ILLINOIS PILOT EROSION-RATE DATA STUDY

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Submitted to:

Federal Emergency Management Agency
Office of Risk Assessment
Federal Insurance Administration
Washington, D.C.

Final Contract Report for:
FEMA Assistance Award No. EMW-91-K-3575
Report 1 of 2

Illinois State Geological Survey
Open File Series 1993-3

January 1993

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Accompanies Report 2 entitled:
Inventory of Federal and State Historical Maps, Charts, and Vertical Aerial Photographs Applicable to Erosion-Rate Studies Along the Illinois Coast of Lake Michigan
By: Michael J. Chrzastowski and Molly E. Read

Illinois State Geological Survey
Open File Series 1993-3

Michael J. Chrzastowski, Ph.D.
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EXECUTIVE SUMMARY

This study documents the source materials, equipment, procedures, and time allocations necessary to conduct a compilation of historical coastal change for determination of probable erosion rates along a Great Lakes coast. This is a pilot study conducted for the Federal Emergency Management Agency (FEMA), Office of Risk Assessment. The purpose is to assist FEMA in the design and implementation of future projects to map historical coastal changes that may be required pending modification to the National Flood Insurance Program (NFIP). This report (Report 1 of 2) is accompanied by a second report that inventories federal and state historical maps, charts, and vertical aerial photographs applicable to future erosion-rate studies along the Illinois coast.

The study area is the Lake Michigan coast of Lake County, Illinois. Along this 26-mile coast of beach-ridge plain and bluffs, five one-mile corridors were selected for documenting historical shoreline and bluffline changes. Data sources consisted of: 1) two sets of survey field sheets at 1:20,000 nominal scale prepared by the U.S. Lake Survey (USLS) for the years 1872-73 and 1909-11; and 2) two sets of vertical aerial photographs at 1:12,000 and 1:14,400 nominal scale collected by private contractor and the State of Illinois for the years 1947 and 1987. The historical shoreline and bluffline data were registered to U.S. Geological Survey 1:24,000-scale Digital Line Graphs. All work was computer-assisted using a Geographic Information System. A stereoplotter was used to correct for the relief displacement on the aerial photographs.

Two databases documenting coastal change result from this study. One is a Historical Shoreline Location Database created by digitizing, combining, and storing historical and recent shorelines and blufflines. The other is a Historical Shoreline and Positional Change Database created by measuring spatial differences along transects spaced 150 feet apart that intercept the historical shorelines and blufflines. The documentation of time invested in the various tasks of this study indicates that the major effort was in the selection and checking of ground control points for the maps. USLS field sheets had substantial mapping inaccuracies that required a significant time investment to obtain acceptable registration. Aerial photographs provided a more accurate data source, but considerable time was needed in the photograph setup for use with the stereoplotter, and great care was needed in the delineation of the bluffline. The primary recommendation from this study is that future studies allow for adequate time investment to establish a network of ground control points.

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PART 1

INTRODUCTION

PURPOSE AND SCOPE

The Lake Michigan coast, and the Great Lakes coasts in general, are subject to erosion and accretion caused by natural and human-induced processes. This report describes a pilot study to compile erosion-rate data for several segments along the Lake Michigan coast in Lake County, Illinois (Fig. 1). The pilot study provides a framework to assist the Federal Emergency Management Agency (FEMA) in planning for future erosion-rate studies that may be needed along U.S. coastal areas as a result of proposed reforms to the National Flood Insurance Program (NFIP). Concurrent with this study in Illinois, other pilot studies were sponsored by FEMA in 1991 and 1992 along U.S. ocean and estuarine coasts in New Jersey, Maryland, Virginia, Louisiana and Oregon. In contrast with these other states, the Illinois pilot study is the only one focused on the coastal settings and coastal dynamics unique to the Great Lakes.

The purpose of this study is to document the source materials, equipment, procedures, and time allocations necessary to conduct a compilation of historical coastal-erosion rates. Two separate databases for documenting historical shoreline locations and position changes for the Lake Michigan coast of Lake County, Illinois were created. These databases are:

1) <u>Historical Shoreline Location Database:</u> created by digitizing, combining, and storing historical and recent shorelines and blufflines from historical maps and vertical aerial photographs.

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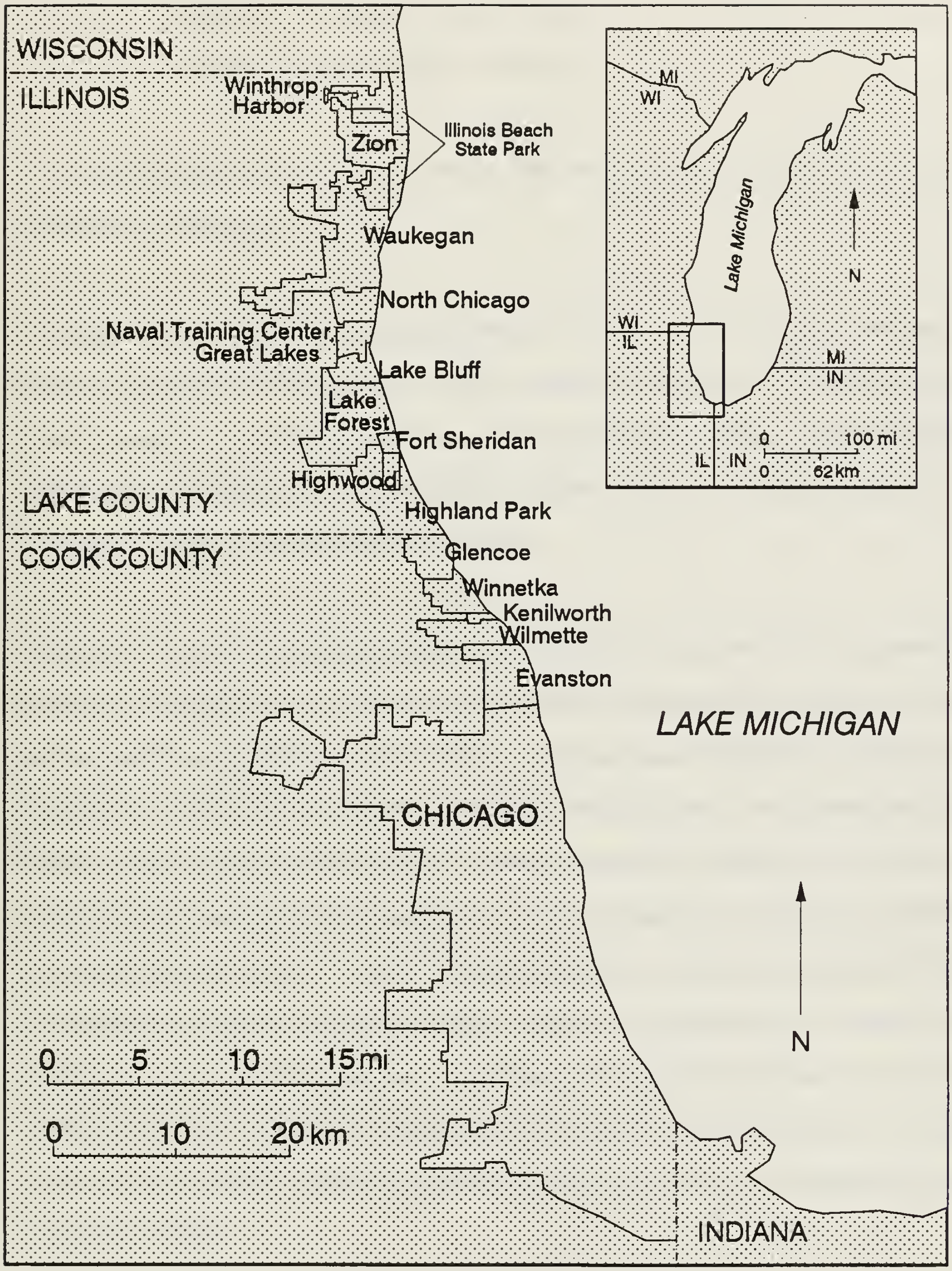

Figure 1. Map of the Illinois coast of Lake Michigan showing municipality and county boundaries.

2) <u>Historical Shoreline Positional Change Database:</u> created by measuring spatial differences along transects that intercept the historical and recent shorelines and blufflines.

The federal, state, and university offices from which data sources were obtained are identified in Appendix A.

This report is accompanied by a second report (Report 2) which is an inventory of data sources that could be used in future erosion-rate data studies. This second report is titled: "Inventory of Federal and State Historical Maps, Charts, and Vertical Aerial Photographs Applicable to Erosion-Rate Studies Along the Illinois Coast of Lake Michigan" (Chrzastowski and Read, 1993).

Although this study creates detailed databases of shoreline and bluffline positions, the focus of this pilot study has been documentation of methods in the database creation and not database quality control. This is not considered a definitive study of erosion rates along this reach of the Illinois coast for three reasons. First, historical shoreline changes have been evaluated for the lake levels that existed at the time of the mapping or the aerial photography without any adjustment of these shorelines to a common lake-level datum. Second, historical bluffline positions were in part evaluated with early historical maps which have major map inaccuracies as well as some ambiguity concerning the position of the change in slope defining the crest of the bluff. Third, the shoreline and bluffline positional change data are presented in an appendix in raw form, awaiting transect-by-transect data screening and database statistical analysis by FEMA.

PREVIOUS STUDIES

The mapping component of this study has two elements. One is the mapping and comparison of historical shoreline positions; the other is mapping and comparison of historical bluffline positions. Previous studies along the Lake County coast have addressed both. This study differs from the previous work in that the emphasis here has been the first intensive use of a Geographic Information System (GIS) in the compilation and processing of shoreline and bluffline map data.

Previous Shoreline Change Studies

Historical shorelines along the Lake County coast have been compiled by the U.S. Army Corps of Engineers (1953) at a scale of 1:30,000 for four surveys completed in 1872-73, 1909-11, 1937-38, and 1946-47, for a total span of 74 years. An important aspect of that shoreline documentation is that shorelines were plotted and compared after adjustment to a common reference of Low Water Datum (LWD), also known as chart datum. Thus absolute erosion and accretion rates were measured independent of any shoreline translation caused by different lake levels at the time of the surveys. The accompanying report summarized calculated recession (and accretion) rates for 20 range lines along the Lake County coast at average spacing of about one mile. These erosion and accretion rates are compared with selected rates calculated for this study beginning on page 109. In another study, Lake County annual shorelines for each of the four years 1952 through 1955 were mapped by the State of Illinois, Division of Waterways (1958) with an accompanying report summarizing erosion and accretion rates for that study period.

Previous Bluffline Change Studies

Bluff recession along the Lake County coast was first discussed in detail by Atwood

and Goldthwait (1908). Bluff recession was mapped and recession rates were calculated by Lineback (1974), and Berg and Collinson (1976). Larsen (1973) examined temporal variation in bluff recession in relation to lake-level fluctuations. In a more recent study, Jibson *et al.* (1990; 1992) and Jibson and Staude (1992) completed mapping of bluff recession and calculation of bluff-recession rates over a 50-year period by comparison of 1:14,400-scale aerial photographs from 1937 and 1987. Characteristics of the bluffs relative to engineering and foundation concerns were studied by DuMontelle (1974) and DuMontelle *et al.* (1975). Roy (1986) developed a computer simulation model for erosion of the Illinois coastal bluffs. The bluff recession rates calculated by Jibson and his colleagues are compared with selected rates calculated for this study beginning on page 113.

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PART 2

STUDY AREA
PHYSICAL CHARACTERISTICS

LOCATION

The Lake Michigan coast of Lake County, Illinois extends about 26 miles in a generally north-south orientation from the Illinois-Wisconsin state line south to the Lake County-Cook County line (Fig. 1). This is about 41 percent of the total Illinois lakeshore. Seven municipalities have shoreline along this coast, and from north to south these are: Zion; Waukegan; North Chicago; Lake Bluff; Lake Forest; Highwood; and Highland Park. Winthrop Harbor is an additional municipality within the coastal zone but it lacks any lakeshore frontage. Table 1 lists the shoreline lengths within the various political units of the Lake County coast. The Lake County coast is covered by three U.S. Geological Survey 7.5-minute topographic quadrangles: Zion; Waukegan; and Highland Park (Fig. 2).

Land ownership and use along the Lake County coast is both private and public. Private residential property only occurs along the coast within three of the seven municipalities. These are Lake Bluff, Lake Forest, and Highland Park. The shoreline within Zion, Waukegan, and North Chicago consists of municipal parkland and commercial/industrial land. The limited shoreline of Highwood is entirely along a municipal water works; the city proper is landward of Highland Park (Fig. 1). State coastal lands extend along the North and South Units of Illinois Beach State Park; federal coastal lands extend along the two U.S. military installations of Naval Training Center, Great Lakes (U.S. Navy) and Fort Sheridan (U.S. Army).

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Table 1. Shoreline lengths along Lake County municipalities, state park land, and U.S. military reservations. Listed from north to south.		
Lakeshore Political or Administrative Unit	Shoreline (statute miles)	% Total Lake County Shoreline
Illinois Beach State Park (North and South units)	6.4	25.0
Zion	0.8	3.1
Waukegan	4.1	16.0
North Chicago	1.4	5.5
Naval Training Center, Great Lakes (U.S. Navy)	1.3	5.1
Lake Bluff	2.6	16.[illegible]
Lake Forest	[illegible].8	12.5
Fort Sheridan (U.S. Army)	1.6	6.2
Highwood	0.1	0.4
Highland Park	4.1	16.0
TOTAL	25.6	100.0

Illinois has not adopted a federally approved Coastal Zone Management (CZM) program. Coastal regulatory functions along the Illinois coast are administered by the Illinois Department of Transportation (IDOT) Division of Water Resources, and the U.S. Army Corps of Engineers, Chicago District.

COASTAL GEOLOGY

General

The sediments, stratigraphy, and geomorphology of the Lake County coast reflect both glacial processes that formed the lake margin and basin, and coastal processes that

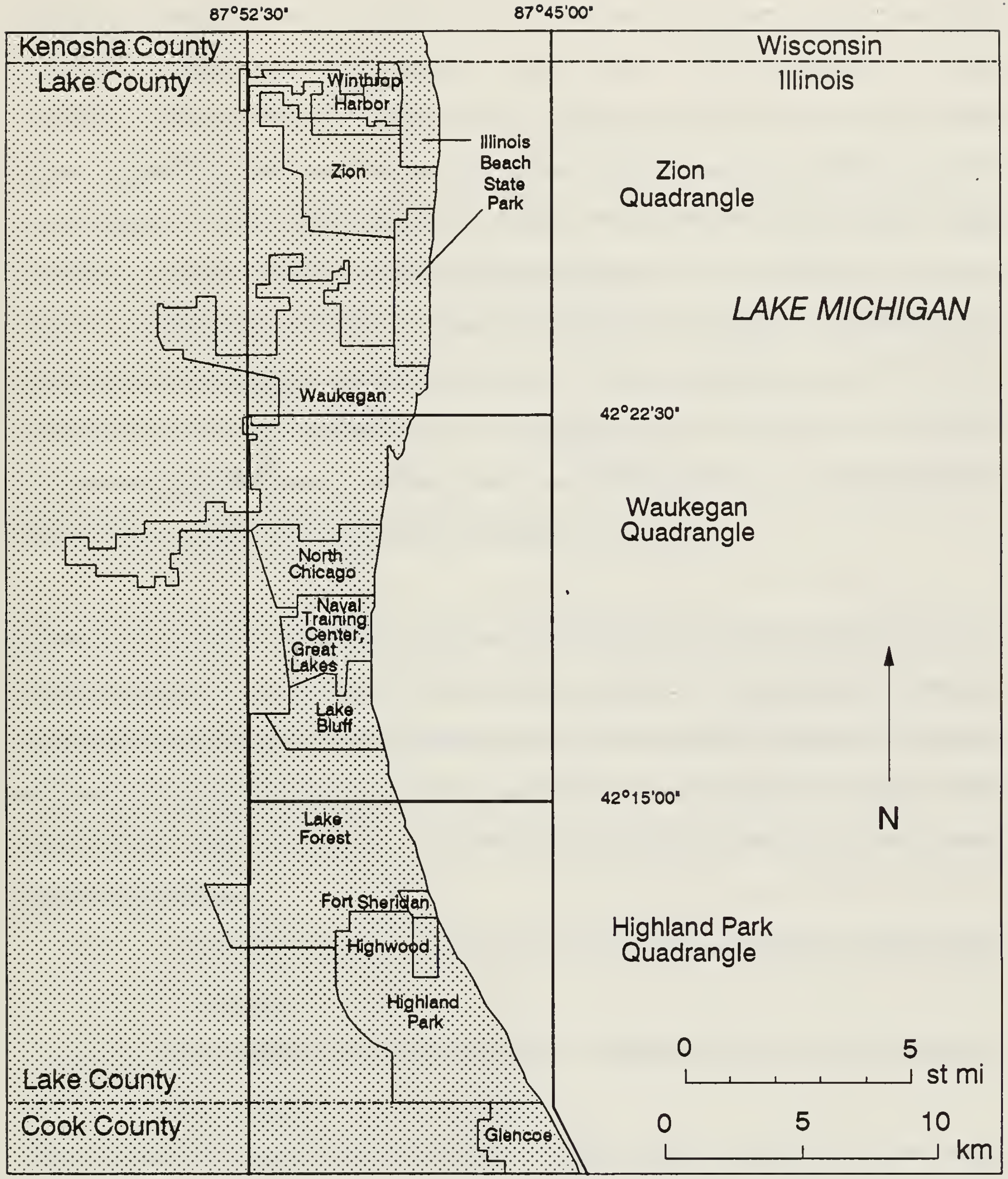

Figure 2. Map of the Lake County coast showing extent of municipalities, military reservations, state park land, and coverage by U.S. Geological Survey 7.5-minute topographic maps.

modified it. The beach and nearshore deposits consist of sand and gravelly sand that forms a lens extending along the coast in a narrow band. This lens pinches out about 1500 feet offshore (Shabica *et al.,* 1991). Lakeward of this coastal sand the lake bottom is glacial till that is either exposed or has a patchy veneer of sand and gravel. The bathymetry of the nearshore and offshore zones along the Lake County coast consists of a rather uniform, gently sloping lake bottom. At a distance of one mile offshore, depths range from 25 to 30 feet. No shoals or lake-bottom irregularities are present that might cause variations in the wave energy impinging along the shore. Greatest wave energy corresponds to the greatest fetch which is in a north-northeasterly direction along the long axis of Lake Michigan (Fig. 1). As a result, net littoral transport along the Lake County coast is southward.

Although all of the Lake County coast was an erosional bluff coast through much of late Wisconsinan and early to mid-Holocene time, evidence from radiocarbon dating of basal peats from coastal marshes indicate that extensive beach-ridge plain accretion occurred along the northern part of the county lakeshore during the previous 4000 years (Larsen, 1985). As a result, the Lake County coast now consists of two coastal geomorphic settings:

1) Zion beach-ridge plain: a low-lying accretion plain in the northern part of the county, and
2) Lake Border Moraines bluff coast: a high-relief coast in the central and southern parts of the county.

These two geomorphic settings, delineated in Figure 3, are described in the following two sections.

Zion Beach-Ridge Plain

From the Illinois-Wisconsin state line south for 12 miles to North Chicago, the shoreline

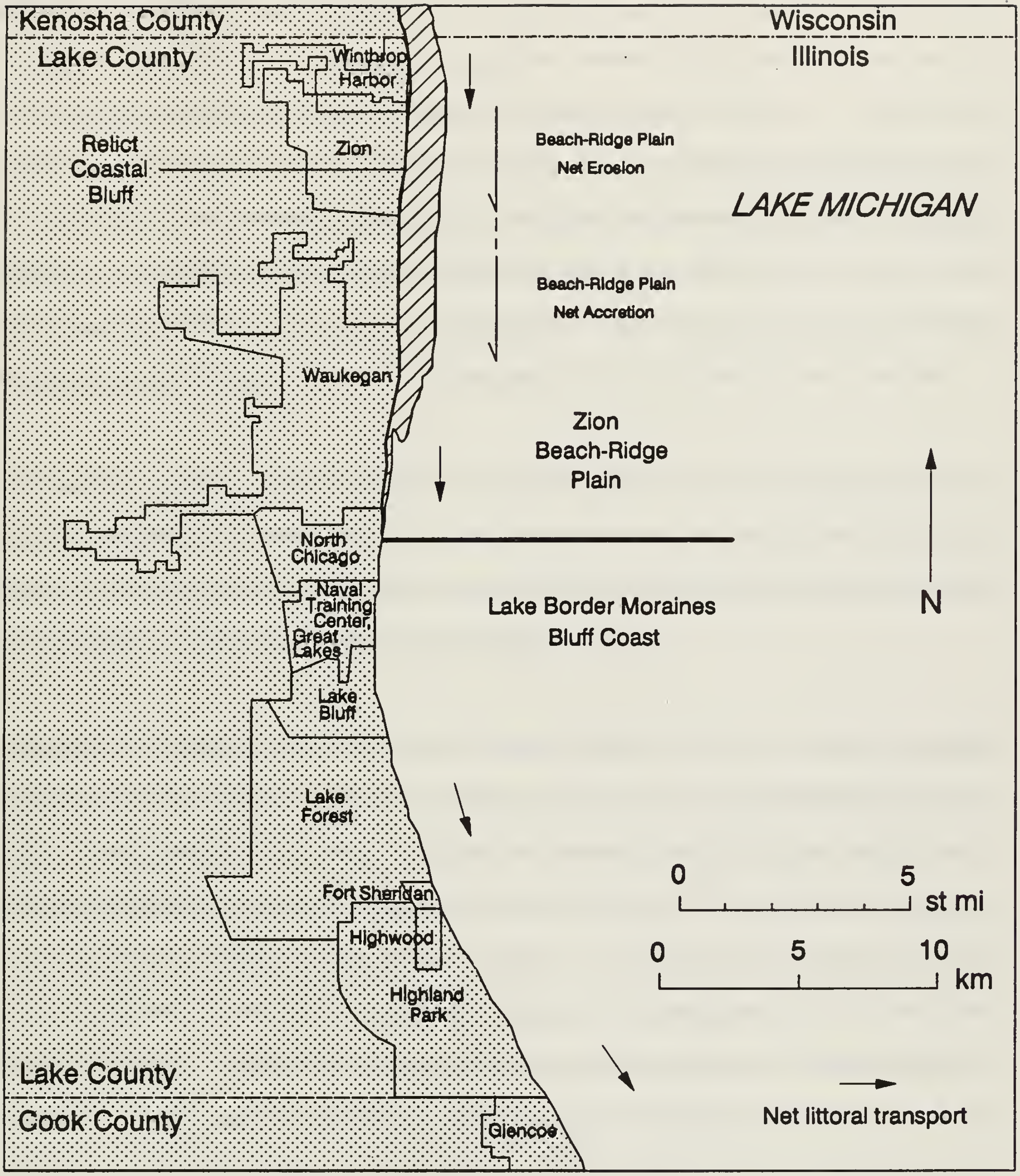

Figure 3. Division of the Lake County coast into two coastal geomorphic settings.

is along an extensive beach-ridge plain. The northern limit of the plain is about 8 miles north of the state line near Kenosha, Wisconsin. Within Illinois the plain has an area of nearly nine square miles and a maximum width of about one mile. Most of the Illinois part of the plain is within the North and South Units of Illinois Beach State Park. This accretion plain consists of low-lying sand ridges and inter-ridge swales of coastal wetlands. Crest elevations along the ridges and dunes are about 10 to 15 feet above mean lake level. The only reach of coastline in Illinois free of any shore-defense structures occurs along 2.6 miles of shoreline in the South Unit of the state park.

This beach-ridge plain consists mainly of gravelly sand, but also includes sand, silt, clay and organic-rich sediments. In coast-perpendicular cross section the plain is lenticular with a maximum thickness of 30 to 35 feet along the shoreline, and thinning both landward and lakeward (Fraser and Hester, 1974).

Radiocarbon dating of inter-ridge basal peats indicates that beach-ridge accretion advanced southward across the Illinois-Wisconsin state line about 3700 BP (Larsen, 1985). The accretion occurred lakeward of formerly coastal bluffs that are now abandoned along the western margin of the plain (Fig. 3). The southward migration of the plain is occurring in a "tank-tread" fashion in that sediment is eroded from the northern (updrift) reach, transported down coast, and deposited along the southern (downdrift) reach. In the northern part of the beach-ridge plain, relict beach ridges are truncated by the modern shoreline, indicating that net erosion has occurred. To the south, in the northern part of the South Unit of Illinois Beach State Park, relict beach ridges are tangential to the present-day shoreline, indicating accretion. The transition zone between net erosion and net accretion is thus presently located in the northern part of the state park's South Unit.

