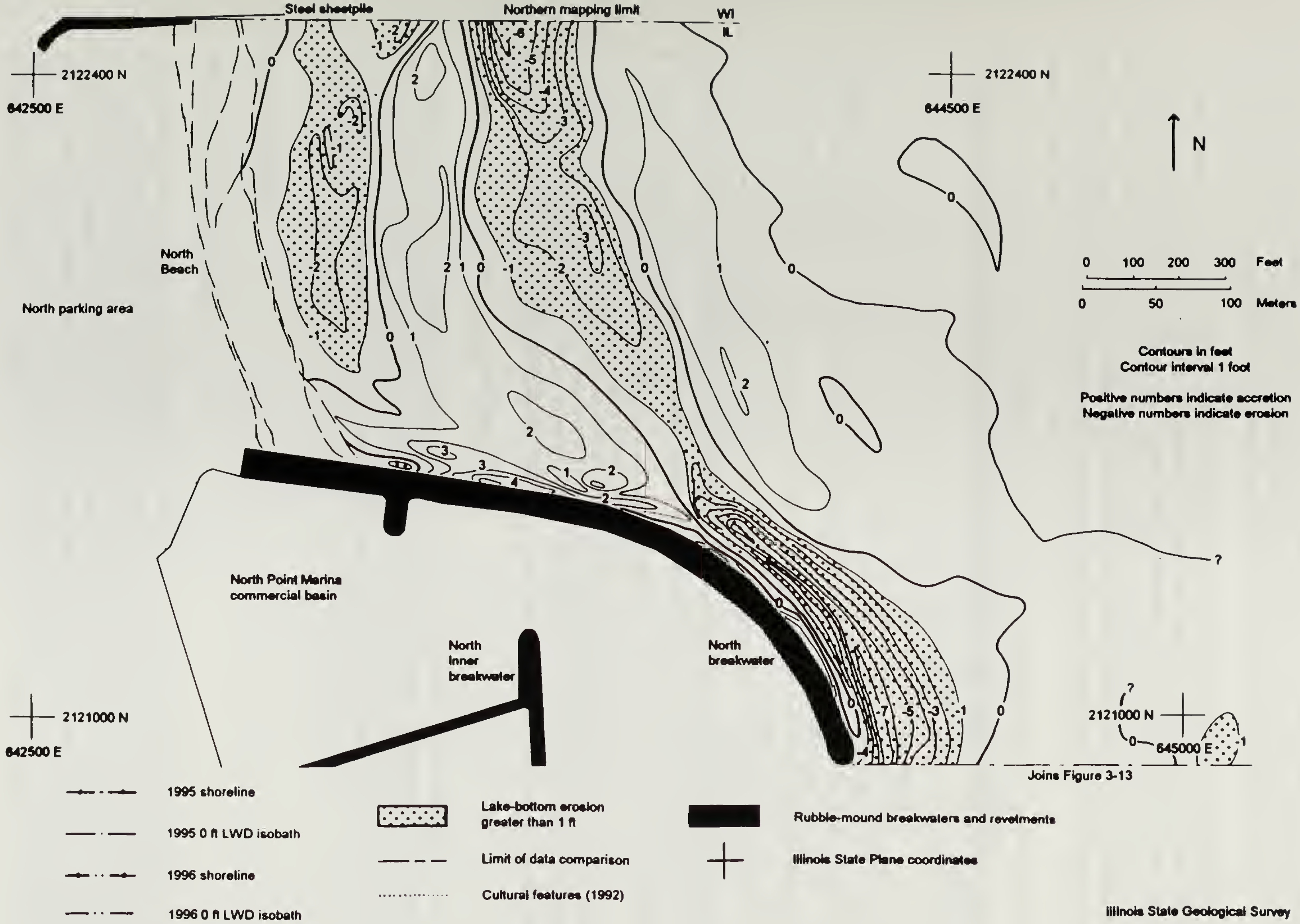

Figure 3-4 1995-1996 lake-bottom change in the North Beach / north breakwater nearshore.

Erosion Erosion in excess of 1 ft also occurred primarily along two distinct NNW-SSE trending bands (Fig. 3-4). The inner erosional band, located about 300 ft offshore, extends from the WI-IL state line to just north of the north breakwater. This band has maximum erosion values of just over 2 ft.

The outer erosional band, located about 850 ft offshore, is a much larger feature. It extends from the WI-IL state line to the south tip of the north breakwater and lies between the inner and outer accretional bands (Fig. 3-4). Erosion of just over 6 ft occurred at the WI-IL state line, while erosion of just over 7 ft occurred lakeward of the northeast face of the north breakwater. Some of the erosion in the central part of the North Beach nearshore can be attributed to the North Beach bar having moved 100 ft landward during 1995-1996. However, most of the erosion is associated with the development of an elongate trough that extends the length of the North Beach nearshore (Fig. 3-3).

Table 3-1 Summary of erosion and accretion volumes in the North Beach nearshore.[1]

	1992-1995[2]	1995-1996
Accretion (+) (cu yds)	44,100	20,400
Erosion (-) (cu yds)	13,100	41,500
Net change (cu yds)[3]	+31,100	-21,100
Annual net change (cu yds/yr)[3]	+10,300	-21,100
Normalized annual net change (cu yds/yr/shoreline ft)[4]	+6	-13

[1] All volumes are computed for lake-bottom elevation changes in excess of 1 ft and occurring below Low Water Datum (LWD). Volumes are rounded to the nearest 100 cu yds.
[2] Three-year comparison between Year-1 (1995) data and data available from 1992; erosion and accretion volumes are for the three-year summation and annual net change is a three-year average.
[3] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[4] Shoreline distance (1600 ft) is based on measurement along a north-south line bounded to the north and south by the defined limits of the nearshore reach. Numbers are rounded to the nearest whole number. Net accretion is indicated by a positive number and net erosion is indicated by a negative number.

Implications of 1995-1996 lake-bottom change

Net erosion during 1995-1996 indicates that 21,100 cu yds more littoral sediment moved southward out of the North Beach nearshore than moved into it from the Wisconsin nearshore. This was the first documented net nearshore erosion in this area since marina construction and indicates that nearshore accretion does not necessarily occur on the updrift side of NPM on an annual basis. Net erosion during 1995-1996 may be the beginning of a new trend or may simply be the result of annual variability in wave climate and sediment supply.

North Beach Bar

Background and significance

The North Beach bar, described in detail in the Year-1 report, is a submerged bar that extends from the WI-IL state line southward towards the NPM north breakwater (Figs. 3-1; 3-3; 3-5). It is a prominent depositional feature that is part of a relatively continuous nearshore bar system that extends from the WI-IL state line to Waukegan Harbor. The bar was absent from the North Beach nearshore in the late 1980s, and was first documented by ISGS in 1990. Since 1990, the bar has been defined as a shoal area at depths less than 9 ft LWD and has consistently been located at least 500 ft lakeward of its contemporaneous shoreline. Between 1992 and 1996, the bar crest moved landward and shallowed from

just under 8 ft LWD to just under 4 ft LWD.

The North Beach bar is significant within the context of coastal-zone management at the marina and state park for two principal reasons:

- The bar functions as part of a primary sediment transport pathway that extends from (and probably north of) the state line toward the NPM north breakwater and ultimately to areas further south.

- The bar is a localized sand reserve that is potentially mineable for use in downdrift beach nourishment.

1995-1996 bathymetric change (Figure 3-5)

The North Beach bar has been a dynamic lake-bottom feature since it was first documented in 1990. Table 3-2 summarizes the principal morphologic characteristics of the bar and Fig. 3-5 schematically illustrates the location of the bar during 1990, 1991, 1992, 1995 and 1996.

Table 3-2 Summary morphologic characteristics of the North Beach bar (1990-1996).

	1990	1991	1992	1995	1996
Distance offshore of North Beach (ft)[1]	700	900	900	600	500
Proximity of tip to north breakwater	150	150	200	250	100
Shallowest closed contour (ft)[2]	6	8	6	5	4
Deepest closed contour (ft)[2]	7	8-9 [3]	8	6	5
Length (ft)[4]	1000	1000	1100	750	1050
Area (sq yds)	10,700	17,100	15,200	14,300	15,600
Volume (cu yds)[5]	34,000	59,100	51,000	33,700	32,700

[1] Distance offshore is the average distance to the bar crest measured due east of the shoreline.
[2] Contours are referenced to Low Water Datum (LWD).
[3] During 1991, most of the bar, with the exception of the northern part, had an atypical plateau-like morphology.
[4] Bar length is measured along the bar axis.
[5] Volumes are rounded to the nearest 100 cubic yards.

In 1995, the North Beach bar was defined by the 5 and 6 ft LWD closed contours. During 1995-1996, the bar shifted approximately 100 ft landward and became defined by both the 4 and 5 ft LWD closed contours. The bar also became more arcuate and extended further southward so that the 5-ft LWD closed contour at its south end lay within 100 ft of the NPM north breakwater. The volume of the bar during 1996 was calculated at 32,700 cu yds (Appendix B).

During 1995-1996, a secondary bar developed 400 to 600 ft lakeward of the North Beach bar. This secondary bar was defined by the 8-ft LWD closed contour and it extended south-southeastward from the WI-IL state line along the North Beach nearshore (Fig. 3-3). In conjunction with the North Beach bar, this bar may function as the main transport pathway for littoral sand moving southward after crossing the WI-IL state line.

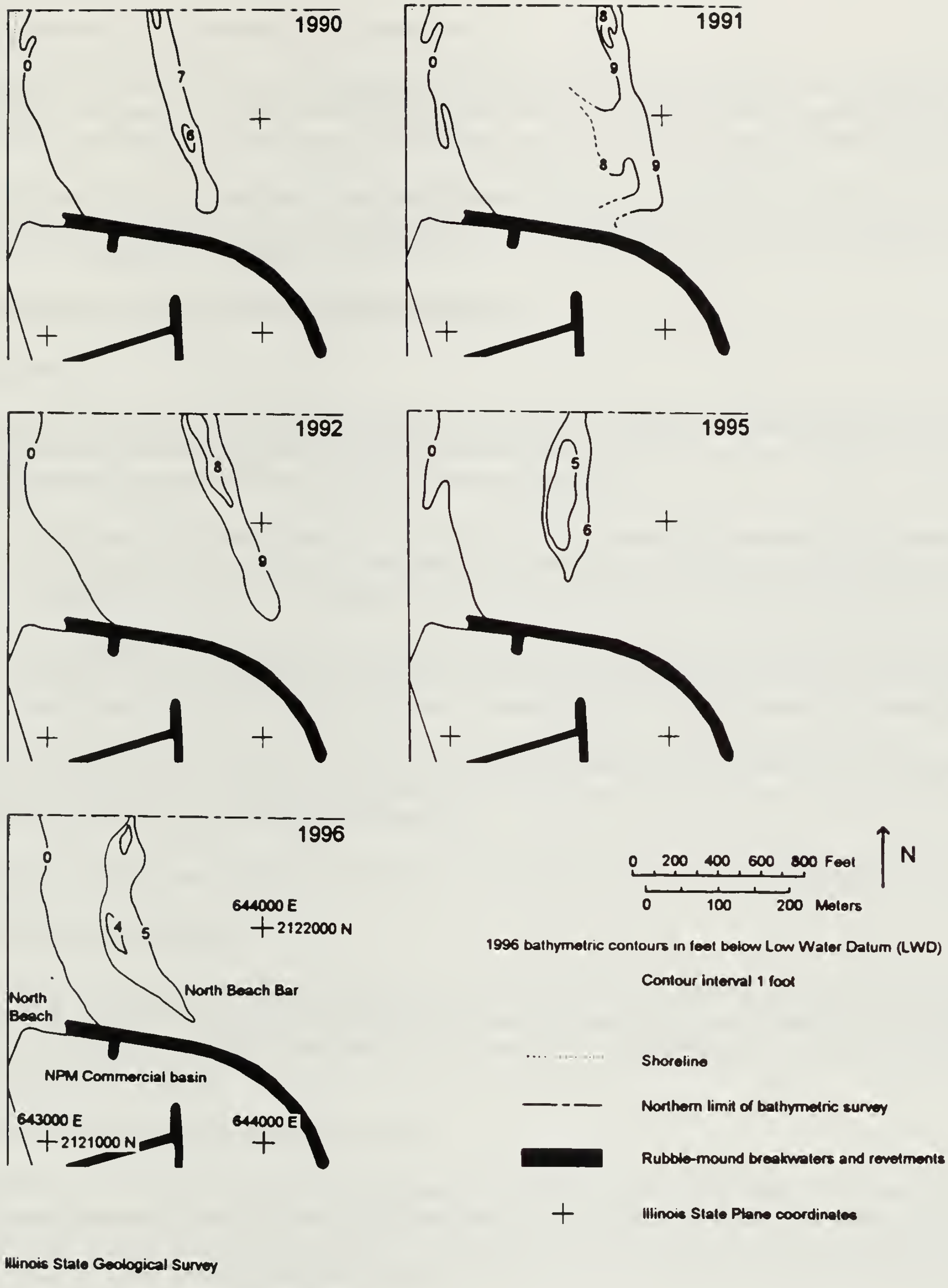

Figure 3-5 Locations of the North Beach bar during 1990, 1991, 1992, 1995 and 1996. Shown is the deepest lake-bottom closed contour that defines the outline of the bar and encloses the bar axis.

Implications of 1995-1996 bathymetric change

Landward movement of the North Beach bar between 1990 and 1996 may be part of ongoing annual variability in bar position, or it is possible that the bar is in the process of shifting landward for eventual accretion or "welding" onto North Beach. This latter process would ultimately increase beach width.

The North Beach bar has maintained a relatively constant area and volume since 1990 (Table 3-2). This testifies to the longevity of the bar and to its persistence despite net erosion across this nearshore during 1995-1996. The bar is a potential sand reserve.

Lake-Bottom Erosion at the NPM North Breakwater

Background

This study's Year-1 Report determined that a lake-bottom erosional trough has existed along the lakeward side of the north breakwater since 1988. This erosional trough probably formed initially, and has since been maintained, by a combination of two environmental factors:

- Incident and breakwater-reflected waves during storm events likely increase shear stress on the sandy lake bottom on the lakeward side of the breakwater. Sufficient shear stress can cause erosion of the substrate and transport of sediment away from the area so that a trough develops.
- Northeasterly waves can induce set-up (increase in lake level) in the North Beach nearshore during storm events. As the storm passes, relaxation of the water column can cause a southward flow of water around the north breakwater at velocities that may be capable of causing erosion.

Preliminary interpretations of seismic-reflection data collected during 1996 indicate that, at the site of the erosional trough, the contact between sand and underlying glacial sediments lies at a depth of about 24 ft LWD, or about 6 ft below the base of the trough.

Table 3-3 summarizes the principal morphological characteristics of the trough between 1988 and 1996.

1996 bathymetry (Figure 3-3)

During 1996, the trough's maximum axial depth of 18.6 ft was the greatest recorded since 1988. As of June 1996, the deepest part of the trough axis was between 3.6 and 5.0 ft deeper than the designed base elevation of the north breakwater at this location. The maximum trough depth occurs about 90 ft lakeward of the breakwater waterline.

1995-1996 lake-bottom change (Figure 3.6)

As indicated in Table 3-3 and Fig. 3-6, the erosional trough deepened by about 7 ft between 1995 and 1996. It also increased in length by about 100 ft so that it extended south of the north breakwater's tip and merged with a trough in the marina entrance. The trough moved an average of 50 ft lakeward of its 1995 position, but became a more pronounced feature with up to 7 ft of relief between the trough axis and adjacent lake-bottom areas to the north.

Implications of trough development

The Year-1 Report documented the presence of a sag along a 400-ft stretch of breakwater between the middle and outer daymarkers (Fig. 3-1). This 400-ft length of breakwater lies adjacent to the northern two thirds of the 1996 erosional trough (Fig. 3-3), in an area where the trough has been present since 1988 (Fig. 3-6). If there is a cause-and-effect relationship between the erosional trough and the breakwater sag, then the deepening and southward extension of the trough between 1995 and 1996 is of concern because

it may cause the sag zone to become more pronounced.

The 1987-1996 nine-year record of lake-bottom change between the WI-IL state line and Camp Logan (Appendix F) indicates that the trough area along the northeast side of the north breakwater is an "erosional hotspot" where the lake bottom in 1996 was up to 3 ft deeper than it was in 1987. This area warrants continued attention because of its proximity to major infrastructure.

Table 3-3 Summary characteristics of the lake-bottom trough adjacent to the north breakwater (1988-1996).

	1988	1989	1990	1991	1992	1995	1996
Distance from north breakwater (ft) [1]	150	200	70	100	90	40	90
Maximum depth of depression (ft LWD) [2]	16	15	13	16	16	11	18
Minimum closed contour depth (ft LWD) [3]	15	n/a [6]	13	16	15 [7]	n/a [6]	17
Depression relief (ft) [4]	2	1	2	3	6	2	7
Depression length (ft) [5]	280	300	600	650	650	850	820

[1] Distance to trough axis is measured orthogonal to the lakeward face of the breakwater from the waterline.
[2] Depth is based on the deepest contour that defines the depression. The north breakwater base elevation adjacent to the depression lies between 13 and 15 ft LWD.
[3] Depth is that of the shallowest closed contour that completely defines the depression.
[4] Difference in elevation between the base of the depression and the lake-bottom immediately to the north and south.
[5] Length of the depression is measured parallel to the lakeward face of the north breakwater.
[6] Depression is a southeastward-opening trough without a contained closed contour.
[7] Depression is part of a larger, southeastward-opening trough.

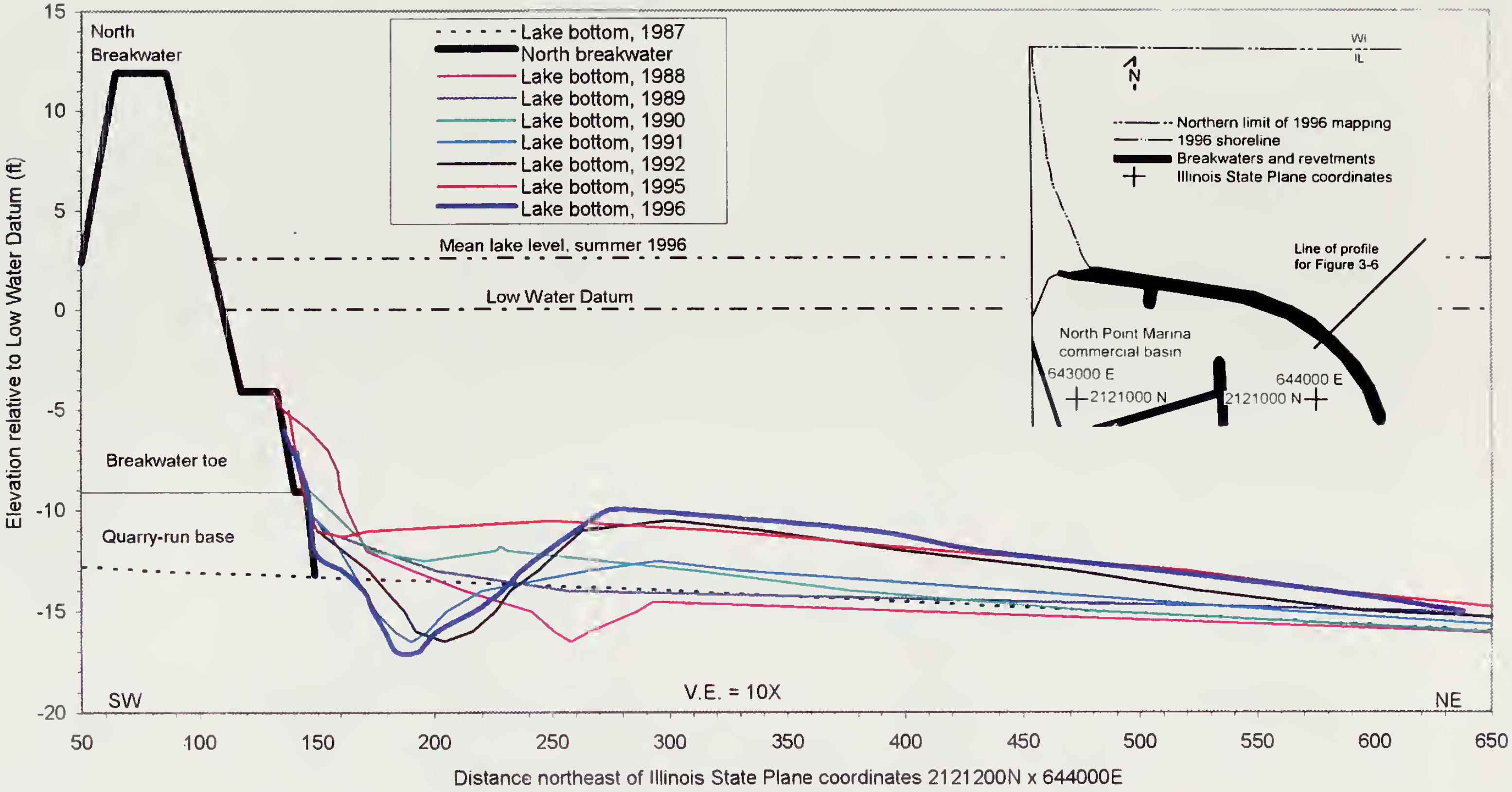

Figure 3-6 Cross-section and profiles showing the relationship between the NPM north breakwater and the adjacent lake-bottom erosional trough. Data are shown for 1987-1992, 1995, and 1996. The maximum 1996 depth of 18.6 ft occurs 300 ft to the southeast of this profile.

Marina Entrance

Background

The marina entrance is defined as that area bounded by the south tip of the north breakwater, the north tip of the south breakwater, the north tip of the north inner breakwater, and the inner spur on the north breakwater (Fig. 3-1). Since the completion of construction at North Point Marina, the marina entrance has been a littoral sediment trap. Shoaling associated with sediment trapping can potentially become a threat to navigation. To mitigate these effects, maintenance dredging was conducted between April and August 1996 in the entrance area and around the north tip of the south breakwater. 18,000 cu yds of sand were removed; this supplemented an earlier, summer 1995, removal of 6,000 cu yds from the approaches to the recreational basin (J. LaBelle, NPM General Manager, pers. comm.).

This study's Year-1 report concluded that between 1992 and 1995, the marina entrance had net accretion of 3,100 cu yds/yr (Table 3-4). The 1992-1995 isopach contour patterns in the marina entrance suggest that most of this material originated in areas updrift of the marina. Littoral sand would tend to be transported into the marina entrance during periods of northeasterly, easterly, and southeasterly waves.

Table 3-4 Summary of erosion and accretion volumes in the North Point Marina entrance area.[1]

	1992-1995[2]	1995-1996
Accretion (+) cu yds	11,800	2,100
Erosion (-) cu yds	2,600	5,400[3]
Net change (cu yds)[4]	+9,200	-3,300[5]
Annual net change (cu yds/yr)[4]	+3,100	-3,300[5]

[1] All volumes are computed for lake-bottom elevation changes in excess of 1 ft and occurring below Low Water Datum (LWD). Volumes are rounded to the nearest 100 cu yds.
[2] Three-year comparison between Year-1 data and data available from 1992; erosion and accretion volumes are for the three-year summation and annual net change is a three-year average.
[3] This is an apparent erosion volume. An unknown component of this volume is due to sediment removal during 1996 dredging (see text).
[4] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[5] Net change is based on comparison of 1995 and 1996 bathymetry and excludes 1996 dredging effects (see text).

The lake-bottom profile between the tips of the north and south breakwaters has attained a relatively stable configuration (Fig. 3-7). The eastern half of the entrance, adjacent to the north breakwater, has maintained water depths of 14 to 16 ft LWD. The hydrodynamics of the marina may be such that currents induced by water-level fluctuations maintain a scour trough along the east side of the entrance (Figs. 3-7, 3-8). The western half of the entrance has maintained more variable water depths of 4.3 to 7.5 ft LWD since 1991 (Fig. 3-7).

1996 bathymetry (Figures 3-7, 3-8)

1996 bathymetry was similar to the 1995 bathymetry. An asymmetric lake-bottom profile, first documented in 1989, was still present in 1996 between the tips of the north and south breakwaters (Fig. 3-7). The northeastern side of the marina entrance remained deeper than the southeastern part, with a 10-ft deep trough extending northwestward towards the commercial basin (Fig. 3-8). Adjacent to the tip of the north breakwater, the trough deepened to 16 ft LWD, about 1 ft deeper than it was in 1995. The lake bottom at this locality was about 1 ft below the design elevation for the base of the north breakwater.

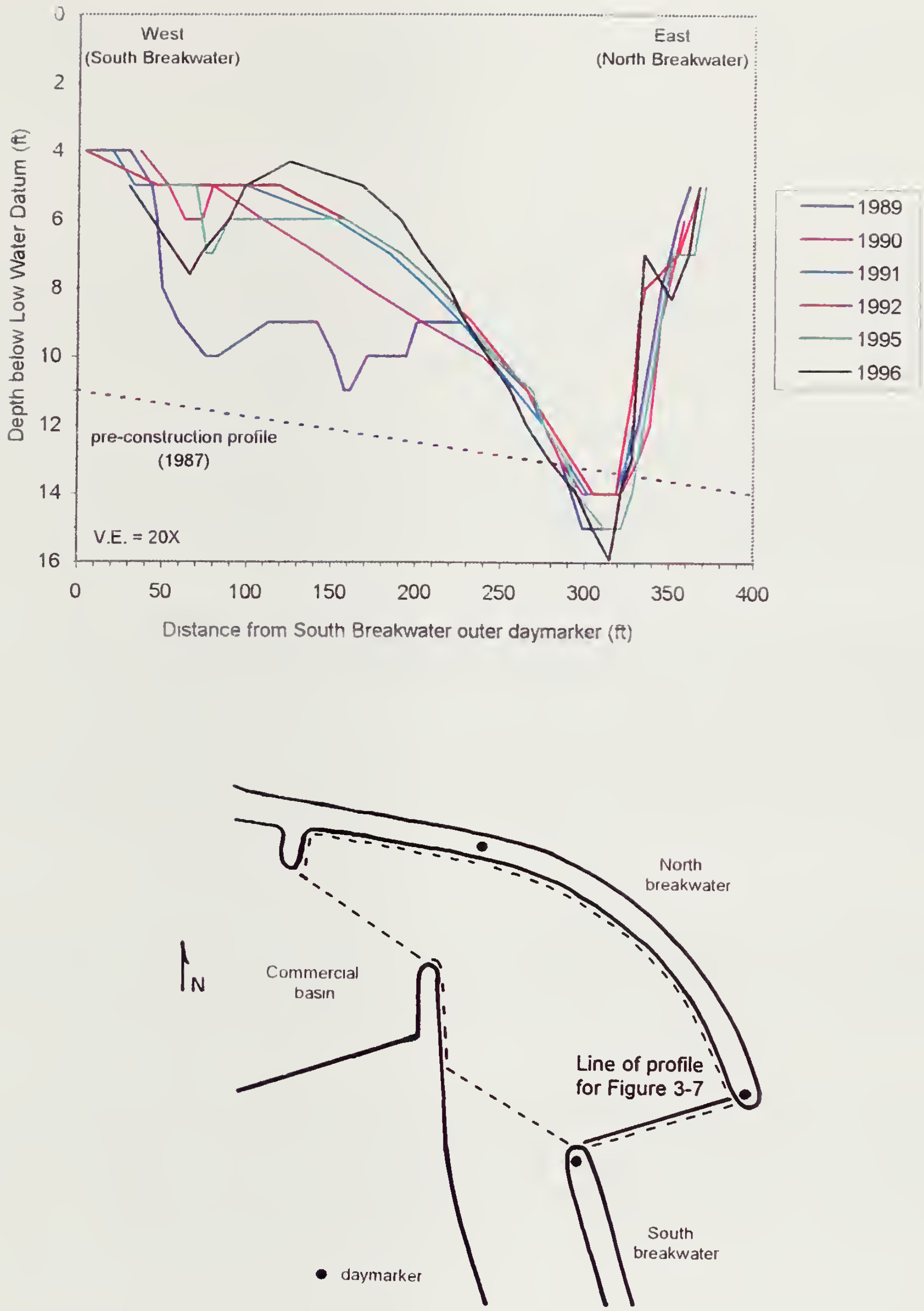

Figure 3-7 Cross-sectional profiles at the entrance to North Point Marina. The profiles extend between the tips of the north and south breakwaters and illustrate the asymmetric bathymetric cross-section that has persisted since 1989. Index map shows profile location and the boundary limits used for annual volume-change calculations. The 1996 bathymetric data were collected in June 1996 during dredging. Continued dredging through August 1996 probably increased water depths on the western side of the entrance.

On the south side of the marina entrance, between the tip of the south breakwater and the north spur of the north inner breakwater, water depths averaged about 8 ft LWD. The irregular contour pattern in this area was due partly to 1996 dredging. A new shoal area developed 100 ft to the northeast of the tip of the south breakwater (Figs. 3-7, 3-8). Minimum depths over this shoal in late June 1996, prior to completion of dredging, were mapped at 4.3 ft LWD.

1995-1996 lake-bottom changes (Figure 3-9)

1996 bathymetric data were collected in the marina entrance during the month of June and therefore prior to the completion of 1996 dredging. Based on a comparison of 1995 and 1996 bathymetric maps, the marina entrance had a net loss of 3,300 cu yds of sediment between 1995 and 1996 (Table 3-4). The erosion volume (-5,400 cu yds) exceeded the accretion volume (+2,100 cu yds) by a factor of 2.5. However, net lake-bottom change was significantly affected by 1996 dredging.

Accretion Accretion in excess of 1 ft occurred primarily in a narrow strip along the inner face of the north breakwater. Accretion of just over 3 ft occurred about 300 ft east of the north breakwater inner spur. Accretion of just over 2 ft occurred in an arcuate shoal area located about 200 ft north of the south breakwater (Figs. 3-8, 3-9). Accretion also occurred in a broad shoal area located about 150 ft northeast of the tip of the south breakwater (Figs. 3-8, 3-9); this latter accretion is discussed in the South Breakwater Nearshore section.

Erosion Most erosion occurred in the area between the tip of the south breakwater and the tip of the north inner breakwater where there was just over 3 ft of lake-bottom change (Fig. 3-9). Most of this "apparent erosion" can be attributed to spring-summer 1996 dredging (see discussion below). Erosion up to 3 ft occurred to the north of the tip of the north inner breakwater. Localized erosion of 1 to 2 ft occurred at the marina entrance adjacent to the tip of the north breakwater. This latter erosional zone was an extension of the erosional nearshore zone that extended southward along the lakeward side of the north breakwater from the North Beach nearshore (Fig. 3-4).

Implications of 1995-1996 lake-bottom change

Dredging during summer 1995 and between April and August, 1996, removed 24,000 cu yds of sediment (J. LaBelle, NPM General Manager, pers. comm.). This had an important influence on lake-bottom change in the marina entrance, contributing to an apparent loss of sediment in an area that was net accretional between 1992 and 1995.

Because 1996 bathymetric data were collected during dredging operations, depths shallower than the recorded minimum of 4.3 ft LWD may have existed prior to the time of survey. Similarly, following completion of dredging in August 1996, water depths in this area may have become greater than those shown in Figs. 3-7 and 3-8. Unless wave climate and littoral sediment supply change significantly, an asymmetric cross-sectional profile may be expected to persist in the marina entrance, necessitating periodic dredging on the west side of the entrance.

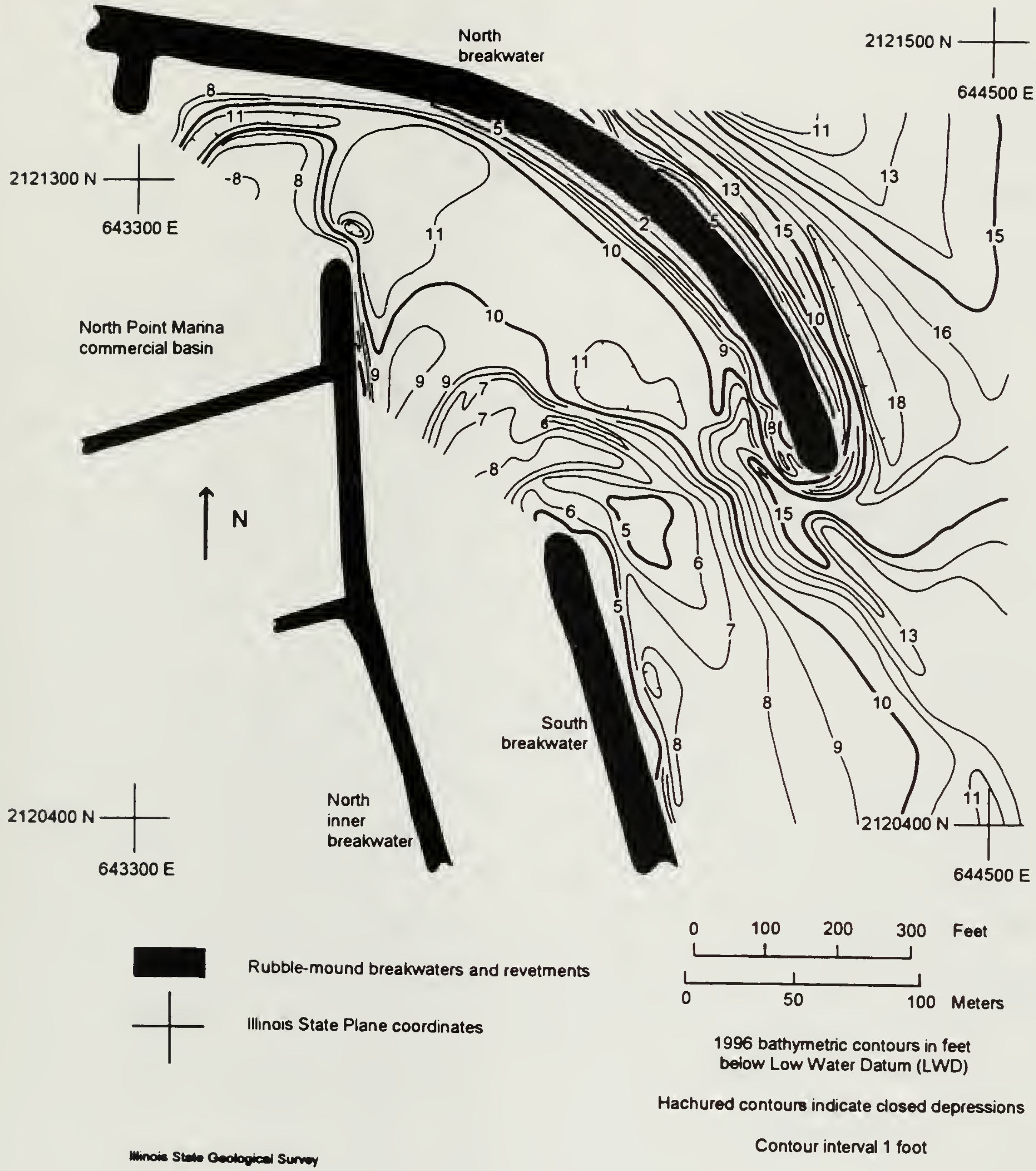

Figure 3-8 1996 bathymetry in the North Point Marina entrance and vicinity. The 1996 bathymetric data were collected during dredging operations. Continued dredging through August 1996 probably increased water depths adjacent to the north tip of the south breakwater.

