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DECEMBER 1978

FINAL REPORT

BEACH EROSION ANALYSIS AND PROTECTION PLANS FOR ILLINOIS BEACH STATE PARK

SUBMITTED TO

OIS DEPARTMENT OF CONSERVATION
ILLINOIS COASTAL ZONE
IAGEMENT PROGRAM

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FOR
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AND

ILLINOIS COASTAL ZONE MANAGEMENT PROGRAM

PREPARED BY

TETRA TECH, INC.

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EXECUTIVE SUMMARY

1. Shore Processes

1.1 Shore processes along the 7-mile coastline between Illinois/Wisconsin State Line and the southern boundary of the Illinois Beach State Park were investigated through a comprehensive review of survey data and previous studies since 1872 through 1977.

1.2 As a result of this review effort, shore processes along the coastline fronting the Illinois Beach State Park were found to be characterized as follows:

A. Geologically, the Park shoreline is part of the lake plain deposit which now occupies a coastline segment between Kenosha and a point about 1 mile south of Waukegan.

B. The Park shoreland has been formed and naturally nourished by the littoral sediment moving southward from the eroding lake-plain shoreland of the State of Wisconsin. However, owing to the limited sediment resources of the lake-plain deposit, the supply rate has progressively dwindled since the geological past.

C. Furthermore, due partly to the increased shoreline fortification and partly to the offshore loss at a number of headlands along the Wisconsin shoreline in recent years, the amount of material being fed into the littoral stream in the area of the source of supply has decreased.

D. At the present rate of decrease in the amount of littoral material crossing the State Line, the supply to the Illinois Beach State Park is predicted to disappear completely in about 40 to 50 years, or by around 2022 AD.

E. One result of the dwindling capacity for sediment supply along the Wisconsin shoreline was a southward migration of the nodal point which divides the erosional shore to the north and the accretional shore to the south. Currently, the nodal point is located between the Park Lodge and the Dead River outlet, and will continue to migrate southward at a rate of approximately 400 feet/year. At this rate of nodal point migration, the erosional zone will spread to the southern boundary of the Park by about 1986 and to the Waukegan Harbor north jetty by about 2014.

1.3 Seven air photo series covering the period 1939 to 1977 were analyzed to determine short-term erosion rates as well as the most recent erosion rates.

A. The result shows that the short-term erosion rates were higher than long-term rates (say, the rates averaged over 1872-1974) by a factor of about 3.

B. These large rates of short-term shoreline erosion were associated with protruding headlands and high lake levels.

2. Predicted Future Erosion

2.1 Consequently, future erosion rates must be predicted combining

A. Long-term erosion rates,

B. Superimposed short-term erosion rates,

C. Effects of dwindling supply from the updrift source, and

D. Effects of spreading erosional zone due to the rapid southward migration of nodal point.

2.2 Taking these factors into consideration, the amount of cumulative shoreline recession to 10, 20, 30, 40, and 50 years in the future was predicted at stations 1,500 feet apart along the State Park shoreline (See Table 2.7.2). According to this prediction, the following scenario is expected to develop in the forthcoming years, should the ongoing erosion is left to proceed:

A. Total shoreland loss due to erosion to 2024 AD for the North and South Units will amount to 385.81 acres, representing an average annual loss for this period of 7.72 acres a year. About 71% of this loss will come from the North Unit, the remaining 29% from the South Unit. These shoreland losses are between 20 to 30% higher than the previously known figures (See Table 3.3.1).

B. As a result of this rapid recession, various backshore properties will be endangered in accordance with the following time table:

- o Lake County Public Water District lower lift station and its ancillary substructures - within about 10 years.
- o Bathhouses - within about 5 years.
- o Park Lodge - currently in imminent danger of being outflanked by the receding shoreline on either side. Will need at least 1400 feet of additional sheet pile wall by 2024.
- o Ranger residence, commissary store, a 1700-square foot lakefront portion of the camp ground parking lot, a 1000-foot segment of the road between Wadsworth Road and Park Lodge, gas-, water- and sewerage-lines plus a portion of the Picnic Ground along this road, in the South Unit - to be wiped out within 50 years.

2.3 Projected over the forthcoming 50 years, average annual loss to be accounted for by the predicted erosion in the North and South Units of the Illinois Beach State Park will amount to $583,400.

2.4 About 57% of this loss will come from the North Unit and about 43%, from the South Unit. By category of items, about 68% of the predicted loss will come from shoreland losses, 23% from property losses, and about 9% from losses in recreational opportunities (See Tables 3.3.8 and 3.3.9).

3. Erosion Control Plan

3.1 Six alternative erosion control plans were investigated. One of these is a "no-action" alternative and the remaining five combine certain acceptable protective structures, recreational facilities, and nourishment plans. (See Table 4.1.1).

3.2 Benefits and costs for three of the latter five action alternatives were determined to show that the benefit/cost ratios will be in excess of 1.00 in all the three (See Table 3.9.6). Benefits and costs for the latter two alternatives, each including an offshore marina as part of the combined protective and recreational approach, have not been determined for this report, inasmuch as a feasibility study for a protective-recreational marina is being contemplated separately.

3.3 The alternative plans were evaluated for comparative merits and demerits, in view of the feasibility for construction and maintenance, the degree of assured performance, the concern for public safety, the concern for aesthetics, and the flexibility for accomodating future development of the Park. Alternative 3 which features armored headlands with initial and periodic beach nourishments was recommended as representing the best overall advantage.

3.4 The recommended plan (See Plate 3) consists of a total of six armored headlands, four in the North Unit and two in the South Unit, with periodic 370,000 cubic yards of beach fill at a 5-year cycle. An annual cost of this alternative plan, averaged over a 50-year project life, is $1,344,000. The first cost is $6,231,000 and the average annual maintenance cost is $900,000. (See Table 3.9.2) The B/C ratio of this alternative is 1.10.

TABLE 3.3.1

PREDICTED SHORELAND LOSSES TO 2024 AD
RESULTING FROM ALTERNATIVE 1 — "NO ACTION"

REGION	(1) PERMANENT LOSSES DUE TO MEAN SHORE-LINE		(2) TEMPORARY LOSSES DUE TO SHORT-TERM FLUCTUATIONS		(1) + (2) COMBINED LOSSES	
	Cumulative to 2024 AD	Annual Rate	Cumulative to 2024 AD	Annual Rate	Cumulative to 2024 AD	Annual Rate
	ACRE	ACRE/YR	ACRE	ACRE/YR	ACRE	ACRE/YR
North Unit	183.56	3.67	90.53	1.81	274.09	5.48
Zion	7.48	0.15	21.12	0.42	28.60	0.57
South Unit	27.46	0.55	84.26	1.69	111.72	2.24
North Unit and South Unit	211.02	4.22	174.79	3.50	385.81	7.72
Grand Total	218.50	4.37	195.91	3.92	414.41	8.29

TABLE 3.3.8

SUMMARY OF AVERAGE ANNUAL LOSSES
RESULTING FROM ALTERNATIVE 1 - "NO-ACTION"

PARK UNIT	ITEM	LOSS
North	Land	$262,400
	Property	71,000
	Sub-Total	$333,400
South	Land	$136,000
	Property	63,000
	Recreational Opportunity	51,000
	Sub-Total	$250,000
PARK TOTAL		$583,400

TABLE 3.3.9

AVERAGE ANNUAL
LOSSES BY CATEGORY

PARK UNIT	LAND	PROPERTY	RECREATIONAL OPPORTUNITY	SUBTOTAL
North	262,400	71,000	0	333,400
South	136,000	63,000	51,000	250,000
Sub-total	398,400	134,000	51000	
PARK TOTAL				$583,400

TABLE 3.9.2

ESTIMATED COSTS FOR ALTERNATIVE 3

(Armored Headlands & Nourishment)

ITEM	QUANTITY	UNIT	UNIT COST ($)	ITEM COST ($1,000)	SUBTOTAL ($1,000)
FIRST COSTS					
ARMORED HEADLAND	600	LF			
Armor Stone, 3 ton	33,900	TON	25	848	
Underlayer, #200 stone	10,800	TON	15	162	
Filter cloth	1,800	SY	5.75	10	1,020
BEACH FILL	370,000	CY	10	3,700	3,700
	SUBTOTAL				4,720
	FIRST COSTS WITH 20% CONTINGENCY				5,664
	ENGINEERING/DESIGN (6%)			340	
	SUPERVISION/ADMINISTRATION (4%)			227	567
	TOTAL FIRST COSTS				6,231
ANNUAL MAINTENANCE COSTS					
1% OF STRUCTURES WITH 20% CONTINGENCY				12	
BEACH NOURISHMENT WITH 20% CONTINGENCY				888	
	TOTAL ANNUAL MAINTENANCE COSTS:				900

TABLE 3.9.6

COMPARISON OF BENEFITS AND COSTS
(In Thousands of Dollars)

ALTERNATIVE	ANNUAL BENEFITS	ANNUAL COSTS	BENEFIT/COST RATIO
2. Nourishment with Sills	1,483	1,334	1.11
3. Armored Head- lands and Nourishment	1,483	1,344	1.10
4. Detached Breakwaters, Fishing Pier, & Headlands	1,483	1,246	1.19

TABLE 4.1.1

SUMMARY OF ALTERNATIVE EROSION CONTROL PLANS

Alternatives	NORTH UNIT			SOUTH UNIT			COST	
	Protective Structures	Nourishment	Recreation Facilities	Protective Structures	Nourishment	Recreation Facilities	Annual cost	B/C Ratio
1. No Action	None	None	None	None	None	None	Damage due to erosion: $583,400	
2. Nourishment with sill (Perched beaches)	Underwater sill 5,000'	Initial 250K cubic yards. Periodic 250K c.y./5 years	None	None	Initial 120K cubic yards. Periodic 120K c.y./5 years.	None	$1,334,000	1.11
3. Artificial headlands	Four armored headlands	Initial 250K cubic yards. Periodic 250K c.y./5 years.	Possible lookout points on headland	Two headlands	Initial 120K cubic yards. Periodic 120K c.y./5 years.	Possible lookout points on headland	$1,344,000	1.10
4. Partial breakwater, pier & headland	Five detached breakwaters + one headland	Initial 100K cubic yards. No periodic nourishment.	Possible lookout points on headland	One headland	Initial 120K cubic yards. No periodic nourishment.	Fishing pier 600' with headland buttress	$1,246,000	1.19
5. Marina in North Unit	Two armored headlands	Initial 100K cubic yards. Periodic 100K c.y./5 years.	Offshore marina & raised causeway on headland buttress	One headland	Initial 120K cubic yards. Periodic 120K c.y./5 years.	Fishing pier 600' with headland buttress	-	-
6. Marina in South Unit	Four armored headlands	Initial 250K cubic yards. Periodic 250K c.y./5 years.	Possible lookout points on headland	None	None	Offshore marina & raised causeway on headland buttress	-	-

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1. INTRODUCTION

1.1 Scope of Work

The objective of this study is to develop technical engineering assessment for feasible shoreline erosion mitigation solutions for the Illinois Beach State Park.

In order to attain this objective, the Scope of Work included the following task elements:

- o Beach erosion rate estimate
- o Examination and optimization of alternative corrective measures
- o Development of phased program

1.1.1 Beach Erosion Rate Estimate

Historical data have been reviewed and to a large extent subjected to reanalysis with a view of not only determining quantitative estimates of the erosion rates but also developing understanding of the nature of physical processes of the existing erosion. From this effort has resulted a clear definition of the unique character of the existing erosion problems and the important constraints under which mitigation plans will be formulated.
The data base for beach erosion has been considerably enhanced by addition of recent erosion data from seven sets of air photos between 1939 and 1977.

1.1.2 *Examination of Alternative Measures*

Various existing methods for beach erosion control have been extensively researched and sorted out with a view to feasible applications to the unique problems at the Illinois Beach State Park. From this evaluation of erosion control methodology, six alternative plans were selected,each combining a balanced set of actions aiming at different levels of objectives and goals to be achieved. Comparative merits and demerits among the selected alternatives were then performed with determination of benefit/cost ratios.

1.1.3 *Development of Phased Programs*

Final recommendations were made with priorities and phased schedules for implementation. Among the recommended programs are the concept of combining the objectives of beach erosion control with those of developing recreational opportunities, in particular with the construction of a wave-slicing fishing pier and an offshore marina. The concept of an offshore marina is being scheduled to receive a detailed feasibility investigation in a study just authorized. Consequently, the recommended programs emerging from the present study may need some degree of adjustment in accordance with the outcome of this separate study.

It is also worthwhile to mention that the Waukegan fillet, a potential borrow area for beach nourishment material, presents a sensitive issue on the ground that whether the material to be extracted from this fillet would belong to the Illinois Beach State Park coastline or to the downdrift shores to Lake Forest is open to question. This aspect is part of the study focusing on the beach erosion control programs for the region between North Chicago and Lake Forest. Since the final resolution of this issue will be dependent upon future development of events, including possible review of the situation by Federal agencies, recommendations as to the source of material made in this study will remain tentative.

1.2 Study Site

1.2.1 Environmental Setting

Figure 1.2.1 defines the boundary of the study site. The study focuses on the Illinois Beach State Park which, located in Lake County, stretches from the Illinois-Wisconsin state line to the southern end of the Park bordered by the property of the Johns Manville Company, a distance of approximately 7 miles. This area has been designated by the Illinois Coastal Zone Management Program as a Geographic Area of Particular Concern (GAPC). From the southern boundary of the Park to the Waukegan Harbor north jetty, the shoreline continues for about 2 miles. A general outline of the shoreline under study is shown in Figure 1.2.2.

Illinois Beach State Park is separated into the north and south units by a short segment of the shoreline which is now mostly occupied by the Commonwealth Edison Company's nuclear power station, a distance of about 3,100 feet or 0.6 miles. The shoreline on the north Park unit measures approximately 3 miles in length, and the south Park unit approximately 3.4 miles. The Illinois Beach State Park, with its north and south units, now provides the largest single body of public recreational lands on Lake Michigan within Illinois.

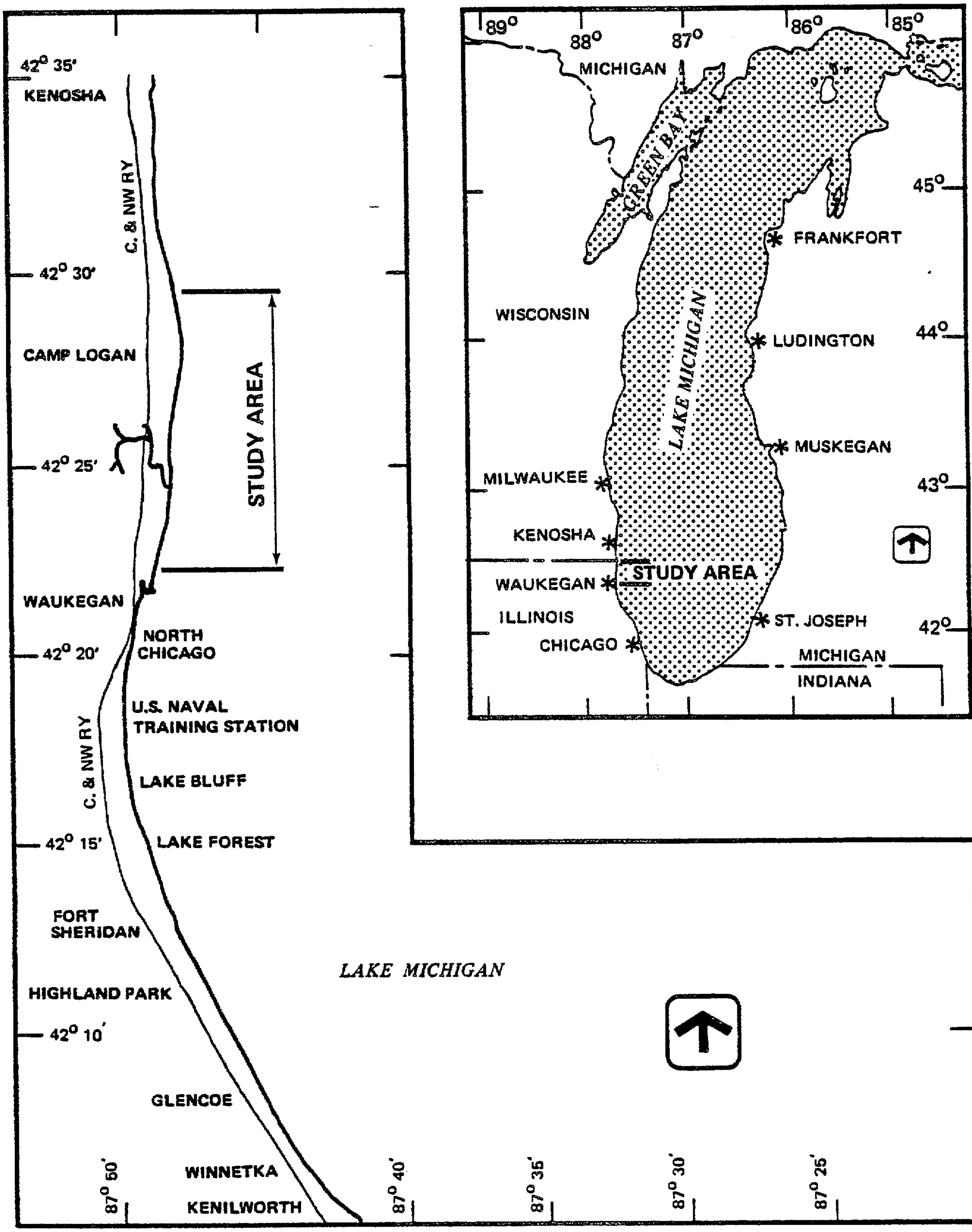


FIGURE 1.2.1 STUDY AREA

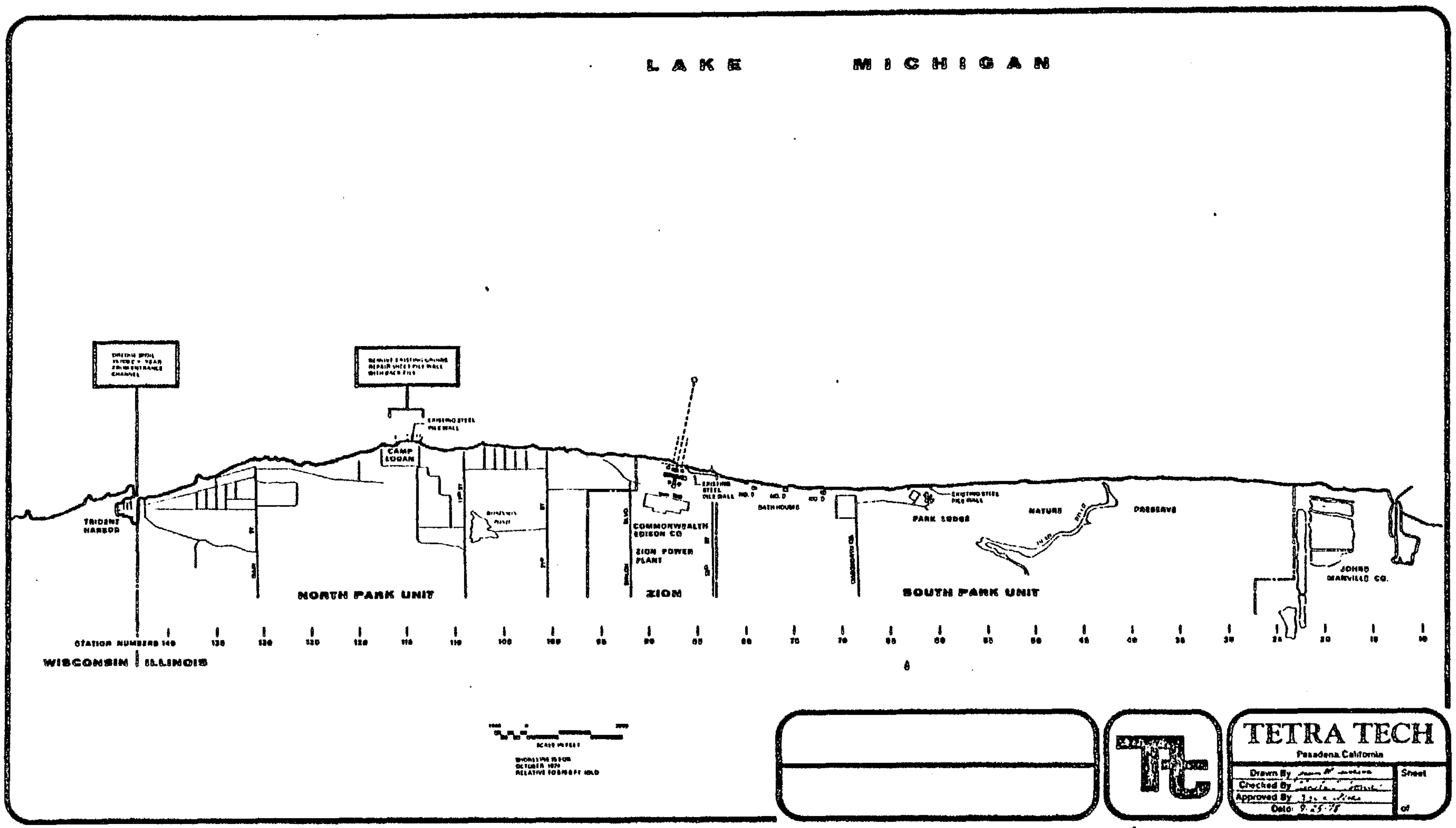


FIGURE 1.2.2 EXISTING SHORELINE CONDITIONS

South Unit

The south unit, which contains approximately 1,800 acres, was acquired in the mid-1940's. It was acquired primarily to preserve a large expanse of the only natural beach and dunes association remaining in Illinois. So important were the natural qualities of the area that the southernmost 900 acres fronting approximately 2 miles of undistrubed shoreline were dedicated as Illinois' first statutorily protected Nature Preserve in 1964. The south unit also contains a park lodge, picnic and camping areas, a swimming beach equipped with three bath houses, and ranger stations.

North Unit

Acquisition of the north unit began in 1971 and is scheduled for completion in 1980. Like the south unit, this area contains large expanses of marsh and prairie vegetation. While several of these are of significance for their natural qualities, in general, the northern area has been considerably more disturbed by man than the south unit. Much of the north unit was subdivided and sold as building lots in a real estate boom in the 1920's. In the intervening years, some 300 homes were constructed in the unit in addition to a State National Guard Camp (Logan), a water treatment plant, etc. The planned future development in the north unit features trails, overlooks, campgrounds, day use, and interpretive facilities. Presently, the lower lift station of the Lake County Public Water District is located only about 250 feet from the lake shoreline immediately south of the 17th Street. A 42-inch buried water intake pipe extends into the lake for about 3,000 feet from this station.

1.2.2. *Existing Problems*

Overview

The overall feature of the shoreline in the study area is characterized by (1) severe erosion in the North Unit, (2) relatively modest erosion in the northern half of the South Unit to the proximity to the Dead River outlet, and (3) a fillet complex south of the Park boundary associated with the Public Service Company pier and the Waukegan north jetty. At the State Line, the 1872 shoreline was approximately 1,200 feet lakeward of the 1977 shoreline. On the other hand, the 1977 shoreline is located more than 1,000 feet lakeward from the 1872 shoreline at the Waukegan north jetty.

Thus, most of the existing severe erosion appears to be concentrated in the North Unit. However, there are indications that the nodal point has been steadily moving southward over the years, engulfing more and more of the Park shoreline in a state of erosion. The nodal point presently lies between the Park Lodge and the Dead River outlet.

North Unit

Between late 1940's and mid-1950's, uncordinated efforts to fortify several short stretches of shore by private home owners between the State Line and 21st Street, and construction of the Camp Logan groin system took place. The unprotected reaches of shore continued to erode, however, with shore recession averaging 20 to 30 feet a year north of Main Street to the State Line between 1947 - 1954. In the more recent years, the recession rates in this reach have occasionally soared to 40 feet a year or more.

The shoreland areas where their attempts had been successful formed small headlands without beaches. Between 1974 and 77, most of these headlands too fell in the lake, and the drowned remnants of the failed headlands and old housing foundations are still recognized from air photos. Air photos also reveal remnants of various protective works which failed, including stone riprap, gabion baskets, and short groins of various materials.

An initial attempt was made to stop the erosion of the northern one-half of the 2,642-foot Camp Logan shore with four concrete groins, each about 150 feet long spaced 400 feet apart. When these groins were outflanked, they were extended shoreward as far as a new steel sheet pile bulkhead. The northern portion of this bulkhead has failed and a crescent-shaped pocket beach has formed between the two broken ends. Except for the southernmost Z-groin, all these groins have failed, leaving small portions on their offshore end still over the lake level.

The 5,300 reach of shore extending from 17th Street to Shiloh Boulevard was formerly a residential suburb in which some lakefront property owners also attempted to stop erosion of their lands with generally similar results. Recession of the pocket beaches between revetted headlands was not as severe as in the northern reach, however, as the original beach was generally 100 to 300 feet wide when development first began in the 1940's. Most of the lakefront road serving the shore properties along with all the headlands in this reach fell into the lake during 1974 - 77. At locations where destroyed headlands still retain their outline in water, the shoreline shows a sign of local accretion, indicating that these structures are acting like submerged breakwater or submerged groin.

Commonwealth Edison Company Property at Zion

The Commonwealth Edison Company recently completed construction of a nuclear power plant along the reach of shore between Shiloh Road and 29th Street. Cooling water intake pipes about 3,000 feet long and discharge lines about 800 feet long extending into the lake are believed well buried below the lake bottom and therefore have no effect on shore processes. A steel sheet pile seawall about 1,200 feet long, with returns at each end protects the main power plant area. During the time of power plant construction, the company constructed a temporary breakwater extending generally southeastward from shore near the extension of Shiloh Road. This breakwater intercepted littoral materials causing a 6-acre fillet to develop along the north side of the breakwater. The south shore of the breakwater was cut back as far as the line of the sheet pile wall. To hold the shoreline in this downdrift reach, an additional 1,200 feet of sheet pile wall was extended into the Park area. Presently, the beach fronting the power station has a width ranging from 100 to 150 feet.

South Unit

The 7,000 feet of shorelands extending from 29th Street southward to the Illinois Beach State Park lodge has served as a recreational beach since its acquisition by the State about 1946. The north end of the beach began to suffer severe erosion shortly after the temporary power plant harbor was constructed in 1970. In compliance with the terms of its permit, the Commonwealth Edison Company constructed a steel sheet pile seawall extending from 29th Street about 1,200 feet southward to protect the State Park beach. When the erosion started to outflank the seawall on the south, the protection was extended downcoast by means of stone riprap. The accretion to the downcoast following the removal of the power plant breakwater has now buried about one-half of the sheet pile seawall.

However, erosion is continuing along the remainder of the recreational beach. Two bathhouse buildings are now being threatened by shore recession. A third bathhouse located at the end of Wadsworth Road had to be abandoned in the winter of 1973-74. The beach fronting the third bathhouse was temporarily stabilized with the placement of concrete blocks along the shoreline, but they are being undermined by wave erosion.

The shoreline fronting the Park Lodge, approximately 700 feet, is protected by a sheet pile wall. In 1974, the beach was cut back as far as the wall. With the placement of about 117,000 cubic yards of replenishment, the beach at this location has been widened to about 100 feet.

The beach between the Park Lodge to the Dead River outlet, a distance of some 60,000 feet, appears to be in a precarious equilibrium. The nodal point is believed to be located somewhere along this reach, threatening to migrate further southward in the future.

The beach from the Dead River outlet to the Johns-Manville property, a distance of some 8,400 feet, is essentially stable and appears to retain a distinct rate of accretion. During the past 30 years, the rate of accretion ranged from about 1.5 feet/year at the northern end to about 7 feet/year at the southern end.

From the Johns-Manville property southward about 8,000 feet to the Waukegan Harbor north jetty, the shoreline has advanced by various amounts historically. In this area, which forms an accretion fillet on the updrift side of the jetty, the shoreline exhibited a large range of fluctuations although the overall trend was toward accretion over a long term. Along the entire fillet area, the accretion over the past 30 years averaged about 12 feet/

year. However, the fillet appears to exhibit a sign of stabilization in recent years. During the 3-year period between 1974 and 1977, the fillet retreated at an average rate of about 5 feet/year.

2. SHORE PROCESSES

2.1 Prior Studies

The Lake Michigan Shoreline within the State of Illinois has received intensive studies since as early as 1940's. Of these numerous studies, those which are most pertinent to this current study are a series of Corps of Engineers studies, a comprehensive documentation of surveys and analyses developed by the Illinois Geological Survey, the literature developed by the Illinois Coastal Zone Management Program, and various scientific reports.

Extensive search and investigation of existing literature and data were performed in this study. A brief discussion of the existing studies and reports which proved most pertinent to the present study is given as follows:

> Illinois Shore of Lake Michigan, Beach Erosion Control Study (1949). Corps of Engineers Chicago District, House Document No. 28, 83rd Congress, 1st Session.

This report represents probably the single most important source of historical erosion data dating back to 1872. Beach profiles, shoreline positions and volume changes are well documented in its comprehensive appendices, for the years 1872, 1910, and 1946. The present study has made a liberal use of these data to establish a coherent historical progress of beach changes from 1872 to the most recent air-photo year of 1977.

The report recognized erosion problems in the reach adjacent to the State Line and recommended using groins to control erosion. However, due to the relative stability of the shoreline within the then-existing Illinois Beach State Park at that time, and the desire on the part of the State to preserve the area in its natural state, no plan for shore protection was recommended for this reach.

<u>National Shoreline Study — Great Lakes Region Inventory Report (1971)</u>. Corps of Engineers North Central Division

The report classified a 5-mile long coastline south of the State Line as "critical erosion area", and a 3-mile shoreline further southward to Waukegan Harbor as "non-critical erosion area". "Critical" erosion areas are defined as those reaches of shoreline having high value economic and recreational resources and a historic record of rapid loss of land and/or structural damage. All other shoreline reaches recording erosion damages are defined as "non-critical" erosion areas.

<u>Interim Report on Illinois Shoreline Erosion (1975)</u>. Corps of Engineers Chicago District.

This important report is the summary of a study undertaken at the request of the Illinois Department of Conservation to develop beach erosion control plans for the shoreline between the State Line and Waukegan. The study evaluated 8 alternative plans but concluded that none of the structural alternatives was justified on grounds of inadequate benefit/cost ratios.

The eight alternatives developed in this study were:

1. Artificial beach nourishment
2. Artificial headlands (5 headlands) and beach fill
3. Offshore breakwaters (5 detached breakwaters) and beach fill
4. Groins (10 groins) and beach fill
5. Revetment, from the State Line to just south of the Park Lodge, 24,000 feet long

6. Shoreland management

7. Partial nourishment and headlands (nourishment north of the power plant and headlands on the south unit)

8. Partial headlands (two headlands in the south unit only) with beach fill, do nothing on the north unit

The study also undertook detailed beach erosion assessments with additional shoreline and profile data up to 1974.

The study concluded:

"Based on the lack of economic feasibility, there does not appear to be sufficient justification to warrant undertaking detailed or phase II studies. Further, there does not appear to be any other overriding consideration which would justify undertaking further studies leading to a possible recommendation and authorization of a Federal shore protection project. Therefore, it is concluded that further detailed investigations are not warranted at this time."

Beach and Bluff Protection (1976). Illinois Coastal Zone Management Program, Vol. III. Corps of Engineers Chicago District

This study covered the entire Illinois shoreline with a view to developing preliminary engineering design for protective works and their cost estimates. The portion of the recommendations made by the study which relates to the Illinois Beach State Park is quoted as follows:

a. The effects of major structures on littoral transport processes along the Illinois shore should be thoroughly investigated. Major structures include the Waukegan and Great Lakes Naval Training Center harbor structures.

The harbor structures at Kenosha, Wisconsin also may have some effect on shore processes occurring along the Illinois shore. No studies have as yet been made which accurately determine the proportion of downdrift erosion attributable to these harbor structures.

b. The offshore sand sampling studies currently being carried out by the Illinois Geological Survey should be completed as this research is important to the success of any beach replenishment program. Accurate estimates of both the quantity and quality of available sand in potential offshore borrow areas will impact on the feasibility of these alternatives.

c. An analysis of the conditions of existing shore protection structures should be made in order that their efficiency in providing erosion proteciton can be estimated.

d. Refinements in the littoral trnasport analysis should be made based on additional data on sediment analysis and volumetric rates of bluff material lost to the lake. These studies are currently being carried out by the Illinois Geological Survey. Also information on possible quantities of sand by-passing major structures would aid in this analysis.

Safewater Harbor Feasibility Study – Illinois Beach State Park (1978). Illinois Department of Conservation

This engineering feasibility study and environmental assessment was undertaken to determine if a safewater harbor can be constructed in an environmentally responsible manner in Lake Michigan at Illinois Beach State Park. Upon evaluation of various alternative plans and their corresponding environmental consequences, the study essentially concluded that an environmentally responsible safewater harbor can be constructed if its size is limited to 500 slips or less, but that any harbors with less than 1,000 ships will not attain a sufficient benefit/cost ratio which would justify Federal aid.

The alternative plans evaluated in the study were characterized by their generally fixed location in the vicinity of the 17th and 21st Street and by the shore-connected marina configurations. The study also stated that the environmental acceptability of any harbor project would be contingent upon the concurrent development and implementation of a Park-wide shore protection plan into which the harbor project was integrated.

Cognizant of other potential configurations and locations for a safewater harbor and also of the need for integrating the safewater harbor feasibility assessment into a Park-wide shore protection plan, the Illinois Department of Conservation has recently authorized initiation of an additional feasibility study on safewater harbor in mid-October, 1978.

<u>"Sediment Distribution between Wisconsin and Chicago on the Lake Michigan Shore" (1975)</u>, <u>"Hydrography of the Lake Michigan Nearshore in Illinois" (1977)</u>, and <u>"Map Atlas, Lake Michigan Shore in Illinois (1975)</u>. All published by Illinois Geological Survey for Illinois Coastal Zone Management Program

These documents represent extensive summaries of recent surveys conducted by the Illinois Geological Survey during 1975 – 1977. They exhibit the thicknesses of sediment on the nearshore bottom, nearshore bathymetry taken in 1974, distribution of existing protective structures, submerged and hazardous structures of the nearshore zone, shoreline and bluff line for April 1975, anticipated 100-year recession bluff line (to 2075 AD), areas of active bluff erosion, and shore ownership.

<u>Other Studies and Reports</u>

Other pertinent literature reviewed in this study is summarized under BIBLIOGRAPHY.

2.2 Geomorphology

A series of excellent studies by the Illinois State Geological Survey have shed light on the sedimentogical and physiographic characters of the Illinois Beach State Park. In particular, the publications entitled:

"Sedimentology of a beach ridge complex and its significance in land-use planning", by Hester, N.C., and G.S. Fraser, 1973, Illinois Geological Survey Environmental Geology Notes 63, and

"Sediment Distribution in a beach ridge complex and its application to artificial beach replenishment", by Fraser, G.S. and N.C. Hester, 1974, Illinois Geological Survey Environmental Geology Notes 67

have been of special value to the understanding of the geomorphological history of the study area.

The sedimentology of the southwestern shore of Lake Michigan generally may be considered to be comprised of two distinct categories: lake plain deposit and lake border moraine formation.

The lake plain deposit is composed of the material eroded from the lake border marine formation by waves, currents and winds. The formation of lake plain deposit forms much of the sandy beaches now found in the Illinois Beach State Park. As shown in Figure 2.1.1, this deposit is essentially a veneer of sandy material with a maximum thickness of about 30 feet and gradually thinning toward offshore. This formation is underlain by the lake border moraine formation consisting mainly of glacial and lake-laid deposits which is generally well consolidated.

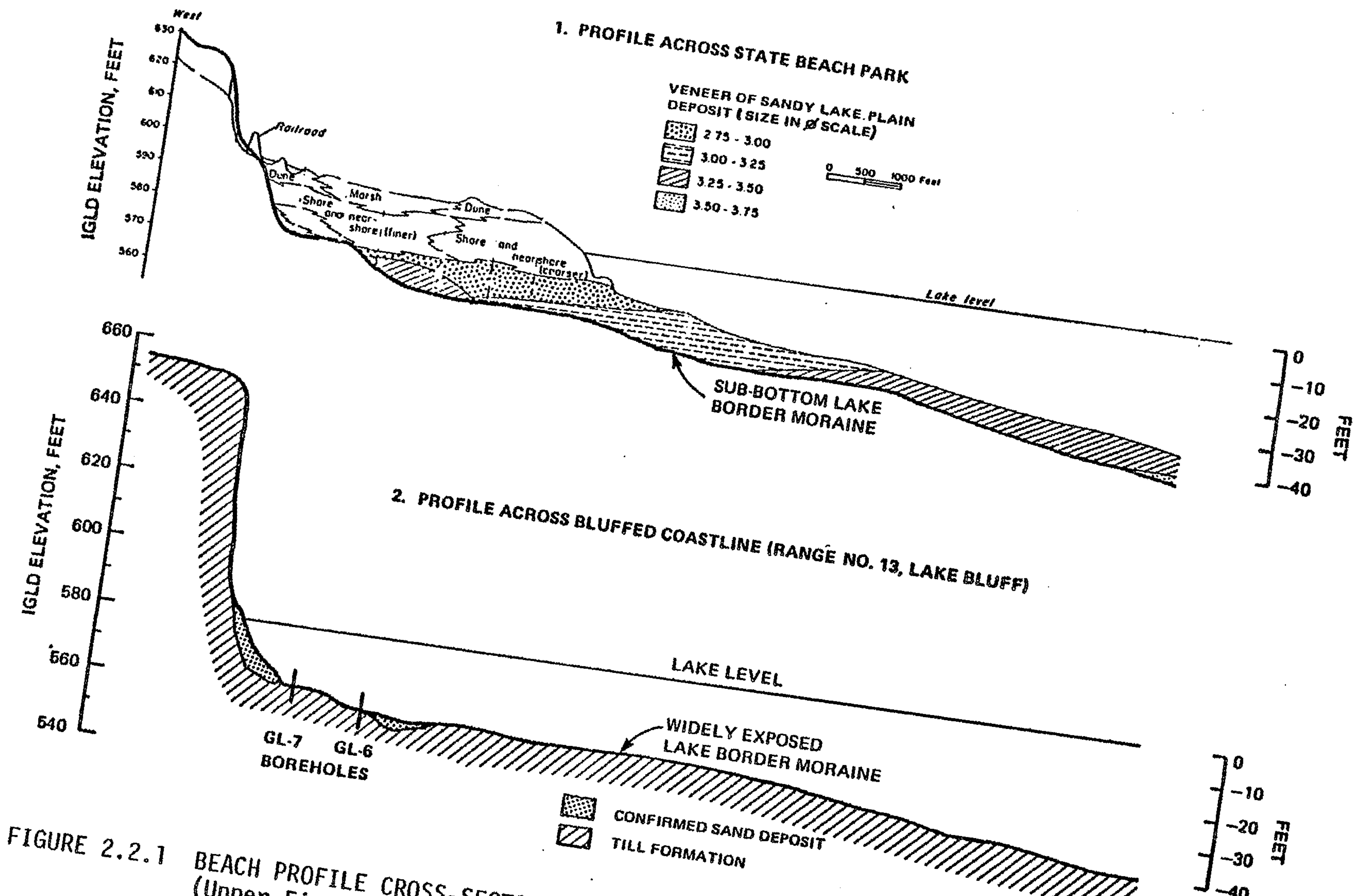


FIGURE 2.2.1 BEACH PROFILE CROSS-SECTIONS THROUGH STATE BEACH PARK AND LAKE BLUFF
(Upper Figure from Fraser and Hester, 1974)

In the Illinois Beach State Park, the lake plain deposit extends from shore about 1 mile landward as far as about the position of the 600-foot IGLD contour line (about 20 feet above lake level), and between 1 and 2 miles lakeward.

Along the southwestern shore of Lake Michigan this lake plain deposit extends northward as far as Kenosha and southward to a point about 1 mile south of Waukegan, a total distance of about 18 miles. Beyond these two points, the coastline is characterized by a bluff line directly exposed to the lake.

The bluffed coastline will usually erode much more slowly than the sandy beach, hence is a relatively poor source of supply of material to the littoral zone. Accordingly, although the coastline updrift of the Illinois Beach State Park stretches a few hundred miles as far as the Door peninsula, the principal source of supply may be considered to occupy only about 7 miles of the lake moraine coastline in Wisconsin.

In the geological past, the lake plain deposit is believed to have extended much farther north than its present northernmost point at Kenosha, which probably supplied a greater amount of littoral material to the shore of Illinois Beach State Park than today. Extensive presence of a beach ridge system found in the present south park unit could be an indication that there once was an overabundance of littoral material arriving at this location. On the basis of radiocarbon dating, the formation of the beach ridge system was estimated to have occurred less than 1,000 years ago.

If we are to assume that the littoral drift during the past 1,000 years has maintained similar intensity and similar direction of predominant movement from north to south as today, it is likely that the northern end of the lake plain deposit has undergone southward migration during this period, which would have gradually reduced the length of the sandy coast updrift of the Illinois Beach State Park to diminish the supply of littoral material passing across the State Line.

Consequently, it is likely that progressive impoverishment of the supply of littoral material to the Illinois shoreline has occurred as part of the natural processes of long-term geological shoreline evolution, associated in particular with the dwindling capacity of the sediment supply along the Wisconsin shoreline updrift of the study area.

2.3 Historical Changes (1872-1977)

2.3.1 Volume Changes

Lake shore processes in Illinois have been well documented through a series of surveys dating back to 1872. Figure 2.3.1 and 2.3.2 show representative beach profiles for 1872, 1946 and 1975 at four equally spaced locations between the State Line and the Waukegan north jetty.

In Figure 2.3.1, it is evident that profile erosion was distinctly more pronounced near the State Line, progressively diminishing southward and reversing its trend to accretion off the Waukegan jetty. It is also seen that most prominent changes in profile occurred at both ends, the State Line and the Waukegan jetty, involving large amounts of volume changes as deep as -20 feet LWD. The profiles between these two extreme locations exhibited considerably less amounts of change, confined mostly to the nearshore zone.

In Figure 2.3.2, it is seen that in 1872, prior to the construction of the Waukegan jetty, the profile at the State Line (Range 1) contained the largest volume of sediment of the four profiles compared, whereas the profile at the Waukegan jetty (Range 3) contained the least volume of sediment.

In 1975, this situation reversed itself alomost completely, so that now the profile at the State Line has the least volume and the profile at the Waukegan the largest volume.

Consequently, during the past 103 years between 1872 and 1975, the dominant lake shore processes on this beach were for the southern profile to accrete at the expense of the northern profiles, leaving the profiles in the intervening zone more or less in a nodal situation.