Since the late 1800s, the most severe coastal erosion documented along the Illinois coast has occurred along the northern reach of the beach-ridge plain, particularly within one-half to one mile south of the Illinois-Wisconsin state line. Examination of historical shorelines dating from 1872 shows that the long-term annual recession rate just south of the state line has averaged about 10 feet/year (U.S. Army Corps of Engineers, 1953; State of Illinois Division of Waterways, 1958; Jennings, 1990). In 1989, following construction of North Point Marina, recession along a lakefill/feeder beach along this reach totalled nearly 200 feet which is the most rapid annual recession of shoreline ever documented on the Illinois coast (Terpstra and Chrzastowski, 1992).

In terms of area and volume, the greatest human-induced accretion of littoral sediment along the Illinois coast has occurred along the southern end of the beach-ridge plain at Waukegan. Beginning in the late 1800s, construction of jetties for the entrance channel to Waukegan Harbor formed a near-total barrier to net southerly littoral transport. A fillet began to form soon after construction of the jetties, and the fillet area and volume increased as several generations of jetty extension occurred (Bottin, 1988). At present a shoreline offset of 2300 feet occurs between the updrift (north) and downdrift (south) sides of the harbor entrance (Fig. 3).

Lake Border Moraines Bluff Coast

For approximately 13.6 miles from North Chicago southward to the southern limit of Lake County, the coast is along bluffs of the Lake Border Morainic Complex. This complex consists of end moraines formed during recession of the Lake Michigan ice lobe about 14,500 to 14,000 B.P. The curvilinear trend of the coast parallels the axes of the moraines. Most of the bluff coast borders the Highland Park Moraine, but the northern reach at North Chicago borders the younger Zion City Moraine (Willman and Lineback, 1970). The bluffs are cut by a series of V-shaped ravines extending up to

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one mile landward with the heads of the ravines near the crest of the Highland Park Moraine. Intermittent streams along these ravines are the primary surface drainage east of the moraine crest into Lake Michigan.

Bluff heights average about 72 feet above mean lake level, but reach a maximum height of 88 feet above mean lake level at Highland Park. Bluff materials are primarily a clay glacial till, but include beds of glacial-lacustrine deposits (Clark and Rudloff, 1990). Average composition of the bluff materials is 10% sand, 42% silt, and 48% clay (Lineback, 1974). The dominance of fine-grained sediments allows steep bluff faces to develop, ranging from 25 degrees to nearly vertical. Because of the predominantly fine-grained composition of the bluffs, only about 10% of the eroded bluff sediment is maintained as beach material. The remainder of the eroded sediment is rapidly transported away from the beach and nearshore zone to the offshore area.

Prior to urban development, the coastal bluffs were nearly all erosional, providing a sediment source to the beaches and littoral stream (Atwood and Goldthwait, 1908). Bluff recession resulted from both wave-induced erosion along the bluff toe and slope failures not directly due to wave erosion. Such slope failures were induced by inhomogeneity within the bluff materials and ground-water fluctuations in zones where coarse materials overlie fine-grained materials of low permeability.

In order to reduce the effects of coastal erosion, numerous shore-defense structures have been constructed along the bluff coast. The earliest and most abundant of these are groins. Two or more generations of groins have been built, with construction beginning in the 1800s or 1890s. Today a nearly continuous groin field extends from the harbor at Naval Training Center, Great Lakes south to the southern limit of Lake County. Aerial photographs from 1991 record a total of 243 groins along this 11.6-

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mile reach, an average of 21 groins per mile. Most of these groins are constructed of steel sheetpile. Some earlier-generation wooden structures remain but these are typically in a deteriorated state. Shore-parallel defense structures such as revetments and bulkheads commonly defend the bluff toes.

WAVE CLIMATE AND LITTORAL PROCESSES

Waves are the principal erosion agent along the Illinois lakeshore. Along this coast and the Great Lakes coast in general, wave magnitude is limited by fetch. The Illinois lakeshore has its greatest fetch (about 300 miles) toward the north-northeast. Waves from the northeast quadrant have the greatest energy and net influence along the Illinois coast.

The Illinois lakeshore does not experience the strength or duration of tropical and extratropical storms that impact the U.S. ocean coasts. The typically rapid eastward track of low-pressure systems limits the duration of winds blowing across the lake surface, and for any given storm high wave conditions generally last only one or two days. The strongest and most frequent storm waves along the Illinois coast occur in late spring and early fall .

Wave observations along the Illinois coast indicate that for any given year, average wave height is 1.5 to 2 feet, maximum wave height is typically about 8 feet, and extreme waves rarely exceed 10 to 12 feet. The average wave period is 4.0 seconds (U.S. Army Corps of Engineers, 1953).

Seiches can result from atmospheric pressure differences along the axis of the lake. Although seiches generally involve no more than a surge in lake level, if these waves

are extreme and move rapidly along the coast, they have the potential of causing rapid and severe shore erosion and property damage. For example, a seiche reaching a height of 10 feet impacted the Chicago lakeshore in June 1954 resulting in shore damage and loss of life (Ewing *et al.*, 1954).

Net littoral transport along the Illinois coast is southward. An exception occurs on the south side of large coastal structures where a localized shadow effect on northerly waves results in net northward transport. Although recent data on littoral transport are lacking, based on data from 1872, 1910, and 1946, the U.S. Army Corps of Engineers (1953) estimated transport along the beach-ridge plain coast at 90,000 cubic yards per year (cu yd/yr), and along the bluff coast at 57,000 cu yd/yr. The transport rate of 90,000 cu yd/yr is likely a reasonable estimate along much of the present-day beach-ridge plain because present conditions are much as they were during the period studied by the Corps. However, along much of the Lake County bluff coast present-day transport rates are likely less than 57,000 cu yd/yr and locally possibly less than half this rate, since in recent decades coastal engineering has restricted the supply and transport of littoral sediment.

During winter months, littoral processes can be affected by a nearshore ice complex that may or may not form depending on the degree and persistence of sub-freezing weather. This ice can protect the beach from wave impact, but the lakeward face of the ice can act as an ephemeral seawall causing downward deflection of wave energy and erosion of the lake floor. Wave-thrusted ice can cause damage to shore structures and induce erosion along beaches and bluff toes. In addition, when breakup of the ice complex occurs, sediment incorporated in the ice by wave action can be transported by ice rafting. Recent studies along the Illinois coast have shown that the development and dissipation of the nearshore ice complex is a factor in the net loss of

sediment from the littoral zone (Reimnitz *et al.*, 1991; Barnes *et al.*, 1992a, 1992b; Kempema *et al.*, 1992a, 1992b). Along reaches of minimal annual littoral transport, this process of sediment loss may be quantitatively significant, but additional studies are needed to fully evaluate the net impact.

DATUMS FOR LAKE LEVEL

Although Lake Michigan and Lake Huron are considered separate lakes, they function hydraulically as a single lake of common elevation connected by the Straits of Mackinac. Thus the phrase "Lakes Michigan-Huron" is commonly used in reference to the lake elevations, and a single mean elevation, seasonal variation, and chart datum are applicable to both lakes.

Historical Datums

Several datum changes have occurred throughout the history of monitoring lake levels in the Great Lakes. Early records of Lakes Michigan-Huron lake levels were referred to local datums or were relative to the so-called "High Water of 1838" which was an extreme high lake level experienced in all the Great Lakes. Datums were later established for low waters of 1903 and 1909. After expansion of level surveys in the eastern U.S., in 1935 the U.S. Army Corps of Engineers established a system of datums for the Great Lakes referenced to Mean Tide New York (MTNY 1935). For bathymetric surveys and chart production, a Lakes Michigan-Huron Low Water Datum (LWD) or "chart datum" was established at +578.50 feet MTNY (1935).

The datums of 1903, 1909, and 1935 were abandoned in the late 1950s and 1960s in favor of the International Great Lakes Datum 1955 (IGLD 1955). IGLD 1955 was established by agreement of the United States and Canadian Coordinating Committee

on Great Lakes Basic Hydraulic and Hydrologic Data. IGLD 1955 was the first single vertical reference to be used by both countries for all the Great Lakes and connecting waterways. The reference zero point was at Father Point (*Pointe-au-Père*), Quebec on the St. Lawrence estuary. At the time IGLD 1955 was established, it was recognized that this datum would need to be revised periodically because of isostatic adjustments still occurring in the Great Lakes region. IGLD 1955 was the datum used through the end of 1991.

Establishment of IGLD 1985

As of January 1, 1992, the datum for Great Lakes water levels is IGLD 1985. The datum year 1985 is the central year of the period 1982-1988 during which level data were collected for the datum revision. For IGLD 1985, a new reference zero point was established at Rimouski, Quebec on the St. Lawrence estuary. This location is approximately four miles west of the former reference at Father Point.

The elevation of Lakes Michigan-Huron LWD is +576.80 feet IGLD 1955 and +577.50 feet IGLD 1985 . The adjustment for Lakes Michigan-Huron LWD from IGLD 1955 to IGLD 1985 is thus +0.70 feet. IGLD 1985 does not change water levels established for flood insurance purposes since these elevations are referenced to National Geodetic Vertical Datum 1929 (NGVD 1929). However, when the North American Vertical Datum 1988 (NAVD 1988) is implemented, it will supersede NGVD 1929, and elevations referenced to NGVD 1929 will be revised.

Table 2 shows common datums used on the Illinois lakeshore and corrections between datums. IGLD elevations are the present standard for lake-level statistics compiled and reported by the National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOAA-NOS) and the U.S. Army Corps of Engineers. LWD is the

Table 2. Conversion table for common datums used for lake levels and coastal elevations along the Illinois shore of Lake Michigan.

Given Datum (in feet)	To Convert to Datum (in feet)						
	IGLD 1955	IGLD 1985	LWD[1]	OHWM[2]	MTNY 1935	MSL 1912	NGVD 1929
IGLD 1955	--	+0.70	-576.80	-580.80	+1.70	+1.74[3]	+1.30
IGLD 1985	-0.70	--	-577.50	-581.50	+2.40	+2.44[3]	+2.00
LWD	+576.80	+577.50	--	+4.00	+578.50	+578.53	+578.10[3]
OHWM	+580.80	+581.50	-4.00	--	+582.50	+582.53	+582.10
MTNY 1935	-1.70	-2.40	-578.50	-582.50	--	+0.04[3]	-0.40
MSL 1912	-1.74[3]	-2.44[3]	-578.53	-582.53	-0.04[3]	--	-0.44[3]
NGVD 1929	-1.30	-2.00	-578.10[3]	-582.10	+0.40	+0.44[3]	--

Acronyms:
IGLD = International Great Lakes Datum
LWD = Low Water Datum
OHWM = Ordinary High Water Mark
MTNY = Mean Tide New York
MSL = Mean Sea Level
NGVD = National Geodetic Vertical Datum

[1]Lakes Michigan-Huron Low Water Datum (chart datum).
[2]Defined by U.S. Army Corps of Engineers.
[3]Elevations referenced to Lockport, Illinois.

standard datum for bathymetric surveys conducted by federal and most state agencies, although lakeshore municipalities may conduct bathymetric surveys referenced to their municipal datums.

Lake-Level Datums and Shoreline Mapping

One difficulty in comparing shoreline mapping along the Illinois shore of Lake Michigan is that no specific lake level or datum is universally used as a shoreline reference. There is no recognized Mean High Water (MHW) as occurs on the U.S. Atlantic Ocean or Gulf of Mexico coasts.

The MHW line is the shoreline reference on ocean-coast historical shoreline maps by the U.S. Coast Survey and U.S. Coast and Geodetic Survey (Shalowitz, 1964). Although the U.S. Army Corps of Engineers defines an Ordinary High Water Mark (OHWM) for the Great Lakes, this is for regulatory functions and is not used as a shoreline mapping datum.

U.S. Geological Survey (USGS) topographic maps note the approximate mean lake elevation of 580 feet (NGVD 1929) and provide selected depth contours referenced to LWD, but the shoreline has no specific datum reference. NOAA-NOS nautical charts have depths referenced to LWD, but also have no specific datum reference for the shoreline.

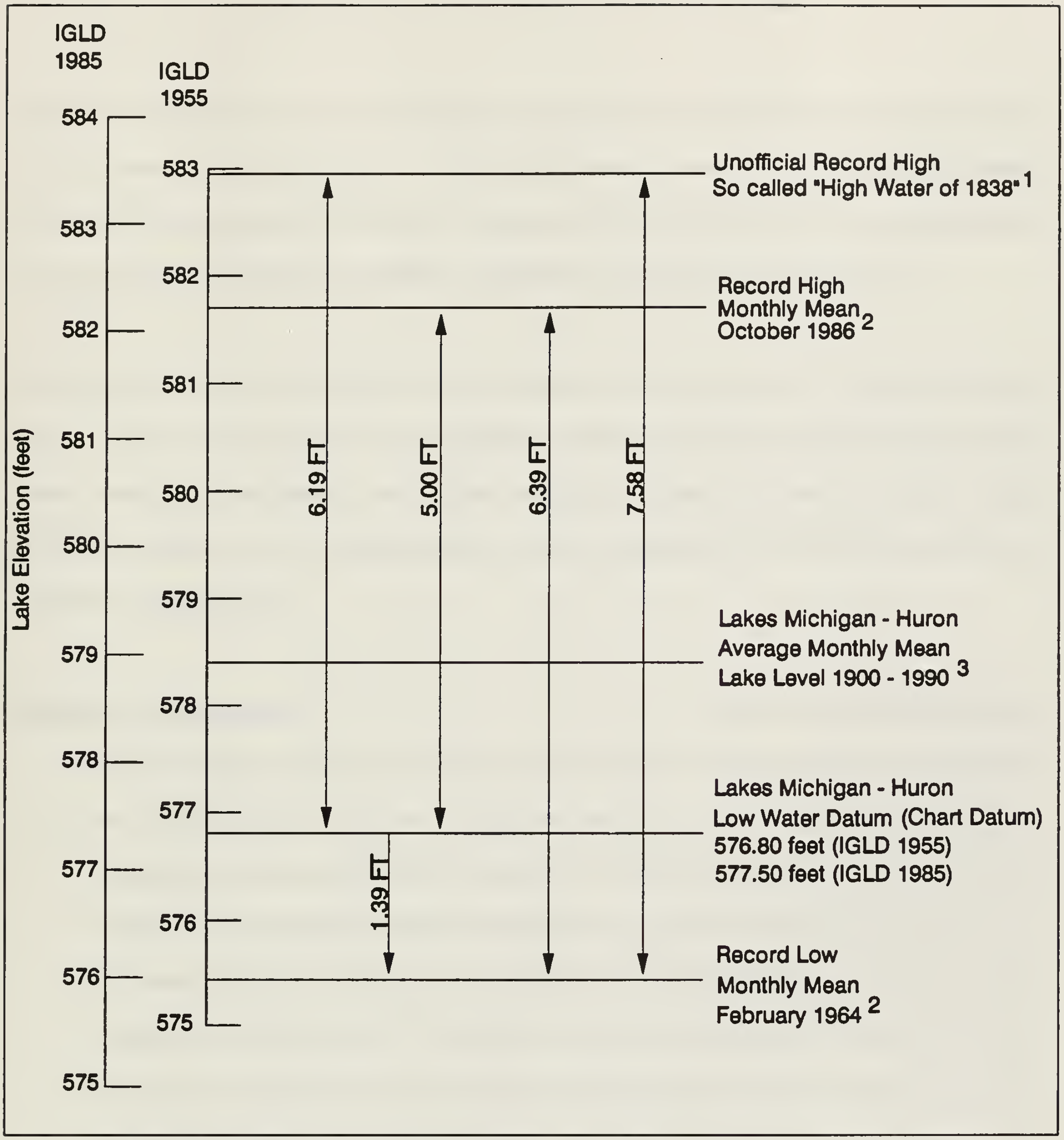
LAKE-LEVEL FLUCTUATIONS

Translations in shoreline position occur on the Illinois coast on varied time scales due to fluctuations in lake level. Yearly, seasonal and monthly lake-level fluctuations are caused by changes in the water budget. The annual fluctuation in lake level for Lakes

Michigan-Huron is about one foot with high water in summer and low water in winter. On time scales of days and hours, seiches occur that are caused by atmospheric pressure differences across the lake, and storm surges occur as strong and persistent winds force waters to accumulate along the coast. A potential extreme storm surge in southern Lake Michigan has been determined to be 1.7 feet (U.S. Army Corps of Engineers, 1978).

Regular monitoring and documentation of lake level by federal agencies began in 1860 with the U.S. Lake Survey. Lake levels along the Illinois and southern Wisconsin coast are currently monitored by NOAA-NOS gauges at Calumet Harbor, Illinois (Station No. 7044) and Milwaukee, Wisconsin (Station No. 7057). The Lake County coast is approximately midway between these gauges. For the Calumet Harbor gauge, the record high monthly mean lake level of 581.80 ft (IGLD 1955) occurred in October 1986; the record low monthly mean of 575.41 ft (IGLD 1955) occurred in February 1964 (Fig. 4). This is a historical extreme range of 6.39 ft in lake-level change. Unofficial lake-level observations on Lakes Michigan-Huron date to about 1800 (U.S. Deep Waterways Commission, 1897). The High Water of 1838 reached an approximate elevation of 582.99 ft (IGLD 1955). A comparison of the High Water of 1838 and the historical record low water in 1964 gives an extreme range of recorded lake-level variation of 7.58 ft.

Although for practical purposes the Lake Michigan coast is considered tideless, both solar and lunar tides have been recorded in southern Lake Michigan with a combined effect less than two inches (U.S. Army Corps Engineers, 1953).



[1] U.S. Deep Waterways Commission, (1897)

[2] NOAA, National Ocean Service; record for gauge at Calumet Harbor, Illinois

[3] U.S. Army Corps of Engineers; Monthly Bulletin of Lake Levels for the Great Lakes

Figure 4. Historical range of lake-level change in Lake Michigan.

CORRIDORS FOR THE EROSION-RATE STUDY

Along the 26 miles of Lake County coast, five one-mile long corridors were selected for the erosion-rate study (Fig. 5). The five corridors were selected to cover the range of variability along the Lake County coast in terms of differing rates and direction of shoreline change, effects of coastal engineering, and bluff recession rates.

This section describes the coastal characteristics of each corridor. Figures 6 through 10 are maps of each of the five corridors showing locations of the upland control points used in the registration of vertical aerial photographs for each corridor. Maps showing location of the control points used in registering the historical maps are included in Appendix B.

<u>Corridor 1: North Point</u> **USGS 7.5′ Zion Quadrangle**

This corridor extends one mile southward from the Illinois-Wisconsin state line and lies entirely within the erosional reach of the Zion beach-ridge plain. Coastal erosion was a major problem for the residential community of Spring Bluff which formerly occupied this lakeshore. Despite various attempts at shore defense, this community was abandoned in the late 1970s, and the State of Illinois acquired the land. The historical shoreline changes along this corridor reveal the most persistent and severe historical shoreline recession on the Illinois lakeshore. The coastal erosion was one impetus for construction of the North Point Marina. Construction of this state-owned, 1500-slip marina began in 1987. The marina basin straddles the pre-construction shoreline and was formed by a combination of excavating into the beach and backshore and building shore-attached, rubble-mound breakwaters into the nearshore.

Corridor 2: Waukegan Harbor — USGS 7.5′ Waukegan Quadrangle

This corridor straddles the jetties defending the entrance to Waukegan Harbor. This is a deep-water, federally maintained harbor with an entrance-channel controlling depth of 23 to 25 feet. The corridor is mainly along the accretionary southern reach of the Zion beach-ridge plain. The natural accretionary trends have been augmented by littoral sediment entrapment against the channel-entrance north jetty. This total to near-total barrier to the net southerly littoral transport has resulted in the greatest human-induced coastal accretion on the Lake Michigan coast. Although the historical shoreline changes are progradational rather than recessional, this area offers the opportunity to evaluate mapping procedures along a reach having a low-slope foreshore (~1:60). This low slope has resulted in pronounced shoreline changes on various time scales, both by entrapment of littoral sediment and by shoreline translations caused by fluctuations in lake level.

Corridor 3: Lake Bluff — USGS 7.5′ Waukegan Quadrangle

This corridor is the northernmost of the three selected corridors along the bluff coast of central and southern Lake County. The corridor is on the south (downdrift) side of the harbor for Naval Training Center, Great Lakes. The harbor is formed by shore-attached, concrete breakwaters that extend 2300 feet lakeward of the pre-construction shoreline. Since their construction in 1923, the breakwaters have formed a total to near-total barrier to littoral transport. This corridor was chosen because it is part of a coastal reach that had natural rates of bluff recession in the late 1800s and early 1900s. Extreme erosion in the mid-1900s followed the breakwater construction and subsequent littoral sediment starvation. The coast has had little to no recession in the late 1900s due to construction of shore-defense structures.

Corridor 4: Lake Forest — USGS 7.5' Highland Park Quadrangle

This corridor is located at the southern end of the shoreline within the City of Lake Forest and adjoins the northern limit of Fort Sheridan. The last major stretch of undefended coastal bluffs on the Illinois coast is present in the southern part of this corridor along the Lake Forest Nature Preserve. Here shoreline and bluffline recession have been unaffected by local coastal engineering throughout the entire time period covered by this study. Modes of slope failure that have occurred here include creep, earthflows, debris falls, and slumps. The northern part of the corridor consists of an engineered coast along residential lakeshore properties, and is typical of most of the Lake County coast extending northward to Waukegan. This corridor reflects this contrast between the entirely engineered northern reach and the entirely undefended southern reach.

Corridor 5: Highland Park — USGS 7.5' Highland Park Quadrangle

The Highland Park corridor is within the reach of the highest bluffs along the Illinois coast. These bluffs are as much as 88 feet above mean lake level in the northern part of the corridor. The corridor is dominated by residential lakeshore property which is typical of nearly all the Lake County coast south of Fort Sheridan. Defense structures are common along the shoreline and/or at the bluff toe. An essentially continuous groin field extends along the corridor.

[illegible]

[illegible]

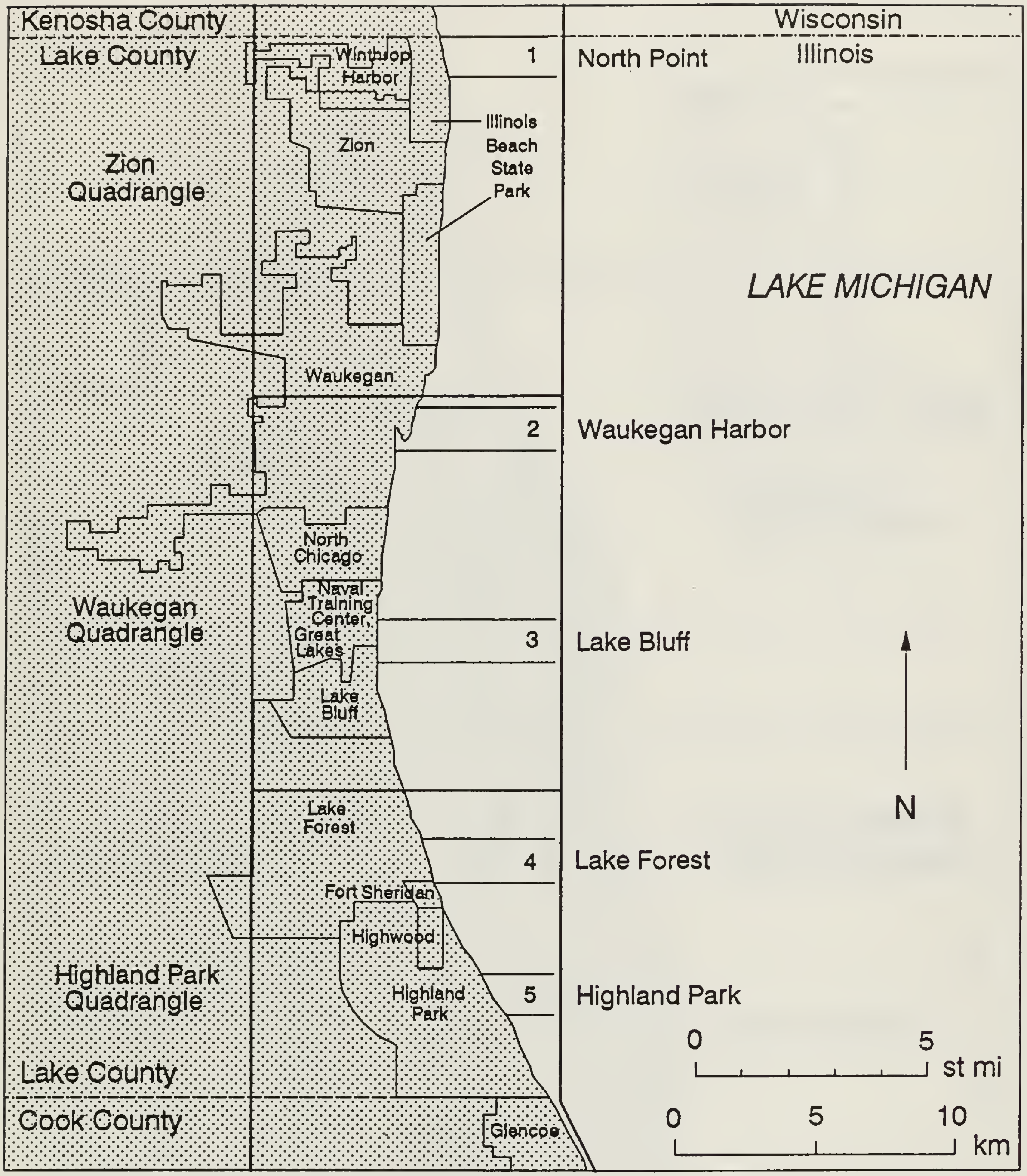


Figure 5. Location and designation of the five one-mile wide corridors along the Lake County coast for which erosion-rate data were generated. The limits of U.S. Geological Survey quadrangles are shown for reference.