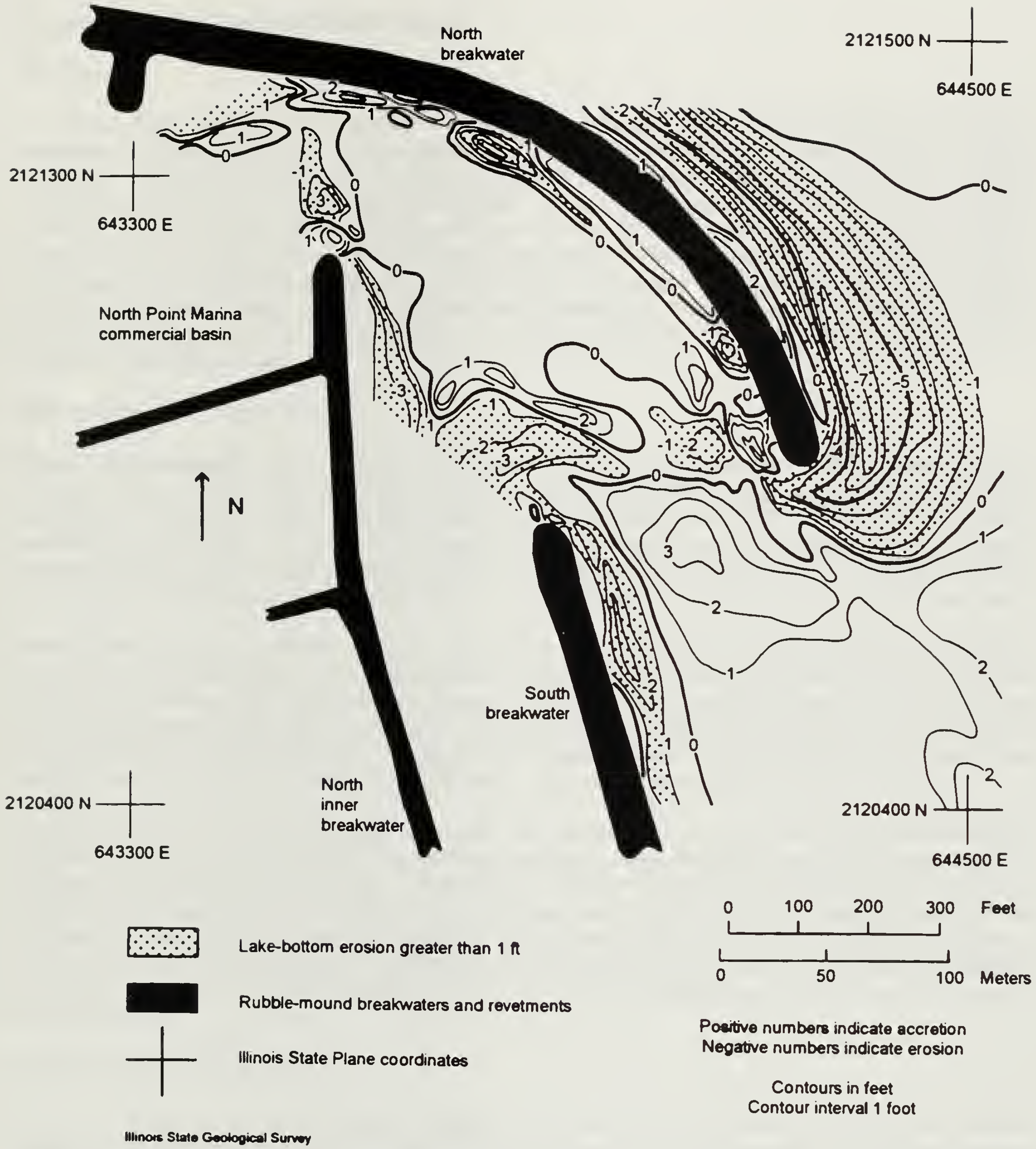

Figure 3-9 1995-1996 lake-bottom change in the North Point Marina entrance and vicinity. Lake-bottom change in the vicinity of the north tip of the south breakwater documents conditions in June 1996 prior to the completion of 1996 dredging.

Recreational and Commercial Boat Basins

Background

In autumn 1994, Hydrographic Survey Company, Inc. (Chicago, IL) was contracted by the Illinois Department of Conservation (IDOC) to conduct a bathymetric survey of the recreational and commercial boat basins at North Point Marina (Hydrographic Survey Company, 1994; see Appendix C). Patrick Engineering, Inc. (Lisle, IL) conducted a bathymetric survey in the approach channel to the recreational basin during 1994/1995, between the south breakwater and the north inner breakwater (Patrick Engineering, Inc., 1995a). The combined data sets represent the first comprehensive bathymetric survey of the marina since construction. The survey data from these projects were obtained by ISGS, converted to LWD format, and used to generate the 1994 bathymetric map shown in Fig. 3-10. Data collected by ISGS in 1996 are used in Fig. 3-11 to illustrate the 1996 bathymetry of the commercial and recreational basins and their approaches.

1994 bathymetry (Figure 3-10)

Figure 3-10 illustrates that, as of autumn 1994, water depths in the recreational basin generally ranged between 9 and 11 ft LWD. The maximum recorded depth of 12 ft LWD was located in two small isolated depressions. Depths in the commercial basin generally ranged from 8 to 10 ft LWD. The maximum recorded depth was 10.1 ft LWD. The irregular contour patterns bear no relation to preconstruction topography and are assumed to be the product of dredging the marina basins. The less irregular bathymetric contour pattern in the commercial basin is partly due to the limited data collected in this basin.

In the approach channel to the recreational basin, south of the tip of the south breakwater, water depths were generally 7 ft LWD or less along the east side of the approach during 1994/1995. Depths along the western side of the approach channel were greater, with a maximum recorded depth of 17 ft LWD. This maximum depth was located in an elongate trough opposite the tip of the south breakwater, near the north inner breakwater. At the entrance to the recreational basin, a depth of 12 ft LWD was recorded. Two hundred feet to the north, a shallow area occurred with a minimum recorded depth of 3 ft LWD.

Bathymetry in both basins generally exceeded the design depth of 8.1 ft LWD (Moffatt and Nichol Engineers, 1986). In the approach to the recreational basin, design depth was exceeded only along the western side of the channel. Figure 3-10 illustrates that design depths were exceeded by up to 3.9 ft in the recreational basin, by up to 2 ft in the commercial basin, and by up to 9 ft at the elongate trough in the approach channel to the recreational basin. It is likely that depths in excess of design depth in the recreational and commercial basins resulted from over-dredging rather than from erosional processes. In the approach to the recreational basin, depths in excess of design depth are likely the result of current-induced erosion.

1996 bathymetry (Figure 3-11)

Figure 3-11 illustrates that the bathymetry within the commercial and recreational basins did not change significantly between 1994 and 1996. In the recreational basin, water depths generally ranged between 9 and 11 ft LWD. The maximum recorded depth of 12.2 ft LWD occurred in the southeast part of the basin. In the commercial basin, depths generally ranged between 7 and 10 ft LWD. The maximum recorded depth of 11.4 ft LWD occurred in an elongate trough at the northeast corner of the basin. As of 1996, water depths in both basins remain greater than the design depth of 8.1 ft.

In the approach channel to the recreational basin, water depths generally ranged between 4 and 10 ft LWD. The maximum recorded depth of just over 19 ft LWD occurred at the elongate trough adjacent to the north inner breakwater due west of the tip of the south breakwater. A second elongate trough was mapped at the entrance to the recreational basin and had a maximum recorded depth of 13.8 ft LWD. Four small isolated topographic highs in the approach channel had crest elevations of just under 6 ft LWD.

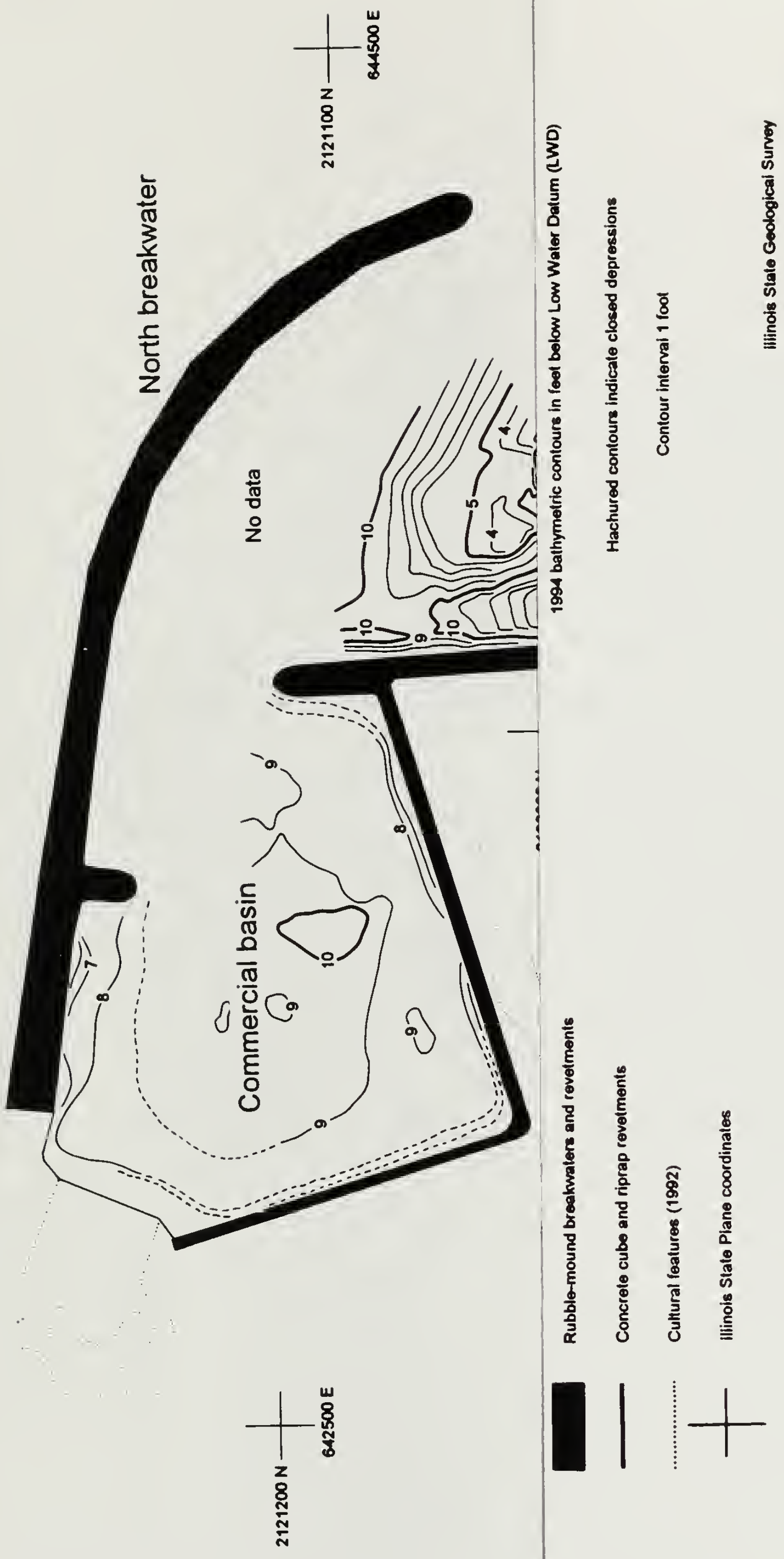

Figure 3-10 1994 bathymetry in the North
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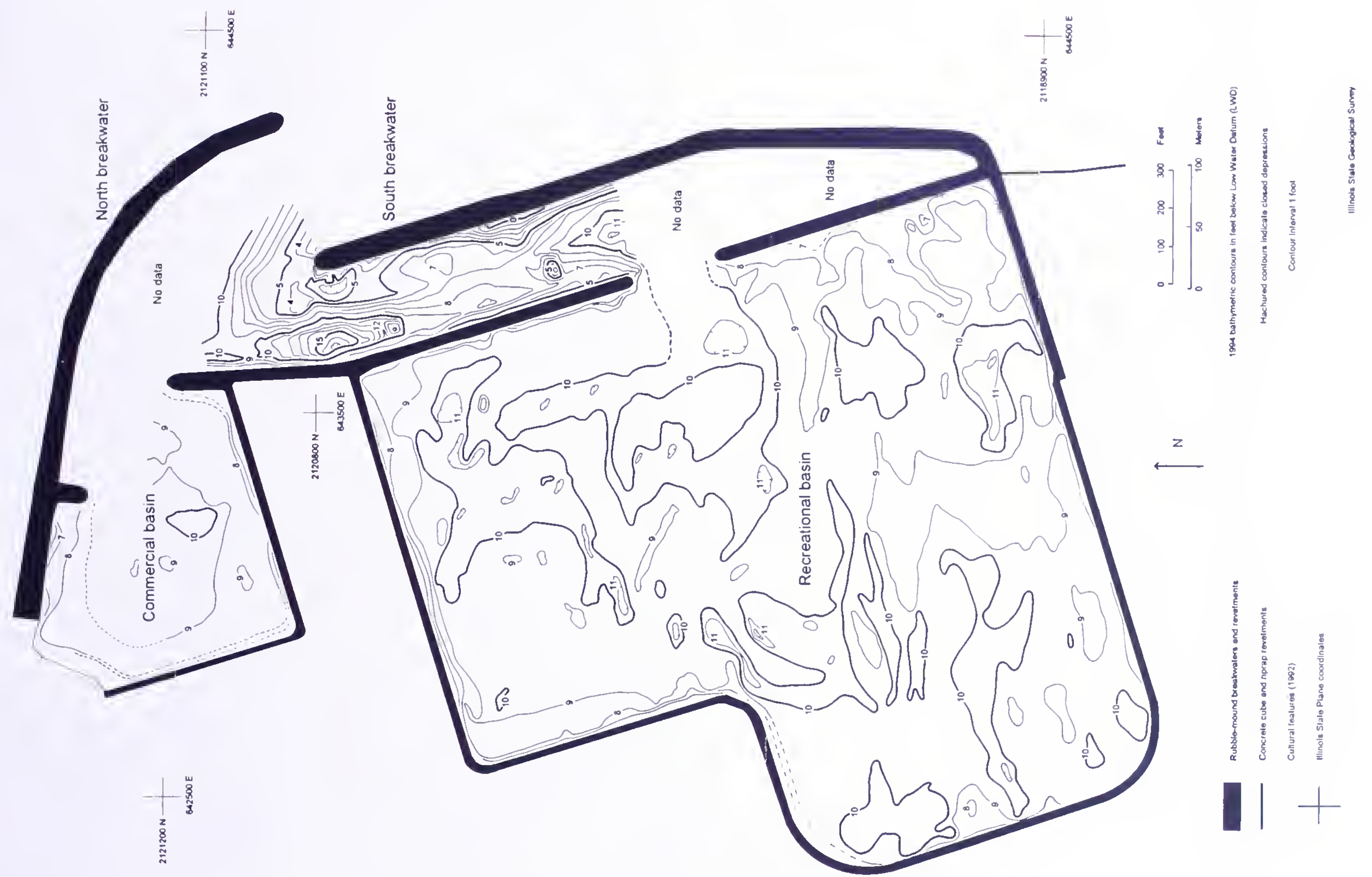


Figure 3-10 1994 bathymetry in the North Point Marina basins and approaches. Data from the boat basins were collected in autumn 1994 and are modified from Hydrographic Survey, Inc. (1994). Data from the approach channel to the recreational basin were collected during 1994 and early 1995 and are modified from Patrick Engineering, Inc. (1995a).

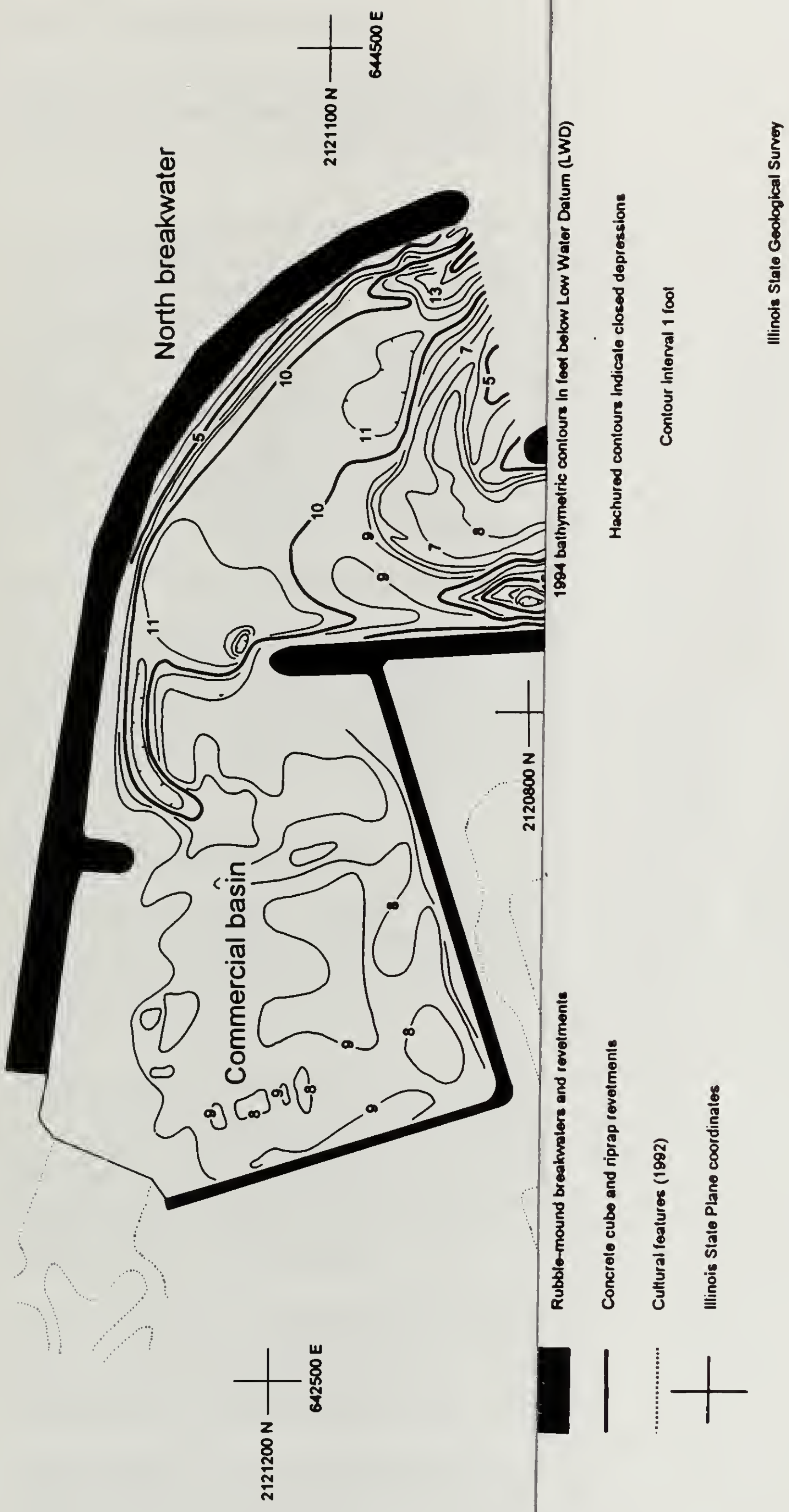


Figure 3-11 1996 bathymetry in the North

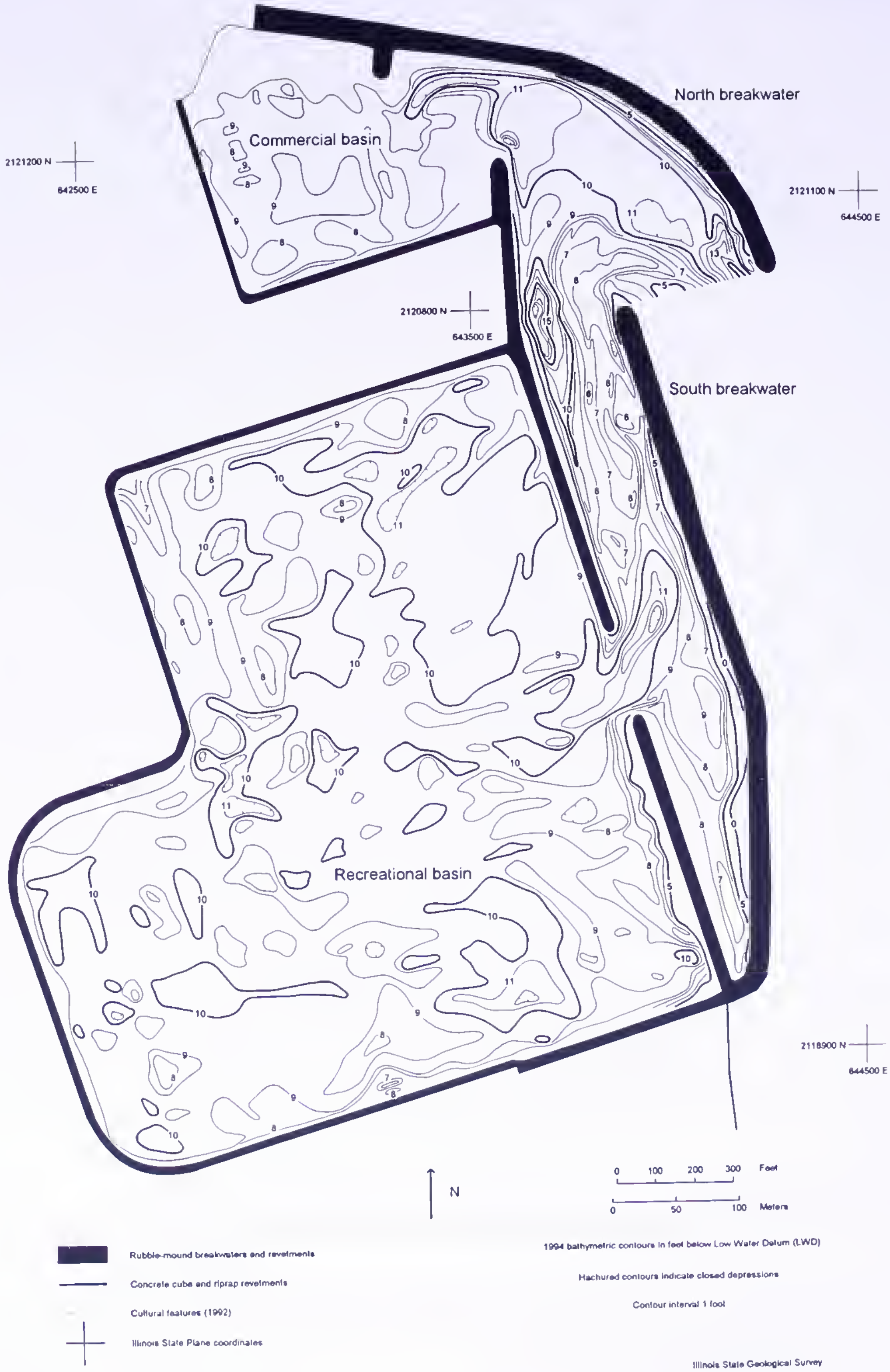


Figure 3-11 1996 bathymetry in the North Point Marina basins and approaches. Data from ISGS surveys in summer and autumn 1996.

1994-1996 lake-bottom change

Bathymetric changes within the recreational and commercial basins between 1994/1995 and 1996 were minimal. Different contour patterns and differences in individual contour locations in Figs. 3-10 and 3-11 are attributed to increased data coverage during 1996 ISGS mapping that permitted more detailed contouring.

In contrast to the recreational and commercial basins, the approach channel to the recreational basin experienced significant bathymetric change. Because 1996 mapping of the approach channel was conducted in September 1996 following completion of 1995-1996 dredging, a large part of the change in approach-channel depth can be attributed to dredging that removed 24,000 cu yds of sand. The combination of dredging and probable current scouring generally increased water depths by 1 to 4 ft. Deepening of 2 to 4 ft occurred at the tip of the south breakwater where a shoal area has typically existed (see Part 3: Marina Entrance). Depths along the west side of the approach channel remained greater than those along the east side. The trough adjacent to the north inner breakwater deepened by 2 to 4 ft to just over 19 ft LWD and a small topographic high near the entrance to the recreational basin deepened by 2 to 3 ft. The elongate erosional troughs adjacent to the north inner breakwater and at the entrance to the recreational basin are probably maintained by current scouring.

Implications of 1994-1996 lake-bottom change

The 19-ft deep erosional trough along the west side of the approach channel to the recreational basin is a significant erosional feature. Its base lies about 7 ft below the design depth for this part of the marina basin floor. The trough axis also lies about 7 ft below the design depth for the base of the adjacent north inner breakwater which is located about 50 ft to the west (see Moffatt and Nichol Engineers, 1986). Any deepening or westward lateral movement of the trough may threaten the stability of the north inner breakwater.

<u>South Breakwater Nearshore</u>

The south breakwater nearshore is defined as the area lying between the southern tip of the north breakwater and the approximate mid-point of the north-south segment of the south breakwater (Fig. 3-1). The northern and southern boundaries are coincident with ISGS profile lines 17 and 32, respectively.

1996 bathymetry (Figure 3-12)

Figure 3-12 shows that a smooth lake bottom slopes lakeward from the south breakwater out to the 14-ft LWD isobath. No nearshore bar occurs, in contrast to the North Beach nearshore, but a broad lobate depositional feature is defined by the 7 and 10 ft LWD isobaths along the northern half of the south breakwater. About 1000 ft east-southeast of the marina entrance, an irregular contour pattern between the 20 and 27 ft LWD isobaths has been identified as an area of glacial till outcrop (see Year-1 Report, Chrzastowski *et al.*, 1996). At the marina entrance, a prominent 16-ft deep trough extends into the marina entrance from the east-northeast.

Nearshore gradients are steeper than at North Beach. Depths within 100 ft of the south breakwater range from 6 ft LWD near the marina entrance to 10.5 ft LWD towards the south end of the breakwater.

1995-1996 lake-bottom change (Figure 3-13)

Between 1995 and 1996, the south breakwater nearshore was net erosional, losing 20,000 cu yds of sand (Table 3-5). The erosion volume (-46,800 cu yds) exceeded the accretion volume (+26,800 cu yds) by a factor of 1.7. The lake-bottom was generally erosional along a narrow strip between the breakwater and the 8-ft LWD isobath. Between the 8 and 15 ft LWD isobaths, the lake-bottom was net accretional, while at depths greater than 15 ft LWD, the lake-bottom was net erosional. Most lake-bottom change occurred

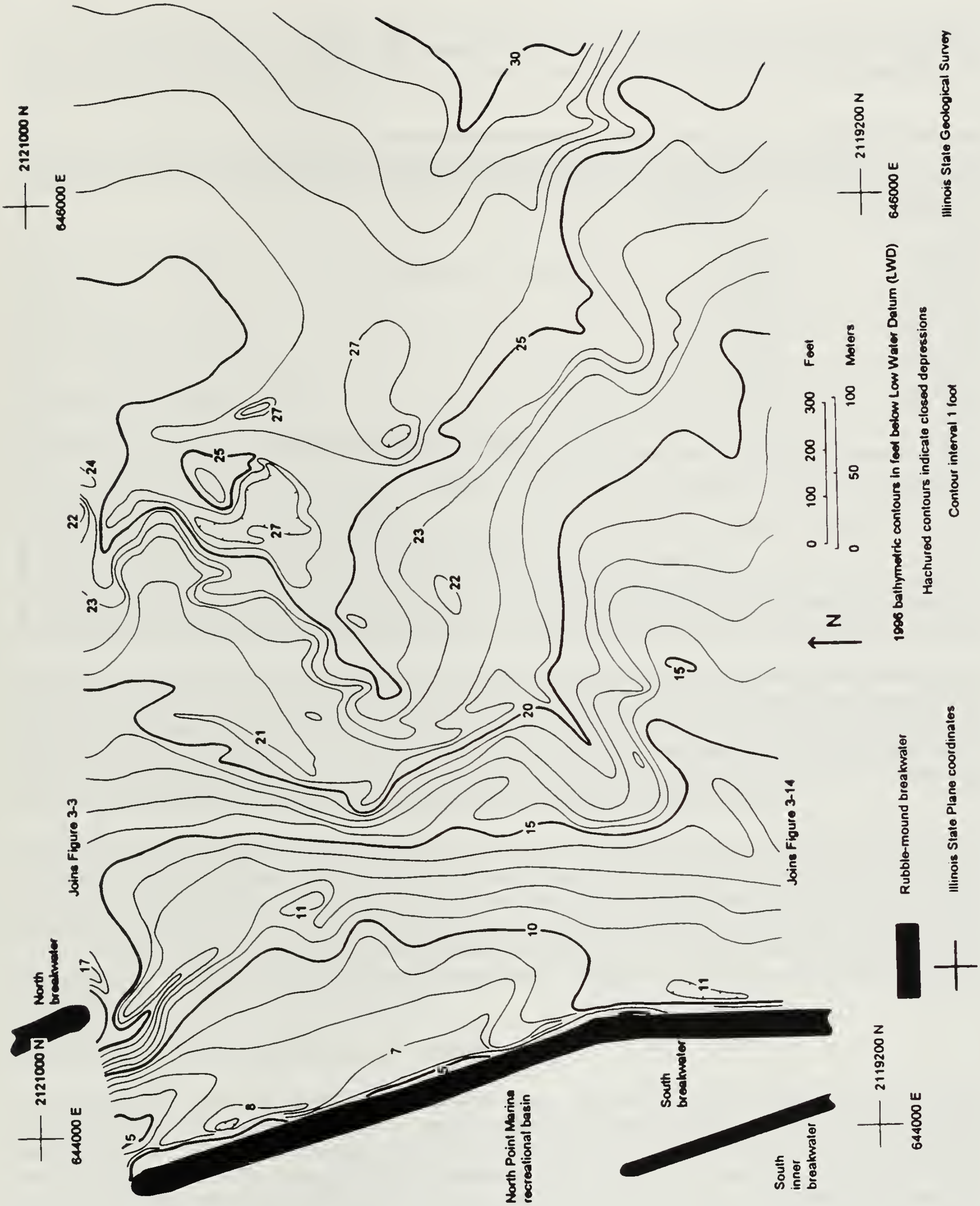


Figure 3-12 1996 bathymetry in the south breakwater nearshore.

in water depths less than 15 ft LWD. The 1995-1996 net erosion of 20,000 cu yds was three times the annual rate calculated for the 1992-1995 period (Table 3-5). While this does represent a significant change, 85% of the erosion occurred over a broad area at least 500 ft offshore from the breakwater and at depths greater than 15 ft LWD.

Table 3-5 Summary of erosion and accretion volumes in the south breakwater nearshore.[1]

	1992-1995[2]	1995-1996
Accretion (+) cu yds	9,100	26,800
Erosion (-) cu yds	28,900	46,800
Net change (cu yds)[3]	-19,800	-20,000
Annual net change (cu yds/yr)[3]	-6,600	-20,000
Normalized annual net change (cu yds/yr/shoreline ft)[4]	-4	-13

[1] All volumes are computed for lake-bottom elevation changes in excess of 1 ft and occurring below Low Water Datum (LWD). Volumes are rounded to the nearest 100 cu yds.
[2] Three-year comparison between Year-1(1995) data and data available from 1992; erosion and accretion volumes are for the three-year summation; annual net change is a three-year average.
[3] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[4] Shoreline distance (1500 ft) is based on measurement along a north-south line bounded to the north and south by the defined limits of the nearshore reach. Numbers are rounded to the nearest whole number. Net accretion is indicated by a positive number and net erosion is indicated by a negative number.

Accretion Accretion occurred primarily along a single accretional zone centered approximately 300 ft offshore of the south breakwater in water depths of 8 to 15 ft LWD (Fig. 3-13). This feature appears on the 1996 bathymetric map (Fig. 3-12) as a lakeward deflection of the 10-ft LWD isobath along the northern half of the south breakwater. The northern tip of this accretional lobe extends westward towards the marina entrance where 3.5 ft of accretion occurred between 1995 and 1996 (Fig. 3-13). At the south end of the accretional lobe, the lake bottom shallowed by 1 ft between 1995 and 1996.

Erosion Erosion in excess of 1 ft occurred in three principal areas. (1) Along a narrow strip within 50 to 100 ft of the south breakwater, the lake bottom generally deepened by about 1.5 ft, locally deepening by 3 ft near the north tip of the south breakwater. (2) Deepening up to 6 ft occurred within 200 ft of the tip of the north breakwater. This erosional area extends into the marina entrance and is the southernmost part of the erosional trough that extends across the North Beach / north breakwater nearshore (Fig. 3-4). (3) Up to 4 ft of erosion occurred in water depths greater than 15 ft LWD in a broad area located 400 to 1600 ft offshore of the bend in the south breakwater.

Implications of 1995-1996 lake-bottom change

The inner part of the south breakwater nearshore appears to have trapped a volume of sediment just greater than that lost from the North Beach / north breakwater nearshore (Fig. 3-4). The accretional lobe defined by the 1-ft lake-bottom change contour in Fig. 3-13 contains 23,200 cu yds of sand. The location and orientation of the lobe suggest that the sediment it is comprised of was derived largely from the erosional trough in the North Beach / north breakwater nearshore. The lobe is about three times the volume of a similar accretional lobe that developed in the same area during 1992-1995 (Foyle *et al.*, 1996). The presence of the lobe indicates that the marina is not a total barrier to littoral sediment transport. The presence of the lobe also suggests that the material lost from the North Beach / north breakwater nearshore during 1995-1996 was deposited a short distance downdrift in the south breakwater nearshore.

Figure 3-13 1995-1996 lake-bottom change in the south breakwater nearshore.

South Parking Area Nearshore

The south parking area nearshore is defined as the area lying between the approximate mid-point of the north-south segment of the south breakwater, and a line projected east of the east-west trending section of Dead Dog Creek (Fig. 3-1). The southern part of this nearshore area occurs lakeward of the IBSP/NU beach nourishment site. The northern and southern limits of the south parking area nearshore are coincident with ISGS profile lines 32 and 52, respectively.

1996 bathymetry (Figure 3-14)

Figure 3-14 shows that the lake bottom along this reach generally has a regular contour pattern indicating a relatively smooth surface. Nearshore gradients are intermediate between those at North Beach and those along the south breakwater. Depths within 100 ft of the shoreline range from 10.5 ft LWD at the south breakwater to 3 ft LWD offshore of Dead Dog Creek (Fig. 3-14).

Two prominent bathymetric features have persisted since 1995. Extending about 600 ft southward from the south breakwater, a line of submerged riprap forms a shoal area with a crest elevation of about 5.5 ft LWD (Fig. 3-14). Between this line of submerged riprap and the riprap-defended shoreline 150 ft to the west, an erosional trough persists since it was first documented in 1990.

1995-1996 lake-bottom change (Figure 3-15)

Between 1995 and 1996, the south parking area nearshore was net erosional, losing 29,700 cu yds of sand (Table 3-6, Fig. 3-15). The erosion volume (-32,700 cu yds) exceeded the accretion volume (+3,000 cu yds) by a factor of 11.0. On average, most lake-bottom change occurred in water depths of 5 to 15 ft LWD where the 1996 lake bottom became about 1 ft deeper than it was in 1995. Wave and current action caused the development of low-relief sand ridges oriented oblique to shore in water depths of 9 to 15 ft LWD.

Because 1500 ft of this coastal reach is fronted by the NPM south breakwater and the south parking area riprap, shoreline position was relatively stable during 1995-1996. However, the 500 ft stretch of shore between the south end of the riprap and Dead Dog Creek experienced localized shoreline recession of up to 70 ft. Nevertheless, the 1996 shoreline remained lakeward of the preconstruction (1987) shoreline along the entire 2000-ft reach.

Accretion Accretion up to 2 ft occurred in isolated patches across the nearshore (Fig. 3-15). Most accretion was related to the redistribution of lake-bottom sand to form low-relief sand ridges in water depths of 9 to 15 ft LWD. Small localized accretion patches along the riprap-defended shoreline on the lakeward side of the south parking area may have originated from a redistribution of back-fill lost at several erosional embayments that developed during spring 1996 (see Part 3: South Parking Area Monitoring). Some of this material may also have been derived from the dredge outfall which supplied an estimated 24,000 cu yds of sediment (Charles Price, NPM Harbor Master, pers. comm.) to the south side of the NPM south breakwater.

Erosion As was the case between 1992 and 1995, erosion was again pervasive along this stretch of nearshore (Fig. 3-15). The greatest erosion of 3 ft occurred in two locations: (1) on the lakeward side of the submerged riprap; and (2) at the south end of the riprap-defended shoreline that marks the lakeward side of the south parking area (Fig. 3-15). The lake bottom between the offshore submerged riprap and the south parking area deepened by up to 1 ft.