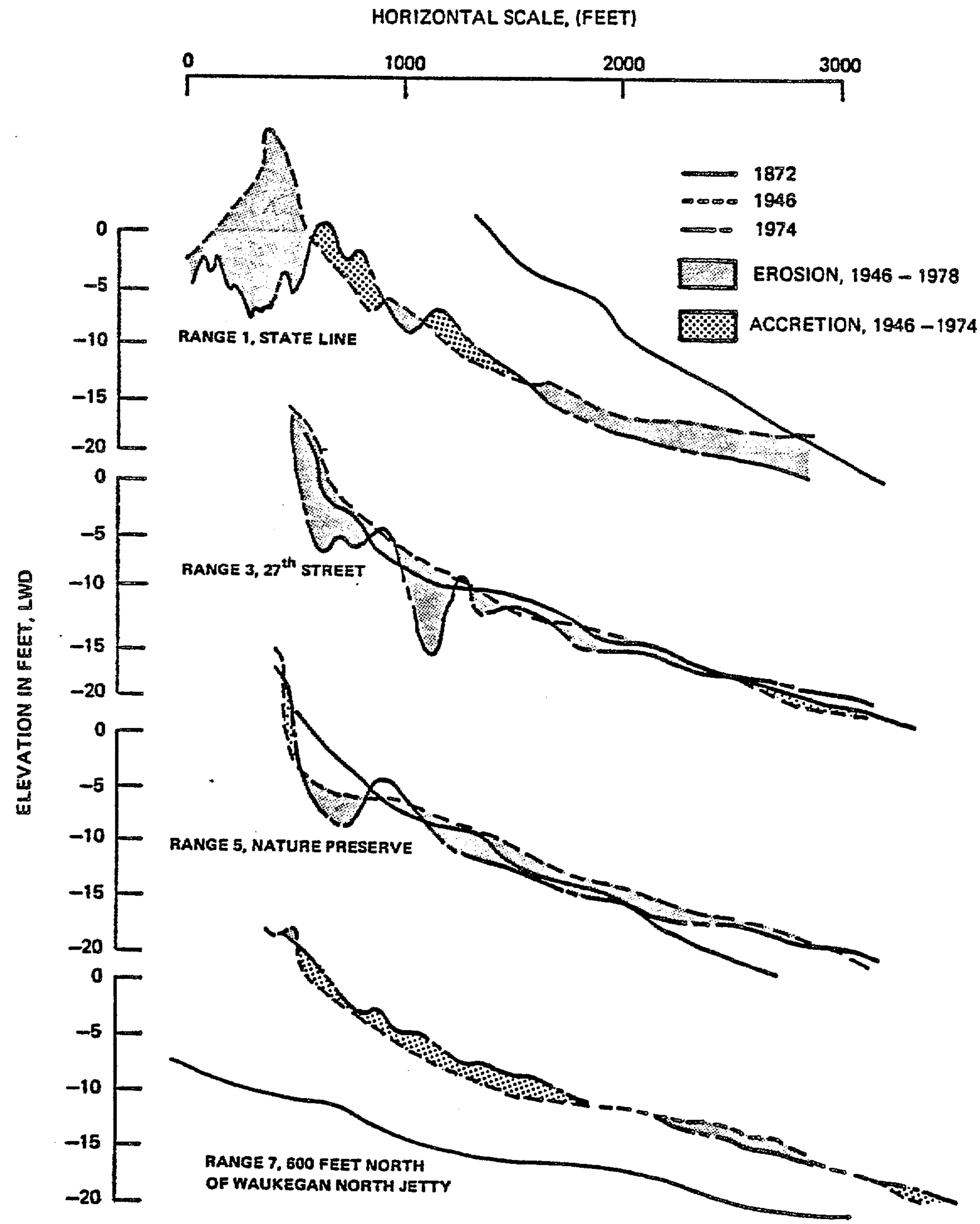


FIGURE 2.3.1 PROFILE CHANGES 1872 – 1975

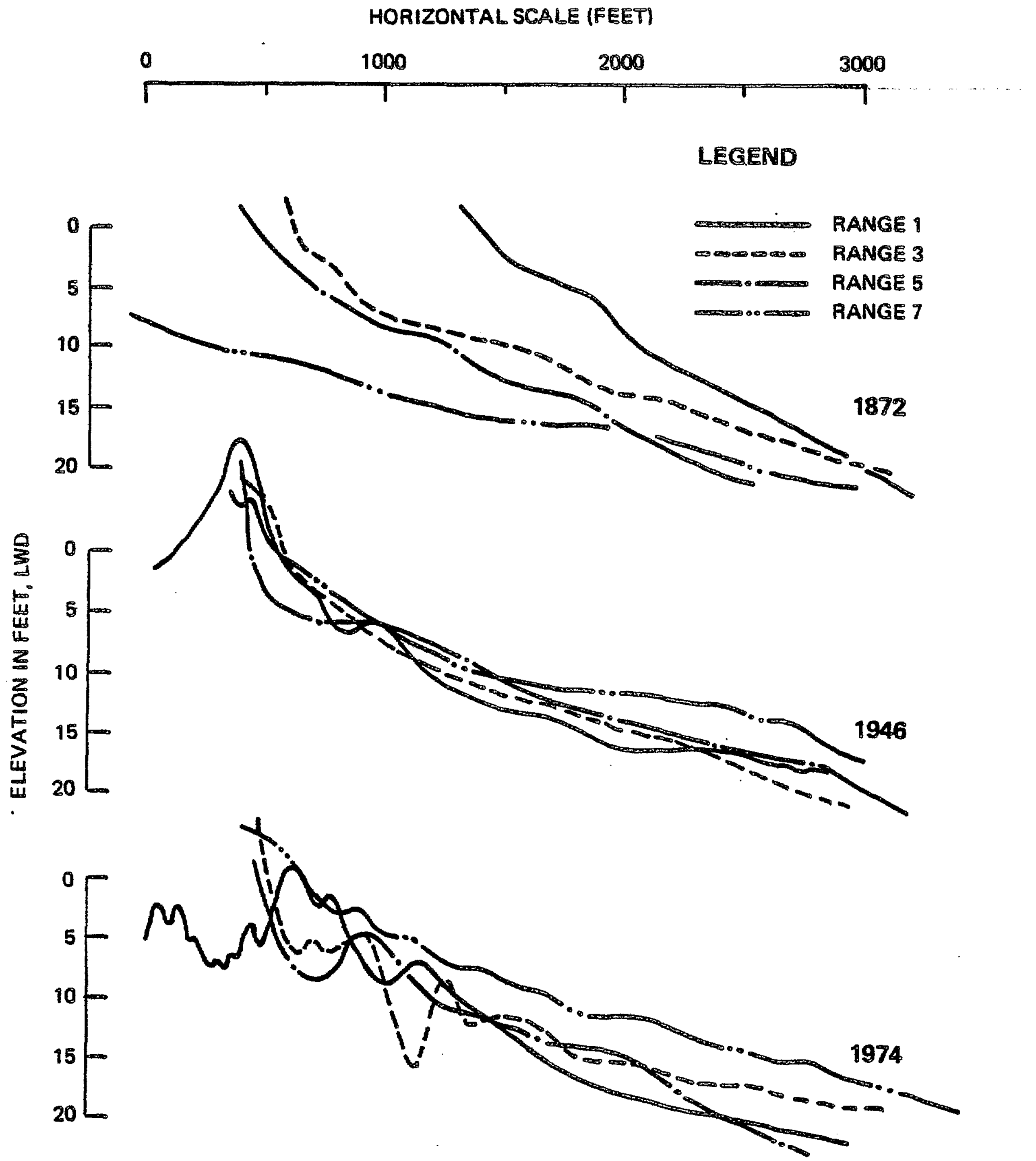


FIGURE 2.3.2: CHANGES IN PROFILE DISTRIBUTION 1872 – 1975

Table 2.3.1 shows volumetric changes in the profiles to -20 feet LWD for successive periods of 1872-1910, 1910-1946, and 1946-1974. Also shown in Table 2.3.1 are the locations of the so-called "no-change" or "nodal" point (denoted NC), where profile changes are reversed from erosion to accretion southward. It is evident that between 1872 to 1974, the no-change points migrated steadily southward from near the State Line to the proximity of Range 5 fronting the Nature Preserve. This in turn means that the extent of eroding shoreland expanded southward during this period of time. As will be shown later (see Section 3.7), the speed of this expansion (or the speed of the no-change point) was about 400 feet/year.

With the southward expansion of the eroding zone, volumetric losses in this zone also increased, say from 50,000 cubic yards during 1872-1910 to about 5,000,000 cubic yards during 1910-1946 and about 2,400,000 cubic yards during 1946-1974. On the other hand, volumetric gain between the no-change point to the Waukegan jetty increased from the period 1872-1910 to 1910-1946.

Table 2.3.2 is an extract of net volume changes and annual change rates between 1872 and 1946, based on "Illinois Shore Study" (1949) by Corps of Engineers Chicago District. This data is updated in Table 2.3.3 by incorporating the 1975 survey data by Illinois Geological Survey.

These data are illustrated in terms of annual rates (Figure 2.3.3), southward cumulative annual rates (Figure 2.3.4), and comparative analysis against 1872 (Figure 2.3.5).

In Figure 2.3.3, it is seen that up to as recently as 1946 most part of the Illinois coast as far south as Winnetka still contained more sediment than in 1872, except for the northern most reach which now fronts the North Unit of the Illinois Beach State Park. The largest net gain was associated with the north fillet of the Waukegan Harbor,

TABLE 2.3.1

VOLUMETRIC CHANGES BETWEEN
APPROXIMATE -20 FOOT CONTOUR
AND LWD, STATE LINE TO WAUKEGAN
HARBOR (thousands of cubic yards)

Reaches	Reach Length, Feet	YEARS		
		1872 to 1910	1910 to 1946	1946 to 1974
1-2	7,700	- 50	-3,501	-1,476
2-3	9,200	NC + 256	-1,721	- 256
3-4	7,600	+ 629	NC + 147	- 197
4-5	7,800	+ 206	+ 957	- 433
5-6	6,700	+ 165	+3,710	NC + 372
6-7	5,500	+1,776	+3,028	No Survey
7-8	1,700	+1,079	+ 768	No Survey
1 to No-Change		- 50	-5,222	-2,362
No-Change to 8		+4,111	+8,610	+ 372

Source: Corps of Engineers Chicago District: "Interim Report on Illinois Shore Erosion" (1975).

TABLE 2.3.2

HISTORICAL VOLUMETRIC CHANGES TO -20 FOOT LWD

RANGE	LANDMARK	NET CHANGE (1000 C.Y.) 1872-1910	1910-1946	1872-1946	AVERAGE ANNUAL CHANGE (1000 C.Y./YR) 1872-1910	1910-1946	1872-1946
1	State Line						
		-50	-3,501	-3,551	-1.3	-97.2	-48.0
2	Camp Logan						
		256	-1,721	-1,465	6.7	-47.8	-19.8
3	Zion Power Plant						
		629	147	776	16.6	4.1	10.5
4	600'N of Lodge						
		206	957	1,163	5.4	26.6	15.7
5	State Park Nature Preserve						
		165	3,710	3,875	4.3	103.1	52.4
6	Johns Manville						
		1,776	3,028	4,804	46.8	84.1	64.9
7	N of Waukegan						
		1,079	768	1,847	28.4	21.3	25.0
8	Waukegan N. Jetty						
		-	-	-	-	-	-
9	Waukegan S. Jetty						
		846	310	1,156	22.3	8.6	15.6
10	S of Waukegan						
		1,348	344	1,692	35.5	9.6	22.9
11	U.S. Steel Plant						
		1,408	1,258	2,666	37.0	35.0	36.0
12	Great Lakes NTC N. Jetty						
		599	1,259	1,854	15.8	34.9	25.0
13	Lake Bluff						
		141	-81	60	3.7	-2.2	0.8
14	Lake Bluff Rockland Rd						
		775	-487	288	20.4	-14.0	3.9
15	Lake Forest College						
		376	-779	-403	9.9	-21.6	-5.4
16	Lake Forest Northmoor Rd						
		1,179	-837	342	31.0	-23.3	4.6
17	Fort Sheridan						
		2,571	-412	2,159	67.7	-11.4	29.2
18							
		2,706	131	2,837	71.2	3.7	38.3
19	Highland Park						
		2,943	-528	2,415	77.5	-14.7	32.6
20							
		3,132	94	3,226	82.4	2.6	43.6
21	Glencoe						
		1,823	345	2,168	48.0	9.6	29.3
22							
		877	142	1,019	23.0	4.0	13.8
23							
		2,713	-318	2,395	71.4	-8.8	32.4
24	Winnetka-Kenilworth Boundary						

Data from U.S. Army Corps of Engineers, 1949. "Illinois Shore of Lake Michigan, Beach Erosion Control Studies"

TABLE 2.3.3

SUMMARY OF HISTORICAL VOLUME CHANGES
IN PROFILES BETWEEN LOW WATER DATUM AND A 20-FT DEPTH
1872 THROUGH 1975

LANDMARK	RANGE NO.	NET VOLUME CHANGE FROM 1872 TO (1000 C.Y.)			AVERAGE ANNUAL CHANGE FROM 1872 TO (1000 C.Y./YEAR)			AVERAGE ANNUAL CHANGE FOR SUCCESSIVE PERIODS (1000 C.Y./YEAR)			AVERAGE ANNUAL CHANGE PER FOOT OF SHORELINE (C.Y./YEAR/FOOT)			
		1910	1946	1975	1910	1946	1975	1872-1910	1910-1946	1946-1975	1872-1910	1910-1946	1946-1975	1872-1975
State Line	1													
		206	-5,016	-6,476	5.4	-67.8	-62.9	5.4	-145.0	-50.3	0.32	-8.66	-3.00	-3.75
Zion Power Plant	3													
		835	1,939	148	22.0	26.2	1.4	22.0	30.7	-61.8	1.43	2.00	-4.03	-0.09
State Park Nature Preserve	5													
		1,941	8,679	8,399	51.1	117.3	81.5	51.1	187.2	-9.7	4.22	15.47	-0.80	6.74
North of Waukegan	7													
		1,079*	1,847*	1,942*	28.4*	25.0*	18.9*	28.4*	21.3*	3.3*	7.93*	5.95*	0.92*	5.27*
South of Waukegan	9													
		2,194	2,848	2,424	57.8	38.5	23.5	57.8	18.2	-11.5	7.09	2.23	-1.41	2.89
U.S. Steel Plant	11													
		2,007	4,520	3,100	52.8	61.0	30.1	52.8	69.9	-49.0	3.13	4.15	-2.91	1.79
Lake Bluff	13													
		916	348	-1,414	24.1	4.7	-13.7	24.1	-16.2	-60.8	1.80	-1.21	-4.54	-1.02
Lake Forest	15													
		1,555	-61	-1,987	40.9	-0.8	-19.3	40.9	-44.9	-66.4	3.48	-3.82	-5.65	-1.64
Ft. Sheridan	17													
		5,277	4,996	1,636	138.9	67.5	15.9	138.9	-7.7	-115.9	8.08	-0.45	-6.74	0.92
Highland Park	19													
		6,075	5,641	3,074	159.9	76.2	29.8	159.9	-12.1	-88.5	9.57	-0.72	-5.30	1.79
Glencoe	21													
		5,413	5,582	4,471	142.2	75.5	43.4	142.4	4.8	-38.3	7.59	0.26	-2.04	2.31
Winnetka	24													

Data Source: (1) U.S. Army Corps of Engineers, 1952. "Illinois Shore of Lake Michigan, Beach Erosion Control Study".
(2) Illinois State Geological Survey, 1975.
(*) Not including Waukegan Harbor, Ranges 8 — 9.

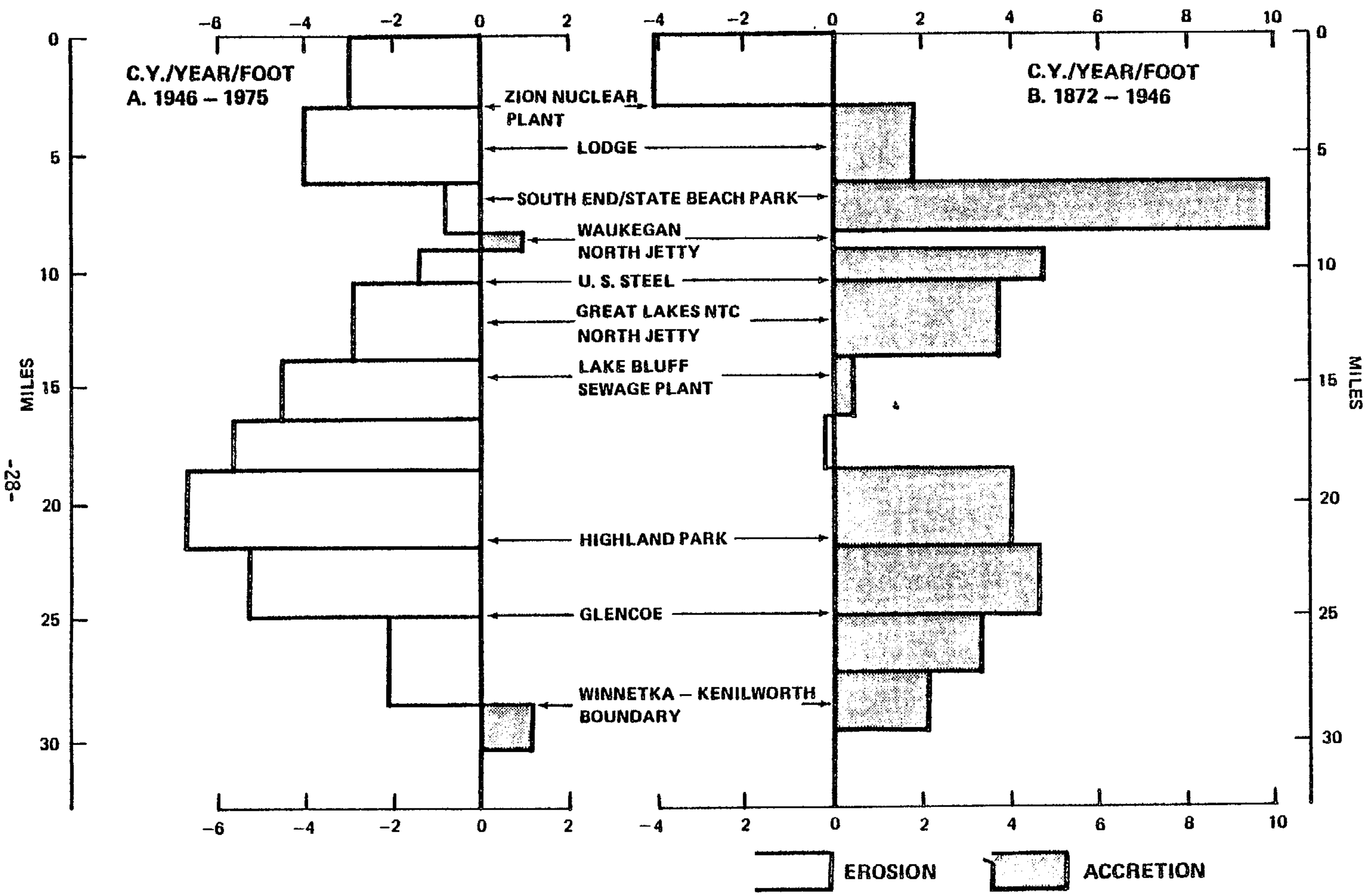


FIGURE 2.3.3 ANNUAL VOLUME CHANGES IN PROFILE

-28-

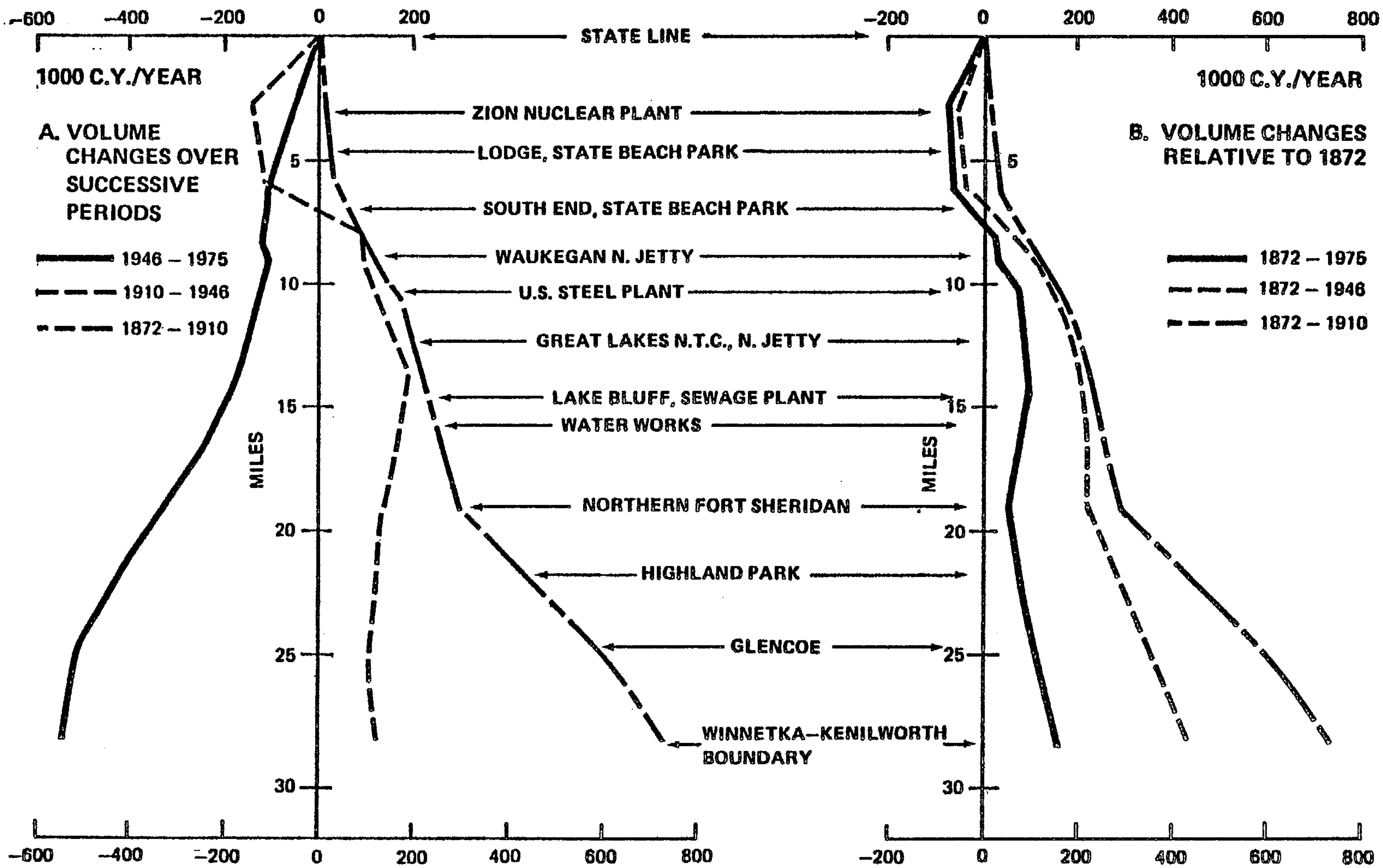


FIGURE 2.3.4 SOUTHWARD CUMULATIVE ANNUAL VOLUME CHANGES IN PROFILE BETWEEN LWD AND -20 FEET

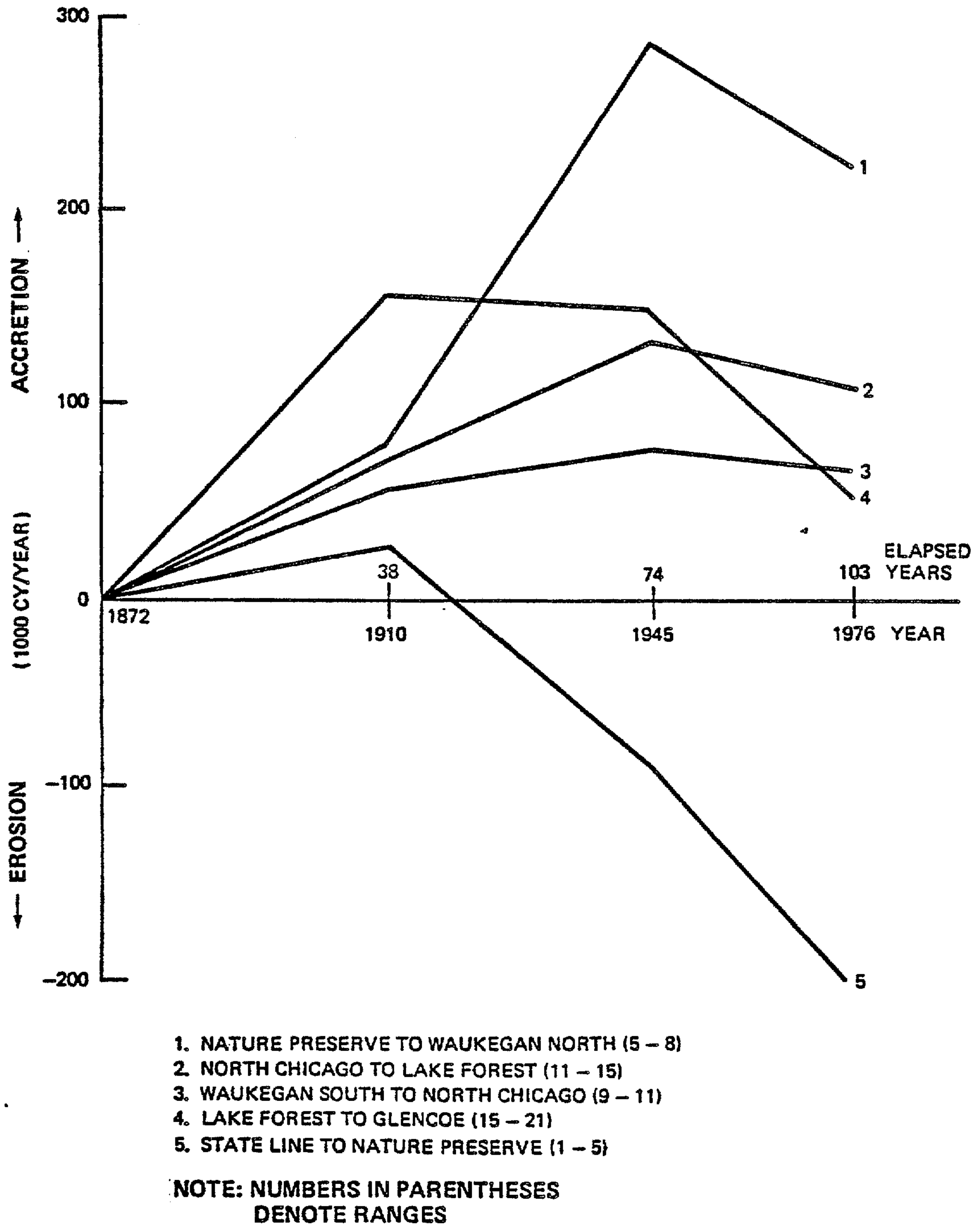


FIGURE 2.3.5 PROGRESSIVE VOLUME CHANGES IN PROFILE RELATIVE TO 1872

as expected. In 1975, all the profiles in this region, with the exception of those on the Waukegan and Winnetka fillets, exhibited a net loss as compared with those in 1946.

Figure 2.3.4 shows (A) cumulative annual volume changes for periods 1872-1910, 1910-1946, and 1946-1975, and (B) cumulative annual changes as compared with the 1872 annual rate for the same periods in the same region. Each point along these cumulative curves indicates a net annual gain or loss in a reach betwen the State Line to that point. According to Figure 2.3.4 (A), it is evident that every reach from the State Line to any given position southward is now losing sand annually (1946-1975). As recently as 1910-1946, the reach to the southern boundary of the State Park remained stable. According to Figure 2.3.4 (B), the State Park shoreline in 1975 contained less material than in 1872, whereas the amount of sand in this reach in 1946 was approximately equal to that in 1872, and in 1910 far more than in 1872.

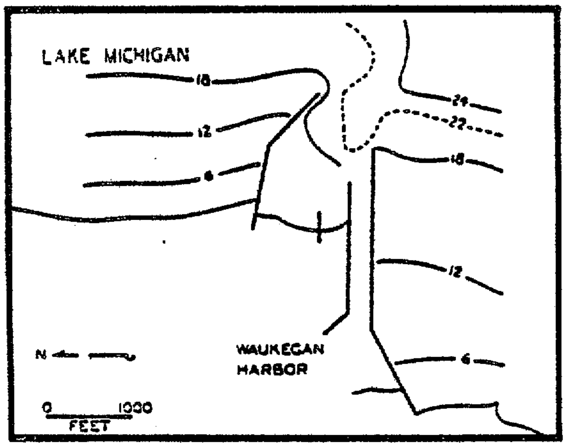
Figure 2.3.5 shows historical trends of annual volume changes for different shoreline reaches in the region. In the reach between the State Line and Nature Preserve (Ranges 1-5) where the no-change point is currently believed to be located, there exists a steep trend for increasing annual sediment loss since around 1910. A similar trend began somewhat more recently in the reach between the Nature Preserve and the Waukegan jetty, around 1945.

2.3.2 *Waukegan Fillet*

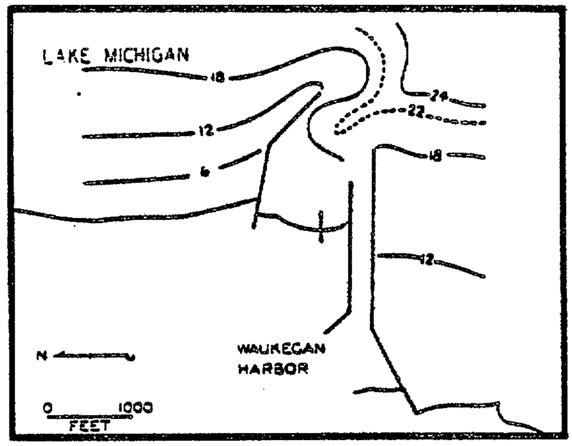
The above review of historical volumetric changes indicates that the beach profiles in the Beach State Park domain used to be gaining sand as a result of impoundment on the north side of the Waukegan jetty as recently as 1946, but that this trend has now shifted to overall erosion along almost the entire coastline of the park. In quantity(see Table 2.3.3), for each foot of shoreline in the area between the State Park Nature Preserve (Range 5) and the Waukegan north jetty (Range 7), the volume gain jumped from 4.22 cubic yards a year during 1872-1910 to 15.47 cubic yards a year during 1910-1946. During this latter period construction of the Waukegan north jetty created an impoundment basin for the sediment arriving from the north. The construction began with a 600 foot offshore segment and the connection to the shore was completed in 1931, making the total length of the jetty 1900 feet. During 29 years between 1946-1975, this enormous accretion north of the Waukegan began to slow down considerably, as indicated by a net average annual loss of 0.8 cubic yards a year per foot of beach in this reach for the period (Table 2.3.3).

Conceivable reasons for a rapid slowdown of accretion in the Waukegan fillet are many. However, one of the principal reasons appears to be the fact that the Waukegan fillet has long reached its full capacity, so that the sediment arriving presently will overflow around the tip of the breakwater to continue its movement down-coast.

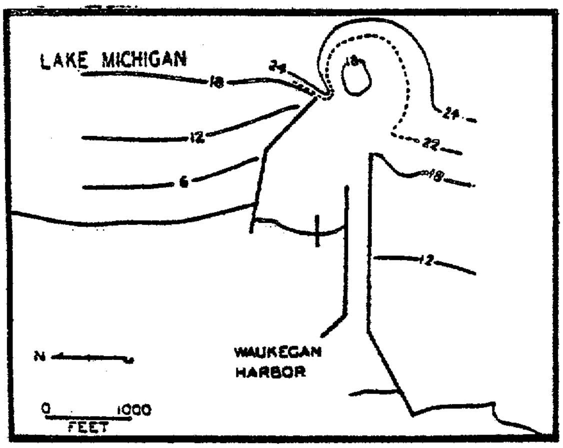
Using a series of suverys made by Corps of Engineers over the period 1933 to 1948, Krumbein and Ohsiek (1950) were able to ascertain this overflow mechanism, as illustrated in Figure 2.3.6. The overflow would begin with the building of a rounded underwater spit to the south of the jetty. This spit will subsequently become elongated to as much as 1500 feet in length. This elongated spit was vulnerable to longshore currents arriving from the south and would become severed from the jetty. The isolated spit, located directly in front of the harbor entrance, was found to migrate southward and gradually deteriorate into a formless veneer of sand on the offshore bottom. Their study of survey maps failed to reveal any evidence that a detached spit would reach a downdrift coastline with a preserved form. The amount of sediment bypassing associated with the spit mechanism was estimated to be of the order of 5,000 cubic yards a year.



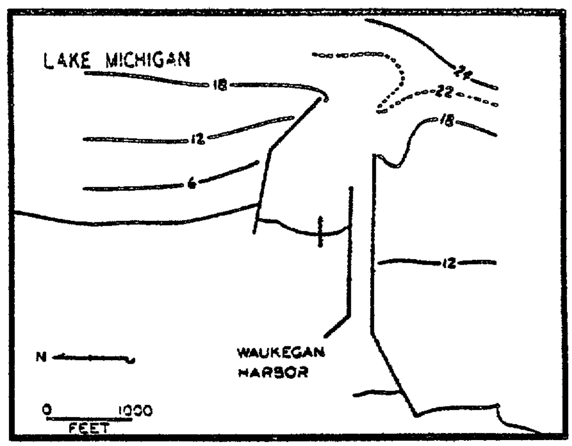
1. INITIAL SPIT BUILDING



2. GROWTH OF UNDERWATER SPIT



3. SEPARATION OF UNDERWATER SPIT



4. FINAL STAGE OF SEPARATION CYCLE

FIGURE 2.3.6

NATURAL BYPASSING CYCLE AT WAUKEGAN HARBOR
(From Krumbein and Ohsiek, 1950)

The slowdown in the fillet growth would mean, in turn, that the updrift expansion of the fillet now also has ceased. Another reasons for the slowdown in the growth of the Waukegan fillet is attributed to the construction of a jetty by the Public Service Company, approximately 1.4 miles north of the Waukegan north jetty. This pier has formed a new fillet of its own with an updrift elongation reaching the proximity of the Dead River outlet in the Nature Preserve. Sediment arrested on this fillet is a loss to the Waukegan fillet. The Public Service pier fillet too has grown rapidly and sediment is now able to actively bypass into the Waukegan fillet. A large elongation of an underwater spit extending from the tip of the pier to the downdrift coast is readily seen from the air at this location.

2.3.3 Shoreline Changes

Figure 2.3.7 and Table 2.3.4 show historical changes in shoreline position dating back to 1872. Most recent changes for the period 1946 to 1977 are included using the result of airphoto analysis conducted for this study. One of the conspicuous features to be recognized in Figure 2.3.7 is that the shoreline in front of the Park Lodge has shown a sign of erosion 1946-1977, whereas this area had remained quite stable (i.e., near-zero change) during 74 years prior to 1946. It thus appears that the no-change or nodal point is now located south of the Park Lodge, somewhere mid-way to the southern boundary of the Park.

Also recognized in Figure 2.3.7 is the recent conspicuous slowdown in the growth rate of the shoreline in the Waukegan fillet, compared between the periods 1872-1910 and 1946-1977. A rather rapid growth of shoreline near the park southern boundary 1910-1946 was apparently caused by the formation of a new fillet north of the Public Service pier. The presence of two peaks of shoreline growth for this period 1910-1946 indicates that there were two active fillets during this period of time.

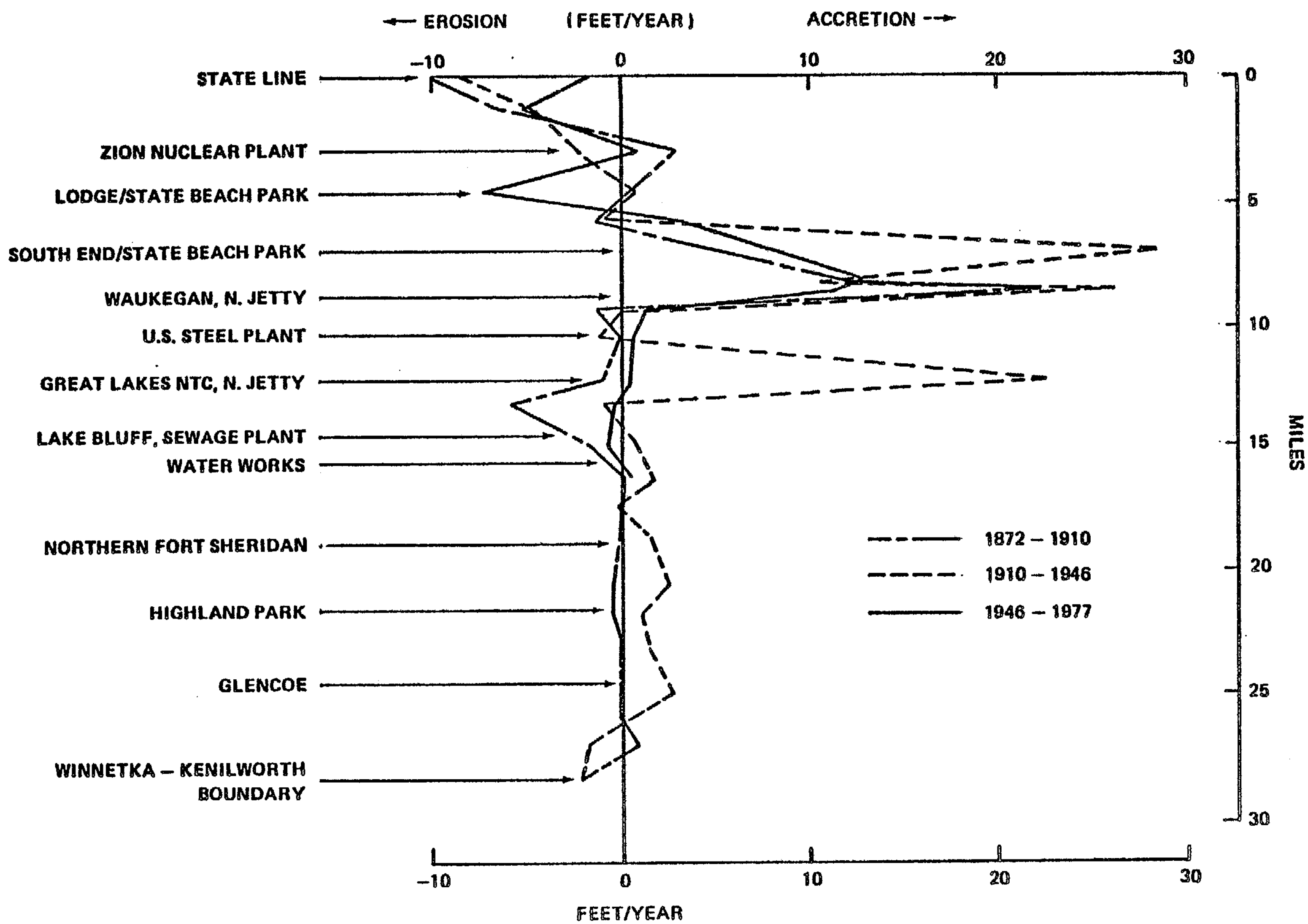


FIGURE 2.3.7 AVERAGE ANNUAL SHORELINE CHANGES

TABLE 2.3.4

SUMMARY OF HISTORICAL SHORELINE CHANGES
AT LOW WATER DATUM
BETWEEN 1872-1977

LANDMARK	RANGE NO.	AVERAGE ANNUAL SHORE-LINE CHANGE, FT/YEAR			
		1872-1910	1910-1946	1947-1977*	
State Line	1	-10.2	-8.6	-1.9	
Camp Logan	2	-6.6	-4.7	-5.2	
Zion	3	2.9	-2.2	0.9	STUDY AREA
27th Street	4	0.3	0.6	-7.3	
600' N. of Lodge	5	-1.6	-1.1	3.4	
Just N. of Johns Manville	6	5.3	28.6	8.7	
1800' N. of Waukegan N. Jetty	7	11.8 11.8	10.6 10.6	12.6 12.6	
Waukegan N. Jetty	8	26.3	25.6	11.3	
Waukegan S. Jetty	9	-1.3	-0.0	1.4	
1800' S. of Range 9	10	-3.4	1.1	-0.5	
U.S. Steel, Near South End	11	-0.0	-1.4	0.6	
G.L.N.T.C., N. Jetty	12	-1.1	22.5	0.3	
5300' S. of G.L.N.T.C. South Jetty	13	-5.8	-0.8	-0.4	STUDY AREA
Lake Bluff, Rockland Road	14	-1.8	0.8	-0.7	
Lake Forest College	15	+0.0	1.7	0.2	
Lake Forest, North-moor Road	16	+0.0	+0.0	–	
North Ft. Sheridan	17	+0.0	1.4	–	
3700' N. of Highland Park Waterworks	18	-0.5	2.5	–	
4800 S. of Highland Park Waterworks	19	-0.5	1.1	–	
3100' N. of Lake County Line	20	+0.0	1.4	–	
Glencoe, Park Avenue	21	+0.0	2.8	–	
Northern Winnetka	22	+0.0	0.3	–	
Winnetka, Elm Street	23	0.8	-1.7	–	
Winnetka-Kenilworth Boundary	24	-2.1	-2.2	–	

Data Source: (1) Rates for 1872-1910 and 1910-1946 are based on: U.S. Army Corps of Engineers, 1952. "Illinois Shore of Lake Michigan, Beach Erosion Control Study."

(2) Rates for 1947-1977 (Marked *) are based on: Air photo analysis performed for this study.

2.4 Recent Changes

2.4.1 Air Photo Digitization

In order to extrapolate the existing historical data to the most recent point of time, recent air photos were used to determine successive shoreline positions. A list of the air photos used is shown in Table 2.4.1, along with the lake levels at the time of photography.

TABLE 2.4.1
AIR PHOTOS ANALYZED FOR THIS STUDY

YEAR	MONTH	PHOTO SCALE	LAKE LEVEL	
			IGLD	DIFFERENCE FROM LWD (576.8 IGLD)
1939	7	1" = 600'	578.3	1.5
47	4	1" = 660'	578.6	1.8
54	6	1" = 400'	580.0	3.2
	7	"	579.9	3.1
	10	"	579.8	3.0
61	9	1" = 400'	578.0	1.2
67	10	1" = 400'	577.8	1.0
74	10	1" = 400'	580.5	3.7
77	5	1" = 400'	578.6	1.8

The selected air photos had an average interval of 6 years, so that short-term shoreline changes can be investigated. Digitization procedures are as follows:

1. A number of permanent ground targets are selected in the photos to permit sufficient overlaps on connecting and successive photos. When two photos are being overlayed to determine comparative shoreline positions, these ground targets are superimposed on one another through reiterative least-mean-square checks.