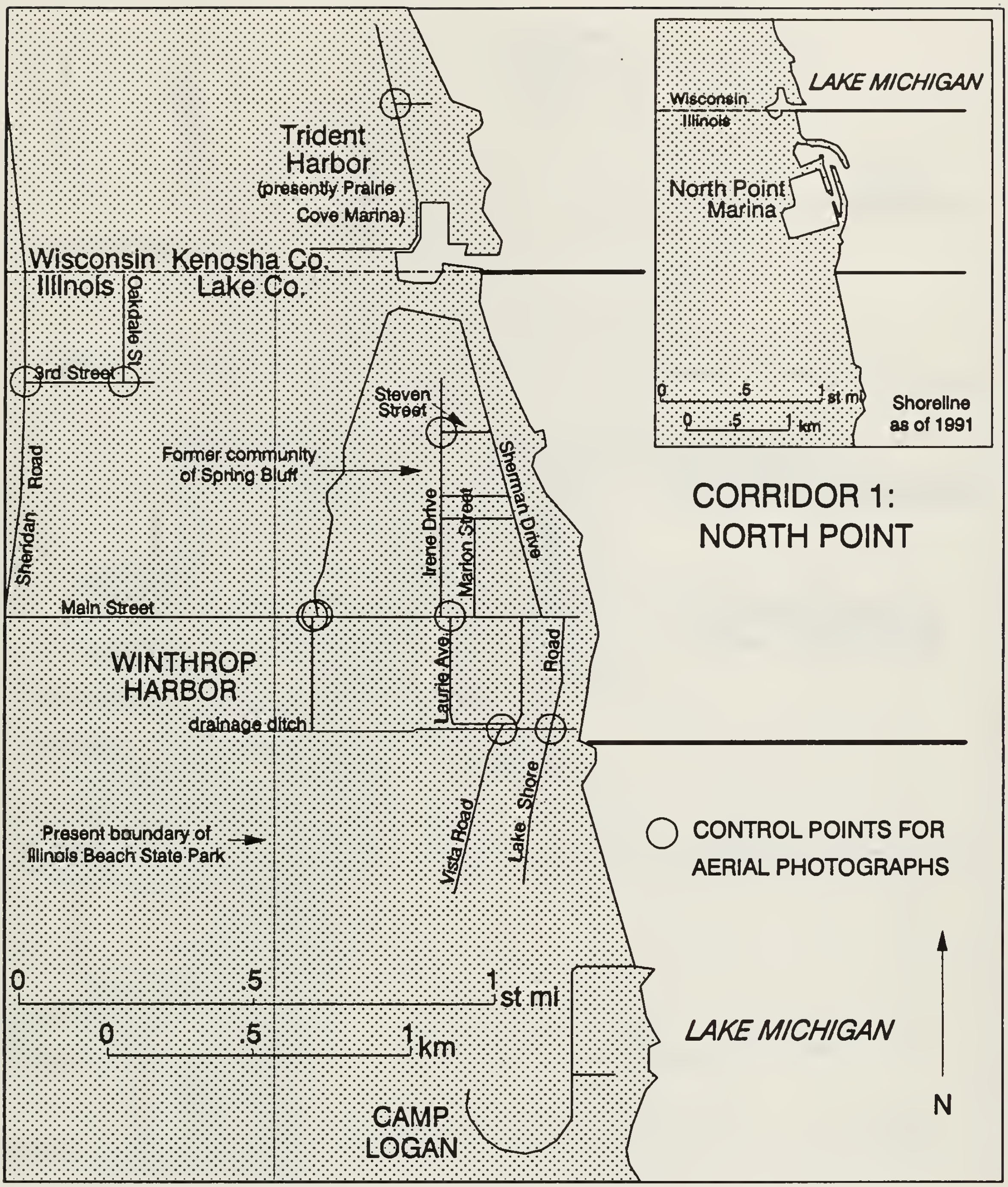


Figure 6. Map of Corridor 1 (North Point) and location of ground control points for registration of vertical aerial photographs. Inset map shows present coast with inclusion of North Point Marina.

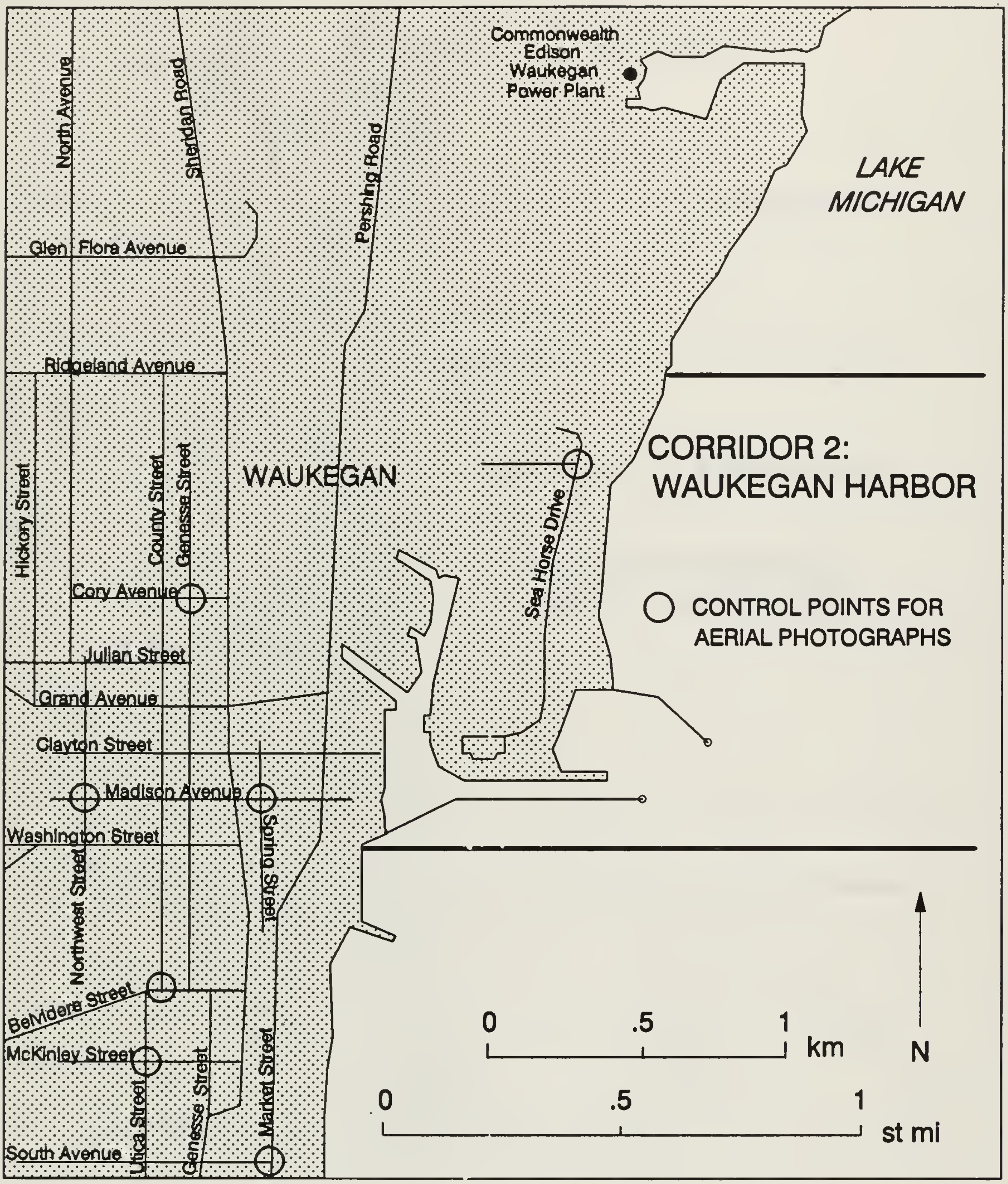


Figure 7. Map of Corridor 2 (Waukegan Harbor) and ground control points for registration of vertical aerial photographs.

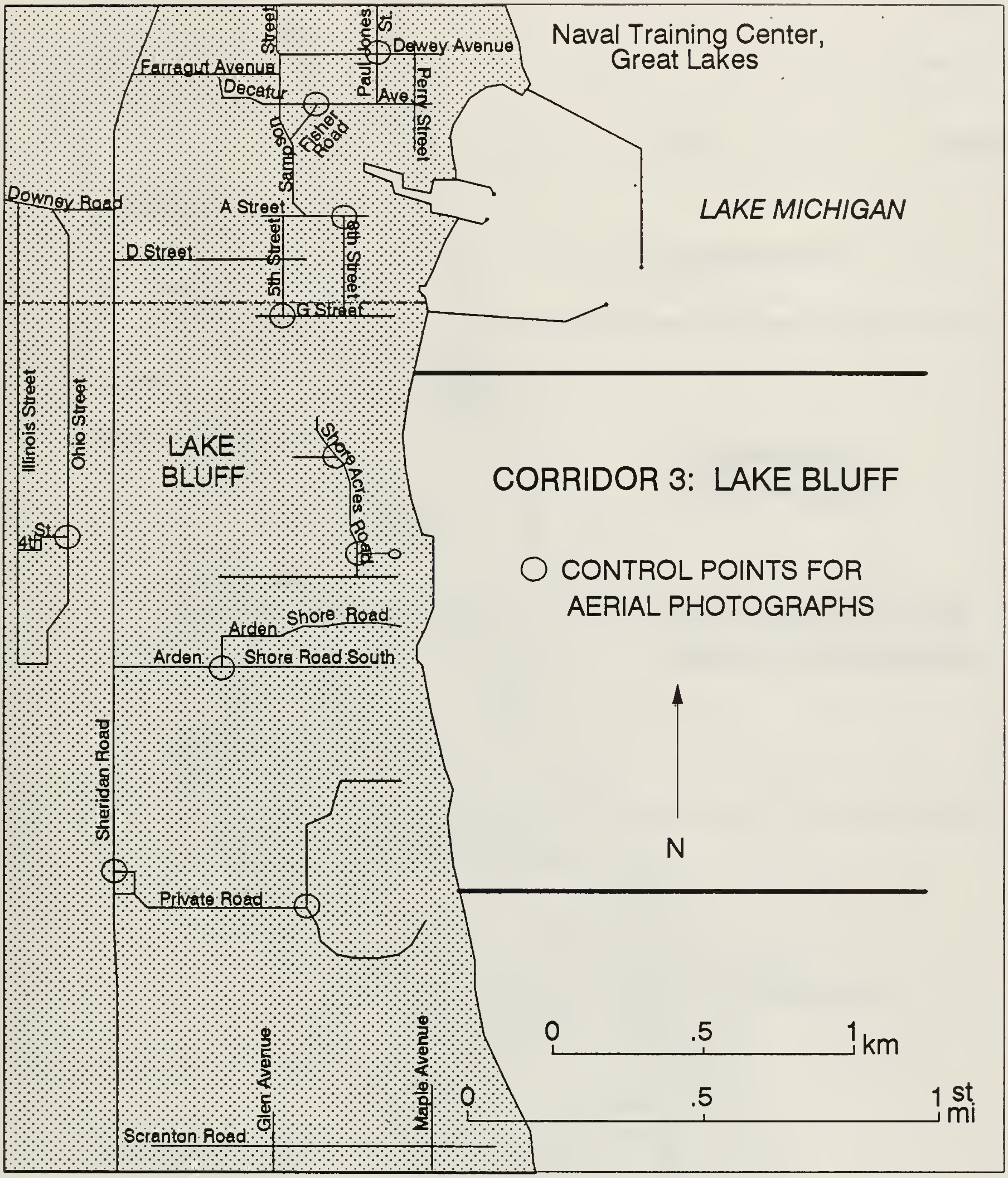


Figure 8. Map of Corridor 3 (Lake Bluff) and ground control points for registration of vertical aerial photographs.

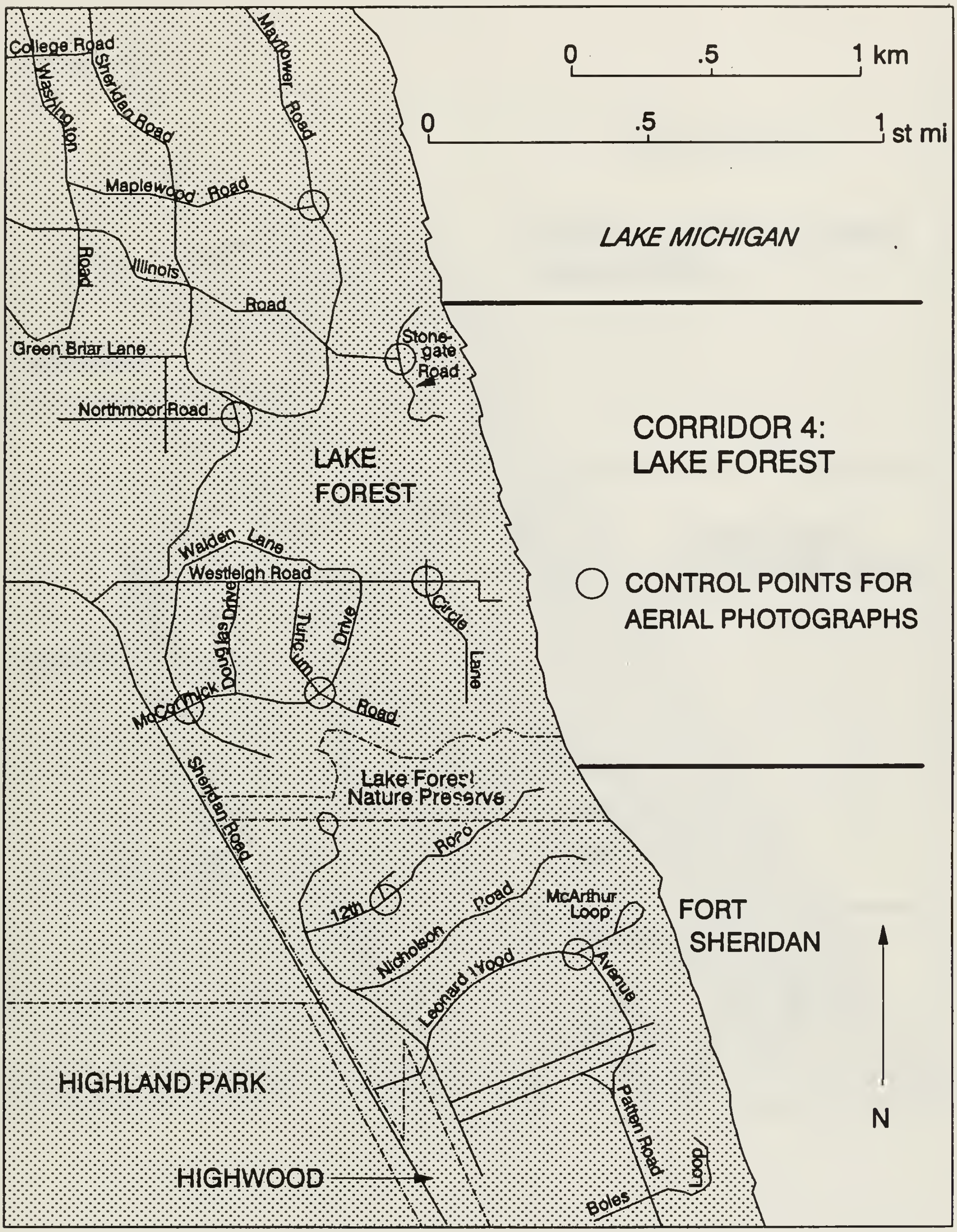
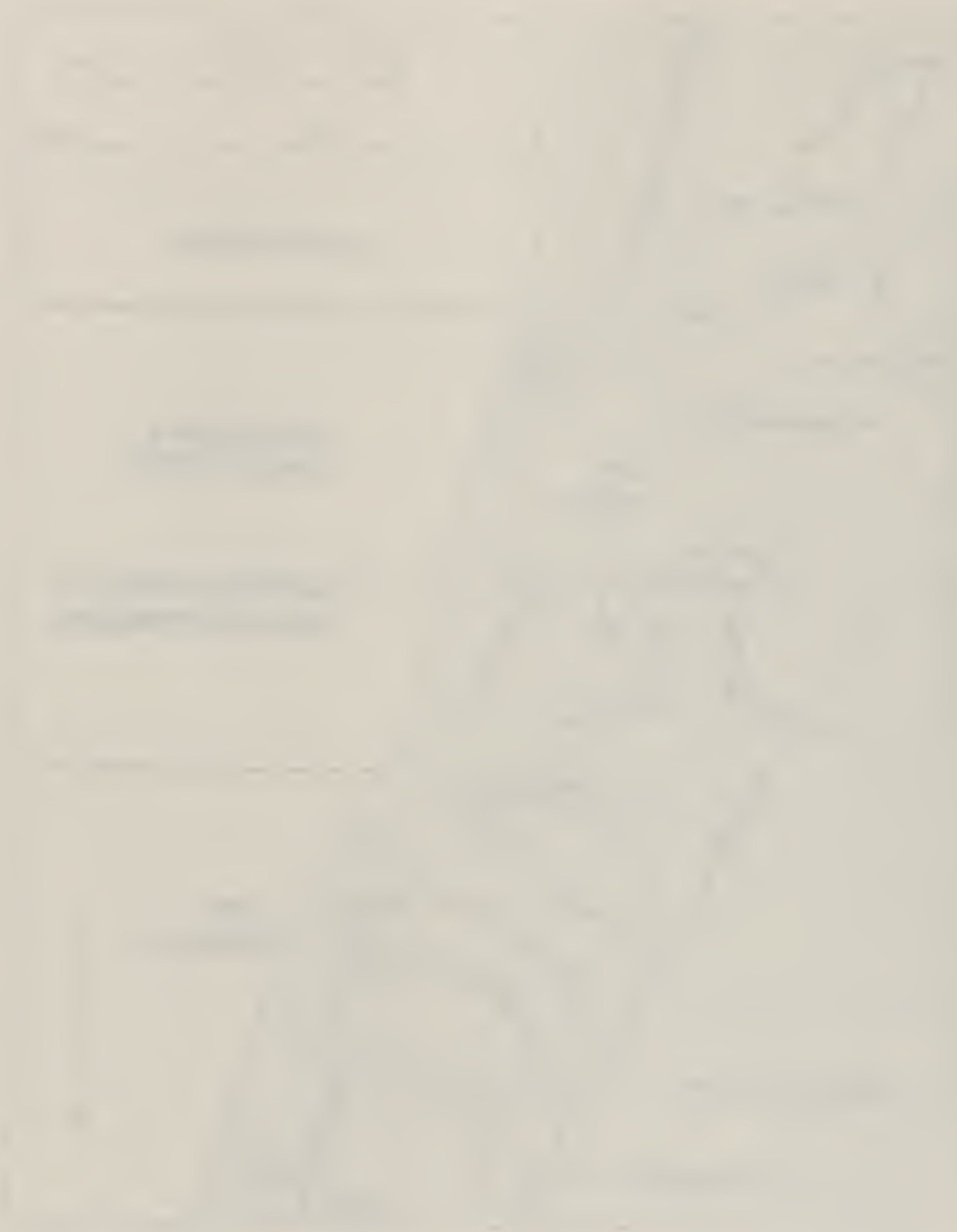


Figure 9. Map of Corridor 4 (Lake Forest) and ground control points for registration of vertical aerial photographs.



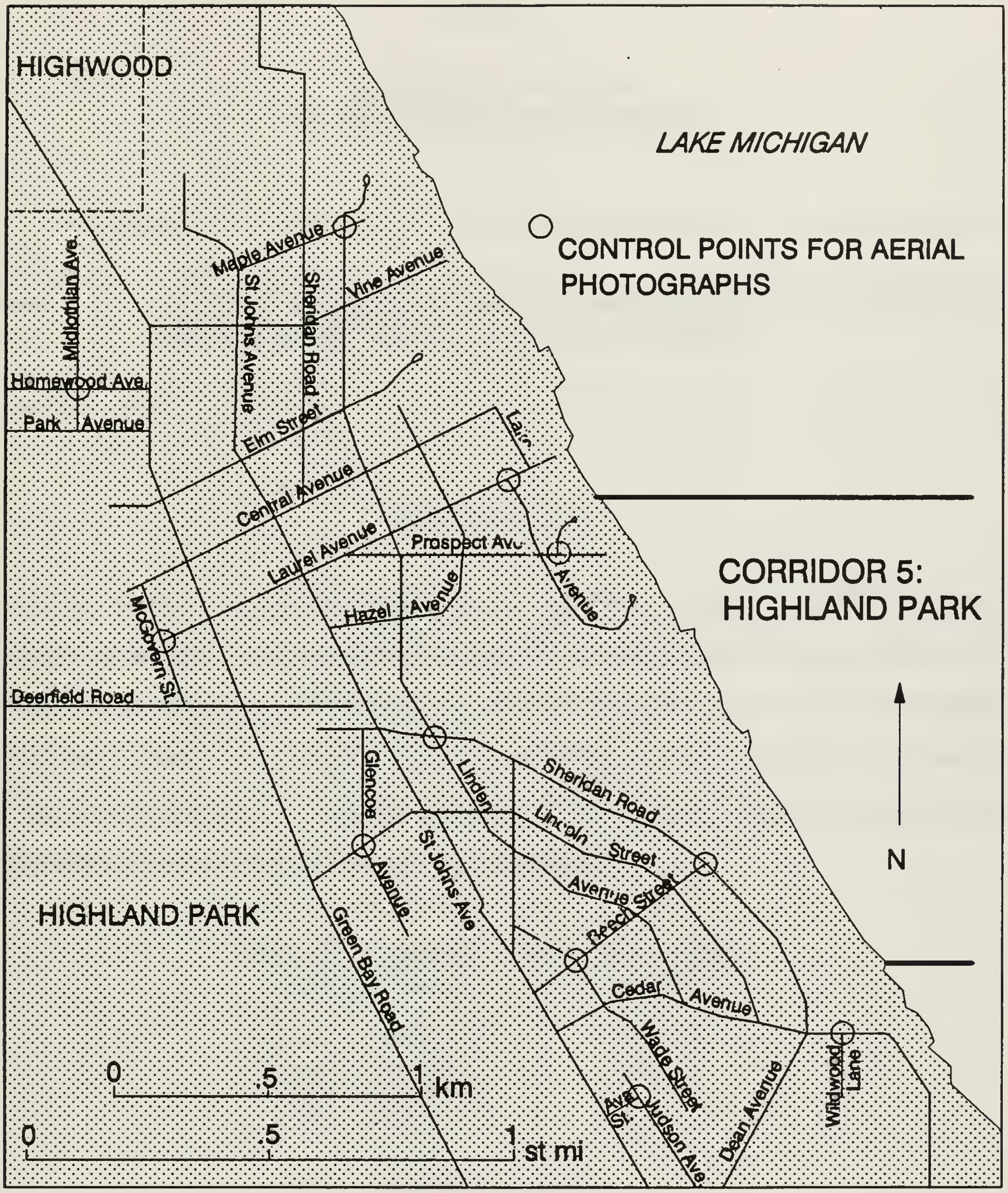


Figure 10. Map of Corridor 5 (Highland Park) and ground control points for registration of vertical aerial photographs.

PART 3

DOCUMENTATION OF SPECIFIC STUDY TASKS

TASK 1: COLLECTION AND DIGITIZING OF SHORELINE DATA TO CREATE THE HISTORICAL SHORELINE LOCATION DATABASE

DATA SOURCES

The data sources for historical shoreline and bluffline locations consisted of two historical map data sets and two vertical aerial photograph data sets, as required by the study. Information on the offices from which these data sources were obtained is included in Appendix A. This study also required data sets to be spaced temporally at approximately 35- to 60-year intervals. The selected data sets meet this requirement. The temporal spacing is the following:

Dates of Successive Data Sources	Temporal Spacing in Years
1872-73 / 1909-11	37
1910-11 / 1947	37
1947 / 1987	40

Historical Maps

The earliest topographic and hydrographic surveys along the Illinois coast were completed in the early 1800s by the U.S. Army Topographical Engineers. Mapping was limited to areas where the U.S. Army was planning or building shore structures for harbors of refuge. Many of these maps appear in the annual reports of the Chief

of Engineers and in Congressional records (*e.g.*, U.S. Congress, 1839).