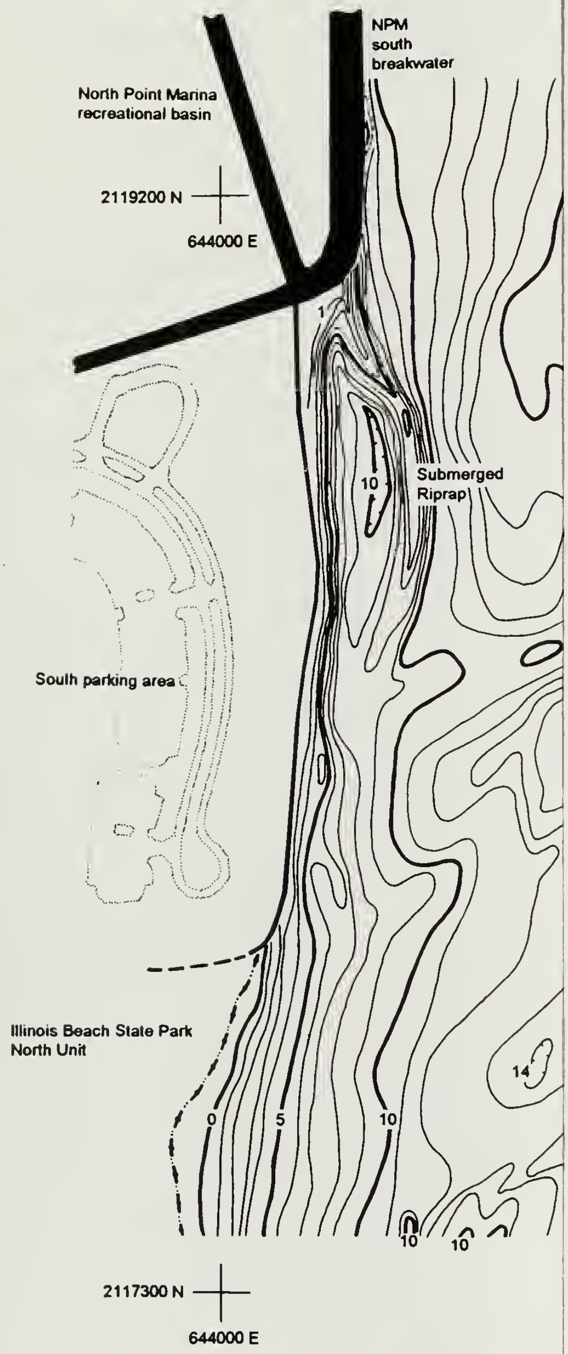


Figure 3-14 1996 bathymetry in the south p

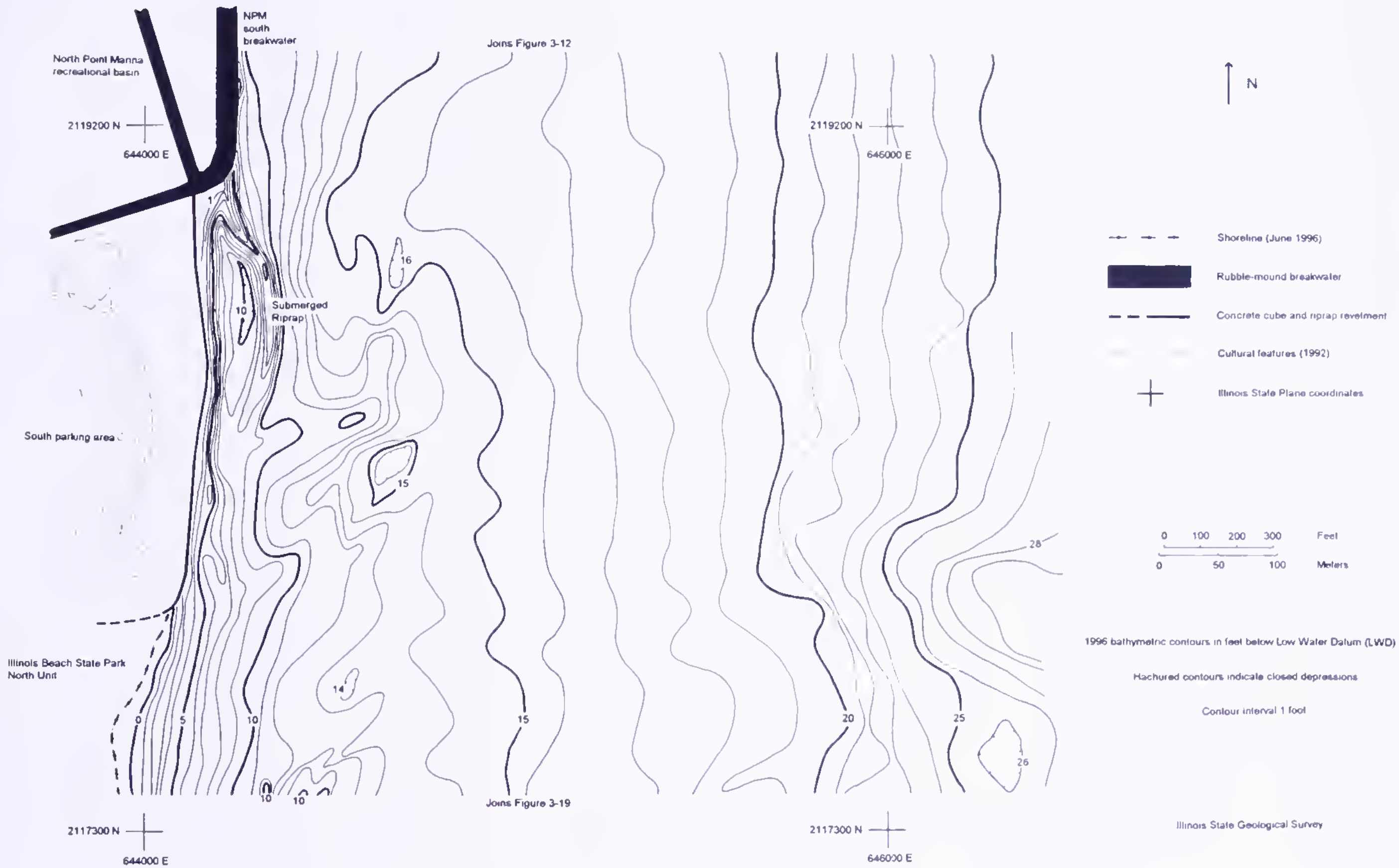


Figure 3-14 1996 bathymetry in the south parking area nearshore.

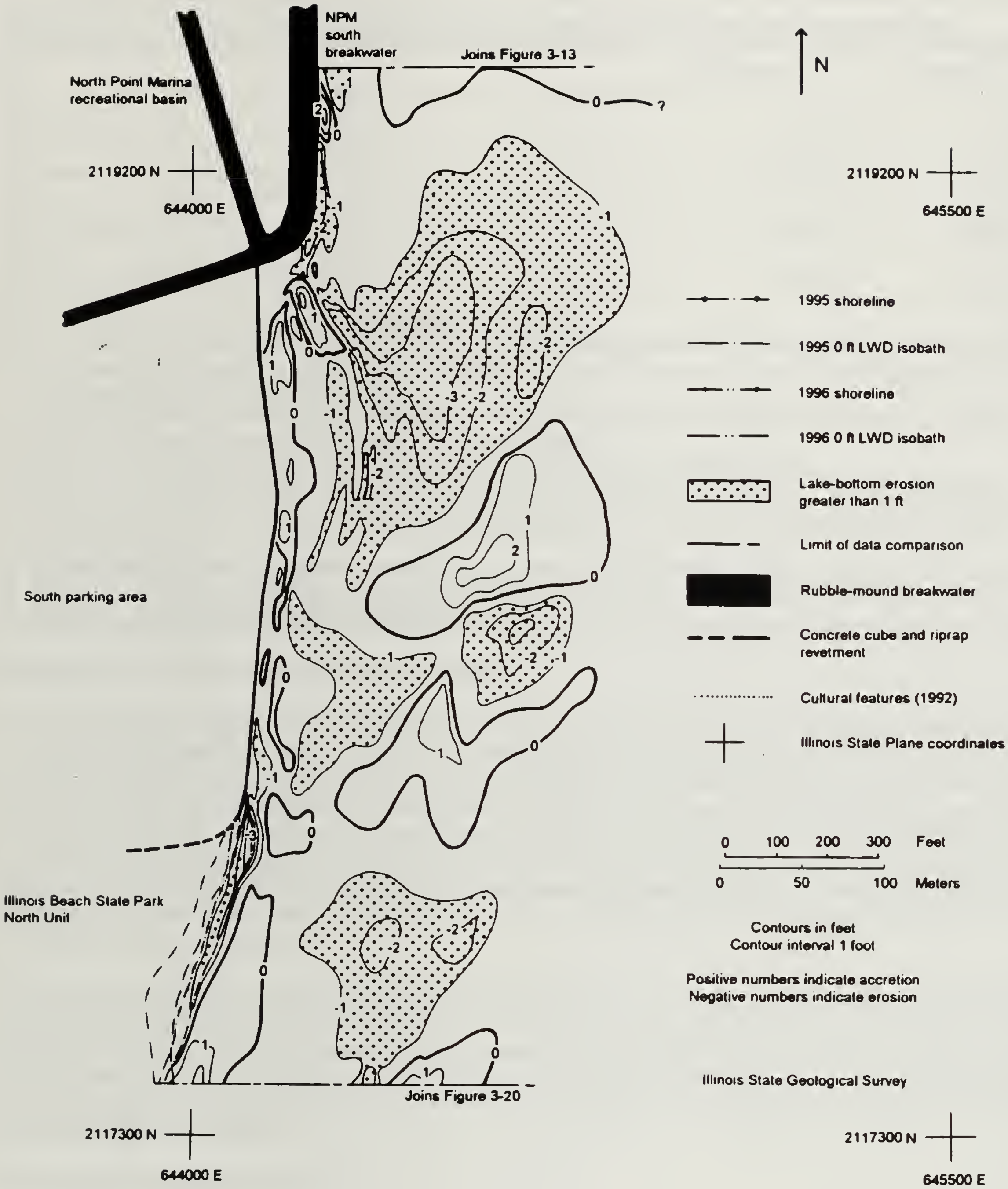


Figure 3-15 1995-1996 lake-bottom change in the south parking area nearshore.

Table 3-6 Summary of erosion and accretion volumes in the south parking area nearshore.[1]		
	1992-1995[2]	1995-1996
Accretion (+) (cu yds)	1,500	3,000
Erosion (-) (cu yds)	33,300	32,700
Net change (cu yds)[3]	-31,800	-29,700
Annual net change (cu yds/yr)[3]	-10,600	-29,700[4]
Normalized annual net change (cu yds/yr/shoreline ft)[5]	-5	-15

[1] All volumes are computed for lake-bottom elevation changes in excess of 1 ft and occurring below Low Water Datum (LWD). Volumes are rounded to the nearest 100 cu yds.
[2] Three-year comparison between Year-1 (1995) data and data available from 1992; erosion and accretion volumes are for the three-year summation and annual net change is a three-year average.
[3] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[4] As the annual net change is based on a 1995-1996 bathymetric comparison, it excludes about 77,000 cu yds of material added to the beach and nearshore. Most of this was added prior to the June 1996 bathymetric survey and consisted of beach nourishment at IBSP/NU, lakefront maintenance at the south parking area, and dredge-sand disposal adjacent to the NPM south breakwater.
[5] Shoreline distance (2000 ft) is based on measurement along a north-south line bounded to the north and south by the defined limits of the nearshore reach. Numbers are rounded to the nearest whole number. Net accretion is indicated by a positive number and net erosion is indicated by a negative number.

Implications of 1995-1996 lake-bottom change

Continued erosion along the south parking area nearshore is part of a long-term historical trend (see Part 3: Regional Coastal Monitoring). Erosion persisted during 1995-1996 despite: (1) the addition of about 46,000 cu yds of beach nourishment at the adjacent IBSP/NU beach-nourishment site between July 1995 and January 1996; (2) the addition of an estimated 20,000 cu yds of sand to the recreational area along the south parking area lakefront between December 1995 and July 1996; and (3) the addition of up to 24,000 cu yds of dredged sand from the marina between July 1995 and August 1996. The three-fold increase in the 1995-1996 annual net erosion rate, when compared with that of 1992-1995 (Table 3-6), may signify a worsening erosion problem for this area, or may simply reflect annual variability in wave climate and sediment supply.

Planned shore defense along the south parking area nearshore, currently under review by state and federal agencies, must account for ongoing, annually variable, lake-bottom erosion in this area. At the site of the proposed offshore submerged breakwater (Patrick Engineering, Inc., 1993, 1995b), the lake bottom deepened by an average of 1 to 1.5 ft during 1995-1996. This rate of deepening exceeds the previously reported rate-estimate of 0.25 ft/yr that was based on 1992-1995 lake-bottom change (Chrzastowski *et al.*, 1996).

South Parking Area Monitoring

Background

During December 1995 and January 1996, an estimated 7,000 cu yds of sand were placed along the 1100-ft length of riprap-defended shore at the NPM south parking area. This was part of a 33,000 cu yd sand addition to the IBSP/NU beach-nourishment site and south parking area lakefront. This was done to fill erosional embayments that developed on the landward side of the concrete-cube and riprap shore defense during storms in autumn 1995.

Between May and July 1996, an additional 13,000 cu yds of sand were placed along the same stretch of shore to fill erosional embayments that redeveloped during spring 1996 storms. The summer 1996 nourishment was obtained from the basin of Prairie Harbor Yacht Club, WI, which was dredged in spring 1996. The sand was trucked to the south parking area, placed on the lakeward side of the access road, and graded to a near-flat surface that extended out to the line of riprap.

Storms during late summer and autumn of 1996 caused renewed erosion along the south parking area and redevelopment of the embayments. During November 1996, the erosional scarp defining the landward limit of these embayments was up to 11 ft high and at one location was located as little as 45 ft east of the parking-area access road.

Monitoring scheme

The shore lakeward of the south parking area was surveyed and photographically monitored between early January 1996 (following completion of the winter 1995 sand placement) and mid November 1996. The area was not monitored during June and July 1996 when the summer sand placement occurred. Five east-west topographic/wading profiles were established at 200-ft intervals along the shore in September 1996.

Monitoring observations (January-November, 1996)

Figure 3-16 illustrates the location of the scarp crest on the lakeward side of the NPM south parking area and along the adjacent IBSP/NU beach-nourishment site between January and November 1996. Along the south parking area, the scarp occupied its most lakeward position in January 1996, immediately following sand placement when the fill extended almost as far as the line of concrete cubes. The most lakeward 10 to 20 ft of fill rested on top of a 3-ft thick shore-attached ice shelf. The first major shift in scarp location occurred on March 19-20 during a major spring storm that adversely affected several parts of the Illinois lakeshore. Nearshore wave heights during this storm ranged from 6 to 8 ft and the waves caused significant loss of lakefront sand behind the south parking area's line of riprap.

The 13,000 cu yds of sand added during summer 1996 filled several erosional embayments created during the March 19-20 and other spring storms but did not extend as far lakeward as the winter 1995 fill. The August 1996 monitoring documented the scarp location immediately following placement of the summer 1996 fill. By November 1996, the scarp had retreated up to 50 ft landward of the January 1996 location.

The greatest scarp retreat generally occurred along the southern 600 ft of shore where the riprap- and concrete-cube shore defense was easily overtopped by waves. This occurred for two reasons. Firstly, the northernmost several hundred feet of shore defense was reinforced with additional riprap in 1994 to mitigate a potential erosion threat to the Illinois Prairie sculpture. Through the 1996 storms, the crest of the shore defense along this stretch remained at a higher elevation than the riprap and concrete cubes situated further south. Secondly, the northernmost 500 ft of riprap-defended shore was partly protected from incoming wave energy by the line of submerged riprap located 150 ft offshore (Figs. 3-1, 3-14).

Maximum scarp recession along the south parking area occurred at a large erosional embayment that developed immediately south of where the shore is protected by the offshore submerged riprap. The embayment lies to the southeast of the entrance to the marina's southernmost keyed-access parking lot (at approximate Northing 2118400). Figure 3-17 photographically illustrates the degree of erosion in this area as of November, 1996 when the landward crest of the embayment lay as little as 45 ft from the adjacent access road.

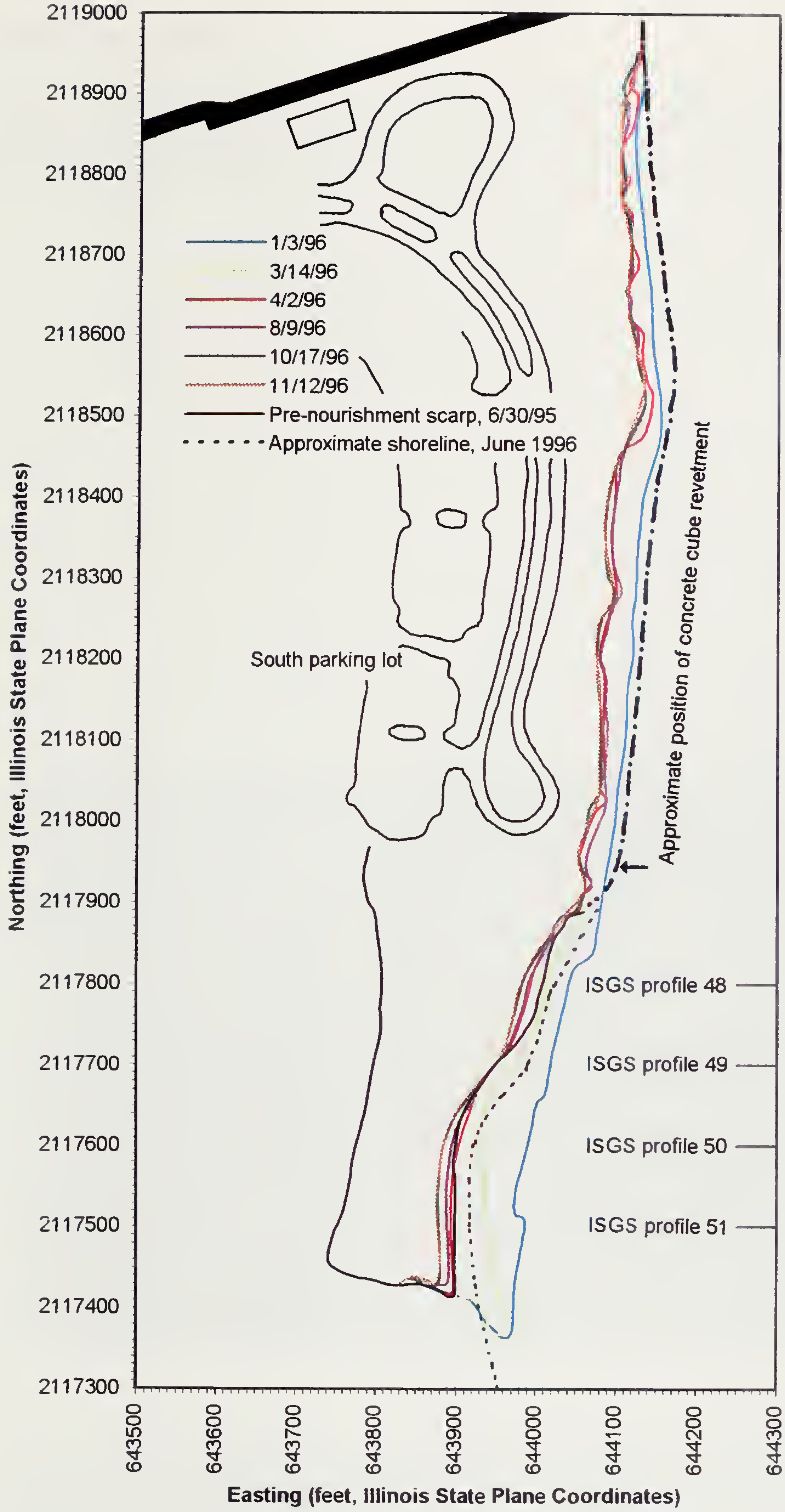


Figure 3-16 Scarp positions at the NPM south parking area lakefront and the IBSP/NU nourishment stockpile between January and November, 1996. The June 1995 scarp position at the IBSP/NU nourishment site is shown for reference as it marks the IBSP / NU stockpile geometry prior to summer 1995 and winter 1995/1996 nourishment events.

Implications of 1995-1996 change

The November 1996 erosional scarp location along the NPM south parking area lakefront was the most landward of all 1996 scarp locations. This indicates that the approximately 20,000 cu yds of sand placed at this site between December 1995 and July 1996 had been eroded and transferred to adjacent and downdrift nearshore areas by November 1996.

Figure 3-17 Photograph showing the riprap-defended shoreline and erosional embayments in the sand and gravel backfill along the NPM south parking area. The scarp height is approximately 11 ft, and up to 50 ft of scarp recession has occurred since January 1996 when the scarp lay along the line of riprap (left side of photo). View is to the south from a point due east of the southernmost keyed-access parking lot gate. The Camp Logan headland is visible in the background (Photo date November 21, 1996).

Submerged Riprap at the North End of the South Parking Area

Background

The submerged riprap referred to in the preceding two sections is located about 150 ft offshore of the riprap-defended shoreline at the south parking area (Fig. 3-1) and is a 600-ft long line of submerged rock that was originally placed as above-water shore protection between late autumn 1988 and early winter 1989. By late 1990, wave-induced erosion of the sandy lake bottom caused undermining that ultimately led to submergence of the riprap. Undermining continued through 1995, with the riprap continuing to subside at an average rate of 0.5 ft/yr. As of 1996, the submerged riprap remains a distinctive shoal area (Fig. 3-14). The history of placement and subsidence of this riprap is described in detail in the Year-1 Report (Chrzastowski *et al.*, 1996).

The submerged riprap is a significant nearshore feature for four principal reasons:

- It trips incoming storm waves along the northern part of the south parking area nearshore. This has the effect of reducing the severity of shoreline recession and back-fill loss.
- It has slowed the rate of lake-bottom deepening along the northern part of the south parking area nearshore. This is illustrated by the lakeward displacement of the 10-ft LWD isobath in Fig. 3-18.
- It is within the footprint of a future submerged breakwater that has been proposed for protection of the south parking area (Appendix D in Chrzastowski *et al.*, 1996).
- The principal negative aspect of the presence of the riprap is that it has induced the formation of an erosional trough on its landward side (Fig. 3-14). This trough has become progressively deeper in tandem with subsidence of the riprap.

Continued annual monitoring of lake-bottom change in this area is important because changes in riprap configuration will have a direct impact on rates of adjacent lake-bottom erosion and on the integrity of the adjacent riprap-defended shoreline at the south parking area. As the submerged riprap continues to subside, its ability to trip incoming waves and thereby reduce the rates of shoreline recession and lake-bottom erosion will diminish.

1995-1996 riprap change (Figures 3-14, 3-15)

The submerged riprap forms a shoal area extending southward from the elbow of the south breakwater (Fig. 3-14). Crest elevations range from approximately 1.5 ft LWD at the north end of the riprap adjacent to the south breakwater, to 7.5 ft LWD at the south end of the riprap. The erosional trough on the landward side of the riprap is marked by water depths of just over 10 ft LWD.

Figure 3-15 shows that the crest of the submerged riprap subsided an average of 0.5 to 1 ft during 1995-1996. The least subsidence occurred where the riprap adjoins the south breakwater. Adjacent to the submerged riprap, a drop in lake-bottom elevation of similar magnitude suggests that the relief, or difference in height between the crest of the riprap and the adjacent lake bottom, has been maintained at about 4 to 5 ft. This indicates that the riprap is subsiding as a relatively intact pile due to undermining, and is not being dispersed across the lake-bottom. The rate of riprap subsidence is not significantly different from the 1991-1995 subsidence rate of 0.5 ft/yr previously reported in the Year-1 Report (Chrzastowski *et al.*, 1996).

Implications of 1995-1996 riprap change

Continued crest subsidence through 1996 indicates that the submerged riprap continued to become

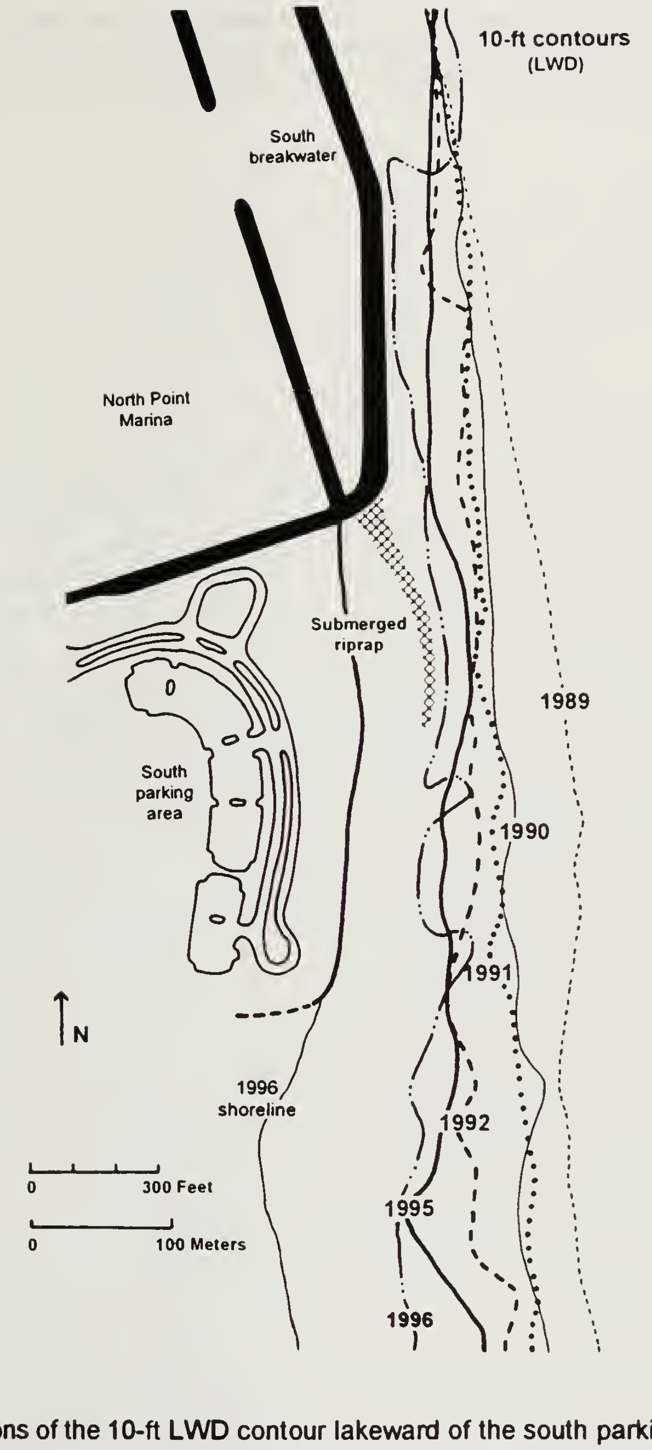


Figure 3-18 Locations of the 10-ft LWD contour lakeward of the south parking area between 1989 and 1996. The 10-ft LWD contour is used as a reference contour to indicate how close to shore water depths of 10 ft LWD occur. Landward migration of the 10-ft LWD contour since 1989 indicates that lake-bottom deepening has occurred. Nearshore gradients became steeper between 1990 and 1996 as the 10-ft LWD contour moved closer to shore. The submerged riprap has slowed landward contour migration along the northern half of the south parking area nearshore.

progressively less effective as a wave tripper. This, in turn, suggests that increased rates of riprap subsidence may be expected to occur along the south parking area's riprap-defended shoreline. Back-fill loss and the development of erosional embayments on the landward side of the shoreline may also be expected to continue.

ILLINOIS BEACH STATE PARK / NORTH UNIT

General Statement

1996 data collection within the North Unit of Illinois Beach State Park (IBSP/NU) focused on the northernmost 3000 ft of shore between the marina / state park boundary and the headland at the north end of Camp Logan (Fig. 2-1). The northernmost 500 ft of IBSP/NU shore, between the marina / state park boundary and Dead Dog Creek (Fig. 3-1), is a site that has received at least 228,000 cu yds of beach nourishment since 1990 (Appendix G). The nearshore adjacent to this beach-nourishment site is discussed in a preceding section (see Part 3: South Parking Area Nearshore).

1996 data and observations from the IBSP North Unit are discussed under the following headings:

- Dispersion of 1994 Beach Nourishment
- Monitoring of 1995-1996 Beach Nourishment
- Spring Bluff Nearshore
- Spring Bluff Shoreline Changes

Dispersion of 1994 Beach Nourishment

In September 1994, 32,000 cu yds of beach nourishment were added to the North Unit nourishment stockpile (Appendix G). This nourishment was a moderately sorted, angular, fine gravel ("pea gravel") with a median grain size of approximately 6 mm. The nourishment, from an inland quarry source, was coarser than the medium to coarse sand previously and subsequently supplied to the site. The material was chosen primarily because of potential longer beach and nearshore residence times.

As of summer 1996, pea gravel still remained at the nourishment site where it was exposed along the erosional scarp. It was overlain by a 0.5 to 2 ft thick veneer of finer sand that was placed during 1995 and 1996 nourishment events. The re-exposure of the 1994 nourishment along the scarp face is significant because it indicates that the majority of the 46,000 cu yds of finer-grained nourishment placed at the site during 1995 and 1996 has been transported downdrift and into the nearshore.

Along Spring Bluff beach (Fig. 3-1), the pea gravel still formed a significant component of the beach material during 1996. The Camp Logan headland continued to act as a partial barrier to southward transport of this material. However, pea gravel still occurred as a progressively decreasing fraction of the beach sand at sites to the south of the Camp Logan headland, indicating that the gravel continued to migrate southward in the nearshore. The minimum rate of littoral transport along the beach for this material was estimated in the Year-1 report to be 0.6 mi/yr.

Monitoring of 1995-1996 Beach Nourishment

Nourishment characteristics and emplacement

Between early December 1995 and early January 1996, approximately 26,000 cu yds of new nourishment were added to the North Unit stockpile as part of a 33,000 cu yd addition to the shore along the NPM south parking area lakefront and the North Unit nourishment site. This 26,000 cu yds supplemented 20,000 cu yds of sand that were added in July 1995, most of which had already been lost by November 1995 (Appendix G). The sediment was a moderately to poorly sorted fine to medium sand and consisted of up to 10% granules and pebbles.

The 1995-1996 nourishment material was obtained from storage stockpiles at the Commonwealth Edison Waukegan Generating Station (Fig. 1-2), being originally derived from maintenance dredging of that

facility's intake and discharge channels and cooling-water basin. The material was trucked to the North Unit nourishment site and dumped along the lakeward flanks of the existing stockpile. Upon initial placement, the most lakeward 10 to 20 ft of nourishment rested on a 3 ft thick shore-attached ice shelf. The top surface of the nourishment pile was graded to an average slope of approximately 1:25 and the lakeward edge of the stockpile was marked by a 6 ft scarp.

Monitoring scheme

The monitoring scheme established in Year-1 (1995) was continued in Year-2 (1996). The scheme consisted of a series of four east-west profiles spaced at 100-ft intervals across the stockpile. These lines were extended into the shallow nearshore. Survey points were also collected around the perimeter of the stockpile along the scarp crest to document scarp recession. Surveys were conducted on a monthly basis between December 1995 and November 1996.

Monitoring observations (January - November 1996)

The results of the 1996 monitoring are presented in graphic format in Fig. 3-16 and Appendix H. Erosion along the lakeward margin of the North Unit stockpile began immediately following completion of the winter 1995-1996 nourishment operations. Significant recession occurred at the south end of the nourishment site, particularly at ISGS profiles 50 and 51, where the scarp crest retreated up to 55 ft between January and March 1996 (Appendix H).

The highest recession rates were documented over a three-week interval between mid March and early April when the scarp crest retreated as much as 60 ft (Fig. 3-16). Most of this retreat occurred during a storm on March 19-20. The storm caused a significant reconfiguration in the geometry of the nourishment pile (Fig. 3-16). For the remainder of the monitoring period between April and November 1996, average scarp recession rates were lower, ranging from 0.5 to 3 ft/month (Appendix H).

Appendix H and Fig. 3-16 illustrate that the November 1996 scarp crest generally occurred landward of the June 1995 scarp crest. The June 1995 scarp crest is significant because it marks the stockpile geometry prior to the addition of beach nourishment in July 1995 and the subsequent addition of beach nourishment in December 1995-January 1996. The relative positions of the June 1995 and November 1996 scarps indicate that the approximately 46,000 cu yds of nourishment placed at the site between July 1995 and January 1996 (see Appendix G) have largely been moved into the nearshore and downdrift.

Appendix H illustrates that scarp recession rates were higher for profiles 50 and 51 than they were for profiles 48 and 49. This occurred because an "apron" of boulders and cobbles extends southward along the beach from the riprap and concrete-cube shore defense as far as Profile 49. These boulders and cobbles armor the shore, preventing the northern part of the stockpile from eroding as rapidly as would occur otherwise. The influence of this rock armoring can be seen in Figure 3-16 where the nourishment stockpile had the greatest amount of scarp recession immediately south of Profile 49.

Implications of 1995-1996 change

Wave-induced erosion at the IBSP/NU beach nourishment site is capable of moving significant volumes of fine- to medium-grained sand from the nourishment site into the adjacent nearshore on an annual basis. This transfer of sediment into the nearshore can be accompanied by significant shoreline recession.

Spring Bluff Nearshore

The Spring Bluff nearshore is defined as the area lying between a line projected east of Dead Dog Creek and a line projected east from the north side of the Camp Logan headland (Figs. 1-2, 3-1). These limits correspond with the locations of ISGS profile lines 52 and 78, respectively. The name Spring Bluff is derived from the former lakeside community of Spring Bluff.

1996 Bathymetry (Figure 3-19)

The principal bathymetric characteristic of the Spring Bluff nearshore in 1996 is the re-establishment of a nearshore bar-trough pair similar to that developed in the North Beach / north breakwater nearshore. The bar occurs 50 to 150 ft lakeward of the shoreline along the southern half of the Spring Bluff shore (Fig. 3-19). Minimum depths along the bar range from approximately 2 ft LWD along the central part of this nearshore to approximately 5.5 ft LWD at the Camp Logan headland. Relief across the bar-trough pair attains a maximum value of 2.7 ft just north of the Camp Logan headland.

A regular bathymetric contour pattern along this nearshore suggests a sandy lake bottom. However, localized bathymetric irregularities occur in water depths less than 3 ft LWD along the northern part of the nearshore. These mark the positions of submerged ruins of former shore structures.

Nearshore gradients are similar to those of the South Parking area nearshore. Depths within 100 ft of the shoreline range from 2 ft LWD in the north to 7 ft LWD adjacent to the Camp Logan Headland (Fig. 3-19).

1995-1996 lake-bottom changes (Figure 3-20)

Between 1995 and 1996, the Spring Bluff nearshore underwent net erosion of 65,200 cu yds. The erosion volume (-77,700 cu yds) exceeded the accretion volume (+12,500 cu yds) by a factor of 6.2 (Table 3-7). The lake bottom generally shallowed by 1 to 3 ft in water depths less than 5 ft LWD. In water depths of 5 to 15 ft LWD, the lake-bottom generally deepened by 1 to 3 ft (Fig. 3-20).

Table 3-7 Summary of erosion and accretion volumes in the Spring Bluff nearshore.[1]

	1992-1995[2]	1995-1996
Accretion (+) cu yds	35,600	12,500
Erosion (-) cu yds	97,400	77,700
Net change (+/-) cu yds	-61,800	-65,200
Annual net change (+/-) (cu yds/yr)[3]	-20,600	-65,200
Normalized annual net change (cu	-8	-25

[1] All volumes are computed for lake-bottom elevation changes in excess of 1 ft and occurring below Low Water Datum (LWD). Volumes are rounded to the nearest 100 cu yds.
[2] Three-year comparison; erosion, accretion, and net change volumes are for the three-year summation and annual net change is a three-year average.
[3] Net accretion is indicated by a positive number and net erosion is indicated by a negative number.
[4] Shoreline distance (2600 ft) is based on measurement along a north-south line bounded to the north and south by the defined limits of the nearshore reach. Numbers are rounded to the nearest whole number. Net accretion is indicated by a positive number and net erosion is indicated by a negative number.

Accretion Accretion of 1 to 3 ft was primarily confined to a narrow strip of nearshore within 150 ft of the shoreline and in water depths less than 5 ft LWD. Along a 600 ft stretch of nearshore adjacent to the Camp Logan headland, accretion up to 3 ft was associated with general nearshore shallowing that accompanied a lakeward translation of the shoreline (Fig. 3-20). Along the remainder of the nearshore to the north, accretion was associated with two processes. These were: (1) landward migration of the northern part of the nearshore bar between 1995 and 1996; and (2) infilling of the northern part of the nearshore trough with littoral sediment supplied from the IBSP/NU nourishment site located updrift.