2. A photo is placed on a digitization board in an arbitrary orientation when tracing the shoreline. The shoreline position is read relative to the digitizer coordinates, then converted to a universal coordinate system which has been established relative to the targets. The universal coordinate system has one of its axes serving as a baseline, so that the shoreline position can be determined as a perpendicular distance from this baseline.

3. Where the ground targets lie on a high bluff, their relative positions to the shoreline are parallexed because they are on different elevations. The degree of parallex depends upon positions of an object in the photo frame, the bluff height relative to existing lake levels, flight altitude and the focal length of the camera. Before finalizing the shoreline position, this parallex error must be corrected.

4. All the shoreline positions are referenced to a single lake level, in this study to 576.8 IGLD.

5. Nominal accuracy of the digitzer board is one hundredth of an inch. Therefore, using a 1" = 400' scale photo, a possible error will be about 4 feet. Repeatability checks revealed that the real accuracy was about 2 — 3 feet.

Figure 2.4.1 shows the distribution of shoreline stations used in the air photo digitization for this study. Separation between consecutive stations is 300 feet. Relationships between these stations and Corps of Engineers profile survey ranges is shown in Table 2.4.2.

NORTH STATIONS

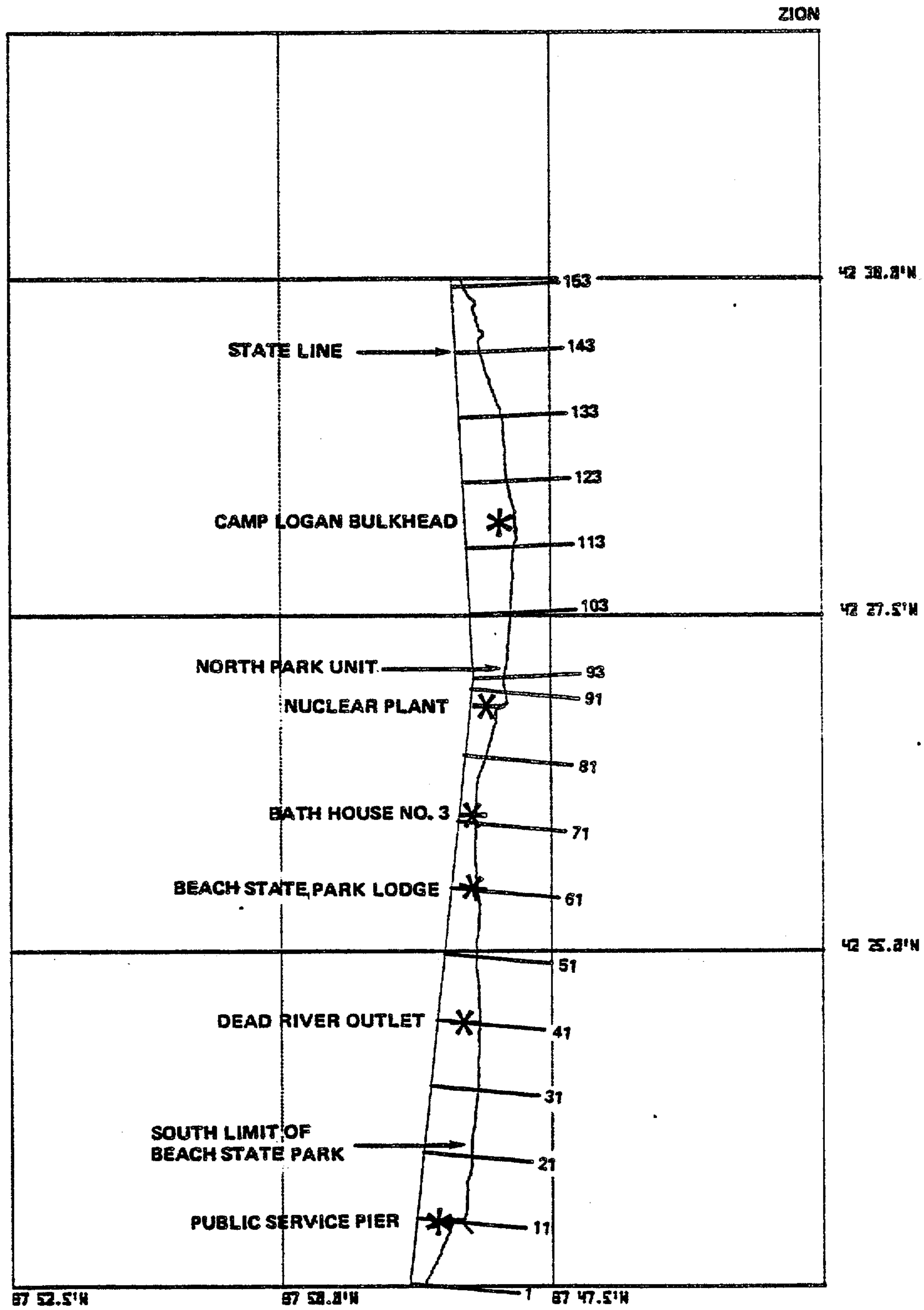


FIGURE 2.4.1

LOCATIONS OF BASELINES AND ALONGSHORE STATIONS FOR AIR PHOTO DIGITIZATION

TABLE 2.4.2

REFERENCES BETWEEN CORPS OF ENGINEERS PROFILE STATIONS (RANGES) AND DIGITIZED STATIONS IN THIS STUDY

LANDMARK	CORPS OF ENGINEERS SURVEY RANGES	DIGITIZED STATIONS IN THIS STUDY
State Line	1	N 144
Camp Logan	2	N 118
27th Street	3	N 87
600' North of Lodge	4	N 63
Nature Preserve	5	N 37
Just North of Johns Manville	6	N 13
1800' North of Waukegan North Jetty	7	S 169
Waukegan North Jetty	8	S 163
Waukegan South Jetty	9	S 157
1800' South of Range 9	10	S 152
U.S. Steel, Near South End	11	S 130
North Jetty, G.L.N.T.C.	12	S 99
5300' South of G.L.N.T.C.	13	S 72
Lake Bluff, Rockland Road	14	S 59
Lake Forest College	15	S 27
Lake Forest, Northmoor Road	16	S 7

2.4.2 *Recent Shoreline Changes (1939-1977)*

Shoreline Positions

The result of digitization is tabulated in Appendix A, which includes shoreline positions for a fixed baseline for 1939, 1947, 1954, 1961, 1967, 1974 and 1977, average annual shoreline recession between these years, and statistics describing beach-area gain and loss between 1939 and 1977.

Figure 2.4.2 shows typical shorelines resulting from the digitized data, those for 1939 and 1977. The shoreline for 1872 is also shown to allow for comparison.

North Unit

It is immediately clear that the 1977 shoreline is considerably more scalloped than the 1939 shoreline. This situation has arisen from the simple fact that there were differential rates of erosion at hard points and in areas between hard points. Practically every shoreline protrusion found in the 1977 shoreline was associated with a hard point, either a revetmented residential property, a bulkheaded shoreline (namely, the sheet pile wall at Camp Logan), or a jetty (namely at Trident Harbor). On the other hand, areas between such hard points eroded rapidly to create a deep embayment, especially on the south side of the hard point. In the late 1940's to mid-1950's, private shoreland owners in the North Unit constructed a number of protective structures on the lakefront. These activities, which occurred later than the 1939 air photo year, accounted for the more severely scalloped shoreline in 1977 than in 1939.

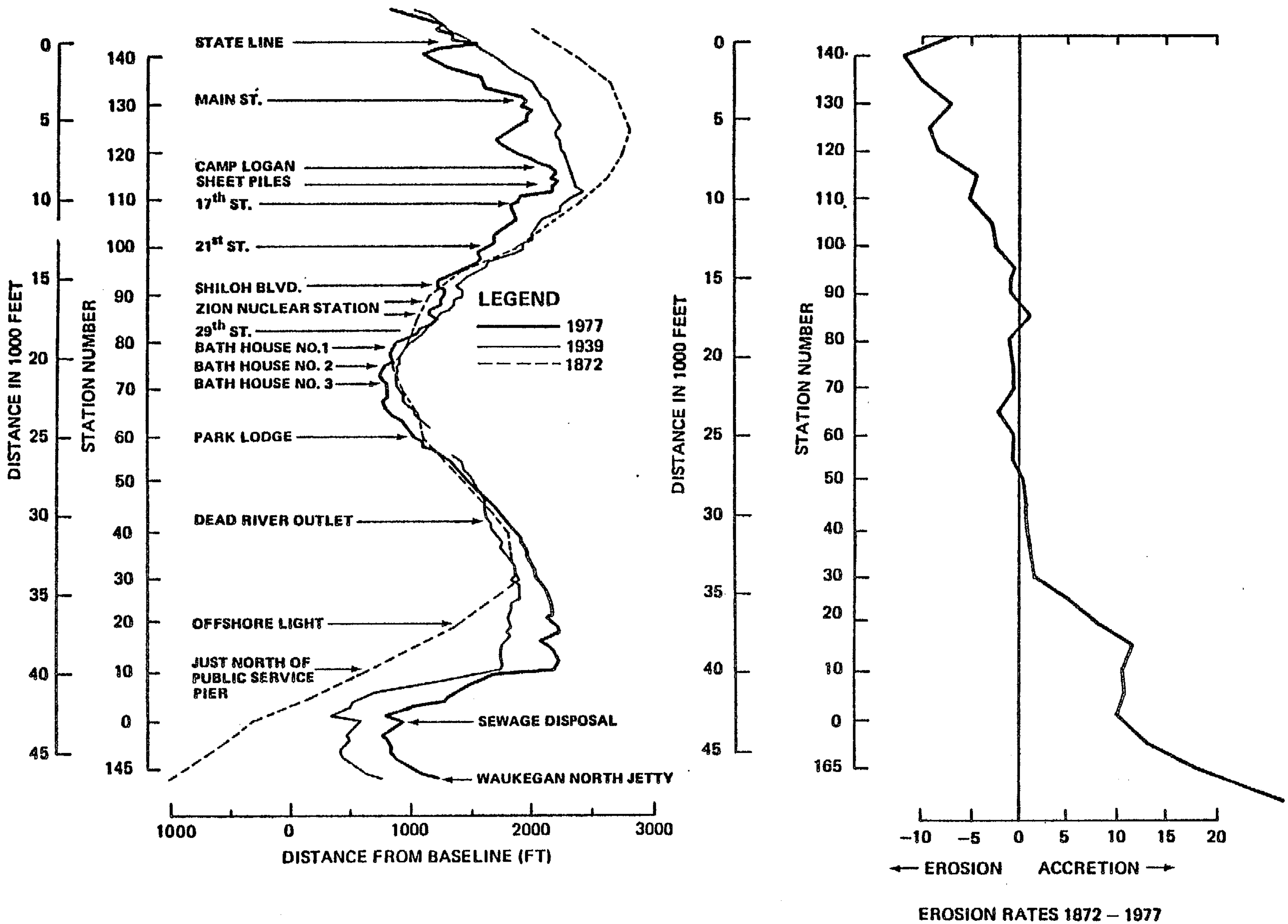


FIGURE 2.4.2 HISTORICAL SHORELINE POSITIONS

Note that the largest scalloping effect occurred just south of the Trident Harbor, where the 1977 shoreline was recessed as much as about 600 feet from the 1939 position showing an average annual erosion of about 15 feet a year.

Influence of Fillets

The shoreline in the vicinity of the Park southern boundary exhibited rhythmic configuration with similar wave-lengths and amplitudes both in 1939 and 1977. These rhythmic features are an indication of periodically spaced rip channels which developed in the surf zone. These channels can be readily recognized from air photos. Rip currents generally transport nearshore sediment into the offshore bottom, hence are a partial cause of beach erosion where natural replenishment of surf zone bed is not sufficient.

It is recognized in Figure 2.4.2 that between 1872 – 1977, a most severe recession was concentrated along a 11,400-foot (or 2-mile) reach south of the State Line. This shoreline is also more directly exposed to the north from which predominant storm waves approach this area.

On the other hand, a shoreline segment south of the Dead River outlet to the position of the Public Service Pier (Station 40 – 10) exhibited a remarkable degree of accretion between 1872 – 1939, and again between 1939 – 1977. The accretion between 1872 – 1939 in this reach was the result of the Waukegan fillet. This fillet began its active growth immediately following the completion of the onshore segment of the Waukegan north jetty in 1931. The intersection of the 1872 and 1939 shorelines at Station 30 in Figure 2.4.2 probably marks the northern extremity of the fillet by 1939.

The more recent part of the accretion in this reach between 1939 – 1977 occurred to a reach further north, namely as far as Station 45, and was probably more representative of the effect of a fillet which formed north of the Public Service pier in later years. By 1977, the northern extremity of this new fillet ended at a position where the 1939 and 1977 shorelines are found to intersect in Figure 2.4.2, around Station 40. This intersection also coincides with the 1872 shoreline at that position, and appears to represent the location of the no-change or nodal point as of 1977.

South Unit

According to Figure 2.4.2, a shoreline segment for the rest of the Park South Unit exhibited remarkably small amounts of changes throughout a 67-year time span between 1872 – 1939. However, it is clear that the changes in this reach during the recent 38 years were considerably greater than those which occurred during the prior 67 years. In particular, these recent changes were concentrated between Station 80 (about 1000 feet south of the Commonwealth Edison power plant) and Station 60 (Park Lodge), the existing swimming beach about 6,000 feet long. As will be described in detail later, most of these changes during 1939 – 1977 were due to an abrupt rise in recession rates in this reach which occurred between 1967 – 1977.

Part of the reason for the recent rise in shoreline recession along the swimming beach is ascribed to the fact that the no-change or nodal point passed this area around 1970. As will be discussed in detail under Section 2.7 "Future Erosion", the nodal point is believed to have been located in front of the Park Lodge in 1970, moving southward at 400 feet a year.

Another possible reason for the recent observed accelerated erosion along the swimming beach is the construction of a temporary breakwater in the Commonwealth Edison property during 1969 – 1972. When this breakwater was constructed in 1969, littoral drift accumulated rapidly on its north shore, creating a 6-acre fillet. The shoreline downdrift of this breakwater began to erode at the same time. According to "Safewater Harbor Feasibility Study – Illinois Beach State Park" (1978), a 400-foot shoreline just south of the power plant property lost approximately 254,000 cubic yards of material to the -8 foot contour over these 3 years, an average annual loss of 21 cubic yards per each foot of shoreline. It is highly probable that an erosion pocket thus created subsequently propagated southward, affecting the entire reach of the swimming beach and accelerating the southward migration of the nodal point.

Presently, the third bathhouse is protected from erosion by concrete blocks placed directly on the water's edge, and the Park Lodge by a sheet pile wall about 700 feet long. The beach in front of these bathhouses is characterized by a row of escarpment about 10 feet high, showing an unmistakable sign of persistent erosion.

2.4.3 Recent Recession Rates (1939 – 1977)

Short-Term Versus Long-Term Rates

Figures 2.4.3, 2.4.4 and 2.4.5 show the recession rates determined from the digitized shoreline data for the periods 1939-47, 47-54, 54-61, 61-67, 67-74, and 74-77. These recession rates are, therefore, short-term recession rates over an average period of about 6 years.

STATE LINE TO WAUKEGAN

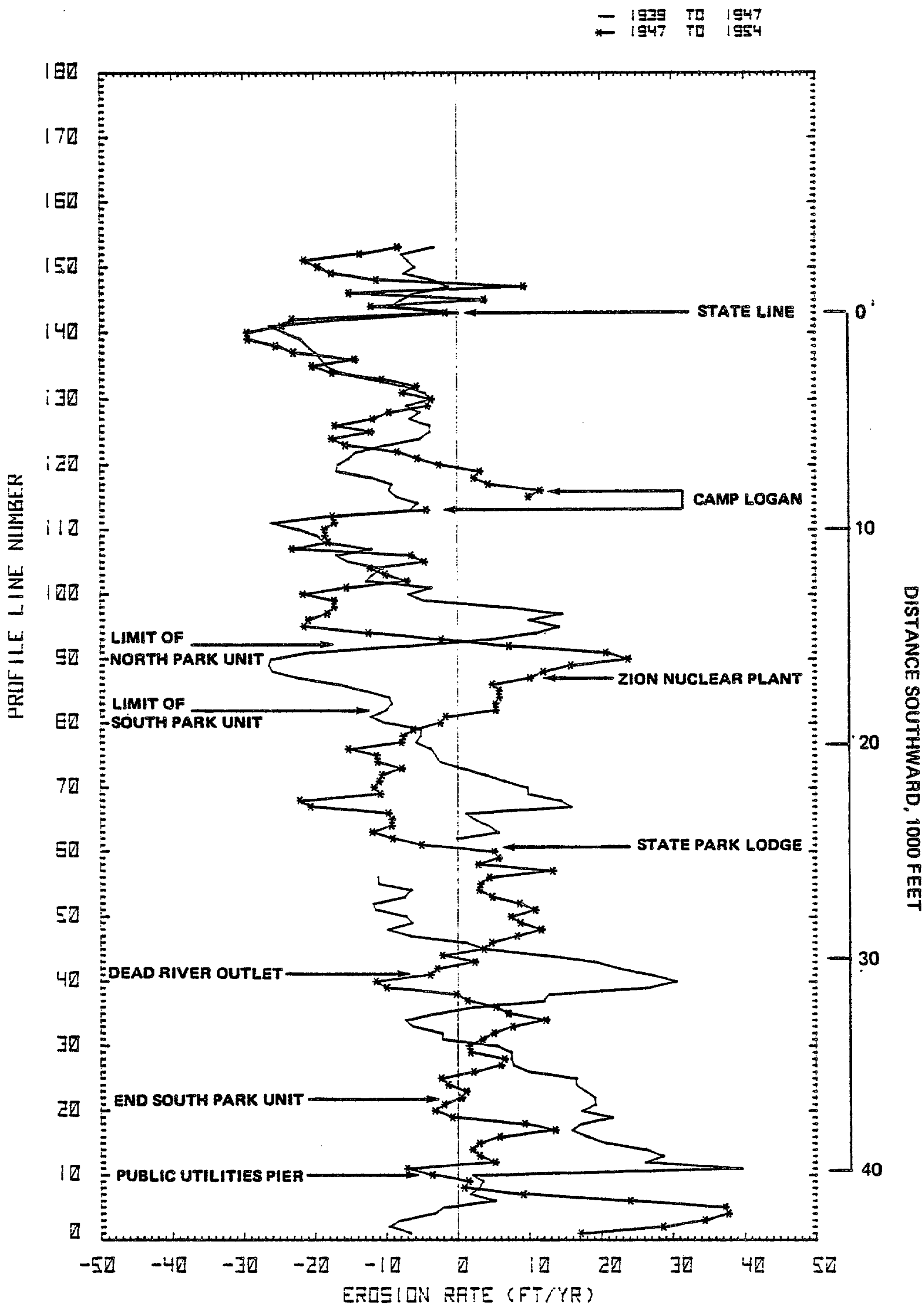


FIGURE 2.4.3: SHORELINE CHANGES BASED ON AIR PHOTO DIGITIZATION, 1939–47, 47–54

STATE LINE TO WAUKEGAN

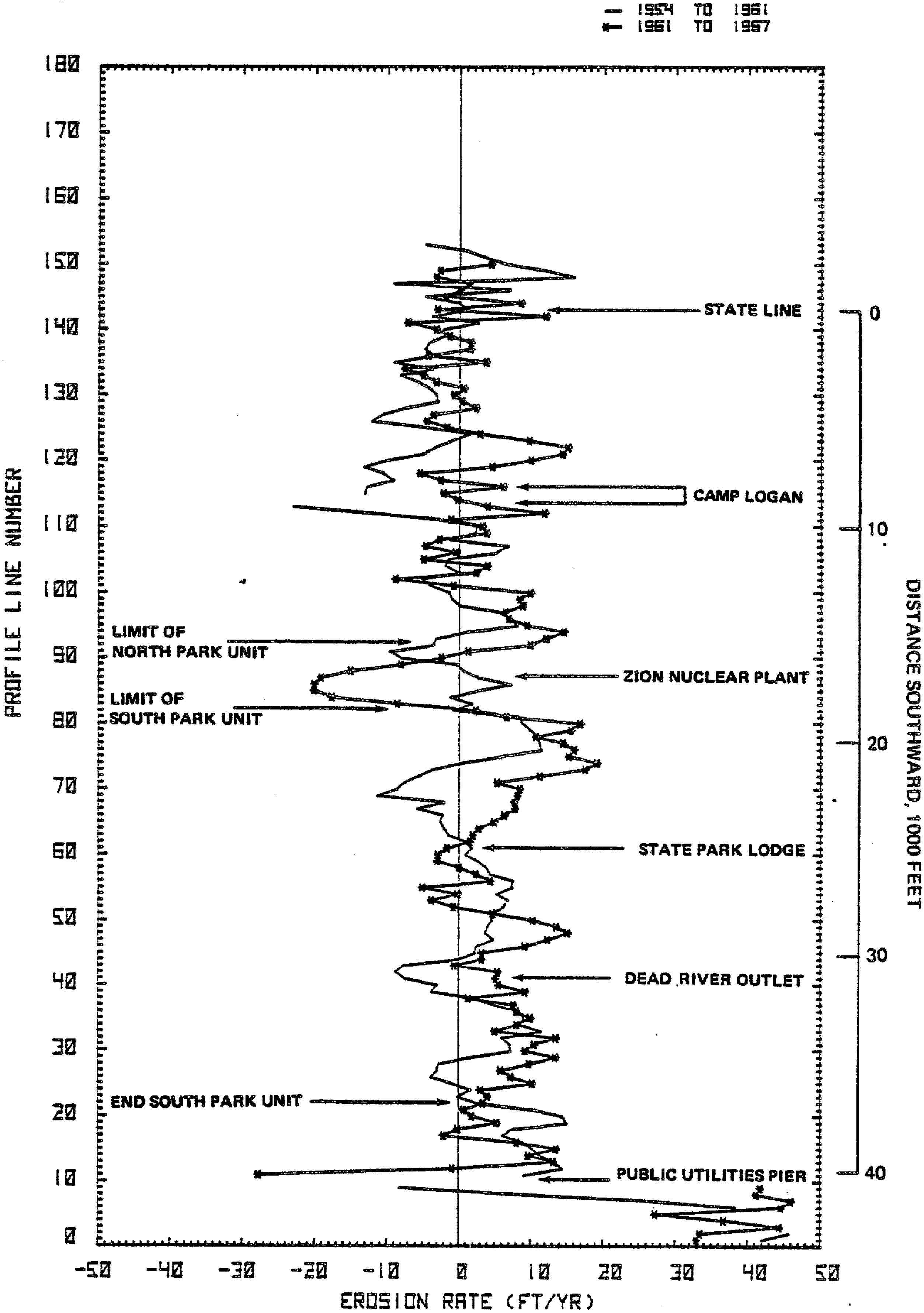


FIGURE 2.4.4: SHORELINE CHANGES BASED ON AIR PHOTO DIGITIZATION, 1954–61, 61–67

STATE LINE TO WAUKEGAN

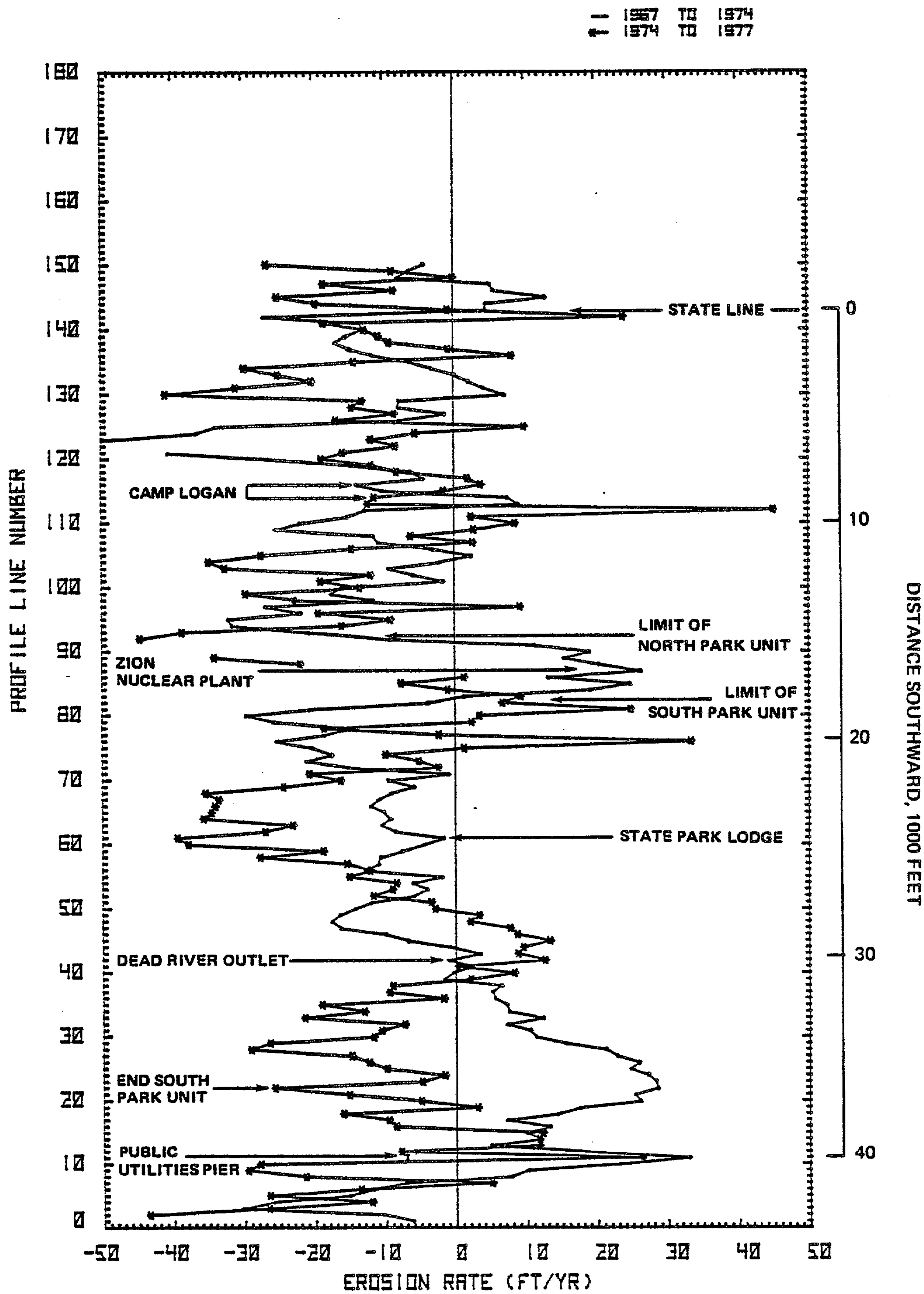


FIGURE 2.4.5: SHORELINE CHANGES BASED ON AIR PHOTO DIGITIZATION, 1967–74, 74-77

It is quite noteworthy that these short-term erosion rates are generally much higher than the longer term erosion rates over, say, a 105-year period such as already discussed under 2.3 "Historical Changes." Namely, short-term erosion rates, averaged over about 6 years, about -40 feet a year, whereas the highest observed 105-year erosion rate was -12 feet a year.

In general, these short-term erosion rates were approximately 3 times higher than the longer-term 105-year rates. The reason for such a large difference between long- and short-term rates is attributed to the fact that the long-term rates would more closely represent an average trend over this period of time, whereas short-term rates would represent more closely short-term fluctuations of erosion rates and episodic events.

According to Illinois Geological Survey, erosion rates in excess of 120 feet per year were not uncommon at specific sites when erosion rates were assessed on the basis of annual measurements. In one recent episode, a single storm lasting 36 hours caused more than 120 feet of shoreline recession at certain localities in the Illinois Beach State Park. Between January and August, 1975, the beach north of the Park Lodge was cut back by about 90 feet.

From the point of view of beach protection, these fundamentally different characteristics of long-term and short-term rates present implications of special importance. For instance, a structure located 100 feet behind the shoreline which is eroding at a 100-year rate of 5 feet a year may be considered to be safe for almost 20 years. However, if this shoreline would exhibit a short-term erosion rate of, say, 15 feet a year, and that this short-term rate has been observed in the past as an average over 5-year terms during a time span of 20 years, it is likely that an additional erosion of at least 75 feet (15 x 5) could occur during a 20-year period. Under this condition, the structure which now stands 100 feet behind the shoreline will be in an imminent danger of erosion within about 5 years, instead of 20 years.

One of the major causes for short-term fluctuation of erosion rates appears to be high lake levels. During the time of high lake levels, waves will act on higher levels on the beach, readily removing the material from foredunes and backshore. In particular, during the time of high lake levels, a headland and a groin will tend to project themselves farther lakeward from the shoreline, therefore acting as a reinforced littoral barrier. Under this condition, the starvation in the lee of these structures will be increased, causing the erosion rate to rise. Specific examples of accelerated erosion rates associated with lake levels rise are shown in the following section.

North Unit

In the North Unit, the following interpretations are made on the short-term recession rates.

1. Rapid recession on the south side of the Trident Harbor hard point and the Camp Logan bulkhead occurred consistently over the periods 1939-47 and 1947-54. The recession rate decreased remarkably during 1954-61 and 1961-67. During these latter two periods, the lake level generally stayed below the 105-year mean lake level of 578.7 IGLD, which probably accounted for the lessening of the recession rate. Recession rates in these already scalloped shorelines rose again to a significant level between 1967-74 and 1974-77. During these recent periods, the lake level was generally above the 105-year mean lake level.

2. Recession rates were generally high and appears to have increased in recent years. For instance, whereas maximum erosion rates found during 1939 – 1954 (Figure 2.4.3) were around -30 feet per year, those during 1967 – 1977 were over -40 feet per year (Figure 2.4.5). Comparing the corresponding lake levels during these two periods, the maximum lake level in both periods was almost equal at about 581 IGLD. However, the duration of continuous

high lake levels above the 105-year mean lake level was longer during the 1957-77 period (about 6 years) as compared with the 1939-54 period (about 3 years).

South Unit

1. Between 1939 – 1967 (Figures 2.4.3 and 2.4.4), short-term rates showed both accretion and recession. However, the swimming beach north of the Park Lodge showed consistent recession since 1967 (Figure 2.4.5).

2. Between 1939 – 1977 (Figures 2.4.3 and 2.4.4), the beach segment south of the Dead River outlet generally tended to show accretion while exhibiting small amounts of local recession. However, during 1974 – 77, the recent three years, the trend reversed itself to distinct recession with up to about -30 feet a year. This area which has begun to recede, fronts the Nature Preserve.

Extreme Shoreline Positions

Figure 2.4.6 shows extreme lakeward and landward shoreline positions that occurred during 1939 -77 based on the digitized data. These shoreline positions are shown relative to the latest 1977 shoreline. From Station 145 (near the State Line) and Station 50 (3000 feet south of the Park Lodge), the 1977 shoreline generally represents the most landward positions during the past 38 years since 1939.

Between Station 50 (3000 feet south of the Park Lodge) to Station 15 (Public Service pier), the present shoreline is generally located on the lakeward side of its most landward position since 1939.

Extreme Erosion Rates

Figure 2.4.7 shows extreme rates of shoreline change, both accretion and erosion, that occurred during 1937-77. The highest extreme erosion rate of -70 feet a year that occurred just

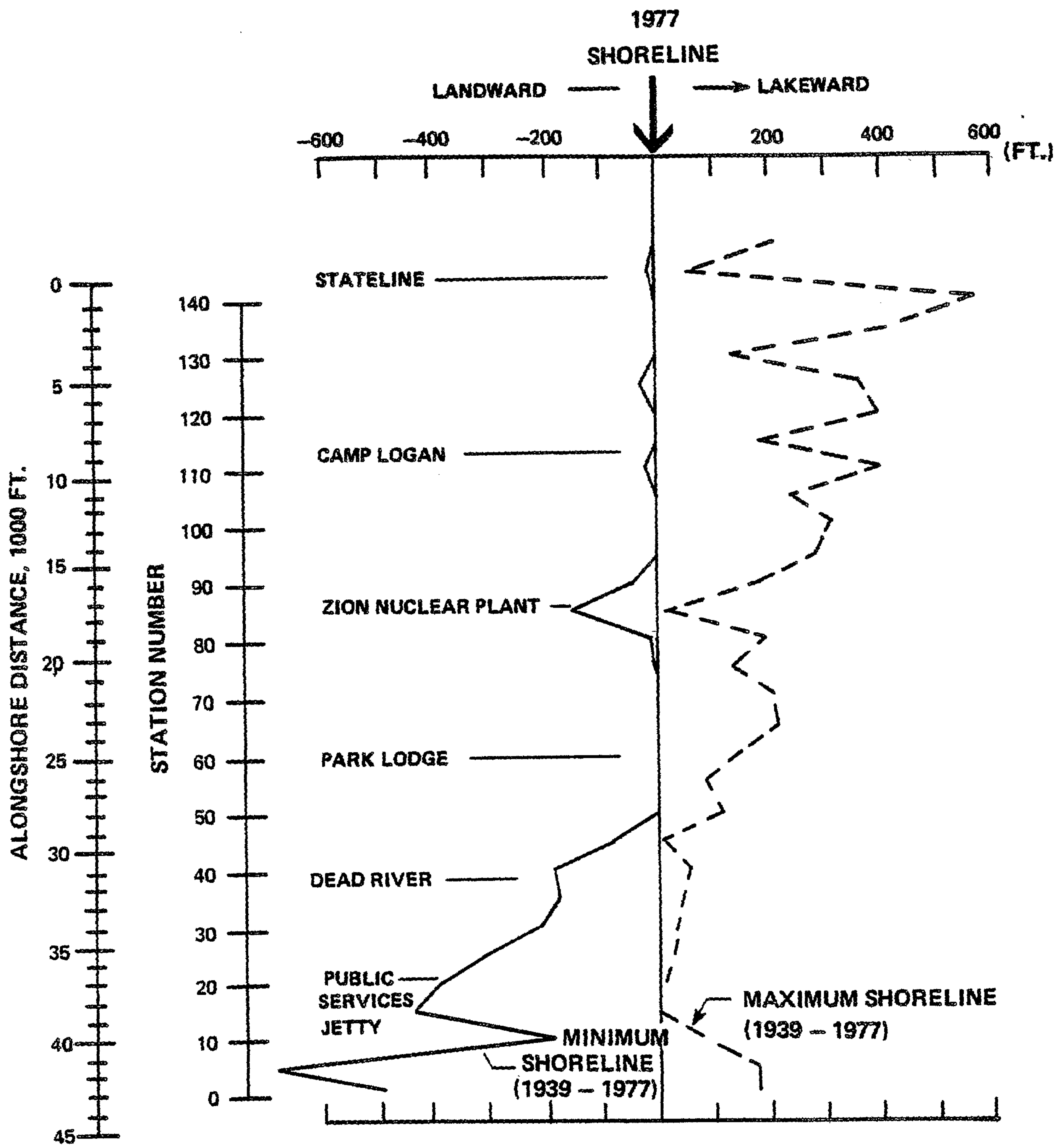


FIGURE 2.4.6: ENVELOPE OF EXTREME SHORELINE POSITIONS 1939–1977
ILLINOIS BEACH STATE PARK

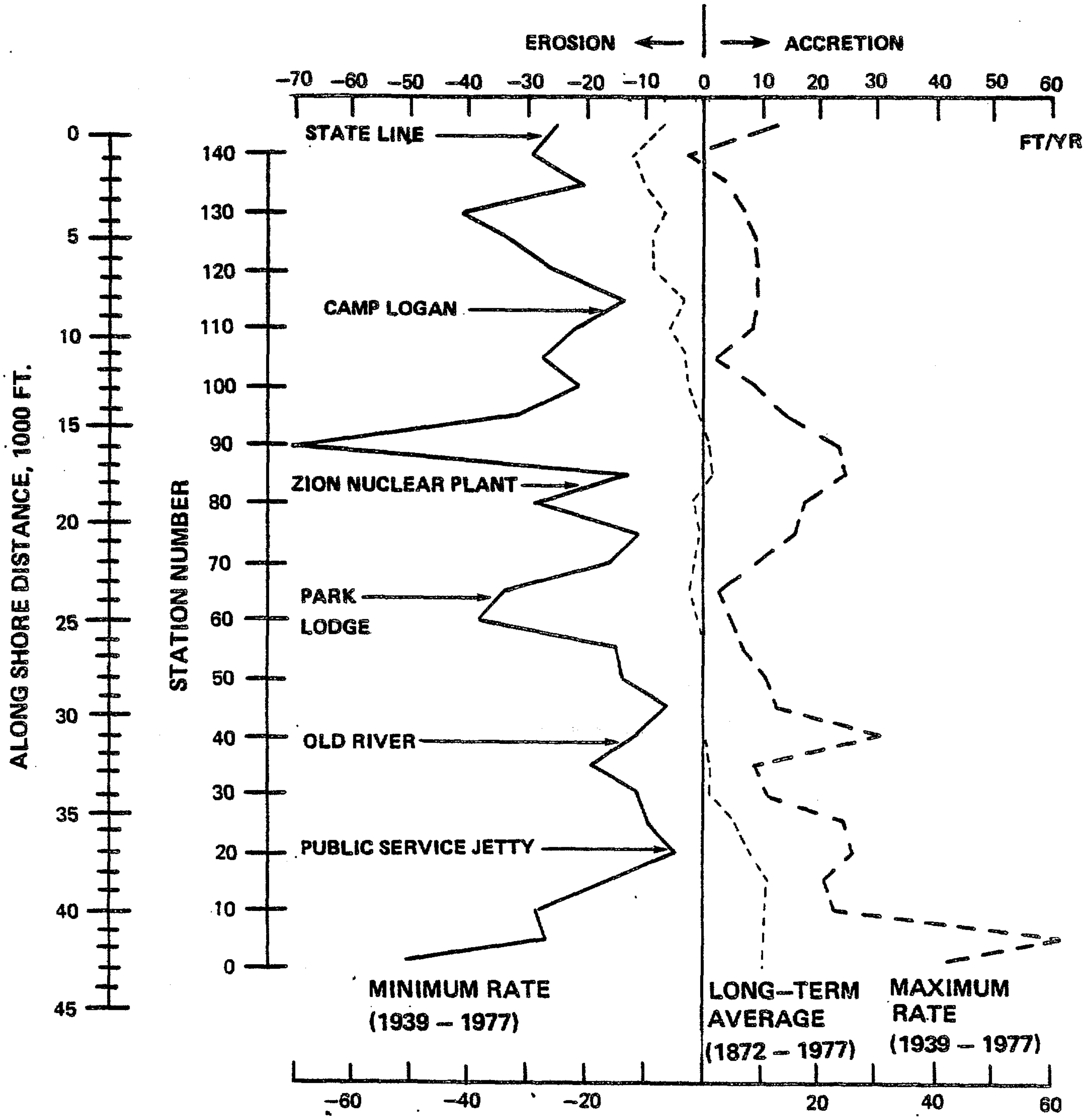


FIGURE 2.4.7: ENVELOPE OF EXTREME SHORELINE CHANGE RATES 1939–1977 ILLINOIS BEACH STATE PARK

north of the power plant property was due to the sudden release of a fillet in 1971 when a temporary breakwater was removed following the construction of the power plant. The same location also exhibited one of the higher accretion rates (25 feet a year), which was associated with the formation of a fillet on the north side of he temporary breakwater.

In general, short-term erosion rates were up to -40 feet a year. An erosion rate of this magnitude has occurred in front of the Park Lodge. Along the shoreline fronting the Nature Preserve (Stations 50 – 30), the magnitude of extreme erosion rates was generally on the same order (about -10 feet a year) as that of extreme accretion rates. In the rest of the Park shoreline, the magnitude of extreme erosion rates generally exceeded that of extreme accretion rates.

2.4.4 Summary of Erosion Rates (1939-77)

Table 2.4.3 summarizes the results of analysis based on air photo data over the period 1939-77. Volumetric changes were calculated based on the ratio:

$$\frac{\text{One Cubic Yard Volume Loss}}{\text{One Square Foot Beach Area Loss}} = 1.15$$

This ratio has been determined from comparison of the observed losses in the profile to -20 foot LWD, as shown in Figure 2.4.8. For the eroding reach north of Waukegan, the ratio was 0.7 for the accreting part of the Waukegan fillet. Since the Waukegan fillet is also showing signs of erosion, a single value of 1.15 was used to represent this ratio.