The first surveys covering a broad extent of the Illinois coast were done by the U.S. Lake Survey. This agency was established in 1841 as a distinct Great Lakes topographic and hydrographic survey unit within the U.S. Army and grew out of the Corps of Topographical Engineers (Woodford, 1991). For over 100 years the U.S. Lake Survey (USLS) performed surveys and produced nautical charts for the Great Lakes, as the U.S. Coast and Geodetic Survey did for the U.S. ocean coasts. The USLS headquarters in Detroit, Michigan existed until October 1970 when this was redesignated the U.S. Lake Center, removed from the U.S. Army Corps of Engineers, and placed within the National Ocean Survey of NOAA[1]. The U.S. Lake Center operated as a NOAA-NOS office until it was closed in March 1976. Since 1976 all functions of the former U.S. Lake Center have been incorporated into the NOAA-NOS offices in Rockville, Maryland.

Earliest USLS mapping for the Lake County, Illinois coast was conducted in 1872 on the northernmost Illinois shore for a distance 4.3 miles south of the Illinois-Wisconsin state line. Surveys from this point southward for the remainder of Lake County are dated 1873. Although two different years are given to these different field sheets, for simplicity these are here commonly referred to as the 1872 survey. The next USLS field sheets along the Lake County coast are dated 1909-11 and 1910-11. For simplicity these are here commonly referred to as the 1910 survey which is the mid-year of the three survey years. This use of 1872 and 1910 is consistent with the shorthand designation previously used in reports by the U.S. Army Corps of Engineers (1953) and the State of Illinois Division of Waterways (1958). When specific field

[1]The National Ocean Survey was renamed the National Ocean Service in 1983. Throughout the remainder of this report, the name National Ocean Service is used for times both prior and subsequent to 1983.

sheets are referred to, the specific sheet date(s) are used.

Both the 1872 and 1910 USLS field sheets show bathymetry, shoreline, and topographic features similar in format to "T sheets" and "H sheets" prepared for the ocean coasts by the U.S. Coast and Geodetic Survey (USC&GS). The USLS field procedures changed with time, but the early topographic surveys were completed with theodolites, stadia rods, and plane table alidades; hydrographic surveys were done with sextants for horizontal control and lead lines for soundings. Field procedures for the USLS surveys are discussed in a report by the U.S. Engineer Department (1873). The field season was typically five months in length from May through September (Woodward, 1991).

The 1872 and 1910 surveys were used in this study as the two sources for historical shoreline and bluffline map data. Stable base (bromide) copies of the field sheets were purchased from NOAA-NOS Hydrographic Surveys Branch, Data Control Section located in Rockville, Maryland. According to that office, no known Descriptive Reports exist to accompany these USLS surveys as accompany USC&GS and NOS surveys.

The identification numbers originally given to these field sheets by the USLS still appear on the sheets and begin with the number "1" followed by a hyphen and a three-digit number. These maps are presently indexed by NOAA-NOS Data Control Section as beginning with the letter "I". This alpha-identification is thus comparable to the indexing "T" for topographic and "H" for hydrographic used by the USC&GS. For consistency with present NOAA-NOS indexing, these USLS maps are here referred to with a letter "I" in the registration number.

Three sheets were needed for each of the two surveys (six sheets total) to provide

total coverage of the coast of Lake County, Illinois. Tables 3 and 4 provide documentation for the sheets of the two surveys. Reproductions of the field sheet coverage for each data set for each of the five corridors are provided in Appendix C. A general description of these sheets follows.

1872 and 1873 U.S. Lake Survey Field Sheets

The 1872 and 1873 surveys include upland land use and land cover for distances inland ranging from about 0.5 to 1.5 miles. Soundings from lead-line surveys extend along shore-normal and shore-oblique track lines up to 1.5 miles offshore and a maximum depth of about 30 feet. All depths are referenced to the lake level at the time of the survey. Notes were added to the sheets by the Corps of Engineers on April 16, 1947 indicating that the lake level at the time of the survey was 580.9 feet above Mean Tide New York (MTNY 1935). This is 2.4 feet above Low Water Datum. Along the bluff coast unlabeled topographic contours apparently have a 20-foot contour interval. The sheets have no geographic grid, but include one magnetic meridian and one true meridian.

1909-11 and 1910-11 U.S. Lake Survey Field Sheets

The 1909-11 and 1910-11 surveys include upland land use and land cover for a distance of about 0.5 to 1 mile inland. Soundings extend along shore-parallel track lines up to 7.5 miles offshore and a maximum depth of 80 to 133 feet depending on the sheet number. Nearshore bathymetric data from the 1872 and 1873 surveys are included for comparison. All depths are corrected to Lakes Michigan-Huron Low Water Datum (578.5 feet MTNY 1935). Land elevations are shown in 10-foot contour intervals above the elevation of Lake Michigan. Geographic grid is referenced to U.S. Standard Datum.

Table 3. Documentation of U.S. Lake Survey field sheets for 1872 and 1873.

Field Sheet No.: I-521

Map Title:	Survey of the Northern and Northwest Lakes West Shore of Lake Michigan From Azimuth Station II North of Kenosha to Azimuth Station IV South of Kenosha
Map Date:	1872 (drawn 1873)
Scale:	1:20,000 (nominal)
In Charge:	Brevet Major-Gen. Cyrus B. Comstock, U.S. Corps of Engineers
Surveyor:	Henry Custer, Asst. U.S. Lake Survey
Map Limits:	North of Kenosha, Wisconsin to 4.3 miles south of the Illinois-Wisconsin state line.

Field Sheet No.: I-552

Map Title:	Survey of the Northern and Northwestern Lakes West Shore of Lake Michigan From Shore Station 81 (South of Azimuth Station VI) to Azimuth Station VII South
Map Date:	1873
Scale:	1:20,000 (nominal)
In Charge:	Brevet Major-Gen. Cyrus B. Comstock, U.S. Corps of Engineers
Surveyor:	Henry Custer, Asst. U.S. Lake Survey
Map Limits:	Fort Sheridan area south to Wilmette

Field Sheet No.: I-553

Map Title:	Survey of the Northern and Northwest Lakes West Shore of Lake Michigan From Azimuth Station IV South to Azimuth Station VI South
Map Date:	1873
Scale:	1:20,000 (nominal)
In Charge:	Brevet Major-Gen. Cyrus B. Comstock, U.S. Corps of Engineers
Surveyor:	Henry Custer, Asst. U.S. Lake Survey
Map Limits:	From 4.3 miles south of the Illinois-Wisconsin state line south to the Fort Sheridan area.

Table 4. Documentation of U.S. Lake Survey field sheets for 1909-1911 and 1910-1911.

<u>Field Sheet No.:</u> **I-1195**

<u>Map Title:</u>	Survey of the Northern and Northwestern Lakes Sheet No. 1 - West Shore of Lake Michigan
<u>Map Date:</u>	1910-1911
<u>Scale:</u>	1:20,000 (nominal)
<u>In Charge:</u>	Lt. Colonel Charles S. Riche, Corps of Engineers U.S. Army
<u>Map Limits:</u>	Fort Sheridan area south to Winnetka (Cook Co.)

<u>Field Sheet No.:</u> **I-1196**

<u>Map Title:</u>	Survey of the Northern and Northwestern Lakes Sheet No. 2 - West Shore of Lake Michigan South of Waukegan, Ill.
<u>Map Date:</u>	1910-1911
<u>Scale:</u>	1:20,000 (nominal)
<u>In Charge:</u>	Lt. Colonel Charles S. Riche, Corps of Engineers U.S. Army
<u>Map Limits:</u>	4.6 miles south of the Illinois-Wisconsin state line south to the Fort Sheridan area

<u>Field Sheet No.:</u> **I-1197**

<u>Map Title:</u>	Survey of the Northern and Northwestern Lakes Sheet No. 3 - West Shore of Lake Michigan South of Kenosha, Wisc.
<u>Map Date:</u>	1909-1911
<u>Scale:</u>	1:20,000 (nominal)
<u>In Charge:</u>	Lt. Colonel Charles S. Riche, Corps of Engineers U.S. Army
<u>Map Limits:</u>	North of Kenosha, Wisconsin to 4.6 miles south of the Illinois-Wisconsin state line

Aerial Photographs

Two data sets of aerial photographs from 1947 and 1987 were used in this study. Both sets of aerial photographs were collected with metric cameras, and were both flown coast-parallel along the Lake Michigan shoreline. Table 5 provides documentation of the aerial photographs used in this study.

Table 5. Documentation of 1947 and 1987 aerial photographs used as data sources.

1947 Aerial Photographs	
Source:	Unspecified private contractor (assumed to be Chicago Aerial Survey)
Flight Date:	April 3, 1947
Nominal Scale:	1:12,000
Project I.D.:	(None specified)
Roll I.D.:	BES-1
Frames Used:	21 through 66
Film Size:	9 inch
Film Type:	Black and white positive prints
Fiducial Marks:	4
1987 Aerial Photographs	
Source:	Illinois Department of Transportation (IDOT)
Flight Date:	March 17, 1987
Nominal Scale:	1:14,400
Project I.D.:	R-3510 ST
Roll I.D.:	(None specified)
Frames Used:	403 through 434
Film Size:	9 inch
Film Type:	Black and white positive prints
Fiducial Marks:	8

Lake Levels Corresponding to Data Sources

Shoreline positions for the different data sources are dependent on the lake levels at the time of mapping or aerial photography. Lake levels at the time of the 1872 and 1873 surveys are indicated by notes on the field sheets. For the 1909-11 and 1910-11 surveys, we computed lake levels by taking an average for the five-month field season (May through September) for each of the three years of records of monthly mean lake levels at the lake-level gauges at Milwaukee, Wisconsin and Calumet Harbor, Illinois. The lake levels for the days of the aerial photographs were computed by averaging mean daily lake levels from these two gauges.

Table 6 lists the lake levels for the data sources and the differences relative to Low Water Datum and 1900-1990 Lakes Michigan-Huron monthly mean lake levels. These lake levels are presented here for complete documentation. These data were not used for any translations of shoreline position to adjust shorelines to a common datum. The 1947 photographs record a lake level closest to Low Water Datum (LWD) of any of the four data sets. The 1987 photographs were collected at a time of high lake level, as lake level was declining from the record high monthly mean of 581.80 feet (IGLD 1955) recorded at Calumet Harbor, Illinois in October 1986.

Table 6. Summary of lake elevations for each of the data sources and lake level differences relative to Lakes Michigan-Huron Low Water Datum and 1900-1990 Lakes Michigan-Huron monthly mean lake level. All elevations are given in feet.

Years of Mapping	Lake Level IGLD 1955	Elevation Difference Above (+) or Below (-) Low Water Datum 576.80 (IGLD 1955)	Elevation Difference Above (+) or Below (-) 1900-1990 Monthly Mean Lake Level 578.34 (IGLD 1955)
1872, 1873	579.20[1]	+ 2.40	+ 0.86
1909, 1910, 1911	578.47[2]	+ 1.67	+ 0.13
1947	577.75[3]	+ 0.95	- 0.59
1947	580.55[3]	+ 3.75	+ 2.21

[1] Based on lake level notes added to the 1872 and 1873 U.S. Lake Survey maps by Corps of Engineers (April 16, 1947).

[2] Average of monthly means for Milwaukee and Calumet Harbor gauges for five months May through September 1909, 1910, and 1911.

[3] Average of daily means for Milwaukee and Calumet Harbor gauges for the day of photography.

EQUIPMENT FOR ANALYSIS OF HISTORICAL MAPS AND AERIAL PHOTOGRAPHS

NOTE: Use of specific hardware and software product names is for informational purposes only and does not constitute an endorsement by the Illinois State Geological Survey.

Hardware

A Geographic Information System (GIS) was used to store, access, manage, and analyze the historical map and aerial photograph data for this study. The initial hardware platform was a PRIME 9955 minicomputer linked to Tektronix 4207-series graphics terminals. Map editing, transect generation and datafile production were done on Sun Sparcstation IPC and IPX workstations.

Historical Maps

Data entry for the historical maps was done by digitizing them on a CalComp 9500 24-inch by 36-inch digitizing board linked initially to the PRIME 9955 computer and later to the Sun IPC workstation. In a few instances a Bausch and Lomb Zoom Transfer Scope (ZTS; Model ZT4-H) was used to optically transfer faintly marked bluff contours from high-resolution but fragile original paper historical maps to bromide copies at slightly different scales from the originals.

Aerial Photographs

Data entry for the aerial photographs was done using nine-inch photographic prints and a Zeiss Stereotope stereoplotter to correct for radial and relief displacement.

A stereoplotter is an instrument designed to achieve a planimetrically correct map using the horizontal (X- and Y- axis) measurements of a pair of photographs called a stereopair. The procedure involves mounting a stereopair on the stereoplotter so that each photograph can be observed by one eye to achieve the 3-D effect called a stereomodel (Raasveldt, 1956). A conventional stereoplotter reconstructs the position and attitude of a pair of photographs to make a stereomodel. Every point on the stereomodel is in the "correct" horizontal position relative to surrounding points, *i.e.*, it is planimetrically correct. Accurate horizontal positions are then determined by compensating for the parallax of the two photographs.

The stereoplotter was connected to a custom-made pantograph that supported a keypad above a GTCO Digi-Pad Super L Series digitizing board linked to the Prime 9955 minicomputer. By exaggerating the stereomodel positions (as translated to the cursor on the digitizing board) 2.5 times, the precision of digitizing is increased from that obtained directly with the 9-inch prints.

Error in the operator-stereoplotter device was measured through repeated measurements of control points on the stereomodels. The repeatability of measurements varied for each stereomodel but was found to be within a few feet.

In order to achieve the required vertical perspective, it was necessary to adjust the stereopair to the stereoplotter in order to reconstruct the relative positions of the photographs at the time each was exposed. Because wind velocity and direction change with time and location, both the altitude and the attitude of the aircraft vary at the time of exposure. Deviations in attitude from straight and level flight are called X-tilt (rotation about the longitudinal axis of the aircraft fuselage) and Y-tilt (rotation about the axis which passes through the aircraft's wings), and these tilts cause changes of scale in a stereomodel. The portion of the stereomodel which has an upward Y-tilt has a smaller scale than the portion which is relatively lower. A photograph having excessive tilt is not a true vertical aerial photograph but an oblique aerial photograph. To obtain accurate coordinate measurements, the X-tilt and the Y-tilt must be adjusted so that the stereomodel has a vertical orientation. This will allow for the creation of a planimetric map, *i.e.*, one which has a constant scale throughout the map and minimal distortion.

A "floating mark" can be placed on the three-dimensional stereomodel by placing identical marks (usually a dot) on the exact same location on each photo. A slight shift in location of the marks on the photographs causes the mark to "float" above or below the stereomodel. The difference in the location of the marks on the photographs is caused by parallax, the difference in the position and attitude of the camera at the time of the exposures.

The adjustment to remove the effects of X-tilt and Y-tilt was done on the Zeiss

Stereotope by shifting, tilting, or rotating one photograph of the pair according to the procedure described below:

1) Use the fiducial marks to identify the principal point (fiducial center) of each photograph.
2) Use a stereoscope and a relative orientation of the stereopair to identify the conjugate principal point (the principal point of the adjacent aerial photograph) for each photograph.
3) Align the principal points and their conjugates in order to mark the flightline of the photographs.
4) Align the photographs along the X-axis plates on the stereoplotter. Fasten one of the photographs to the plate.
5) Adjust the second photograph along the X-axis to achieve stereoscopic viewing.
6) Check for stereoscopic perception throughout the stereomodel.
7) Follow the procedure in the Stereotope Manual for adjustment for X-tilt and Y-tilt.
8) Record the adjustments for X-tilt and Y-tilt.

The stereoplotter was used for all bluffline mapping, but subsequent checking of the data set required revision of the bluffline in Corridors 4 and 5 with a pocket stereoscope to improve map accuracy.

Appendix D shows the X-tilt and Y-tilt adjustments made for each stereomodel. All are within a range of adjustment which indicates that the aerial photographs used are near vertical and have minimal X-tilt and Y-tilt.

Software

The software used for the study was ARC/INFO, a GIS package developed by Environmental Systems Research Institute, Inc. (ESRI), with headquarters in Redlands, California. As the name indicates, ARC/INFO consists of two components, ARC and INFO. ARC utilizes a data model that allows representation of geographic elements (displayed as points, lines, or polygons) in either a raster-based or a vector-based format. The vector-based mode of ARC was used to compile, manipulate, and store the graphic components of map and aerial photograph information, in this case the locations of the historical shorelines, blufflines, transects, and associated cultural features used as ground control. INFO is relational database management software that was used to create and maintain descriptive tabular information associated with the map and photograph features, such as shoreline dates, transect code numbers, and coordinates of line intersections. INFO's programming capabilities were used to manipulate the data to generate the Historical Shoreline Positional Database and report it in an easily accessible format (Task 4).

Initial map and aerial photograph digitizing and editing were carried out on the PRIME platform using ARC/INFO Rev. 5.0. Most of the editing and all transect generation and database production were carried out on the Sun platform using ARC/INFO Rev. 6.0.

DATA REVIEW AND PREPARATION

Scale Determination

Historical Maps

The scale of each U.S. Lake Survey field sheet was determined by measuring the scale bar located on each map and calculating the actual scale represented by that bar. The

results of the scale determination are shown in Table 7. It should be noted that these measured scales are applicable only to the particular set of bromide copies received from NOAA-NOS for this study. Other sets of bromides produced at different times may have different scales.

Table 7. Comparison of nominal and measured historical map scales.

U.S.Lake Survey Field Sheet	Nominal scale	Measured scale
I-521 (1872)	1:20,000	1:20,160
I-552 (1873)	1:20,000	1:20,124
I-553 (1873)	1:20,000	1:20,124
I-1195 (1910-11)	1:20,000	1:20,064
I-1196 (1910-11)	1:20,000	1:20,136
I-1197 (1909-11)	1:20,000	1:19,932

Aerial Photographs

For the aerial photographs, the nominal scale was 1:12,000 for the 1947 photographs and 1:14,400 for the 1987 photographs. Because scale varies continuously over a photograph, according to both ground relief and distance from the principal point, the nominal scale was checked by measuring distances between road intersections on selected photographs in different locations and computing a mean measured scale. The mean measured scale of the 1947 photographs was 1:11,840, and the mean measured scale of the 1987 photographs was 1:13,320.

Control Point Selection

Historical Maps

Selection of ground control points common to the historical maps and the 1:24,000 digital line graph (DLG) maps is the primary requirement for accurate registration of the

historical maps to the digital base maps. Ideally, ground control points represent precisely the same location on both the historical maps and DLG base maps. However, both the 1872 and 1910 historical maps show only narrow strips of land ranging from about 0.5 to 1.5 miles landward of the shoreline, and as a result the number of land-based features available as control points is limited, especially in areas of sparse development. The major land-based features on these maps are roads, railroads, and the topographic contours delineating ravines. Additionally, both sets of historical maps identify points that were apparently used in the horizontal control for the topographic and hydrographic surveys, but because no location information occurs on the maps, and Descriptive Reports were not available, these points could not be used in map registrations. The primary features used as control points on the historical maps were road intersections and occasionally railroad crossings and bridges. In a few areas of particularly scarce cultural features, it was necessary to create control points at arbitrary locations using the procedure described beginning on page 58.

Aerial Photographs

Ground control points were selected for orienting common points on the stereomodel to the USGS 1:24,000 digital line graph (DLG) base maps. Wherever possible, control points were selected that were also used in registration of the historical maps, but additional control points were selected as well. All ground control points selected for the aerial photographs were road intersections. In some cases, the centerlines of roads were readily visible on the aerial photographs as dark lines formed by adjoining concrete slabs, but in other cases centerline positions were visually estimated. Roads which intersect at right angles were selected where possible, because these intersections qualify as well-defined points. It was assumed that the centerpoints of road intersections were unchanged since 1947.

Although ground control points should ideally be distributed peripherally to the area of interest, a lack of major coastal structures or other offshore subaerial features precluded control points lakeward of the shoreline. Where possible, ground control points were located near the bluffline and along the center of the flightline in an effort to minimize the error near the bluffline.

Control Point Stability Determination

Historical Maps

The ideal control point is one which has not changed position with time, and is represented as a point feature at the scale of both the base map and the map from which data are collected. On the base maps, road intersections are represented as points, because roads were digitized by their centerlines. On the historical maps, however, roads are represented as double lines, requiring point intersections to be constructed by visually determining the intersection of the road centerlines. Where bridges and railroad crossings were used as control points (in areas where road intersections were scarce), corresponding source map points were also visually determined.

Since DLG maps contain centerline road intersections that conform to U.S. National Map Accuracy Standards (Ellis, 1978), it was decided to use road intersections as ground control points wherever possible. In both 1872 and 1910, however, much of the Lake County coastal area was rural. Dirt roads were common and thus not strictly fixed in location or configuration. Although many modern-day roads closely follow the route of these earlier roads, others do not. Also, road intersections are subject to displacement as roads are widened, straightened, or otherwise altered. Therefore, the stability of each intersection selected as a possible ground control point had to be demonstrated before it could be used. The procedure used to determine the stability

of potential control points is described below. The term "intersection" is used in discussing the procedure, but it is applicable to and was used for railroad crossings and bridges as well.

1) Identify potential ground control points common to the historical map and DLG base map. In areas of long-term development, such as Corridor 2 in Waukegan, this was straightforward since the basic road grid present today already existed in 1873. In areas more sparsely developed, such as Corridor 3 in 1873, road geometries and relative positions were used to produce a list of candidate road intersections and other control points.

2) Measure the distance from the Chicago and North Western Railroad tracks to each proposed intersection on the historical map. Since this railroad runs approximately north-south through most of Lake County, most distances were measured along east-west lines. Where the railroad bearing deviated significantly from north-south, such as in Corridor 5, distances were measured perpendicular to the railroad. The Chicago and North Western Railroad was the major stable cultural feature throughout the study area, and was therefore used for the initial determination of control point stability. However, this feature leads to some uncertainty because it is shown as a single track on most of the historical maps, as a double track on the current USGS paper 7.5-minute topographic maps, and as a single line on the DLG maps. According to information supplied by the Chicago and North Western Railroad, the first track was laid in 1854 and is presently the easternmost track. A second track, laid immediately west of the first one, was constructed sometime between 1854 and 1904, within the right-of-way limits of the

original track. Due to this ambiguity in age of construction, and the representation of the tracks as a single line on the DLG base maps, wherever a double track was present, the midpoint between the two tracks was used as the measuring point.

3) Measure the distance from the railroad to each proposed intersection on the DLG base map. Two methods of doing this were possible: using the ARC/INFO "DISTANCE" command to determine the distance on the computer screen between the two points, or measuring with an engineer's scale on the USGS 7.5-minute topographic quadrangles, from which the DLGs are derived. The DISTANCE command did not result in precisely reproducible measurements, and repetitions of the DISTANCE command resulted in measurements that differed by 50 feet or more. In contrast, measuring distances with an engineer's scale, especially by the same individual, were reproducible to 0.01 inch, which is 20 feet on the 1:24,000 quadrangle maps. For this reason, an engineer's scale was used for measurements of distance from the railroad to a proposed control point.

4) Convert the measured map distance (in inches) to ground distances (in feet). Measured values were multiplied by 2000 for the 1:24,000 map measurements, and by the appropriate scales listed in Table 7 for each historical map.

5) Compare the two values. If the values differed from each other by 20 feet or less and/or 1 percent or less, the points were defined to be stable.

Percent lateral movement was defined as:

$$\frac{|D_m - D_d|}{(D_m + D_d)/2} \times 100$$

where:

D_m = distance from stable feature to proposed control point on historical map
D_d = distance from stable feature to proposed control point on DLG base.

The 20-foot requirement was selected for two reasons. First, 20 feet is the accuracy limit to which measurements on the map with an engineer's scale were reproducible. Second, 20 feet is the limiting root-mean-square (RMS) error for planimetric coordinates for 1;24,000 maps, according to the American Society of Photogrammetry and Remote Sensing's Interim Accuracy Standards for Large Scale Maps (ASPRS, 1989). The 1% criterion was added to prevent widely spaced stable points from being rejected due to paper shrinkage or expansion.

6) Check the stable points relative to each other. Once stable ground control points were determined by measuring from the railroad, a further check on the points was done by measuring their distances from each other. The same stability criterion was applied to these distances. This was particularly useful in areas where the railroad consisted of multiple tracks (such as Corridor 2 in Waukegan), or where the tracks were difficult to distinguish on the historical maps.