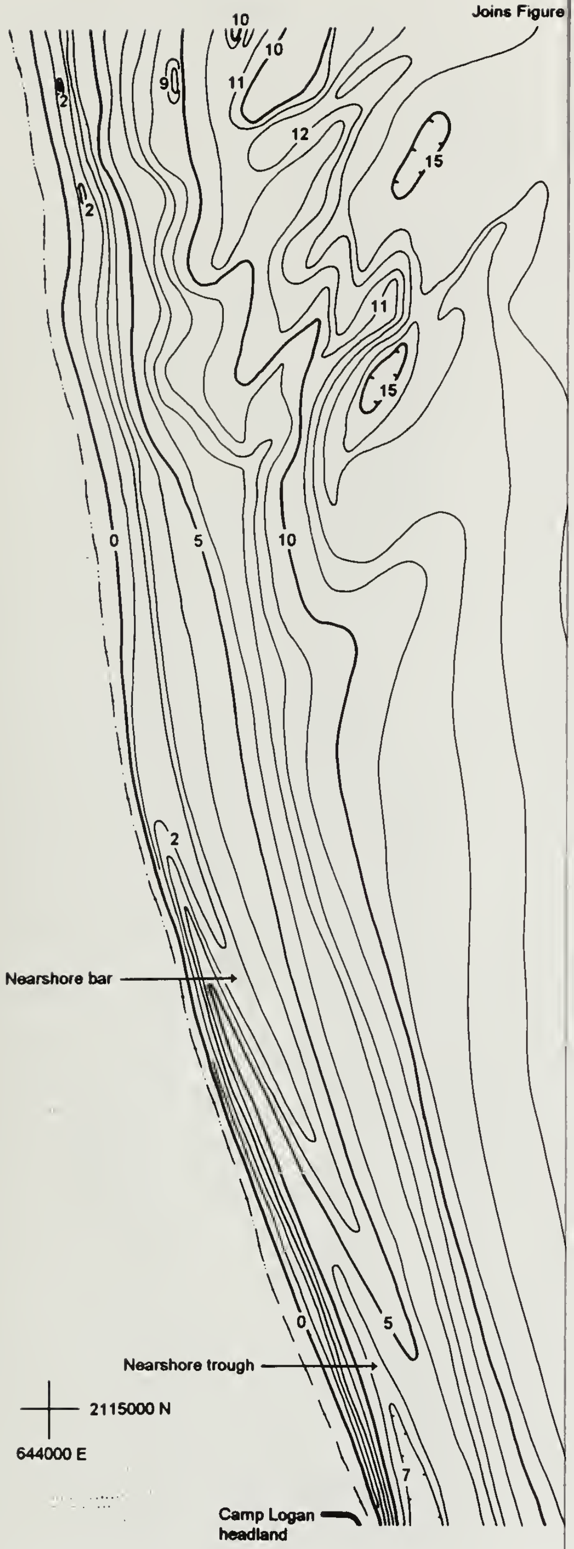


Figure 3-19 1996 bathymetry in the Spring

Figure 3-19 1996 bathymetry in the Spring Bluff nearshore.

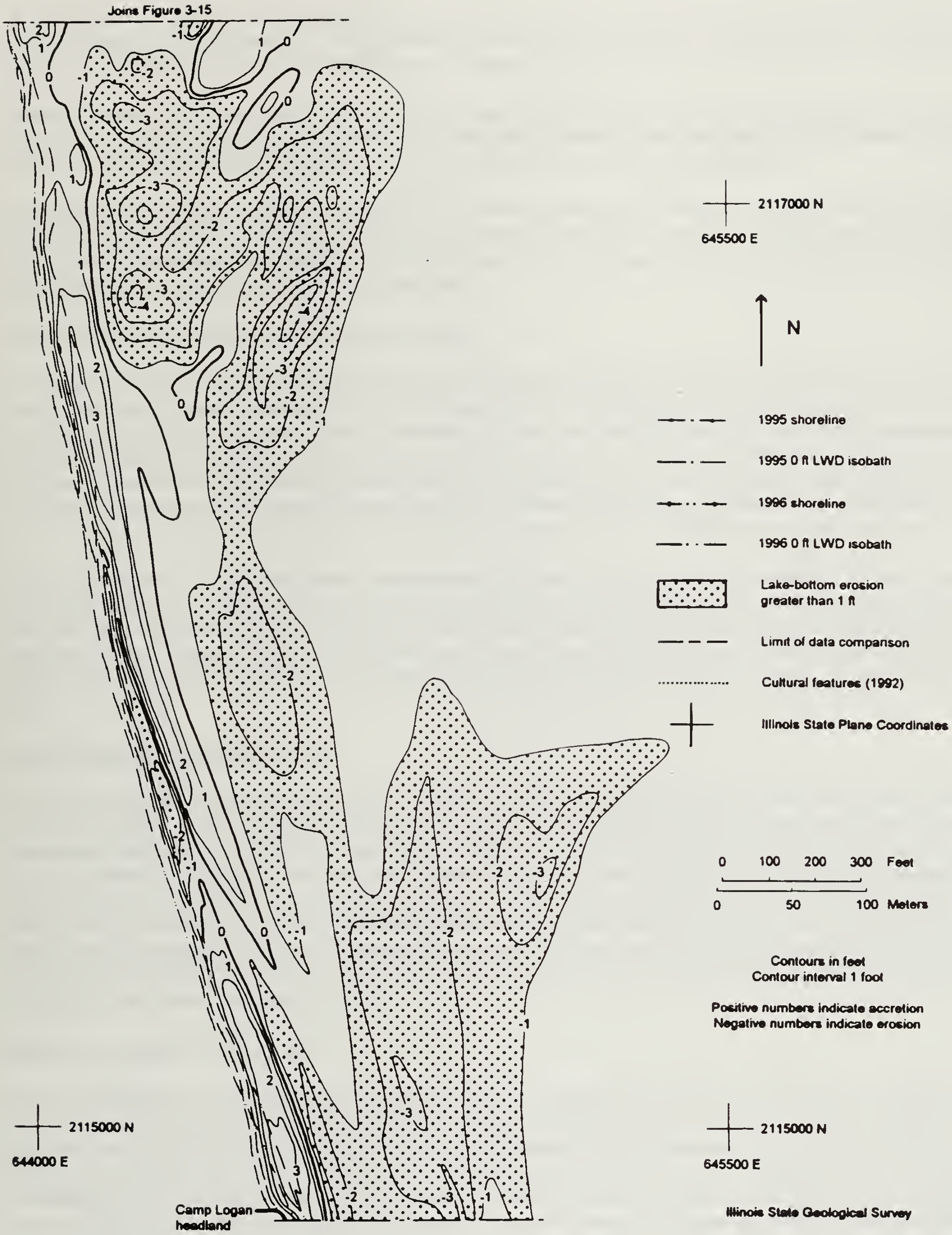


Figure 3-20 1995-1996 lake-bottom change in the Spring Bluff nearshore.

Small localized patches with accretion up to 1 ft occurred in water depths of 10 to 15 ft LWD along the northern part of this nearshore. This accretion is related to storm-wave remolding of the sandy lake bottom and development of shore-oblique sand ridges (Fig. 3-19).

Erosion Erosion occurred in two general areas. Along the central part of the Spring Bluff nearshore, up to 30 ft of shoreline recession occurred. This shoreline recession was accompanied by lake-bottom erosion of up to 2.5 ft in water depths of 1 to 5 ft LWD, within 100 ft of the shoreline.

In water depths of 5 to 15 ft LWD, erosion of 1 to 3 ft was pervasive. Localized areas showing over 3 ft of erosion occurred along the northern half of the nearshore and were related to storm-wave remolding of the sandy lake bottom and development of erosional troughs. These troughs developed between the shore-oblique trending sand ridges described above.

Implications of 1995-1996 lake-bottom change

Net nearshore erosion during 1995-1996 continued long-term erosion trends for the Spring Bluff area (see Part 3: Regional Coastal Monitoring). The normalized annual net change rate of -25 cu yds/yr/shoreline ft exceeded that of all adjacent areas to the north and indicates that this was the area of most extensive lake-bottom erosion between the WI-IL state line and Camp Logan. The 1995-1996 net annual erosion rate was approximately three times greater than that calculated for the period 1992 to 1995 (Table 3-7). Continued monitoring is necessary to determine if the three-fold increase signifies a worsening erosion problem for this area or whether it is due to annual variability in wave climate and sediment supply.

Sand supplied from the IBSP/NU beach-nourishment site likely contributed to an overall reduction in net nearshore erosion. The positive effect of sediment input from updrift was most apparent along a narrow accretional zone between the shoreline and the nearshore bar (Fig. 3-20); however this sediment input was insufficient to counteract overall net erosion across the entire nearshore. Continued lake-bottom erosion in water depths greater than 5 ft LWD will ultimately cause the shoreline to move landward (Fig. 3-20).

Spring Bluff Shoreline Changes

Due to the proximity of Spring Bluff beach to a major coastal engineering structure, there has been some concern expressed for the conservation of the natural setting of this segment of the North Unit shore. Specifically, this concern centers on the degree to which erosion has adversely affected the shore since marina construction in 1987. There has been a misconception of a loss of land and beach area compared to that which existed prior to marina construction. Comparison of map data and ground and aerial photography indicates that although substantial erosion has occurred since marina construction, as of 1996 there still remains a net gain of beach width compared with that prior to marina construction in 1987. The 1996 shoreline still lies 40 to 115 ft lakeward of its 1987 location. The following discussion focusses on the data that document this net gain.

Shoreline changes (Figure 3-21)

During 1995-1996, sand supplied from the IBSP/NU beach-nourishment site likely contributed to an overall reduction in the rate of shoreline recession along the Spring Bluff shore. In summer 1996, the northernmost 1200 ft and southernmost 200 ft of shoreline lay at or lakeward of the 1995 shoreline. In between, along a 1200 ft stretch of shore, the 1996 shoreline lay up to 30 ft landward of the 1995 shoreline. Since 1987, the predominant control on shoreline position has been periodic sediment supply from the IBSP/NU nourishment site and adjacent nearshore areas which allows beach expansion and shoreline progradation. Between nourishment events (Appendix G), erosion caused by wave attack causes shoreline recession and a reduction in beach width.

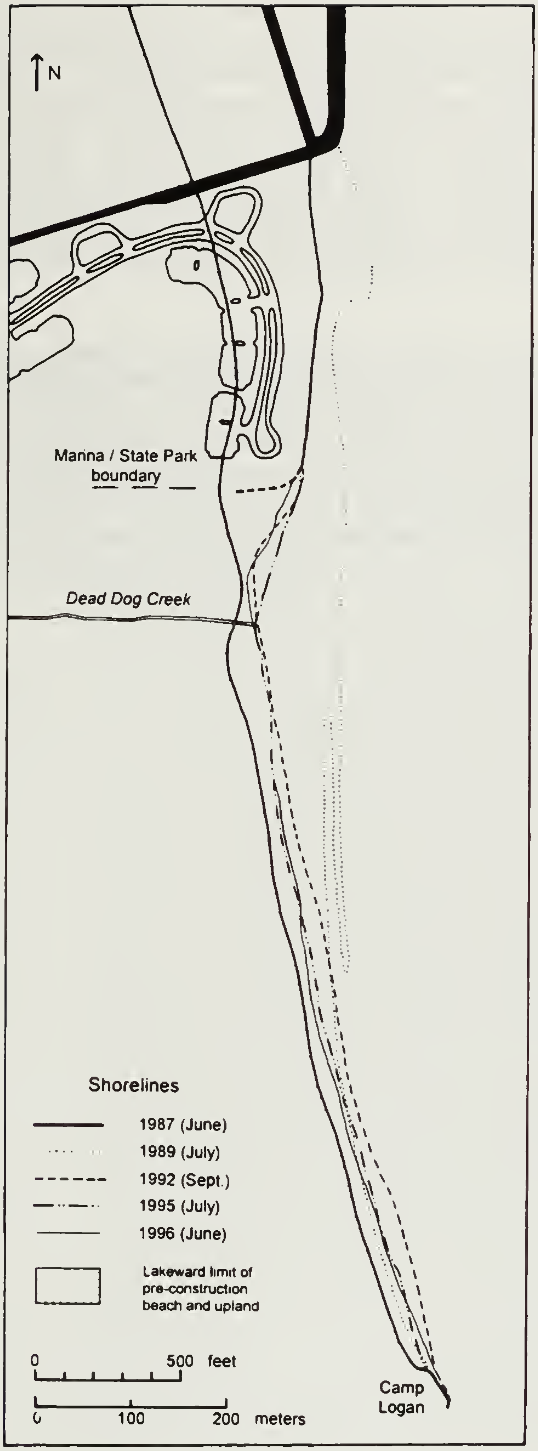


Figure 3-21 Map showing shoreline positions along the south parking area and Spring Bluff. Shorelines are shown for the years 1987, 1989, 1992, 1995, and 1996.

Figure 3-21 illustrates shoreline positions between the NPM south breakwater and the Camp Logan headland at selected intervals between 1987 and 1996. The 1987 shoreline reflects coastal configuration just prior to marina construction. The most lakeward shoreline position occurred in 1989 in response to placement and southward dispersal of NPM dredge material following marina construction (see Year-1 Report, Chrzastowski *et al.*, 1996). The 1989 shoreline is significant because shoreline recession has generally occurred since that time. Shorelines are also shown for 1995 (Year-1 of this study), and for 1996. All of these shoreline positions are primarily the result of beach and nearshore erosional and accretional changes. Fluctuations in shoreline position due to annual differences in lake level are considered insignificant because a steep slope characterizes much of the lower beach and shallow nearshore.

The 1996 shoreline remained lakeward of the 1987 shoreline (Fig. 3-21). Placement and southward dispersal of NPM dredge material between 1987 and 1989 resulted in a gain in beach area of 13 acres and a lakeward movement of the shoreline. Between 1989 and 1995, however, shoreline recession resulted in the loss of 8 of these acres at an average rate of 1.3 acres/yr. Between 1995 and 1996, shoreline recession and progradation along different parts of the shore caused only the minor loss of an additional 0.05 of an acre. Therefore, beach area did not change significantly during 1995-1996. The reduced rate of beach loss (0.05 acres/yr) during 1995-1996 can be attributed to shoreline stabilization induced by the input of beach nourishment from updrift.

General Statement

1996 data collection within Illinois Beach State Park's South Unit (IBSP/SU) primarily involved the collection of topographic and bathymetric profile data and shoreline position data at ten range line locations as part of the regional coastal monitoring scheme (see Appendix J). The results of this monitoring are discussed within the context of regional coastal change in the following section on Regional Coastal Monitoring.

Additionally, monitoring continued along 2400 ft of riprap-defended shoreline adjacent to the IBSP/SU camping area (Figs. 3-22, 3-23). Although no nourishment was added at this site in 1996, 24,000 cu yds of beach nourishment had been placed along the shore during summer 1995. Monitoring during 1996 was done to document any potential adverse erosion effects that might accompany continued depletion of the beach nourishment.

Figure 3-22 Photograph showing the south end of the IBSP/SU beach-nourishment site. A precipitous drop-off exists between road level and the adjacent riprap and beach. For scale, the concrete cubes in the foreground along the east side of the access road measure 3 ft by 4 ft by 4 ft. View is to the north with the Zion Nuclear Power Plant in the background (photo date February 25, 1997).

Figure 3-23 Location of the 1995 beach-nourishment site in the South Unit of Illinois Beach State Park.

Most of the 1995 beach nourishment was depleted by November 1995. 1996 monitoring recorded only minor changes in shoreline position and nearshore bathymetric profiles. The shallow nearshore at depths less than 4 ft LWD maintained a relatively stable to slightly net-erosional configuration (Appendix I). The shoreline returned to its pre-nourishment position along a line of pre-existing riprap and concrete-cube shore defense. Runoff eroded narrow gullies on the nourishment sand remaining between the east edge of the shore-access road and the lakeward side of the nourishment pile which rests on the riprap slope (Fig. 3-23). Several of these gullies exposed the concrete-cube and roadbed of the shore-access road. Figure 3-22 illustrates that the scarp crest on the lakeward side of the remaining nourishment lies within as little as 4 ft of the shore-access road and that there is a steep drop-off of 2 to 4 ft between road level and the adjacent riprap and beach. Severe waves could overtop the riprap and cause erosion of the roadbed.

REGIONAL COASTAL MONITORING

General Statement

Coastal monitoring at North Point Marina and Illinois Beach State Park is designed to address erosion and coastal-management concerns specific to these individual coastal areas. To adequately evaluate the gain, loss, and transport of littoral sediment along the marina and state park properties, and to help predict future coastal change, it is necessary to examine coastal processes from a regional perspective. A regional evaluation would ideally extend along the 18 miles of shore between Kenosha, WI and North Chicago, IL which is the lakeshore extent of the Zion beach-ridge plain. For practical purposes, the northern and southern limits of the study area (WI-IL state line, Waukegan Harbor) provide boundaries that define a distinct coastal reach.

At the north end of the study area, the WI-IL state line is a political boundary important to coastal management but it also corresponds to a partial barrier to littoral sediment transport caused by the intercept, dredging, and removal of sediment at Prairie Harbor Yacht Club, WI. At the south end of the study area, the jetties and entrance channel at Waukegan Harbor now form a partial barrier to littoral sediment transport and have historically trapped a large percentage of the sediment transported southward along the NPM and state park nearshore. Thus, the shore from the WI-IL state line to Waukegan Harbor is appropriately treated as a distinct coastal reach having an updrift origin (sediment crossing the state line), a pathway for littoral sediment transport, and a terminus (sediment trapped at Waukegan Harbor).

In this report, the 9.7 miles of shore between the WI-IL state line and Waukegan Harbor is referred to as the WI-IL state line / Waukegan Harbor (SL/WH) coastal reach. The following discussion examines coastal changes and processes along the entire reach from four different perspectives for the 124-year interval between 1872 and 1996. These four headings are:

- Shoreline change
- Beach and nearshore profile change
- Lake-bottom change
- Littoral sediment budget

Shoreline Change

Data compilation

Comparisons of shoreline positions over time provide a means of quantifying beach-area gains and losses and rates of shoreline change. A primary complication in this procedure is referencing the shorelines to a common datum. Otherwise, differences in shoreline position can be wholly or partly a result of differences in lake level at the time of measurement. The position of the 0-ft LWD contour, or LWD shoreline (U.S. Army Corps of Engineers, 1953), provides a datum-corrected shoreline reference and permits an accurate measurement of shoreline change when shorelines are compared over different years.

For the SL/WH coastal reach, the LWD shoreline was mapped in 1872 and 1910 (see U.S. Army Corps of Engineers, 1953). In 1974, the shoreline was mapped by the ISGS using vertical aerial photography (Illinois State Geological Survey, 1975, 1988, and unpublished data) which documented shoreline position for the lake level at the time of photography. In 1996, the ISGS mapped shoreline position at 200-ft intervals along the SL/WH coastal reach using a prism pole and total station and delineated the shoreline for lake level at the time of survey. The 1974 and 1996 shoreline data, although not datum-corrected, can be used to make map comparisons between 1974 and 1996 and can be compared with earlier 1872 and

1910 LWD-shoreline data to identify generalized trends in shoreline change over the past 124 years.

Historical trends (Figure 3-24)

Historically, there has been a persistent trend in shoreline recession (landward shift) along the northern segment of the SL/WH coastal reach, shoreline stability along the shore centered on the mouth of Dead River, and shoreline progradation (lakeward shift) from just south of Dead River to the entrance channel at Waukegan Harbor. Figure 3-24 shows shoreline positions within the SL/WH coastal reach for the years 1872, 1910, 1974, and 1996.

Between the WI-IL state line and the Dead River area, shoreline recession has dominated over the past 124 years. The long-term rate of recession was generally highest near the WI-IL state line and lowest near Dead River. In the North Beach area adjacent to the WI-IL state line, the shoreline moved up to 1050 ft landward between 1872 and 1996 resulting in an average annual shoreline recession rate of up to 8.5 ft/yr. Because the North Beach shoreline position has been stabilized since 1987 due to sediment entrapment on the updrift side of NPM, a longer-term comparison for the 148-yr interval (1839-1987) prior to marina construction indicated shoreline recession rates of 10 ft/yr (Jennings, 1990). Sediment entrapment on the updrift side of NPM since 1987 has resulted in the 1996 shoreline lying in approximately the same location as the 1974 shoreline (Fig. 3-24). At NPM, shoreline position has been fixed since breakwater construction in 1988.

Between the marina and the Camp Logan headland, long-term trends clearly document that shoreline recession has been a persistent natural process in this area. Shoreline recession would naturally occur here whether or not the marina was constructed. However, shoreline recession rates have slowed since 1987 due to beach nourishment at IBSP/NU. Beach nourishment has resulted in the 1996 shoreline lying in approximately the same location as the 1974 shoreline in Fig. 3-24.

The 0.6 mile of shore immediately south of the Camp Logan headland illustrates high recession rates that are similar to those that occurred between the state line and Camp Logan. However, this 0.6 mile of shore underwent greater rates of shoreline recession during the 1974-1996 interval when the shoreline retreated as much as 350 ft, an average rate of almost 16 ft/yr (Fig. 3-24).

In the area from about 3000 ft north of Dead River to about 2000 ft south of Dead River, shoreline position has been relatively stable over the past 124 years (1872-1996). This stretch of shore lies along the transition zone that separates the northern erosional segment of the SL/WH coastal reach from the southern accretional segment.

Between the Dead River area and Waukegan Harbor, shoreline progradation and beach expansion have dominated. Geologic evidence indicates that accretion would have occurred in this area even if no coastal structures had been built (Chrzastowski and Trask, 1995). However, a major influence on shoreline stability and progradation along this shore has been sediment entrapment on the updrift sides of the jetties at the Commonwealth Edison Waukegan Generating Station and Waukegan Harbor. The greatest amount of change occurred on the north side of Waukegan Harbor where the shoreline moved as much as 2300 ft lakeward between 1872 and 1996. This resulted in an average annual rate of shoreline progradation up to 18.5 ft/yr.

Beach and Nearshore Profile Change

Data collection

Regional bathymetric profiling was conducted by ISGS during summer and autumn 1996 to update bathymetric data along the SL/WH coastal reach. The profile scheme relied on a series of 23 beach and nearshore profile lines spaced at 1700 to 1900 ft intervals along the shore. The scheme is shown in Appendix J. Nine primary lines (Range Lines 1-9) are at locations established by the Illinois Division of

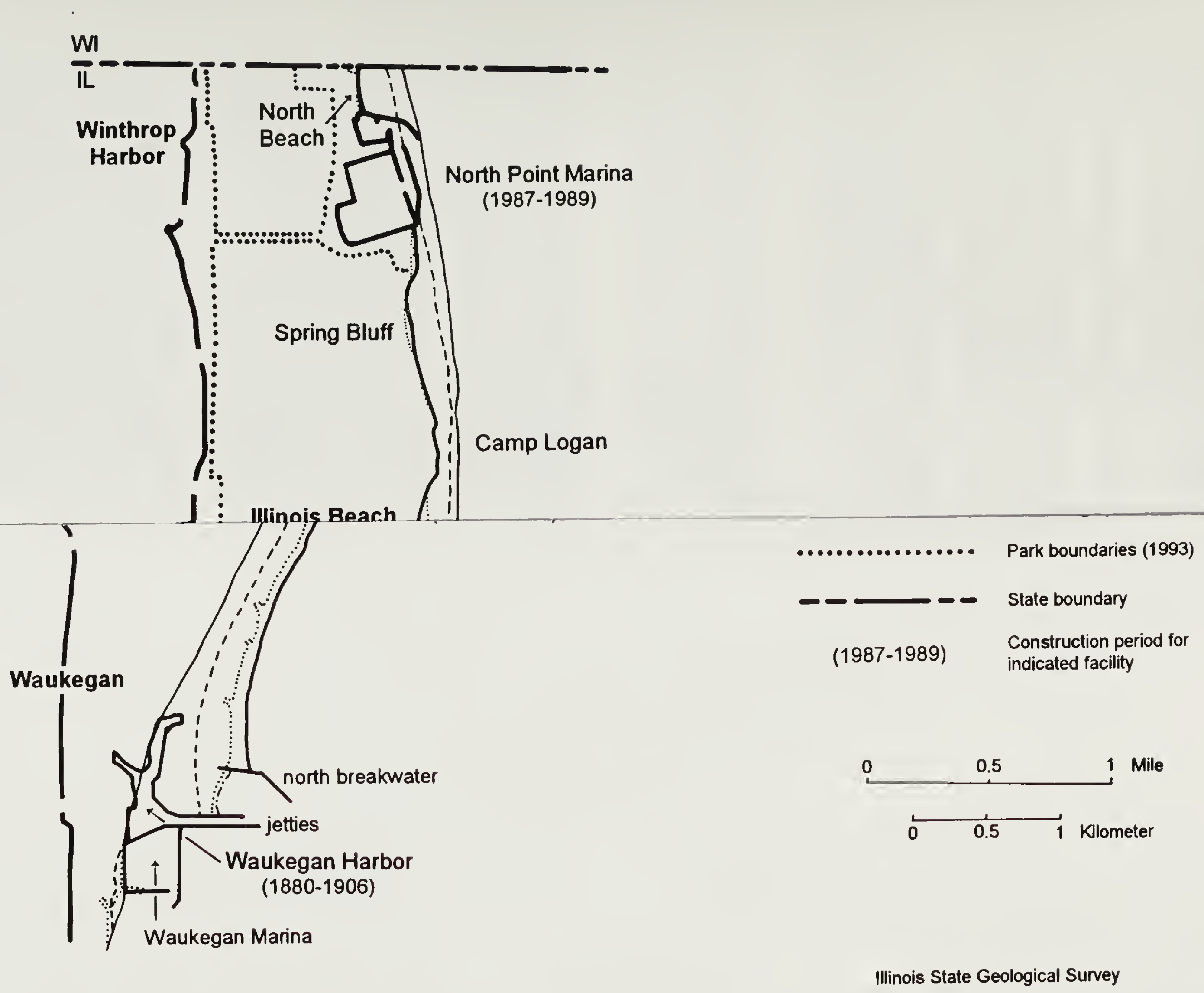


Figure 3-24 Shoreline positions within the SL

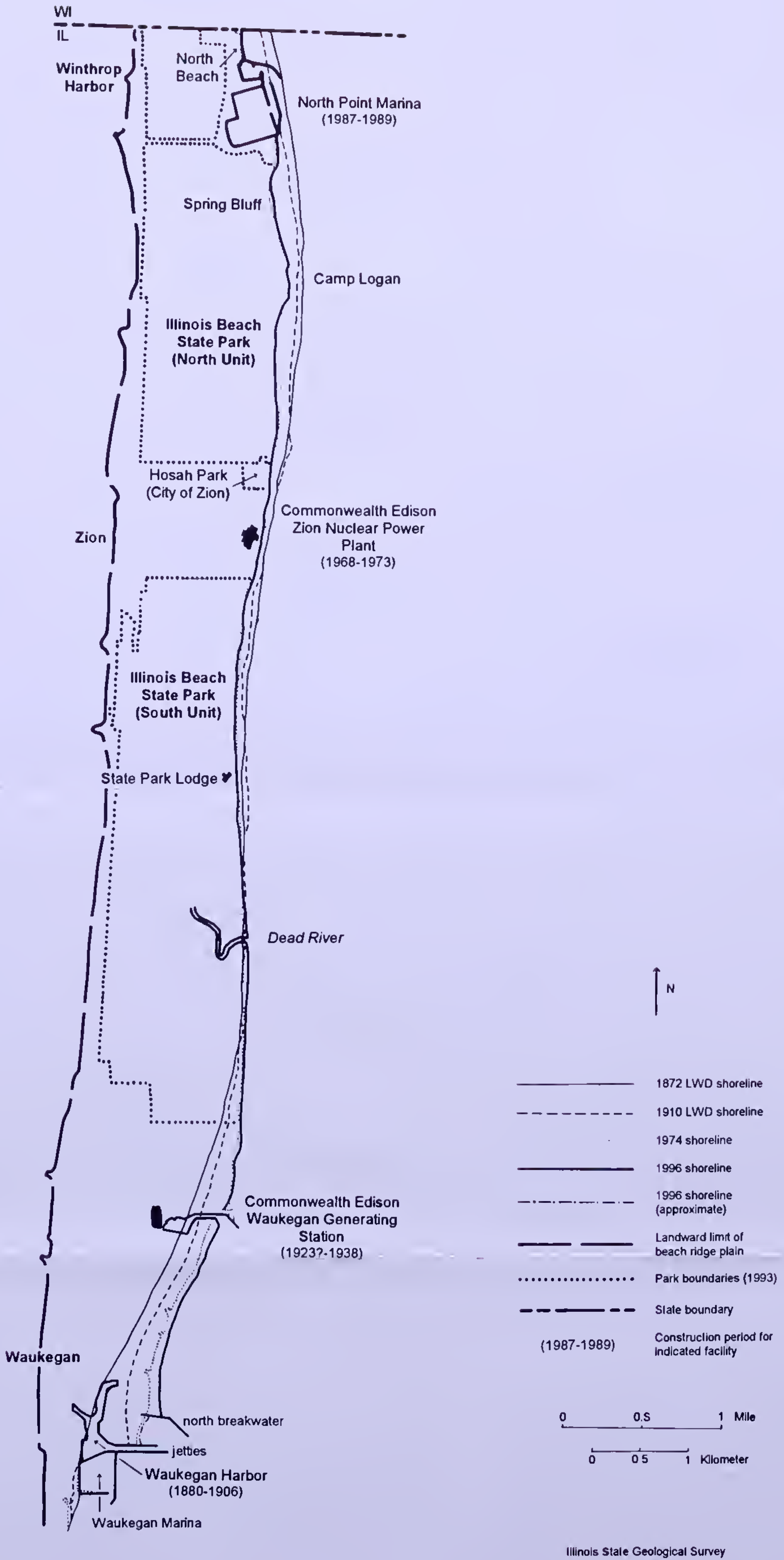


Figure 3-24 Shoreline positions within the SL/WH coastal reach (1872-1996). Shorelines are shown for the years 1872, 1910, 1974, and 1996.

Waterways in 1946 (see Appendix C). Fourteen new intermediate or "secondary" range lines (Appendix J; alpha-numeric line designations) were established by ISGS in 1996 to provide more detailed coverage. At all 23 line locations, 1996 bathymetric data were supplemented with data compiled from U.S. Lake Survey bathymetric surveys of 1872 and 1909-1911 (U.S. Lake Survey, 1872, 1873, 1909-1911, 1910-1911; U.S. Army Corps of Engineers, 1953) and from bathymetric surveys conducted by the ISGS in 1974 (Illinois State Geological Survey, 1975, 1988). For ease of reference, the U.S. Lake Survey 1909-1911 and 1910-1911 data are referred to as 1910 data in Fig. 3-25.

Selected profile comparisons (Figure 3-25)

Figure 3-25 compares 1872-1996 bathymetric profile data along Range Lines 1, 3, 5, 7 and 9 within the SL/WH coastal reach. The value of these profile comparisons is that they show changes at specific sites from a cross-sectional perspective. Lake-bottom erosion and accretion patterns derived from these data are used to generate maps of lake-bottom change in the following section on Lake-Bottom Change.

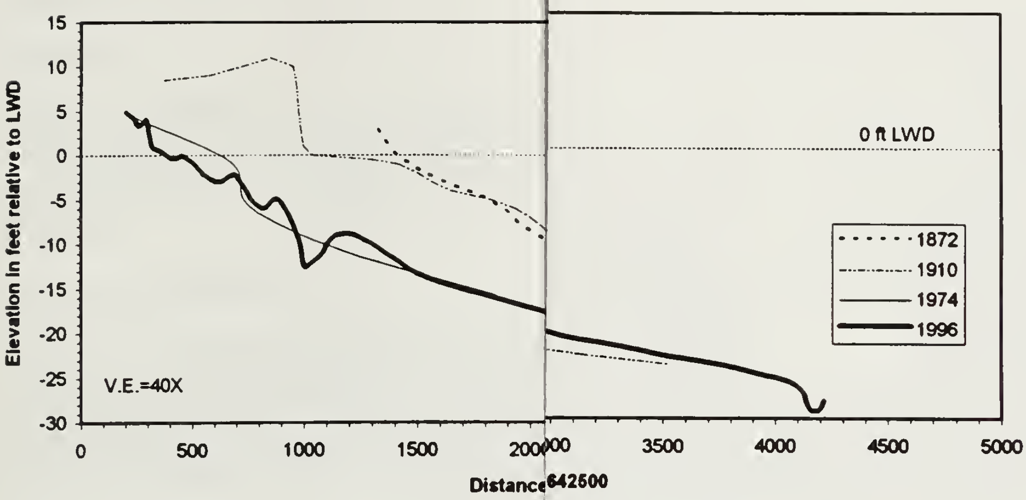
Range Line 1 (adjacent to the WI-IL state line) Profile data at this site show the most severe erosion documented within the SL/WH coastal reach between 1872 and 1996. The 1872-1996 record is dominated by net erosion. However, during the 1974-1996 interval, net accretion occurred in water depths less than 15 ft LWD. This is attributed to sediment entrapment on the updrift side of North Point Marina subsequent to 1987 (Fig. 3-25).

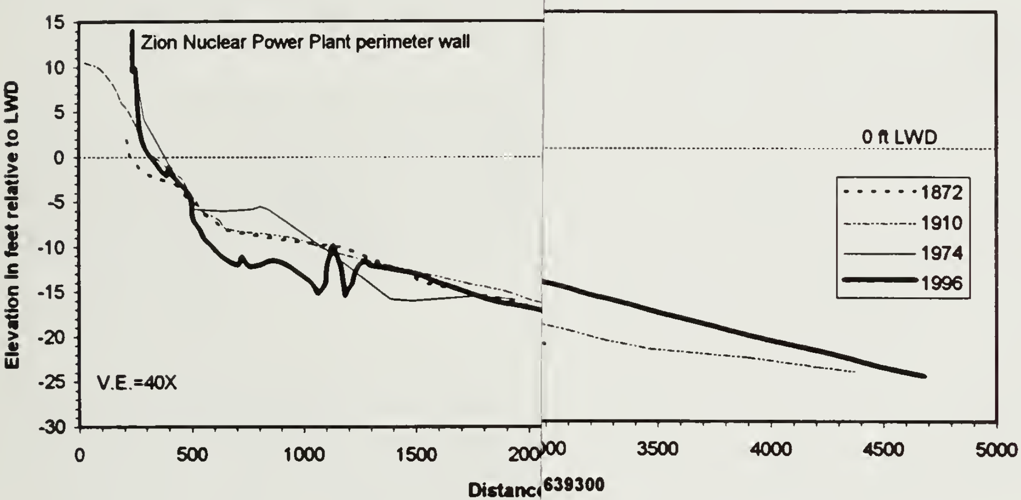
Range Line 3 (at Commonwealth Edison Zion Nuclear Power Plant) This site is located in the northern erosional segment of the SL/WH coastal reach and shows less pronounced erosion than that which occurred at Range Line 1. Placement of fill and shore defense for the power plant in the late 1960s accounts for a lakeward shift of the shallow nearshore profile for both 1974 and 1996. However, long-term erosion along this stretch of shore is illustrated by persistent lake-bottom deepening between 1872 and 1996.

Range Line 5 (approximately 2000 ft downdrift of Dead River) This site is located in the transition zone between the erosional northern segment and the accretional southern segment of the SL/WH coastal reach. In a general sense, the profile shows only minor erosional and accretional fluctuations about an apparent "steady-state" mean. Between 1872 and 1974, this profile was net erosional. Between 1974 and 1996, the profile switched to net accretional.

Range Line 7 (3000 ft updrift of Waukegan Harbor) This site is located within the historically accretional southern segment of the SL/WH coastal reach. The data provide a classic example of profile change at a net-progradational coast. The profile shows significant lake-bottom accretion between 1872 and 1996. However, the rate of coastal progradation slowed by about 50% between 1974 and 1996 when compared with rates of change prior to 1974 (Fig. 3-25). The 50% rate reduction may be expected if this updrift fillet area is beginning to approach an equilibrium state. Although accretion would have occurred if Waukegan Harbor had not been built, the significant lake-bottom accretion at this site is largely attributed to entrapment of littoral sediment on the updrift side of the jetties and outer breakwater at Waukegan Harbor.

Range Line 9 (500 ft downdrift of Waukegan Harbor) Lake-bottom accretion at this site between 1872 and 1996 amounted to only about 50% of that shown on Profile 7. The lesser amount of accretion at Profile 9 occurred because the breakwater, jetties, and entrance channel at Waukegan Harbor trapped a large part of the littoral sediment and reduced the volume capable of bypassing Waukegan Harbor. Most accretion on the south side of Waukegan Harbor occurred between 1872 and 1910 (Fig. 3-25). This can be attributed to sediment bypassing the harbor entrance prior to 1902-1906 when the jetties were extended and the north breakwater was constructed (Chrzastowski and Trask, 1995). In a general sense, a relatively stable nearshore profile has persisted since 1910 at Range Line 9. The 1996 profile records an accretional mound centered about 4100 ft offshore which is interpreted as lake-bottom accretion resulting from sediment naturally bypassing the harbor entrance.