TABLE 2.4.3
SUMMARY OF BEACH CHANGES BY SHORE REACHES 1939-1977
(37.85 Elapsed Years)

LANDMARK	REACH			CHANGES			
	STATIONS FROM	TO	LENGTH 1000 L.F.	BEACH AREA 1939 - 77 1000 S.F.	VOLUME 1939 - 77 1000 C.Y.	AVERAGE ANNUAL VOLUME 1000 C.Y./YR	ANNUAL VOLUME PER FOOT OF SHORELINE C.Y./YR/FT
Park North Unit	144 -	90	16.2	-4763.54	-5478.07	-144.73	-8.93
Zion Nuclear Plant	90 -	83	2.1	-193.12	-222.09	-5.88	-2.79
Park South Unit, Including Lodge	83 -	50	9.9	-1032.45	-1187.32	-31.37	-3.17
Park South Unit, Including Nature Preserve	50 -	21	8.7	1463.32	1682.32	44.46	+5.11
Subtotal	144 -	21	36.9	-4525.79	-5204.65	-137.51	-3.73
Park South Unit To Public Service Pier	21 -	11	2.7	1321.79	1520.06	40.16	+14.9
P.S. Pier to Waukegan North Jetty	11 - thru 175 -	1 163	7.3	3082.49	3544.86	93.66	+12.8
	21-1, 175-163		10.0	4404.28	5064.92	133.82	+13.4
TOTAL	STATE LINE TO WAUKEGAN NORTH JETTY		46.9	-121.51	-139.73	-3.69	-0.08

NOTE: Sediment volume estimated to depth - 20 ft. (LWD)

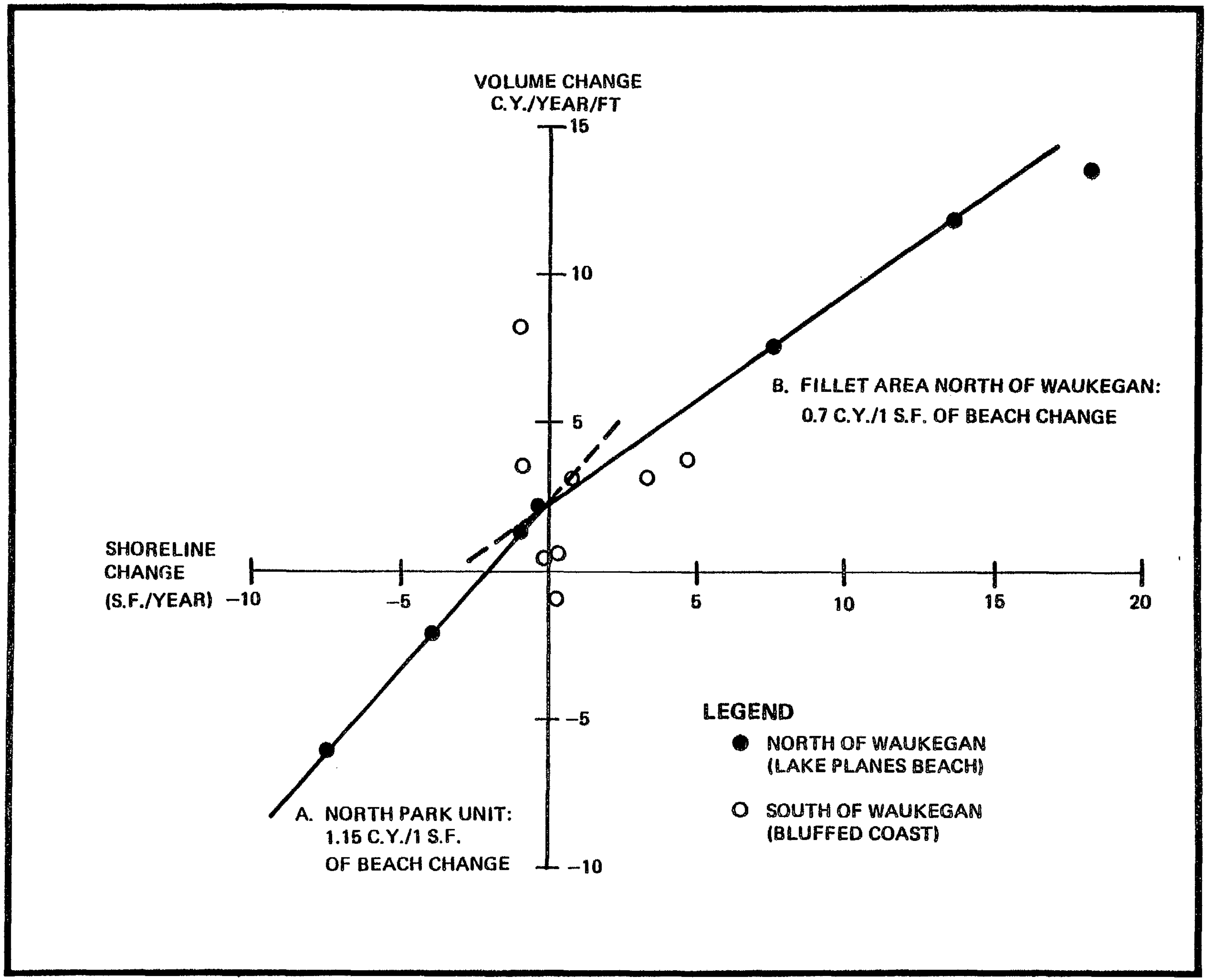


FIGURE 2.4.8 VOLUMETRIC CHANGE RATES TO -20 FOOT LWD VERSUS SHORELAND CHANGE RATES

According to Table 2.4.3, average annual volume losses were 144,730 cubic yards a year in the North Unit, 5,880 cubic yards a year in the Zion nuclear station property, and 31,370 cubic yards to the nodal point in the South Unit. Between the nodal point to the southern boundary of the Park, the annual gain was 44,460 cubic yards.

For the entire shoreline of the Park, combining both the North and South Units, the volumetric loss averaged 3.73 cubic yards a year per each foot of the shoreline. For the entire shoreline from the State Line to the Waukegan Harbor north jetty, the volumetric loss averaged 0.08 cubic yards a year per each foot of the shoreline.

2.5 Characteristics of Lakeshore Processes

Of the various unique characteristics of the lakeshore processes, those which are most pertinent to the problems in the Illinois Beach State Park are: (1) headland or hard point, (2) lake level, (3) wave, and (4) ice.

2.5.1 Headland

Figure 2.5.1 shows alongshore erosion rate distribution in the vicinity of the State Line. There are two prominent headlands in this region: one the Trident Harbor entrance jetties and the other the Camp Logan sheet pile wall bulkhead. The Trident Harbor jetty now extends approximately 300 feet lakeward from the recessed shoreline on the Illinois side. The Camp Logan headland, formed due to the recession of the unprotected shore on its either side, extends also about 300 feet lakeward from the adjacent embayed shoreline.

Downdrift of the Camp Logan headland, there are a series of small headlands which have been formed at revetmented fortification of private homes. Most of these revetments have fallen into the lake bottom, and only their remnants can be seen either on the shore or in the surf zone today.

In Figure 2.5.1, it is clear that, whereas the erosion rate decreased exponentially approaching the Camp Logan bulkhead from the north, it made a quantum jump immediately downdrift of the bulkhead, say from about 4 feet a year to 6 feet a year. Following this jump in the erosion rate, the erosion rate again decreased further southward, but maintaining a higher rate than would have been without the quantum jump at the bulkhead.

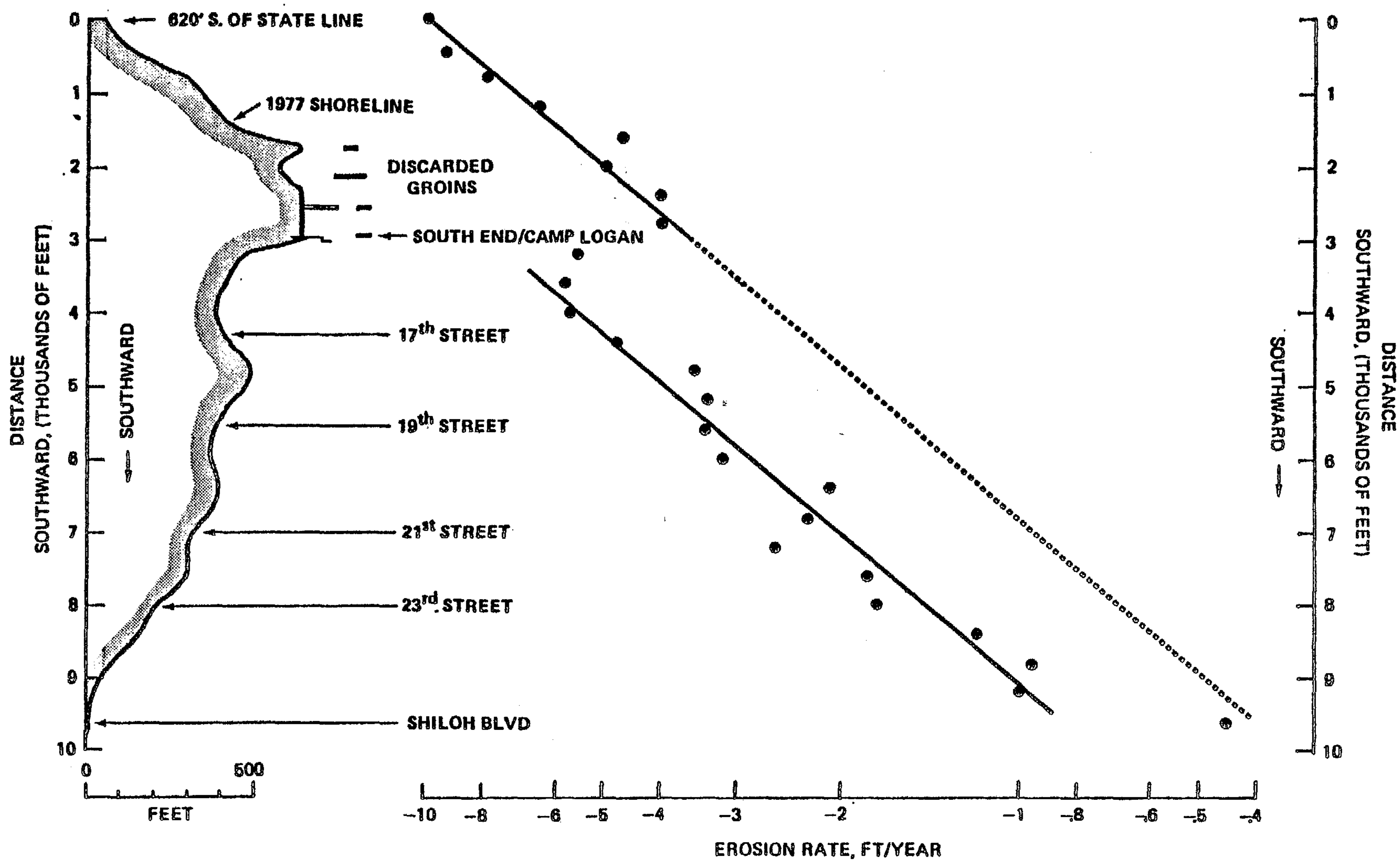


FIGURE 2.5.1 EROSION RATE DISTRIBUTION DOWNDRIFT OF A HEADLAND

This situation is strongly indicative of the possibility that the shore processes in the reach downdrift of the bulkhead are operating at a distinctly lower supply of littoral material than those on the updrift beach. The littoral material bypasses the Camp Logan bulkhead and would move downdrift along the lake bottom without feeding the downdrift shore for some distance. The location of possible land fall of this lake-bottom littoral drift appears to occur at a 10,000-foot position, or off the Shiloh Boulevard about 7,000 feet downdrift from the bulkhead, where the erosion rate abruptly reduces from about 1 foot a year to 0.4 feet a year. The length of the reach outflanked by littoral drift, about 7,000 feet between the south end of the bulkhead and the Shiloh Boulevard, is about 700 feet landward from the bulkhead line.

Other small headlands, those between 17th, 19th, 21st and 23rd Streets, also are found to create a quantum jump in erosion rate, but their range of influence to the downdrift reach is quite limited. The lakeward protrusion of these small headlands is about 100 feet on the average.

Numerous headlands of various sizes litter the Wisconsin shoreline between Kenosha and the State Line, and no doubt, these headlands, due to their capability to divert the nearshore sediment stream to the lake bottom, are part of the causes for the present dwindling supply of littoral sediment on the Illinois shore.

If shore recession continues, the bulkheaded nuclear station and the bulkheaded State Lodge will eventually function as a headland with the resultant influence on the shore downdrift from each structure.

Protection of these bulkhead must be accompanied by proper feeding operations to such an extent that at no time will the bulkhead be exposed to the lake without a beach separating it from the direct wave action.

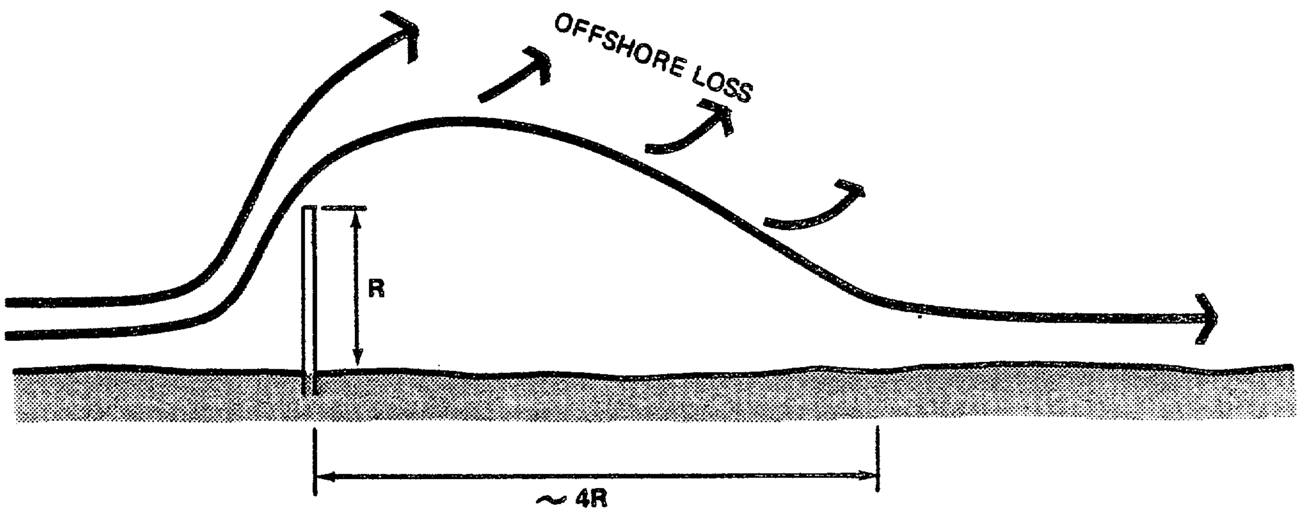
2.5.2 *Natural Bypassing and Outflanking*

Figure 2.5.2 illustrates bypassing processes of littoral stream at a littoral barrier.

As shown in Figure 2.5.2, littoral drift arriving at a barrier is first diverted offshore. After passing the tip of the barrier, the sediment thus carried away from the shore will again turn in the downdrift direction and gradually toward the shore under the influence of wave mass transport. However, this sediment, already in deeper water, will move only slowly and will not be able to make a landfall on the downdrift coast until after having traveled some distance alongshore. During this process, the sediment will be dissipated to the offshore bottom to a greater extent than would when it is moving inside the surf zone.

Usually, the distance downdrift of a barrier where the beach is outflanked by littoral drift, is about 4 times the length of the barrier (See Figure 2.5.2.-1). In the case where the barrier is relatively short, and/or there is an abundant quantity of littoral drift, the accreting updrift shoreline will quickly approach the tip of the barrier, allowing the increasing amount of littoral drift to overflow into the downdrift side in the process. In time, the downdrift shoreline will find a new equilibrium compatible with the diminished but continuously supplied littoral drift. This situation is presently in progress at the Public Service Company pier south of the Park boundary.

1. STRAIGHT SHORELINE



2. RECESSED SHORELINE

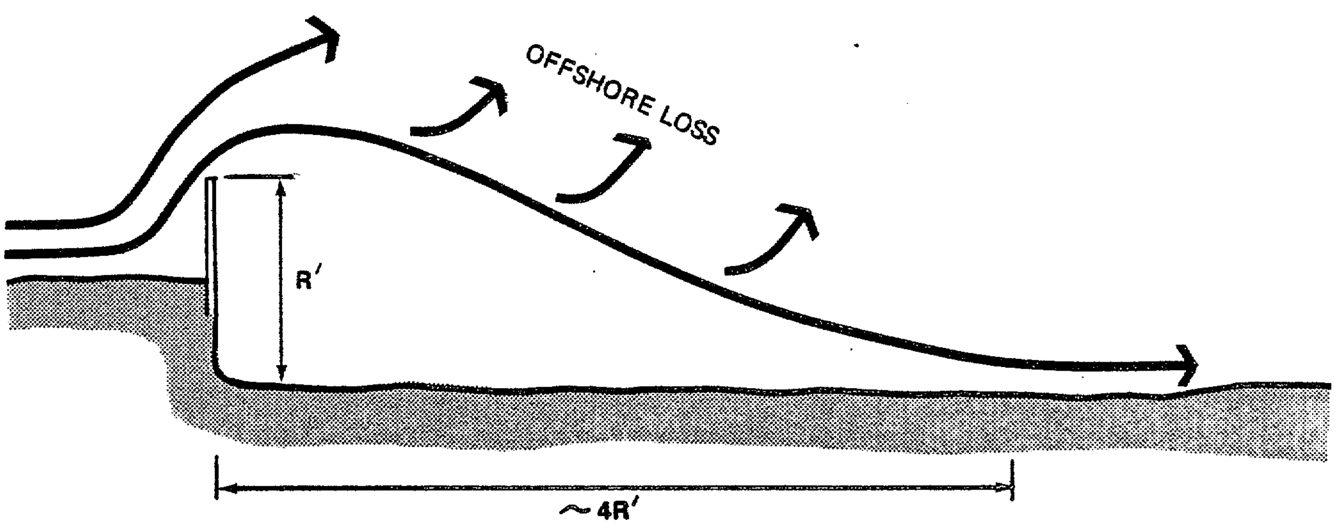


FIGURE 2.5.2

OUTFLANKING BY LITTORAL DRIFT DURING BYPASSING

On the other hand, in the case of a long barrier or in the case where there is little sediment in the littoral stream, the downdrift shoreline will erode at a faster rate than in the case of a short barrier and/or the case of abundant littoral drift. Furthermore, fillet growth will take a longer period of time before allowing littoral drift to overflow around the tip of the barrier. This process can be even further prolonged if the barrier functions as a sand trap, such as at the Waukegan Harbor, which would reduce the volume of bypassing material to the downdrift coast by interception. As a result, by the time the downdrift coast finds a new equilibrium, the area outflanked by littoral drift will have been lengthened considerably. The length of this area will now be about 4 times the length of the barrier measured from the recessed downdrift shoreline, hence longer than 4 times the physical length of the barrier. (See Figure 2.5.2-2)

Along the Beach State Park shoreline, where the quantity of littoral drift is in a state of deficit, the limiting length of a barrier which would not cause adverse downdrift effects appear to be on the order of around 100 feet.

2.5.3 *Lake Level Fluctuation*

The lake level of Lake Michigan fluctuates with seasonal and multi-year cycles. The annual cycle generally exhibits a range of about 1 foot, with a high in early summer and a low in mid-winter. During the summer high, waves are generally modest, and hence the seasonal cycle does not usually impose a severe adverse effect on the shoreline. However, during the period when the lake level is on the rise on a long-term trend, the usual mid-winter drop in lake level may not materialize, maintaining a high lake level during the late-fall and early-spring storm season. This situation has been noted for causing abruptly increased damages on the shore.

Multi-year lake level fluctuations are erratic in periodicity and are not necessarily predictable. It has been noted that these longer-term fluctuations would occur at between 6 to 30-year cycles. Hence, given a record of past several years, it is not impossible to anticipate lake level fluctuations to about 5 years to come. The recorded multi-year fluctuations exhibited an extreme range of 6.5 feet from a low of 575.4 IGLD in March 1964 to a high of 581.9 IGLD in July 1886. A maximum recorded range within a given cycle occurred recently, between a low of 575.5 in 1964 to a high of 581.0 in 1973 and 74, a range of 5.5 feet over a period of 9 years. This latest high lake level was one of the longest sustained high levels on record. This was preceded by another sustained high between 1951 – 1955, in which the lake level rose approximately 4.5 feet within less than 3 years between 1950 and 1952.

The present lake level has been falling for four successive years from the high of 581.0 IGLD in 1973 and 1974. The average lake level during the past 33 years since 1945 through 1977 was 578.4 IGLD, slightly lower than a 105-year mean lake level of approximately 578.7 IGLD. The Low Water Datum for Lake Michigan is 576.8 feet above mean water level at Father Point, Quebec, International Great Lakes Datum (IGLD).

The effect of a high lake level on beach erosion is not merely displacing the shoreline and allowing the waves to act on higher levels on the shore. A high lake level also forces a littoral barrier to protrude farther out to the lake because of the displaced shoreline. As a result, a barrier will exert an enhanced adverse effect on the downdrift shore, raising the erosion rate as well as increasing the loss of material to the lake bottom.

This effect has already been discussed under Section 2.4.3 "Recent Recession Rates (1939-1977)". The observed short-term erosion rates usually rose to three times the long-term erosion rates as the lake level rose.

2.5.4 Wave

Waves in Lake Michigan are typically short-period waves with dominant periods in the range of 3 to 5 seconds. These waves have wave lengths of 50 to 130 feet in deep water and only about 40 to 80 feet at a depth of 10 feet.

These wave characteristics, owing to their short wave lengths, are better able to interact with small objects than would a long-period ocean swell. For instance, a small man-made island approximately 100 feet in diameter just south of the Park South Unit, located approximately 600 feet offshore in water depth of about 15 feet, has created a stable accretional apex on the shore. It appears that a structure such as a fishing pier equipped with suitably distributed cross members could act as a wave slicer.

Storm waves generally approach the study site from between the north and the northeast, occurring most frequently when the extratropical storm tracks descends to lower latitude during late-fall and early-spring. These storms would also send waves from the southeast quadrant, but the fetch in this direction is much more restricted than in the northeast quadrant.

During summer months, the cold lake water creates a atmospheric pressure gradient against the low pressure over the land, driving a lake breeze. The lake breeze will rotate clockwise due to Coriolis deflection and will attain daily maximum in late afternoon blowing from the southeast quadrant. Therefore, the summer wave regime is more frequently from the southeast quadrant, with average heights of 1 foot. These waves are persistent in occurrence, but not sufficient to reverse the dominant southward littoral drift along the lake shoreline.

2.5.5 Ice

Ice provides protection against waves when it forms on the lakeshore for an average 3.5 month period on the study site. The ice normally would not cause additional impact on beach sediment budget, but would affect the structural integrity of protective works through physical impacts, excessive stresses, and freeze-thaw cycles.

2.6 Sediment Budget

Sediment budget is a book-keeping technique to take account of various input and output components of sediment in a given confinement of littoral system. This is a particularly useful method from the point of view of establishing a reliable estimate of the quantity of littoral drift.

Table 2.6.1 shows the result of an estimated sediment budget for the entire reach between the State Line and the Waukegan north jetty. This budget has been arrived at with necessary checks with the recorded volumetric data on littoral material, as follows:

The input into this reach is the littoral drift crossing the State Line southward, and the material entering the littoral stream within the reach from shore erosion. The output consists of loss to inland due to wind transport, loss to shore due to accretion, loss to offshore bottom due to wave action and dissipation during bypassing, and loss due to dredging.

The loss to inland due to wind was estimated to be of the order of 0.5 cubic yards a foot of shoreline annually. This amount is typical of lakeshore situations in the Lake Michigan.

The loss to offshore due to wave action is somewhat difficult to estimate. According to "Interim Report on Illinois Shoreline Erosion" by Corps of Engineers Chicago District (1975), between 1946 - 74 (28 years), volumetric loss on beach profiles from the top of bluff to approximate -20 foot contour LWD, between Kenosha and the nodal point south of the State Line, was about 300,000 cubic yards a year. On the other hand, a gain of 250,000 cubic yards a year was recorded between the nodal point to the Waukegan north jetty. The difference, 50,000 cubic yards a year,

TABLE 2.6.1

SEDIMENT BUDGET, ILLINOIS BEACH STATE PARK

LANDMARK	REACH LENGTH 1000 LF	SEDIMENT VOLUME (1000 C.Y./YEAR) LOSS TO DUNES	LOSS TO LAKE BOTTOM OVER -20 FT (LWD)	VOLUME CHANGES IN BEACH & PROFILE	GAIN (+) & LOSS (-) TO LITTORAL STREAM	LITTORAL STREAM BUDGET
					-15 Trident Hbr	
State Line						141
Park North Unit	16.2	8	8	-145	+129	
						270
Zion Nuclear Plant	2.1	1	1	-6	+4	
						274
Park South Unit	9.9	5	5	-31	+21	
Lodge						295
Park South Unit	8.7	4	4	+45	-53	
						242
	2.7	1	1 3*	+40	-45	
Public Service Pier						197
	7.3	4	4	+94	-102	
Waukegan North Jetty						95
					-40 Waukegan Hbr	
						55*

NOTE: (*) denotes bypassing loss

is considered to be an offshore loss which occurred between Kenosha and Waukegan, a distance of about 13.8 miles. This loss is equivalent to about 0.7 cubic yards a year for each foot of shoreline in this reach. For the present purpose of sediment budget, we will use 0.5 cubic yards a year per foot of shoreline as the rate of sediment loss to offshore bottom due to wave action.

The quantity of littoral drift bypassing the Waukegan Harbor has been estimated variously in the past. Table 2.6.2 shows the annual dredging record at the Waukegan Harbor, extracted from the annual reports of the Office of the Chief of Engineers, since 1944. Lake level is a factor in the maintenance dredging of an entrance channel serving navigation. High levels reduce maintenance dredging requirement, whereas low levels increase requirement. Hence there are a number of years in which the dredging was not conducted, and successive years where the dredging was performed (Table 2.6.2).

An average dredging rate over the 32-year period was about 17,000 cubic yards a year, but in those successive years where there was maintenance dredging the average appears to be more likely on the order of 40,000 cubic yards a year.

As will be shown in the following Chapter 2.7 "Future Erosion", the Wisconsin shoreline from Kenosha to the State Line was losing an average 164,300 cubic yards a year during 1956-74, of which the shoreland alone accounted for a loss of 53,600 cubic yards a year (See Table 2.7.1). Consider an offshore loss due to wave action in this reach amounting to 21,000 cubic yards a year (i.e., unit loss of 0.5 cubic yards/year per foot x 8 miles). The amount of littoral drift crossing the State Line southward is then predicted to be 143,300 (= 164,300 -21,000) cubic yards a year, or say 140,000 cubic yards. This amount represents all the material between the shoreline to the -20 foot contour LWD.

Using this amount, 14,000 cubic yards a year, as an input at the State Line, the amount of littoral drift predicted to arrive at the Waukegan north jetty is estimated to be 95,000 cubic yards. Of this amount, 40,000 cubic yards a year (42%) is captured in the Harbor and eventually removed to the offshore lake bottom through dredging; 5,000 cubic yards a year (5%) contributes to spit building. This leaves 50,000 cubic yards a year (53%) of littoral material which is not accounted for by either dredging or spit building. This amount is considered to represent a portion of the littoral drift which, after bypassing the Waukegan north jetty, settles on the offshore bottom south of the Waukegan Harbor.

Now that the Waukegan fillet has grown to a state of saturation, it is not surprising that as much as 95,000 cubic yards a year is capable of overflowing the Waukegan north jetty. This overflowing material is a virtual loss to the beach processes in the region. The amount that settles inside the Waukegan Harbor is contaminated by industrial pollutant and has to be disposed of in the offshore zone. The amount that either contributes to spit building or settles on the lake bottom south of the Waukegan Harbor is too far removed from the shore to benefit the littoral stream along the downdrift shoreline.

It must be noted that the sediment budget as described above is considered valid only on the order of magnitude. Sediment budget in any given year would undoubtedly fluctuate considerably, depending upon lake levels and storm frequencies. Furthermore, volumetric losses along shoreline reaches have been estimated on the basis of widely separated profile lines (See, for instance, reach lengths in Table 2.3.1), hence would only represent a gross estimate.

It is also noted that the sediment volumes estimated in the littoral stream represent the amount of sediment moving on both the nearshore and offshore bottom between the shorelines and the 20-foot contour. Consequently, although the estimated volumes for the littoral stream appear large (namely, as much as 295,000 c.y./year at the State Lodge, on Table 2.6.1), only a part of this amount is expected to occur in the surf zone close to the shoreline.

TABLE 2.6.2

MAINTENANCE DREDGING AT WAUKEGAN AND KENOSHA HARBORS
(As Reported In Annual REPORT OF CHIEF OF ENGINEERS)

F. Year	WAUKEGAN HARBOR			KENOSHA HARBOR		
	Yds^3	$Cost(K)	Dredge	Yds^3	$Cost(K)	Dredge
1976	40000	75	?	60000	?	(2)
75	?	122.4	?	0		
74	?	27.9	?	0		
73	0			0		
72	0			0		
71	0			0		
1970	0			33450	35.5	(1)
69	33456	58.1	(1)(2)	17449	43.9	(2)
68	0			0		
67	32491	25.9	(3)	46842	29.3	(3)
66	40224	38.5	(3)	10762	17.4	(3)
65	41279	?	(3)	New Work = 250,654 yds^3		
64	50812	48.0	(1)(3)	25897	31.3	(1)(3)
63	47191	41.2	(1)(3)	30280	22.5	(1)(3)
62	0			16805	14.3	(1)
61	39900	27.1	(3)	0		
1960	12629	17	(3)	73452	54	(1)(3)
59	0			40701	18	(3)
58	108200	90	(1)	0		
57	0			70485	45	(1)
56	0			0		
55	0			0		
54	0			0		
53	0			51225	29	?
52	0			0		
51	0			0		
1950	29640	34	?	41967	18	?
49	0			28814	17	?
48	56041	40	?	17951	20	?
47	0			25386	19	?
46	0			19679	13	?
45	0			20226	10	?
44	0			29983	11	?
(Totals)	531863			661354		

NOTE: (1) = Dipper Dredge "Kewaunee"
(2) = Hopper Dredge "Hoffman"
(3) = Hopper Dredge "Hains"

2.7 Future Erosion

2.7.1 Erosion Rate Acceleration

Future erosion rates are expected to be higher than those that prevailed in the past, for the following reasons:

1. From a geological point of view, the ongoing erosion at the Beach State Park is part of the long-term shoreline evolution in which the lake plain deposit updrift of the State Line has been progressively impoverished. Following this trend, the strength of the source of littoral material north of the State Line will continue to diminish in the future.

2. The eroding shoreline in the Beach State Park has been, and still is, receiving some littoral material from the eroding shoreland in Wisconsin. This supply will continue to diminish and, at some point in the future, will be completedly exhausted. Under such conditions, the erosion rates in the Beach State Park shoreline should accelerate with time.

3. The nodal or no-change point has been known to migrate southward and is presently situated south of the Park Lodge. This phenomenon, in itself, is an indication that the erosion rate will increase not only in time but also in space.

4. As the State Park shoreline continues to erode in the future, the shoreland adjacent to the State Line will be progressively offset landward from the Trident Harbor hard point. The offset shoreline will receive progressively less sediment supply since it will be outflanked by the sediment bypassing the Trident Harbor hard point. Since the deficit of supply resulting from this situation will be proportional to the amount of offset, the deficit of sediment supply in the North Unit will accelerate even more rapidly than the rest of the shoreline.

5. The Wisconsin shoreline from the State Line to Kenosha is presently believed to be about 60% fortified. This shoreline, which is mostly occupied by residential districts, is expected to be increasingly fortified in the

coming years. This means that the decreasing supply rate of littoral material from Wisconsin should become more pronounced with time in the future, resulting in a further deceleration of supply rate to the Illinois shoreline.

In view of these various reasons, a careful evaluation of possible future trends of erosion rates in the Beach State Park shoreline has been performed. The evaluation is based on the following procedure:

- Predict the southward migration of nodal or no-change point.
- Establish a correlation between the shoreland loss rates observed south of the State Line (to the nodal point), and those north of the State Line (to Kenosha).
- Use the above correlation to predict the future shoreland loss rates south of the State Line (to the nodal point) corresponding to the time when the shoreland north of the State Line will completely exhaust its supply.
- Determine the compounded acceleration rate of shoreland losses from the above.
- Establish successive positions of the nodal points and the corresponding shoreland loss rates south of the State Line, as a function of elapsed years from 1974.
- Derive relationships between the "observed shoreland loss" and the distribution of "shoreline recession rate" along the reach between the State Line and the nodal point.
- Using these relationships, predict shoreline recession rate for any given future year as a result of the accelerated erosion and the southward migration of the nodal point.
- Accumulate these recession rates for 10, 20, 30, 40 and 50 elapsed years from 1974 to derive "cumulative permanent" recessions or "predicted mean shoreline" positions at each point along the shoreline.

- o Derive the effects of short-term shoreline fluctuation over a 50-year time span to determine additional "temporary" recession.
- o Add the "cumulative permanent" recessions and "temporary" recessions to determine the "maximum" predicted future shoreline recession after 50 years from 1974.

Figure 2.7.1 shows the historical southward migration of the no-change (or nodal) point. According to this figure, the no-change point was located at Camp Logan around 1910, between Shiloh Boulevard and Park Lodge around 1946, and in the vicinity of the Dead River outlet around 1974. Using a best fit curve through these points, the nodal point is found to migrate at an average speed of 400 feet a year southward. At this rate of migration, the no-change point is expected to reach the southern end of the Park South Unit around 1986, the Public Service Pier around 1994, and the Waukegan Harbor north jetty around 2014 AD. In less than 10 years, the entire south unit will begin to erode, and within about 40 years the entire shoreland to Waukegan (including the Waukegan fillet) will begin to erode.

Table 2.7.1 shows the historical erosion rates between 1872 and 1974 based on the Corps of Engineers Surveys for 1872, 1910 and 1946 and the Illinois Geological Survey's data in 1974 from the top of the bluff to approximate -20 foot contour LWD. According to this table and Figure 2.7.2, annual erosion rates below the LWD between Kenosha to State Line remained remarkably constant at around 110,000 cubic yards a year since 1872. However, erosion rates above the LWD for the same reach underwent a steady decline during the same period. By extrapolating this trend linearly into the future, it can be shown that between 1974 and 2022 AD, the erosion rate above the LWD between Kenosha and State Line will average 21,000 C.Y./Year, and that after 2022 AD the erosion for this reach will be nill. Thus, after 2022 AD, the littoral material arriving in the littoral zone off the Illinois Beach State Park will consist of offshore sediment

TABLE 2.7.1

HISTORICAL EROSION RATES BETWEEN
KENOSHA TO NO-CHANGE POINT, 1872-1974

Reaches		Volume Changes in 1000 C.Y./Year		
		1872 - 1910	1910 - 1946	1946 - 1974
Kenosha Hbr to State Line	Above LWD	-94.7	-80.6	-53.6
	Below LWD	-110.5	-111.1	-110.7
Subtotal		-205.2	-191.7	-164.3
State Line to No-Change Pt.	Above LWD	-23.2	-16.7	-51.1
	Below LWD	-1.3	-164.4	-84.4
Subtotal		-24.5	-161.1	-135.4

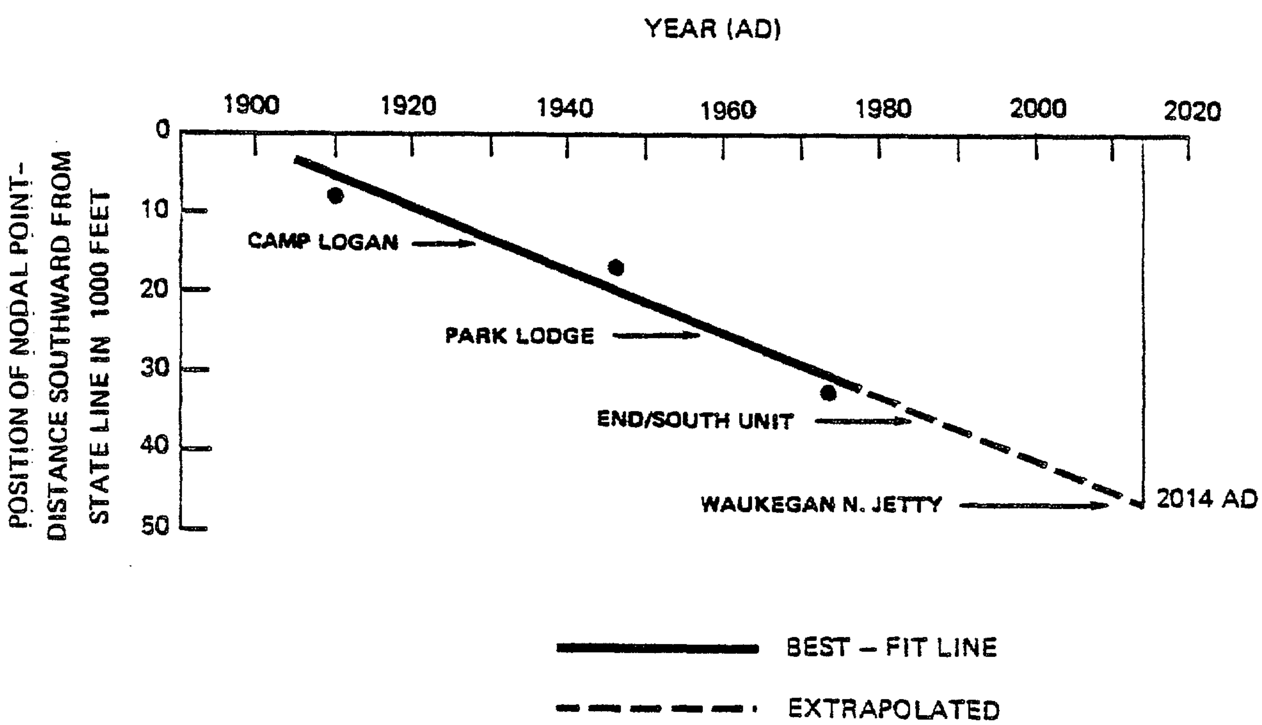


FIGURE 2.7.1 MOVEMENT OF NODAL POINT

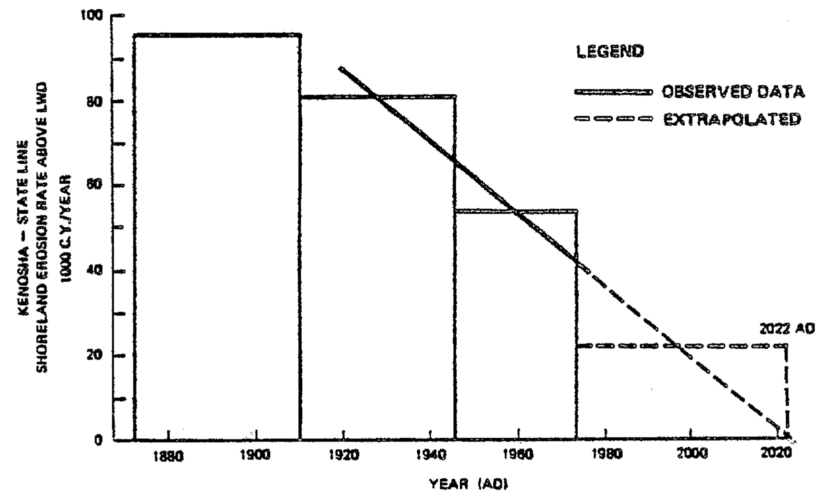


FIGURE 2.7.2 HISTORICAL EROSION RATES ON SHORELAND FROM KENOSHA TO NO–CHANGE POINT

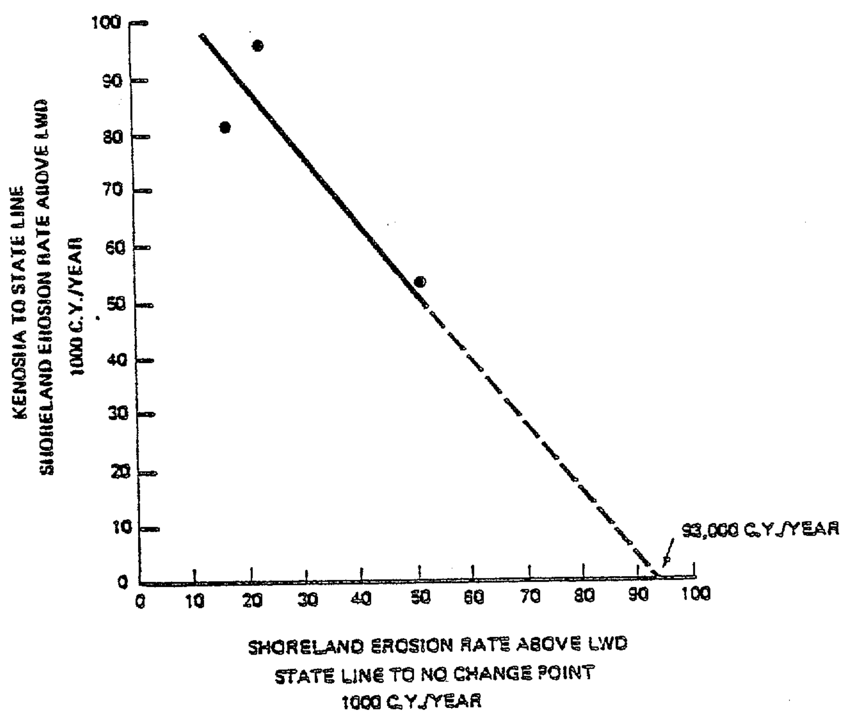


FIGURE 2.7.3 CORRELATION FOR SHORELAND EROSION RATES ABOVE LWD, BETWEEN AREAS ACROSS STATE LINE

alone, which is not effective in protecting the shoreland.

The steady historical decline in the erosion rate above the LWD along the Wisconsin shoreline is correlated with the observed corresponding steady rise in the erosion rate south of the State Line to the no-change point. This correlation is shown in Figure 2.7.3. According to this correlation, the erosion rate south of the State Line to the no-change point above the LWD corresponding to a zero erosion on the Wisconsin shoreland predicted to occur in 2022 AD, can be estimated to be about 93,000 C.Y./Year. This rate is an average erosion rate between the State Line and the point of no change, which has been predicted to reach the Waukegan north jetty in 2014 AD, about the same time when the shoreland above the LWD from Kenosha to the State Line would cease to erode, i.e. by 2022 AD. In other words, this average erosion rate of 93,000 C.Y./Year will come essentially from the entire 8.75-mile reach from the State Line to the Waukegan north jetty beginning around 2020 AD, or about 40 years hence.

Since the most recent erosion rate (1946-1974) between the State Line to the Waukegan north jetty is 24,300 C.Y./Year above the LWD (Corps of Engineers, 1975) the projected 2020 AD erosion rate for the same reach (i.e., 93,000 C.Y./Year) represents an increase over the existing rate by a factor of 3.8. This increase will be occuring over a time span of 40 years (1974 to 2014), meaning that the future erosion rate of the shoreland above the LWD in the Illinois Beach State Park will increase at an annual compounded rate of about 2.84% in the future. Thus, the shoreland erosion above the LWD in the reach south of the State Line will approximately double by 2000-AD, approximately triple by 2015 AD, and approximately quadruple by 2022 AD.

For instance, the annual shoreland loss rate (Q) for any given year is obtained by

$$Q = Q_o (1 + r)^n$$

in which Q_o is the shoreland loss rate for the starting year, r is the compounded rate of 2.84%, n is the elapsed years.

2.7.2 *Future Erosion Rates*

Alongshore distribution of erosion rates roughly follow an exponential relationship, such that

$$R = R_o e^{-aX} \tag{1}$$

in which

R = Erosion rate in feet/year at a given point X along the downdrift coast

R_o = Erosion rate at the point of origin X = o, i.e. at State Line.

a = Coefficient to be determined from empirical data.

Figure 2.7.4 shows actual erosion rate distribution for the period 1939-77 based on air photo data. Plots fall within a band bounded by the minimum and maximum erosion rates. The minimum erosion rates represent a trend from 1939 and 1977, while the maximum erosion rates represent effects of short-term fluctuations and local effects. Since our interest is to consider predicted trends and predicted short-term fluctuations, we will first derive our predictive equation based on the long-term trend (1939-1977).