Potential ground control points that met all the stability criteria were defined as stable and were used as registration-testing points. These are listed in Appendix E.

Aerial Photographs

Although care was exercised in control point selection, specific tests for stability were not conducted for the aerial photographs for two reasons:

1) Photography is not subject to surveying and mapping errors.

2) The aerial photographs were considerably more recent than the historical maps, and therefore the photographs were more likely to conform to the DLG base maps as far as locations of road intersections and other cultural features were concerned.

Appendix F shows that 4 to 5 horizontal control points were used for each stereomodel. A minimum of 2 control points appeared in successive stereomodels and frequently one common control point was used in three successive stereomodels thereby adding to the overall accuracy of the mapping.

Creation of Additional Control Points

Occasionally, when working with the historical maps, it was necessary to create additional control points to obtain a usable registration because of the scarcity of cultural features. Frequently this was done by extending a straight line so that it crossed a different non-parallel linear feature where no intersection between the two features actually existed. An example is extending a road centerline to intersect a railroad line that the road does not actually cross.

Examples of less straightforward control point creation methods are presented below. Such procedures were not necessary for the aerial photographs, because they contained an adequate amount of data for registration.

In Corridor 3 in 1873, a problem arose in registering the historical maps when not enough stable cultural points could be located to achieve an acceptable registration. In particular, two ground control points were created for the 1873 corridor 3 map by two different techniques, described below. The associated Arcedit commands used are listed in Appendix G.

Creation of control point at extension of Sheridan Road and Chicago and North Western Railroad tracks. This ground control point was created with the following steps:

1) Add extension of Sheridan Road south so that it crosses the Chicago and North Western Railroad tracks south of 18th Street in the town of North Chicago. Use the longest straight-line segment of Sheridan Road to determine the bearing of the extension.

2) Create a node at the intersection of the Sheridan Road extension and the railroad tracks.

3) Measure the angle between the Sheridan Road extension and the railroad tracks on the USGS 7.5-minute quadrangle. The same angle must be formed by the addition of the arc extending Sheridan Road on the digital map. This angle was 30 degrees, so the southern segment of the extension, south of the newly created intersection, was rotated 30 degrees clockwise using the newly created node as a pivot point. If this rotation results in the expected alignment of the Sheridan Road extension with the railroad tracks, as it did in this case, the newly created node is in the correct location and can be used as a ground control point. If the rotation does not result in an alignment of the two features, the amount and direction of deviation of the rotated segment from the railroad tracks will indicate the direction along the tracks in which the new node on the extension arc should be shifted, and the procedure is repeated until alignment occurs. A tic is then added at the node location.

Creation of control point at bridge along Chicago and North Western Railroad tracks. A second ground control point was added at the railroad bridge over a ravine west of the intersection of Sheridan Road and Clark Avenue, North Chicago. The creation of this point was necessary because the stream flowing in this ravine is ephemeral, and therefore not mapped on the DLG base map, even though it was clearly mapped on the 1873 historical map. The point was created on the digital base map using the following steps:

1) Three distinct intersections near the bridge were identified: Illinois Route 137 and the Chicago and North Western Railroad tracks; Sheridan Road and Farragut Avenue; and 12th Avenue and Missouri Street. Points were added at each of these intersections.

2) The distance in inches was measured from the bridge to each of the three intersections on the USGS 7.5-minute quadrangle. The distance was converted to feet and the resulting number was added to each of the Y coordinates of the points on the intersections on the digital map. Three new points were then added to the digital map with the new X-Y coordinates. This resulted in a point north of each of the intersection points at a distance equal to that of the bridge from the corresponding intersection.

3) A circle was then drawn through each of the newly created points using the corresponding intersection point as the circle center. Each circle, then, had as its radius the distance from the intersection to the bridge. This resulted in three circles, each containing the unmapped bridge somewhere on its circumference.

If this procedure is carried out precisely, the three circles thus drawn will meet in a single point, and that point becomes the new control point. More realistically, a small

triangle is created where the three circumferences intersect. In this case, the maximum distance across the small triangle was about 8 feet, less than the 0.01 inch (20 feet) minimum resolution achievable on the USGS 7.5-minute quadrangles on which the distance measuring was performed. The railroad tracks passed through this small triangle, and so the control point was added along the tracks midway between the two legs of the triangle intersected by the tracks.

Similar procedures were also used in corridor 4 on the 1910 maps. Since corridor 4 was located on two different historical maps, each with its own scale, each part had to be digitized separately, and stable ground control points had to be located for each part. The southern part of the corridor had sparsely distributed cultural features, and so the three-circles method of adding points was used for establishing a ground control point at a bridge on Westleigh Road for this part of the corridor.

It should be emphasized that decisions on adding ground control points and refinement of the methods described above must be made on a case-by-case basis. Although it is preferable to use ground control points that are present on all maps for registration purposes, when historical maps with limited cultural features are all that is available, these point creation methods can be extremely useful in adding ground control.

MAP AND AERIAL PHOTOGRAPH REGISTRATION AND DIGITIZING

Selection of a Registration

Data collection consisted of converting the analog-format data of a conventional map or aerial photograph to digital format for use on a computer. Once a satisfactory set of stable ground control points has been established, the historical maps and aerial

photographs must be registered to the digital base maps to collect the data. Selecting an appropriate set of registration points from the available ground control points is a critical step in the process of data collection, because an unsatisfactory registration can result in mislocated data.

The general procedure in registering a historical map or aerial photograph was:

1) All satisfactory ground control points on the historical map or stereomodel to be digitized were identified and marked. The larger the number of available control points, the more flexibility there will be for deleting points associated with unsatisfactory registrations.
2) A new coverage was created based on tics from the DLG base maps.
3) A tic was added to the coverage corresponding to each of the ground control points determined to be stable. The tic addition procedure was done as precisely as possible by zooming in closely on the background DLG base map to the road intersection or other point feature representing the ground control point.
4) The newly added tics were saved into the coverage.
5) The map or stereomodel was registered on the digitizing board using four or five selected tics spaced as widely apart as possible. Because of the scarcity of cultural features on most of the historical maps and the difficulty of locating stable control points, only four tics were used on each of the maps. Stereomodels were registered with either four or five points. A previous study has shown that the number of ground control points does not significantly affect X and Y coordinate positioning (Underwood and Anders, 1991).
6) The root-mean-square (RMS) error (computed in board inches and map feet) and the X and Y scales computed for the registration were

recorded. The RMS error is a measure of the goodness of fit of the historical map or stereomodel with the digital base map, and is determined by calculating the deviation between the control point locations in the source map or photograph from those in the output coverage. RMS error is defined as the square root of the average of the squared discrepancies.

$$RMSE = \sqrt{\frac{\sum_{j=1}^{N} d_J^2}{N}}$$

where:

RMSE = root mean square error

d = discrepancy between same point on base map and stereomodel

j = identification number of the control point

N = number of control points.

A perfect fit between the base map and the historical map or stereomodel would have an RMS error of 0.000 feet. The larger the error, the worse the fit.

7) The registration was examined to determine whether it was satisfactory. According to the ASPRS Interim Accuracy Standards for Large Scale Maps (ASPRS, 1989), the limiting RMS error for planimetric coordinate conversion for 1:24,000-scale maps (the scale from which the DLG base maps were digitized) is 20 feet. The value of the RMS error in map feet should be less than this number. In addition, the computed X and Y scales of the map should match the measured scale of the source map or photograph as closely as possible. The X and Y scales should also

closely match each other unless there is substantial reason to believe the source map has undergone shrinkage or expansion in one dimension only or that not all tilt has been removed from a stereomodel.

In some cases it was not possible to achieve both an acceptable X and Y scale and an acceptably low RMS error in the same registration. In such cases, the registration resulting in the best X and Y scales was used for digitizing. If no registration could be found in which the X and Y scales matched each other and the calculated map scale, a registration was chosen in which the X scale matched the calculated map scale as closely as possible, in preference to one in which the Y scale matched. This was done because in most of Lake County, the shoreline is oriented roughly north-south (the Y direction), and so any deviations in X scale from the calculated map scale affect the positioning of the shoreline in an east-west direction more seriously than any deviations in Y scale. Since erosion occurs in an approximately shore-perpendicular direction, misplacement of the shore in this direction must be minimized, and this was done by matching the calculated map X scale as closely as possible.

8) If the registration data appeared satisfactory, a few key roads were digitized (preferably streets passing through control points) or other linear features common to the DLG base map and the source map or aerial photograph to test how well they matched. Such features were digitized in widely scattered portions of the map or aerial photograph.

9) If no significant distortion or displacement was evident in the lines digitized from the test registration, the registration was considered satisfactory and the digitizing proceeded. If distortion or displacement

was evident in the test lines, then another set of tics was selected for registration, and steps 5 through 8 were repeated.

Historical Maps

Of all available stable ground control points, the ultimate selection of those used for digitizing a particular segment of the map was based on the following criteria:

1) A set of four points yielding a scale close to that measured for the map in both north-south and east-west directions.
2) A set of four points yielding a low RMS error.
3) A set of four points with a good geographic distribution with respect to the segment of the map to be digitized, *i.e.*, as widely distributed as possible without being a great distance outside the area to be digitized. Where possible, two points north of the corridor and two south of it were used.
4) A set of four points defining a quadrilateral without a re-entrant angle (*i.e.*, no interior angle greater than 180 degrees).

In all cases but one (Corridor 5, 1873), the selected registration had an RMS error less than 20 feet. In that particular case, a 22-foot RMS error was accepted because the X and Y scales matched the calculated map scale and each other far better than other attempted registrations. Appendix E lists the four ground control points used for each registration of historical maps, their associated X and Y scales, and their RMS errors in both board inches and map feet.

Aerial Photographs

The stereomodels for the 1947 aerial photographs had RMS errors ranging from 4 to

19 feet. The stereomodels for the 1987 aerial photographs had RMS errors ranging from 3 to 19 feet. The maximum RMS error for both the 1947 and 1987 photographs of 19 feet is within the ASPRS Interim Accuracy Standard of 20 feet. Appendix F lists the ground control points and RMS errors, in board inches and map feet, for registration of control points on the stereomodels to the same points on the DLG base maps.

Digitizing

Structures

Shore structures are not included as part of the digital database. Although it was possible to identify shore-perpendicular structures on the aerial photographs such as groins, jetties, and shore-attached breakwaters, it was not possible to adequately and thoroughly identify shore-parallel structures along the beach or at the bluff toe on either the 1947 or 1987 photographs. Many structures at the bluff toe were completely obscured by the vegetation canopy. Many stone and concrete structures along the beach lacked sufficient reflective contrast on the black and white photographs to be distinguished from beach sand. Many more structures than were distinguishable on the photographs were known to be present, based on examination of low-angle oblique color photographs on file at the Illinois State Geological Survey (ISGS), and previous ISGS mapping of coastal structures along the Illinois coast (Illinois State Geological Survey, 1988). Rather than document an incomplete set of structures that might be misinterpreted as complete, no structures are included in the database.

Historical Maps

In conjunction with the digitizing procedure, historical maps were simultaneously interpreted for a) bluffline, b) shoreline, and c) road centerlines.

Digitizing of the features of interest was accomplished by tracing them with a crosshairs-type 16-button cursor. Digitizing was done using a point-by-point method, in which each point on the feature is specifically entered by pressing a button on the cursor, rather than by a continuous pen-type tracing method. The minimum resolution of points entered was approximately 0.01 inch. Shorelines, blufflines, and centerlines of roads were digitized. It was important to digitize as many streets and roads as possible so that any necessary adjustments of the digital map could be made.

Aerial Photographs

For the northern two corridors (Corridor 1, North Point, and Corridor 2, Waukegan Harbor), shorelines and road centerlines were digitized from single sets of 1947 and 1987 aerial photographs (*i.e.*, not stereopairs) using the digitizing board rather than the stereoplotter. Stereopairs were not used since no bluffs occur near the shore in these corridors, and so the correction for relief displacement provided by stereopairs was not required. The procedure for digitizing from the aerial photographs for these two corridors follows the procedure outlined for the historical maps rather than the procedure described below for the aerial photographs.

For the stereomodels, shorelines and blufflines were digitized from the stereomodel. Adjustment of the "floating mark" on the stereoplotter was used to compensate for displacement of features on the photographs caused by the relief between the shoreline and bluffline.

DATA EDITING

After registration and digitizing, processing of the digitized maps was carried out to improve the quality of the coverages. Two types of processing took place, rubber

sheeting and correction of feature misalignments. The procedures used to edit the digitized maps are not dependent on the type of data source, so this section does not distinguish between historical maps and aerial photographs.

Rubber Sheeting

Rubber sheeting is the process of adjusting a digital map for distortions that may occur in the digitized source maps. Such distortions may be a result of imperfect registration, inadequate source data, and distortion of the map medium, among other causes. Rubber sheeting corrects for these distortions through the geometric adjustment of coordinates. During rubber sheeting, the coverage is differentially stretched, as lines and points are moved using a piecewise transformation that preserves straight lines (ESRI, 1991). Rubber sheeting requires a set of deformation vectors called links that define how the coverage is to be transformed. The tail of each link vector is attached to a point on the map to be rubber sheeted (in this case the historical map and aerial photograph coverages), and the head of the vector is attached to a point on the reference map (in this case the digital line graphs). During the adjustment procedure, the points at the tails of the link vectors are brought into coincidence with the points at the heads of the links.

Selection of the points to be used in defining the link vectors is therefore as important as selecting the points used for the initial ground control. Improper selection of links can cause serious misalignment of coverage features. Link vector points, like ground control points, must represent features on the ground that have not moved over time. Also, they ideally must be point features (rather than lines or polygons) at the scale of both the source map and the reference map to which rubber sheeting is to occur.

The main features used as links in this study were road intersections. Intersections

being considered as link vector endpoints on the historical maps were checked for stability by measuring their distance from known stable features such as the Chicago and North Western Railroad. (See the complete discussion of criteria for stability in the section on Control Point Stability Determination beginning on page 54.)

Each corridor was examined individually for each year to determine the need for rubber sheeting. After stable points were determined, the distance between the digitized stable point and the corresponding point on the DLG base map was measured. If the distance exceeded the U.S. National Map Accuracy Standard for 1:24,000-scale maps of 40 feet (Ellis, 1978), a link connecting the two points was added for rubber sheeting. If the distance was less than 40 feet, no link was added. For some corridors in some years, all digitized stable points fell within 40 feet of their DLG counterparts, and so for these coverages, no rubber sheeting was performed.

Appendix H contains a list of all intersections considered and used as link-vector endpoints. The ARC/INFO commands used to perform the rubber sheeting are listed in Appendix G.

Considerations associated with rubber sheeting

During the rubber sheeting process, several items were noted regarding this method of map adjustment. These are discussed below.

1) For accurate rubber sheeting, an adequate number of road intersections must have been digitized from the source map or aerial photograph. An inadequate number of digitized intersections precluded accurate rubber sheeting in Corridor 2 (1947) and Corridor 3 (1947 and 1987).
2) The effects of rubber sheeting must be carefully examined by comparing the adjusted map to the unadjusted map. In some cases, rubber

sheeting may actually increase the overall displacement of features on the source map with respect to those on the base map, even though it improves the match between particular points.

3) At boundaries between adjacent source maps or photographs, it is recommended that rubber sheeting of each map or photograph take place before the adjacent coverages are spliced. In this way, each map can be adjusted independently using the nearest available rubber sheeting points, and when adjacent maps are joined, the misalignment should be reduced.

Misalignments

Where shorelines or blufflines of two adjacent coverages met or overlapped, they never matched each other exactly. The mismatches or offsets were as small as one or two feet or as large as 200 feet. The method used in editing the misalignments was dependent on whether the mismatch was greater than or less than the U.S. National Map Accuracy Standard of 40 feet (Ellis, 1978).

In cases where the misalignment was less than five feet or where the features to be aligned crossed each other, the splicing was done by simply snapping the nodes together at an approximate midpoint between them and deleting any overlapping vertices. An example of such a minor misalignment was noted in the pair of 1987 aerial photography coverages for Corridor 1.

In cases where the misalignment was greater than five feet but less than the U.S. National Map Accuracy Standard of 40 feet, the shorelines were spliced together with the following procedure:

1) Locate the midpoint of the suture zone in the shore-parallel dimension.

2) Add a temporary arc through that point in a shore-perpendicular orientation.

3) Split each of the two dangling shoreline arcs where they intersect the temporary arc.

4) Locate the midpoint of the temporary arc between the two shoreline segments, and add a temporary label at that point. This label will be the future location of the node common to both shoreline segments.

5) Delete the dangling arcs and the temporary arc.

6) Move the endpoint nodes of each of the two shoreline arcs to the temporary label so that they snap together at that location.

7) Move the adjacent vertices of each shoreline arc in the same direction that its endpoint node was moved but a smaller distance. Repeat the vertex-moving procedure with vertices farther from the splice node, gradually decreasing the move distance to zero while moving away from the splice point in both directions so that a reasonably straight shoreline results.

8) Delete the temporary label.

In those cases where the misalignment was greater than 40 feet, each situation was examined on a case-by-case basis. In each case, the maps on both sides of the gap were examined in an effort to find a reason for the existence of the mismatch. The solution of the problem sometimes involved a re-registration and redigitizing of one or both of the maps.

Some misalignments occurred as a result of avoidable registration errors. A particularly striking example of such a misalignment was found between the two coverages digitized from adjacent sheets of the 1873 historical map in Corridor 4. Examination

of the two mismatching coverages revealed that the southern one had a reasonably good match with the DLG base map, but the northern one showed a westward displacement of the streets with respect to those of the base map. A test coverage was then created from the five available tics on the unsatisfactory coverage, and several possible registrations were tested. The elimination of one of the five tics resulted in a significantly better registration with respect to consistency of scale than any of the registrations which included that particular tic. When the location of that tic, at Scott Street and McKinley Road, was examined on both historical and modern maps, it was found that McKinley Road had been moved eastward about 80 feet with respect to the nearby Chicago and North Western Railroad, which it parallels. The misalignment of shorelines apparently resulted from an error in the X-scale of the map caused by the relocation of the intersection represented by the offending tic. Because of the clustered nature of the tics, a fairly small error in the vicinity of the cluster of tics rapidly multiplied with increased distance from the cluster of tics. It is likely that this is how an 80-foot relocation of a road just north of downtown Lake Forest became a 200-foot shoreline displacement a couple of miles farther south. Adequate determination of control point stability before registration would have eliminated the necessity of redigitizing the cover.

Another type of misalignment which can exceed the U.S. National Map Accuracy Standard can be caused by mapping error on the historical maps. An example of such a mapping error occurs in the southernmost portion of the shoreline of the 1910-11 Field Sheet No. I-1196 in Corridor 4, where the mouth of the large ravine just north of Westleigh Road has been misplaced on the field sheet to the south by about 250 feet with respect to all other years mapped and the DLG base maps. This ravine misplacement resulted in an approximate 60-foot eastward displacement of the shoreline and bluffline in the southern 1000 feet of the corridor after the map was

digitized. To repair the mismatched features in this area, each of the arcs to be edited was split about 1000 feet north of the suture zone. The southern segment of each arc was then rotated into alignment with its counterpart on the south side of the suture zone, with the new node at the splitting point used as the pivot point in each case. The angle of rotation necessary to correct the 60-foot displacement was 3.0 degrees clockwise.

A procedure for error checking of the data after completion of the editing process was to superimpose data from different years and check for temporal trends of shoreline and bluffline position. Any lakeward shift of the bluffline identified a location where the digital data were checked for possible poor registration or other problems.

POTENTIAL SOURCES OF ERRORS

A number of potential sources of error may apply to the creation of this erosion-rate database. Some of these errors are associated specifically with the data sources being used, while others are associated with the equipment or procedures used. These potential sources of error or ambiguity are discussed below.

Data Sources

DLG base maps

The 1:24,000 DLG base maps may themselves contain digitizing errors. Small errors at intersections used for control points may adversely affect registration and rubber sheeting. An example of such an error was noted on the DLG base map for the 7.5-minute Highland Park Quadrangle at the intersection of Sheridan Road and Roger Williams Avenue. On the DLG this intersection was offset about 12 feet west from its position on the paper copy of the quadrangle. The control point at this intersection

therefore had to be shifted 12 feet east to account for this offset.

Historical Maps

Map shrinkage and expansion. Paper copies of maps may shrink or expand with time, changing the scale of the original map. Therefore, all source maps used should be on stable-base materials, such as bromide prints or mylar. However, since bromides or mylar copies are simply derived from photographic reproductions of the original paper maps, they will replicate any distortion present on those maps before they were photographed for reproduction. An effect of such distortion is shown in Table 7. Although the nominal scale of each of the six sheets used in the study was 1:20,000, the measured scales ranged from 1:19,932 to 1:20,160.

Map inaccuracies. Since the U.S. Lake Survey field sheets were primarily intended to show hydrography, not all land features were mapped with maximum precision. Comparison of the historical maps with modern maps identified some inaccuracies on both 1872 and 1910 maps such as misplaced ravines and roads that were either mismapped or subsequently moved. An example of a mismapped ravine that required significant adjustment of map features is described on page 72. Additionally, the potential for change in position of roads, railroads, bridges, and any other cultural features that might be used as control points requires careful checking for position consistency between historical map data sets and modern maps. An example of a mismapped or relocated road that significantly affected map registration is discussed on page 71.

Mapping dates. Since no descriptive reports were available for the U.S. Lake Survey field sheets, the exact month and even the exact year of the surveys was not known. This is a particular problem when the map date is given as a range such as 1909-1911

for U.S. Lake Survey field sheet I-1197. Accurate calculation of the amounts of shoreline translation required to adjust shoreline positions to a common datum was therefore impossible. (See the section Adjusting Shoreline Positions to a Common Datum, page 105, for a complete discussion of this issue.)

Scarcity of control points. The historical maps contained few cultural features in rural areas, and acceptable ground control points were difficult to locate. In some cases, it was necessary to create control points where none existed. The section Creation of Ground Control Points, page 58, discusses this procedure. The creation of a control point by one of the methods discussed in that section will generally result in less accuracy for position of that control point than if it were a feature represented on both the historical map and the base map.

Map registration. It was noted during the registration and digitizing procedure for the historical maps that some combinations of control points resulted in what appeared to be excellent map registrations as far as RMS error was concerned. However, the X and Y scales associated with these low RMS errors differed significantly from the calculated map scale or from each other, and maps digitized using such registrations showed poor alignment of roads and other cultural features. Improvement in position of such features, and presumably of the shoreline and bluffline as well, could be achieved by using registrations that had more acceptable X and Y scales but higher RMS errors.

Aerial Photographs

Photographic resolution. Although the scale of the 1947 aerial photographs is slightly greater than that of the 1987 photographs, the 1987 photographs have better resolution, which can be attributed to improved film quality and more sophisticated

camera systems. Control points and landforms are therefore considered to be located with more precision on the 1987 photographs.

Determination of bluffline. Blufflines are not always well defined, and consequently each stereoplotter operator can digitize the bluffline according to his/her own bias and judgement. Digitizing the bluffline requires judgement in designating where the relatively flat upland plain ceases and the bluff face begins. The change in slope at the bluffline can be transitional, and the rate of change in slope can vary from place to place. In addition, trees and other vegetation along the bluff can obscure the true bluffline. If the outline of the tree canopy is digitized by mistake, the result is a crenulated bluffline, segments of which may be positioned lakeward of the actual position. Finally, shadows were a particular problem in delineating the bluffline where the ground and vegetation were completely darkened. If the bluff face is in shadow, it is difficult to see the structures on the bluff face. The accuracy of the delineation of the true bluffline is dependent on operator skill and discretion, and on the quality of the aerial photographs.

Determination of shoreline. Some error occurs in digitizing the shoreline because of waves observable in both the 1947 and 1987 aerial photographs. Digitizing the shoreline requires the operator to make a judgement as to the extent of the swash zone across the beach. The shoreline was digitized at the lower limit of the swash zone which was an approximation of a still-water interface. Additionally, shadows often obscured delineation of the shoreline where wet beach sand and the lake water both appeared dark. Where the bluff face was in shadow and the shoreline was adjacent to the bluff toe, it was occasionally difficult to delineate the shoreline. As with determination of the bluffline, the accuracy of the delineation of the shoreline is dependent on operator skill and discretion, and on the quality of the photographs.

Shore structures. Light-colored shore structures such as riprap and concrete and quarry stone revetments are difficult to distinguish from beach sand on black and white photographs due to the lack of contrast in reflectivity.

Equipment

Hardware

Use of custom-modified stereoplotter. This study used a Zeiss Stereotope stereoplotter that was custom-modified by the Illinois State Geological Survey to be used with a digitizing board linked to a computer platform. One component of the equipment was a custom-made pantograph that has several mechanical parts that are potential sources of error as in any mechanical device. The use of this custom-modified equipment introduces some level of error, since quality mechanical linkages were not available, and the range of error was not determined.