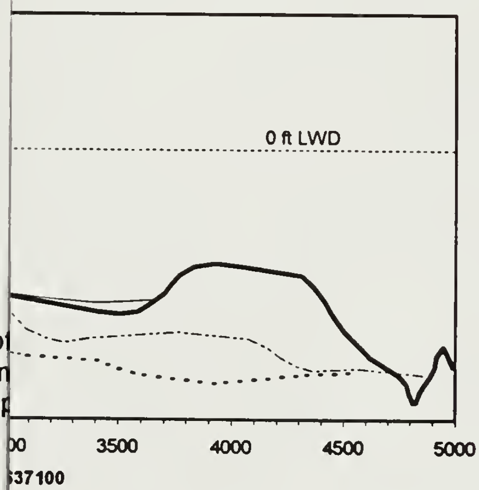
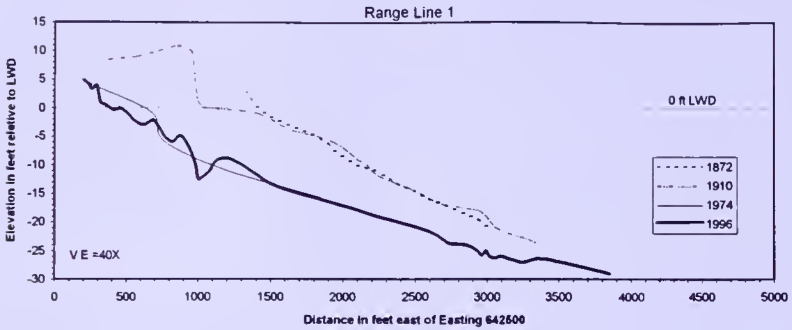
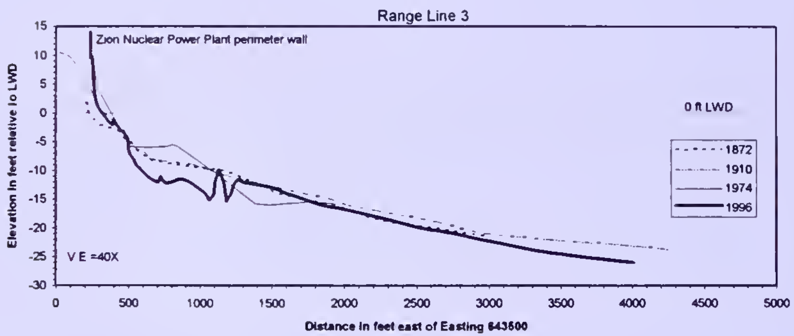
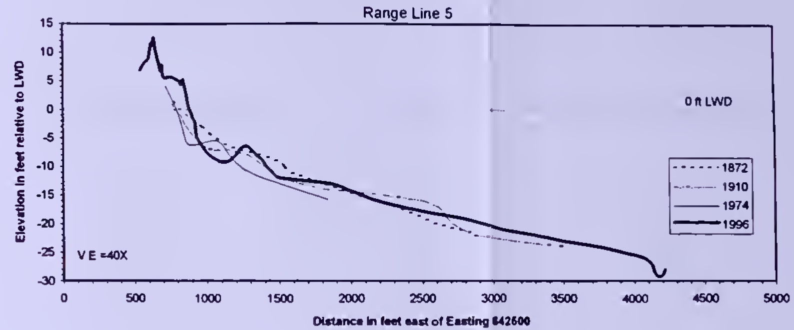
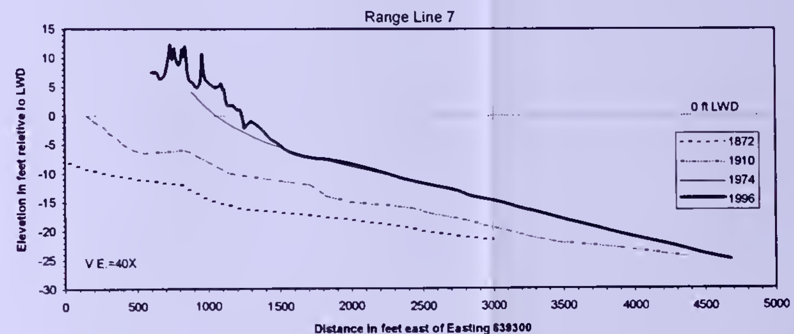


Figure 3-25 Comparative bathymetric pro
Profiles are shown for Range Lin
1910, 1974, and 1996 (see App









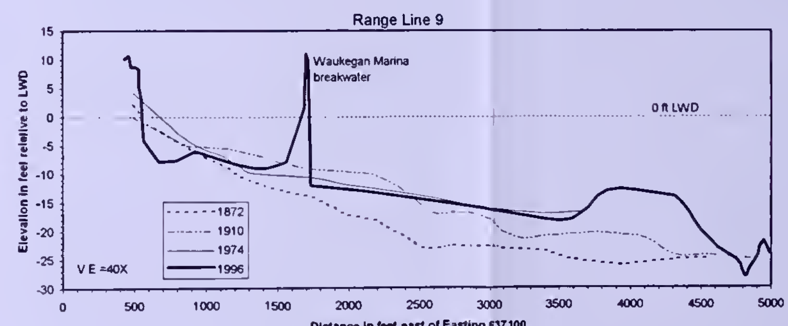


Figure 3-25 Comparative bathymetric profiles within the SL/WH coastal reach (1872-1996). Profiles are shown for Range Lines 1, 3, 5, 7, and 9 and show bathymetry during 1872, 1910, 1974, and 1996 (see Appendix J for profile locations).

Lake-Bottom Change

General

Historical bathymetric data for the SL/WH coastal reach and the range-line profile data collected by the ISGS in 1996 were used to produce maps that show lake-bottom change for three time intervals that span 124 years of record. These three intervals are 1872 to 1910 (38 years), 1910 to 1974 (64 years), and 1974 to 1996 (22 years). Figures 3-26, 3-27, and 3-28 show lake-bottom change during these three intervals.

1872-1910 (Figure 3-26)

Framework This 38-year interval includes the time of major construction of Waukegan Harbor (1902-1906) when the jetties were built to their present length and the outer part of the north breakwater was built as an offshore structure. Other than this development at the south end of the coastal reach, the remaining shore was in a natural state. No inputs from beach nourishment are documented, although dredging occurred at Waukegan Harbor between 1889 and 1910 (Appendix K).

Accretion Accretion occurred primarily along the 2.5 miles of shore between the south end of IBSP/SU and Waukegan Harbor. Accretion generally ranged from 1 to 7 ft, with maximum accretion of just over 13 ft occurring on the updrift side of the north jetty at Waukegan Harbor. Most of this latter accretion was a response to construction of the harbor jetties between 1880 and 1906. An additional area of accretion (1 to 3 ft) occurred in the nearshore at the present site of Hosah Park.

Erosion Two principal erosion areas are illustrated in Fig. 3-26. The first extended from the WI-IL state line southward for two miles. Erosion generally ranged from 1 to 3 ft and was greatest near the present site of North Point Marina where just over 6 ft of lake-bottom erosion was documented. The second main erosion area extended along the central and southern shore of IBSP/SU to the present site of Waukegan Generating Station. Erosion generally ranged from 1 to 3 ft, with a maximum of just over 4 ft occurring in the nearshore just south of the mouth of Dead River.

1910-1974 (Figure 3-27)

Framework This 64-year interval encompasses the period of most widespread coastal development along the SL/WH coastal reach. The residential community of Spring Bluff developed just south of the state line and a variety of shore-defense structures were built along the lakefront properties. Shore defense structures were also built at the Camp Logan U.S. Army facilities. The Zion Nuclear Power Plant was constructed and resulted in localized filling of the shallow nearshore as well as construction of a temporary pier used while building the power plant. The jetty and cooling-water channel were constructed at Waukegan Generating Station, and a shore attachment was added to the north breakwater at Waukegan Harbor. No inputs of sediment from beach nourishment are documented. Dredging continued at Waukegan Harbor and began at Commonwealth Edison Waukegan Generating Station (Appendix K).

Accretion Accretion occurred primarily along the 3.5 miles of shore between Dead River and Waukegan Harbor. Accretion generally ranged from 1 to 11 ft. Maximum accretion of just over 15 ft occurred just south of the jetty at Waukegan Generating Station. Most of the latter accretion probably occurred subsequent to construction of the jetty between 1928 and 1938. Accretion of just over 9 ft occurred on the updrift side of the shore attachment for the Waukegan Harbor north breakwater (Fig. 3-27).

Erosion Erosion dominated between the WI-IL state line and Dead River. Erosion was most pervasive along the IBSP/NU and present NPM nearshore where lake-bottom erosion generally ranged from 1 to 7 ft (Fig. 3-27). The most severe erosion (11 ft) was focussed in the vicinity of present-day NPM. Further south, between the Zion Nuclear Power Plant and Dead River, nearshore erosion generally ranged from 1 to 3 ft (Fig. 3-27).

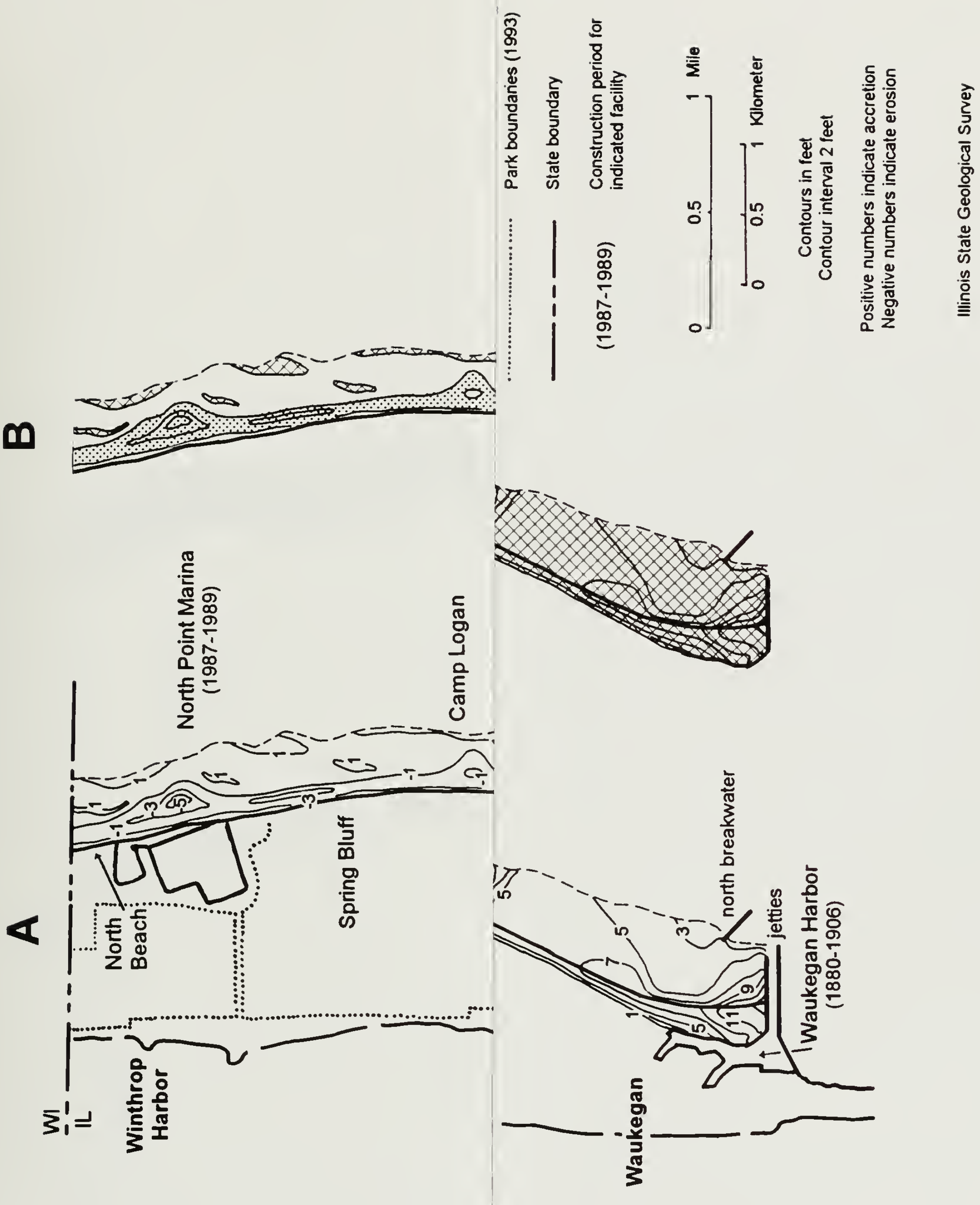


Figure 3-26 1872-1910 lake-bottom change in contour format (A) and shade

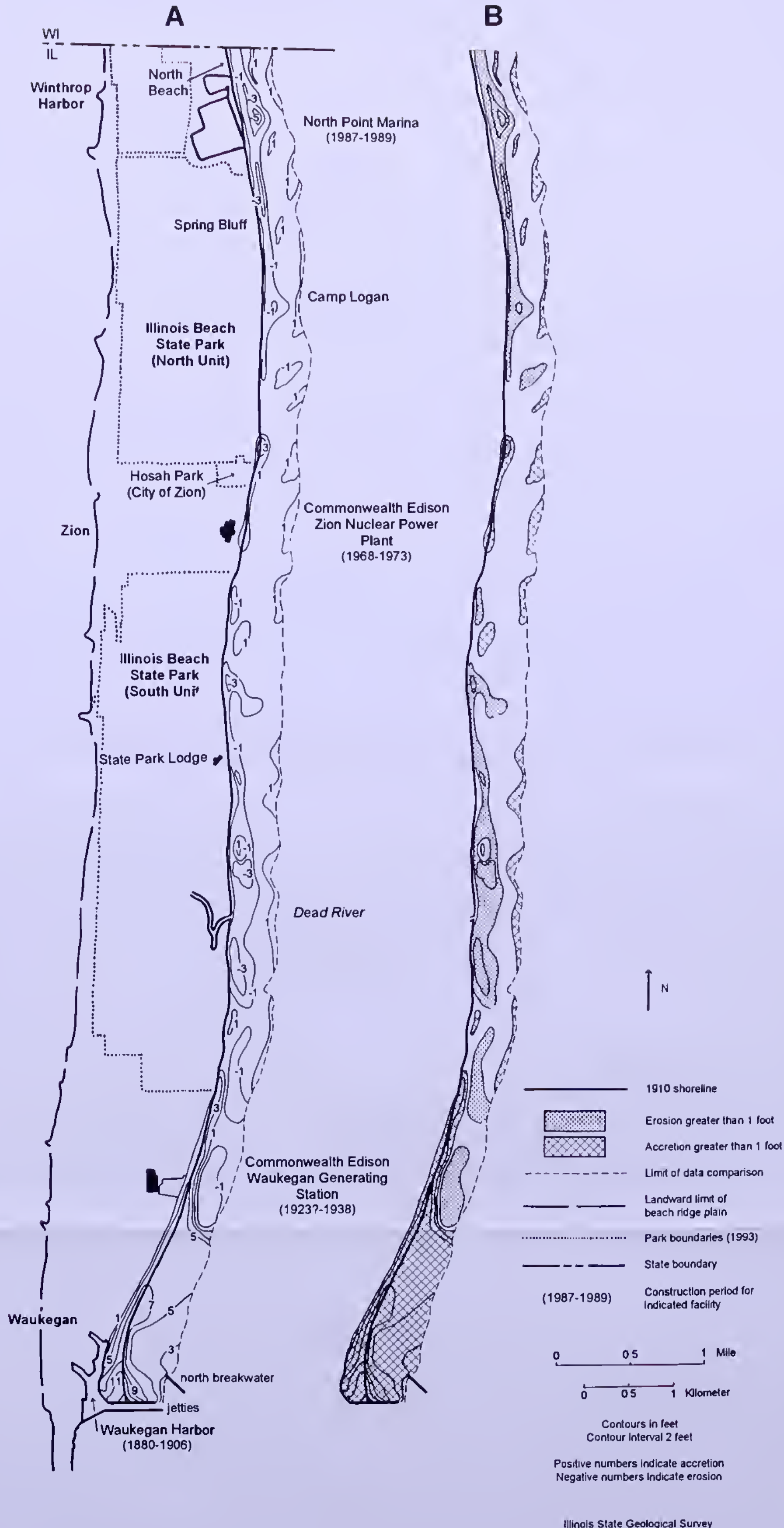


Figure 3-26 1872-1910 lake-bottom change along the SL/WH coastal reach. The 1910 shoreline is shown. Lake-bottom changes are shown in contour format (A) and shaded-area format (B).

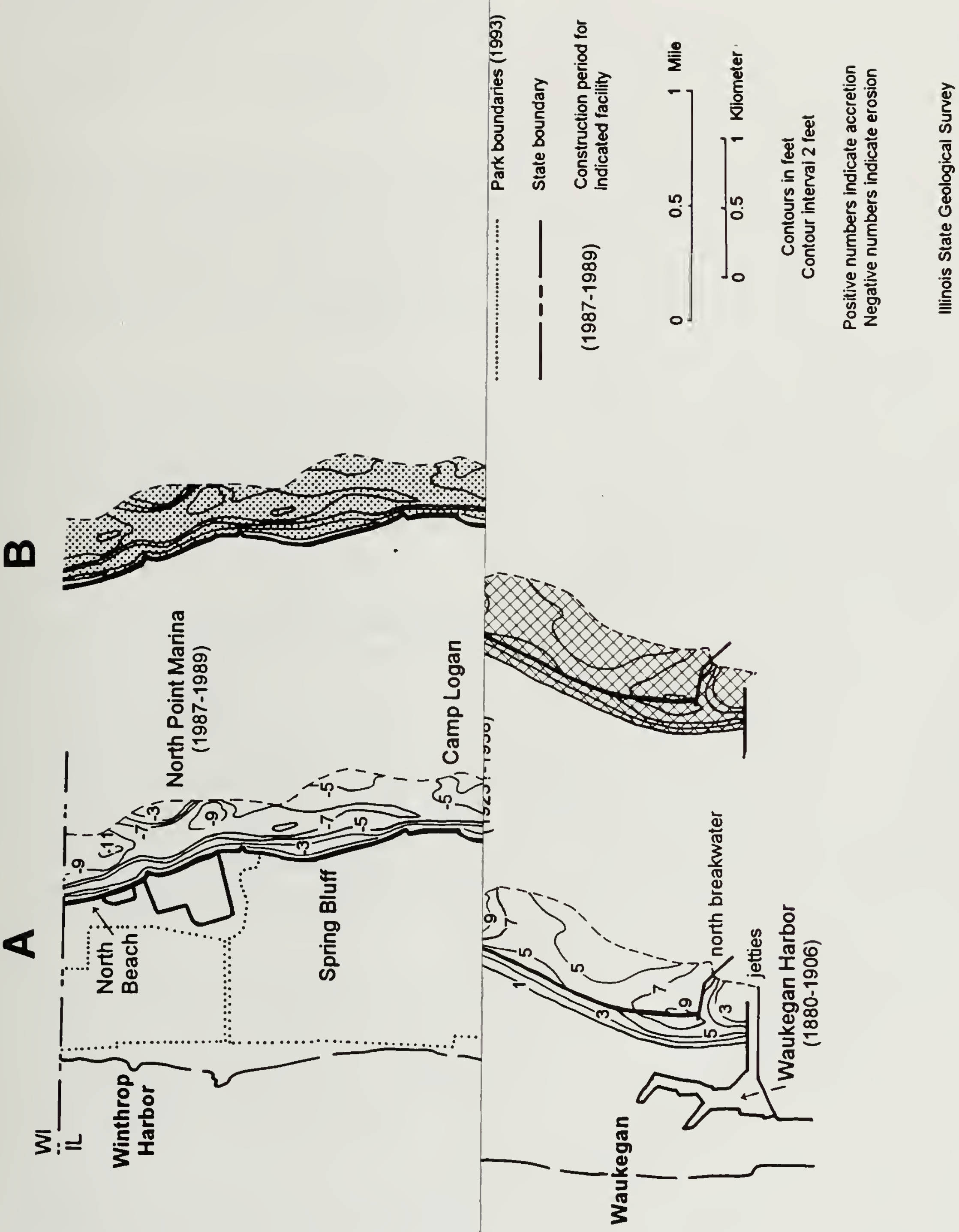


Figure 3-27 1910-1974 lake-bottom change in contour format (A) and shade

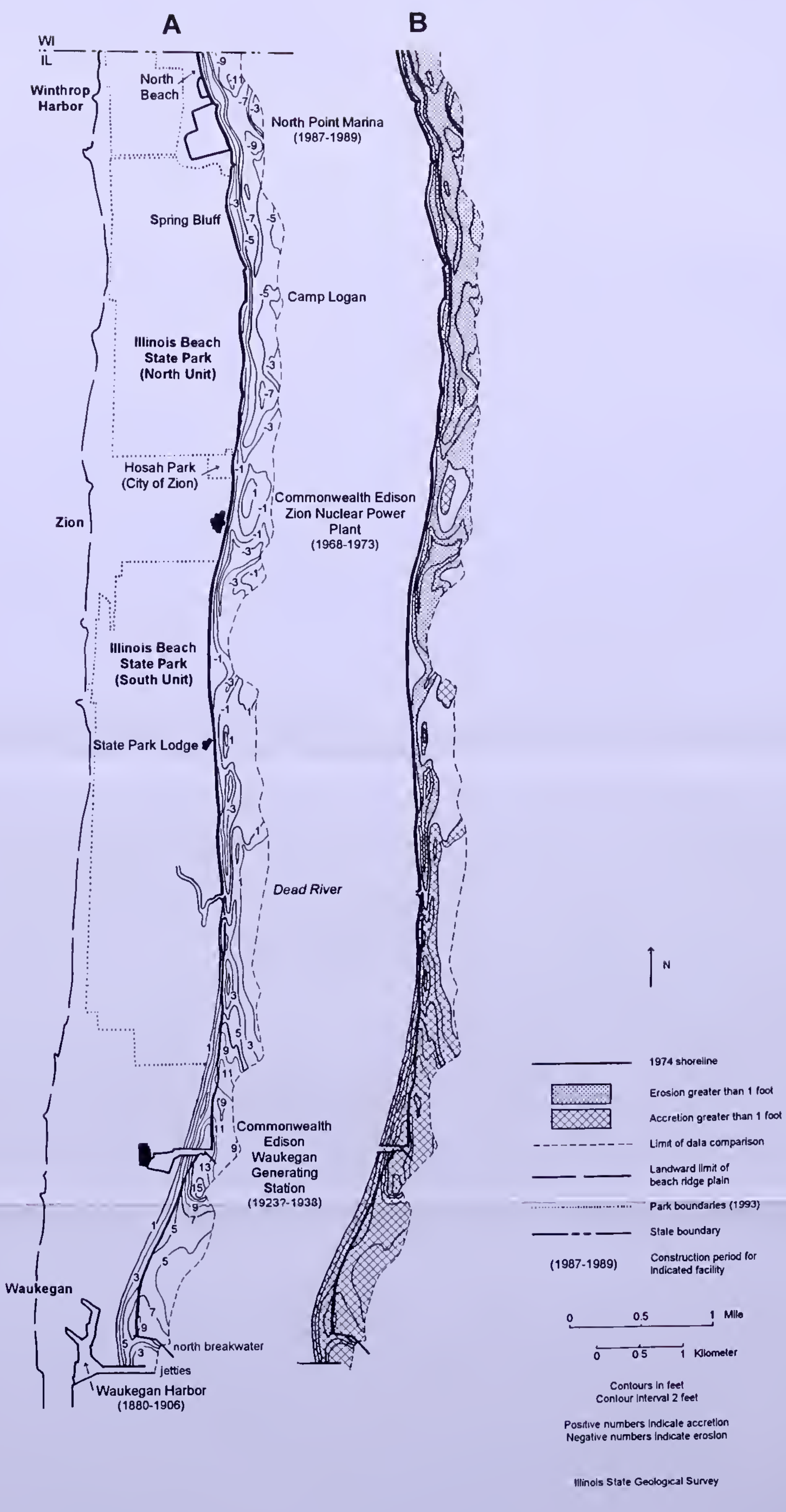


Figure 3-27 1910-1974 lake-bottom change along the SL/WH coastal reach. The 1974 shoreline is shown. Lake-bottom changes are shown in contour format (A) and shaded-area format (B).

1974-1996 (Figure 3-28)

Framework This 22-year interval includes the construction of North Point Marina (1987-1989) and the associated downdrift discharge and dispersion of sand dredged from the marina basin. The latter ten years of this interval include the first major beach nourishment at IBSP/NU. Dredging continued at Waukegan Harbor and at the Commonwealth Edison Waukegan Generating Station (Appendix K). Some of the material dredged from the latter site was backpassed to updrift beach-nourishment sites in the IBSP North and South Units and thus initiated sand recycling within the coastal reach.

Accretion Accretion occurred in three principal areas. (1) Most accretion again occurred along the 3.5 miles of shore between Dead River and Waukegan Harbor. Maximum accretion of almost 7 ft occurred on the north side of the Waukegan Harbor breakwater. (2) The second principal accretional area occurred on the north (updrift) side of North Point Marina where the lake-bottom shallowed by 1 to 2 ft. (Fig. 3-28). This was a reversal in the net erosional trend documented in this area between 1872 and 1974. Data indicate that erosion persisted at this site up until the time construction began on the NPM north breakwater in 1987. (3) The third accretional area was located just downdrift of the Zion Nuclear Power Plant at the north end of IBSP/NU. Up to 5 ft of accretion occurred in this area.

Erosion Erosion dominated from near the NPM entrance southward to the mouth of Dead River. Erosion generally ranged from 1 to 5 ft between the marina and the Zion Nuclear Power Plant (Fig. 3-28). The most severe erosion was focussed at Spring Bluff where maximum lake-bottom erosion was just over 8 ft. This occurred despite the input of several hundred thousand cubic yards of sand derived from construction of the marina basin and from beach nourishment at IBSP/NU subsequent to 1987. Between the north end of IBSP/SU and Dead River, nearshore erosion generally ranged from 1 to 3 ft (Fig. 3-28).

Volumetric summary (Table 3-8)

Figures 3-26 through 3-28 show the spatial distribution of accretion and erosion along the SL/WH coastal reach. Volume changes determined from these isopach maps are summarized in Table 3-8 and discussed below.

1872-1910 During the 1872-1910 interval, the net change for the coastal reach was accretion of 68,400 cu yds/yr (Table 3-8). Accretion occurred primarily in nearshore areas to the south of present-day DNR property, while erosion occurred primarily in nearshore areas adjacent to present-day DNR property. The construction of Waukegan Harbor had a significant impact on the net volume change for the coastal reach. Nearshore accretion between the south end of IBSP/SU and the updrift side of Waukegan Harbor, combined with localized accretion elsewhere along the coastal reach, was sufficient to outweigh nearshore erosion that was focussed along the present-day NPM, IBSP/NU, and central IBSP/SU shore. Accretion exceeded erosion by a factor of about 3:1 (Table 3-8).

1910-1974 During the 1910-1974 interval, the net change for the entire coastal reach was accretion of 25,200 cu yds/yr, or only about 40% of the annualized rate between 1872 and 1910 (Table 3-8). Most accretion occurred in nearshore areas south of Dead River and was greatest at the updrift side of Waukegan Harbor and at the jetty at Waukegan Generating Station. Erosion dominated in nearshore areas adjacent to present-day DNR property at NPM, IBSP/NU and the north end of IBSP/SU. Table 3-8 indicates that while annualized accretion volumes remained similar to the 1872-1910 interval, annualized erosion volumes increased by a factor of 2.5.

1974-1996 During the 1974-1996 interval, a major change occurred along the SL/WH coastal reach. The nearshore changed from being net accretional (prior to 1974) to net erosional, losing 64,900 cu yds/yr (Table 3-8). Again, most accretion occurred in nearshore areas south of Dead River and was greatest at the updrift side of Waukegan Harbor and updrift of the jetty at Waukegan Generating Station. However, annualized accretion rates were only about 50% of those documented prior to 1974 (Table 3-8). This may be related to the entrapment areas at Waukegan Generating Station and Waukegan Harbor approaching

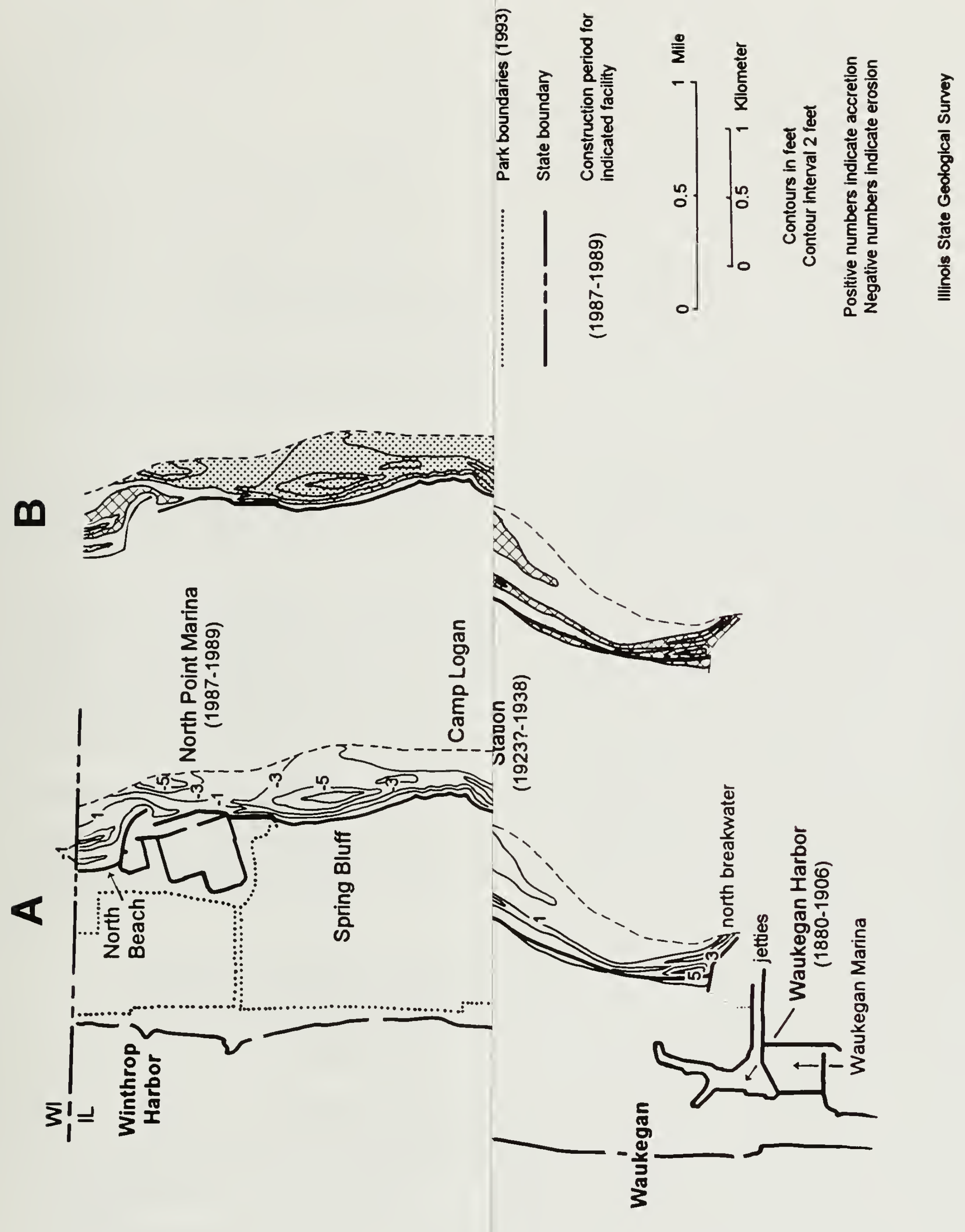


Figure 3-28 1974-1996 lake-bottom change
in contour format (A) and shade

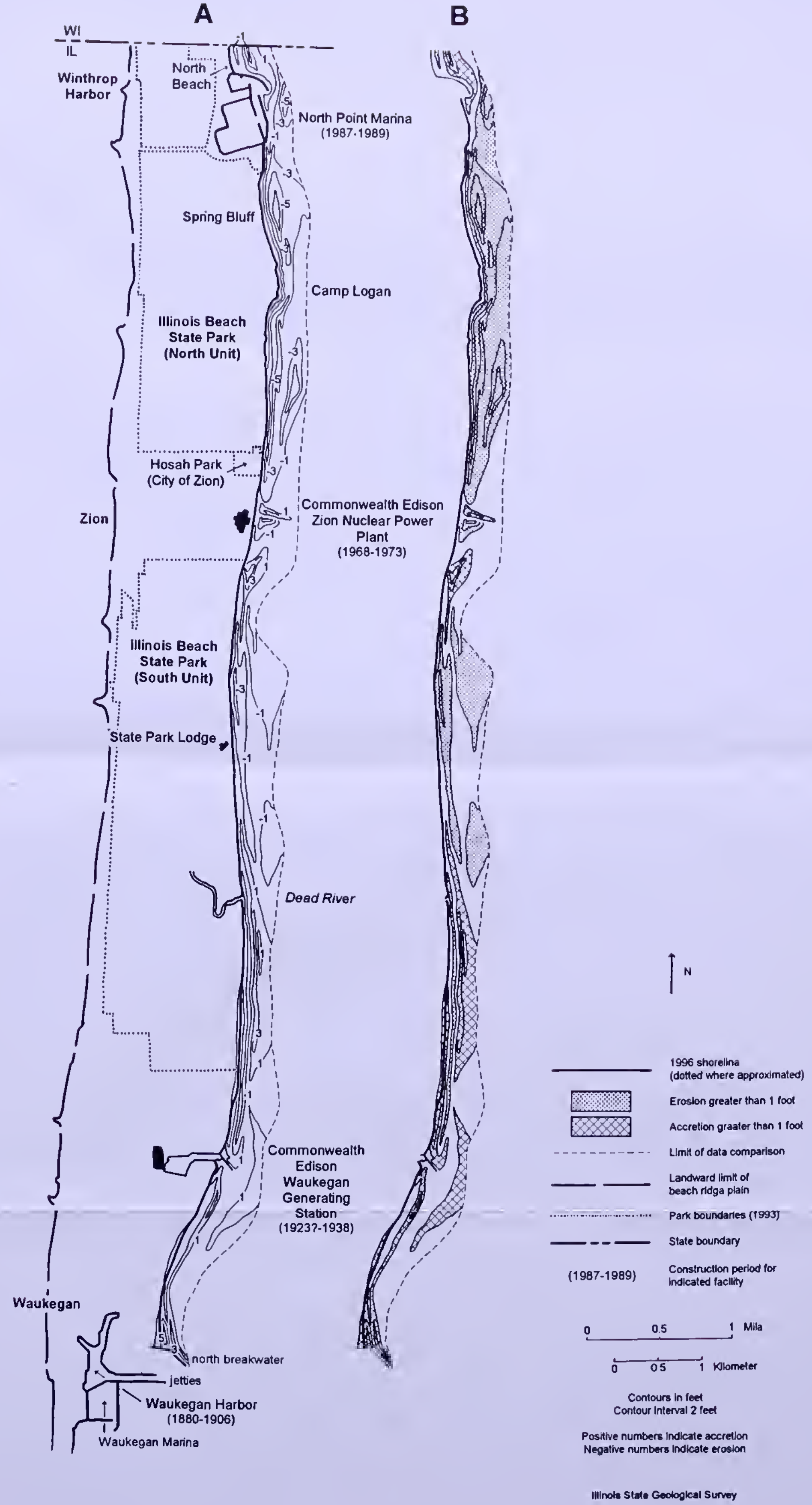


Figure 3-28 1974-1996 lake-bottom change along the SL/WH coastal reach. The 1996 shoreline is shown. Lake-bottom changes are shown in contour format (A) and shaded-area format (B).