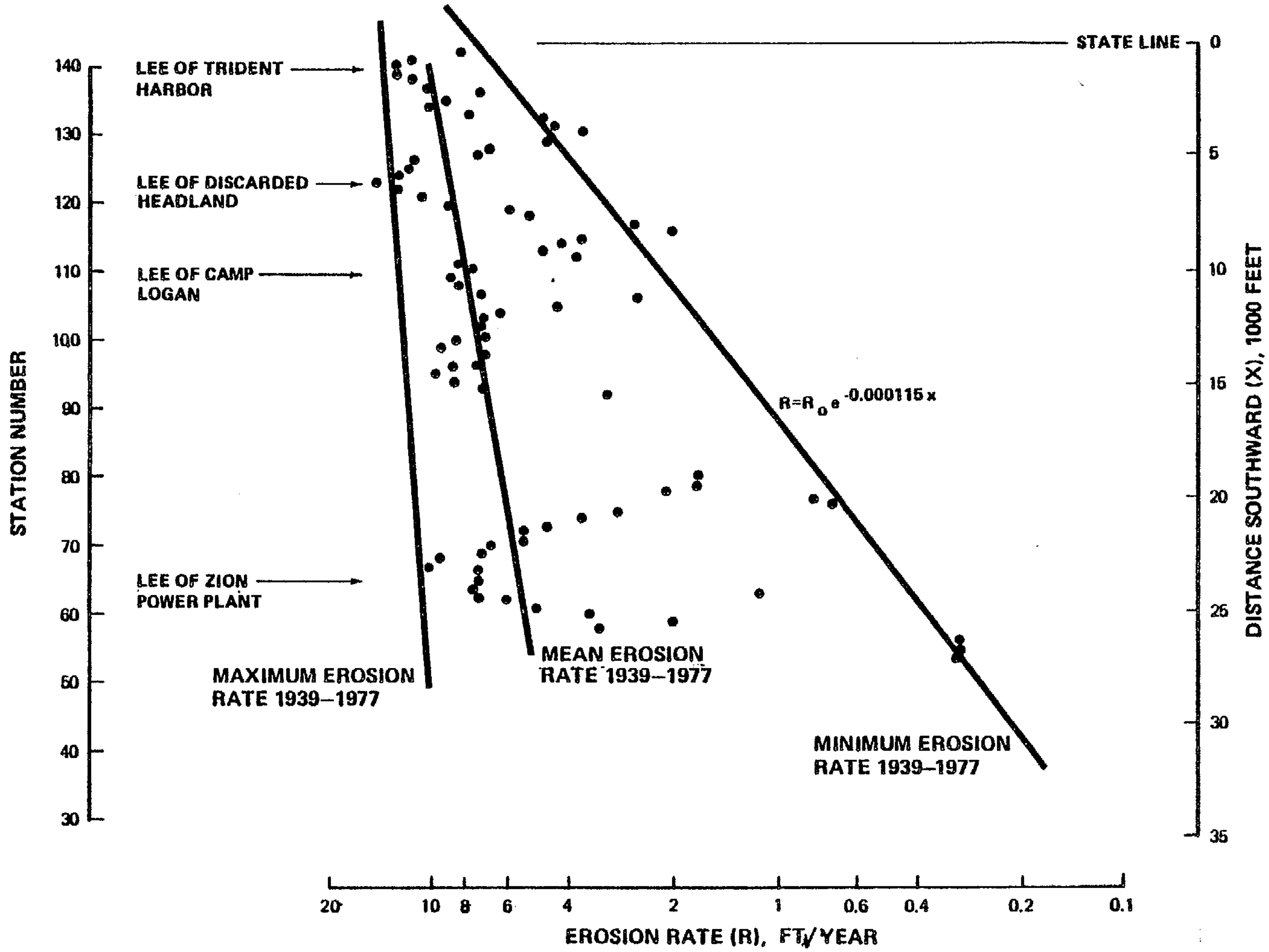


FIGURE 2.7.4 ALONGSHORE EROSION RATE DISTRIBUTION FOR 1939-77

From Figure 2.7.4, a is found to be 0.000115; hence the alongshore erosion rate distribution reduces to

$$R = R_o e^{-0.000115 x} \tag{2}$$

Shoreland volume loss, Q, is defined from integration of R between X = 0 to X = X* (no-change point). Thus

$$Q = Z \int_0^{x^*} R \, dx = \frac{ZR_o}{a} \left[1 - e^{-ax^*}\right]$$

or

$$R_o = \frac{a}{\left[1 - e^{-ax^*}\right]} \cdot \frac{Q}{Z} \tag{3}$$

where Z = height of the berm above the LWD, assumed to be 8 feet.

a = 0.000115

Given a known value of shoreland loss, Q, and no-change point, X*, the recession point can now be determined using equation (2). The shoreland loss, Q for any future year is obtained by

$$Q = (24{,}300) \; . \; (1.0284)^n$$

(in cubic yards/year)

in which 24,300 C.Y./Year is the observed shoreland loss rate between 1947 - 74, 1.0284 is an annual compounded incremental acceleration of erosion, as determined in the preceding section, and n is the elapsed years. The no-change point X* measured southward from the State Line elongates at a rate of 400 ft/year southward. With both Q and X* thus determined for any given year, annual recession rate (feet/year) for a given year is calculated from equation (2).

2.7.2 *Erosion Rate Prediction*

Table 2.7.2 and Figure 2.7.5 show the result of predictions using these procedures. Table 2.7.3 shows the cumulative recessions for elapsed years of 10, 20, 30, 40 and 50, starting from 1974.

Temporary short-term recessions were derived by accumulating for 10 years the maximum observed short-term erosion rates based on air photo data. Since these maximum rates are averages over about 6 to 7 years, and since the maximum rates occurred at each shoreline location once over a 38-year period (1939-77), these rates will have to be accumulated for 8 to 9 years (6 to 7 years x 50/38) in order to account for their cumulative effects over a 50-year time span. Considering that these maximum rates are based on the past 38-year records, and therefore that they may be exceeded in the future in light of the diminishing supply of littoral material, a 10-year accumulation, instead of a 8-year accumulation, was used.

The final column in Table 2.7.3 gives the sum of the permanent cumulative recession for 50 years based on mean shoreline prediction, and the cumulative temporary recession due to short-term erosion rate fluctuations for 10 years. These results are also shown in Figure 2.7.5. The resultant 50-year erosion with reference to the 1974 shoreline is shown in Plate 1.

Effects of these predicted erosion rates on the State Park shoreland are discussed in further detail under Section 3.3 "Alternative 1 - No Action."

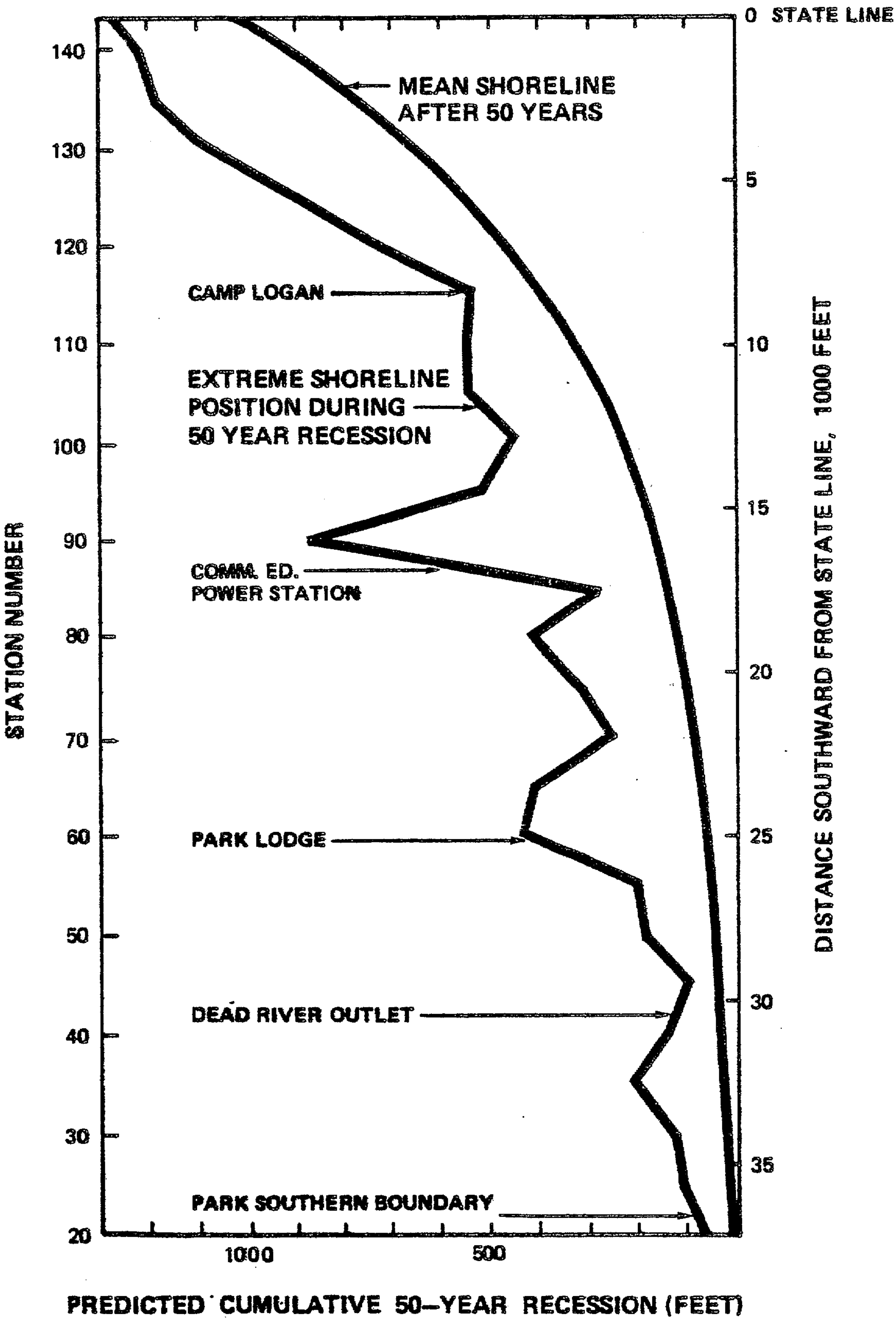


FIGURE 2.7.5 PREDICTED 50-YEAR SHORELINE RECESSION COMBINING LONG-TERM MEAN AND SHORT-TERM MEAN

TABLE 2.7.2

PREDICTED SHORELAND LOSSES TO 2024 AD

REGION	(1) PERMANENT LOSSES DUE TO MEAN SHORE-LINE		(2) TEMPORARY LOSSES DUE TO SHORT-TERM FLUCTUATIONS		(1) + (2) COMBINED LOSSES	
	Cumulative to 2024 AD	Annual Rate	Cumulative to 2024 AD	Annual Rate	Cumulative to 2024 AD	Annual Rate
	ACRE	ACRE/YR	ACRE	ACRE/YR	ACRE	ACRE/YR
North Unit	183.56	3.67	90.53	1.81	274.09	5.48
Zion	7.48	0.15	21.12	0.42	28.60	0.57
South Unit	27.46	0.55	84.26	1.69	111.72	2.24
North Unit and South Unit	211.02	4.22	174.79	3.50	385.81	7.72
Grand Total	218.50	4.37	195.91	3.92	414.41	8.29

TABLE 2.7.3

PREDICTED SHORELINE RECESSION BASED
ON ACCELERATED EROSION RATES AND
SHORT-TERM RATES

STATION NUMBER	PERMANENT RECESSION OVER GIVEN ELAPSED YEARS BASED ON ACCELERATED EROSION RATES (IN FEET)					TEMPORARY RECESSION DUE TO SHORT-TERM FLUCTUATIONS (IN FEET)	TOTAL 50 YEARS RECESSION
	ELAPSED YEARS						
	10	20	30	40	50	10 YEARS ACCUMULATION	
143	-111.38	-256.73	-447.41	-698.35	-1029.26	-250.0	-1279.26
140	-100.43	-231.49	-403.42	-655.94	-928.06	-294.0	-1222.06
135	-84.52	-194.81	-339.50	-529.92	-781.02	-203.0	-1184.02
130	-71.68	-166.34	-291.33	-475.60	-674.47	-409.0	-1083.47
125	-59.85	-137.97	-240.44	-375.30	-553.13	-338.0	-891.13
120	-50.37	-116.11	-202.35	-315.83	-465.49	-263.0	-728.49
115	-47.28	-97.71	-170.29	-265.79	-391.74	-132.0	-523.74
110	-39.79	-82.23	-143.31	-223.68	-329.67	-222.0	-551.67
105	-30.02	-69.20	-120.60	-188.24	-277.44	-274.0	-551.44
100	-25.27	-58.24	-101.49	-158.42	-233.48	-216.0	-449.48
95	-21.26	-49.01	-85.41	-133.32	-196.49	-320.0	-516.49
90	-17.89	-41.25	-71.88	-112.19	-165.35	-702.0	-867.35
85	-15.06	-34.71	-60.49	-94.42	-135.16	-132.0	-267.16
80	-14.13	-29.21	-50.91	-79.46	-117.11	-296.0	-413.11
75	-11.89	-26.19	-42.84	-66.87	-98.55	-203.0	-301.55
70	-8.98	-20.69	-36.05	-56.27	-82.94	-163.0	-245.94
65	-7.55	-17.41	-30.34	-47.36	-69.80	-345.0	-414.80

- continued on next page -

TABLE 2.7.3

PREDICTED SHORELINE RECESSION BASED
ON ACCELERATED EROSION RATES AND
SHORT-TERM RATES
(continued)

STATION NUMBER	PERMANENT RECESSION OVER GIVEN ELAPSED YEARS BASED ON ACCELERATED EROSION RATES (IN FEET)					TEMPORARY RECESSION DUE TO SHORT-TERM FLUCTUATIONS (IN FEET)	TOTAL 50 YEARS RECESSION
	ELAPSED YEARS						
	10	20	30	40	50	10 YEARS ACCUMULATION	
60	-6.36	-14.65	-25.53	-41.52	-58.74	-378.0	-436.74
55	-5.35	-12.33	-22.30	-34.35	-50.24	-150.0	-200.24
50	-4.50	-10.38	-18.08	-28.23	-41.60	-144.0	-185.60
45	-3.79	-8.73	-15.22	-23.75	-35.01	-67.0	-102.01
40	-3.19	-7.35	-12.81	-19.99	-29.46	-114.0	-143.46
35	-2.68	-6.18	-10.78	-16.82	-25.72	-190.0	-215.72
30	-2.26	-5.20	-9.07	-14.16	-20.87	-117.0	-137.87
25	-2.12	-4.38	-7.63	-11.96	-17.56	-98.0	-115.56
20	-1.60	-3.69	-6.42	-10.03	-14.78	-50.0	-64.78

3. EROSION CONTROL ALTERNATIVES

3.1 Rationales and Criteria

3.1.1 Rationales

Key rationales governing the plan formulation for a viable beach erosion control program for the Illinois Beach State Park are summarized below in light of the unique character of the problems detailed in the preceding chapters.

1. Deficit of supply: The shoreline of the Illinois Beach State Park faces a fundamental deficit of supply of littoral material across the state line from Wisconsin. This deficit is in part the result of geological processes and in part the result of the fact that the Wisconsin shoreline, which has been the dominant historical source of supply of littoral material from its eroding beaches and bluffs, are now increasingly fortified with structural protection. For instance, an Army Corps of Engineers report (1975) estimates that an 8.5 mile shoreline between the state line and Kenosha Harbor used to supply approximately 205,000 cubic yards of material annualy to the littoral stream during 38 years between 1872 and 1910. This supply during the recent 28 years between 1946 and 74 was dwindled to about 164,000 cubic years a year, or to about 80% of the amount for the 1872-1910 period.

The eroding coastline along the Wisconsin shoreline between Kenosha and the State Line is considered to contain an average 81% of material suitable for beach deposit. With continued armoring of the coastline, this important source of supply will be denied to the downdrift coast of the Illinois Beach State Park.

Implications of the shoreline fortification in Wisconsin are to be gauged not only in terms of the quantity of material lost but in terms of the quality of the material now left available for the Illinois Beach State Park shoreline. With the shoreline increasingly fortified, the bulk of the littoral material must now be derived from the nearshore bottom which, owing to its fine size, is not generally suitable to becoming part of a stable beach. Indeed, this situation is well evidenced along the Wisconsin shoreline by the almost universal lack of an updrift fillet at a number of reveted headlands between the State Line and Kenosha Harbor.

In the formulation of a beach protection program for the Illinois Beach State Park, therefore, it is reasonable to assume that future contributions of littoral material from the Wisconsin shore across the state line would be decreasing. This in turn implies that a man-made source of littoral material must be introduced south of the state line in order to make up for the deficit in supply.

2. Offshore loss: The loss of nearshore material to offshore bottom due to wave and current action is an inherent part of natural processes. The loss will increase, however, as the littoral material becomes finer in size, and also as the man-made structures enhance offshore-directed currents. These two factors, fine size of material and man-induced offshore loss, will combine to aggravate the offshore loss of material with time, since the fine material diverted offshore at structures is likely to settle in waters too far removed from shore to be able to return to a downdrift beach.

An evidence for this situation is found on the Camp Logan beach where a Z-groin merely 120 feet long has been causing substantial loss of littoral material to approximately 5,000 feet of shoreline on its downdrift reach. A groin or head land will protrude further out to the lake relative to the shoreline during the time of high lake levels, thus straddling an increased part of the surf zone and causing a greater degree of adverse effects on the downdrift coastline.

Another major cause of offshore loss is found at the Public Service Company Pier at the Waukegan north jetty, where the sediment attempting to bypass from the north fillet to the south shore is partly lost to the lake bottom. A conservative estimate of the amount thus lost, as has already been discussed, is 3,000 and 5,000 cubic yards/year, respectively. At Trident Harbor, an offshore loss would occur due to the entrance jetty, probably at a level of a few thousand cubic yards a year.

As a consequence, the beach erosion protection plan must take into account considerations for minimizing the offshore loss of littoral material. For this purpose, the protruding length of any protective and existing structures must be given a critical evaluation. Furthermore, the smoothing of shoreline configuration to eliminate discontinuities of the shoreline geometry must also receive a special attention.

3. Sediment residence time: The littoral material moving southward along the Beach State Park Shoreline eventually would sink in the fillet north of the Waukegan Harbor north breakwater. Now that the fillet is believed to have grown to its capacity, a large proportion of the material arriving here is believed to overflow the sink to be lost to the lake bottom. Conversely, if the fillet can be reduced in size either by mechanical sand extraction or by man-induced or controlled reduction of the arriving material, it will be able to operate as a more efficient sink.

The rationale is, then, to retard the southward movement of littoral material before it exits the Park boundary to reach the fillet. Various means of achieving this objective are available, including among them, compartmentizing the littoral stream into a suitable number of segments, creating wave shadow zones to decelerate the longshore currents by suitably spaced offshore structures etc. An additional method will be a mechanical recycling of sediment from the Waukegan fillet to the Beach State Park shoreline.

3.1.2 Criteria

Several important criteria and constraints are in evidence in the formulation of a viable erosion control program for the Illinois Beach State Park, as follows:

1. Aesthetics: A program which will accomplish the objective of erosion control at the expense of one of the essential attributes of the Beach State Park Shoreline, i.e., aesthetics, will not be acceptable. This consideration particularly applies to the beach fronting the State Park Nature Preserve, a distance of some 12,000 feet southward from the Park Lodge to the Johns-Mansville Company property. This particular area is to be kept in a state of natural appearance, hence any control action intended to benefit this area must be done without the physical presence of man-made structures within its domain. In the case a backpassing plan is adopted to recycle the sediment from the Waukegan fillet to the beach further north, routes of pipeline or roads for trucking present temporary adverse impacts on the aesthetics of the area.

The north unit of the Beach State Park, some 16,000 feet from the State line to Shiloh Boulevard, is fronted by abandoned residential districts and a former State National Guard camp. This area is intended to be devoted to land-based forms of recreation including camp sites, picnic grounds, hiking trails, scenic overlooks, a visitor center, etc., hence is considered less sensitive.

2. Recreational consideration: An erosion control plan which would obstruct the view of the lake and which would create hazards to bathers and hikers will not be acceptable. Structures which are likely to belong to this category are offshore breakwaters and groins. Sheet-pile walls and revetments would make access to the beach difficult and must be located outside the primary recreational area. An artificial headland, when suitably designed, will be less obtrusive than a groin, and could also serve as a lookout point for park visitors.

One of the important considerations from the point of view of recreation is a recreational small craft harbor. The Illinois Department of Conservation has recently sponsored a feasibility study for a recreational harbor to be sited in the north park unit between the 17th and 21st Street. A recreational harbor, if properly designed, could not only enhance the public use of the Park, but also serve as a means of beach protection.

The present study is required to consider shoreline stabilization action which will be effective with and without a recreational/safewater harbor structure. The feasibility study, just completed, has provided several alternative plans, all of which are shore-connected, hence requiring sand bypassing schemes in one way or the other. Furthermore, the proposed locations for these alternative plans are more or less fixed in the vicinity of the 17th and 21st Streets. The present study, which focuses on beach stabilization, will take these plans into consideration from the point of view of shore stabilization, and will further endeavor to consider other alternative concepts including an offshore-island scheme and different locations for the site. An engineering development of these concepts with sufficient details to both shore stabilization and marina feasibility has been authorized to begin shortly by the Illinois Department of Conservation.

3. Zion nuclear power plant: The Commonwealth Edison Company's Zion nuclear power plant facilities occupy a 5,300-foot reach of shore between the 17th Street and Shiloh Boulevard. The plant separates the Illinois Beach State Park into its north and south units; hence, any mitigation plans to be implemented in the park domain are likely to affect the plant's shoreline, and vice versa. Presently, the premises of the power station are fronted by a narrow beach only about 150 feet wide and are protected by a 1,200-foot long sheet pile wall with returns on each end. With continued erosion on this beach and inevitable attempts to harden its premises against erosion, the Zion nuclear station will become an armored headland protruding to the lake and serving as a littoral barrier to the shorelines of the Illinois Beach State Park.

3.2 Range of Possible Alternatives

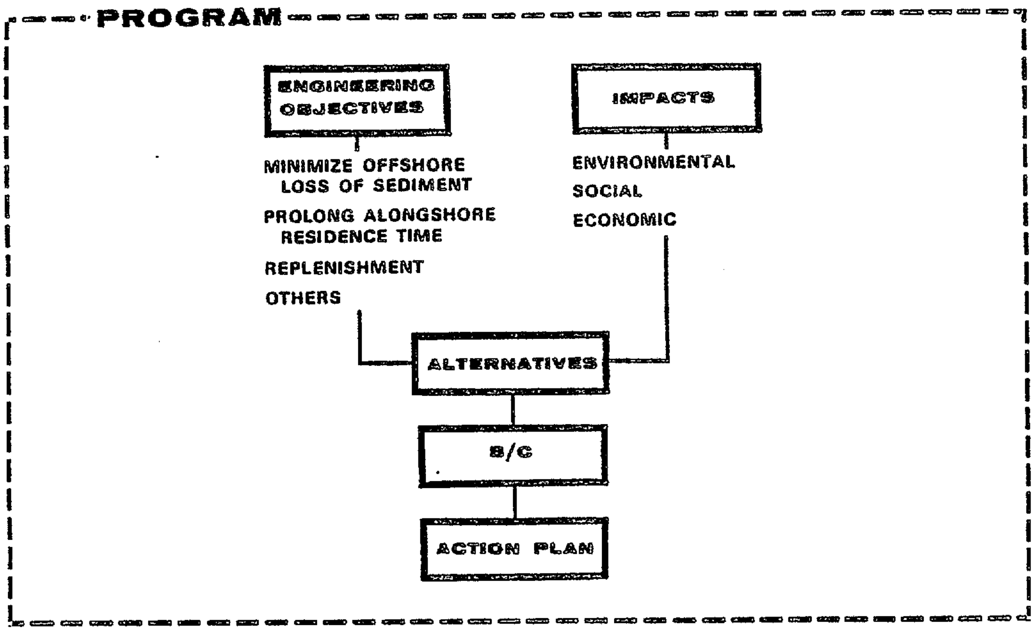
3.2.1 Approaches

Table 3.2.1 illustrates strategies with an array of various conceivable engineering methods to be considered in the formulation of erosion control plans. In light of the rationales already discussed in the preceding sections, these methods are catalogued under four identified objectives as follows:

- o Minimize offshore loss of sediment
- o Prolong alongshore residence time of sediment
- o Replenishment
- o Others

TABLE 3.2.1

STRATEGIES FOR FORMULATION OF EROSION CONTROL PLANS



ENGINEERING OBJECTIVES

MINIMIZE OFFSHORE LOSS OF SEDIMENT

* HALT SAND MOVEMENT OFFSHORE
  - SILL
  - SPOIL REEF
  - PERCHED BEACH
  - SAND TRAP
* HARDEN BEACH, BLUFF
  - SEA WALL
  - REVETMENT/RIPRAP
  - BLUFF STABILIZATION
* REDUCE WAVE ENERGY
  - FULL OR PARTIAL BREAKWATER
  - SUBMERGED BREAKWATER
  - FLOATING BREAKWATER
  - WAVE SCREEN
  - WAVE SLICER
  - OFFSHORE ISLAND
* CONTROL MAN-MADE LOSS
  - UTILIZE DREDGE SPOIL
  - REGULATE FILLET SIZE
  - REGULATE GROIN LENGTH
  - REGULATE NEW CONSTRUCTION

PROLONG ALONGSHORE RESIDENCE TIME

* RETARD LONGSHORE CURRENT
  - GROIN
  - HEADLAND
  - PIER
* REDUCE WAVE ENERGY
* RECYCLING/BACKPASSING

REPLENISHMENT

* BACKPASSING
* OFFSHORE SOURCE
* LAND QUARRY

OTHERS

* LONG-TERM DEVELOPMENT
* RECREATIONAL FACILITIES

These methods are evaluated for their merits and demerits in special consideration of the unique criteria, constraints and problems of the Illinois Beach State Park.

It is important to emphasize that various engineering methods known to mitigate beach erosion have mixed records of performance. Frequently, the success achieved in a given environmental setting has failed to duplicate itself in another. Also frequently, the degree of success achieved by a structure has been offset by a new problem or problems which it itself has created. Furthermore, all the methods require periodic maintenance for functional integrity over their life cycle.

From the analysis of engineering methods will be derived an assortment of "feasible alternatives". Each of these alternatives will then be programmed into a system of actions with priorities and phased implementation schedule aimed at bringing the optimal benefit for the level of efforts envisaged. The final recommendations will be based not only on the consideration of benefit/cost ratio to capitalize on federal funding assistance to the maximum extent possible, but also of the feasible State appropriations to enable their practical implementation.

3.2.2 Methods to Prevent Offshore Loss of Sediment

Typical methods are:

- o Sill
- o Spoil reef or mound
- o Perched beach
- o Sand trap

<u>Sill, Spoil Reef and Perched Beach</u>

The primary function of these methods is to physically intercept bed-load movement on the nearshore bottom by means of a vertical wall oriented in parallel to the coast. Since the methods aim at halting the bed-load movement alone, the wall may be built as a low submerged structure. Where a sand trap is required, a partial breakwater capable of providing a wave sheltering function as well as bed-load interception is needed.

The submerged wall may be constructed as a hard sill built with revetment, rock or concrete block mounds or even with a sheet pile wall, or as a spoil reef with a natural angle of repose. The beach slope inshore of the sill may accrete naturally where abundant longshore drift is available, or it can be replenished artificially to create a "perched beach."

The simplicity of the concept of "sill" or "perched beach" is most appealing. It essentially represents an offshore version of a backfilled seawall, aimed at retaining not only the backshore but also the underwater and beach profiles as well. Also, like the sea wall, the "sill" or perched beach" is subject to toe erosion, wasting of backfill material through the gaps of the sill, and outflanking erosion at both ends of the sill. The device will probably be most effective in a relatively small embayment where both flanks of the sill can be closed with a connecting structure to the shore.

The sill or perched beach is a means of retarding, not preventing, the offshore loss. Therefore, it requires periodic refill. Another disadvantage is that it may present a navigation hazard, hence must be properly marked to warn operators of the small craft.

A perched beach constructed in Larvotto Bay, Monte Carlo, Monaco, has been reported a success (L. Tourmen, 1968). In this case, a bay, only about 1,400 feet wide, was compartmentized with three parallel jetties, with a sill connecting between these jetties at their offshore end.

A sand mound constructed off Durban Harbor, South Africa (Zwanborn, 1968) is a massive structure, extending about 4.5 km long and requiring 8 million cubic meters of fill material. The mound rose only 5 meters in waters 12 meter deep. With its wide crest, 61 meter, the mound was credited with achieving an average 30% reduction in wave height. The shoreline thus protected exhibited a distinct sign of stabilization, but erosion reportedly continued outside the protected area. Tentatively, a sand mound with a height of 10 feet and a crest width of 100 feet placed in a water depth of 15 feet will achieve approximately 60% in wave height reduction (Shore Protection Manual, 1975).

This mound will require approximately 5,000 cubic yards of material every 100 feet of its length. Therefore, an annual average dredging of 15,000 cubic yards from the Trident Harbor entrance channel will be sufficient to fill a 300 feet segment of such a mound. Using a total 150,000 cubic yards of dredged material projected over a 10-year period from Trident Harbor, approximately 3,000 feet of such a sand mound can be constructed, provided that this material is sufficiently free of contaminants to allow for placement in the nearshore zone.

The sand mound thus can act not only as a sill but also as a wave attenuator. Because of lake level fluctuations, the mound will lose some of its wave attenuating function during the time of high lake levels. On the other, a broad crest width will help maintain an adequate range of this function against lake level changes. Before implementing this method, a careful evaluation of attrition rate and changes in cross-sectional configuration due to wave action must be made.

<u>Sand Trap</u>

A sand trap provides a borrow area located in the wave shelter behind an offshore breakwater. The borrow area may take the form of a pit below the surrounding sea bed to ensure good trapping efficiency and hold capacity. This device has been used with success at a number of places where concentrated impoundment of arriving littoral drift is desired to allow efficient dredging.

The sand trap is usually placed off an updrift fillet somewhat away from the existing jetty, so that the littoral material may be trapped before initiating the bypassing movement. A suitable location of a sand trap for the Beach State Park may be north of the Public Service Company pier.

3.2.3 Methods to Harden Beaches

Typical methods are:

- o Sea Wall
- o Revetment/riprap

These are well-established methods to harden the shoreline. The primary purpose is to separate the backshore from wave action with incidental function as a retaining wall. However, it will not maintain the beach, or may even aggravate erosion in front of the structure when it is exposed to direct wave impact. It will also become an obstacle to the public access to the beach.

The seawalls and revetments have exhibited mixed records of performance in the study area. Most of the hard points which were constructed with stone revetments by private homeowners in the Park north unit have fallen in the lake. Usually, as the hard points become isolated from continued erosion on the unprotected adjacent shore, the armoring must be extended on both sides to the receding shore in order to avoid outflanking. Where such an additional protection has not been provided, erosion typically worked its way to the unprotected backfill and eventually destroyed the hard points.

Whereas revetments and seawalls are suitable to providing spot protection to short reaches of shore, they can only be successful when adequate maintenance and necessary extention are provided in accordance with the change in the shoreline condition. As the adjacent unprotected shoreline on either side is left to continued erosion, the successful isolated hard point will only become an increasingly undesirable littoral barrier. This is particularly true in the study area where, owing to the deficiency in the natural supply of sediment in the littoral stream, a protruding hard point is usually unable to develop a fillet on the updrift side. Accordingly, revetments and seawalls must be employed with care and only within the framework of an overall protection plan.

An extreme case of shore hardening with seawalls and revetments is found in the Chicago Lake Front. The City of Chicago has hardened a major part of its lake front with seawalls, revetment and recreational boat harbors. Although a beach in its natural state thus has disappeared, the shoreland property of Chicago has become an outstanding park system with facilities for golfing, swimming, fishing and hiking.

This extreme approach is not a favored method for the Illinois Beach State Park, where the shoreland is dedicated to the conservation of its naturalness.

3.2.4 Methods to Reduce Wave Energy

Typical methods are:

- o Full or partial breakwater
- o Submerged breakwater
- o Floating breakwater
- o Wave screen
- o Wave slicer
- o Offshore island

Partial Breakwater

Recently, an increasing attention has been paid to the possible benefit of detached partial breakwater as a means of beach protection. Namely, at Lakeview Park on Lake Erie, a series of 3 offshore breakwater segments each 250 feet long and 160 feet apart have been constructed. Although detailed results of its performance are still under investigation, preliminary indications are that the system has been highly effective in stabilizing the local beach. Evaluation of the effect of this system on the downdrift coast due to the reduced supply of littoral material is not available.

Numerous detached breakwaters have been built in Japan with various degrees of success and failure. Most successful ones were of a permeable rock-fill type which would prevent superelevation of water between the structure and the shore. Most failures were associated with insufficient crest height against wave overtopping, toe scour, subsidence due to piping, and inadequately large spacings between breakwater segments, among others. The primary beneficial function of detached breakwater is to provide a wave shelter on the beach while allowing a free, though somewhat inhibited, passage of longshore current to the downdrift coast. The sheltered shoreline will develop an apex toward offshore, and where there is sufficient protection, the apex could reach the breakwater, forming a tombolo. In order to prevent this from happening, a certain amount of wave energy is admitted into the sheltered area using proper ratios of length, spacing and distance from shore to the breakwater. Reduced wave energy in the sheltered area will also make it possible for relatively fine material to deposit on the shore.

The most obvious disadvantage is the visible presence of the structure above the lake surface. Other disadvantages will include, among others, high cost of construction, navigation hazard, and hazards to swimmers.

<u>Full Breakwater</u>

Full breakwater, on the other hand, would completely separate the littoral zone from the lake. Thus, while providing a complete protection to the beach, a fill breakwater will forefeit natural state of the beach. This particular method could only be considered as the last resort to be employed when the lake shore erosion has reached a critical stage with little or no sand left on the nearshore bottom, and when the beach regime has been reduced to a state of unnaturalness.

Submerged Breakwater

Submerged breakwater as a means of wave energy reduction has been well investigated. One important requirement of a properly functioning submerged breakwater is an adequate clearance of the breakwater crest to the water surface. In Lake Michigan, lake level fluctuations will cause this clearance to change with time, reducing the efficiency of the structure during the time of high lake levels. Submerged breakwater system constructed in Miigata, Japan, has been afflicted with a series of difficult maintenance problems, including among them, subsidence due to toe erosion associated with piping effects. Eventually, after some 20 years of experimentation, the entire system has been raised above the sea level to become a full breakwater.

Permeable interlocking blocks, such as those recently introduced at some locations in the Great Lakes, may be used for construction of a submerged breakwater. Because of their permeability, a submerged breakwater built with these blocks will certainly present an advantage of reducing the piping effect. However, the total performance of these blocks, including the ability to maintain structural integrity, is yet to be demonstrated.

Floating Breakwater

Floating breakwater presents a most tempting aspect as a low cost beach protection structure. However, various types of this structure known today are either in experimental stage or generally considered to lack sufficient structural integrity to function under severe conditions of wave and ice. Wave screen and wave slicer are also considered to belong to the same category of unproven efficacy under real conditions.

Offshore Island

Offshore island is a concept essentially parallel to that of partial detached breakwater in terms of its role as energy attenuator. Additionally, an offshore island will offer recreational opportunities. The concept of an offshore island is of particular interest to the Illinois Beach State Park where both beach protection and enhancement of recreational opportunity are a pressing concern.

An offshore recreational harbor could be designed to provide a wave shelter along considerable reaches of shoreline while allowing for the continuity of the alongshore littoral stream under an elevated causeway to the shore. Such a marina may be sited at an offshore location with a suitable configuration, so that the formation of an accretional apex in its shelter will occur on the eroded coastline. This will not only help rectify the shoreline curvature, but also will allow the littoral transport to function efficiently even under the condition of reduced wave energy. A large shelter forming behind an offshore island will enable relatively fine material to remain attached to the nearshore profile, thus reducing the potential offshore loss of littoral material which would have occurred otherwise. An offshore island will also act as a large-scale sill to arrest the offshore movement of bed load.

3.2.5 Methods to Control Man-Made Losses

Typical methods are:

- o Utilize dredge spoil
- o Regulate fillet size
- o Regulate groin
- o Regulate new construction

Dredge Spoil Utilization

Trident Harbor requested a permit to dredge a total of 150,000 cubic yards for a 10-year period, from its entrance channel beginning 1978. The permit to conduct this maintenance dredging has been granted. Previously, in 1976, Trident Harbor acquired a permit to dredge 12,500 cubic yards in its entrance channel. The dredged material will be disposed off-site.

The annual dredging rate of about 15,000 cubic yards from the Trident Harbor entrance channel represents 13 to 20% of the variously predicted littoral drift rates at this location. Since the material is dredged out of the entrance channel, it is considered essentially unpolluted and of a size suitable for beach nourishment. Furthermore, as has already been discussed in the preceding section, the possibility exists that this spoil may be utilized for constructing an offshore sand mound (a 10-year dredged material totalling 150,000 cubic yards would be sufficient to build 3,000 feet of mound 10 feet high and 100 feet wide at the crest). In light of the fact that a suitable source of sandy material for beach replenishment is lacking in this region, some consideration must be provided to turn the disposal of the dredged material from Trident Harbor to a beneficial use for the Beach State Park shoreline.

Fillet Size Regulation

The method to regulate the fillet size at the Public Service Company pier and the Waukegan jetty has already been discussed in conjunction with the concept of a sand trap. The objective of a fillet size regulation is to maintain a sufficient degree of sand trapping capacity at these fillets, so that an offshore loss due to overflow and bypassing can be minimized. At the same time, some of the trapped material may be mechanically backpassed to the Beach State Park shoreline to recycle the littoral material and thus to prolong the residence time of sediment within the Park domain.

Groin Regulation

Adequate groin length is difficult to determine where insufficient littoral material exists, as along the north unit shoreline. The adverse role of the existing groin at Camp Logan, only about 120 feet long, has already been discussed. In light of the partly uncertain nature and partly detrimental effect of the groin, and also in consideration of its disruption of shoreline esthetics and hazards to bathers, future introduction of additional groins on the Beach State Park shoreline is considered inadvisable.

New Construction Regulation

Mitigating actions taken to relieve local problems can readily lead to adverse effects on the downdrift coast. An erosion control plan intended to the Beach State Park domain will be an integration of various balanced and interactive actions. However, the plan's success will depend to some extent upon new protective constructions which may be undertaken by private interests at Trident Harbor and on the City of Zion frontage.

For instance, Trident Harbor reportedly is intending to increase its berth capacity from the present 200 boats to 1400 boats. Such a drastic expansion will inevitably require substantial enlargement of the entrance channel both in width and offshore extension. Unless all excavated material, including annual maintenance dredging, is placed on the shore south of the harbor, the north Park shoreline would be adversely affected.

At the Commonwealth Edison Company property, the shoreline lies only within about 150 feet from the steel sheet pile wall. Should the erosion worsen in the future, some substantial protection actions will be needed to protect the power plan facilities. If such actions should involve structures which would contribute to offshore loss of littoral material, an adverse downdrift effect is anticipated. Erection of such structures, particularly groins, should be regulated on the basis of mutual consent between the Beach State Park and the Commonwealth Edison Company. The present study assumes that the nuclear station will maintain its beach front without resorting to groins.

3.2.6 Methods to Retard Longshore Current

Typical methods are:

- o Groin
- o Headland
- o Pier

Groin

Groin is among the oldest known methods of shore protection. Where there is abundant littoral drift, groin's role to build or widen a beach through trapping of littoral drift has been well recognized. Furthermore, groin will also curtail the longshore transport by reorienting the compartmented shoreline more nearly perpendicular to the predominant wave direction.

Disadvantages of groin generally lie in the increased offshore loss from the formation of a concentrated rip current on its updrift side and also in the reduction of longshore transport rate to the downdrift coast. The former is particularly critical for the Beach State Park shoreline, where the important concern is to minimize the offshore loss of sediment from the already impoverished littoral stream. For this reason, it is questionable whether or not a groin could provide a net positive benefit on the Beach State Park shoreline. The presence of a groin on the Beach State Park shoreline would present some degree of hazard to bathers.

Headland

An artificial headland is generally constructed with a relatively short protrusion from the shore with the purposes of (1) compartmenting the shoreline into shorter manageable segments, (2) creating a series of hard points to hold the shoreline, and

(3) trapping mainly beach drift (i.e. littoral transport associated with the final breaker line close to the shoreline). Because of its less obtrusive dimension, and also of its potential benefit for providing a look-out point on the beach, the headland concepts warrants a special consideration in this study.

Since the headland is built as a relatively short structure, the potential offshore loss of sediment due to an artificial rip current can be minimized. In order to enhance this effect, a headland may be oriented at angles to the shore away from the incident predominent waves. Also, since the headland will mainly intercept the beach drift, the littoral drift out in the surf zone and over the longshore bar will be left with little interruption. This particular function of the headland to selectively trap the beach drift is considered highly important, especially in view of the fact that in the Great Lakes shoreline the beach drift is quite often the prevailing mode of littoral drift, particularly during the time of modest wave activities in summer.

For an artificial headland to be successful in the study area which is afflicted with the deficit of littoral material, some degree of artificial replenishment is deemed necessary. The amount required for replenishment will undoubtedly be less than would without a headland, since the downdrift transport is now decelerated by a headland. Periodic nourishment, especially nourishment close to the headland, is deemed essential, since the headland progressively protruding into the surf zone from the eroding shoreline will begin to act like a groin. A proper separation of headlands should be governed by the consideration as to whether or not the compartmented shoreline can be maintained in a reasonably smooth configuration with reasonable amount of replenishing efforts. Too large a separation will leave some part of the compartment without the benefit of the headlands.

Under this condition, the shoreline will erode at mid-point between the headlands, creating a sharply indented shoreline or embayment.

Although there is no universal guideline for the design of a headland system, an order-of-magnitude estimation is attempted as follows:

In reference to the well-known study by Eagleson (1965), the distance X, in which the longshore current diminishes to less than 95% of its full capacity adjacent to a littoral barrier, is expressed as

$$X = 5.80\ [H_b \cos\alpha \cdot \sin \theta_b]/f$$

where

H_b is breaker height, α is beach slope, θ_b is breaker angle, and f is Darcy-Weisbach friction coefficient. Assuming a negligible beach slope ($\cos \alpha \simeq 1$), a breaker angle of 20 degrees to shore, and f = 0.02, the above equation reduces to

$$X \simeq 100\ H_b,\ (H_b \text{ in feet})$$

In the case of a 5-foot breaker, the zone of deceleration will be 500 feet long. Since this zone will extend both updrift and downdrift of the headland, a compartment 1,000 feet long will be entirely occupied by the zone of deceleration. A compartment 2,000 feet long will leave a middle 1,000 foot stretch to the full strength of the longshore current. Under this wave condition, if we are to assume, tentatively, that the littoral transport is proportional to the square of the longshore current velocity, a simple calculation will show that the transport rate in this compartment will reduce to approximately a half of the normal rate.

The existing method of headland design is highly empirical, and its efficacy must be expected to vary from place to place. Consequently, it is inevitable that the performance of the headlands, after construction, must be monitored carefully, and that the replenishment plan be fine-tuned with accumulating experience.

Pier

A pile-supported pier, when suitably equipped with cross and bracing members, will act as a wave slicer while interacting with longshore currents. A pier will also provide additional recreational activities of fishing to park visitors.

The presence of a widened beach surrounding a fishing pier is a familiar scene along many a coastline. A fishing pier also usually adds to the scenic value. A fishing pier may be buttressed on a headland, so that its accreting function may be combined with that of a headland.