Software

Error in ARC/INFO Rev. 6.0 software. Although this did not finally contribute to error in the project results, a bug in the node-attributing capabilities of ARC/INFO Rev. 6.0 caused several days of delay as the problem was first identified and then bypassed by development of alternate procedures. The bug caused the internal record numbers of transect arcs and nodes to be rearranged each time the BUILD NODE command was executed. This resulted in erroneous endpoint coordinates for many of the transects. According to ESRI, Inc., makers of ARC/INFO, this bug has been fixed in ARC/INFO Rev. 6.1.

Procedures

Coastal versus non-coastal bluffs. Some of the bluff recession recorded was due to fluvial processes as a result of a stream traversing a ravine instead of or in addition to

erosion by wave action. A distinction thus needs to be made among coastal bluffs, which are influenced by wave action, non-coastal bluffs, which are free of wave action and influenced primarily by fluvial processes, and bluffs influenced by both wave and fluvial processes. In areas where ravines intersected the coast in an approximately perpendicular orientation, these non-coastal bluffs along the ravines could be easily identified and their transect intercepts eliminated from the data set. However, in some cases ravines intersected the coast approximately tangential to it, and in such cases it could not be determined from the data sets whether fluvial or coastal processes were dominant for a given bluff. An example from Corridor 5 is shown in Figure 11; the transects that intersect this bluff are transects 519-522 in Appendix K. Where the bluff was clearly fluvially controlled, as when a transect ran directly into a ravine, the symbol *** is used in the data tables in Appendix K and on the accompanying diskette. In cases where a coastal component may be present, the actual intercept is given, but it must be emphasized that the possibility of a fluvial component of bluff erosion in situations such as these must be considered on an individual basis. In some cases it may not be possible to determine the relative effects of fluvial and/or coastal processes without field examination.

Digitizing inaccuracies. If cultural features are digitized inaccurately, the quality of the rubber sheeting will be unacceptable. Likewise, careful placing of tics at control points is important to achieving an acceptable registration.

RMS error as a measure of map accuracy. Limiting RMS error is not an accurate predictor of digital map accuracy because of geometric error propagation as one moves away from the center of the group of registration points. This is especially true when tics are tightly clustered. An example of such error propagation is described on page 71. It is important for tics to bracket the area to be digitized, and for digitizing to be

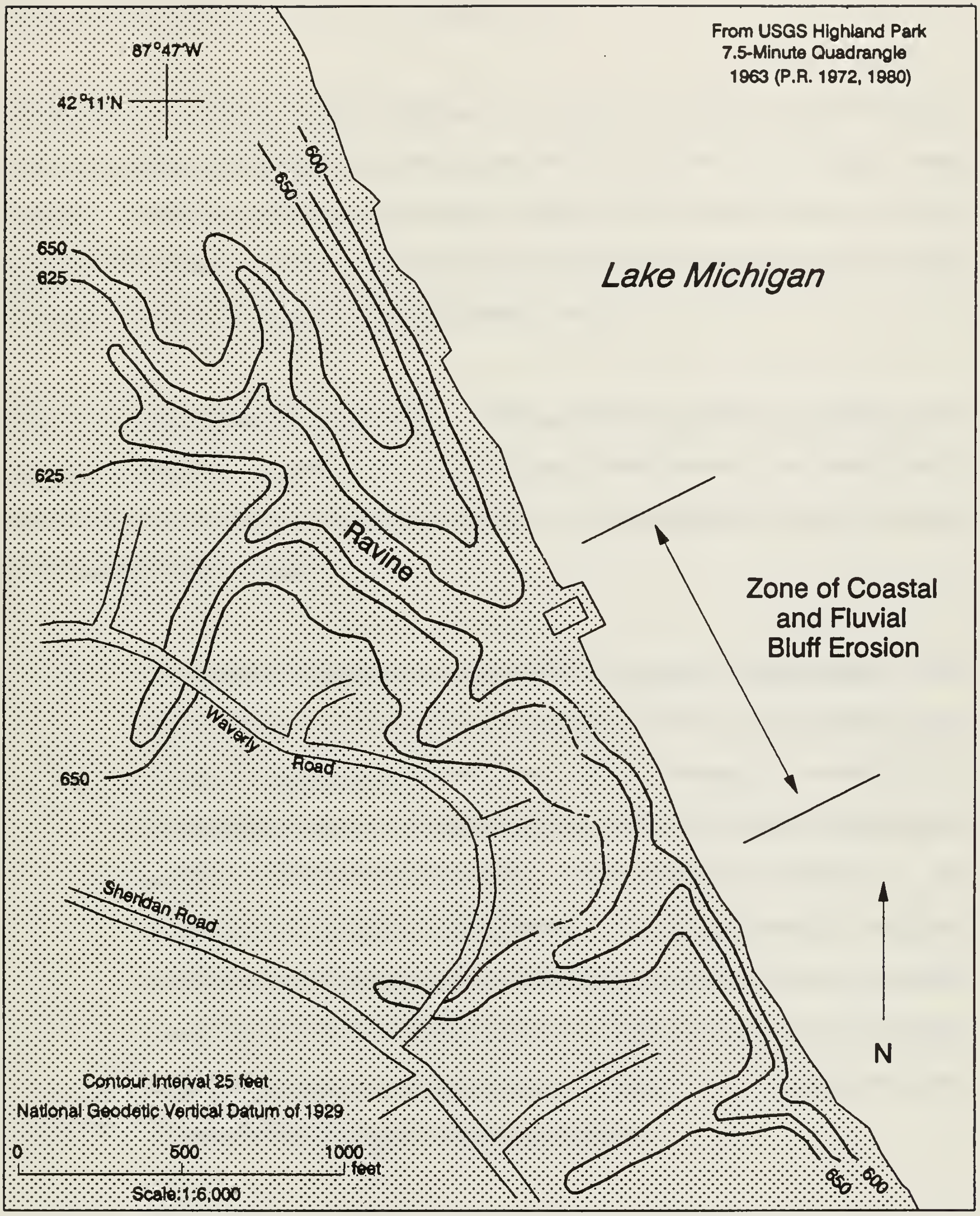


Figure 11. Sketch map of bluffs and ravines in Corridor 5, Highland Park. The large ravine with a tangential approach to the coast provides an example of where the transect grid will intercept sections of the bluff face that may be influenced more by fluvial erosional processes rather than wave-induced erosion.

limited to the area of tics used for the registration.

Operator error. Although modern digitizers are accurate, the visual acuity and eye-hand coordination of the digitizer operator can limit the accuracy of the digital maps produced. Operators must use great care and skill, but it is generally accepted that digitizer and tracing errors are random and are dampened when averaged over finite distances of shoreline (Underwood and Anders, 1991).

Problems in digitizing aerial photographs. Because this was a pilot study, some work needed to be repeated in order to account for and correct problems identified after a "first round" of work with the aerial photographs. Problems identified after the original work was performed included:

1) <u>Inadequate positioning of tics relative to the DLG base maps.</u> The hardware and software used for this study allows for increasingly more detailed (though progressively less precise) viewing of coverages by a zooming-in process. Positioning of ground control points during the tic-addition process was affected by the degree of zooming in. In particular, more precise placement of tics was possible using the zooming-in feature built into the ARC/INFO software than was possible using the zooming-in feature of the Sun platform. Ground control points could be placed to the nearest foot of their corresponding base map intersections by using the software zoom.

2) <u>Computed scale not recorded during registration.</u> Initially, the importance of recording the X and Y scales as calculated by the computer during the aerial photograph registration process was not

recognized. However, as the project proceeded, it became clear that low RMS error alone was insufficient to insure a high-quality digitized product. This is an important issue related to digitizing, and is further discussed beginning on page 63.

3) <u>Insufficient numbers of measured scales from the aerial photographs.</u> In order to judge the computed X and Y scales discussed above, they must be compared to the actual scale as calculated from the photographs themselves. Since scale varies from photograph to photograph within a given flight series, and even within any particular photograph itself, it is important to measure scale on each photograph in several places. If the range in measured scale on a given photograph is large, it may be more appropriate to compare the computed X and Y scales to the value measured for the actual area in which digitizing is occurring, rather than to some average for the entire photograph.

4) <u>Digitizing insufficient numbers of roads.</u> The importance of digitizing a sufficient number of roads cannot be overemphasized. Digitizing roads serves two purposes. First, the roads can be used to check the quality of the registration while digitizing is in progress. Second, in the data editing phase, roads can provide control intersections for link vector endpoints used in rubber sheeting. Without an adequate number of digitized roads, rubber sheeting cannot be performed, and there is little or no check on the quality of the digitizing as it is taking place. In Corridor 2 (1947) and Corridor 3 (1947 and 1987), an insufficient number of digitized roads precluded rubber sheeting, even though in the case of Corridor 3 (1987), for example, an approximately 115-foot

offset of one road relative to the DLG base map indicated that adjustment or redigitizing should have taken place.

5) Problems in determining bluffline position. As previously discussed, determining the position of the blufflines during digitizing from aerial photographs requires considerable judgement by the operator. Since there were three operators, there were three different interpretations of bluffline position. If more than one person is to digitize blufflines, a check should be done on consistency of interpretation among the various individuals who will be performing this task.

Due to the problems listed above, the original work with the aerial photographs resulted in digital maps that were judged to be of insufficient quality to be used in the pilot study. Therefore, for Corridor 4 and Corridor 5, the aerial photographs for both 1947 and 1987 were re-interpreted for bluffline position using a pocket stereoscope and were redigitized, with care being taken to account for all of the factors listed above. The results presented in Appendix K are from these redigitized photographs.

TOTAL ACCEPTABLE ERROR

To quantify historical shoreline change rates with a minimum of error, it is necessary for the shoreline change to be large or for the time interval between data sources to be large (Crowell *et al.*, 1991; Underwood and Anders, 1991). Errors are cumulative, with each map or aerial photograph used as a data source having its own associated error. Since total acceptable error is difficult to quantify due to the large number of potential sources of error, it was estimated in this study by examining a comparison of the digital shorelines that resulted from the work.

When blufflines of different temporal spacing are compared, any temporal lakeward shift in bluffline position is clearly a mapping error since a bluff position can only be either stable through time (no erosion) or translate landward (erosion). The option of a translation lakeward (accretion) has no basis in terms of natural processes. Measurement of temporal lakeward shift of the bluffline is here used as a measure of acceptable error. Corridor 5 is selected for this analysis since this corridor was mapped most rigorously and has the best data set registration of the five corridors. In a comparison of bluffline positions for each of the four data sets for this corridor, the maximum temporal lakeward translation is 32 feet between the 1910 historical map and the 1947 aerial photographs, considering only bluffs that clearly have no fluvial component. This distance is less than the U.S. National Map Accuracy Standard of 40 feet for 1:24,000-scale mapping (Ellis, 1978). Thus this is considered an acceptable error.

TASK 2: STORING AND ACCESSING HISTORICAL SHORELINE LOCATION DATA

DESCRIPTION OF PLOTFILES

The historical location database was generated and stored using the Arcplot module of ARC/INFO (Rev. 6.0). Plotfiles of the database are included on a 3.5-inch diskette provided with this report. Plots of the shoreline and bluffline maps are included in Appendix I. Each of the historical shorelines and blufflines is identified by a unique color and/or symbol. The oldest and most recent data are shown in black and red respectively as described in the project requirements. The years and corresponding color/symbols are:

Year	Color	Symbol
1872, 1873	Black	Dashed Line
1909-11, 1910-11	Green	Solid Line
1947	Blue	Solid Line
1987	Red	Solid Line

TASK 3: GENERATION OF SHORELINE TRANSECT DATA FOR CREATION OF THE HISTORICAL SHORELINE POSITIONAL CHANGE DATABASE

TRANSECT GENERATION

In order to generate the shoreline and bluffline positional data, a transect program was executed on the Historical Shoreline Location Database. The transect generation procedure and program are discussed below. Specific ARC/INFO commands used to carry out the procedure are given in Appendix G. Although the transect generation process was carried out on both shoreline and bluffline data, for simplicity the term "shoreline" is used below to refer to both data sets.

Creation of Transects

A baseline, or spine, was digitized approximately parallel to the shoreline in each of the five study corridors. This baseline was located about one mile lakeward of the most lakeward shoreline. The line was added at the graphics terminal by using the terminal crosshairs to determine the starting and ending points of a line approximately parallel to the shoreline.

The first transect line was generated by creating a copy of the baseline and rotating it 90 degrees clockwise, so that it was perpendicular to the original baseline and therefore approximately perpendicular to the shorelines. The first transect was located perpendicular to the north end of each study corridor. Once this transect was generated, the spine arc was no longer needed, and so it was deleted from the coverage. At this point the northernmost transect arc was renumbered using the

BUILD LINE command in the Arc module of ARC/INFO so that the internal numbering of the transect arcs, represented by the ARC/INFO item $RECNO would be preserved. This assigned the internal Arc number $RECNO = 1 to the northernmost transect and created an arc attribute table. An attribute table was also created for the nodes of the initial transect arc by using the BUILD NODE command. These attribute tables were set up to contain transect codes and years and all transect-shoreline intercept data.

The remaining transect lines were generated by creating a sequence of parallel copies of the original transect line, 150 feet apart. Although the Statement of Work for this contract notes on page 5 that transects should be spaced 50 meters apart (164.05 feet), subsequent discussions with the contract Project Officer determined that the preferred transect spacing is 150 feet.

During this procedure, the command LIST was issued at regular intervals to insure that the internal number $RECNO and internal coverage number <COVER># were being incremented by one for each successive arc. (This command was used frequently because of the presence of the software bug discussed on page 77, 86, and would not otherwise normally be necessary.) After all transects were generated, the $RECNO and <COVER># numbers were 1-35 from north to south.

The items CODE and YEAR were added to the arc and node attribute tables of the transect coverage and given the appropriate values. The item CODE contained the transect number, which followed the numbering scheme listed below.

Corridor	Transect numbers
1	101-135
2	201-235
3	301-335
4	401-435
5	501-535

The transects and the nodes at their endpoints were attributed in Arcedit. Following attributing, each arc and node contained the proper code and year in its respective attribute table. The coverages were then rebuilt as line coverages.

Intersection of Transects with Shorelines

Copies of the master transect coverages were made for each shoreline coverage for the intersection process. The copies were brought into each of the corridor shoreline coverages to produce the intersections of the transect lines with the shorelines. The Arcedit commands used for this procedure are given in Appendix G, and the geometry of the transects and shoreline is shown in Figure 12. Following the intersection procedure, all shoreline segments and all transect arc segments west of the shoreline were deleted. Each remaining transect segment then had a length equal to the distance between the spine-transect intercept and a new node at the shoreline-transect intercept. These new nodes were attributed with the appropriate shoreline year and transect code number. The X and Y coordinates of each node were added to the node attribute table so that the node at the east (lakeward) end of each transect contained the coordinates of the spine-transect intersection, and the node at the west end contained the coordinates of the shoreline-transect intersection. A list of the coordinates from the INFO node attribute table was output as an ASCII file, which was projected from the Lambert conformal conic projection into latitude and longitude in

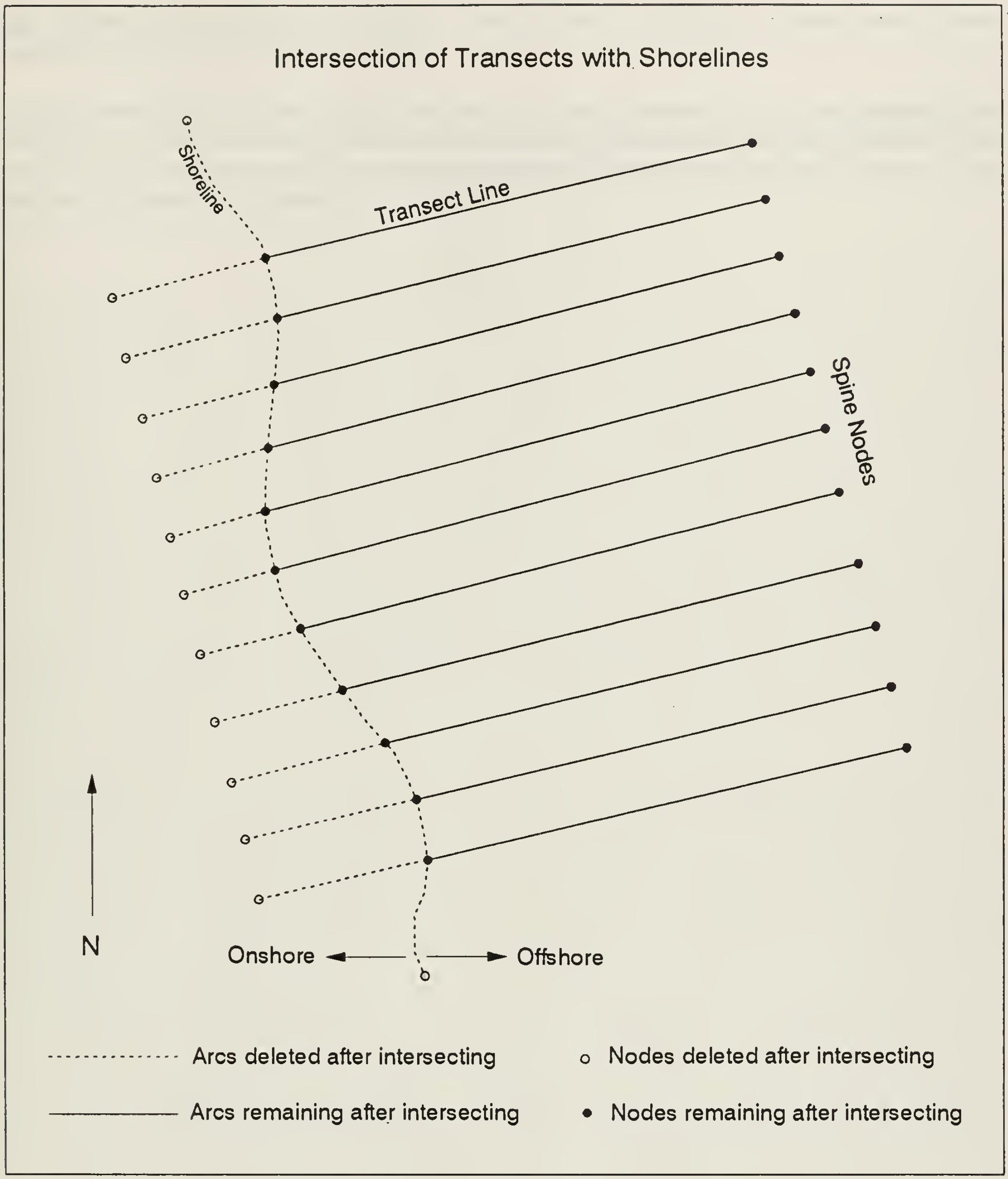


Figure 12. Transect geometry used to generate the Historical Shoreline Positional Change Database. The transects were constructed from a spine (*i.e.*, a baseline) located approximately one mile lakeward of and parallel to the shoreline.

the degrees-minutes-seconds format. The projected latitude-longitude coordinates were then imported back into INFO.

The shoreline year, transect code number, and coordinates of the spine-transect and shoreline-transect intercepts were input into an INFO program that combined the data from the arc and node attribute tables and output them in the required format. This program is listed in Appendix J.

TASK 4: STORING AND ACCESSING THE HISTORICAL SHORELINE POSITIONAL CHANGE DATABASE

After creation on the Sun platform, the Historical Shoreline Positional Change Database was transferred to 3.5-inch diskettes in ASCII format. DOS emulator software (DOS Windows 1.0) was used to export the data from the Unix-based Sun platform to ASCII files that could be sorted and edited on DOS-based personal computers. Appendix K lists the Historical Shoreline Positional Change Database after it was imported to WordPerfect 5.1 and sorted by transect code and year, and further text editing was carried out. It should be noted that the original database on the diskette accompanying this report is in raw ASCII format and did not have this text editing performed.

The database is sorted geographically from the northernmost transect to the southernmost transect. For each transect, the four shorelines or blufflines are listed chronologically from earliest to most recent. An example of the Appendix K format for Corridor 1 is shown below.

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
101	42°29'39.90"	-87°46'47.97"	1872	5,410.53	42°29'32.12"	-87°47'59.70"
101	42°29'39.90"	-87°46'47.97"	1909-11	5,748.00	42°29'31.65"	-87°48'04.17"
101	42°29'39.90"	-87°46'47.97"	1947	6,017.21	42°29'31.25"	-87°48'07.73"
101	42°29'39.90"	-87°46'47.97"	1987	6,503.25	42°29'30.56"	-87°48'14.18"
102	42°29'38.43"	-87°46'47.68"	1872	5,383.69	42°29'30.70"	-87°47'59.05"
102	42°29'38.43"	-87°46'47.68"	1909-11	5,735.92	42°29'30.18"	-87°48'03.71"
102	42°29'38.43"	-87°46'47.68"	1947	6,025.80	42°29'29.77"	-87°48'07.55"
102	42°29'38.43"	-87°46'47.68"	1987	6,520.47	42°29'29.06"	-87°48'14.11"
:	:	:	:	:	:	:
135	42°28'49.86"	-87°46'38.08"	1872	5,162.45	42°28'42.45"	-87°47'46.50"
135	42°28'49.86"	-87°46'38.08"	1909-11	5,592.48	42°28'41.83"	-87°47'52.19"
135	42°28'49.86"	-87°46'38.08"	1947	5,628.48	42°28'41.78"	-87°47'52.68"
135	42°28'49.86"	-87°46'38.08"	1987	6,215.10	42°28'40.93"	-87°48'00.45"

TASK 5: SOURCE MAP RECONNAISSANCE STUDY

An inventory was completed of historical and recent field sheets, maps, charts, and vertical aerial photographs applicable to creation of an erosion-rate database for the Illinois coast of Lake Michigan. The inventory and supporting discussion are included in an accompanying report (Report 2) titled "Inventory of Federal and State Historical Maps, Charts, and Vertical Aerial Photographs Applicable to Erosion-Rate Studies Along the Illinois Coast of Lake Michigan." A complete citation of this report is given under References Cited (Chrzastowski and Read, 1993).

TASK 6: ACCURACY ASSESSMENT OF THE U.S. LAKE SURVEY FIELD SHEETS

The procedure used for checking registration control points on the U.S. Lake Survey field sheets provides a means to make a semi-quantitative assessment of the accuracy of these maps. This procedure involved selecting pairs of points (such as road intersections and railroad crossings) common to the bromide copies of the field sheets and the paper copies of the most recent corresponding USGS 7.5-minute topographic quadrangles. Distances between points were measured in map inches and multiplied by the map scale to yield ground feet distances for the field sheets and USGS maps, which were compared. This is a shorthand and purely office-based procedure to assess the map accuracy. A formal accuracy assessment of the USLS field sheets would require comparing distances between control points on the field sheets directly against distances between corresponding points on the ground as measured by electronic distance meter or a global positioning system.

A limitation of this accuracy assessment is that it is only based on point measurements in the vicinity of the corridors used in this study and is not a general assessment across any one of the field sheets. In addition, this assessment does not distinguish between field sheets, but rather, groups these for an overall assessment of the 1872-73 and 1909-11 mapping. Another important limitation is that it is assumed that the USGS quadrangles document true position, and thus any differences in the paired-point measurements reflect map inaccuracies solely in the field sheets. This assumption dismisses inherent and acceptable inaccuracies in the USGS quadrangles, since the

location of well-defined points on the USGS maps such as intersections of roads, railroads, and bridges are only positioned within the requirements of U.S. National Map Accuracy Standards for 1:24,000-scale maps. These standards allow 90% of such points to be mapped within 40 feet of their actual position (Ellis, 1978).

Tables 8 and 9 summarize results of the paired-point measuring test for the 1872-73 and 1909-11 field sheets. The variable map accuracy of the field sheets is demonstrated in these summaries. Comparison of some pairs of points results in essentially equivalent distance measurements on the two maps. Other point pairs compared result in distance differences of tens to hundreds of feet, even exceeding 1,000 feet. However, such extremes cannot be assumed to be gross mapping errors since they may reflect changes in road locations. The best way to determine if a feature has moved is through extensive historical research. If it can be documented that a feature has moved, that point should not be part of an accuracy evaluation.

The breakdown by corridor has the advantage of demonstrating how the historical map accuracies can vary locally. Present-day maps have a rather uniform accuracy across the map sheet because of photogrammetric control. Such is not the case with historical maps. Some areas of good ground control could be mapped more accurately than those with minimal control. Map areas that had to be bridged between areas of better control are areas of apparent lesser map accuracy. For example, for the 1872-73 maps the measurement differences in the vicinity of Corridor 3 are greater than for all other corridors. At the time of the 1872-73 mapping this corridor was a coastal area of minimal development, and therefore the number of road intersections available for measurement is limited. In contrast, the distribution of measurement differences in Corridor 2 has the smallest range and dispersion because of the large number of street intersections and the stability of the road grid in the downtown Waukegan area.