Table 3-8 Nearshore net-change volumes for the SL/WH coastal reach (1872-1996)[1]			
	1872-1910	1910-1974	1974-1996
Accretion (+) (cu yds)[2]	3,812,600	6,706,000	1,138,500
Erosion (-) (cu yds)[2]	1,211,600	5,093,100	2,567,000
Net change (cu yds)[2]	+2,601,000	+1,612,900	-1,428,500
Annualized accretion (+) (cu yds/yr)[3]	100,300	104,800	51,700
Annualized erosion (-) (cu yds/yr)[3]	31,900	79,600	116,600
Annualized net change (cu yds/yr)[3]	+68,400	+25,200	-64,900

[1] All volumes are computed for lake-bottom elevation changes in excess of 1 ft and occurring below Low Water Datum (LWD) and exclude the effects of beach nourishment and dredging (see Appendix K). Volumes are rounded to the nearest 100 cu yds.
[2] Total volume for the 38-yr (1872-1910), 64-yr (1910-1974), or 22-yr (1974-1996) interval indicated.
[3] Annualized volumes were obtained by dividing the total volume for any given interval by the number of years in that interval.

an equilibrium state. A significant change occurred adjacent to the WI-IL state line where net accretion occurred in the North Beach area on the updrift side of the NPM north breakwater. This marked a significant change from long-term erosional trends at this site. Erosion continued to dominate in nearshore areas adjacent to DNR property between the entrance to NPM and Dead River.

While annualized accretion along the coastal reach slowed, annualized erosion continued to increase (Table 3-8). Erosion became 1.5 times greater than that documented during 1910-1974 and 3.6 times greater than that during 1872-1910. As a result, erosion outweighed accretion by almost 2:1 during 1974-1996, a marked reversal from earlier, pre-1974, net-accretional trends. Most erosion remained focussed in the same general areas in which it occurred prior to 1974 (Figs. 3-27, 3-28). This illustrates the increasing severity of the erosion along the northern part of the coastal reach despite this area having received a major input of sand from beach nourishment subsequent to 1987.

Implications of 1872-1996 Shoreline and Lake-Bottom Change

Between 1872 and 1996, the SL/WH coastal reach maintained a persistent general trend of increasing erosion and decreasing accretion. This has several important implications for the coastal reach and for specific localities within the reach:

- The progressive increase in annualized erosion rates between 1872 and 1996 coupled with a significant (50%) decrease in annualized accretion rates during 1974-1996 caused the system to switch from being net accretional during 1872-1974 to being net erosional during 1974-1996. This long-term trend, and the switch to net erosional conditions, suggests that erosion will persist within the SL/WH coastal reach.

- The decrease in annualized accretion rates during 1974-1996 affected primarily the southern part of the SL/WH coastal reach between Dead River and Waukegan Harbor. It is anticipated that the shoreline in this area will continue to be stable to progradational and that the nearshore will continue to be net accretional.

- Net accretion occurred on the updrift side of North Point Marina between 1974 and 1996 due to partial entrapment of littoral sand crossing the WI-IL state line. This net accretion has mitigated the historical shoreline recession, land loss, and lake-bottom erosion that existed at this site prior

to 1974.

- The 124-year record of shoreline and lake-bottom change along the SL/WH coastal reach suggests that the greatest erosion will continue to be focussed in the area between the WI-IL state line and the Camp Logan headland.

- The 124-year record also indicates that the northern part of the coastal reach has become increasingly important as a source area for sediment supply to areas further south. Between 1974 and 1996, all of the accretion along the southern segment of the coastal reach could be accounted for through erosion along the northern segment of the reach.

Year-2 Littoral Sediment Budget

General statement

Earlier sections of this report documented that the 1995-1996 net annualized erosion rate along the northernmost 1.5 miles of the SL/WH coastal reach was almost six times greater than the annualized erosion rate for the 1992-1995 interval. This illustrates that annual rates of lake-bottom change can be highly variable along this particular part of the study area and, potentially, throughout the entire study area. Such annual variations are caused primarily by fluctuations in sediment supply, wave climate, and lake level. While annual data are critical for documentation of short-term changes, analysis of data collected over several years permits averaging across the annual variability to determine longer-term trends that can be used for predictive purposes.

The Year-2 littoral sediment budget is presented below. It follows the procedure established in Year-1 by quantifying the volumes of littoral sediment moving southward past specific geographic reference points within the SL/WH coastal reach. These volumes are dependent on lake-bottom and coastal changes occurring in adjacent updrift and downdrift areas. Four specific reference points are used:

WI-IL State Line — This marks the updrift end of the SL/WH coastal reach. Sediment moving southward across the state line is derived from erosion along the Wisconsin shore. The volume of sediment crossing the state line is the principal source of new sediment to the SL/WH coastal reach. A minimum estimate of that volume is obtained by summing net-accretion volumes in areas of sediment entrapment near the north (updrift) side of North Point Marina.

Camp Logan headland — The Camp Logan headland is a subtle promontory at Camp Logan that has been stabilized by several generations of shore defense. The headland is a useful reference point for monitoring littoral sediment transport because substantial data exist for beach and nearshore erosion between the marina and the headland. Net erosion volumes from the updrift beach and nearshore provide an estimate of the volume of littoral sediment moving south past Camp Logan.

South end of IBSP/SU — The south end of IBSP/SU is used as reference point to highlight the of rates of littoral sediment transport at the south end of DNR property at IBSP. Littoral sediment moving past this point is partly trapped at either Waukegan Generating Station or Waukegan Harbor further downdrift.

Waukegan Generating Station — Dredging at Waukegan Generating Station makes this site a useful observation point because the material dredged had to have moved southward in the nearshore past IBSP/SU. Dredge volumes can be used, in conjunction with dredge data from Waukegan Harbor, to estimate rates of littoral sediment transport at the south end of IBSP/SU.

Waukegan Harbor	The harbor entrance forms the south end of the SL/WH coastal reach. Littoral sediment moving southward out of the coastal reach is partly trapped at Waukegan Harbor. Dredge data from the harbor entrance can be used in conjunction with data from Waukegan Generating Station to estimate rates of littoral sediment transport at the south end of IBSP/SU. Dredge data solely from Waukegan Harbor can also be used to estimate littoral sediment transport rates at the downdrift end of the SL/WH coastal reach.

The Year-2 littoral sediment budget is an interim budget that represents an update of the Year-1 budget and incorporates results from both Year-1 and Year-2 data collection. Table 3-9 summarizes the volume of littoral sediment transport at the five reference points listed above using a three-year average (1992-1995), the most recent annual change (1995-1996), and a four-year average (1992-1996). The following budget discussion focuses primarily on the four-year (1992-1996) data. As of this annual report, the four-year average may be the best current approximation of littoral transport rates along the SL/WH coastal reach. However, subsequent annual reports will continue to refine the sediment budget as annual bathymetric coverage of the entire coastal reach is continued.

Minimum sediment volume crossing the WI-IL state line (Figure 3-29)

In the Year-1 study, the annual volume of littoral sediment crossing the state line was computed by summing net accretion volumes derived from maps of 1992-1995 lake-bottom change at three entrapment areas just south of the state line. The entrapment areas were the North Beach / north breakwater nearshore, the marina entrance, and an accretional lobe lakeward of the marina entrance.

Repeating this procedure but incorporating the 1996 bathymetric data is problematic for three reasons. First, net erosion occurred during 1995-1996 in the North Beach / north breakwater nearshore. This means that a net accretion volume could not be utilized to estimate input across the state line. Second, in the marina entrance, dredging occurred in 1995-1996 and thus any entrapment of sediment was masked by the net loss of sediment due to that dredging. Third, while an accretional lobe again occurred lakeward of the marina entrance, the morphology and size of the lobe suggest that up to 90% of its volume may have been derived from erosion in the North Beach / north breakwater nearshore and was not directly related to sediment input from across the WI-IL state line.

Considering these factors, it is not possible to compute a volume crossing the state line based on 1995-1996 bathymetric comparisons alone. It is reasonable to assume that sediment did cross the state line. However, if the erosional trends in the North Beach / north breakwater nearshore are attributed to a change in sediment supply, the volume of littoral sediment crossing the state line in 1995-1996 may have been markedly reduced compared to previous years. Subsequent years of annual bathymetric comparisons will provide a better framework from which to understand this new apparent trend.

The 1992-1995 net accretion in the three entrapment areas totaled 42,800 cu yds. This indicates that, on average, at least 14,200 cu yds/yr of sediment crossed the state line between 1992 and 1995 (Table 3-9; Chrzastowski *et al.*, 1996). This is a minimum estimate because the volume that bypassed the marina is unknown. For 1995-1996, it can only be concluded that the average volume of littoral sediment crossing the state line was greater than zero and may have been as great as 14,200 cu yds. A zero input is unlikely because of the requirement for 1996 dredging in the entrance channel to Prairie Harbor Yacht Club, WI. Accretion in the entrance channel is consistent with a sediment supply from the north. Since the entrance channel is unlikely to be a 100%-efficient trap for littoral sediment, a component of the littoral sediment would have bypassed the channel and crossed the WI-IL state line. Development of a new nearshore bar in the North Beach / north breakwater nearshore during 1995-1996 also attests to an input of littoral sediment from the Wisconsin nearshore.

A four-year (1992-1996) average rate of littoral sediment transport can be obtained if the 1992-1995 three-year accretion (42,800 cu yds) is simply averaged over four years (1992-1996). This assumes that the

1995-1996 input was zero and indicates that the average volume of littoral sediment crossing the state line between 1992 and 1996 was 10,700 cu yds/yr (Table 3-9). This is a conservative estimate and agrees to within 25% of the 1992-1995 average.

Minimum littoral sediment transport rate at the Camp Logan headland

During 1995-1996, net nearshore erosion totaled 21,100 cu yds in the North Beach / north breakwater nearshore (Table 3-1), 20,000 cu yds in the south breakwater nearshore (Table 3-5), 29,700 cu yds in the south parking area nearshore (Table 3-6), and 65,200 cu yds in the Spring Bluff nearshore (Table 3-7). This is a total of 136,000 cu yds of sand derived solely from nearshore erosion (Table 2-1).

Three significant sediment inputs occurred during the 1995-1996 interval. (1) Loss of back-fill material from erosional embayments at the NPM south parking area in late 1995 and 1996 contributed about 20,000 cu yds of sand to the nearshore. Approximately 7,000 cu yds of this volume had been transferred to the nearshore prior to 1996 ISGS bathymetric-data collection. (2) Dredging at NPM, and placement of the dredged material at the south side of the marina, contributed an additional 24,000 cu yds of sand to the nearshore. It is conservatively assumed that 50% (12,000 cu yds) of this volume was added to the nearshore prior to 1996 ISGS bathymetric-data collection. (3) Beach nourishment at IBSP/NU in July 1995 and in December 1995-January 1996 contributed about 46,000 cu yds of sand to the nearshore (Appendix G). Combined, these three inputs contributed 65,000 cu yds of sand to the nearshore north of Camp Logan.

Summing the contributions from nearshore erosion (136,000 cu yds), from backfill erosion and dredge discharge (19,000 cu yds), and from beach nourishment (46,000 cu yds), yields a 1995-1996 net erosion volume of 201,000 cu yds (Table 3-9). This is the minimum volume of littoral sediment that moved southward past the Camp Logan headland between 1995 and 1996.

Between 1992 and 1995, net lake-bottom erosion between the marina entrance and the Camp Logan headland totaled 113,400 cu yds (Chrzastowski *et al.*, 1996). During 1994, 32,000 cu yds of beach nourishment were added to the IBSP/NU beach-nourishment site (Appendix G). It is conservatively assumed that 50% (16,000 cu yds) of this volume had been transferred to the nearshore by the time of Year-1 bathymetric data collection in summer 1995. Summing these two volumes (129,400 cu yds) indicates that at least 43,100 cu yds/yr of sand moved southward past the Camp Logan headland between 1992 and 1995 (Table 3-9).

To obtain a four-year (1992-1996) average rate of littoral sediment transport at the Camp Logan headland, the 1995-1996 data were merged with the 1992-1995 data. Summing the 1995-1996 total erosion volume of 201,000 cu yds with the 1992-1995 total erosion volume (129,400 cu yds) yields a volume of 330,400 cu yds. This is an average four-year net erosion rate of 82,600 cu yds/yr for the nearshore between the state line and Camp Logan (Table 3-9). This value is a minimum estimate of the average annual volume of littoral sediment that moved southward past the Camp Logan headland between 1992 and 1996.

Minimum littoral sediment transport rate at the south end of IBSP/SU

Dredge volumes from the Commonwealth Edison Waukegan Generating Station and Waukegan Harbor can be used to determine an estimate of the volume of littoral sediment in transport at the south end of IBSP/SU. In using these dredge data, a long-term (decade-scale) average is advantageous because it minimizes variability caused by annual to biennial fluctuations in the volume and frequency of material dredged. Conversely, it is also beneficial to utilize dredge volumes exclusively from the 1990s as they may be more representative of the dredge volumes that are currently required to maintain design depths at the dredge sites. Recent data may also reflect recent changes in dredge volumes required to compensate for increased sediment input at the dredge sites due to the arrival of sand eroded from updrift beach-nourishment sites. Post-1990 dredge data are utilized in the following paragraphs. The method of computation is summarized in Appendix K.

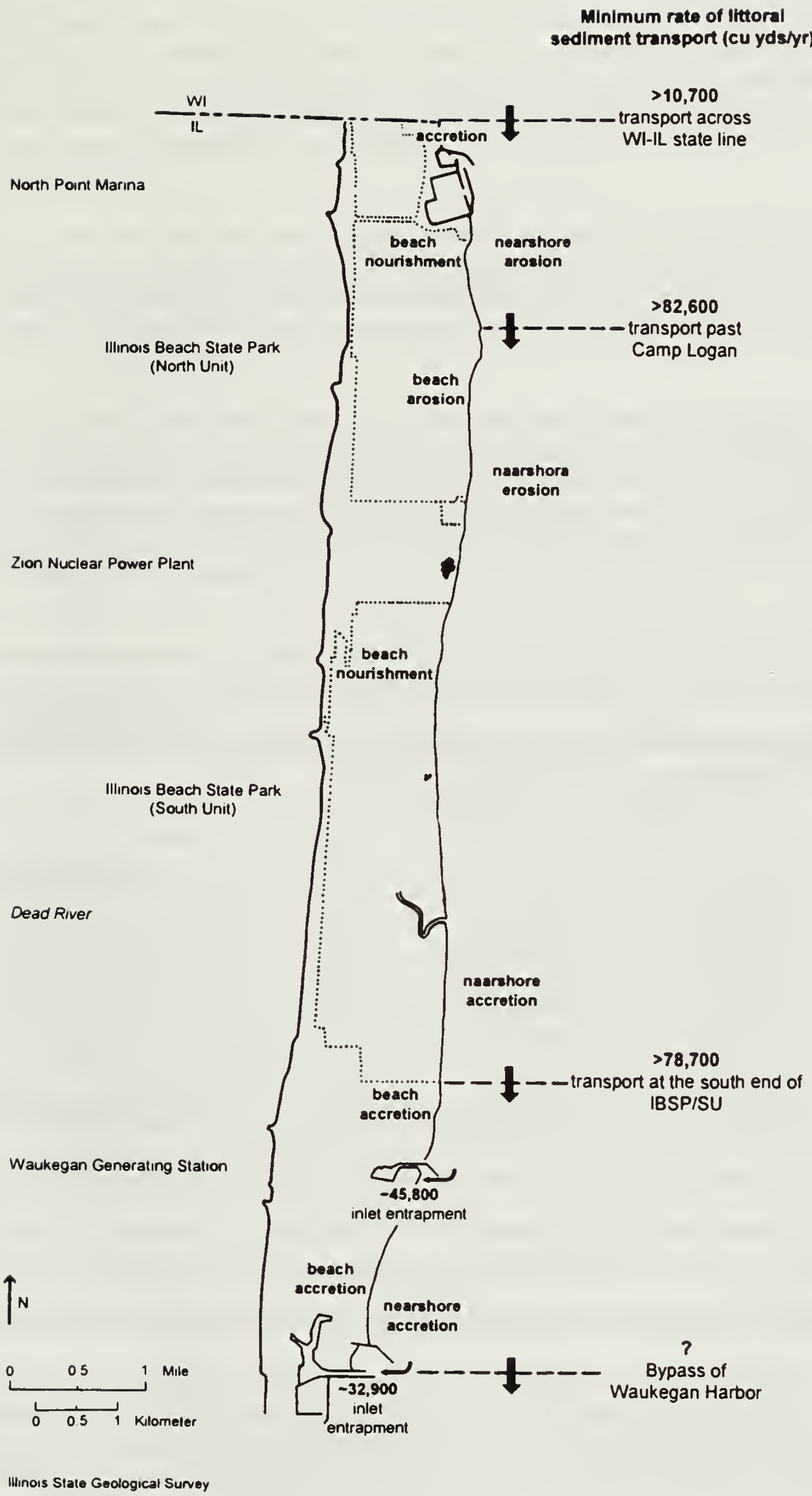


Figure 3-29 Schematic illustration of the four-year (1992-1996) interim littoral sediment budget model for the SL/WH coastal reach.

During 1995-1996, dredging removed 80,000 cu yds of sand from the Waukegan Generating Station and 53,300 cu yds of sand from Waukegan Harbor (Table 3-9). Summing these volumes indicates that 133,300 cu yds/yr of sand were dredged from the south end of the SL-WH coastal reach during 1995-1996. Because this dredging occurred in nearshore areas to the south of IBSP/SU, this necessitates that at least 133,300 cu yds/yr of sediment moved southward in the nearshore at the south end of IBSP/SU during 1995-1996 (Table 3-9).

Between 1992 and 1995, dredging removed 103,200 cu yds of sand from Waukegan Generating Station and 78,200 cu yds of sand from Waukegan Harbor (Appendix K). The combined volume of 181,400 cu yds means that 60,500 cu yds/yr of sand were dredged from the south end of the coastal reach during 1992-1995. Therefore, at least 60,500 cu yds/yr moved southward in the nearshore at the south end of IBSP/SU during 1992-1995 (Table 3-9).

To obtain a four-year (1992-1996) average rate of littoral sediment transport at the south end of IBSP/SU, 1995-1996 data were merged with 1992-1995 data. Between 1992 and 1996, dredging removed 183,200 cu yds of sand from Waukegan Generating Station and 131,500 cu yds of sand from Waukegan Harbor (Appendix K). The combined volume of 314,700 cu yds means that 78,700 cu yds/yr of sand were dredged from the south end of the coastal reach between 1992 and 1996. Therefore, at least 78,700 cu yds/yr moved southward in the nearshore at the south end of IBSP/SU between 1992 and 1996 (Table 3-9).

Table 3-9 Annualized littoral sediment transport volumes at specific reference points along the SL/WH coastal reach[1]

	3-year average (1992-1995)	1-year change (1995-1996)	4-year average (1992-1996)
Crossing the WI-IL state line	>14,200	>0, <14,200	>10,700
Passing the Camp Logan headland	>43,100	>201,000	>82,600
Passing south end of IBSP/SU	>60,500	>133,300	>78,700
Entrapment at Waukegan Generating	34,400[2]	80,000[2]	45,800[3]
Entrapment at Waukegan Harbor	26,100[2]	53,300	32,900[3]

[1] All volumes are rounded to the nearest 100 cu yds.
[2] This volume is based on an interpolation of dredge volumes for the interval 1992-1995. See Appendix K for computation method.
[3] This volume is based on an interpolation of dredge volumes for the interval 1992-1996. See Appendix K for computation method.

Minimum rate of littoral sediment transport at the south end of the SL/WH coastal reach

Between 1992 and 1996, dredging at Waukegan Harbor removed 131,500 cu yds of sand, yielding an average annualized rate of 32,900 cu yds/yr (Table 3-9). This indicates that an average 32,900 cu yds/yr of littoral sediment moved southward past the north breakwater at Waukegan Harbor and became trapped at the harbor entrance between 1992 and 1996 (Fig. 3-29). An unknown volume bypassed the harbor entrance and continued to areas further downdrift.

Littoral sediment budget summary

The littoral sediment budget summarized in Table 3-9 presents data for the 1992-1995, 1995-1996, and 1992-1996 intervals. The three- and four-year averaged data provide the best approximation of recent rates of littoral sediment transport along the NPM and IBSP nearshore. The four-year average has the advantage of a longer time frame. The following listing summarizes the key components of the Year-2 (four-year average) littoral sediment budget.

- Littoral sediment moved south across the WI-IL state line at an averaged rate of at least 10,700 cu yds/yr between 1992 and 1996. This sediment contributed to accretion on the updrift side of the NPM north breakwater, within the marina entrance, and lakeward of the northern half of the south breakwater. Net erosion during 1995-1996 precluded estimation of sediment input from across the state line during 1995-1996.

- Although some volume of sediment crossed the WI-IL state line during 1995-1996, the North Beach / north breakwater nearshore became net erosional, losing 21,100 cu yds of lake-bottom sand. This is the first year since marina construction that this nearshore was net erosional.

- It is not known what volume of sediment bypassed the marina without being trapped in the marina entrance or in the accretional lobe in the south breakwater nearshore.

- Between 1992 and 1995, nearshore erosion occurred primarily between the marina entrance and the Camp Logan headland. Between 1995 and 1996, nearshore erosion occurred along the entire nearshore between the state line and the Camp Logan headland. Overall, between 1992 and 1996, the entire nearshore lost at least 62,400 cu yds/yr of sand to areas downdrift of Camp Logan. 62,400 cu yds/yr is this area's average net erosion rate between 1992 and 1996 considering only lake-bottom changes.

- Between 1992 and 1996, beach nourishment at IBSP/NU, sand dredged from NPM, and erosion at the NPM south parking area, contributed an average 20,200 cu yds/yr to the nearshore updrift of the Camp Logan headland. When combined with the nearshore erosion rate (62,400 cu yds/yr), this yields an average total erosion rate of at least 82,600 cu yds/yr. This is a minimum estimate of the average annual volume of littoral sediment that moved southward past Camp Logan over the four-year interval (Fig. 3-29).

- Combining the volume of material dredged from the Commonwealth Edison Waukegan Generating Station and from Waukegan Harbor between 1992 and 1996 provides a minimum estimate of 78,700 cu yd/yr for the littoral sediment supply approaching the Commonwealth Edison facility from updrift. The proximity of this facility to IBSP/SU means that this volume is also a minimum estimate for littoral sediment transport along the southern end of IBSP/SU.

- The minimum volume of littoral sediment moving southward out of the SL/WH coastal reach between 1992 and 1996 is estimated at 32,900 cu yds/yr. This is based on the entrapment volume at Waukegan Harbor. It is not known how much sediment naturally bypassed the harbor to areas further downdrift.

The Year-1 report used the volume of littoral sediment in transport at the south end of IBSP/SU to approximate the "carrying capacity" of the littoral system along the SL/WH coastal reach. The volume of littoral sediment in transport (at least 68,400 cu yds/yr) was determined from a 32-year average of dredge volumes at both Waukegan Generating Station and at Waukegan Harbor. This volume was used to provide an estimate of the minimum volume of beach nourishment that would be required to mitigate erosion along the shore between NPM and Camp Logan.

Using the same procedures, but limiting the dredge data to the four-year interval between 1992 and 1996,

the carrying capacity is calculated at 78,700 cu yds/yr. This is a 15% increase over the previously reported estimate, but this volume is apparently an underestimate. The 1992-1996 data indicate that an average 82,600 cu yds/yr was eroded from the nearshore between the WI-IL state line and Camp Logan. This suggests that, for the 1992-1996 interval, the minimum volume of beach nourishment required to mitigate erosion between NPM and Camp Logan, the area where most of the erosion occurred, would have been at least 82,600 cu yds/yr.

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APPENDIX A: EXECUTIVE SUMMARY FROM THE YEAR-1 (1995) REPORT

This appendix provides the Executive Summary from the Year-1 report. This is presented here as a means towards providing continuity for the reader on a year-to-year basis during this four-year study:

The Illinois State Geological Survey (ISGS) began a four-year study in 1995 to examine erosion and accretion trends along the Lake Michigan shore at North Point Marina (NPM) and the North and South Units of Illinois Beach State Park (IBSP). This study is funded by the Illinois Department of Natural Resources (DNR) which is responsible for coastal management at these facilities. The goal of the study is to develop a sediment budget for the coastal system to provide a basis for planning and implementing long-term coastal-management strategies. An immediate objective is to provide information on erosion and accretion trends relevant to ongoing coastal-management concerns.

In the marina vicinity, and in the northern part of the IBSP North Unit, survey data collected in 1995 were compared with data from 1987 through 1992. In the three-year interval 1992-1995, a minimum of 14,200 cu yds/yr of littoral sediment moved south across the WI-IL state line. Most of this sediment accumulated in the nearshore between the state line and the NPM north breakwater. Some sediment was transported southward around the north breakwater and accumulated lakeward of the marina entrance and inside the entrance. The marina entrance has been a sediment trap since the breakwaters were constructed in 1988-89. The 1992-95 data comparison strongly suggests that littoral sand crossing the state line has bypassed the north breakwater and has contributed to shoaling in the marina entrance.

Net erosion dominated across the lake bottom from the marina south breakwater to the Camp Logan headland. Locally, this erosion lowered the lake bottom to elevations below those that existed in 1987 prior to marina construction. For the entire shore along the marina property, the most severe erosion continues lakeward of the south parking area, undermining the existing line of shore defense. Without additional engineering measures to protect this area, additional subsidence of the existing shore defense is certain. As this shore defense subsides, erosion will advance landward toward the parking access roads.

The shore in the northern part of the IBSP North Unit, between the marina/state park boundary and the Camp Logan headland, has undergone extreme coastal change. Shoreline and nearshore changes between 1987 and 1995 were evaluated to assess overall trends. Between 1987 and 1989 the reach gained 13 acres of beach from the southward dispersion of sediment dredged from the marina basin. Since 1989, shoreline recession has occurred. As of 1995 only 5 acres remains of this previous 13-acre gain. The 1989-1995 rate of beach area loss has been 1.3 acres/yr. During this same time interval, a total of 202,000 cu yds of beach nourishment was supplied to this shore (avg. 33,700 cu yds/yr). The nourishment slowed the rate of shoreline recession, but the nourishment volumes have been insufficient to counteract an annual net loss of sediment from the beach and nearshore. A preliminary analysis of the nearshore sediment budget suggests that a nourishment rate of at least 68,400 cu yds/yr would be required annually downdrift of the marina to maintain a balanced sediment budget and to halt net erosion.

In July 1995, beach nourishment consisting of fine to medium sand was supplied to the north ends of both the North Unit (20,000 cu yds) and the South Unit (24,000 cu yds). Monitoring of the nourishment documented that the sand was nearly all dispersed into the shallow nearshore by November 1995. At both sites, the most rapid dispersion occurred during a single storm on September 7-8.

APPENDIX B: METHODS AND TERMINOLOGY

Units of Measure

All measurements in this report are given in U.S. customary units (*i.e.*, feet, miles, acres, cubic yards). This is to facilitate comparison of present-year data with previous coastal monitoring data and with past and present engineering projects at the marina and state park. Table B-1 provides factors for converting U.S. customary units to metric units.

Table B-1 Factors for converting from U.S. customary units to metric units.

U.S. customary units	Conversion factor	Metric units
	Length	
foot	0.3048	meter
mile	1.609	kilometer
	Area	
square foot	0.0929	square meter
square yard	0.8361	square meter
square mile	2.59	square kilometer
acre	0.4047	hectare
	Volume	
cubic yard	0.7646	cubic meter

To convert from U.S. customary units to metric units, multiply by the conversion factor in the central column.

Terminology

Terms used in this report which are common to Lake Michigan coastal monitoring are defined as follows:

bathymetry — The measurement of water depths. The compilation of water-depth data along a survey line is the basis for constructing a bathymetric profile of the lake bottom; compilation of such data across an area is the basis for producing a bathymetric map.

erosion / accretion — The loss (erosion) or gain (accretion) of sediment. Erosion and accretion can have a vertical component as well as a lateral component. Unless otherwise stated, the erosion and accretion discussed in this report refer to vertical change.

fan delta — A term used to describe a high-relief and lobate sediment deposit commonly formed where intermontane streams flow out onto a lowland area. In this report, "fan delta" is used to describe the high-relief, lobate sand and gravel feature that was formed during 1987-1988 on the south side of North Point Marina as a result

of the hydraulic dredging of the marina basin. The term "fan delta" is used to refer to the entire sand body, both above and below lake level.

isobath A line on a bathymetric map connecting points of equal water depth or equal lake-bottom elevation (*i.e.*, equal bathymetry). In this report, the terms "isobath" and "bathymetric contour" are synonymous.

isopach A line on a map connecting points of equal thickness of a specific material. In this report, isopach maps are presented for the thickness of sediment gained or lost between given time intervals. These isopach maps indicate the vertical amount of lake-bottom erosion and accretion that are determined from a temporal comparison of bathymetric data.

littoral transport The movement of sediment along the beaches and nearshore by waves and wave-induced currents. The sediment involved in the transport is referred to as "littoral drift."

Low Water Datum (LWD) This is the reference plane, or datum, for measuring lake levels and lake-bottom depths (bathymetry). The datum facilitates comparison of lake-bottom elevations from different months or years independent of changes in lake level. All lake-bottom elevations in this report are referenced to LWD (see Table B-2).

nearshore The nearshore is here defined as the zone between the shoreline and water depths of about 20 to 25 ft LWD. This is the zone of major littoral sediment transport along the lake bottom. The nearshore does not include the beach or any other areas above mean lake level.

net erosion / net accretion When all the erosion and accretion volumes for an area are summed, the net change is determined.

updrift / downdrift The predominant (strongest) waves along a coast cause net littoral sediment transport away from the direction of wave attack. Updrift refers to the direction from which net transport originates; downdrift refers to the direction towards which net transport occurs. For the segment of Illinois coast discussed in this report, net littoral transport is southward, driven by northerly waves. Thus, updrift means "to the north" and downdrift means "to the south."

Field Procedures

Establishing horizontal and vertical control

All horizontal and vertical control for field surveys relied on existing bench marks or other survey marks in the study area. New control points were established by running traverses from existing control. All survey work for establishing and verifying horizontal and vertical control used a LIETZ/SOKKISHA Set 4-A Total Station.[1] A LIETZ SDR20 Electronic Note Book was used in conjunction with the Total Station to provide a digital record of all survey data. Data were downloaded at the end of each field day onto a laptop computer and later processed using MICROSOFT Excel spreadsheet software. All horizontal control (X-Y data) was recorded using Illinois State Plane coordinates. Vertical control (Z data) was referenced to Mean Sea Level (MSL) and subsequently corrected to Low Water Datum (LWD) for presentation in map format (see Data Processing).

[1]Note: Use of specific product names in this report is for informational purposes only and does not constitute endorsement by the Illinois State Geological Survey.

Beach profiling and beach-nourishment monitoring

A LIETZ/SOKKISHA Set 4-A Total Station and one or more prism poles were used for collecting all beach profile data. Beach profile data were typically collected between the backshore vegetated-ridge line and the shallow nearshore (to depths of approximately 5.5 ft below lake level at the time of survey). The Total Station and back-sight prism were set at reference points of known State Plane Northing (X), Easting (Y), and elevation (Z). The prism pole survey rod was positioned on successive measurement points along predetermined profile lines, generally along a given Northing, and the respective X, Y, and Z data were obtained for each point. To monitor nourishment stockpiles, a similar procedure was employed to determine stockpile topography (profile survey) and areal extent (circumnavigation survey). Each stockpile profile generally originated on a stable substrate such as an adjacent access road or the landward semi-vegetated crest of the stockpile. To determine rates of stockpile erosion and magnitudes of volume change, the location of the crest along the stockpile's erosional scarp was mapped by positioning the prism pole at 45-ft increments along this line. Elevations along the scarp crest were typically 1 to 12 ft above lake level at the times of survey.

Collection of bathymetric data

Bathymetric data were collected using one of two methods.

1) Fathometer Method: Bathymetric data beyond wading depths were collected with a ROSS Model 803 Portable Survey Fathometer mounted onboard either a 12.5 ft or 15 ft ZODIAC-type inflatable boat. The fathometer measured depth in feet. Fathometer calibration was performed at the beginning of each day of data collection. During profiling, the survey boat was maintained on the desired profile line by a person onshore using a transit fixed on the azimuth of the line (typically N90E). Radio or visual signals to the boat operator were used to keep the boat within one boat width (5.6 ft) of the line. Offshore distance to the boat was measured by a MOTOROLA Mini-Ranger III system (accurate to +/- 10 ft) which used a microwave signal to determine distance between a transceiver mounted on the boat and an onshore transponder. The Mini-Ranger III system included a control console onboard the survey boat that provided an LED display of distance in meters from the onshore transponder. The fathometer operator monitored the console display to make fix marks and annotations on the fathometer record to provide a location reference for the depth (Z) data.

2) Wading Method: Shallow-water bathymetric data were collected to wading depths (approximately 5.5 ft below lake level at the time of survey) to provide coverage for shallow-water areas where the boat-mounted fathometer could not always provide a good record. This procedure, which was an extension of the beach-profiling transects, involved a person wading into the water along the designated profile line holding a prism pole on successive points. An onshore Total Station operator then shot these points to obtain X-Y-Z data. Data-point spacing was such that all significant lakebed elevation changes (> 0.5 ft) were recorded. A wet suit aided prolonged stay in the water.

Collection of seismic-reflection data

High-resolution seismic-reflection profile data were collected using a FERRANTI-ORE Geopulse System. Profile data were collected in water depths ranging from 8 to 60 ft LWD using a 0.75 x 0.75 mile grid pattern with transect lines oriented predominantly north-south and east-west. East-west transects extended up to 1.75 miles offshore.

During profiling, the Geopulse System was operated from a 17-ft BOSTON WHALER. Boat speed during profiling averaged 3 to 4 knots. A portable hand-held MAGELLAN NAV5000 DLX Global Positioning System receiver was used for position-fixing (latitude and longitude). Seismic reflection data were recorded on magnetic data tapes and also printed out in real-time on the system's graphic recorder. To provide location references during profiling, graphic records were annotated with time (CDT), latitude, and longitude every 5 to 10 minutes and at points of course change.

The Geopulse System operates on a principle similar to the fathometer used in bathymetric profiling. However, the acoustic source (boomer plate) and receiver (20-element linear hydrophone array) are towed up to 50 ft behind the survey vessel. The lower frequencies used in seismic-reflection profiling allow the acoustic signal to pass through the lake bottom and to reflect off sub-bottom sediment layers before returning to the water surface to be detected by the hydrophone array. The graphic data printouts are an approximation of a geologic cross-section along the line of profile, except that the vertical (Y) axis represents round-trip travel times rather than true depths. Subsequent laboratory processing of the data utilized the velocity of sound in water and in sediment (4920 ft/s and 5580 ft/s, respectively) to determine depths to specific geologic contacts such as the sand / clay-till interface.

Data Processing

Datums

Three different datums are commonly used in the presentation of topographic and bathymetric data from the Great Lakes region. These are:

- Lakes Michigan-Huron Low Water Datum (LWD)
- International Great Lakes Datum (IGLD) 1955 or 1985
- National Geodetic Vertical Datum (NGVD) 1929
  (also called Mean Sea Level (MSL))

Table B-2 shows conversion factors for adjusting elevations between these different datums.

Datums for bathymetry All bathymetric profiles and maps in this report are referenced to LWD. All bathymetric measurements collected by boat-mounted fathometer required a correction to LWD based on lake level relative to LWD at the time of each bathymetric profile. For these corrections, hourly lake-level data (meters, IGLD 1985) were compiled from lake-level gauges at Milwaukee, Wisconsin and

Table B-2 Conversion factors for different lake-level and topographic datums used in this study.

Given Datum (in feet)	To convert to Datum (in feet)			
	LWD[1]	IGLD[2] (1955)	IGLD[2] (1985)	NGVD[3] (1929)
LWD	——	+ 576.80	+ 577.50	+ 578.10
IGLD (1955)	– 576.80	——	+ 0.70	+ 1.30
IGLD (1985)	– 577.50	– 0.70	——	+ 2.00
NGVD (1929)	– 578.10	– 1.30	+ 2.00	——

Acronyms: LWD = Low Water Datum (also called Chart Datum)
IGLD = International Great Lakes Datum
NGVD = National Geodetic Vertical Datum (also called Mean Sea Level)

[1]LWD is the datum used for all lake-bottom depths reported by the ISGS. This is also the datum used for all depths on Lake Michigan nautical charts published by the National Ocean Service (NOS), and is commonly the datum used for profile data reported by the U.S. Army Corps of Engineers (COE).

[2]IGLD is the international datum for reporting Great Lakes water levels. The datum adjustment from 1955 to 1985 was necessary to compensate for regional crustal uplift due to post-glacial rebound. All lake levels reported by NOS and COE since 1992 are referenced to IGLD 1985.

[3]NGVD (1929) is the datum used for all topographic information on U.S. Geological Survey topographic maps of the Illinois coast of Lake Michigan. This datum is also referred to as Mean Sea Level (MSL).