The beach thus accreted usually forms an apex somewhere downdrift from the pier, and the sediment depositing in the apex is likely to be more stable than on an open beach owing to the reduced wave energy. A pier may be extended at angles to the shore away from the direction of predominant waves, in order to distribute the accreting apex on a wider reach of the coastline.

A fishing pier appears to be not only a particularly attractive option in the South Park Unit, but also it provides shore stabilization benefits and excellent recreational benefits.

Lake Michigan offers the sport fisherman an abundance of opportunities. Lake fishing is excellent, with lake trout, coho, chinook and perch being most prominent. Until the early 1940's, the sport fishery was stimulated by lake trout abundance. Lake fisheries have suffered the effects of overfishing, alewife competition and lamprey predation. Restorative programs begun in the 1950's and the plantings of lake trout and other predator species (coho and chinook salmon, and steelhead trout in 1967) have all but revived the Lake Michigan sport fishery. As of 1971, approximately 14 million trout and salmon were stocked in the Great Lakes and the surrounding inland waters.

3.2.7 Methods to Recycle and Backpass Littoral Transport

There exist four major sinks of littoral material in the general vicinity of Illinois Beach State Park, namely Trident Harbor, a fillet between Nature Preserve and the Waukegan north jetty, the Lake Bottom, and the inland dunes. Of these four sinks, the sediment lost in Trident Harbor and the Waukegan fillet can be recovered and may be used to feed the Beach State Park shoreline.

In particular, the Waukegan fillet is important for its size. The method to trap the sediment arriving at the Waukegan fillet or at the Public Service Company pier has already been discussed. Whereas a sand trap is a relatively straightforward concept and can be designed to trap any given volume of sand, a method to transfer this volume to feeder beaches within the Beach State Park will present difficulties. Not only will the conventional hydraulic pipeline require a long distance to reach the points of discharge within the Beach State Park (say, at least 2 miles to the nearest discharge point at the Park Lodge), but also the routing of a pipeline through the intervening area of Nature Preserve will present temporary adverse environmental effects. Over-the-land hauling through the inland route is a possibility, but an access to the sand trap can only be gained through sensitive industrial properties which now occupy most of the Waukegan fillet.

Self-propelled hopper dredges are unable to dump the material in shallow enough water to reasonably assure any beneficial effect on shore erosion. Split-hull or bottom dump barges can be used to dump the material up to six feet of water, but not directly on the beach.

Borrowing from the Waukegan fillet also raises the question as to whether or not the existing and future impounded fillet material should be due to the Illinois Beach State Park or to be bypassed to the downdrift coast south of Waukegan Harbor. Possible adverse effects of Waukegan Harbor, a Federally authorized project, on the existing erosion along the downdrift coast to Lake Forest are presently being investigated as part of the study sponsored by the Illinois Department of Transportation through the Coastal Zone Management Office. The availability and utilization of the material from the Waukegan fillet for the Illinois Beach State Park shores thus appears to be an institutional question to be resolved.

3.2.8 Replenishment

Source of Material

In light of the fundamental deficit of littoral material in the Park shoreline, artificial nourishment is an indispensible part of the erosion control plan. Recent investigations by the Illinois Geological Survey indicated that the lake bottom in the vicinity of the Park is lacking a major source of borrow material suitable for replenishing the beach (personal communication with Dr. C. Collinson). It is recognized that excavation of borrow areas within the North Park Unit would conflict with the proposed development of the Illinois Beach State Park. Questionability of utilizing the Waukegan fillet has already been discussed in the preceding section.

It appears that beach nourishment would have to depend to an increasing extent on commercial borrow areas in the future. Feed material of good quality is available from commercial borrow areas within suitable distance from the study site, namely those at Crystal Lake, only about 30 miles from the Park. Coarse sand conforming the Federal guidelines was obtained from Crystal Lake at about \$5 - 6/ton or \$8 - 9/C.Y. from Crystal Lake on 1977 price level. Generally, the price of sand would range between \$5 - 10/C.Y. depending upon the quality, haulage and rehandling.

Method of Fill Placement

An insight into how a beach fill would behave after placement on the beach along the Park shoreline may be gained from the recorded behavior of a man-made fillet which was created by the construction of a temporary breakwater at the Commonwealth Edison nuclear station in 1969. The breakwater was removed in 1972, which resulted in releasing an estimated 6-acre fillet to free downdrift transport.

Shorelines determined from air photos of 1967 and 1974 reveal their position prior to the fillet formation (1967) and two years after the release of the fillet. According to this data, the 1974 shoreline for a distance of 2,700 feet to the south end of the station property gained about 7 acres over the 1967 shoreline, a quantity essentially equivalent to the size of the fillet. By 1977, or 2.6 years further later, this gain dwindled to about 3 acres. An average attrition of the fillet size between 1974 through 1977 was, thus, 1.6 acre/year or at the rate of about 22% a year.

Accordingly, it appears that if the replenishment material is left as a free stockpile on the beach without any holding structure, its dissipation could be completed in about 5 years. This indicates that following the initial placement of replenishment material it would be a prudent procedure to undertake maintenance replenishment at about 5-year intervals. With a holding structure retarding the dissipation rate, the replenished beach is expected to retain some portion of the initial material at the end of five years.

This also brings up the importance of the need for minimizing the loss of beach material once it is placed for replenishment. In order to ensure this objective, any replenishment must be accompanied by structural means of holding the material within the intended areas to the utmost extent possible.

Degree of Protection

Another question which may be taken into consideration is whether one could afford to provide a total protection to the entire range of the Beach State Park shoreline in the face of the fundamental deficit of available littoral material either from natural or man-made sources. A view-point which may be taken is, therefore, that the North Park Unit may be allowed to erode to some extent to provide feed material for the South Unit. This premeditated erosion in the North Unit shall be carefully controlled in such a way as to transform the resulting shoreline into a smooth configuration. In the meantime, attempts to minimize the offshore loss, to reduce the alongshore transport rate and to diminish wave energy input to the shoreline, will be implemented so that the beach system with its moderated sediment supply could still maintain an acceptable degree of equilibrium with the input energy level.

3.3 Alternative 1 – No Action

3.3.1 Recommendations

Although this alternative is essentially a "do nothing" option, it is advisable to consider the following acitons as part of the Park maintenance operations.

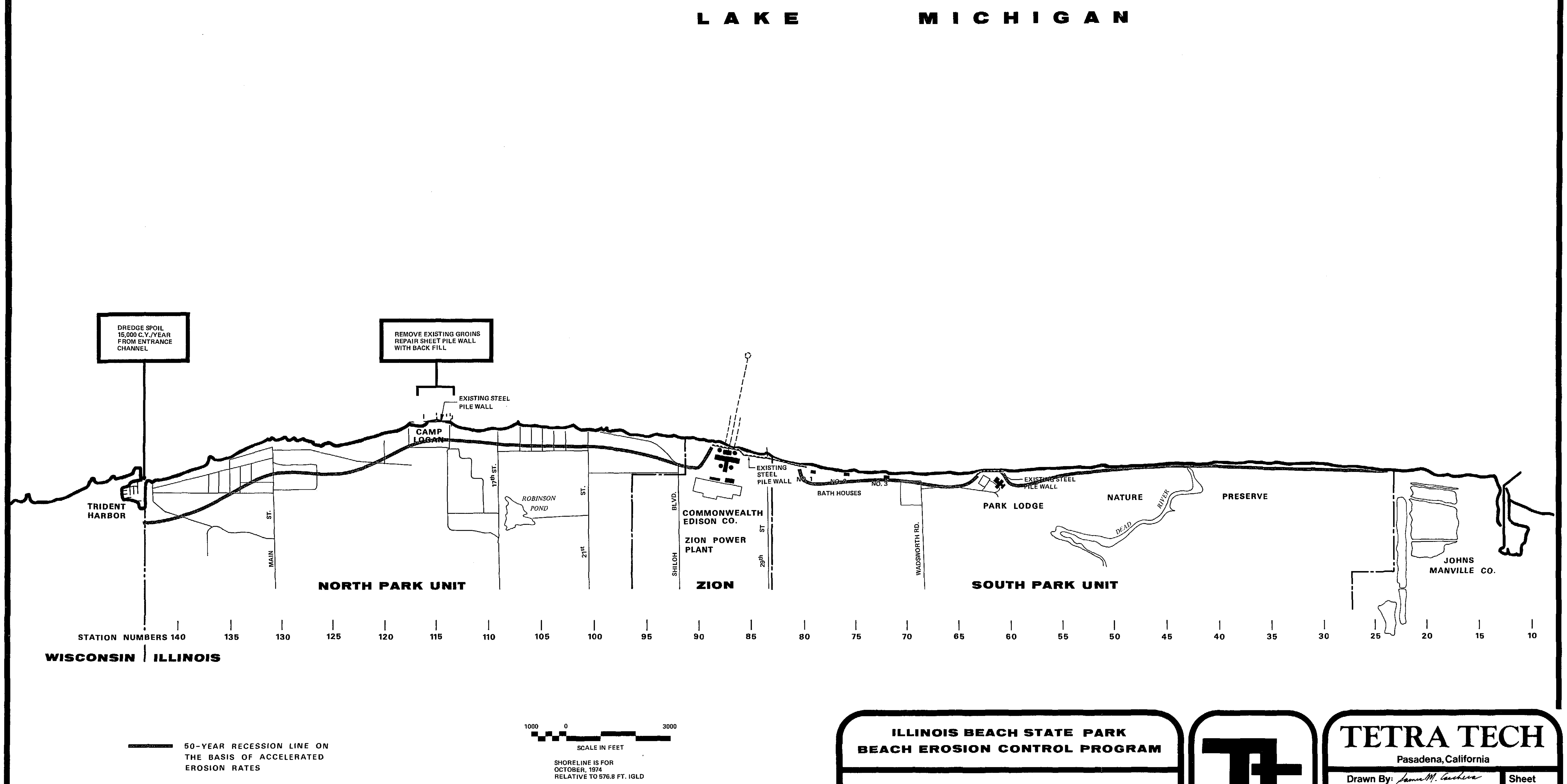
- o Clean up the existing remnants of destroyed groins off the Camp Logan sheet pile wall, and
- o Repair the sheet pile wall which has been breached by the lake at its northern end.

These recommendations are based on the expectation that a hardened Camp Logan lakefront will become an artificial headland as the adjacent shorelines continue to erode from no action. This headland will be a useful gain at little cost to the Park.

The Z-groin on the southern end of the Camp Logan sheet pile wall is contributing to the offshore loss of sediment. However, this groin is in good condition, and the cost for its removal does not appear warranted at the present time.

3.3.2 Expected Shoreline Changes

Future shoreline changes to 2024 AD have already been discussed in the section under "SHORE PROCESSES". The erosion will accelerate due to the continuous impoverishment of the supply capacity along the Wisconsin shore, and will spread over the entire shoreline within the Park as the nodal or no change point will continue its southward migration at about 400 ft/year. It has been estimated that the nodal point will reach the southern end of the Park by around 1986 and the Waukegan north jetty by around 2014 AD.



ILLINOIS BEACH STATE PARK
BEACH EROSION CONTROL PROGRAM

ALTERNATIVE NO. 1
NO ACTION

TETRA TECH
Pasadena, California

Drawn By:
Checked By:
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Date: 9-25-78

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The expected shoreland losses from "no action" on the Illinois Beach State Park shoreline have already been discussed under 2.7 "Future Erosion" and as summarized in Tables 3.3.1 and 3.3.2. The predicted 50-year recession line resulting from this alternative is shown in Plate 1.

Considering only the losses relative to mean shoreline (i.e., permanent damage), the loss cumulative to 2024 AD will total 211.02 acres or 4.22 acres a year, of which about 87% comes from the North Unit. If we are to consider the losses combining both the recession of mean shoreline plus the temporary short-term recession, the loss to 2024 AD will amount to 385.81 acres or 7.72 acres a year, of which 71% comes from the North Unit.

It is thus clear that whereas the predominant part of the damage (87%) will come from the permanent loss in the North Unit, the South Unit will suffer more from short-term temporary damages. This is quite important in view of the fact that in the South Unit a number of existing facilities lie close to the lakefront which are vulnerable to short-term temporary shoreline fluctuations. Actual local losses on the downdrift side of a hard point could be greater than the predicted values. These areas will be outflanked increasingly by the arriving sediment as the shoreline recession on the downdrift beach will make it hard to be nourished by the sediment bypassing the hard point. This situation will be particularly true to a reach adjacent to the State Line where an increasing amount of offset of the shoreline relative to the hard point at Trident Harbor is expected. This in turn would affect the rest of the downdrift shoreline with additional erosion. The same also holds true to the South Unit which will be affected adversely by the progressively protruding hard point at the Zion nuclear station. This has not been taken into acocunt in our prediction for the South Unit, hence our prediction should be considered to be on the modest side.

TABLE 3.3.2
PREDICTED SHORELINE RECESSION BASED
ON ACCELERATED EROSION RATES AND
SHORT-TERM RATES

STATION NUMBER	PERMANENT RECESSION OVER GIVEN ELAPSED YEARS BASED ON ACCELERATED EROSION RATES (IN FEET)					TEMPORARY RECESSION DUE TO SHORT-TERM FLUCTUATIONS (IN FEET)	TOTAL 50 YEARS RECESSION
	ELAPSED YEARS						
	10	20	30	40	50	10 YEARS ACCUMULATION	
143	-111.38	-256.73	-447.41	-698.35	-1029.26	-250.0	-1279.26
140	-100.43	-231.49	-403.42	-655.94	-928.06	-294.0	-1222.06
135	-84.52	-194.81	-339.50	-529.92	-781.02	-203.0	-1184.02
130	-71.68	-166.34	-291.33	-475.60	-674.47	-409.0	-1083.47
125	-59.85	-137.97	-240.44	-375.30	-553.13	-338.0	-891.13
120	-50.37	-116.11	-202.35	-315.83	-465.49	-263.0	-728.49
115	-47.28	-97.71	-170.29	-265.79	-391.74	-132.0	-523.74
110	-39.79	-82.23	-143.31	-223.68	-329.67	-222.0	-551.67
105	-30.02	-69.20	-120.60	-188.24	-277.44	-274.0	-551.44
100	-25.27	-58.24	-101.49	-158.42	-233.48	-216.0	-449.48
95	-21.26	-49.01	-85.41	-133.32	-196.49	-320.0	-516.49
90	-17.89	-41.25	-71.88	-112.19	-165.35	-702.0	-867.35
85	-15.06	-34.71	-60.49	-94.42	-135.16	-132.0	-267.16
80	-14.13	-29.21	-50.91	-79.46	-117.11	-296.0	-413.11
75	-11.89	-26.19	-42.84	-66.87	-98.55	-203.0	-301.55
70	-8.98	-20.69	-36.05	-56.27	-82.94	-163.0	-245.94
65	-7.55	-17.41	-30.34	-47.36	-69.80	-345.0	-414.80

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TABLE 3.3.2
PREDICTED SHORELINE RECESSION BASED ON ACCELERATED EROSION RATES AND SHORT-TERM RATES
(continued)

STATION NUMBER	PERMANENT RECESSION OVER GIVEN ELAPSED YEARS BASED ON ACCELERATED EROSION RATES (IN FEET)					TEMPORARY RECESSION DUE TO SHORT-TERM FLUCTUATIONS (IN FEET)	TOTAL 50 YEARS RECESSION
	ELAPSED YEARS 10	20	30	40	50	10 YEARS ACCUMULATION	
60	-6.36	-14.65	-25.53	-41.52	-58.74	-378.0	-436.74
55	-5.35	-12.33	-22.30	-34.35	-50.24	-150.0	-200.24
50	-4.50	-10.38	-18.08	-28.23	-41.60	-144.0	-185.60
45	-3.79	-8.73	-15.22	-23.75	-35.01	-67.0	-102.01
40	-3.19	-7.35	-12.81	-19.99	-29.46	-114.0	-143.46
35	-2.68	-6.18	-10.78	-16.82	-25.72	-190.0	-215.72
30	-2.26	-5.20	-9.07	-14.16	-20.87	-117.0	-137.87
25	-2.12	-4.38	-7.63	-11.96	-17.56	-98.0	-115.56
20	-1.60	-3.69	-6.42	-10.03	-14.78	-50.0	-64.78

The Corps of Engineers (1975) "Interim Report on Illinois Shoreline Erosion" estimated an average loss of 4.2 acres a year in the North Unit and 1.9 acres a year in the South Unit for the next 50 years. Our predicted values which takes into consideration the effects of temporal and spatial acceleration of erosion rates plus those of short-term shoreline fluctuations, are respectively 5.5 and 2.24 acres a year, hence between about 20 to 30% higher than the Corps predictions.

The estimated 50-year average shoreline recession rates in the North Unit range from about 26 feet a year adjacent to the State Line to about 10 feet a year at the south end. As a result, all the discarded residential sites presently occupying the lakefront will be practically wiped out by 2024 AD. The existing Lake County Public Water District lower lift station, which is located only approximately 250 feet from the shoreline south of the 17th Street (Station number 110 in this study) will definitely fall into the lake within 40 to 50 years, and is considered to come within the range of temporary shoreline fluctuations within about 10 years from now. The projected 50-year acreage loss of about 274 acres in the North Unit is equivalent to 20% of the total acreage for the North Unit.

In the South Unit, the entire shoreland will begin to be affected by permanent erosion within less than 10 years. The estimated 50-year average shoreline recession rates here range from about 8 feet a year at its northern end to about 1.4 feet a year at the southern end. The three bathhouses which lie within about 100 feet from the lake will definitely fall into the lake within between 40 and 50 years from now, and in about 5 years will be within the range of temporary shoreline fluctuations which average about 20 ft/year here. The scenic foredune complex which now separates the campground behind these bathhouses and the lake will be wiped out within 50 years, and so will the ranger residence, part of the camp ground parking lot, part of the connecting road between Wadsworth Road and Park Lodge, and part of the picnic area along this road. The beach fronting the bathhouses is the only swimming beach in the entire Beach State Park domain, and the resultant steepened beach profile which would inevitably result from the severe erosion could be a factor for recreational use.

The Park Lodge is presently protected by a sheet pile wall approximately 700 feet along the lake front. The beach in front of the sheet pile wall, extended to a width of about 100 feet by artificial nourishment, is in imminant danger of erosion from short-term shoreline fluctuation which has been observed to attain as much as 38 feet a year at this location. In order to prevent being outflanked by erosion, the sheet pile wall will have to be extended landward and the wall itself protected with a riprap to avoid wave scour at the base. By 2024 AD, the necessary extension of the sheet pile wall will amount to at least 1400 feet.

Although the permanent damage of shoreland in the South Unit is relatively mild as compared with the loss in the North Unit, most of the damages in the South Unit would arise from a threat to existing lake front facilities from temporary short-term shoreline fluctuations, The loss to the ecology in the Nature Preserve will remain moderate for at least 50 years, during which time erosion will be limited to within a 100 to 200 foot width of the beach front, without affecting the more productive marsh lands in the backshore.

3.3.3 Expected Damages

North Unit

According to the "Interim Report on Illinois Shore Erosion" by Corps of Engineers Chicago District (1975), the property value of a lakefront lot in the North Unit for a standard 60' x 125' lot (the 60-foot length facing the lake) was rated as follows:

1st Tier	$42/front foot
2nd Tier	$22/front foot
3rd Tier	$17/front foot
4th Tier	$17/front foot
5th Tier	$17/front foot

These figures were based on the 1972 private appraiser's report on land characteristics and prices prepared for the Illinois Department of Conservation. The land acquisition cost of a quarter-mile swath facing the lakefront in the North Unit used by the Department of Conservation escalated by a factor of slightly over 2.0 between 1972 and 1978. Using this escalation factor, the following current values for the lakefront property are derived:

1st Tier	$84/front foot	or	$29,300/acre
2nd Tier	$44/front foot	or	$15,300/acre
3rd Tier	$34/front foot	or	$11,850/acre
4th Tier	$34/front foot	or	$11,850/acre
5th Tier	$34/front foot	or	$11,850/acre

The prime lending rate in April 1975 was 7.5%, but rose to 9.75% as of September 1978, giving a capital recovery factor of 2.25% over the period. In the "Interim Report of Illinois Shore Erosion" (1975), Corps of Engineers used an interest rate of 5 7/8%. At a capital recovery factor of 2.25%, the current interest rate is derived to be slightly over 8%. The current interest rate according to the Corps of Engineers guideline is 6 7/8% or 0.06875. Using 6 7/8% for the current interest rate, and interest and amortization factor over a 50-year time span is determined as 0.07132. The result of this analysis is shown in Table 3.3.3.

TABLE 3.3.3
VALUE OF LAND LOSSES
(North Unit)

Tier	Acres Lost	Present Value of Losses
Tier 1	20.7	$ 606,500
Tier 2	20.7	316,700
Tier 3, 4 & 5	232.6	2,756,300
Total	274.0	$3,679,500
Interest & Amortization Factor		0.07132
Average Annual Damages		$262,400

Public acquisition of the shoreland in the North Unit has resulted in the removal of all houses which would have been subject to future erosion; some had already fallen in the lake. Therefore, damages for this category are not applicable.

Damages to roads were considered to be negligible, since the majority of the roads subject to potential erosion are now un-useable, and those that remain have not been assessed as to their worth owing to their inconsistency with stated Department of Con-servation development plans. They will not be used for vehicular traffic, and in most cases will serve no utilitarian purpose.

The Lake County Public Water District lift station on 17th Street is expected to come within the range of imminent erosion within about 10 years. The current value of this facility is tentatively assessed at $1 million. Using the interest and amor-tization factor of 0.07132, the loss is estimated at $71,000 per year.

As a consequence, the average annual damage to the North Unit will total $333,400 over a period of 50 years from 1974, arising entirely from the shoreland losses.

South Unit

Damages resulting from future shoreland erosion in the Park South Unit can be estimated on the basis of the actual value of the lands lost, or in terms of recreational opportunities for-feited on land lost to erosion.

The value of land losses is summarized in Table 3.3.4.

TABLE 3.3.4
VALUE OF LAND LOSSES
(South Unit)

Tier	Acres Lost	Present Value of Losses
Tier 1	28.00	$ 820,400
Tier 2	28.00	428,400
Tier 3	55.72	660,300
	Total 111.72	$1,909,100
	Interest & Amortization Factor	0.07132
	Average Annual Damages	$136,000

Damages will also involve the loss of three bathhouses, one commissary store, the ranger residence, part of the camp ground parking lot, part of the road connecting the end of Wadsworth Road and the Park Lodge, a gas line, a water line and a sewerage line paralleling this road, plus the required fortification of the Park Lodge lakefront property. The value of the loss arising from these categories is summarized in Table 3.3.5.

TABLE 3.3.5
VALUE OF PROPERTY LOSSES
(South Unit)

ITEM	QUANTITY	UNIT COST	TOTAL
Bathhouses	3	120,000	$360,000
Commissary Store	1	30,000	30,000
Ranger Residence	1	70,000	70,000
Parking Lot	1,700 SF	4.40	7,500
Road	1,000 LF	8.80	8,800
Park Ldg Sheet Pile	1,200 LF	180.00	216,000
Riprap	1,900 LF	50.00	9,500
Gas Water and Sewerage Lines	3,000 LF	60.00	180,000
		Total	$881,800
	Interest & Amortization Factor		0.07132
	Average Annual Damage		$ 63,000

Annual visitation loss was estimated on the assumption that as a result of on-going and future erosion the steepening beach profile and narrowing beach widths would significantly affect the capability for the swimming beach to accomodate visitors. Already in recent years, notably since about 1973 when the erosion began to affect the swimming beach area, the park visitation began to decline. (See Table 3.3.6) This happened when the state-wide park visitation was on a steady rise. In 1978, visitation is projected to reverse

TABLE 3.3.6

RECENT STATISTICS OF PARK VISITATION

	PARK VISITATION	
YEAR	ILLINOIS BEACH STATE PARK	STATE-WIDE (ILLINOIS)
	(Million)	(Million)
72	1.511	25.7
73	1.696	25.1
74	1.438	25.9
75	1.366	28.1
76	1.372	29.8
77	1.367	30.2
78	1.367*	—

Source: Illinois Department of Conservation, Springfield, Illinois

Note: (*) Projection to December 1978 based on recorded visitation of 1.127 million to August this year as compared to 1.065 million for the same period in 1977.

the decline slightly, but will still remain about 17% below the peak year visitation in 1973. It is therefore not unreasonable to assume that the majority of the visitation is attracted by the beach, although a visitor may not necessarily engage in swimming. Tentatively, a 30% figure is used to represent that portion of park visitation which will use the beach in one way or the other. Visitation belonging to this category, using the average annual 1972-1978 visitation of 1.457 million, is 0.437 million.

Presently, the bathing and scenic part of the beach where the visitor will engage in recreational activities occupies about 6500 feet of lakefront. Considering about 200 feet of width behind the shoreline as an integral part of the beach, this yields about 30 acres as recreational beach area. Thus, each acre of recreational beach supports approximately 14,600 visitors a year. A $1.50 value for each visitation is assigned to yield annual worth of the recreational beach of $657,000. In the course of the next 50 years the entire 30-acre beach parcel will be lost to erosion.

The remaining 70% of the visitation, 1.020 million, are attracted to land-based recreation on approximately 1,500 acres of land in the South Unit. Thus, each acre supports 680 visitors a year. An activity day value of $1.00 was employed to yield the resulting worth per each acre of $680. A land loss of 82 acres (excluding the 30-acre swimming beach already accounted for) will occur over the next 50 years due to shore erosion, which represents an average annual worth of $55,800.

The value attributable to the loss of recreational beach and land-based recreational activities is summarized in Table 3.3.7.

TABLE 3.3.7

LOSS OF RECREATIONAL
OPPORTUNITY DUE TO EROSION

(South Unit)

	Recreational Beach	Land Based Recreation
Present annual visitation/acre	14,600	680
Visitation value	1.50	1.00
Present annual value/acre	21,900	680
Acres lost over 50 years	30	82
Present value of loss	$ 657,000	$ 55,800
Total	$712,800	
Interest & Amortization Factor	0.07132	
Average Annual Loss	$ 51,000	

Table 3.3.8 summarizes the total average annual loss which would occur over the next 50 years in the Illinois Beach State Park as a result of the no-action alternative.

TABLE 3.3.8

SUMMARY OF AVERAGE ANNUAL LOSSES
RESULTING FROM ALTERNATIVE 1 - "NO ACTION"

PARK UNIT	ITEM	LOSS
NORTH	Land	$262,400
	Property	71,000
	Sub-Total	$333,400
SOUTH	Land	$136,000
	Property	63,000
	Recreational Opportunity	51,000
	Sub-Total	$250,000
	PARK TOTAL	$583,400

TABLE 3.3.9

AVERAGE ANNUAL
LOSSES BY CATEGORY

PARK UNIT	LAND	PROPERTY	RECREATIONAL OPPORTUNITY	SUB-TOTAL
North	262,400	71,000	0	333,400
South	136,000	63,000	51,000	250,000
Sub-Total	398,400	134,000	51,000	
			GRAND TOTAL	$583,400

Annual loss in the entire Beach State Park over a 50-year time span amounts to $583,400. Of this, losses in the North Unit account for 333,400 or about 57%, and those in the South $250,000 or about 43%. In terms of item categories, land losses total $398,400 or about 68% of the total loss. Losses in recreational opportunity, at $51,000, is about 9% of the total, derived entirely from the South Unit, whereas property losses, at $134,000 is about 23% of the total.

3.4 Alternative 2 – Nourishment With Sill

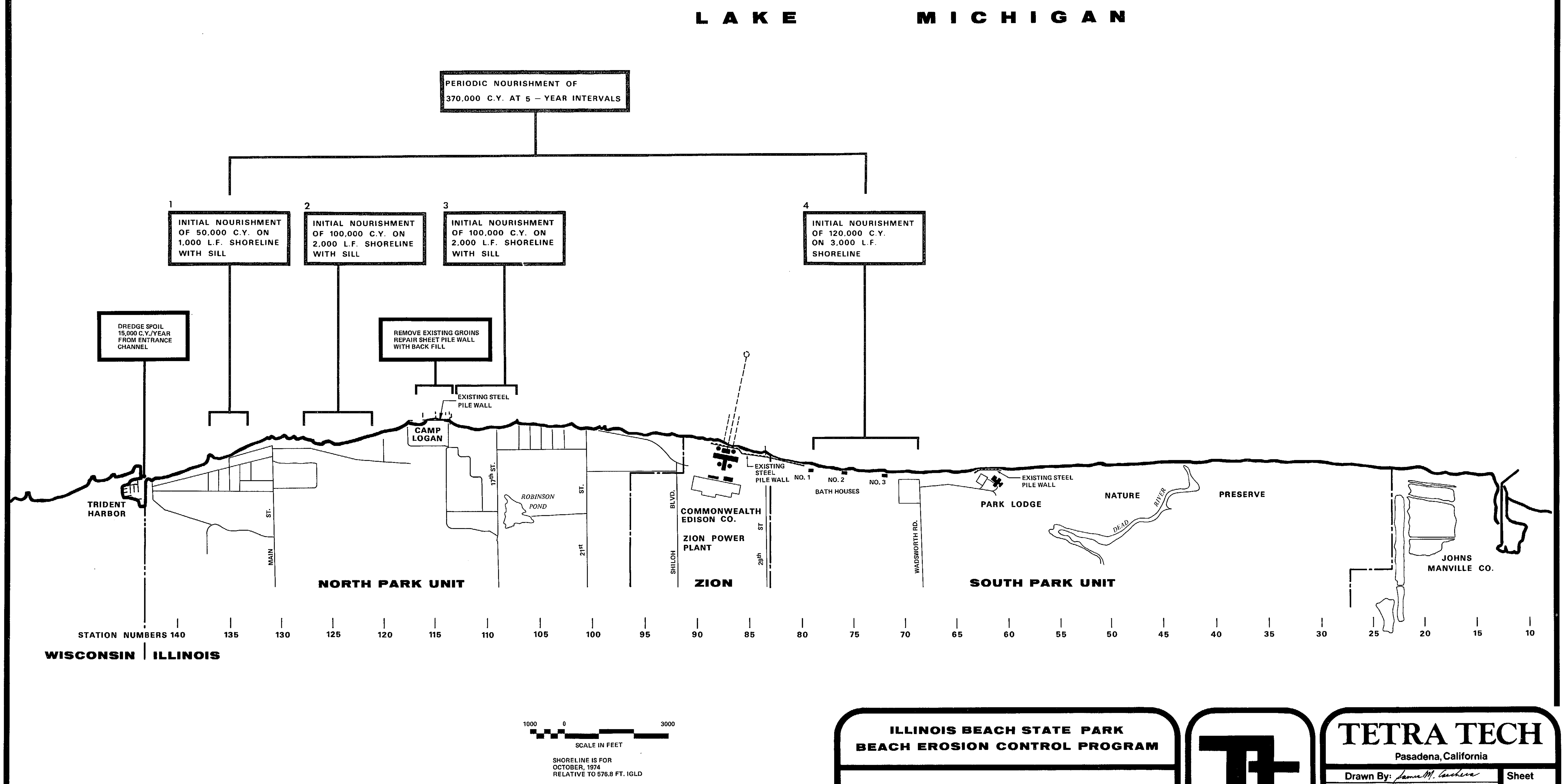
3.4.1 Recommendations

This alternative consists of beach nourishment as the principal feature, with an offshore sill structure holding the material from dispersing toward offshore. No other structure will be erected. This alternative is illustrated in Plate 2.

The basic concept of this alternative is to protect only the shoreland and its immediate vicinity offshore, leaving the offshore profile to erode. Furthermore, the sill will be placed in the embayed part of the coastline in such a way as to reshape the entire North Unit coastline into a smooth configuration. Additionally, the site of fill placement is located on the lee side of existing head points to emphasize proteciton for those parts of the shoreline which are eroding most actively (see Figure 2.7.4).

This alternative consists of four replenishment sites, three of them in the North Unit and one in the South Unit. All the sites in the North Unit are equipped with a sill to form a perched beach. The sill is located in shallow water on a 6-foot contour line with both ends terminating on the shore, thus completely encircling the nourishment material. The replenishment site in the South Unit is not equipped with a sill.

Total amount of initial replenishment is 370,000 cubic yards for the four sites. A maintenance replenishment involving the same amount at five-year intervals is specified.



ILLINOIS BEACH STATE PARK
BEACH EROSION CONTROL PROGRAM

ALTERNATIVE NO. 2
NOURISHMENT WITH SILL

TETRA TECH
Pasadena, California

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3.4.2 *Expected Beach Changes*

The recent erosion rate between 1939 to 1977 in the entire North Unit (16,200 feet) has averaged about 145,000 cubic yards a year, including losses from both the shoreland and the offshore profile. In five years, this will amount to 725,000 cubic yards.

Since the shoreland loss projected into the future in this area will average 5.48 acres a year for the next 50 years, the corresponding volume loss from the shoreland alone will be approximately 354,000 cubic yards in 5 years, in which an average beach elevation of 8 feet is assumed.

Within the selected 5000-LF reach for nourishment, a 5-year shoreland loss is estimated to be approximately 150,000 cubic yards. The recommended initial placement for this reach (Sites 1, 2 and 3) totals 250,000 cubic yards. Without the sill, this material will be rapidly removed from the area of placement. For instance, in analogy to the observed dissipation of the 6-acre fillet which was created during the construction of the Commonwealth Edison nuclear power plant, assume an annual 20% dissipation ratio. At this rate, a complete dissipation of a fill will take approximately 5 years. With the sill in place, which has returns connected to the shore to encircle the fill material, it is not unreasonable to hope to limit the dissipation to about 10% a year. Thus, at the end of five years, about 50% of the fill material will have left the area either by longshore transport or offshore loss, leaving behind about 125,000 cubic yards. The projected 5-year dissipation of 125,000 cubic yards is approximately equivalent to the 150,000 cubic yards which was predicted as a 5-year loss without a sill.

This replenishment schedule is recommended to be repeated at 5-year intervals to ensure sufficient shoreline stability. It is advisable that the behavior of the beach fill be monitored periodically, so that any adjustment in the replenishment schedule can be made properly.

The unprotected shoreland between replenishment sites will be left to serve as "sacrificial" beach. The rate of erosion on these unprotected reaches will undoubtedly diminish in the future since they will receive the benefit of additional littoral material from the adjacent protective beaches, except for the reach between the State Line and Site 1. It is hoped that the spoil from the maintenance dredging at the Trident Harbor entrance channel (estimated 75,000 cubic yards in 5 years) be used to replenish this reach.

Replenishment at Site 4 is intended to protect an area where bathhouses and the Park Lodge are in imminent danger of erosion. This area is also the only adequate public bathing beach in the Park. No sill will be erected in consideration of possible hazards to swimmers, and the fill material will be left free to feed both offshore and alongshore areas.

The projected 50-year shoreland loss between 29th Street to the vicinity of the Park Lodge is approximately 55 acres, averaging about 1.1 acres a year or 5.5 acres in 5 years.

A feed volume of 120,000 cubic yards was chosen to exceed this 5-year loss rate of 71,000 cubic yards in the expectation that the feed material, in the absence of a sill, will feed the offshore profile as well as the downdrift coast. The proportion between off-shore and downdrift feeding on the lake shoreline is essentially unknown. Tentatively, this ratio may be assumed to be 2:3 between Site 4 and the Park Lodge, a distance of about 1 mile. This would mean that about 3/5 of the feed material, or about 72,000 cubic yards, will stay along the shore to feed this section of the beach, an amount essentially equivalent to the predicted 5-year loss of 71,000 cubic yards for the same reach.

3.5 Alternative 3 — Artificial Headlands

3.5.1 Recommendations

Alternative 3 is shown in Plate 3.

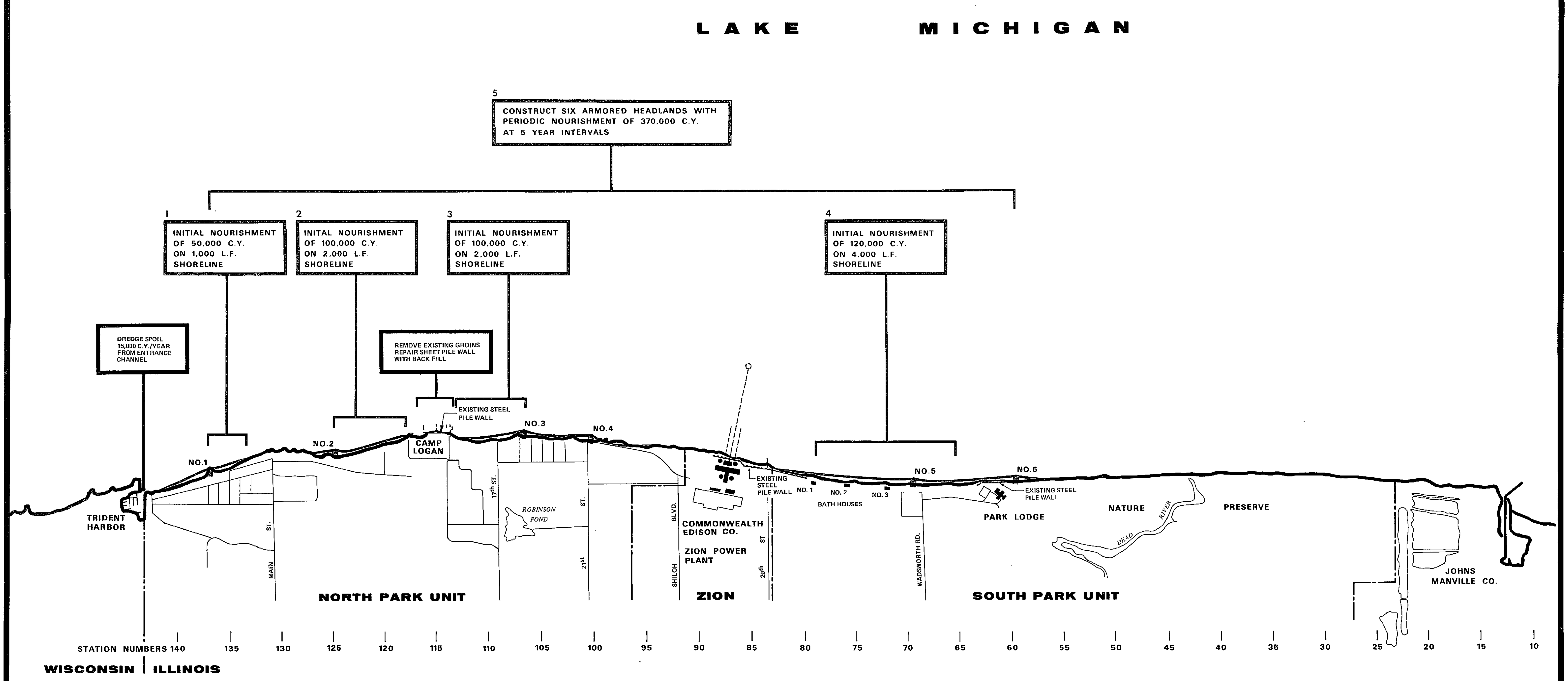
This alternative recommends a total of six artificial headlands with initial and periodic artificial nourishment in the intervening compartments. Four of the headlands are located in the North Unit. Considering the protruding shoreline off Main Street and the Camp Logan sheet pile wall as additional headlands, separations between headlands average about 2,400 feet in the North Unit.

The remaining two headlands are located on the South Unit, strung between a point off Wadsworth Road and the Park Lodge, a separation of approximately 3,000 feet.

The recommended replenishment schedule is identical to that included in Alternative 2.

3.5.2 Expected Beach Changes

Since the headlands would be more efficient retardant than the sill in retarding the alongshore movement of littoral material, especially beach drift, and since the replenishment plan involves the same amount of fill material, Alternative 3 is expected to provide a more stable protection than Alternative 2. In particular, the beach immediately updrift of each headland would develop accretion.



ANTICIPATED SHORELINE

1000 0 3000
SCALE IN FEET

SHORELINE IS FOR OCTOBER, 1974 RELATIVE TO 576.8 FT. IGLD

ILLINOIS BEACH STATE PARK
BEACH EROSION CONTROL PROGRAM

ALTERNATIVE NO. 3
ARTIFICIAL HEADLANDS

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Pasadena, California

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As compared with the sill, however, the headland system will still lose some sediment to offshore. Furthermore, the downdrift beach adjacent to a headland will tend to lose a fill somewhat more rapidly than along the rest of the compartmentized beach. In order to minimize this effect, the headland is oriented at angles away from the predominant waves, i.e. in an approximate E 20°S direction.

With an average 2,400 foot separation between headlands, it is hoped to reduce the alongshore sediment transport to approximately half of the normal rate for waves of about 5 feet in height (See Section 3.2.6). For smaller waves which are more frequent in occurrence and which account mainly for beach drift, headlands will act as a more efficient barrier. Against the full range of probable wave heights expected at this site, the gross annual littoral drift in the presence of headlands hopefully would be reduced to about 25% of the normal rate.

The two headlands in the South Unit aim at maintaining a stable compartment in front of the Park Lodge, and further to create a fillet on the north side of headland No. 5 in order to stabilize the swimming beach.

In the North Unit, an initial 250,000 cubic yards of beach fill will be placed on the downdrift shore of headlands No. 1, No. 2 and the Camp Logan sheet pile wall. The compartment between No. 3 and No. 4 will not be replenished with a fill. This area will receive sediment overflowing from the updrift compartments between No. 1 through No. 3. Use of dredge spoils from the Trident Harbor outer channel as a beach fill between the State Line and headland No. 1 will further help stabilize the North Unit. With the recommended replenishment plan for initial and periodic fills, the North Unit is expected to remain stable until the time when the supply of nearshore littoral material associated with the shoreland erosion on the Wisconsin shoreline becomes exhausted in the future, expected to occur around 2022 AD.

In the South Unit, an initial 120,000 cubic yards of fill material will be placed on either side of headland No. 5 at an approximately 2 : 1 proportion on the updrift and downdrift sides, respectively. Natural transport will shift some of this material toward headland No. 6 in a relatively short time.