Table 8.	Range and dispersion in the distribution of paired-point measurement differences for the U.S. Lake Survey 1872-73 field sheets and the most recent USGS 7.5-minute quadrangle.				
	Corridor 1	Corridor 2	Corridor 3	Corridor 4	Corridor 5
Number of pairs of intersections measured	21	29	44	106	70
Minimum difference between measurement on USLS field sheet and USGS quadrangle (feet)	1	0	0	0	2
Maximum difference between measurement on USLS field sheet and USGS quadrangle (feet)	267	113	1585	1000	281
Mean difference (feet)	72	81	149	50	60
Standard deviation (feet)	81	29	314	108	60
50th percentile value (median difference) (feet)	42	34	56	31	48
90th percentile value (feet)	**219**	**82**	**165**	**78**	**122**

In addition, most of these intersections are right-angle intersections. This allows for greater precision in measurements than the oblique intersections used as control in the more rural settings of corridors 3, 4, and 5.

It might be expected that the 1909-11 maps would generally have greater map accuracy due to better ground control and improvements in surveying equipment and techniques. A comparison of the measurement statistics for each corridor for each

Table 9. Range and dispersion in the distribution of paired-point measurement differences for the U.S. Lake Survey 1909-11 field sheets and the most recent USGS 7.5-minute quadrangles.

	Corridor 1	Corridor 2	Corridor 3	Corridor 4[1]	Corridor 5
Number of pairs of intersections measured	25	78	61	118	152
Minimum difference between measurement on USLS field sheet and USGS quadrangle (feet)	6	1	1	3	0
Maximum difference between measurement on USLS field sheet and USGS quadrangle (feet)	179	151	140	352	115
Mean difference (feet)	60	46	39	56	29
Standard deviation (feet)	57	32	30	61	23
50th percentile value (median difference) (feet)	26	39	23	43	28
90th percentile value (feet)	**133**	**87**	**76**	**98**	**58**

[1]The numbers given for Corridor 4 are averages of the numbers for the northern part of the corridor, on field sheet I-1196, and the southern part of the corridor, on field sheet I-1195. The number of pairs of measured intersections given is the sum for both parts.

survey set shows that the 1909-11 maps have somewhat smaller measurement differences, which might reflect greater map accuracy. However, the difference in accuracy between these two maps is not statistically significant. It should also be noted that where minimal numbers of cultural features had been mapped, it could not be determined whether apparent map inaccuracies were due to actual mapping errors or to the lack of ground control.

The question arises as to how these USLS field sheets fare when compared to U.S. National Map Accuracy Standards (NMAS). To correctly evaluate this would require comparing locations and distances of well-defined points on the USLS field sheets with ground survey data. This comparison to measurements on a paper map does not constitute a valid test, but nevertheless, the comparison provides a general evaluation.

Strict requirements exist to meet NMAS (Ellis, 1978). As previously stated, for maps at scales of 1:24,000 or greater, 90% of all tested well-defined points need to be located on the map within 40 feet of their true location. Tables 8 and 9 list the 90th percentile values of the measurement differences for each of the corridors (highlighted in the tables). The 90th percentile value is the measured distance that is exceeded by 10% of the points. For the corridors on the 1872-73 field sheets, the 90th percentile values range from 78 to 219 feet with an average value of 133 feet; for the 1909-11 field sheets the range is 58 to 133 feet with an average of 90 feet. These differences are so great that even considering the potential 40-foot position inaccuracy of points on the USGS maps, more than 40 feet of position error can be attributed solely to the field sheets.

It should be noted that this semi-quantitative assessment of source map accuracy was carried out using points that were selected for the purpose of ground control, not for the purpose of assessing map accuracy. If points are to be selected specifically and only for accuracy assessment, then the following criteria for point selection would apply:

1) Select points distributed as widely over the map as possible.
2) Select the same number of points for each map.
3) Select points in the following sequence of reliability, from most to least reliable:

- Control points marked on the map or described in Descriptive Reports.
- Railroad track crossings and intersections.
- Road intersections.
- Corners of prominent buildings.
- Bridges.

This assessment substantiates why difficulties occurred and should be expected in attempting to register these field sheets to a DLG base map. The map inaccuracies of the USLS field sheets are a factor that would prevent or complicate a single registration from being used for digitizing across an entire field sheet.

TASK 7: TIME ITEMIZATION

The time study reported here is for all work completed between January 1, 1992 and August 31, 1992. The official completion date of the contract was October 31, 1992. The months of September and October 1992 were a designated review period for the final report. An early phase of the contract agreement was conducted from April through December 1991, but none of that time is reported here since it was not documented by the original Principal Investigator.

Six staff members were assigned to this study. During the project, staff kept logs of tasks performed and total time invested. Table 10 summarizes these time investments per task per payroll title. The summary includes efforts on both the erosion-rate pilot study reported here, and the accompanying inventory of historical maps, charts, and aerial photographs applicable to erosion-rate studies (Chrzastowski and Read, 1993). The total time investment for all tasks was 1498 hours which is 37.5 work weeks (9.4 months).

Much work on the inventory of historical maps, charts, and aerial photographs was completed by a Junior Supportive Scientist. Major efforts on this inventory by this person are reflected in the large amount of time expended on source data collection, and report writeup (*i.e.*, inventory preparation). This person also had significant time investment in operational activities such as contacting and obtaining data from source agencies.

Table 10. Summary of time investments per task and per payroll title for the erosion data study.

PAYROLL TITLES / TASKS	ASSOCIATE PROFESSIONAL SCIENTIST (2)[a]	ASSISTANT PROFESSIONAL SCIENTIST (1)	ASSISTANT SUPPORTIVE SCIENTIST (1)	JUNIOR SUPPORTIVE SCIENTIST (1)	TECHNICAL ASSISTANT (1)	TOTAL HOURS (PER TASK)
SOURCE DATA COLLECTION	9[b]	1.5	0	81	3.5	95
SOURCE DATA REVIEW & PREPARATION (AERIAL PHOTOGRAPHS)	2	5	4	0	14.5	25.5
SOURCE DATA REVIEW & PREPARATION (HISTORICAL MAPS)	1	33	42	0	7	83
SHORELINE DIGITIZING (AERIAL PHOTOGRAPHS)	47	6	9	20	38	120
SHORELINE DIGITIZING (HISTORICAL MAPS)	0	32	40	0	0	72
DATA PROCESSING	31	50	31	0	0	112
SETUP & EXECUTION OF TRANSECT PROGRAM	0	70.5	65	0	0	135.5
TRAINING	28	5	3	8	12	56
OPERATIONAL ACTIVITIES	10.5	10	8	22	5.5	56
REPORT WRITEUP	273.5	95	67	265	42.5	743
TOTAL HOURS (PER PAYROLL TITLE)	402	308	269	396	123	1498

a-number of staff at specified payroll level
b-all values are rounded to 0.5 hour increments

The task of greatest time investment for both the erosion-rate study and inventory was report writing (743 hours). This largely reflects this being a pilot study and the need for the erosion-rate study to thoroughly document procedures.

A total of 135.5 hours was spent on the transect program. The time investment is anomalously high for this task because it results from working around a "bug" in the ARC/INFO software used for the transect generation. It is estimated that this task could have been completed in about half the time if not for this computer software problem.

Registration and digitizing of aerial photographs required 120 hours, but only required 72 hours for the historical maps. The greater time for the aerial photographs reflects the greater number of stereoplotter setups and registrations needed per shoreline reach as compared to the maps.

Source data review and preparation includes the time invested in the selection and checking of ground control points. The much greater time spent on historical maps (83 hours) compared to the aerial photography (25.5 hours) relates to the difficulties encountered in obtaining satisfactory control points on the historical maps which have various map inaccuracies.

The total time investment for staff members to be trained and/or train was 56 hours. Most of this time involved training in use of the stereoplotter. Operational activities totaling 56 hours included progress meetings, correspondence, computer systems consultation, and other intermittent, short-term activities peripheral to the primary focus of the computer-assisted mapping.

An example of the time needed per shoreline mile to proceed from initial preparation of a U.S. Lake Survey field sheet or aerial photograph to a final digital shoreline or bluffline data set is summarized here for Corridor 5 (Highland Park). This corridor is selected as an example because it reflects the time investment needed to obtain the best registration of source map to base map that was achieved in this study. For both the historical maps and aerial photographs, work can be divided into three broad categories: 1) selecting and checking ground control points; 2) registration and digitizing; and 3) editing. Table 11 summarizes the time in hours and percent time per operation for work on these two data sources for Corridor 5. Total time spent with the historical maps was 24 hours, and with the aerial photographs 40 hours. The greater time investment for the aerial photographs (1.6 times greater) was the general rule because of the additional stereoscope setups and registrations compared to the historical maps. For Corridor 5, three setups and registrations were required compared to one registration for the historical map. The time working with the aerial photographs includes the work done with a pocket stereoscope.

Table 11. Comparison of time necessary for completion of digital shoreline data sets using historical maps and aerial photographs, Corridor 5.

Historical Maps Operations	Time (hours)	% Total Time
1) Selecting and Checking Ground Control Points	13	55
2) Registration and Digitizing	5	[illegible]0
3) Editing	6	[illegible]
TOTAL	24	100
Aerial Photographs Operations	**Time (hours)**	**% Total Time**
1) Selecting Ground Control Points	3	7.5
2) Registration and Digitizing	32	80
3) Editing	5	12.5
TOTAL	40	100

PART 4

DISCUSSION

The data compiled in this study must be interpreted and applied with consideration for factors such as natural and human processes influencing the erosion rate and refinements that could have been done but were beyond the scope of this study. The following discussion focuses on four important factors that affect data interpretation and application:

1) Comparison of corridor data quality;
2) Adjustment of shorelines to a common datum;
3) Comparison of results with previous studies;
4) Framework for interpreting coastal erosion rates.

COMPARISON OF CORRIDOR DATA QUALITY

Five one-mile long corridors illustrating the varied geomorphic settings along the Lake County coast were selected for this study. Slightly different mapping procedures were used in each corridor because of differences in corridor characteristics. For example, in Corridors 1 and 2, aerial photographs were not digitized with a stereoplotter because low-relief topography did not require parallax correction. Data quality in each corridor was affected by number and distribution of ground control points, quality of registration, type and number of features digitized, and the degree of rubber sheeting. The following briefly summarizes the strengths and weaknesses of the data sets for each of the corridors.

Corridor 1: North Point

Since this corridor is on the beach-ridge plain, it lacks coastal bluffs, and thus did not require use of the stereoplotter for digitizing from the aerial photographs. Shorelines were digitized directly from single aerial photographs. Because this was an area of limited cultural development in 1872 and 1910, ground control points are not numerous on the historical maps, but any errors in the digital mapping are small compared to the extreme rate of shoreline erosion. The shoreline change database documents the erosional trend, but since the shorelines are not corrected to a common datum, the magnitudes of the temporal changes are in part influenced by differences in lake level.

Corridor 2: Waukegan Harbor

As was the case for Corridor 1, the beach-ridge plain setting of this corridor precluded need for use of the stereoplotter, and shorelines were digitized directly from single aerial photographs. The abundance of road intersections in nearby Waukegan provided numerous ground control points for all four data sources. The database documents the temporal trend of shoreline accretion, although since shorelines are not corrected to a common datum, the absolute positions of the shorelines are affected by differences in lake level. As in Corridor 1, the rate of shoreline change is large compared to errors that may have occurred in the digital mapping.

Corridor 3: Lake Bluff

Of the five corridors mapped, Corridor 3 is clearly the least satisfactory database. The corridor illustrates the problems that can occur if insufficient ground control exists for the historical maps, and if an insufficient number of street intersections and other control points are digitized from the aerial photographs. One problem in the database is that in some cases younger blufflines are lakeward of older ones. The database for

this corridor has no geologic significance and should not be used in any application to erosion rates. The database for this corridor demonstrates that if ground control is not adequately used, the shoreline change maps are meaningless.

Corridor 4: Lake Forest

This corridor presented several problems, including errors on the source maps, inadequate ground control, and difficulty in matching features from adjacent map sheets that joined within the corridor. These problems were somewhat resolved after careful comparison of the source maps with modern maps and several repeated efforts in selecting stable ground control points. Discrepancies in the bluffline positions mapped with the stereoplotter made it necessary to replot the bluffline with the aid of a stereoscope and digitize it from single aerial photographs. Since all ground control was located at an elevation near that of the bluff crest, the problem of relief displacement was alleviated. With the same registration, additional road intersections were digitized for use in rubber sheeting. As a result, map accuracy was improved, although the 1910 bluff line continued to be located landward (west) of its actual position as a result of the error described on page 71. The database created for this corridor is considered to be of higher quality than that for Corridor 3.

Corridor 5: Highland Park

As was the case for Corridor 4, this corridor also initially presented several problems. After digitizing with the stereoplotter, blufflines were reinterpreted using a stereoscope and redigitized from single aerial photographs. Additional roads were added to assist in control for rubber sheeting. The large number of ground control points available for this corridor and the careful reinterpretation of the bluffline resulted in a database that is considered the highest quality achieved in this study. There are still localized errors in bluffline position with younger blufflines lakeward of older ones, but none by as

much as the NMAS of 40 feet. Statistical analysis of the database for Corridor 5 can provide valid erosional trends applicable to this coastal reach.

ADJUSTING SHORELINE POSITIONS TO A COMMON DATUM

Shorelines in this study were digitized as they appeared on the U.S. Lake Survey field sheets and on the aerial photographs. The lake levels and differences in lake level for the four data sources are summarized in Table 6. It was beyond the scope of this study to adjust the shorelines for each of these four data sources to a common lake level, but for accurate documentation of temporal shoreline changes, such adjustment would be necessary. This section provides examples of the amount of translation in shoreline position that would be necessary for each of the corridors.

Along shore structures such as breakwaters, bulkheads, revetments, and riprap, differences in lake level have little effect on shoreline position since the structures present a vertical or near-vertical slope. However, the lateral translation of the shoreline along a sandy beach can be significant at different lake levels depending on the slope of the foreshore and upper shoreface.

Foreshore slopes at selected profile locations along the Illinois lakeshore have been tabulated by the U. S. Army Corps of Engineers (1953; p. 22) based on 1946 profiling along established ranges previously surveyed in 1872 and 1909-11. Although more recent data may exist for specific sites, the Corps of Engineers study is the only regional compilation to date.

The Waukegan Harbor corridor (Corridor 2) is a special case because of its accretionary history, but considering the other four corridors, the Corps of Engineers report on

foreshore slopes for a total of six profiles that are either within the corridors used in this study or are within one mile of the corridor borders. Two profiles are applicable to Corridor 1 on the beach-ridge plain, with foreshore slopes of 1:20 along Range 1, at the state line, and 1:31 along Range 2, located about 2600 feet south of the corridor. The average of these slopes, 1:26, is used here as representative of Corridor 1. Along the bluff coast a slope of 1:20 is recorded for Range 13 which is located within Corridor 3. A slope of 1:22 occurs along Range 15 located one mile north of Corridor 4; a slope of 1:14 occurs along Range 18 located three-quarters of a mile north of Corridor 5. The average of these two foreshore slopes (1:18) is here used as representative of the bluff coast for Corridors 4 and 5.

The Waukegan Harbor corridor has low foreshore slopes resulting from the extensive fine sand accretion that has occurred updrift of the harbor jetties. A slope of 1:68 occurs along Range 8 on the updrift side of the northernmost jetty. This slope is used for the 1909-11, 1947, and 1987 calculations. A slope of 1:29 is used for the 1872 mapping since at this time the beach and nearshore had yet to be influenced by the Waukegan Harbor jetties. The 1:29 slope is taken from a profile on the beach-ridge plain (Range 5) located two miles north of the corridor which is assumed to be a representative southern beach-ridge plain foreshore slope unaffected by shore structures.

By using lake levels at the time of the surveys and the Corps of Engineers foreshore slopes, a first-approximation calculation can be made of the amount of translation needed to adjust the shoreline positions to a common datum. Table 12 lists the translations required to adjust the shoreline for each of the survey years for each of the corridors to the elevation of the Lakes Michigan-Huron 1900-1990 monthly mean lake level, and also to the elevation of the Lakes Michigan-Huron Low Water Datum

Table 12. Example shoreline translations needed to adjust shoreline positions to a common datum of either 1900–1990 monthly mean lake level or Low Water Datum.

Shoreline Survey Year	Lake Level (feet) IGLD (1955)	Corridor	Representative Foreshore Slope[1]	Lake Level Difference from Monthly Mean Lake Level 578.34 ft. (IGLD 1955)	Shoreline Translation (ft) to 1900–1990 Monthly Mean Lake Level – = Lakeward + = Landward	Lake Level Difference from Low Water Datum 576.80 ft. (IGLD 1955)	Shoreline Translation (ft) to Low Water Datum – = Lakeward + = Landward
1872–73	579.20[2]	1) North Point	1:26	+0.86	–22.4	+2.40	–62.4
		2) Waukegan Hbr.	1:29		–24.9		–69.6
		3) Lake Bluff	1:20		–17.2		–48.0
		4) Lake Forest	1:18		–15.5		–43.2
		5) Highland Park	1:18		–15.5		–43.2
1909–11	578.47[3]	1) North Point	1:26	–0.13	+3.9	+1.67	–36.1
		2) Waukegan Hbr.	1:68		+8.8		–113.6
		3) Lake Bluff	1:20		+2.6		–33.4
		4) Lake Forest	1:18		+2.3		–30.1
		5) Highland Park	1:18		+2.3		–30.1
1947	577.75[4]	1) North Point	1:26	–0.59	+15.3	+0.95	–24.7
		2) Waukegan Hbr.	1:68		+40.1		–64.6
		3) Lake Bluff	1:20		+11.8		–19.0
		4) Lake Forest	1:18		+10.6		–17.1
		5) Highland Park	1:18		+10.6		–17.1
1987	580.55[4]	1) North Point	1:26	+2.21	–57.5	+3.75	–97.5
		2) Waukegan Hbr.	1:68		–150.3		–255.0
		3) Lake Bluff	1:20		–44.2		–75.0
		4) Lake Forest	1:18		–39.8		–67.5
		5) Highland Park	1:18		–39.8		–67.5

[1]From U.S. Army Corps of Engineers (1953).
[2]Lake level for 1872 bathymetric survey calculated by U.S. Army Corps of Engineers and stamped on field sheet on April 16, 1947.
[3]Average of five months May through September 1909 and 1911 for records at Milwaukee, Wisconsin and Calumet Harbor, Illinois.
[4]Average of mean daily lake level for Milwaukee, Wisconsin and Calumet Harbor, Illinois.

(LWD). In this exercise it is assumed that a single foreshore slope applies to the entire corridor. This simplification ignores the fact that the foreshore and upper shoreface slopes will adjust to varying degrees with changes in lake level (Hands, 1980).

Using the assumption of a single, uniform foreshore slope along each corridor, this method of calculating shoreline translations demonstrates that mapped shoreline positions may need to be shifted tens of feet and even hundreds of feet in order to be adjusted to a common datum.

In this example case, both landward and lakeward translations are necessary to adjust to Monthly Mean Lake Level. For the corridors other than the Waukegan Harbor corridor, the range in required shoreline translation is 2.3 to 57.5 feet. To adjust to LWD, translations for all data sets are lakeward and range from 17.1 to 97.5 feet. The Waukegan Harbor corridor requires considerably larger adjustments of 150.3 feet and 228.8 feet for adjustment to Monthly Mean Lake Level and LWD, respectively.

These shoreline translations are computed based on a simplistic approach and are a first approximation at best. If such shoreline translations were done as part of a mapping effort, numerous closely spaced profile data would be needed along the entire coastal reach being mapped to assure that the calculated translations account for variations in the beach and nearshore morphology. Such profile data would be needed for the time (or approximate time) of each map and aerial photograph. The effort would clearly be major. Further, the translations would introduce errors in the analysis of shoreline change. In some cases the amount of translation needed to achieve a common datum may be much greater than the actual change in position between any two data sources.

This example case of shoreline translation is presented to emphasize two issues concerning lake level that need to be addressed in the development of a reliable database of erosion rates along the Illinois coast:

1) If shoreline change *per se* is the reference for monitoring coastal erosion, the interdependence of lake level and shoreline position must be considered when comparing shorelines at different lake levels.

2) If shorelines are compared at a common lake-level datum, a decision must be made concerning what datum is preferred and how the shoreline translations will be done for the various map and/or aerial photograph data sources.

When using published data on shoreline erosion/accretion history, it is important to determine what the datum is for shoreline position. It is also important to be aware that some previous work has ignored the issue of shoreline translation with lake level change, and uncorrected erosion/accretion rates have been reported.

COMPARISON WITH PREVIOUS STUDIES

Shoreline Change

Historical shoreline changes for Lake County were determined by the U.S. Army Corps of Engineers (1953) by comparing shoreline positions mapped in 1872 and 1910 by the U.S. Lake Survey, and shorelines mapped in 1946 by the Corps. The temporal position differences and rates of change are reported for specific range lines perpendicular to the Illinois coast that were first established for the 1872-73 U.S. Lake Survey hydrographic surveys and subsequently reoccupied. The shoreline positions along each range line are reported based on shoreline adjustment to Low Water Datum (LWD). In this section, the shoreline changes along the Corps of Engineers range lines

are compared to the changes along the nearest corresponding transect from this study. Two range lines occur within the Corridor 2 (Waukegan Harbor) boundaries and can be compared to two transect lines. Each of the other corridors contain one range line corresponding to one transect. Since this study does not have shorelines corrected to LWD, comparison with the Corps data provides an evaluation of the difference obtained for shoreline change with and without a datum adjustment.

Comparisons of the net shoreline changes and annual shoreline changes are summarized in Tables 13 and 14. Two factors apply to interpreting these tables:

1) The Corps of Engineers mapped the shoreline in 1946 and this study mapped the 1947 shoreline.
2) All values for accretion or erosion between data sets were rounded to the nearest ten feet.

The trend of shoreline change (*i.e.,* accretion or erosion) is the same in all cases except for the 1910-1946/47 comparison for Corridor 3 in which the Corps reported 30 feet of erosion and this study determined 10 feet of accretion. Other than for Corridor 2, the differences range from 30 to 130 feet. Most of the differences (63%) are 40 feet or less. The greatest difference occurs in comparison of Corridor 2. The low-slope foreshore of this extensive accretion plain results in a large amount of lateral translation of the shoreline with change in lake level. The large differences between the studies, ranging from 90 to 300 feet, reflect the potential for extreme sensitivity of this low-slope feature to even minor changes in lake level.

Table 13. Comparison of 1872 to 1910 and 1910 to 1946-1947 shoreline changes documented along survey ranges by the U.S. Army Corps of Engineers (1953) and shoreline changes along nearest corresponding transect from this study.

Corridors with Corresponding USACE Range Number and ISGS Transect Number	Shoreline Change in Feet (E = erosion; A = accretion)		
	U.S. Army Corps of Engineers (1953)	ISGS (This Study)	Difference (USACE-ISGS)
Corridor 1: North Point			
USACE Range 1			
ISGS Transect 101			
1872-1910	390 (E)	340 (E)	50
1910-1946/47	310 (E)	270 (E)	40
Corridor 2: Waukegan Harbor			
USACE Range 7			
ISGS Transect 213			
1872-1910	450 (A)	750 (A)	300
1910-1946/47	380 (A)	470 (A)	90
USACE Range 8			
ISGS Transect 222			
1872-1910	1,000 (A)	1,170 (A)	170
1910-1946/47	920 (A)	680 (A)	240
Corridor 3: Lake Bluff			
USACE Range 13			
ISGS Transect 314			
1872-1910	220 (E)	90 (E)	130
1910-1946/47	30 (E)	10 (A)	40
Corridor 4: Lake Forest			
USACE Range 16			
ISGS Transect 410			
1872-1910	(No change)	10 (E)	10
1910-1946/47	(No change)	30 (E)	30
Corridor 5: Highland Park			
USACE Range 19			
ISGS Transect 518			
1872-1910	20 (E)	100 (E)	80
1910-1946/47	40 (A)	70 (A)	30

Table 14. Comparison of 1872 to 1910 and 1910 to 1946-1947 annual shoreline changes documented along survey ranges by the U.S. Army Corps of Engineers (1953) and shoreline changes along nearest corresponding transect from this study.