Calumet Harbor, Illinois. These gauges are operated by the National Ocean Service (NOS) of the National Oceanic and Atmospheric Administration (NOAA).

Because the study area is located approximately midway between the gauges at Milwaukee and Calumet Harbor, hourly lake levels for the two gauges were averaged to compute hourly lake levels in the study area during the times of bathymetric survey. The difference between these hourly lake levels and LWD was an hourly correction used to reference fathometer-derived lakebed elevations to the LWD reference plane. This correction ranged from 2.5 to 2.9 ft for the bathymetric data collected during summer 1996.

Datums for topography LWD was also the datum used for elevations above lake level such as beach elevations and elevations on the beach-nourishment stockpiles. LWD was used because it permitted direct comparison of profile and map data above and below water. Any compiled elevation data that were referenced to IGLD, NGVD, or MSL were adjusted to LWD using the correction factors given in Table B-2.

Constructing and measuring maps of lake-bottom change (isopach maps)

All maps of lake-bottom change (isopach maps) recorded changes in excess of 1 foot. This cutoff allowed for possible elevation errors in the collection and processing of the fathometer data. Only lake-bottom changes occurring below the 0-ft LWD plane were used in volume calculations. The landward limit of contoured map data occurs along the line of intersection between the most landward topo-bathymetric profile and the 0-ft LWD plane. The lakeward limit of contoured data occurs at the limit of data overlap between the two comparative years. The shoreline shown on each isopach map is the most recent shoreline of the two comparative years.

Isopach maps were constructed using one of two methods. With the first method, bathymetric (and topographic) contour maps were superimposed to obtain contour intersection points. Elevation changes at these intersection points were then used to create an isopach contour map depicting areas and magnitudes of elevation change. With the second method, topo-bathymetric profiles were used. At given range-line locations along the shore, the elevation difference between two comparison profiles was determined at approximate 100-ft intervals extending offshore to the limit of data overlap. The data points were then plotted along each range line marked on a base map and subsequently contoured.

Isopach maps created using either of the above two methods were used to compute erosion and accretion volumes. To compute volumes, a LIETZ Planix-7 digital planimeter was used to measure the area within each isopach contour interval. Each of these areas was multiplied by the mid-contour value to give volume (*e.g.*, the area between the 2 and 3 ft contours was multiplied by the mid-contour value, 2.5 ft). All volumes between contours were then summed to give total erosion and accretion volumes and net volume change.

Volumetric analysis of the North Beach Bar

Annual sediment volumes were calculated for the North Beach bar by subtracting an inferred non-barred bathymetric profile from the barred bathymetric profile for the year of survey (*e.g.*, 1996). Four east-west profiles were used (ISGS Profiles 2, 4, 6, and 8) to obtain representative bar cross-sectional areas along the length of the bar. Areas were measured using a digital planimeter. The cross-sectional areas were then integrated along the north-south length of the bar to provide the bar volume for each year.

Determining the bar volume was dependent on the boundaries chosen to define this bathymetric feature. The following boundaries were used:

- North boundary: The WI-IL state line (note: the bar apparently continues north of the state line, thus these volume calculations apply only to the Illinois segment).

- West boundary: A line along the axis of the trough on the landward side of the bar-trough pair (as seen on bathymetric profiles).
- South boundary: Defined by the southern edge of the bar, as interpreted from bathymetric maps.
- East boundary: Defined as the break in slope between the lakeward edge of the bar and the smooth lake bottom lying lakeward of the bar (as seen on bathymetric profiles). Of the four boundaries, this was the most subjective.

APPENDIX C: PREVIOUS COASTAL MONITORING

General Statement

The following paragraphs summarize previous coastal monitoring along the northern Illinois shore of Lake Michigan from which data were extracted for this report. Summary results of previous ISGS monitoring at North Point Marina between 1987 and 1992 were presented in the Year-1 Report (Chrzastowski et al., 1996). Compilation of earlier regional-scale coastal data from several state and federal agencies permits the documentation of long-term, regional-scale coastal changes adjacent to NPM and IBSP.

Nearshore bathymetric data for the Illinois shore of Lake Michigan between the IL-WI state line and Waukegan, IL is available as far back as 1872. The first comprehensive bathymetric data sets were collected by the U.S. Lake Survey during 1872-1873 and 1909-1911. Subsequent regional surveys were conducted by the U.S. Army Corps of Engineers in 1946 (U.S. Army Corps of Engineers, 1953), by the Illinois Division of Waterways in the early 1950s (State of Illinois, Division of Waterways, 1958), and by the Illinois State Geological Survey (ISGS) in 1974 (Illinois State Geological Survey, 1975). Between 1987 and 1992, the ISGS conducted a five-year monitoring program in the vicinity of NPM between the WI-IL state line and Camp Logan. In 1994, Hydrographic Survey Company, Inc. was contracted by the Illinois Department of Conservation (IDOC) to conduct a bathymetric survey of the recreational and commercial boat basins at NPM. During 1994 and early 1995, Patrick Engineering, Inc. conducted a bathymetric survey in the approaches to the recreational boat basin at NPM. During 1995, ISGS resumed bathymetric work at NPM and along the northern Illinois shore during Year-1 of this study.

Bathymetric Surveys of North Point Marina Boat Basins (1994-1995)

In 1994, IDOC contracted Hydrographic Survey Company, Inc. to perform a bathymetric survey of the commercial and recreational boat basins at North Point Marina. During 1994-1995, Patrick Engineering, Inc. conducted a bathymetric survey in the approaches to the recreational boat basin. In this Year-2 report, these 1994-1995 data were compiled, converted into LWD format, and used in conjunction with a similar survey conducted by ISGS in summer / autumn 1996 to determine rates and patterns of lake-bottom change within the marina since 1994.

Bathymetric Surveys in the vicinity of North Point Marina (1987-1992 and 1995)

Bathymetric surveys were conducted by the ISGS in the NPM vicinity between 1987 and 1992, in the area between the WI-IL state line and Camp Logan. This study's Year-1 Report (Chrzastowski et al., 1996) contains bathymetric and lake-bottom change maps from 1987 through 1992 for this area. Table C-1 summarizes the annual lake-bottom accretion, erosion, and net volumetric changes documented in that five-year study and also incorporates results from Year-1 of this study. The 1987 to 1995 summation of lake-bottom change volumes illustrates net nearshore accretion over the eight-year interval. However, Table C-1 also shows that annual accretion volumes have decreased progressively since 1987-1988. Over the same period, annual erosion volumes, though decreasing in large part due to the positive effects of beach nourishment, remained high. The net result is that erosion began to outpace accretion during 1989-1990 and the shore became net erosional on an annual basis following the 1988-1989 interval (Table C-1).

As of 1995, the lake bottom between the WI-IL state line and the Camp Logan headland contained 62,000 cu yds of sand more than it contained in 1987 just prior to marina construction (Table C-1). However, exacerbated erosion during 1995-1996, as discussed in this report, indicates that the nearshore as of 1996 has lost more sand than it gained from beach nourishment and littoral sediment input between 1987 and 1995. The pervasive and areally-extensive erosion between 1987 and 1996 is illustrated in Appendix F.

Regional Bathymetric Surveys of 1872, 1910, 1946, and 1974

The U.S. Lake Survey (1872, 1873, 1909-1911, 1910-1911) published the first comprehensive set of maps documenting nearshore water depths along the northern Illinois shore of Lake Michigan. Data were presented as a series of 1:20,000-scale soundings maps. The U.S. Army Corps of Engineers (1953) published bathymetric profiles and regional bathymetric- and shoreline-position maps based on data collected by the Corps in 1946 and on data collected by the U.S. Lake Survey during 1872 and 1909-1911. Multi-year bathymetric profiles (1872, 1910, 1946) were presented for five of 9 range lines spaced at 0.3 to 1.8 mile intervals between the WI-IL state line and Waukegan Harbor. Subsequently, the Illinois Division of Waterways (1958) also published multi-year bathymetric profiles along these range lines, as well as shoreline-position maps, primarily using data from the late 1940s and early 1950s.

Table C-1 1987-1995 annual nearshore accretion and erosion volumes and net volumetric change between the WI-IL state line and the Camp Logan headland.[1]

Year Interval	Accretion	Erosion	Net Change (+ accretion; – erosion)	
	cu yds	cu yds	cu yds/yr	cu yds/yr/shoreline ft [2]
1987-88	309,000	52,000	+257,000	+33
1988-89	235,000	107,000	+128,000	+17
1989-90	112,000	241,000	–129,000	-3[4]
1990-91	105,000	126,000	–21,000	–3
1991-92	65,000	165,000	–100,000	–13
1992-95	102,000[3]	175,000[3]	-24,000[4]	-3[4]
Summation 1987-1995	928,000	866,000	+62,000	+8

[1] All volume calculations are for lake-bottom changes greater than 1 foot and are recorded to the nearest thousand cu yds. The nearshore is defined as that area between the shoreline and approximately the 20 ft LWD isobath. The upper boundary to the volume calculations is 0 ft LWD. Volumes are derived from comparison of annual bathymetric data collected in the late spring or summer of each year.

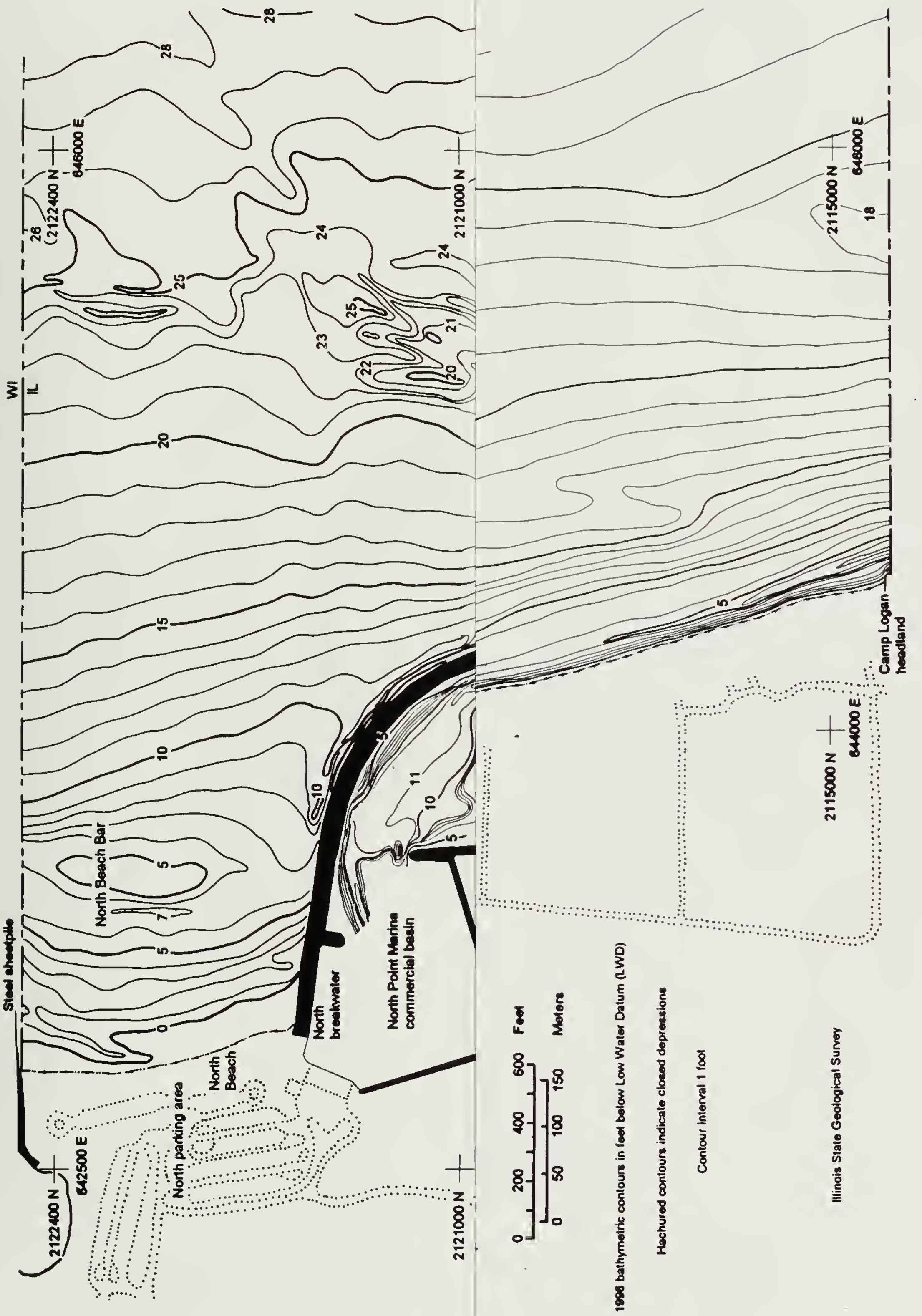
[2] Normalized volume is based on a shoreline distance of 7700 ft which is the north-south distance between the WI-IL state line and the limit of mapping at the Camp Logan headland.

[3] Accretion and erosion volumes for 1992-1995 are a three-year summation.

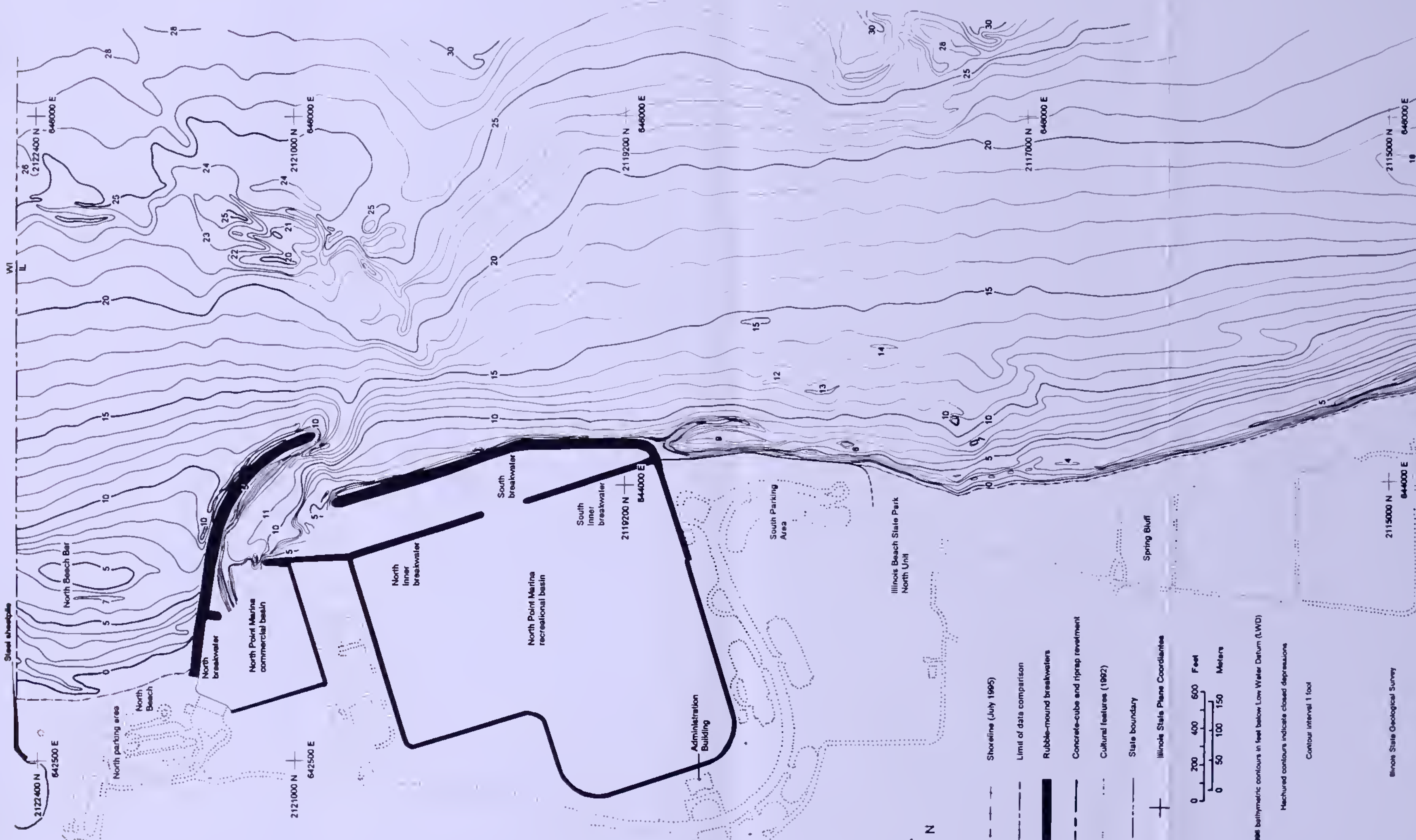
[4] This is the annualized net change for the three-year interval. Normalized volume is adjusted to the annual rate

Two ISGS coastal atlases (Illinois State Geological Survey, 1975, 1988) presented nearshore bathymetric contour maps based primarily on data collected by ISGS in 1974. For this Year-2 report, data were extracted from these maps to augment profile data along the 9 range-line transects between the WI-IL state line and Waukegan Harbor (see Part 3: Regional Coastal Monitoring). Thus, at each range line location, bathymetric data coverage exists for the years 1872, 1910, 1946, and 1974. Regional bathymetric profiling conducted by ISGS in summer and autumn 1996, as part of this study's Year-2 report, provides the most up-to-date bathymetric data along this part of the Illinois shore. The resultant data set is used in this report as the basis for calculating long-term, regional-scale, lake-bottom change.

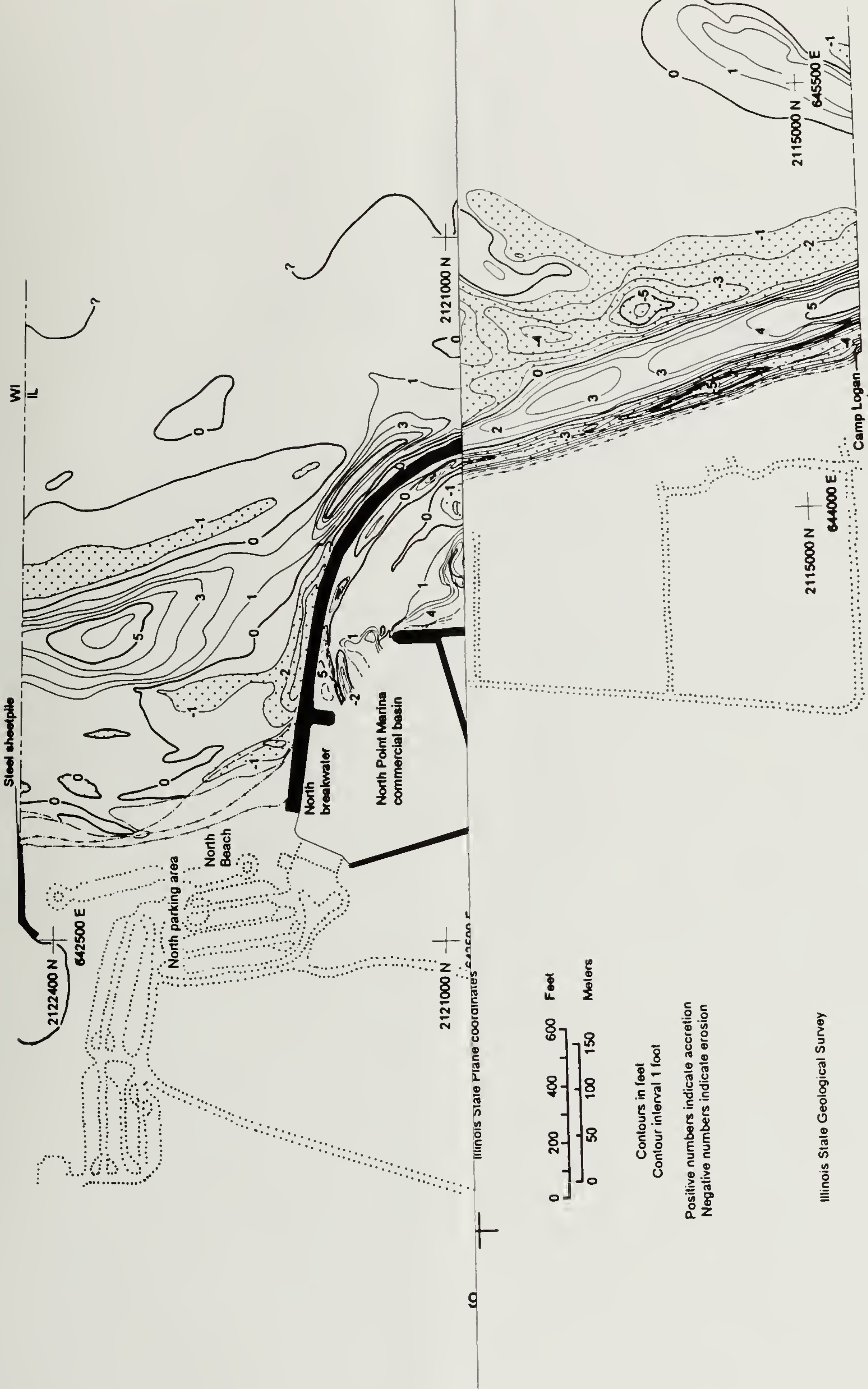
APPENDIX D: YEAR-1 (1995) BATHYMETRIC VICINITY



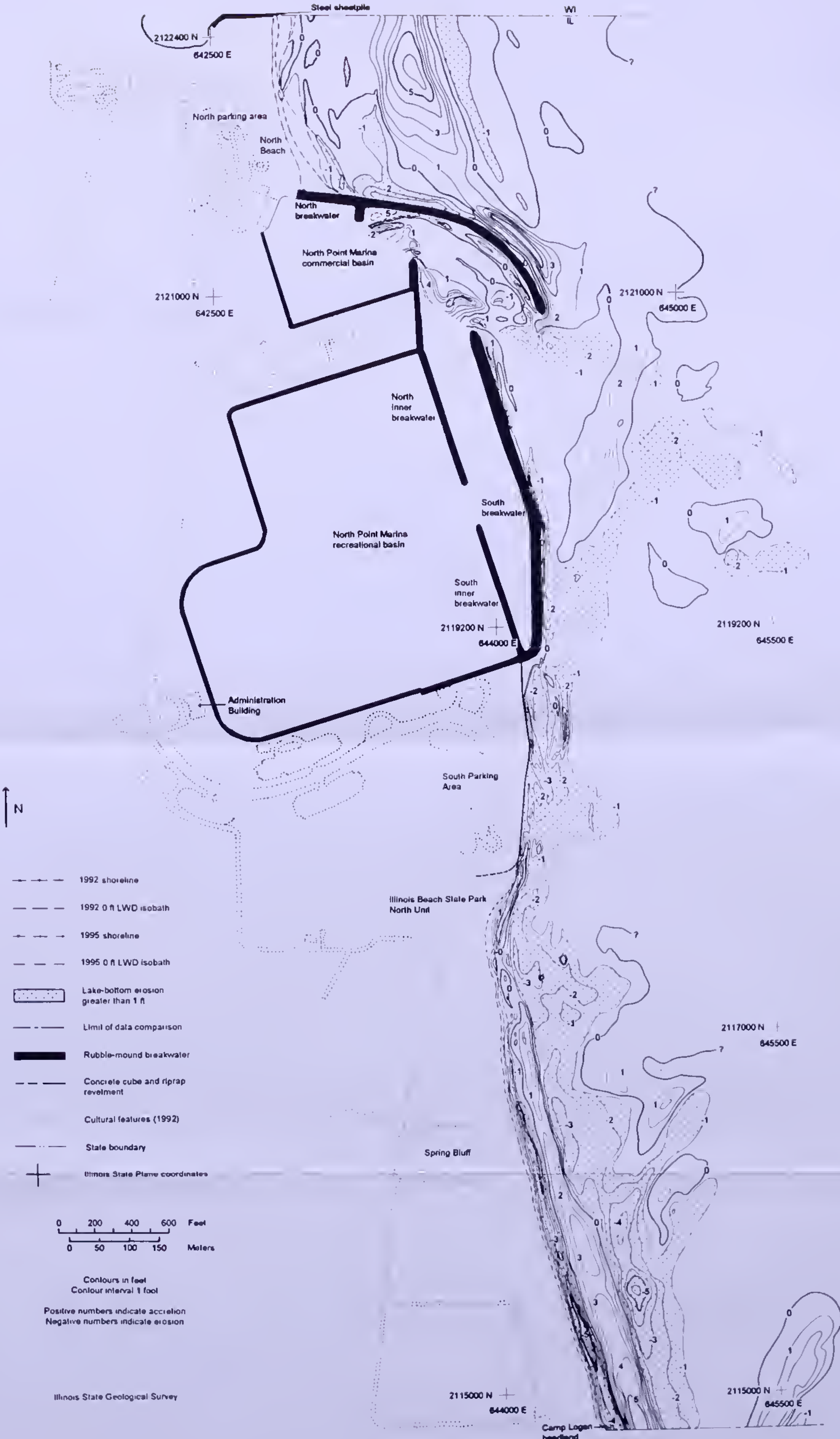
APPENDIX D: YEAR-1 (1995) BATHYMETRIC CONTOUR MAP FOR THE NORTH POINT MARINA VICINITY



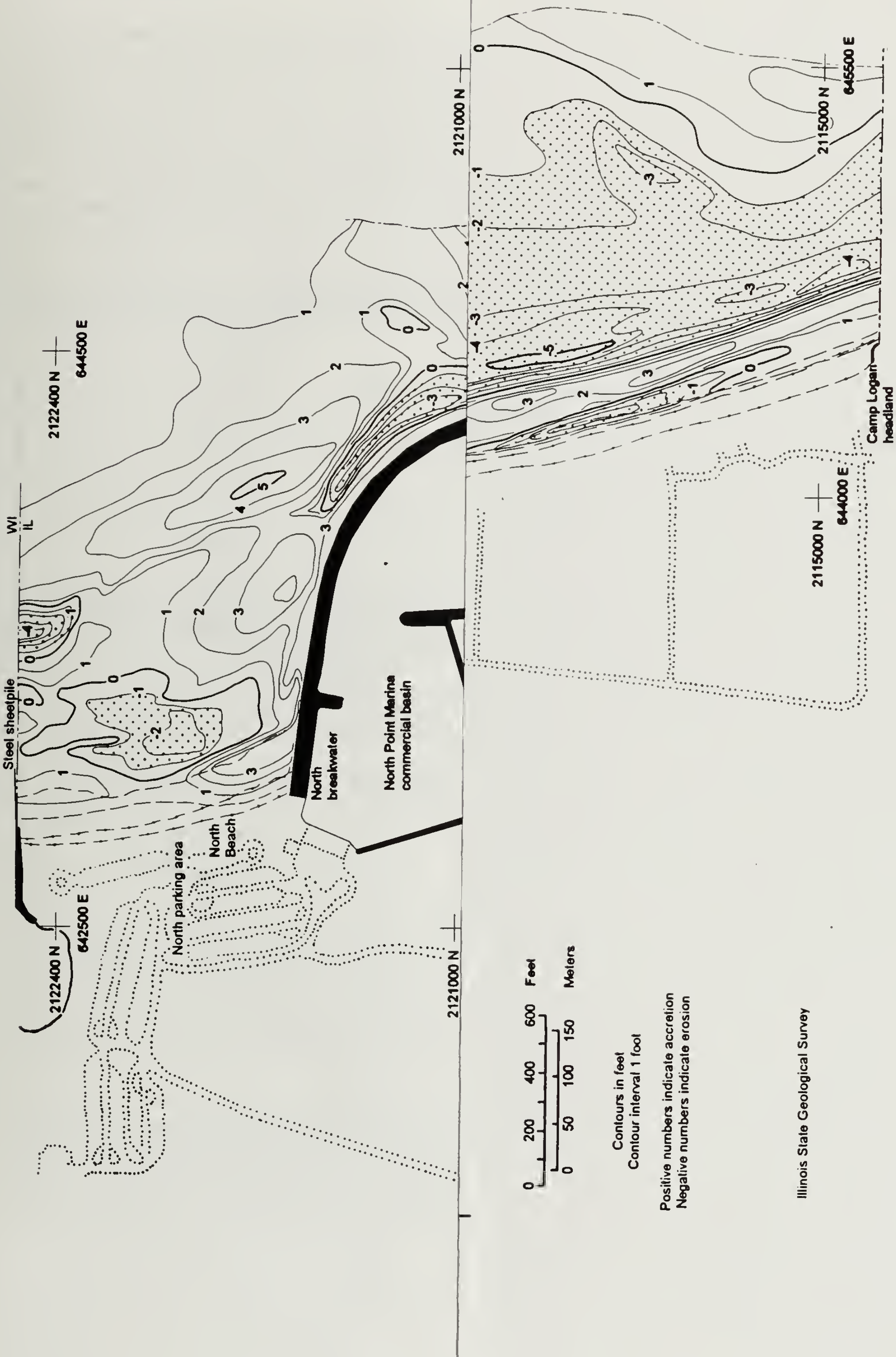
APPENDIX E: YEAR-1 LAKE-BOTTOM CHAN
(1992-1995)



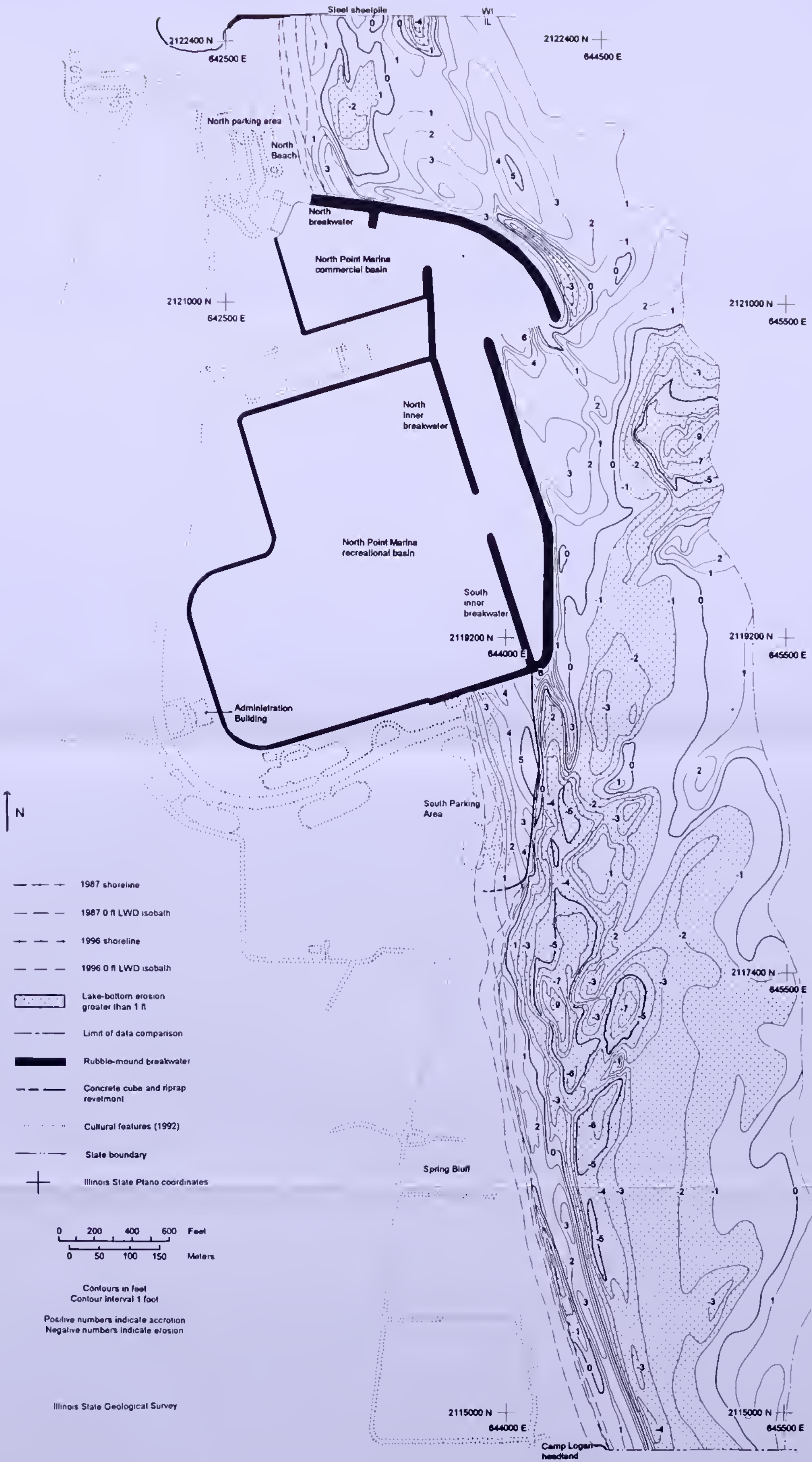
APPENDIX E: YEAR-1 LAKE-BOTTOM CHANGE MAP FOR THE NORTH POINT MARINA VICINITY (1992-1995)



APPENDIX F: 1987-1996 LAKE-BOTTOM CHAN LOGAN



APPENDIX F: 1987-1996 LAKE-BOTTOM CHANGE BETWEEN THE WI-IL STATE LINE AND CAMP LOGAN



APPENDIX G: BEACH NOURISHMENT AT ILLINOIS BEACH STATE PARK / NORTH UNIT (1987-1996)

General Statement

Beach nourishment has been placed periodically at the IBSP/NU beach-nourishment site since 1987 when significant construction first began at North Point Marina. The resulting beach-nourishment stockpile at the north end of IBSP/NU (Figs. 1-2, 3-1) functions as a "feeder beach" that supplies sand to downdrift beach and nearshore areas. Table G-1 provides a time-series summary of the individual beach nourishment events that supplied a total of approximately 1,728,000 cu yds of sand between 1987 and 1996. Approximately 330,500 cu yds of this material is still retained above lake level landward of the 1996 shoreline. About 295,100 cu yds of this latter volume is retained beneath the NPM south parking area and is unavailable for beach nourishment (Chrzastowski *et al.*, 1996); the remainder (35,400 cu yds) is stored at the IBSP/NU nourishment site.

Table G-1 Summary of beach nourishment volumes placed at the IBSP/NU beach-nourishment site.[1]

Year	Volume[1]	Comments
1987-89	1,500,000[2]	Minimum estimate; nourishment supplied from construction of NPM
1990	150,000	Beach nourishment supplied from dredging at Prairie Harbor Yacht Club
1994	32,000	Beach nourishment with quarry-derived pea gravel
1995	~46,000	Nourishment applied in July 1995 and in December 1995-January 1996
1996	0	
1987-96	1,728,000[3]	

[1] Volumes are rounded to the nearest 100 cu yds.
[2] Approximately 330,500 cu yds of this volume is still retained landward of the 1996 shoreline, either beneath the NPM south parking area (295,100 cu yds) or at the IBSP/NU beach nourishment site (35,400 cu yds). The remaining 1,169,500 cu yds has been transferred to the nearshore. The 295,100 cu yds beneath the NPM south parking area is unavailable for beach nourishment.
[3] This volumes excludes 24,000 cu yds of sand supplied to the nearshore during 1995-1996 dredging at NPM and 20,000 cu yds of sand supplied to the nearshore through 1995-1996 erosion of sand back-fill along the adjacent south parking area lakefront.

Chronology of Beach Nourishment

The initial placement of at least 1,500,000 cu yds of sand (Moffatt and Nichol Engineers, 1986) was the result of dredging and construction of the 72-acre NPM facility. Most of the dredged material was placed on the south side of the south breakwater under what is now the NPM south parking area and the IBSP/NU beach-nourishment site (Fig. 3-1). This material was a sand, silt, and gravel mix reflecting the grain-size composition of the Zion beach ridge plain. It was supplied to the nourishment site via slurry pipe and resulted in the formation of a large fan delta.