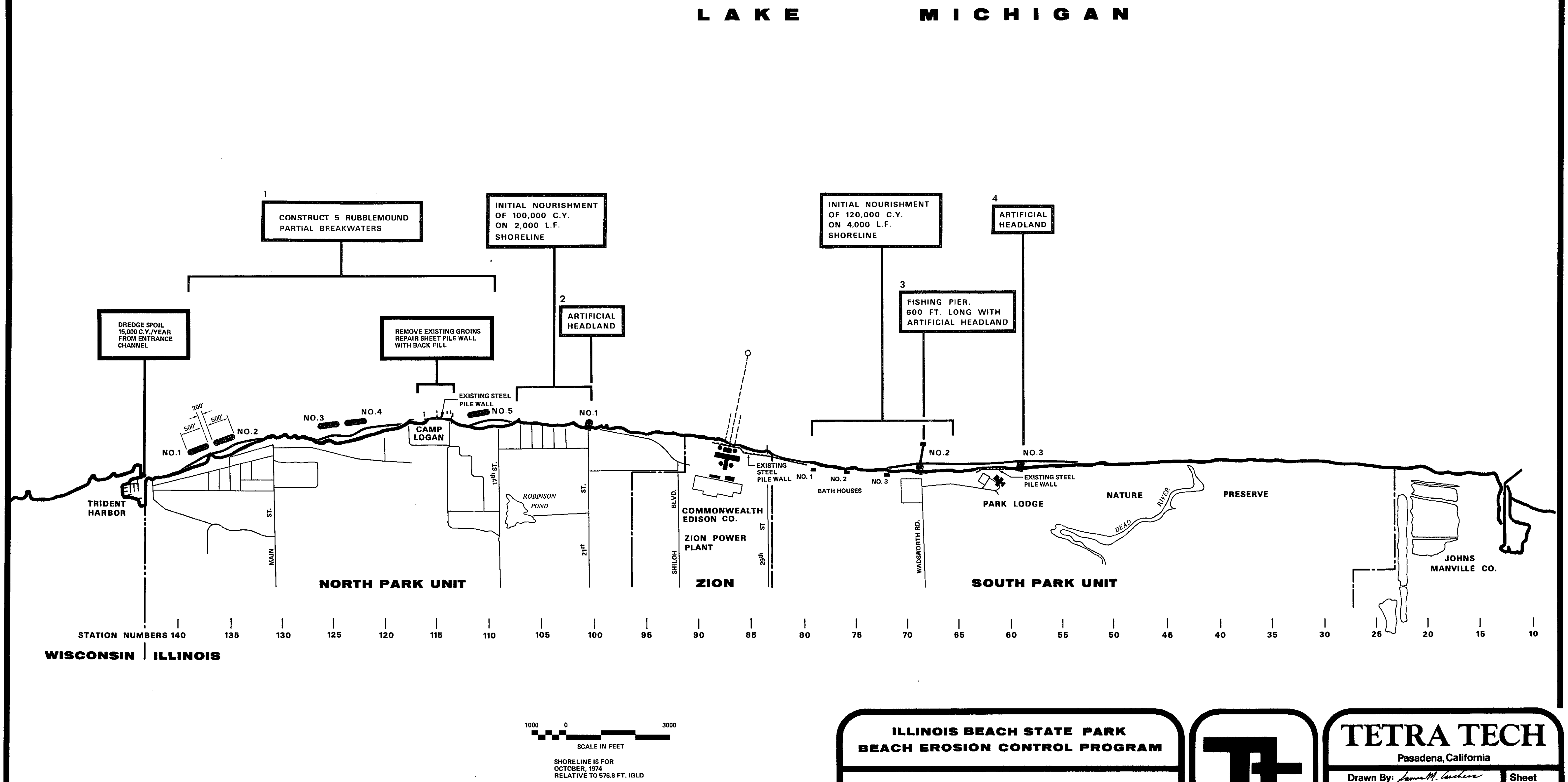
Periodic maintenance of the headland revetments and the Camp Logan bulkhead will be required. The protruding shoreline off Main Street will remain as a sacrificial beach, eroding slowly in the future. The performance of a headlanded shoreline is not accurately predictable. It is deemed necessary to monitor shoreline changes following the construction of headlands, so that a proper adjustment in the replenishment schedule can be implemented. Compartmented shoreline with limited beach segments are more readily amenable to control efforts than a long single stretch of coastline.

3.6 Alternative 4 — Partial Breakwater, Pier and Headland

3.6.1 Recommendations

Alternative 4 is illustrated in Plate 4.

This alternative consists of five detached rubble mound breakwaters in the North Unit in order to provide more definite wave shelter along the rapidly eroding pockets, a headland near the southern boundary of the North Unit, plus a headland-buttressed fishing pier and an independent headland in the South Unit.



ILLINOIS BEACH STATE PARK
BEACH EROSION CONTROL PROGRAM

ALTERNATIVE NO. 4
PARTIAL BREAKWATER, PIER & HEADLAND

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The partial or detached breakwaters in the North Unit are aligned along a smooth configuration at an approximate 6-foot contour line and are placed off the existing embayed beaches. Headland No. 1 replaces a possible partial breakwater in light of the small indentation of the shoreline at this location. This headland shall receive an initial fill of 100,000 cubic yards on the updrift side.

In the South Unit, a headland-buttressed fishing pier, approximately 600 feet long, is positioned off the Camp Ground parking lot, providing combined functions of longshore drift retardation (both beach and nearshore drifts), sheltering a downdrift beach against predominant waves, and providing recreational fishing and a lookout platform. The fishing pier will have suitably distributed cross beams to act as an effective wave slicer. Headland No. 3 provides a fillet beach fronting the Park Lodge. An initial fill of 120,000 cubic yards is recommended around the fishing pier.

The concept of this alternative is to emphasize structural protection in preference to artificial nourishment, in view of the fact that the availability of proper feed material is becoming increasingly difficult in this region. Therefore, no periodic nourishment is deemed necessary in this alternative. Nevertheless, use of dredge spoils from the Trident Harbor outer channel as a beach fill in the lee of breakwater No. 1 is highly recommended.

All the obtrusive protective structures are distributed in the North Unit, while such structures are avoided in the South Unit. Headland No. 3 in the South Unit can be designed to serve as a lookout point as well.

3.6.2 *Expected Beach Changes*

An increased degree of beach protection is expected to be attained by this alternative as compared with the previous alternatives 2 and 3. With proper maintenance of the detached breakwaters and the Camp Logan bulkhead, beach erosion in the North Unit will be virtually arrested by this scheme, except for a protruding shoreline off Main Street which will act as a sacrificial beach. The beach north of headland No. 1 will benefit from a fillet formed updrift of this headland.

In the South Unit, littoral drift is expected to slow down considerably within approximately 1,500 feet on either side of the fishing pier, as this area receives combined protection of headland 2 and the fishing pier. Erosion of the offshore profile in this area will also slow down since wave shadows cast by the fishing pier will cover the offshore zone as well. In time, underwater contours around the fishing pier are expected to move offshore, creating a groin-type underwater barrier which in turn will either facilitate accretion or retard on-going erosion on the updrift profiles. Headland No. 3 will provide an updrift fillet fronting the Park Lodge. Under this condition, the existing sheet-pile wall in front of the Park Lodge will function as a sufficient protection.

3.7 Alternative 5 — Marina in North Unit

3.7.1 Recommendations

Alternative 5 is illustrated in Plate 5. This alternative, along with Alternative 6, features a recreational boat harbor as an integral part of the protection plan, with a marina located off the North Unit in Alternative 5 and off the South Unit in Alternative 6.

The offshore marina will be connected to the shore with a pier structure, allowing partial passage of littoral stream past the location. In the North Unit, such a marina with a 1000-slip capacity, located off Main Street, will provide protective influence over an approximately 1.5 mile stretch of shoreline between the State Line and the Camp Logan bulkhead. Beyond this protective reach, between the Camp Logan bulkhead and the southern boundary of the North Unit, the shoreline is protected by two headlands with an initial beach fill of 100,000 cubic yards. Periodic nourishment of essentially the same amount at 5-year intervals are needed to stabilize the shoreline on this reach.

In the South Unit, the protective plan is identical to that proposed in Alternative 4. Since the presence of a marina in the North Unit is expected to reduce the benefit of sediment supply from Wisconsin to this location, periodic 5-year nourishments of 120,000 cubic yards each are recommended.

3.7.2 Expected Beach Changes

A large offshore marina located off Main Street will be an effective trap for sediment arriving from Wisconsin over a width of at least 1,000 feet from the shore. Consequently, the offshore profiles north of the marina will at least slow down or may even begin to accrete. The latter will not necessarily be a preferable choice as it would starve the downdrift coast. Therefore, the marina configuration will have to be determined under a premeditated sediment budget plan enabling a suitable partition between the amount to be trapped locally and that to be bypassed toward down-coast. Such a plan shall also allow for a sufficient accretion for the reach between Main Street and the Camp Logan bulkhead, so that this reach of the coastline will develop into a smooth shoreline capable of facilitating down-coast transport of littoral drift. The Camp Logan bulkhead will have to be maintained so that along with artificial headlands 1 and 2, it will provide protection on the downdrift side of the marina.

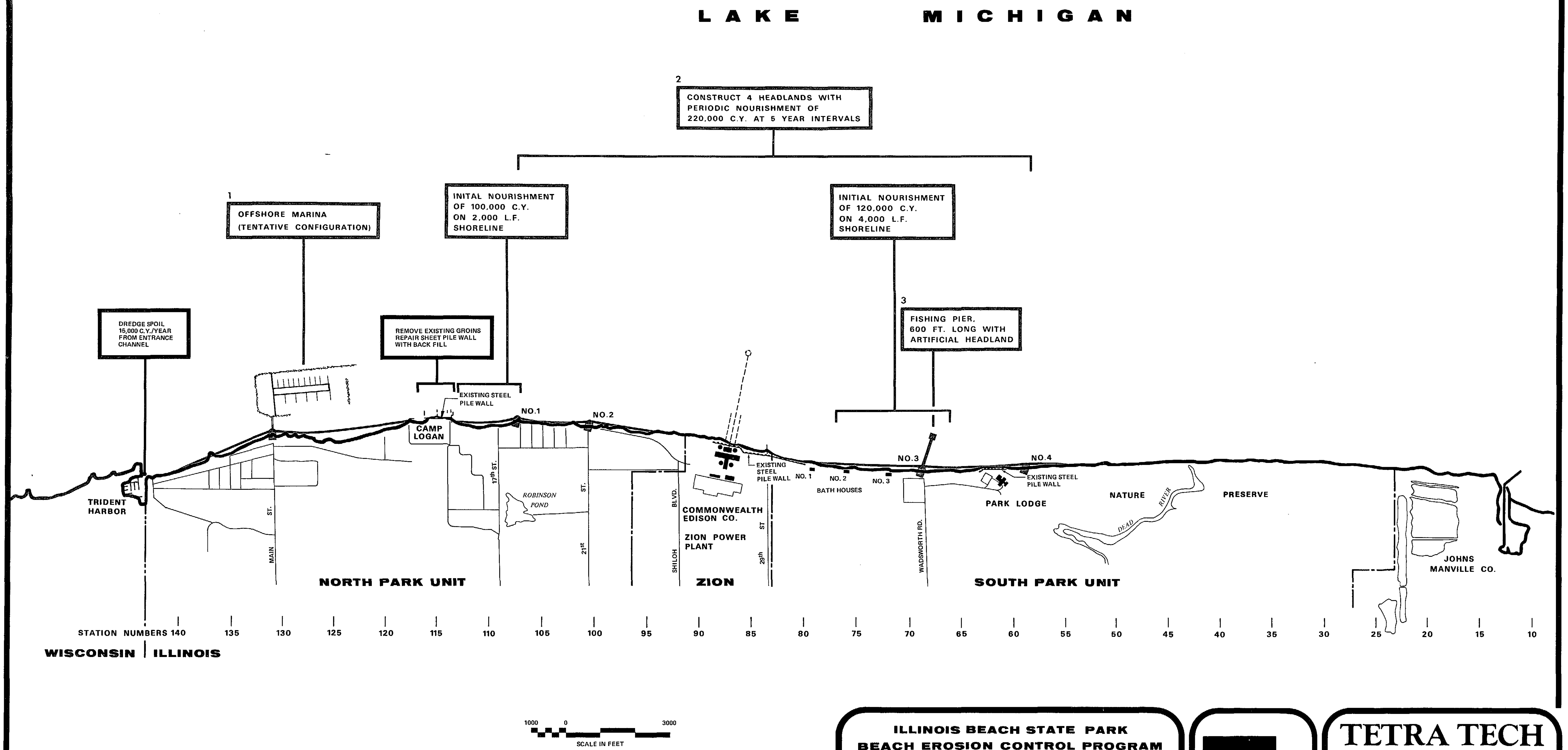
These recommended plans for the North Unit are expected to convert the presently disturbed shoreline in this area into a suitable recreational beach. In particular, the beach in the lee of the marina south of Main Street could become an additional swimming beach in the future.

3.8 Alternative 6 — Marina in South Unit

3.8.1. Recommendations

This alternative is illustrated in Plate 6.

This alternative envisages planning an offshore marina in the South Unit, and treating the shoreline in the North Unit entirely as protective beach. Placement of a marina in the South Unit could provide a definite advantage of concentrating all the key recreational facilities in the same general location. On the other hand, the North Unit will be stabilized by means of relatively obtrusive headlands and periodic nourishment, so that this area



SHORELINE IS FOR OCTOBER, 1974 RELATIVE TO 576.8 FT. IGLD

ILLINOIS BEACH STATE PARK
BEACH EROSION CONTROL PROGRAM

ALTERNATIVE NO. 5
MARINA IN NORTH UNIT

TETRA TECH
Pasadena, California

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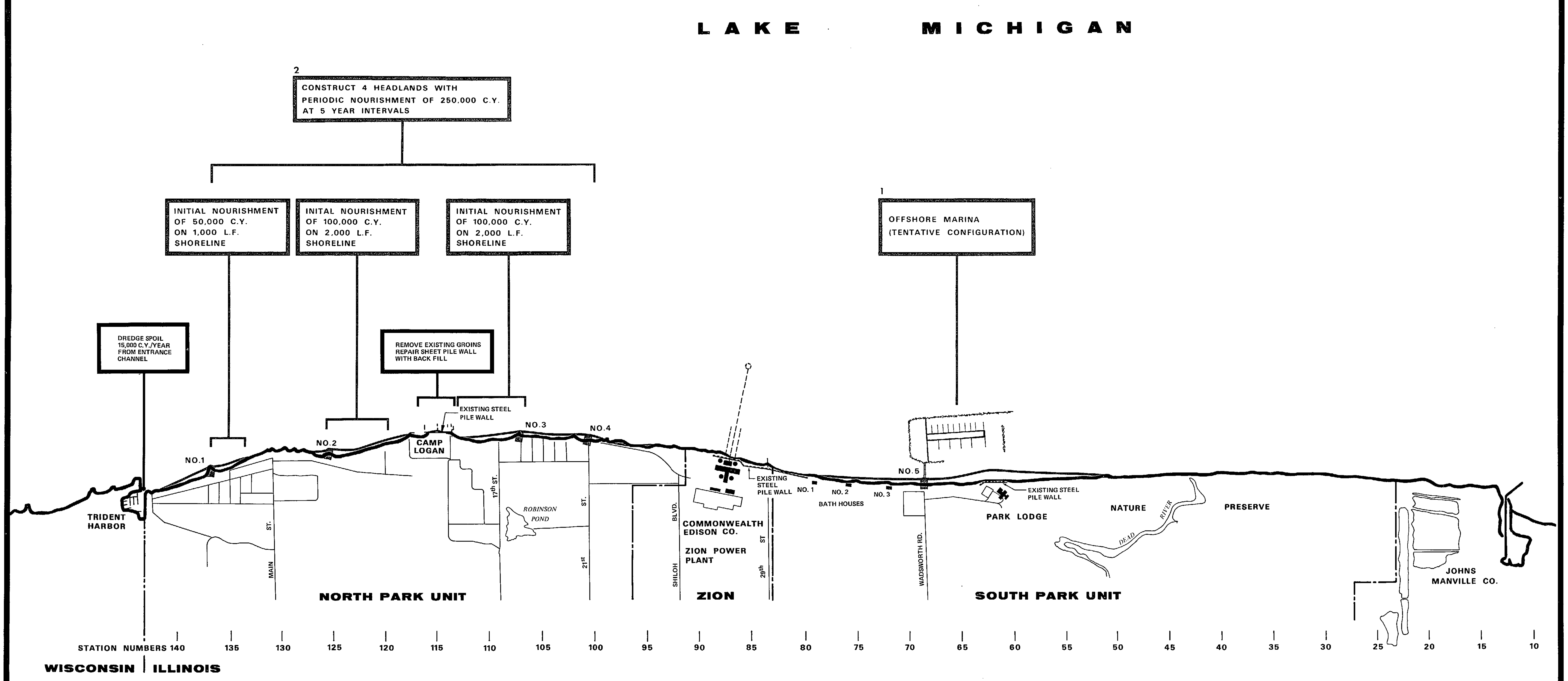

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SCALE IN FEET

SHORELINE IS FOR OCTOBER, 1974 RELATIVE TO 576.8 FT. IGLD

ILLINOIS BEACH STATE PARK
BEACH EROSION CONTROL PROGRAM

ALTERNATIVE NO. 6

MARINA IN SOUTH UNIT

TETRA TECH
Pasadena, California

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Date: 9-25-78

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will remain chiefly as a land-based recreational zone. It is possible that in the future a fishing pier may be installed in the North Unit, preferably off headland No. 1 in order to more efficiently capture the nearshore and offshore sediment arriving from Wisconsin.

All replenishment actions are concentrated on the North Unit, in accordance with a schedule identical to that proposed in Alternative 3 (Artificial Headlands).

3.8.2 *Expected Beach Changes*

Expected beach changes in the North Unit will be the same as already described under Alternative 3. In the South Unit, the beach fronting the Park Lodge and the bathhouses will receive a stabilizing influence from the marina. Part of the sediment by-passing underneath the connecting elevated causeway will develop an apexed beach in front of the Park Lodge. Longshore current retardation and wave shelter will enable the beach updrift of the marina to be more resistant to wave and current erosion. This updrift area will also benefit from a fillet attached to headland No. 5.

As compared with Alternative 5, a marina placed in the South Unit will virtually eliminate a potential adverse effect of such a large structure on the Commonwealth Edison beach front. On the other hand, a marina in the North Unit requires a well-functioning sediment bypassing plan, either by partitioning the natural drift in the case of an offshore marina or by mechanical bypassing in the case of a shore-based marina, in order to maintain an adequate supply of littoral material to the Commonwealth Edison beach front.

3.9 Impacts of Alternative Plans

3.9.1 *Estimated Costs*

All costs are based on September 1978 price levels. A 20% contingency was included in all costs. Engineering/design and supervision/administration costs of 6 and 4% respectively are included in the estimates of the first costs.

Estimated costs for fill material were tentatively based on a unit cost of $5.00 a cubic yard. It is evident that no local borrow area is available. The cost of graded commercial sand may range from $4.00 to $10.00 a cubic yard depending on the quality, the quantity, and the haulage. Since the beach replenishment is one of the most expensive cost items, the final costs will be highly sensitive to the available unit cost of feed material.

Alternative 1

Costs for repairing the Camp Logan steel sheet pile bulkhead and removing the dilapidated groins off the bulkhead are not included in the cost for this alternative, as these actions are regarded as part of the regular park maintenance operations. Therefore, there will be no cost for Alternative 1 (No Action).

Alternative 2 through 4

Costs for Alternatives 2 through 4 were developed, as shown in Tables 3.9.1 through 3.9.3. These are also summarized in Table 3.9.4 to determine annual project costs. An interest and amortization factor of 0.07132 was derived based on an interest rate of 6 7/8% and an amortization rate of 0.00257 over 50 years of project life.

A marina placed in the South Unit could exert an immediate downdrift effect on the beach fronting the Nature Preserve where the shoreline is believed to be in a precarious state of equilibrium.

TABLE 3.9.1

ESTIMATED COSTS FOR ALTERNATIVE 2

(BEACH NOURISHMENT WITH OFFSHORE SILL)

ITEM	QUANTITY	UNIT	UNIT COST	ITEM COST	SUBTOTAL
				($1,000)	($1,000)
FIRST COSTS					
OFFSHORE SILL	5,000	LF			
Steel sheet pile core	50,000	SF	10	500	
Riprap, #200 stone	9,000	TON	15	135	635
BEACH FILL	370,000	CY	10	3,700	3,700
	SUBTOTAL				4,335
	FIRST COSTS WITH 20% CONTINGENCY:				5,202
	ENGINEERING/DESIGN (6%):			312	
	SUPERVISION/ADMINISTRATION (4%)			208	520
	TOTAL FIRST COSTS				5,722
ANNUAL MAINTENANCE COSTS					
5% OF STRUCTURES WITH 20% CONTINGENCY				38	
BEACH NOURISHMENT				888	
	TOTAL ANNUAL MAINTENANCE COSTS:				926

TABLE 3.9.2

ESTIMATED COSTS FOR ALTERNATIVE 3

(Armored Headlands & Nourishment)

ITEM	QUANTITY	UNIT	UNIT COST ($)	ITEM COST ($1,000)	SUBTOTAL ($1,000)
FIRST COSTS					
ARMORED HEADLAND	600	LF			
Armor stone, 3 ton	33,900	TON	25	848	
Underlayer, #200 stone	10,800	TON	15	162	
Filter cloth	1,800	SY	5.75	10	1,020
BEACH FILL	370,000	CY	10	3,700	3,700
SUBTOTAL					4,720
FIRST COSTS WITH 20% CONTINGENCY					5,664
ENGINEERING/DESIGN (6%)				340	
SUPERVISION/ADMINISTRATION (4%)				227	567
TOTAL FIRST COSTS					$6,231
ANNUAL MAINTENANCE COSTS					
1% OF STRUCTURES WITH 20% CONTINGENCY				12	
BEACH NOURISHMENT WITH 20% CONTINGENCY				888	
TOTAL ANNUAL MAINTENANCE COSTS:					900

TABLE 3.9.3
ESTIMATED COSTS FOR ALTERNATIVE 4
(DETACHED BREAKWATERS, PIER & HEADLANDS)

ITEM	QUANTITY	UNIT	UNIT COST ($)	ITEM COST ($1,000)	SUBTOTAL ($1,000)
FIRST COSTS					
DETACHED BREAKWATER	2,500	LF			
Armor, 6 ton	117,000	TON	25	2,925	
Underlayer, 1 ton	101,000	TON	22	2,222	
Quarry run	118,000	TON	12	1,416	
Filter cloth	335,000	SY	6	2,010	8,573
ARMORED HEADLAND	200	LF	1,700	340	340
FISHING PIER					
Pier	600	LF	2,000	1,200	
Concrete buttress	300	CY	220	66	
Reinforced steel	32,100	LBS	0.75	24	1,290
EXCAVATION DIKES	30,000	CY	3	90	90
BEACH FILL	220,000	CY	10	2,200	2,200
	SUBTOTAL				12,493
	FIRST COSTS WITH 20% CONTINGENCY				14,991
	ENGINEERING/DESIGN (6%):			899	
	SUPERVISION/ADMINISTRATION (4%):			600	1,499
	TOTAL FIRST COSTS				16,490
ANNUAL MAINTENANCE COSTS					
0.5% OF BREAKWATERS WITH 20% CONTINGENCY				51	
1% OF HEADLANDS WITH 20% CONTINGENCY				4	
1% OF FISHING PIER WITH 20% CONTINGENCY				15	
	TOTAL ANNUAL MAINTENANCE COST				70

TABLE 3.9.4

SUMMARY OF ESTIMATED ANNUAL COSTS

(IN THOUSANDS OF DOLLARS)

ALTERNATIVE	CONSTRUCTION COSTS WITH 20% CONTINGENCY	ENG/DESIGN AND SUPERV/ADM	TOTAL FIRST COSTS	ANNUAL INTEREST/ AMORTIZATION (0.07132)	ANNUAL MAINTE-NANCE	TOTAL ANNUAL COSTS
1. No Action	0	0	0	0	0	0
2. Nourishment, With Sill	5,202	520	5,722	408	926	1,334
3. Armored Head-land and Nourishment	5,664	567	6,231	444	900	1,344
4. Detached Break-water, Pier, & Headland	14,991	1,499	16,490	1,176	70	1,246

NOTE: Annual Interest Rate = 6 7/8% or 0.06875

Amortization Rate = 0.00257 over 50-year project life

3.9.2 *Estimated Benefits*

Table 3.3.8 shows the annual damages associated with beach erosion to total $583,400 annually over a 50 year time span for the entire Beach State Park. Of this total annual loss, land loss represents the single largest category, 68% followed by property loss 23%, and recreational opportunity loss 9%.

Alternatives 2 through 4 are all designed to protect against these damages. Therefore, average annual benefits of $583,400 can be attributed to these alternatives due to the resulting stabilization of shore land in the Illinois Beach State Park. No benefits can be attributed to Alternative 1 (No Action), since shore land damages would continue to accelerate in the future.

Additionally, Alternatives 2 through 4 would provide a significant benefit in terms of enhanced recreational opportunity. In view of the fact that the Illinois State Beach Park provides one of the very few natural swimming beaches in close vicinity to one of the nation's major population centers, the stabilized coastline along with the increasing emphasis on the park conservation on the part of the State of Illinois will certainly lead to excess demand for use in the Illinois Beach State Park. Under this condition, it is not unreasonable to assume that visitation to the park would increase at least at the same rate with the state-wide increase in park visitation.

The state-wide park visitation has climbed during the past six years at a uniform rate of about 10% a year. Applying this growth rate to the Illinois Beach Park average annual visitation during the next 50 years is projected to be approximately 3-5 million.

On the other hand, let us assume that a swath 200 feet on the lake front is an integral part of the beach. This swath covers an

TABLE 3.3.8

SUMMARY OF AVERAGE ANNUAL LOSSES
RESULTING FROM ALTERNATIVE 1 - "NO-ACTION"

PARK UNIT	ITEM	LOSS
North	Land Property	$262,400 71,000
	Sub-Total	$333,400
South	Land Property Recreational Opportunity	$136,000 63,000 51,000
	Sub-Total	$250,000
PARK TOTAL		$583,400

NOTE: This Table reinserted here for easy reference.

already disturbed area along the entire 2.9 mile shoreland of the North Unit and an already developed recreational facility for about 6,000 feet in the South Unit. This would yield about 100 acres of the park property for recreational use. Considering a maximum 26,600 visitors day per acre for each season (See "Interim Report on Illinois Shoreline Erosion", 1975), the park can accomodate approximately 3 million visitors a season.

Presently, visitation to the park is on the order of 1.4 million a year. Therefore, the park will be gaining approximately 2 million additional visitors a year. Using a 30% figure to represent that portion of park visitation which is attracted to beach related activities, the gain in visitation attributable to the stabilized shoreline will amount to about 600,000 a year. A value of $1.50 is assigned to each user activity day, yielding $900,000 as the value gained a year as a result of shoreline stabilization.

This benefit will accrue to each of the Alternatives 2 through 4. Although a fishing pier incorporated in Alternative 4 will be a definite additional lure to park visitors, it will more likely contribute to accelerating the increase in park visitation, rather than increasing the visitation beyond the projected capacity limit. Therefore, a value gain of $900,000 a year will be adpoted as average annual induced benefits associated with recreational opportunity.

The basic philosophy of all the alternative plans is to eliminate the net loss of shoreland on the Illinois Beach State Park over a 50-year project life. Undoubtedly, there will be an unexpected local erosion or erosion in the future. However, from the littoral sediment budget point of view, these unexpected events will balance out to be a zero net gain or loss in shoreland and over the 50-year project life. The actions have been so designed as to prevent unexpected erosion from occurring on an area of sensitive value. Therefore, there will be no net gain in value associated with added acreage.

The net annual benefits resulting from each alternative are summarized in Table 3.9.5.

TABLE 3.9.5

SUMMARY OF AVERAGE ANNUAL BENEFITS

(In Thousands of Dollars)

ALTERNATIVES	LAND LOSSES	PROPERTY LOSSES	RECREATION	TOTAL NET BENEFITS
1. No Action	0	0	0	0
2. Nourishment, with Sill	398	134	951	1,483
3. Armored Headland and Nourishment	398	134	951	1,483
4. Detached Breakwater Fishing Pier and Headland	398	134	951	1,483

3.9.3 *Comparison of Benefits and Costs*

Annual benefits and costs associated with each alternative are summarized in Table 3.9.6

TABLE 3.9.6
COMPARISON OF BENEFITS AND COSTS
(In Thousands of Dollars)

ALTERNATIVE	ANNUAL BENEFITS	ANNUAL COSTS	BENEFIT/COST RATIO
2. Nourishment, with Sill	1,483	1,334	1.11
3. Armored Headland and Nourishment	1,483	1,344	1.10
4. Detached Breakwater, Fishing Pier, and Headland	1,483	1,246	1.19

It is evident that all the three alternatives, 2 through 4 provide benefit/cost ratios in excess of 1.00

4. PHASED PROGRAM

4.1 Selection of Best Alternative

4.1.1 Comparative Analysis

Table 4.1.1 shows an overview of the six alternative erosion control plans evaluated in this study. Chief among the criteria on which to evaluate comparative advantage and disadvantage of these alternatives are (1) feasibility for construction, (2) feasibility for maintenance, (3) degree of assured performance, (4) public safety, (5) aesthetics, and (6) flexibility accomodating future development of the Park.

Alternatives 2 and 3 are entirely dedicated to the purpose of erosion control, and do not include any consideration for incorporating recreational facilities into the protection plan. On the other hand, Alternatives 4, 5 and 6 do take into account such consideration. Of these latter three alternatives 4 through 6, Alternative 4 represents a minimum degree of combined recreational and protective concepts. Alternatives 5 and 6 represent a maximum degree of combined recreational and protective concept.

Comparing between Alternatives 2, 3, and 4, Alternative 3 is considered to provide the best overall advantage, for the following reasons:

1. Whereas the artificial headland can be constructed starting from the shore, the sill requires underwater construction and could create unexpected difficulties for installation.
2. Inspection for structural damage is more difficult for the sill than for the headland.

TABLE 4.1.1

SUMMARY OF ALTERNATIVE EROSION CONTROL PLANS

Alternatives	NORTH UNIT			SOUTH UNIT			COST	
	Protective Structures	Nourishment	Recreation Facilities	Protective Structures	Nourishment	Recreation Facilities	Annual cost	B/C Ratio
1. No Action	None	None	None	None	None	None	Damage due to erosion: $583,400	
2. Nourishment with sill (Perched beaches)	Underwater sill 5,000'	Initial 250K cubic yards. Periodic 250K c.y./5 years	None	None	Initial 120K cubic yards. Periodic 120K c.y./5 years.	None	$1,334,000	1:11
3. Artificial headlands	Four armored headlands	Initial 250K cubic yards. Periodic 250K c.y./5 years.	Possible lookout points on headland	Two head-lands	Initial 120K cubic yards. Periodic 120K c.y./5 years.	Possible lookout points on headland	$1,344,000	1.10
4. Partial breakwater, pier & head-land	Five detach-ed breakwa-ters + one headland	Initial 100K cubic yards. No periodic nourishment.	Possible lookout points on headland	One head-land	Initial 120K cubic yards. No periodic nourishment.	Fishing pier 600' with headland buttress	$1,246,000	1.19
5. Marina in North Unit	Two armored headlands	Initial 100K cubic yards. Periodic 100K c.y./5 years.	Offshore marina & raised causeway on head-land butt-ress	One head-land	Initial 120K cubic yards. Periodic 120K c.y./5 years.	Fishing pier 600' with headland buttress	-	-
6. Marina in South Unit	Four armored headlands	Initial 250K cubic yards. Periodic 250K c.y./5 years.	Possible lookout points on headland	None	None	Offshore marina & raised causeway on head-land butt-ress	-	-

3. The underwater sill becomes a hazard for swimmers and small craft approaching the shore.

4. In the case that offshore recreational facilities such as an offshore marina is being planned in the future, the underwater sill could become a nuisance owing to its hazardous nature. On the other hand, the headland could be reinforced to become a buttress for an elevated causeway or a pier should an offshore marina or a fishing pier be planned at the same location.

5. The headland can be designed to provide lookout points or fishing stands to park visitors.

6. In Alternative 4, the performance of detached breakwaters is more definitive and hence is believed to provide a more assured protection, than either a perched beach (Alternative 2) or a headlanded beach (Alternative 3). However, the detached breakwater is not a delectable choice from the aesthetic point of view, and it could present a navigational hazard. It is also a temptation for swimmers to reach from the shore. Once the detached breakwaters are committed off the North Unit shoreline, the North Unit would, to large extent, lose its potential to become a beach-related recreational ground, and will be destined to develop as a land-based recreation ground.

4.1.2 Selection of Alternative 3

Consequently, of the three Alternatives 2, 3, and 4, Alternative 3 appears to offer the best overall advantage in terms of construction, maintenance, public hazard, aesthetics and flexibility to accomodate future Park development.

Alternatives 5 and 6 incorporate a high-cost marina as part of the combined protection-recreation approach. However, each of these alternatives can be developed as an extension of the other previous alternatives, particularly Alternatives 3 and 4.

For instance, in Alternative 5, the protection plan in the South Unit is almost identical to those of Alternative 3 and 4. Substitute the proposed fishing pier with a headland, then the South Unit protection plan in Alternative 5 is the same as that in Alternative 3. Or, remove the proposed periodic nourishment plan for the South Unit in Alternative 5, then the protection plan for the South Unit in Alternative 5 is the same as in Alternative 4. Alternative 5 is considered to represent either a follow-up plan or an advanced version of Alternative 3 or 4. A periodic nourishment for the South Unit in Alternative 5 is considered essential, since a marina in the North Unit will become an efficient trap of littoral drift.

Also, in Alternative, 6, which includes an offshore marina in the South Unit, the protection plan for the North Unit is identical to that in Alternative 3. In consideration of potential navigational hazards to the small craft operating out of a marina in the South Unit, the protection plan for the North Unit does not include detached breakwater. Consequently, Alternative 6 is also considered to be a possible advanced version of Alternative 3.

4.2 Phased Implementation

4.2.1 Preliminary Consideration

On the basis of feasibility for construction, feasibility for maintenance, degree of assurance for anticipated performance, public safety, aesthetics, and flexibility for accomodating future development of the Park, Alternative 3 is considered to offer the best overall advantage. Selection of either Alternatives 5 or 6 shall be made upon completion of an extended safewater harbor feasibility study for the Illinois Beach State Park which is about to be commenced.

In the implementation of Alternative 3, it must be borne in mind that the nourishment plan is scheduled on 5-year cycles. This is based on the following consideration:

1. A 5-year duration is a convenient length of time in which the performance of the implemented actions can be monitored to enable necessary adjustments as needed on a more or less continuous basis in the future. A 10-year cycle, on the other hand, would leave too much time between successive nourishments, so that each nourishment could become discontinuous quantum actions.

2. The lake level fluctuations can be more reasonable anticipated for a duration of 5 years than 10 years. Since the lake level plays a major role in influencing the short-term erosion rates, a nourishment plan can be more readily adjusted against anticipated lake levels at a 5-year, than a 10-year, interval.

In the implementation of Alternative 3, the component actions should be commenced in the Park Lodge area and be gradually moved northward. The rationales for this consideration are as follows:

- o The Park Lodge is the single most expensive property to protect in the Illinois Beach State Park.
- o A headland collects a larger amount of littoral drift on its updrift, rather than downdrift sides. Therefore, moving the construction of successive headlands in the updrift direction, littoral drift can be captured to a maximum extent.
- o A headland constructed on the downdrift coast will have little adverse effects on the updrift coast. On the other hand, a headland constructed on the updrift coastline will diminish the supply of drift to the downdrift coastline. Therefore, as the construction moves in the downdrift direction, the headlands will have to be constructed at a progressively more eroded coastline.

4.2.2 *Phases for Implementation*

The following phases of actions are recommended for the implementation of the selected plan, Alternative 3.

<u>PHASE 1</u> (Year 1)

1. Commence the construction of Headland No. 6.

2. When Headland No. 6 is approximately 50% complete or when the development of an updrift fillet becomes noticeable during the construction of Headland No. 6, commence the construction of Headland No. 5.

3. Immediately upon the completion of Headlands No. 6 and No. 5, place the initial nourishment of 120,000 cubic yards on a 4,000 foot shoreline.

4. Before the placement of beach fill, existing concrete blocks in front of the bathhouse No. 3 must be removed and stored off-site.

<u>PHASE 2</u> (Year 1 – 3)

1. Remove all the existing broken groins in front of the Camp Logan bulkhead before initiation of Phase 2.

2. Protection plans for the North Unit can be undertaken within the same year as those for the South Unit, or can be delayed till the following year, should budgetary appropriations make such a delay necessary. The delay will not adversely affect the overall function of the proposed plan. In any case, the construction for the North Unit should commence only after the completion of the protective works in the South Unit.

3. In the North Unit, the sequence of construction should proceed from Headland No. 4 toward Headland No. 1. Construction of successive headlands should allow about 50% completion of the previous headland.

4. Upon completion of Headlands 3 and 4, place the initial nourishment of 200,000 cubic yards on a 2,000-foot shoreline.

5. Construct Headlands No. 2 and No. 1. This action may be implemented in the third year of the program.

6. Upon completion of Headlands No. 2 and No. 1, place the initial nourishment of 150,000 cubic yards on a 3,000-foot shoreline.

7. The Camp Logan sheet-pile bulkhead may be repaired following the completion of all the Phase-2 works in the North Unit. It is expected that littoral drift from the updrift nourishment would fill the existing erosion pocket, making the repair work for the bulkhead somewhat easier.

<u>PHASE 3</u> (Year 1 — 5)

1. Following Phases 1 and 2, the changes in beach profile along the entire Park shoreline should be monitored. It is recommended to survey beach profiles between the crest of the foredune to a depth of 10 feet LWD at 4-month intervals for the first year, and twice yearly for the remaining years of project implementation.

2. The performance of the protective works should be evaluated continuously on the basis of survey data analysis and beach inspection, so that any adjustments in the design of protective

works or nourishment plan be completed prior to the next periodic nourishment.

3. Also, during this period, any damage on the protective structure should be maintained without delay.

PHASE 4 (Year 6)

1. Place the maintenance nourishment of 370,000 cubic yards or any adjusted quantity on the protective shoreline. It is desirable to carry out this periodic nourishment as a single operation. However, when this is not permissible for budgetary or other reasons, the periodic nourishment may be conducted over a 2- to 3-year period. Under these latter circumstances, the nourishment should commence in the South Unit and move progressively to the north.

2. In the event that the rising price of sand makes it impossible to continue periodic nourishment with the prescribed volume, a certain suitable revision may be made to reduce the amount of beach fill. Such a revision may include installation of additional headlands and/or combination of headlands and sill. Decisions for the most suitable revision shall be based on the results of the recommended monitoring operations.

3. Revisions to the selected protection plans should be made in a flexible way, so that any more additional revisions could be implemented as a logical extension of the adopted revision. The state of the art of the coastal science and coastal engineering is basically empirical. In the face of various uncertainties to be expected over the 50-year project life, among them the development of certain coastal

zone management practices in the State of Wisconsin, inflation, unexpected lake level fluctuations, extraordinary storms, changes in ice conditions in the lake which would alter the length of open water season, hence the amount of wave energy input to the littoral zone, it is highly desirable to be prepared for revisions in order to be able to fine-tune the control actions on a continuous and as-needed basis.

4.3 Long-Term Considerations

The following special recommendations are made in consideration of long-term protection benefits.

1. Periodic survey programs

   Irrespective of the types and scopes of immediate protection plans adopted, a program for systematic and periodic surveys on beach processes be initiated under the guidance and participation of qualified specialists. Illinois Geological Survey has already been active in such works and is ideally qualified for the leadership role in this recommended survey program. The extent and schedule of this program shall be determined in accordance with the advice from Illinois Geological Survey.

2. Coordination with Commonwealth Edison Company

Commonwealth Edison Company is expected to continue protective actions for its lakefront shoreline. Since this shoreline is an integral part of the entire reach between the State Line and Waukegan, it is strongly recommended that Commonwealth Edison Company and Illinois Department of Conservation coordinate their respective protective actions to ensure maximum overall benefits while avoiding possible adverse mutual impacts.

3. Coordination with State of Wisconsin

The littoral sediment budget on the shoreline of Illinois Beach State Park is sensitively dependent upon the beach processes along the Wisconsin shoreline north of the State Line. It is strongly recommended that the State of Illinois initiate necessary actions toward establishing coordinations with the State of Wisconsin in order to ensure maximum overall benefits while avoiding possible adverse mutual impacts from their respective shoreline management actions.