In 1990, 150,000 cu yds of nourishment were placed at the IBSP/NU nourishment site (Fig. 3-1). The material was derived from dredging of Prairie Harbor Yacht Club, WI and was trucked to the site. This material was again primarily fine- to medium-grained sand with a gravel component. It was applied solely to the area between the marina / state park boundary and Dead Dog Creek located 500 ft to the south in IBSP/NU (Fig. 3-1). Nourishment was limited to this 500 ft stretch of shore because the northernmost

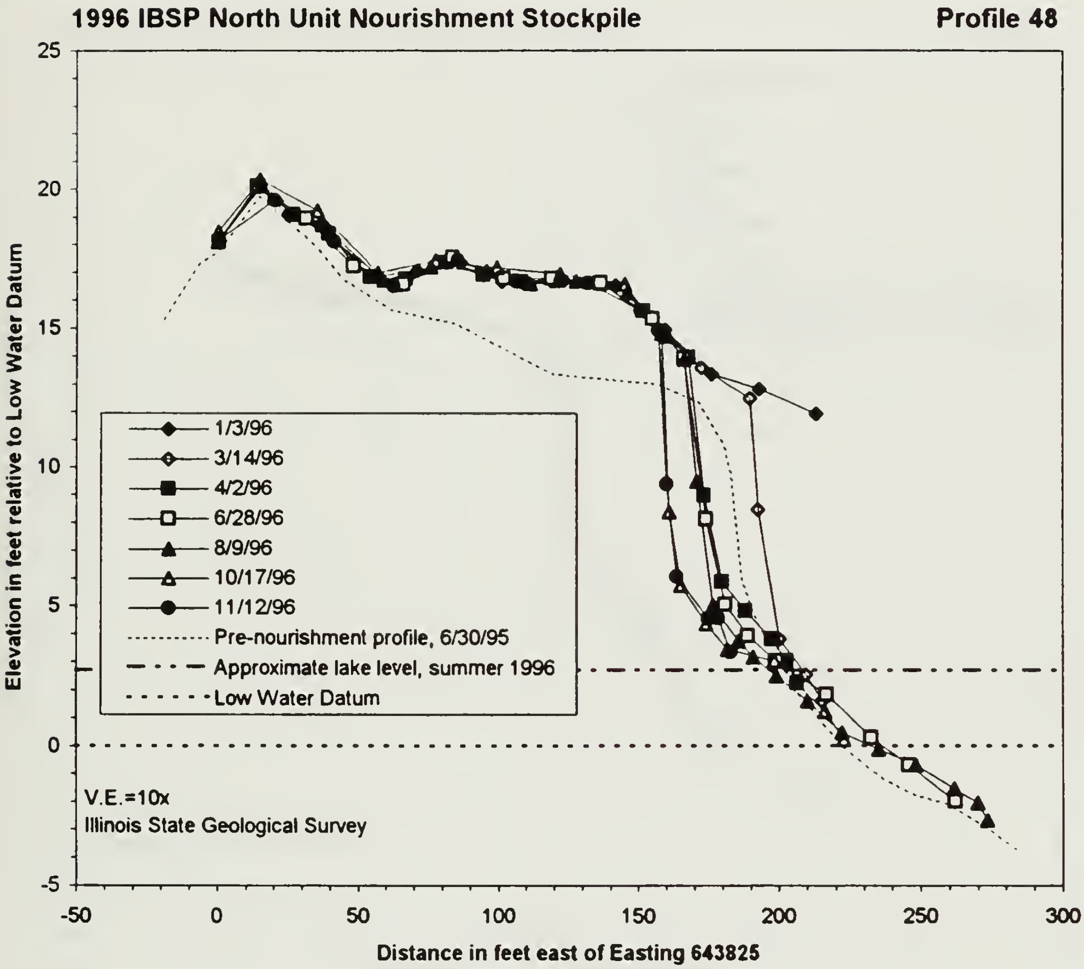
1000 ft of the pre-existing nourishment pile had been paved-over to form the NPM south parking area in 1989.

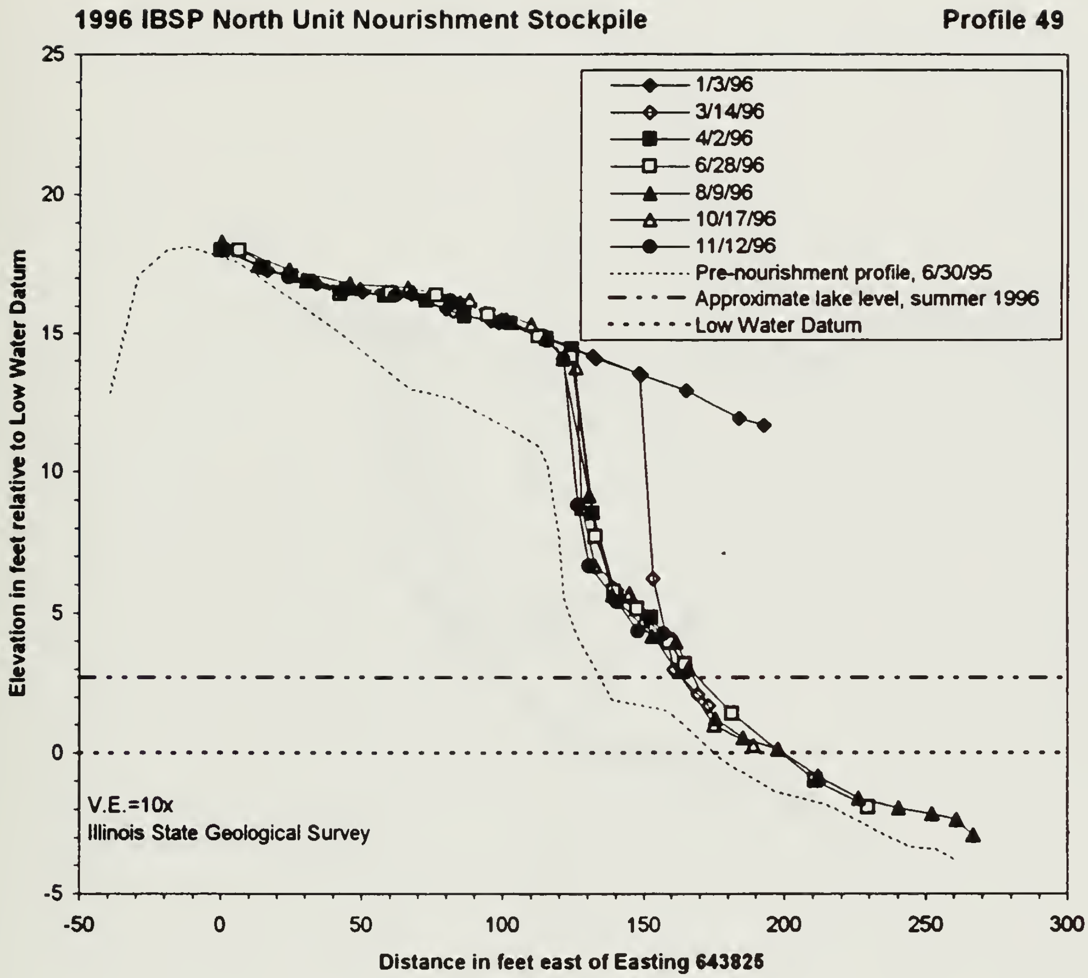
In 1994, 32,000 cu yds of quarry-derived "pea gravel" were placed at the IBSP/NU beach-nourishment site The material was a fine gravel with a median grain size of approximately 6 mm and was trucked onsite.

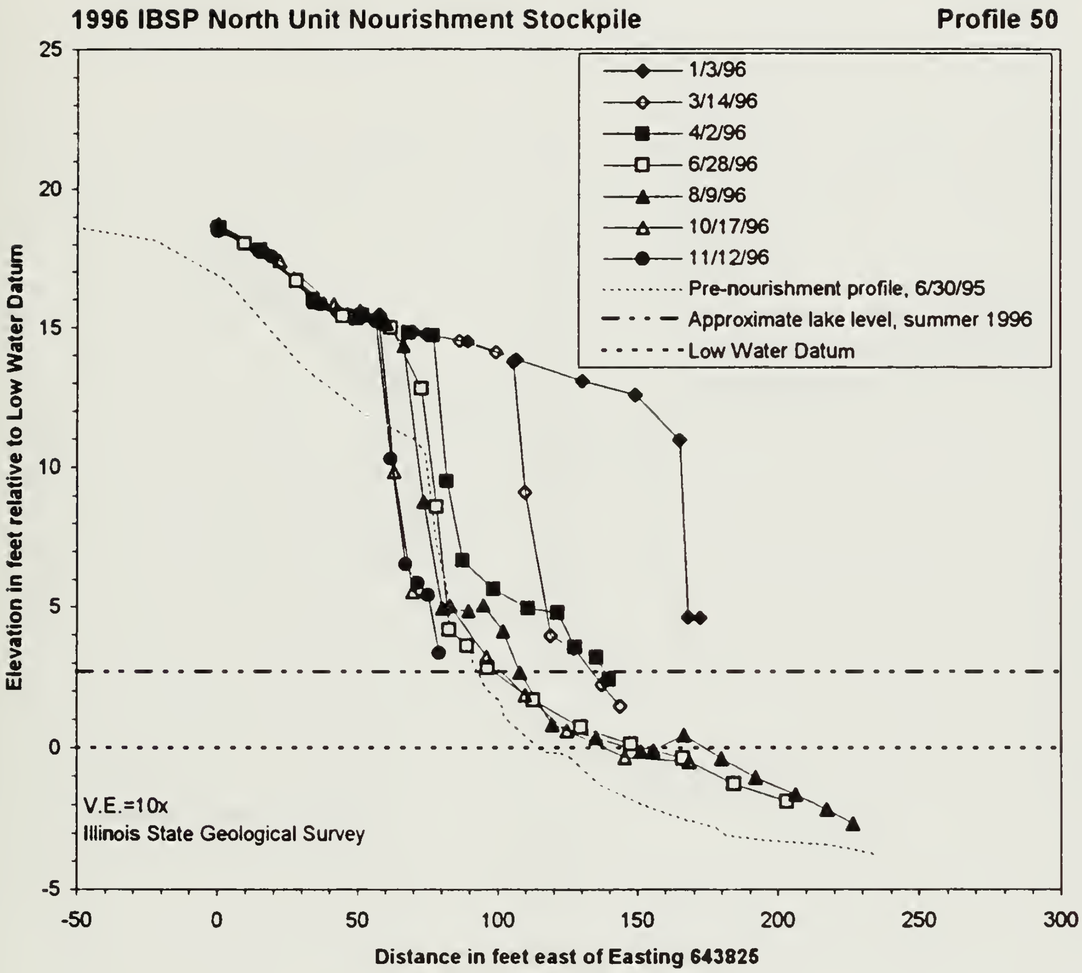
Two beach-nourishment events occurred in 1995. During July 1995, 20,000 cu yds of fine- to medium-grained sand were placed at the beach nourishment site between the NPM south parking area and Dead Dog Creek. Wave erosion had removed most of this material by November 1995.

Between early December 1995 and early January 1996, about 26,000 cu yds of new nourishment were added to the North Unit stockpile as part of a 33,000 cu yd addition to the stockpile and the adjacent lakefront along the NPM south parking area. The approximately 26,000 cu yds of nourishment were placed along the 500 ft of shore that had earlier received nourishment in July 1995. In the case of both 1995 nourishment projects, the nourishment material was obtained from storage stockpiles at the Commonwealth Edison Waukegan Generating Station (Fig. 1-2). The material was originally derived from maintenance dredging of that facility's intake and discharge channels and cooling-water basin. The material was trucked to the North Unit nourishment site and dumped along the lakeward flanks of the existing stockpile.

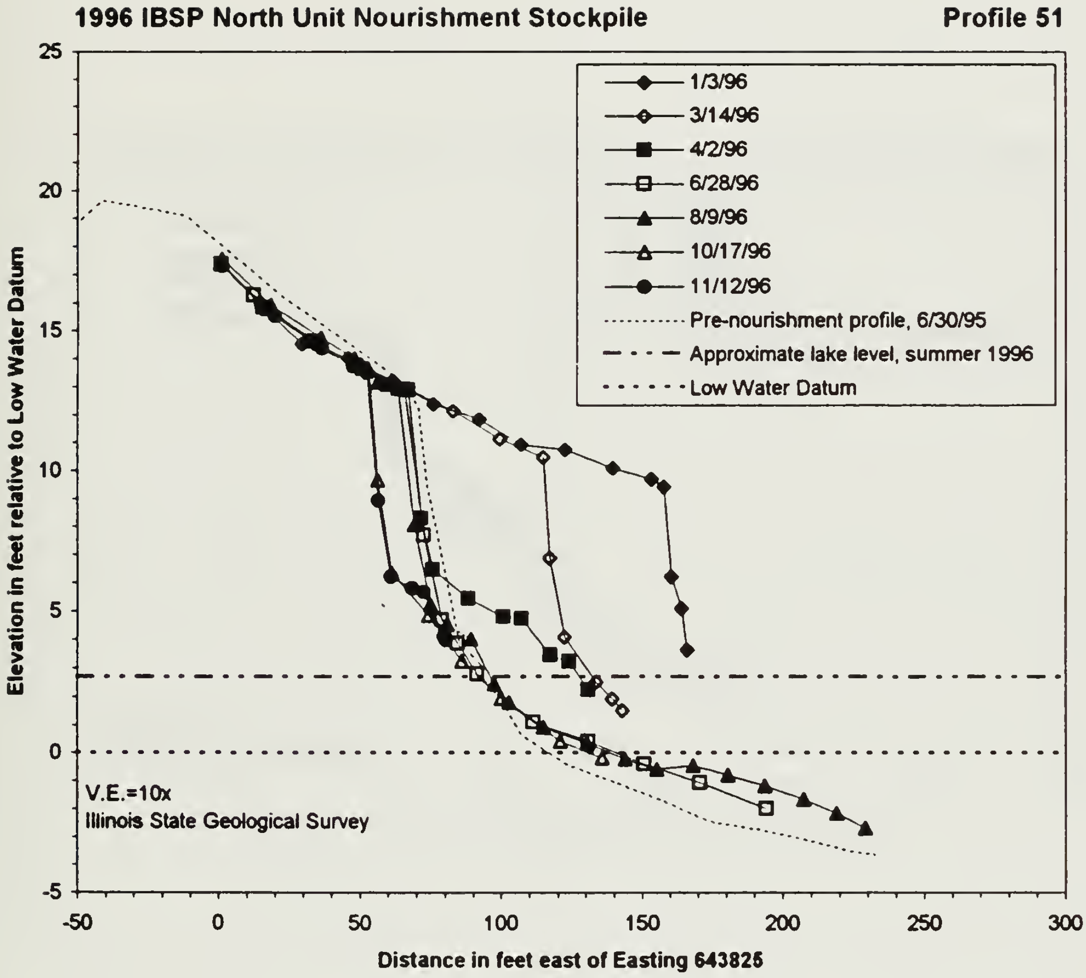
APPENDIX H: PROFILES ACROSS THE BEACH-NOURISHMENT SITE AT ILLINOIS BEACH STATE PARK / NORTH UNIT




1996 IBSP North Unit Nourishment Stockpile
Profile 49
1/3/96
3/14/96
4/2/96
6/28/96
8/9/96
10/17/96
11/12/96
Pre-nourishment profile, 6/30/95
Approximate lake level, summer 1996
Low Water Datum
V.E.=10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643825
25
20
15
10
5
0
-5
-50
0
50
100
150
200
250
300



1996 IBSP North Unit Nourishment Stockpile
Profile 50
1/3/96
3/14/96
4/2/96
6/28/96
8/9/96
10/17/96
11/12/96
Pre-nourishment profile, 6/30/95
Approximate lake level, summer 1996
Low Water Datum
V.E.=10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643825
25
20
15
10
5
0
-5
-50
0
50
100
150
200
250
300


1996 IBSP North Unit Nourishment Stockpile
Profile 51
1/3/96
3/14/96
4/2/96
6/28/96
8/9/96
10/17/96
11/12/96
Pre-nourishment profile, 6/30/95
Approximate lake level, summer 1996
Low Water Datum
V.E.=10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of Easting 643825
25
20
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-5
-50
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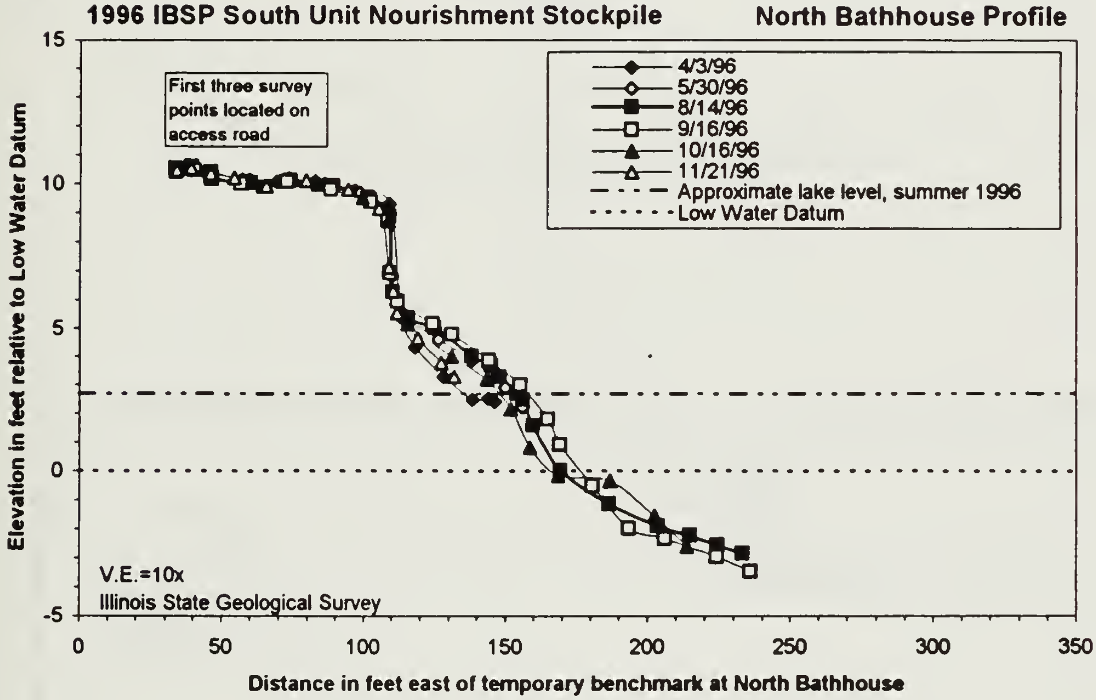
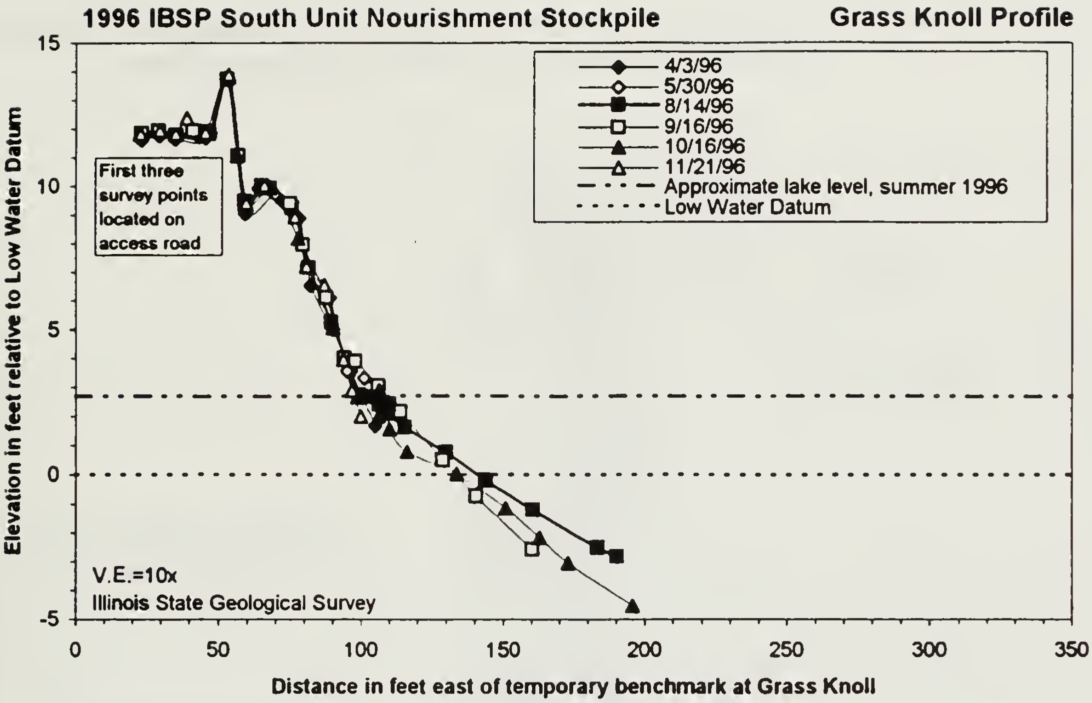
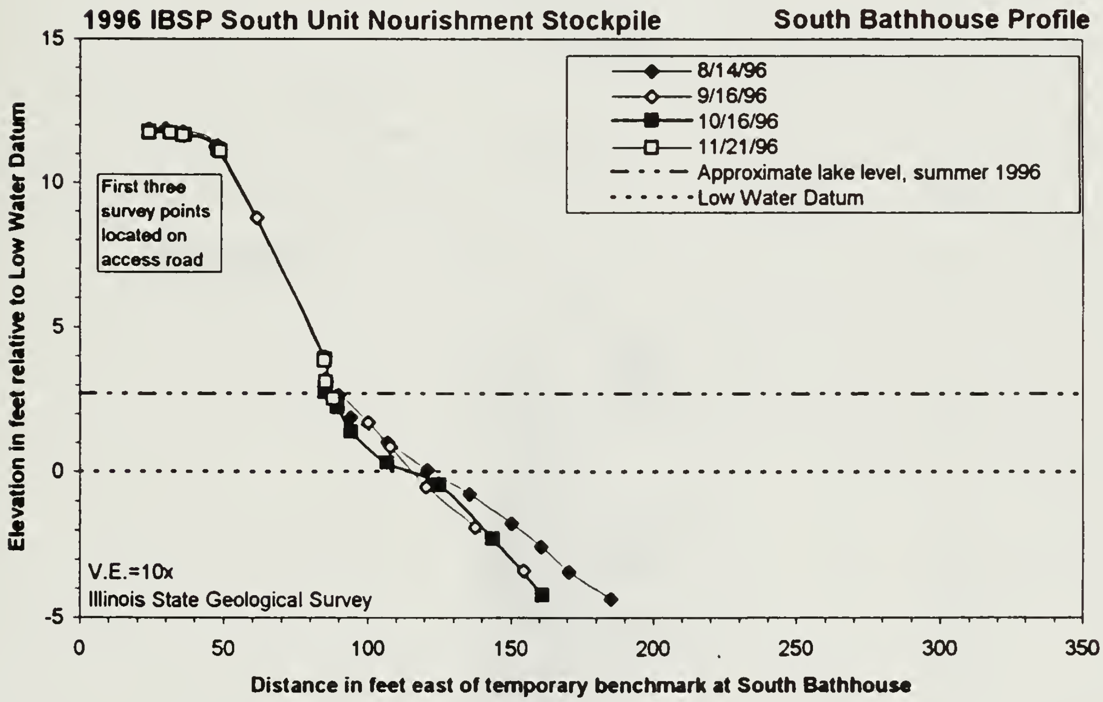
250
300

APPENDIX I: PROFILES ACROSS THE BEACH-NOURISHMENT SITE AT ILLINOIS BEACH STATE PARK / SOUTH UNIT




1996 IBSP South Unit Nourishment Stockpile
Grass Knoll Profile
4/3/96
5/30/96
8/14/96
9/16/96
10/16/96
11/21/96
Approximate lake level, summer 1996
Low Water Datum
First three survey points located on access road
V.E.=10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of temporary benchmark at Grass Knoll
15
10
5
0
-5
0
50
100
150
200
250
300
350


1996 IBSP South Unit Nourishment Stockpile
South Bathhouse Profile
8/14/96
9/16/96
10/16/96
11/21/96
Approximate lake level, summer 1996
Low Water Datum
First three survey points located on access road
V.E.=10x
Illinois State Geological Survey
Elevation in feet relative to Low Water Datum
Distance in feet east of temporary benchmark at South Bathhouse
15
10
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0
-5
0
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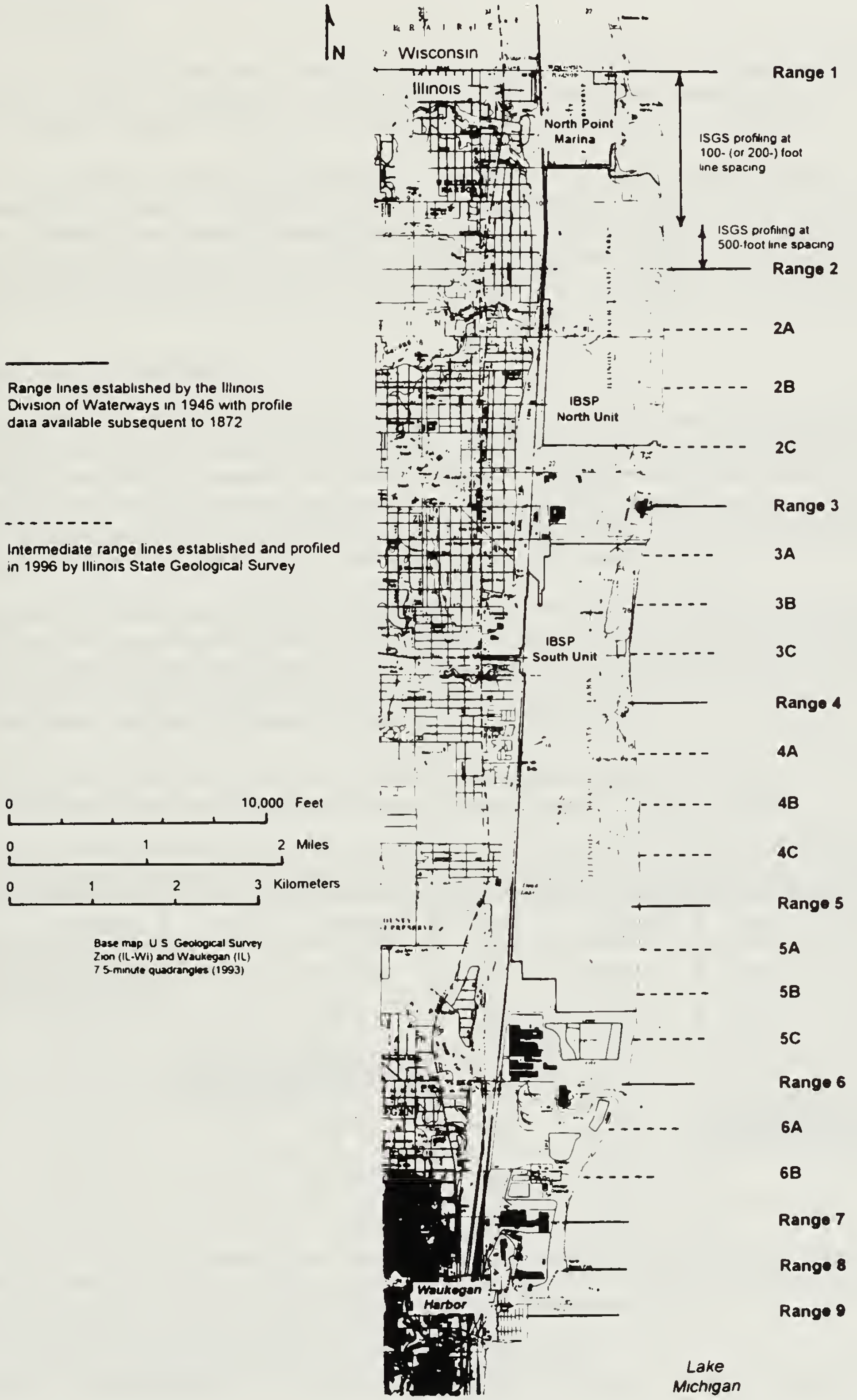
200
250
300
350

APPENDIX J: 1996 REGIONAL BATHYMETRIC PROFILING SCHEME WITHIN THE WI-IL STATE LINE / WAUKEGAN HARBOR (SL/WH) COASTAL REACH



APPENDIX K: NEARSHORE DREDGE VOLUMES

General Statement

Two principal dredging areas occur within the SL/WH coastal compartment. These are located at the Commonwealth Edison Waukegan Generating Station and at Waukegan Harbor (Fig. 1-2). Tables K-1 and K-2 tabulate available records concerning dredging dates and volumes at both sites.

Dredge volumes provide information important to the management of coastal sand resources. Firstly, the data indicate the amount of material that is being removed through non-natural processes from the nearshore. Secondly, the amount of material dredged can be used to provide an estimate of the amount of sediment trapping occurring at the dredge site. This in turn permits estimation of the amount of littoral sediment transport occurring at that site. The data provided below are used in Part 3: Regional Coastal Monitoring.

Waukegan Generating Station

Construction of the Waukegan Generating Station jetty, cooling-water basin, and intake channel occurred between 1923 and 1938. Dredge records are available for a 38-year period from 1958 through 1996 when dredging was done, on average, once every two years. Dredging was confined to the cooling basin, to the water intake / discharge channels, and along the jetty out to water depths of approximately 8 ft LWD. Because dredging occurred in areas landward of the facility's jetties, resultant lake-bottom changes typically were not documented in federal- and state-agency bathymetric surveys.

Dredge volumes at Waukegan Generating Station are shown in Table K-1. Because a component of the littoral sediment in transport past this facility is trapped at or landward of the jetty, these dredge volumes provide an estimate of littoral sediment transport along this reach of the Illinois shore. It is a minimum estimate because shoreline progradation to the south, and the requirement for periodic dredging at Waukegan Harbor, suggest that littoral sediment bypasses the facility.

Between 1958 and 1996, the total volume dredged at Waukegan Generating Station was 1,421,100 cu yds. For this 38-year interval, this yields an average dredging rate of 37,400 cu yds/yr.

Table K-1 Dredge volumes for Commonwealth Edison Waukegan Generating Station 1958-

Year	Volume[2]	Year	Volume[2]	Year	Volume[2]	Year	Volume[2]
1872-1910	0[3]	1972	100,000	1981	20,000	1992	114,000[5]
1958	120,000	1979	103,000	1988	42,000	1995	100,000[5]
1961	125,000	1910-1974	718,000	1988	102,700	1996	none
1963	50,000	1976	78,700	1987	50,700[4]	1974-1996	703,100
1965	100,000	1977	105,500	1988	7,000		
1968/69	120,000	1979	47,000[3]	1990	35,500		

[1] Volumes are rounded to the nearest 100 cu yds. All dredged material was placed at an onshore nourishment stockpile
[2] Volumes were provided by T.B Platt, Regulatory Compliance Engineer, Commonwealth Edison.
[3] This interval was prior to construction of Waukegan Generating Station.
[4] Records show two possible dredge volumes. The lesser volume of the two is listed.
[5] Volumes were accurately determined from stockpile surveys following placement.

Waukegan Harbor

Construction of Waukegan Harbor began in 1880 and the harbor had attained its present configuration by 1932 (Chrzastowski and Trask, 1995). The jetties, shore-attached breakwater, and the deep-water entrance channel combine to make Waukegan Harbor the largest barrier to littoral sediment transport on the northern Illinois coast, and one of the largest littoral transport barriers in the Great Lakes region.

Dredging to maintain a harbor at Waukegan began in 1889 . Prior to 1977, and again in 1982, sediment dredged from the harbor was discharged into deep water about 2.5 miles lakeward (east) of the harbor entrance. First in 1977, and consistently since 1984, dredged material has been discharged into a nearshore disposal area about three-quarters of a mile south of the harbor.

Table K-2 Dredge volumes for Waukegan Harbor 1889-1996.[1]

Year	Volume[2]	Year	Volume[2]	Year	Volume[2]	Year	Volume[2]
1889	17,800	1914	31,900	1931	90,200	1974	~10,000
1897	63,100	1918	31,200	1993	28,500	1910-1974	1,566,200
1897	9,100	1918	37,100	1934	29,000	1976	~48,400
1893	50,300	1917	73,600	1936	18,700	1976	34,700
1897	128,900	1918	28,900	1934	89,900	1977	130,000
1898	58,200	1919	50,500	1939	89,900	1982	85,400
1909	33,700	1929	16,800	1948	56,000	1984-	81,000
1903	26,700	1924	36,800	1950	29,600	1985	26,200
1909	280,900	1922	59,000	1993	108,200	1993	101,000
1906	5,000	1923	30,000	1993	12,600	1950	49,500
1907	9,100	1924	50,000	1961	39,900	1961	49,500
1907	5,000	1925	41,700	1993	47,200	1993	56,800
1909	14,900	1926	60,500	1964	50,800	1994	44,900
1910	53,500	1927	73,600	1965	41,300	1956	53,300
1872-1910	758,200	1028	77,400	1966	49,400	1974-1996	800,500
1912	7,800	1929	unknown	1967	32,500		
1913	10,200	1930	111,500	1969	33,500		

[1] Dredge data were obtained from annual reports of the U.S. Army Corps of Engineers and from data on file at the offices of the Chicago District. All dates from 1889 to 1975 are for federal fiscal years July through June; dates from 1976 to 1996 are for federal fiscal years October through September.

[2] Volumes are bin measures which are a measure of both sediment and water. Estimated water volume is 10 to 20 percent. The dredge volumes are not corrected for water content. All volumes are rounded to the nearest 100 cu yds

[3] M.K. Tibbetts, U.S. Army Corps of Engineers (pers. comm.).

Table K-2, adapted from Chrzastowski and Trask (1995), summarizes the dredge records for Waukegan Harbor from 1889 through 1996. In general, dredging at Waukegan Harbor occurred every one to two years. The primary dredging area was the channel between the jetties and the lakeward approach to this channel. Historical bathymetric data verifies that some natural bypass of the harbor jetties occurred during this time (Chrzastowski and Trask, 1995). Thus, the dredge record at Waukegan Harbor provides a minimum estimate of littoral sediment transport at the south end of the study area.

During the interval 1889-1996, 3,124,900 cu yds of sand were dredged from the Waukegan Harbor area. For this 107-year period, this yields an average dredging rate of 29,200 cu yds/yr.

Dredge Volumes for the Littoral Sediment Budget

Data from Tables K-1 and K-2 were compiled in Tables K-3 and K-4 below for use in the regional littoral sediment budget presented in Part 3 of this report. Dredge volumes from 1990 through 1996 were used to determine average dredge volumes for the 1992-1995, 1995-1996, and 1992-1996 intervals.

Table K-3 Interpolation method to determine the average annual dredge volumes at Waukegan Generating Station for use in the littoral sediment budget calculations (see Table 3-9).[1]

Calendar Year	1990	1991	1992	1993	1994	1995	1996
Dredge volume (cu yds) & timing	35,500	None	114,000[2] Oct	None	None	100,000[3]	None

Dredge volume for 1992-95 interval:	14,300[2] + 88,800[3] = 103,200 cu yds =	34,400 cu yds/yr
Dredge volume for 1995-96 interval:		80,000 cu yds/yr[4]
Dredge volume for 1992-96 interval:	103,200 + 80,000 = 183,100 cu yds =	45,800 cu yds/yr

[1] Sediment budget calculations are based on annual to multi-annual summer-to-summer intervals between 1992 and 1996.
[2] This volume is an approximation of sediment entrapment at the site over the two years since 1990 dredging. The amount of sediment entrapment that would have occurred between summer and autumn 1992 is estimated at 14,300 cu yds.
[3] Of the 100,000 cu yds dredged in 1995, 20,000 were dredged prior to the spring and the remaining 80,000 cu yds were dredged in the autumn. Since previous dredging occurred three years earlier in 1992, the annual rate of sediment entrapment at this site between 1992 and 1995 is estimated at about 33,300 cu yds/yr, or 2,775 cu yds/mo. The amount trapped between October 1992 and summer (June) 1995 is estimated at about 88,800 cu yds.
[4] The amount trapped between summer 1995 and summer (June) 1996 equals 80,000 cu yds which is the volume dredged in autumn 1995.

Table K-4 Interpolation method to determine the average annual dredge volumes at Waukegan Harbor for use in the littoral sediment budget calculations (see Table 3-9).[1]

Calendar Year	1990	1991	1992	1993	1994	1995	1996
Dredge volume (cu yds) & timing	49,500	79,500 Sept	None	66,600[2]	44,900	None	53,300 Aug-Oct

Dredge volume for 1992-95 interval:	66,600/2[2] + 44,900 = 78,200 cu yds =	26,100 cu yds/yr
Dredge volume for 1995-96 interval:		53,300 cu yds/yr
Dredge volume for 1992-96 interval:	78,200 + 53,300 = 131,500 cu yds =	32,900 cu yds/yr

[1] Sediment budget calculations are based on annual to multi-annual summer-to-summer intervals between 1992 and 1996.
[2] This volume represents accumulation for the approximately two years since September 1991 dredging. Dividing this volume by two(2) provides an estimate of the amount of sediment entrapment that occurred subsequent to summer 1992.