APPENDIX A

RECENT SHORELINE CHANGES DETERMINED FROM AIR PHOTO DIGITIZATION

APPENDIX A-1: SHORELINE POSITIONS (IN FEET TO LWD SHORELINE)

PROFILE NUMBER	YEAR 1939	1947	1954	1961	1967	1974	1977
1	348	297	420	723	923	880	749
2	417	342	549	878	1081	1008	896
3	484	421	670	1039	1309	1097	1028
4	536	509	782	1234	1458	1276	1245
5	616	601	870	1304	1470	1363	1294
6	718	757	931	1207	1478	1395	1359
7	917	930	996	1191	1471	1420	1433
8	1130	1152	1158	1223	1474	1527	1471
9	1336	1363	1373	1314	1568	1638	1562
10	1513	1528	1502		1607	1766	1694
11	1728	2034	1983	2048	1879	2109	2177
12	1755	1957	1995	2098	2092	2219	2199
13	1738	1959	1981	2075	2155	2189	2219
14	1739	1941	1956	2037	2096	2179	2209
15	1746	1906	1928	2001	2083	2153	2184
16	1760	1900	1942	2006	2055	2146	2124
17	1789	1911	2009	2053	2040	2091	2066
18	1823	1956	2023	2075	2074	2173	2132
19	1792	1958	1952	2060	2092	2214	2221
20	1826	1959	1935	2039	2050	2232	2219
21	1804	1952	1937	2013	2017	2194	2154
22	1800	1948	1951	1969	1989	2188	2121
23	1815	1953	1961	1960	1984	2181	2169
24	1831	1959	1949	1960	1978	2167	2163
25	1838	1965	1948	1941	2002	2175	2149
26	1890	1967	1983	1955	1999	2179	2147
27	1890	1950	1993	1971	2006	2165	2127
28	1883	1941	1988	1968	2027	2175	2100
29	1880	1938	1950	1960	2041	2149	2081
30	1836	1879	1890	1941	1997	2076	2046
31	1866	1849	1874	1925	1988	2061	2033
32	1842	1824	1861	1903	1984	2035	2016
33	1842	1793	1849	1930	1961	2046	1991
34	1810	1753	1841	1902	1951	2003	1970
35	1794	1770	1820	1885	1946	1995	1946
36	1758	1775	1813	1872	1921	1959	1955
37	1724	1817	1827	1862	1908	1944	1920
38	1752	1850	1848	1861	1869	1913	1890
39	1729	1931	1859	1832	1888	1876	1882
40	1681	1916	1833	1811	1844	1841	1863
41	1649	1858	1830	1776	1807	1823	1824
42	1652	1827	1806	1742	1775	1767	1800
43	1617	1766	1783	1727	1723	1746	1768
44	1621	1715	1700	1698	1716	1711	1736
45	1618	1647	1674	1690	1709	1662	1696

APPENDIX A-1 (Cont'd): SHORELINE POSITIONS (IN FEET TO LWD SHORELINE)

PROFILE NUMBER	YEAR 1939	1947	1954	1961	1967	1974	1977
46	1590	1598	1632	1650	1705	1636	1659
47	1592	1541	1601	1635	1709	1596	1616
48	1563	1487	1571	1598	1689	1567	1572
49	1524	1474	1537	1566	1648	1533	1541
50	1506	1451	1504	1537	1599	1498	1491
51	1491	1402	1480	1515	1543	1459	1450
52	1471	1379	1442	1486	1481	1439	1409
53	1429	1371	1406	1455	1431	1403	1380
54	1405	1354	1376	1413	1411	1368	1347
55	1401	1316	1338	1390	1359	1345	1306
56	1334	1248	1279	1333	1359	1270	1239
57		1159	1255	1285	1299	1222	1182
58		1193	1214	1241	1240	1166	1094
59		1144	1184	1203	1184	1132	1083
60		1115	1152	1158	1139	1108	1010
61		1140	1104	1116	1106	1094	992
62	1134	1132	1066	1072	1081	1021	951
63	1088	1132	1045	1034	1046	973	913
64	1046	1079	1013	997	1014	949	857
65	1025	1043	976	957	986	916	827
66	1001	1009	939	922	960	876	788
67	954	1075	927	884	931	855	768
68	926	1036	877	861	907	844	752
69	936	1012	934	852	901	859	796
70	900	975	890	828	878	812	770
71	888	939	860	805	837	830	777
72	871	901	824	783	851	745	739
73	856	860	804	777	883	736	722
74	876	857	776	778	894	772	746
75	868	845	762	803	895	754	757
76	880	852	742	823	920	743	830
77	889	844	787	867	954	825	819
78	916	876	821	900	964	861	813
79	932	894	849	920	1014	835	841
80	981	904	886	949	1050	844	852
81	1046	952	940	999	1039	895	959
82	1084	1007	1045	1040	1054	1025	1043
83	1107	1037	1074	1086	1034	1042	1066
84	1170	1097	1138	1129	1021	1154	1151
85	1205	1104	1145	1163	1040	1212	1192
86	1216	1087	1122	1172	1049	1141	1144
87	1292	1120	1192	1211	1095	1277	1147
88	1346	1146	1232	1236	1144	1286	1229
89	1356	1152	1266	1264	1214	1321	1233
90	1404	1204	1375	1317	1302	1434	1253

APPENDIX A-1 (Cont'd): SHORELINE POSITIONS (IN FEET TO LWD SHORELINE)

PROFILE NUMBER	YEAR 1939	1947	1954	1961	1967	1974	1977
91	1407	1248	1397	1327	1334	1413	1266
92	1350	1296	1348	1321	1381	1317	1202
93	1391	1422	1405	1382	1455	1311	1211
94	1442	1524	1435	1442	1530	1310	1268
95	1522	1630	1475	1532	1589	1366	1342
96	1606	1682	1531	1582	1624	1471	1421
97	1617	1729	1597	1636	1675	1488	1512
98	1721	1770	1646	1645	1698	1618	1559
99	1844	1808	1683	1676	1726	1604	1528
100	1900	1847	1690	1680	1739	1627	1592
101	1908	1879	1767	1738	1733	1721	1672
102	1984	1886	1835	1798	1743	1702	1671
103	1975	1884	1811	1810	1824	1758	1673
104	2005	1925	1836	1822	1845	1829	1739
105	2042	1926	1892	1880	1850	1866	1795
106	2057	1927	1879	1915	1912	1890	1853
107	2124	2032	1865	1913	1884	1809	1816
108	2203	2061	1931	1921	1904	1824	1808
109	2214	2064	1930	1946	1969	1793	1800
110	2254	2084	1949	1967	1986	1833	1855
111	2339	2139	2014	1994	1987	1880	1886
112	2404	2263	2137	2048	2119	2031	2147
113	2346	2296	2264	2098	2122	2185	2154
114	2346	2304		2157	2155	2207	2177
115	2327	2262	2334	2239	2225	2154	2150
116	2312	2239	2323	2230	2266	2170	2179
117	2282	2212	2243	2176	2160	2129	2133
118	2272	2181	2197	2121	2088	2045	2024
119	2268	2139	2161	2065	2092	1990	1960
120	2243	2115	2096	2023	2083	1899	1851
121	2206	2090	2050	2012	2099	1817	1776
122	2204	2097	2036	2011	2102	1740	1718
123	2201	2123	2010	2001	2059	1713	1683
124	2180	2139	2012	2021	2039	1784	1769
125	2187	2158	2071	2039	2028	1793	1818
126	2231	2202	2078	1990	1962	1908	1864
127	2207	2156	2070	1992	1970	1960	1938
128	2179	2139	2071	2014	2028	1972	1935
129	2154	2099	2069	2047	2048	1994	1960
130	2127	2099	2072	2049	2044	2094	1988
131	2101	2067	2011	1981	1984	2014	1934
132	2069	2013	1971	1929	1908	1922	1870
133	2041	1948	1872	1812	1782	1782	1717
134	2008	1883	1756	1728	1682	1660	1583
135	1972	1832	1685	1619	1641	1598	1561

APPENDIX A-1 (Cont'd) SHORELINE POSITIONS (IN FEET TO LWD SHORELINE)

PROFILE NUMBER	YEAR 1939	1947	1954	1961	1967	1974	1977
136	1909	1764	1660	1633	1606	1526	1547
137	1858	1707	1541	1506	1515	1412	1410
138	1794	1633	1450	1419	1428	1310	1287
139	1741	1574	1362	1345	1337	1229	1202
140	1690	1505	1292	1277	1257	1165	1132
141	1630	1428	1251	1268	1224	1131	1084
142	1568	1445	1278	1250	1322	1134	1196
143	1499	1500	1488	1497	1478	1510	1508
144	1442	1372	1285	1283	1335	1367	1316
145	1366	1307	1334	1300	1288	1378	1313
146	1283	1238	1129	1178	1179	1218	1196
147	1246	1238	1305	1239	1246	1282	1234
148	1173	1146	1065	1178	1158	1102	1102
149	1131	1074	947	1032	1016	971	948
150	1035	990	849	896	922	891	823
151	967	914	759	785		813	
152	911	851	753	760		769	
153	871	846	786	752		786	

APPENDIX A-2:

EROSION RATES (FEET/YEAR)

PROFILE NUMBER	1939	1947	1954	1961	1967	YEAR 1974	1977
1		-6.6	17.1	41.9	32.9	-6.2	-50.4
2		-9.7	28.6	45.6	33.4	-10.5	-43.5
3		-8.1	34.4	51.2	44.3	-30.3	-26.6
4		-3.4	37.7	62.7	36.7	-26.0	-12.0
5		-1.9	37.3	60.2	27.2	-15.3	-26.5
6		5.1	24.0	38.2	44.5	-11.9	-13.6
7		1.6	9.1	27.1	45.9	-7.3	5.0
8		2.9	0.9	9.0	41.1	7.6	-21.4
9		3.5	1.5	-8.2	41.7	10.1	-29.6
10		2.0	-3.6	7.9		22.9	-27.8
11		39.6	-7.1	9.0	-27.8	32.9	26.3
12		26.1	5.2	14.3	-0.9	18.2	-7.8
13		28.6	3.0	13.1	13.1	4.9	11.7
14		26.2	2.0	11.3	9.6	12.0	11.7
15		20.6	3.0	10.2	13.4	10.0	12.2
16		18.1	5.8	8.8	8.0	13.2	-8.5
17		15.8	13.5	6.1	-2.1	7.2	-9.6
18		17.2	9.3	7.3	-0.2	14.2	-16.0
19		21.5	-0.8	14.9	5.2	17.5	2.9
20		17.2	-3.2	14.4	1.8	26.0	-5.0
21		19.2	-2.0	10.5	0.7	25.3	-15.2
22		19.1	0.5	2.5	3.3	28.5	-25.7
23		17.8	1.1	-0.1	4.0	28.2	-4.8
24		16.5	-1.4	1.5	3.0	27.1	-1.7
25		16.4	-2.4	-1.0	10.1	24.7	-9.8
26		10.0	2.2	-3.9	7.2	25.8	-12.3
27		7.8	6.0	-3.1	5.8	22.8	-14.8
28		7.5	6.5	-2.8	9.7	21.2	-29.0
29		7.4	1.7	1.4	13.3	15.4	-26.4
30		5.5	1.5	7.1	9.2	11.3	-11.7
31		-2.1	3.4	7.0	10.4	10.4	-10.6
32		-2.2	5.0	5.9	13.4	7.2	-7.3
33		-6.3	7.7	11.3	5.0	12.2	-21.4
34		-7.4	12.3	8.5	8.0	7.5	-13.0
35		-3.2	7.1	9.0	9.9	7.1	-19.0
36		2.1	5.3	8.3	7.9	5.5	-1.8
37		12.0	1.4	4.9	7.5	5.1	-9.4
38		12.7	-0.3	1.9	1.3	6.3	-8.9
39		26.2	-9.9	-3.8	9.2	-1.7	2.1
40		30.4	-11.4	-3.1	5.5	-0.4	8.2
41		27.0	-3.8	-7.5	5.0	2.3	0.3
42		22.6	-2.9	-8.8	5.3	-1.0	12.6
43		19.3	2.3	-7.7	-0.7	3.3	8.8
44		12.2	-2.2	-0.3	3.0	-0.7	9.5
45		3.8	3.7	2.2	3.1	-6.7	13.3

APPENDIX A-2 (Cont'd):

EROSION RATES (FEET/YEAR)

PROFILE NUMBER					YEAR		
	1939	1947	1954	1961	1967	1974	1977
46		1.0	4.7	2.4	9.1	-9.9	8.7
47		-6.6	8.3	4.7	12.2	-16.2	7.6
48		-9.9	11.7	3.7	15.0	-17.5	2.1
49		-6.4	8.7	3.9	13.4	-16.5	3.2
50		-7.2	7.4	4.5	10.2	-14.4	-2.9
51		-11.5	10.8	4.8	4.6	-12.0	-3.5
52		-11.9	8.6	6.1	-0.8	-6.0	-11.6
53		-7.5	4.8	6.8	-3.8	-4.1	-8.9
54		-6.5	2.9	5.2	-0.3	-6.1	-8.4
55		-11.1	3.1	7.3	-5.1	-2.0	-15.0
56		-11.2	4.4	7.4	4.3	-12.8	-12.1
57			13.2	4.2	2.2	-11.0	-15.4
58			2.8	3.8	-0.1	-10.7	-27.7
59			5.7	2.6	-3.1	-7.5	-18.8
60			5.0	0.8	-3.0	-4.6	-37.8
61			-5.0	1.7	-1.7	-1.7	-39.4
62		-0.3	-9.1	0.8	1.4	-8.5	-26.9
63		5.6	-12.0	-1.5	1.8	-10.5	-23.1
64		4.3	-9.3	-2.1	2.7	-9.3	-35.7
65		2.4	-9.3	-2.7	4.8	-10.1	-34.5
66		1.0	-9.7	-2.3	6.3	-12.0	-34.0
67		15.8	-20.6	-5.9	7.7	-10.9	-33.5
68		14.3	-22.1	-2.2	7.6	-9.1	-35.4
69		9.9	-10.8	-11.3	8.0	-6.0	-24.4
70		9.7	-11.7	-8.7	8.3	-9.5	-16.3
71		6.7	-11.0	-7.6	5.2	-0.9	-20.7
72		3.8	-10.6	-5.7	11.2	-15.2	-2.4
73		0.6	-7.9	-3.7	17.4	-21.1	-5.2
74		-2.4	-11.2	0.4	19.0	-17.6	-9.9
75		-3.1	-11.4	5.7	15.1	-20.3	1.2
76		-3.7	-15.3	11.3	15.9	-25.3	33.3
77		-5.8	-7.9	11.1	14.3	-18.6	-2.3
78		-5.2	-7.6	10.9	10.6	-14.8	-18.6
79		-5.0	-6.1	9.8	15.4	-25.6	2.3
80		-10.1	-2.4	8.7	16.6	-29.6	3.4
81		-12.2	-1.7	8.2	6.5	-20.6	24.8
82		-10.0	5.3	-0.8	2.3	-4.0	6.7
83		-9.2	5.2	1.7	-8.6	1.2	9.2
84		-9.5	5.8	-1.3	-17.7	19.0	-1.0
85		-13.2	5.7	2.4	-20.2	24.7	-7.6
86		-16.8	4.8	7.0	-20.1	13.2	1.2
87		-22.4	10.1	2.6	-19.2	26.1	-50.2
88		-25.9	12.0	0.6	-15.1	20.3	-22.0
89		-26.4	15.8	-0.3	-8.2	15.4	-34.0
90		-26.0	23.8	-8.0	-2.5	19.0	-70.2

APPENDIX A-2 (Cont'd):

EROSION RATES (FEET/YEAR)

YEAR

PROFILE NUMBER	1939	1947	1954	1961	1967	1974	1977
91	-20.6	20.7	-9.7	1.2	11.3	-56.8	
92	-7.1	7.2	-3.6	9.8	-9.2	-44.6	
93	4.0	-2.3	-3.2	12.0	-20.6	-38.6	
94	10.8	-12.4	1.0	14.4	-31.5	-16.0	
95	14.2	-21.5	7.9	9.4	-32.0	-9.1	
96	9.9	-20.9	7.1	6.8	-21.9	-19.4	
97	14.6	-18.2	5.4	6.3	-26.8	9.2	
98	6.5	-17.3	-0.1	8.7	-11.6	-22.8	
99	-4.7	-17.3	-1.1	8.3	-17.5	-29.6	
100	-6.9	-21.6	-1.5	9.8	-16.2	-13.4	
101	-3.7	-15.5	-4.0	-0.9	-1.7	-19.0	
102	-12.8	-7.1	-5.2	-8.9	-5.9	-11.9	
103	-11.9	-10.1	-0.1	2.3	-9.5	-32.6	
104	-10.4	-12.3	-2.0	3.8	-2.2	-34.9	
105	-15.2	-4.6	-1.6	-5.0	2.3	-27.4	
106	-17.0	-6.5	5.0	-0.6	-3.0	-14.6	
107	-12.0	-23.1	6.6	-4.7	-10.8	2.5	
108	-18.5	-18.0	-1.4	-2.8	-11.5	-6.2	
109	-19.5	-18.5	2.2	3.8	-25.3	2.7	
110	-22.2	-18.6	2.5	3.1	-21.9	8.5	
111	-26.1	-17.2	-2.8	-1.2	-15.3	2.3	
112	-18.3	-17.5	-12.3	11.7	-12.7	45.1	
113	-6.5	-4.3	-23.0	3.9	9.1	-12.3	
114	-5.6	-10.1		-0.3	7.4	-11.4	
115	-8.5	9.9	-13.2	-2.2	-10.1	-1.6	
116	-9.5	11.6	-12.8	6.0	-13.9	3.7	
117	-9.2	4.3	-9.2	-2.6	-4.5	1.8	
118	-11.8	2.2	-10.6	-5.5	-6.1	-8.2	
119	-16.8	3.1	-13.3	4.5	-14.6	-11.8	
120	-16.7	-2.6	-10.2	9.9	-26.3	-18.8	
121	-15.2	-5.6	-5.1	14.2	-40.4	-15.8	
122	-14.0	-8.4	-3.5	14.9	-52.0	-8.4	
123	-10.2	-15.6	-1.2	9.6	-49.6	-11.8	
124	-5.3	-17.6	1.3	2.8	-36.6	-5.6	
125	-3.8	-12.1	-4.4	-1.8	-33.8	9.9	
126	-3.8	-17.1	-12.1	-4.6	-7.9	-16.8	
127	-6.7	-11.8	-10.8	-3.6	-1.4	-8.5	
128	-5.2	-9.5	-7.8	2.2	-8.0	-14.5	
129	-7.1	-4.1	-3.1	0.2	-7.8	-13.1	
130	-3.7	-3.6	-3.2	-0.8	7.1	-40.9	
131	-4.5	-7.7	-4.2	0.5	4.3	-30.9	
132	-7.4	-5.7	-5.9	-3.3	2.0	-20.2	
133	-12.2	-10.5	-8.2	-5.1	0.0	-25.0	
134	-16.3	-17.5	-3.9	-7.6	-3.2	-29.7	
135	-18.2	-20.3	-9.2	3.6	-6.3	-14.2	

APPENDIX A-2 (Cont'd):
EROSION RATES (FEET/YEAR)

PROFILE NUMBER	YEAR 1939	1947	1954	1961	1967	1974	1977
136		-18.9	-14.3	-3.8	-4.4	-11.5	8.1
137		-19.8	-22.9	-4.8	1.4	-14.8	-0.8
138		-21.0	-25.4	-4.3	1.4	-16.9	-9.2
139		-21.8	-29.3	-2.2	-1.4	-15.4	-10.7
140		-24.1	-29.4	-2.2	-3.3	-13.1	-12.8
141		-26.3	-24.5	2.4	-7.2	-13.3	-18.5
142		-16.0	-23.1	-3.8	11.8	-27.0	24.0
143		0.2	-1.6	1.2	-3.1	4.5	-0.8
144		-9.2	-12.0	-0.2	8.4	4.6	-19.6
145		-7.7	3.7	-4.7	-1.9	12.9	-25.0
146		-5.9	-15.1	6.9	0.1	5.6	-8.6
147		-1.1	9.3	-9.1	1.2	5.1	-18.5
148		-3.5	-11.3	15.7	-3.3	-8.0	-0.1
149		-7.4	-17.6	11.8	-2.7	-6.4	-8.8
150		-5.9	-19.5	6.4	4.3	-4.4	-26.6
151		-6.8	-21.4	3.5		2.2	
152		-7.8	-13.6	1.0		0.7	
153		-3.2	-8.3	-4.7		2.6	

APPENDIX A-3: BEACH AREA LOSSES (IN 1000 SF)

PROFILE LINE	BEACH AREA CHANGE 1939 - 1977	AVERAGE BEACH CHANGE PER YEAR	ALONGSHORE CUMULATIVE 1939 - 1977	ALONGSHORE CUMULATIVE YEARLY
1	120.40	3.18	120.40	3.18
2	143.59	3.80	263.99	6.98
3	163.42	4.32	427.41	11.30
4	212.80	5.63	640.22	16.93
5	203.59	5.38	843.81	22.32
6	192.43	5.09	1036.24	27.41
7	154.81	4.09	1191.04	31.50
8	102.47	2.71	1293.51	34.21
9	67.88	1.80	1361.39	36.01
10	54.51	1.44	1415.90	37.45
11	134.49	3.56	1550.39	41.00
12	133.21	3.52	1683.60	44.53
13	144.41	3.82	1828.01	48.35
14	141.22	3.73	1969.23	52.08
15	131.34	3.47	2100.57	55.55
16	109.36	2.89	2209.93	58.45
17	83.09	2.20	2293.02	60.64
18	92.72	2.45	2385.73	63.10
19	128.78	3.41	2514.52	66.50
20	117.94	3.12	2632.45	69.62
21	105.24	2.78	2737.69	72.40
22	96.26	2.55	2833.95	74.95
23	106.03	2.80	2939.97	77.75
24	99.44	2.63	3039.42	80.38
25	93.49	2.47	3132.90	82.86
26	77.12	2.04	3210.02	84.90
27	71.03	1.88	3281.05	86.78
28	65.15	1.72	3346.20	88.50
29	60.12	1.59	3406.32	90.09
30	62.79	1.66	3469.11	91.75
31	50.37	1.33	3519.48	93.08
32	52.20	1.38	3571.68	94.46
33	44.63	1.18	3616.30	95.64
34	47.99	1.27	3664.30	96.91
35	45.64	1.21	3709.93	98.12
36	59.04	1.56	3768.98	99.68
37	58.67	1.55	3827.65	101.23
38	41.54	1.10	3869.18	102.33
39	45.86	1.21	3915.05	103.54
40	54.64	1.45	3969.69	104.99
41	52.43	1.39	4022.12	106.37
42	44.48	1.18	4066.60	107.55
43	45.44	1.20	4112.04	108.75
44	34.62	0.92	4146.65	109.67
45	23.50	0.62	4170.16	110.29

APPENDIX A-3 (Cont'd): BEACH AREA LOSSES (IN 1000 SF)

PROFILE LINE	BEACH AREA CHANGE 1939 - 1977	AVERAGE BEACH CHANGE PER YEAR	ALONGSHORE CUMULATIVE 1939 - 1977	ALONGSHORE CUMULATIVE YEARLY
46	20.47	0.54	4190.63	110.83
47	7.21	0.19	4197.83	111.02
48	2.66	0.07	4200.49	111.09
49	5.15	0.14	4205.64	111.23
50	-4.62	-0.12	4201.01	111.11
51	-12.27	-0.32	4188.75	110.78
52	-18.76	-0.50	4169.99	110.29
53	-14.72	-0.39	4155.27	109.90
54	-17.48	-0.46	4137.79	109.43
55	-28.54	-0.75	4109.25	108.68
56	-28.59	-0.76	4080.66	107.92
57	37.54	0.99	4118.20	108.92
58	-23.17	-0.61	4095.03	108.30
59	-4.95	-0.13	4090.08	108.17
60	-20.08	-0.53	4069.99	107.64
61	-56.09	-1.48	4013.91	106.16
62	-54.84	-1.45	3959.07	104.71
63	-52.52	-1.39	3906.55	103.32
64	-56.72	-1.50	3849.83	101.82
65	-59.34	-1.57	3790.48	100.25
66	-63.66	-1.68	3726.82	98.56
67	-55.46	-1.47	3671.37	97.10
68	-51.98	-1.37	3619.39	95.72
69	-41.84	-1.11	3577.55	94.62
70	-38.97	-1.03	3538.59	93.59
71	-33.23	-0.88	3505.35	92.71
72	-39.71	-1.05	3465.64	91.66
73	-40.01	-1.06	3425.63	90.60
74	-38.81	-1.03	3386.82	89.57
75	-33.50	-0.89	3353.33	88.69
76	-15.29	-0.40	3338.03	88.28
77	-21.07	-0.56	3316.96	87.73
78	-30.87	-0.82	3286.09	86.91
79	-27.48	-0.73	3258.61	86.18
80	-38.75	-1.02	3219.87	85.16
81	-26.20	-0.69	3193.67	84.46
82	-12.59	-0.33	3181.08	84.13
83	-12.52	-0.33	3168.56	83.80
84	-5.76	-0.15	3162.81	83.65
85	-4.06	-0.11	3158.75	83.54
86	-21.68	-0.57	3137.07	82.97
87	-43.73	-1.16	3093.34	81.81
88	-35.18	-0.93	3058.16	80.88
89	-36.97	-0.98	3021.19	79.90
90	-45.75	-1.21	2975.44	78.69

APPENDIX A-3 (Cont'd): BEACH AREA LOSSES (IN 1000 SF)

PROFILE LINE	BEACH AREA CHANGE 1939 - 1977	AVERAGE BEACH CHANGE PER YEAR	ALONGSHORE CUMULATIVE 1939 - 1977	ALONGSHORE CUMULATIVE YEARLY
91	-42.47	-1.12	2932.97	77.57
92	-44.53	-1.18	2888.44	76.39
93	-53.98	-1.43	2834.46	74.96
94	-51.90	-1.37	2782.56	73.59
95	-53.72	-1.42	2728.84	72.17
96	-55.30	-1.46	2673.54	70.71
97	-31.43	-0.83	2642.11	69.88
98	-48.58	-1.28	2593.53	68.59
99	-94.89	-2.51	2498.65	66.08
100	-92.32	-2.44	2406.33	63.64
101	-70.70	-1.87	2335.63	61.77
102	-93.86	-2.48	2241.77	59.29
103	-90.60	-2.40	2151.17	56.89
104	-79.73	-2.11	2071.44	54.78
105	-74.22	-1.96	1997.22	52.82
106	-61.34	-1.62	1935.88	51.20
107	-92.73	-2.45	1843.15	48.75
108	-118.90	-3.14	1724.26	45.60
109	-124.33	-3.29	1599.93	42.31
110	-119.74	-3.17	1480.19	39.15
111	-136.05	-3.60	1344.14	35.55
112	-77.13	-2.04	1267.01	33.51
113	-57.67	-1.53	1209.34	31.98
114	-50.73	-1.34	1158.61	30.64
115	-53.06	-1.40	1105.55	29.24
116	-39.88	-1.05	1065.67	28.18
117	-44.63	-1.18	1021.05	27.00
118	-74.57	-1.97	946.47	25.03
119	-92.52	-2.45	853.95	22.58
120	-117.76	-3.11	736.20	19.47
121	-129.14	-3.42	607.06	16.06
122	-146.04	-3.86	461.01	12.19
123	-155.43	-4.11	305.59	8.08
124	-123.15	-3.26	182.44	4.83
125	-110.82	-2.93	71.62	1.89
126	-110.06	-2.91	-38.44	-1.02
127	-80.77	-2.14	-119.21	-3.15
128	-73.39	-1.94	-192.59	-5.09
129	-58.21	-1.54	-250.80	-6.63
130	-41.79	-1.11	-292.59	-7.74
131	-50.31	-1.33	-342.90	-9.07
132	-59.78	-1.58	-402.67	-10.65
133	-97.46	-2.58	-500.13	-13.23
134	-127.72	-3.38	-627.85	-16.60
135	-123.40	-3.26	-751.25	-19.87

APPENDIX A-3 (Cont'd): BEACH AREA LOSSES (IN 1000 SF)

PROFILE LINE	BEACH AREA CHANGE 1939 - 1977	AVERAGE BEACH CHANGE PER YEAR	ALONGSHORE CUMULATIVE 1939 - 1977	ALONGSHORE CUMULATIVE YEARLY
136	-108.97	-2.88	-860.21	-22.75
137	-134.85	-3.57	-995.06	-26.32
138	-152.45	-4.03	-1147.51	-30.35
139	-161.89	-4.28	-1309.40	-34.63
140	-167.69	-4.43	-1477.09	-39.07
141	-164.09	-4.34	-1641.18	-43.41
142	-111.53	-2.95	-1752.72	-46.35
143	2.59	0.07	-1750.13	-46.29
144	-37.97	-1.00	-1788.10	-47.29
145	-15.95	-0.42	-1804.05	-47.71
146	-26.21	-0.69	-1830.25	-48.41
147	-3.64	-0.10	-1833.89	-48.50
148	-21.39	-0.57	-1855.29	-49.07
149	-54.76	-1.45	-1910.05	-50.52
150	-63.80	-1.69	-1973.85	-52.20
151	-44.48	-1.18	-2018.33	-53.38
152	-42.18	-1.12	-2060.51	-54.50
153	-23.64	-0.63	-2084.14	-55.12

APPENDIX B

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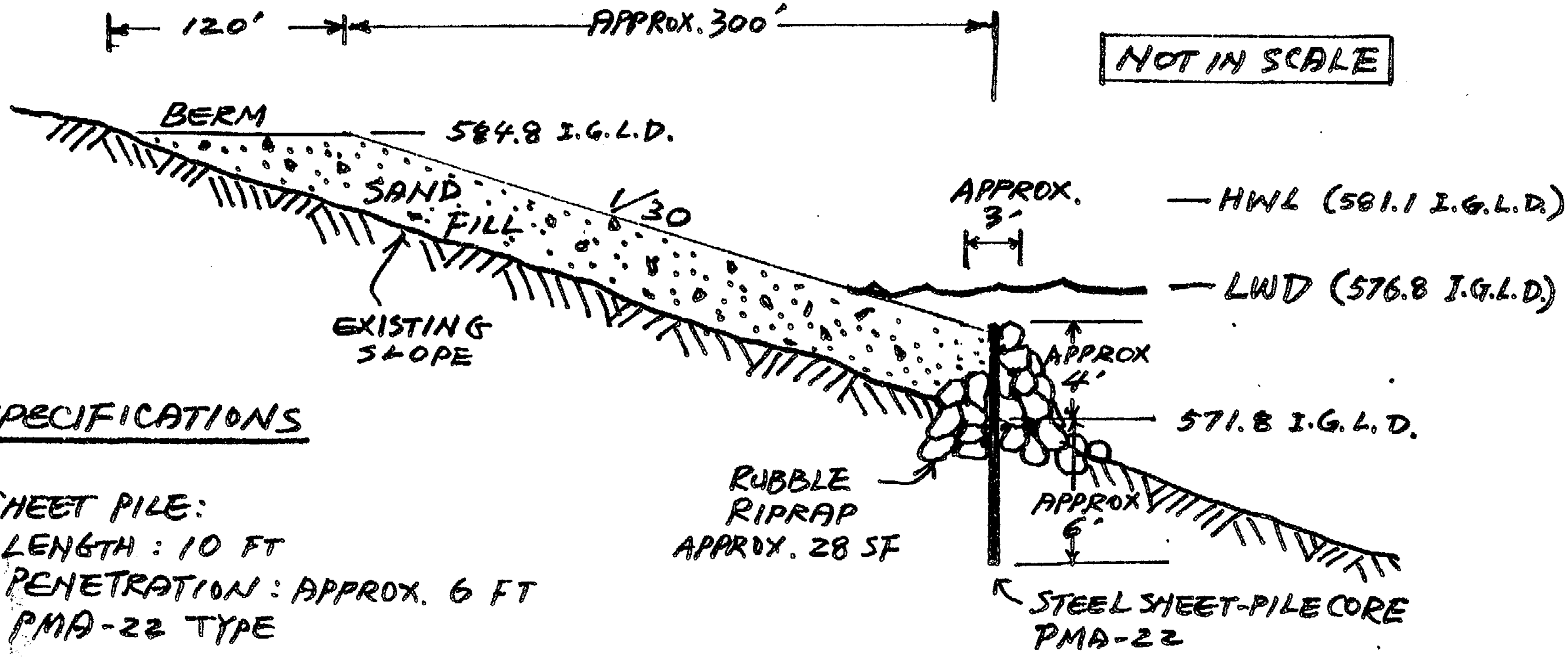
APPENDIX C

DESIGN COMPUTATIONS

NOURISHMENT WITH SILL (PERCHED BEACH)



SPECIFICATIONS

SHEET PILE:
- LENGTH : 10 FT
- PENETRATION : APPROX. 6 FT
- PMA-22 TYPE

SILL RIPRAP:
- CREST WIDTH : 3 FT
- BASE WIDTH : APPROX. 12 FT
- TOTAL VOLUME FOR 5000-LF REACH : 5,200 C.Y. (≑ 9,000 TON)

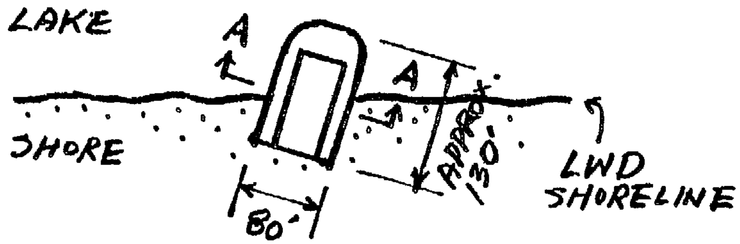
SAND FILL:
- X-SECTION : 150 S.Y.
- TOTAL FILL VOLUME : 250,000 C.Y.

NOTE: RIPRAP ON SHORE SIDE OF SHEET PILE IS ONLY FOR TOE PROTECTION. RIPRAP ON LAKE SIDE BE SLOPED AT 1/2 TO PERMIT WAVE BREAKING & TOE PROTECTION WHILE REDUCING WAVE REFLECTION.

TETRA TECH INC.
PASADENA. CALIF.

SUBJECT ALTERNATIVE #2
NOURISHMENT WITH SILL
COMPUTED C.J.S. CHECKED [illegible]

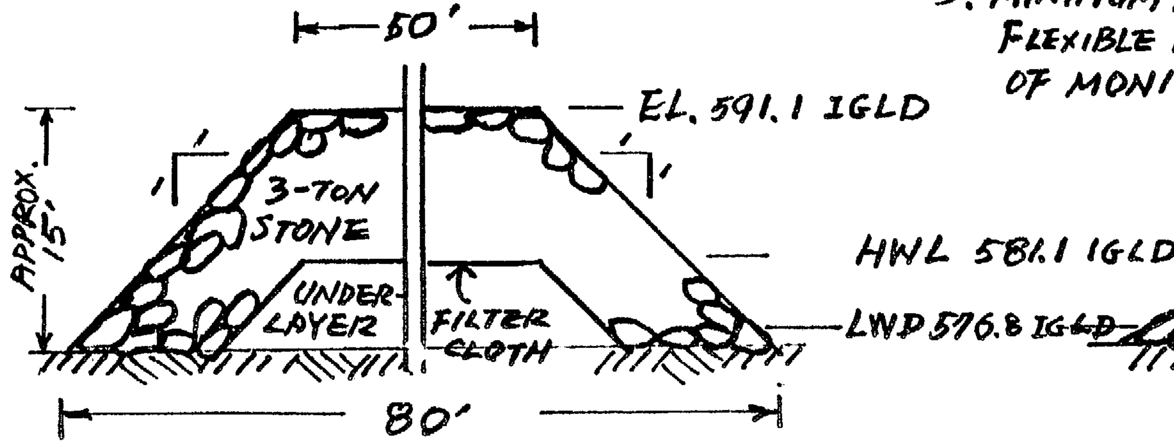
PROJECT ILLINOIS BEACH STATE PARK EROSION
FILE NO APPENDIX C
DATE SEP 13 PAGE 1 OF 4 PAGES



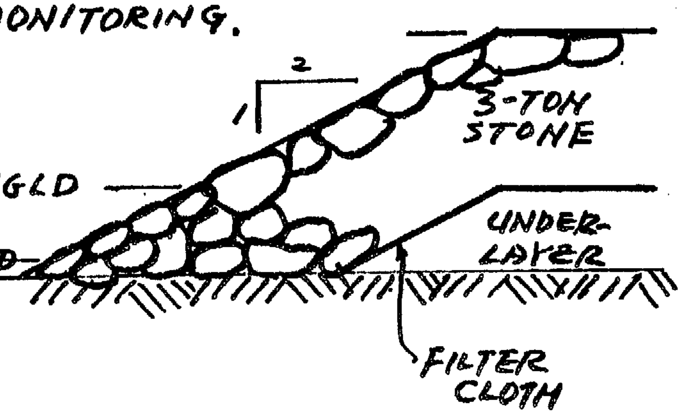
ARTIFICIAL HEADLAND

BASIC CONCEPTS:

1. MINIMUM PROTRUSION INTO LAKE TO AVOID OFFSHORE DEFLECTION OF LITTORAL DRIFT DURING HIGH LAKE LEVELS.
2. BROAD CREST TO PROVIDE LOOKOUT POINTS.
3. MINIMUM INITIAL STRUCTURE, TO PERMIT FLEXIBLE MODIFICATION BASED ON RESULTS OF MONITORING.



TRANSVERSAL SECTION A-A



LONGITUDINAL SECTION

ESTIMATED QUANTITIES

ARMOR:	3-TON STONE	33,900	TON
UNDERLAYER:	#200 STONE	10,800	TON
FILTER CLOTH:		1,800	SY
SAND EXCAVATION & CONSTRUCTION DIKES		70,000	CY

TETRA TECH INC.
PASADENA, CALIF.

SUBJECT ALTERNATIVE #3 ARTIFICIAL HEADLAND

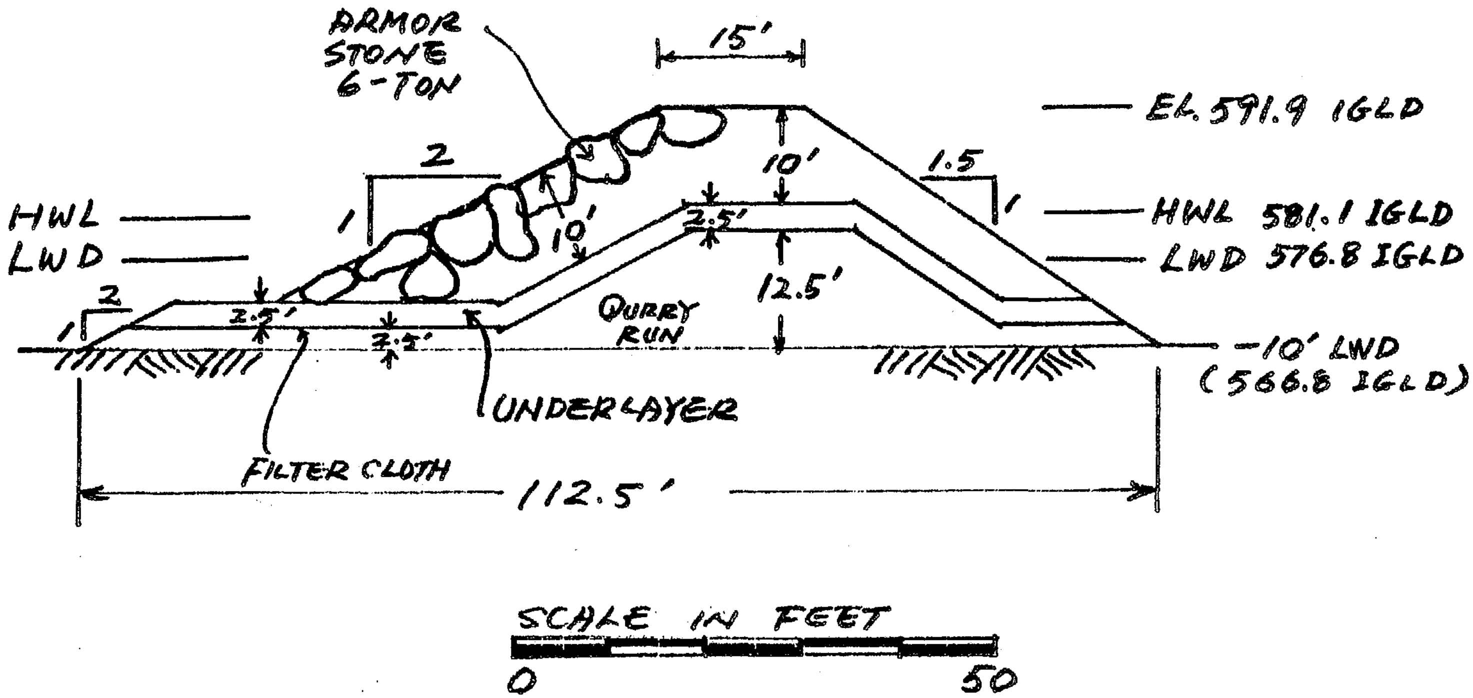
COMPUTED C.J.S. CHECKED PEY

PROJECT ILLINOIS BEACH STATE PARK EROSION

FILE NO APPENDIX C

DATE SEP 13 1978 PAGE 2 OF 4 PAGES

DETACHED BREAKWATER



ESTIMATED QUANTITIES

ARMOR: 6-TON	117,000	TON
UNDERLAYER: 1-TON	101,000	TON
QUARRY RUN:	118,000	TON
FILTER CLOTH	335,000	S.Y.

TETRA TECH INC.
PASADENA, CALIF.

SUBJECT ALTERNATIVE #4
DETACHED BREAKWATERS
COMPUTED C.T.L. CHECKED PEG

PROJECT ILLINOIS BEACH STATE PARK EROSION
APPENDIX C
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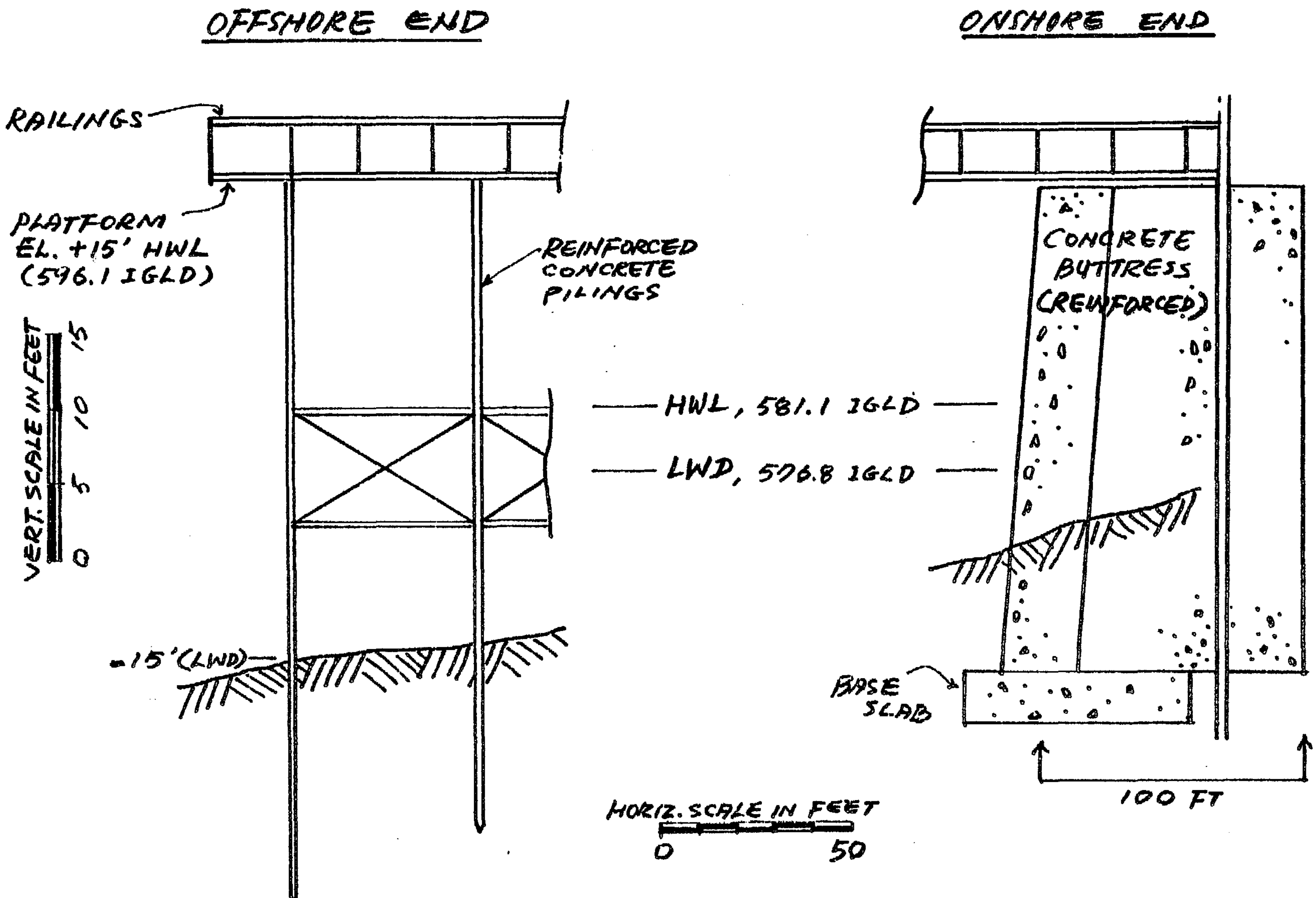

ESTIMATED QUANTITIES

PIER : 600 LF
CONCRETE : 300 C.Y.
STEEL (REINF.) : 32,100 LBS.

TETRA TECH INC.
PASADENA, CALIF.

SUBJECT ALTERNATIVE #4
FISHING PIER

COMPUTED C.J.S. CHECKED

PROJECT ILLINOIS BEACH STATE PARK EROSION

FILE NO APPENDIX C

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