Corridors with Corresponding USACE Range Number and ISGS Transect Number	Average Annual Shoreline Change[1] in Feet/Year (E = erosion; A = accretion)		
	U.S. Army Corps of Engineers (1953)	ISGS (This Study)	Difference (USACE-ISGS)
<u>Corridor 1: North Point</u>			
USACE Range 1			
ISGS Transect 101			
1872-1910	10.2 (E)	9.0 (E)	1.2
1910-1946/47	8.6 (E)	7.3 (E)	1.3
<u>Corridor 2: Waukegan Harbor</u>			
USACE Range 7			
ISGS Transect 213			
1872-1910	11.8 (A)	19.7 (A)	7.9
1910-1946/47	10.6 (A)	12.7 (A)	2.1
USACE Range 8			
ISGS Transect 222			
1872-1910	26.3 (A)	30.8 (A)	4.5
1910-1946/47	25.6 (A)	18.4 (A)	7.2
<u>Corridor 3: Lake Bluff</u>			
USACE Range 13			
ISGS Transect 314			
1872-1910	5.8 (E)	2.4 (E)	3.4
1910-1946/47	0.8 (E)	0.3 (A)	1.1
<u>Corridor 4: Lake Forest</u>			
USACE Range 16			
ISGS Transect 410			
1872-1910	(No change)	0.3 (E)	0.3
1910-1946/47	(No change)	0.8 (E)	0.8
<u>Corridor 5: Highland Park</u>			
USACE Range 19			
ISGS Transect 518			
1872-1910	0.5 (E)	2.6 (E)	2.1
1910-1946/47	1.1 (A)	1.9 (A)	0.8

[1]For the 1910 to 1946/47 calculations, USACE data calculated to 1946, ISGS data calculated to 1947.

These comparisons are a relative indicator of the error in the shoreline positions that results when they are not adjusted to a common datum. The differences between shoreline changes reported in this study and those reported by the Corps of Engineers numbers are partly due to lack of datum adjustment.

Table 14 summarizes average annual shoreline changes. Other than for Corridor 2, the differences in rate of change between the Corps of Engineers study and this study range from 0.3 to 3.4 feet/year. Most of the differences (75%) are 1.3 feet/year or less. Again, the larger differences for Corridor 2 reflect the beach and nearshore morphology. For all other corridors, these comparisons suggest that the data sets from this study have annual rates of shoreline change within about 1.5 feet/year of the rates that would be computed if shorelines were adjusted to LWD. This difference may not be significant for some applications, but given the accuracy requirements in a shoreline change study such as this, this difference is probably unacceptable. Comparison of shorelines at a common datum is mandatory for an accurate assessment and quantification of shoreline change.

Bluffline Changes

As noted in this study and in previous studies of bluff recession along the Illinois coast, rates of bluff recession are extremely variable over short time periods, and bluff segments with high retreat rates can be located immediately adjacent to segments with much lower rates. This complicates comparison with published work, because the data for individual transects may not be reported, and proper comparison can only be done with identically located transects and equivalent time frames.

Results for this study suggest some differences in rates of bluffline change compared

to those reported in previous studies. For example, Jibson *et al.* (1992) compared 1872 to 1987 bluffline positions and reported an average recession rate for the bluff coast of 0.62 feet per year. In this study, data from Corridors 4 and 5 give an average rate of 1.01 feet/year over the same time period. Data for Corridor 3 are dismissed because of inherent inaccuracies in the mapped bluffline position. Berg and Collinson's (1976) reported recession rates for specific transects best matched those of this study in Corridor 4 along the Lake Forest Nature Preserve (transects 433 and 435, this study). At this locality for the period 1947 to 1975, Berg and Collinson (1976) reported a recession rate of 1.01 feet/year. In this study, the calculated rate between 1947 and 1987 is 1.81 feet/year. More thorough comparison of a greater number of transects is necessary to adequately evaluate how various studies agree or disagree with this one.

FRAMEWORK FOR INTERPRETING COASTAL EROSION RATES

Coastal Storms

No complete record of storm history has been compiled for the Illinois coast. The record of coastal erosion in the popular press as well as in government reports and scientific papers essentially parallels the history of high lake levels. Figure 13 shows this correlation between lake level and publication of coastal erosion reports for 1860 through 1991. By only looking at the frequency and distribution of publications concerning coastal erosion, the perception might be that the temporal clustering of these publications is associated with a temporal clustering of greater storm intensity or frequency. However, the correlation is with high lake levels rather than with storm occurrences. Storm activity occurring during times of above-average lake level does cause the greatest erosion of beaches and bluffs and damage to shore structures.

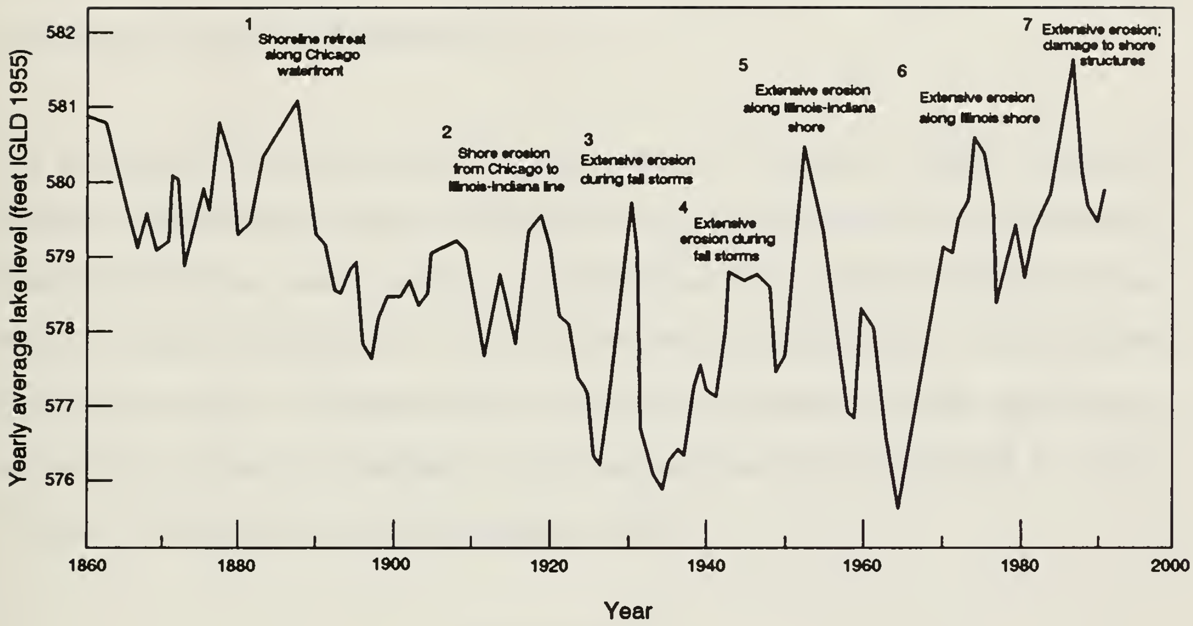


Figure 13. Yearly average lake levels for Lake Michigan 1860 to 1991 with times of government reports, newspaper articles, and scientific papers concerning erosion along the Illinois lakeshore. Published reports of erosion coincide with periods of high lake levels. 1: Ex. Doc., 47th Cong. (1880); Ex. Doc. 36, 48th Cong. (1884), cited in Illinois Division of Waterways (1958); 2: House Doc. 710, 65th Cong. (1917), cited in Illinois Division of Waterways (1958); 3 and 4: newspaper accounts of severe storms along the coast causing extensive erosion, cited in Illinois Division of Waterways (1958); 5: Illinois Division of Waterways (1958), Olson (1958); 6: Larsen (1973), Hester and Fraser (1973), Fraser and Hester (1974); 7: Chicago Shoreline Protection Commission (1988). Figure modified from Fraser *et al.* (1990).

However, at low lake levels storm energy has a greater effect on erosion across the nearshore bottom. Erosion of this surface can cause a lower nearshore profile and a steeper shoreface profile, which makes the coast more vulnerable to erosion during subsequent times of high lake level.

The most recent extreme coastal storm occurred on February 8, 1987 when Lake Michigan monthly lake levels were about 2.2 feet above long-term monthly average. The high lake levels, a storm surge, and sustained northerly winds of 60 miles per hour or more caused overtopping of shore structures, severe erosion, and extensive structural damage. In Chicago alone, the cost of emergency repairs and cleanup exceeded $2 million, and damage to the coastal infrastructure exceeded $1 million (Chicago Shoreline Protection Commission, 1988).

Human Influence

Historical coastal erosion along the Lake County shore has been influenced by human interference with the supply and transport of littoral sediments and resulting impact on the littoral sediment budget.

In its natural setting, the Lake County coast was part of a continuous pathway for littoral sediment transport that extended along the western shore of Lake Michigan from near Sheboygan, Wisconsin southward to the Indiana shore. Shore structures have formed total, near-total, or partial barriers to this littoral transport and segmented the once-continuous littoral cell into numerous shorter-length cells. As a result, the total volume of littoral sediment transported within any given cell is generally less than what existed prior to the segmentation of the Lake County coast. Structural defenses that have slowed the sediment influx from shore and bluff erosion have also

contributed to the reduced sediment supply within these cells. The combined effects of coastal defense and barriers to littoral transport has been that for any given segment of Lake County coast, the influx and transport of littoral sediment is significantly less than what existed prior to human influence.

The two major barriers to littoral transport along the Lake County coast are the jetties for Waukegan Harbor and the shore-attached breakwaters for Naval Training Center, Great Lakes. Reconnaissance jet-wash probing of the fillet at Waukegan suggests that a total of approximately 12 million cubic yards has been trapped, depriving the downdrift coast (Shabica and Pranschke, 1992). Data are lacking for the total entrapment of littoral sediment at the Naval Training Center, but sufficient accumulation has occurred to cause an updrift fillet and extensive shoaling across the northern part of the harbor. Sediment entrapment at Waukegan Harbor and the Naval Training Center has resulted in downdrift reduction in beach widths and reduced volume of beach and nearshore sediments.

Comparison of 1975 and 1989 data from fathometer profiles and jet-wash probes of sediment thickness show there has been a reduction in total thickness of beach and nearshore sediments along the Lake County coast south of Fort Sheridan since 1975 (Shabica *et al.*, 1991). This net loss of sediment has significant implications for the long-term stability of the coast:

1) Lack of an adequate beach and nearshore sand body could lead to erosion across the underlying glacial-till surface. The resulting steepening of the shoreface profile will in turn make the beaches and bluffs more vulnerable to wave erosion.

2) Erosion across the glacial till may result in the undermining of shore-defense

structures that have shallow footings in the till. Such undermining may cause instability or damage to the shore-defense structures which could reduce their effectiveness and lead to nearby shore and bluff erosion.

This deficit of littoral sediments may be a significant factor in future Lake County coastal erosion unless the deficit is offset by proper mitigation. Although there have been localized beach nourishment projects such as in 1991 at Forest Park Beach in Lake Forest (Chrzastowski and Trask, 1992), at present there is no regional nourishment or beach and nearshore sand-management program along the Lake County shore south of Naval Training Center, Great Lakes.

The depletion of littoral sediments along the Lake County coast illustrates the type of impact that can occur due to urbanization and coastal engineering along the bluff coasts of the Great Lakes region. Coastal changes occurring along the bluffs, beaches, and nearshore as a result of over 100 years of human activity are possibly only now becoming significant. These processes will affect any comparisons using the historical coastal change data, and will introduce an uncertainty in using historical trends to project future trends.

PART 5

RECOMMENDATIONS AND SUMMARY

RECOMMENDATIONS FOR FUTURE FEMA-SUPPORTED LAKE MICHIGAN EROSION-RATE STUDIES

The following recommendations would benefit future studies similar to this one. The recommendations are grouped under ten major headings that represent different components of such a study. These components are:

I	Study Design	VI	Digitizing
II	Source Materials	VII	Data Processing
III	Field Investigations	VIII	Errors
IV	Equipment	IX	Data Reporting
V	Data Review and Preparation	X	Study Applications

I - STUDY DESIGN

1) <u>Literature review</u>

Because shoreline change studies are a common focus of coastal research, it is recommended that the first phase in future erosion-rate studies be a thorough literature review of previous studies of coastal change and erosion rates in the area of interest. Review of previous work may identify shortfalls that warrant improvement to meet desired accuracy, or may document procedures that meet or exceed the accuracy requirements. An example of the latter is the 1872 to 1910 shoreline change along

the Lake County coast determined by the U.S. Army Corps of Engineers (1953), in which shoreline comparisons were based on a common reference of Low Water Datum (LWD). Such a datum correction was beyond the scope and time/cost resources of this pilot study. Independent mapping specifically for FEMA should compare findings with previous work to identify inconsistencies and/or provide verification.

2) Geologic Framework

Future studies such as this should not be viewed solely as a cartographic or photogrammetric exercise. These studies should include spatial and temporal shoreline and bluffline position comparisons combined with an evaluation of the local and regional coastal geology and coastal processes. Each distinct geomorphic segment of coast must be mapped on a case-by-case basis, with appreciation for the local coastal geology and coastal processes that potentially affect the rate of translation of the shoreline and bluffline. Local variations in erosion rates that might otherwise be smoothed in the mapping process may actually have a geologic basis. Temporal comparisons may document locally extreme rates of erosion that are due to rapid, relatively short-lived adjustments to natural or human-induced coastal change, and such erosion rates may not be valid for projection of future shoreline (or bluffline) positions. A review of historical information will contribute some of this background, but this review needs to be supplemented with an understanding of trends in coastal processes and the local and regional shoreline responses to changes in coastal dynamics.

3) Shoreline datum

Future FEMA-supported shoreline mapping along the Great Lakes coasts needs to recognize the lack of a standard datum for shoreline mapping. This is an important

difference between the Great Lakes and ocean coasts. Mean High Water (MHW) has been the datum used in ocean-coast shoreline mapping by the U.S. Coast and Geodetic Survey and the National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), but there is no comparable visually recognized reference along the Great Lakes coasts. Early shoreline surveying along the Great Lakes mapped the shoreline that was present at the time of the survey in part because there was no record to which the range of lake-level change could be related.

The wide range in lake levels on various time scales complicates the use of a lake-level datum. If a lake-level datum is used, translations will need to be performed on shorelines from historical maps and aerial photographs, and these translations will become sources of error in the mapping. It is recommended that FEMA erosion-rate studies for the Lake Michigan coast consider using a reference independent of lake level. Temporal translations in the bluffline could be the reference for coastal change along high-relief coastal reaches. Temporal changes in the vegetation line could be the reference along low-relief coastal reaches. If a lake-level dependent datum is used for shoreline comparisons, the prime candidate in terms of available data is Low Water Datum (LWD). The zero contour on LWD-corrected bathymetric maps, surveys and profiles can then be used on the datum-corrected shoreline.

4) <u>Establishing Ground Control</u>

In the early stage of a study like this, the decision must be made as to how control points will be established. Exact locations of physical and cultural features can be determined by precision field surveying, but this is a time-consuming and costly procedure. A relatively less costly and highly accurate method is to identify control points by stereoscopic aerial photointerpretation with a stereoplotter and a few known

ground control points for reference. Applying such a procedure to future erosion-rate studies would be consistent with modern mapping methods, which use aerial photographs and a stereoplotter in order to identify and precisely locate physical and cultural features over large areas. To avoid duplication of efforts, it is recommended that the appropriate offices of coastal municipalities and/or counties be contacted to obtain ground control that may already have been established by these local governments.

5) Project Staff Assignments

In allocating staff on a project of this nature, it is recommended that if more than one person is to digitize from the source materials, work assignments be distributed by geographical segments rather than by task. Continuity in effort by geographical segment allows accuracy and consistency among different-year sources to be constantly checked. Although this will require that each staff member be familiar with each data capture technique, the resulting ongoing accuracy checks will result in greater overall efficiency.

II - SOURCE MATERIALS

1) Stable-Base Materials

The use of stable-base materials such as bromide or mylar copies of historical maps is mandatory in order to circumvent the problem of shrinkage and expansion that occurs with other materials. Paper copy maps should be avoided.

2) Nautical Charts

Nautical charts are inappropriate as a source material for this work. This is true for

both the charts published by the U.S. Lake Survey and the charts published subsequently by NOAA, National Ocean Service. The topographic and hydrographic data presented on these charts are derived from the topographic and hydrographic field surveys conducted by the chart-producing agencies. These field sheets present the survey data in greater detail and at larger scale than the nautical charts. The field sheets thus supersede all nautical charts as source materials. If nautical charts are referenced, it is important to recognize that the topographic and hydrographic data are from the most recent surveys prior to the date of the chart, not from the date of the chart edition itself.

3) <u>Accuracy of Historical Maps vs. Aerial Photographs</u>

If future coastal erosion-rate studies along Lake Michigan require incorporating regional shoreline and bluffline position data from the late 1800s and early 1900s, the sole source for this information is the U.S. Lake Survey field sheets. However, future studies should consider whether the potential value of this information is outweighed by inaccuracies in the location of land-based features and the extreme difficulty in achieving an acceptable registration for these maps. The registration problem is particularly critical for field sheets with areas of limited cultural development. Although vertical aerial photographs are generally limited to the post-1930s and therefore cannot provide the long-term average that the field sheets can, the information documented by photography does not have the accuracy limitations of the historical maps, and the resulting erosion rates may be calculated with a higher degree of confidence.

4) <u>Project Emphasis on Historical Maps vs. Aerial Photographs</u>

Topographic maps and field sheets can be used in conjunction with vertical aerial

photographs but should not be used as substitutes. Maps are abstract representations of the physical terrain, and consequently, digitizing from any topographic map introduces errors based on the subjectivity inherent in contouring on the map. Further error is introduced by the subjective identification of the bluffline on the map on the basis of contour spacing. Vertical aerial photographs depict the terrain without bias other than that of the optical-film system.

5) Temporal Factors in Selecting Aerial Photographs

Aerial photographs for vegetated bluff coasts should be selected from photographic flights done in winter or early spring in order to minimize the degree to which the tree canopy obscures the bluffline. If available, aerial photographs recorded when the bluff face is illuminated by the sun should be selected to facilitate identification of structures and delineation of the bluffline.

6) Supportive Aerial Photographs

If the same flight sequence of aerial photographs is available at different scales, large-scale prints and enlargements should be used to provide supportive information. Although digitizing from large-scale photographic prints is not possible with the stereoplotter, enlargements can assist in identifying structures that may not be clearly distinguishable on the smaller prints. In addition, features can be digitized directly from single large-scale prints in areas of low relief, where relief displacement is minimal and reduced horizontal accuracy is acceptable. Improved identification of natural and physical features can be achieved by using color photographs from the same year or a closely temporally spaced year. Color photographs can assist in identifying structures that have low contrast on panchromatic prints.

III - FIELD INVESTIGATIONS

1) Ground and/or Aerial Reconnaissance

Familiarity with the coastal reaches to be mapped will aid in making decisions in the selection of ground control points, digitizing, rubber sheeting, and identifying data errors indicated by anomalous trends in shoreline change. It is recommended that the coastal areas to be mapped be inspected by ground reconnaissance, a low altitude flight, and/or a study of historical aerial photographs. A flight would allow collection of low-angle oblique photographs that could be referenced in the subsequent mapping stages. Additional site-specific visits may be necessary where the map data raise questions about bluff erosion processes or show anomalous temporal trends in shoreline or bluffline change.

2) Use of Global Positioning System

As previously noted in item I-4, the most efficient procedure for supplementing ground control points is to use stereoscopic aerial photointerpretation. In areas of limited cultural development, field surveying by optical and electronic techniques may be necessary in order to improve the network of ground control points. However, a more efficient procedure to cover a broad area and establish many control points would be to use a portable receiver for the Global Positioning System (GPS). Relatively inexpensive GPS equipment allows positions to be determined within about 50 feet. Higher-quality GPS equipment allows locations to be determined with greater accuracy.

IV - EQUIPMENT

1) Use of Stereoplotter

A stereoplotter compensates for the radial displacement that is inherent to all photographs, as the instrument plots the correct position of the feature. This method is preferable to using a projector or zoom transfer scope to transfer details from single photographs to a base map. Modern stereoplotters can make measurements of a few micrometers on a stereopair, increasing the precision of mapmaking. Analytical stereoplotters have additional capabilities such as correction for camera lens distortion, X-tilt, and Y-tilt.

V - DATA REVIEW AND PREPARATION

1) Selecting Ground Control Points

The selection of ground control points is probably the most critical step in achieving a successful registration of source materials. A sufficient number and distribution of ground control points should be selected to allow for several potential registrations to be tested. Additionally, it must be verified that each point used for ground control is a stable point that represents the same location on both the source map and the base map. This process can be streamlined for maps by making paper or mylar copies of data sources that are enlarged or reduced to a common scale. By overlaying these copies, relocated roads, streams, and other features will stand out, as will mapping errors. Points associated with such features can be eliminated early in the control point selection process. Use of this method with aerial photographs is not recommended because of parallax.

2) Bluffline evaluation

Digitizing the bluffline requires judgement in designating where the relatively flat upland plain ends and the bluff face begins. The change in slope can be transitional, and the rate of change in slope can vary from place to place. Before digitizing begins on the stereoplotter, overall bluffline morphology should be thoroughly reviewed by the operator, and decisions should be made on how the bluffline will be defined. It is recommended that for a given segment of coast, all bluffline interpretation be done by the same operator.

VI - DIGITIZING

1) Root-Mean-Square (RMS) Error and Registration

The potential low correlation between low RMS error and an acceptable registration should be kept in mind. Even if the RMS error is small, an unacceptable registration may result if the computed scales in the X and Y directions do not match each other as well as the scale of the source map. It is recommended that RMS error alone not be used to measure quality of the registration or the quality of the resulting digital product.

2) Use of Test Lines

For each registration that has acceptable map scales and meets RMS error requirements, several test lines should be digitized. These test lines should include roads or other features that appear on both source map and base map, so that their alignment and degree of rotation can be checked. It is particularly important to digitize roads that pass through all control points, including those not used in the registration being tested.

3) <u>Digitizing Cultural Features</u>

Once a registration has been selected, as many cultural features as possible should be digitized. Particularly important are point features that will later be critical to the rubber sheeting process, such as road intersections, railroad crossings, and bridges.

VII - DATA PROCESSING

1) <u>Rubber Sheeting</u>

Accuracy of the digital maps can be improved by rubber sheeting. However, points used for link vectors between source maps and base maps should be checked for positional stability using criteria that are equally as stringent as those used in selecting ground control points. Following rubber sheeting, each adjusted map should be carefully compared with its unadjusted version to identify possible areas of increased misalignment. To reduce the degree of splicing necessary between adjacent digital maps, the rubber sheeting process should be carried out before splicing.

2) <u>Checking Transect Data</u>

As the transect data that document shoreline and bluffline change are generated, they should be checked immediately after output for errors in transect generation, coordinate projection, data manipulation, or programming. Errors during these stages are difficult to pinpoint without checking for accuracy after every step in the processing.

3) <u>Non-Coastal Factors in Bluff Erosion</u>

In evaluating bluffline recession it is important to recognize that the recession may not be directly dependent on wave-induced erosion that causes undercutting of the bluff

toe. Bluffline recession may result from the interaction of ground water and bluff materials. For example, a common form of bluffline recession along the Lake Michigan coast is by landsliding where permeable sand layers overlie low-permeability clays. Additionally, in areas where ravines approach the coast, it is important to recognize that the position of some segments of the bluffline may be controlled by fluvial processes rather than by coastal processes. Erroneous rates of coastal erosion will be calculated if recession by other processes is included in the data set.

VIII - ERRORS

1) Systematic and Nonsystematic Errors

Limitations in map accuracy must be recognized. Systematic and nonsystematic errors, including unknown errors, are inherent in any mapping project. Systematic errors include instrument bias and may be measurable using more precise equipment. Operator bias is an example of nonsystematic error, which may be difficult if not impossible to measure. Additionally, physical features such as blufflines and shorelines pose distinct mapping challenges, since identification is open to interpretation.

2) Maximum Acceptable Error

A standard for maximum acceptable error must be determined. However, given the large number of sources of potential errors, the total error for any individual digital product is difficult to quantify. Once the maximum acceptable error standard is determined, any relative values of erosion or accretion that fall within this range should not be considered significant in determining erosion rates.

3) Accuracy Assessment

If determining source map accuracy is to be a part of future studies, points on the maps must be selected with that purpose in mind. Extensive historical research will usually be required to determine whether a source map point differing in location from its base map counterpart represents a feature that has been relocated or one that has been mismapped. Once this determination has been made, points associated with features that have been relocated should be excluded from the accuracy assessment.

IX - DATA REPORTING

1) Reporting Transect Data

The data-reporting format as detailed in the contract specified that the distance between the spine-transect intercept and the shore-transect intercept be given to the nearest 0.01 foot. These numbers have therefore been reported in this format in Appendix K. It is recommended, however, that any numbers to the right of the decimal point in these distances be deleted, as their presence may erroneously imply that they have significance.

2) Accuracy Statements

It is important to avoid overstating the accuracy of the erosion data, as this could lead to the interpretation that the rates of erosion and accretion are more precisely measured than is actually the case. In future studies, the distinction between precision (increments of measurement) and accuracy (what the measurements actually represent) must be made in the clearest possible terms.

X - STUDY APPLICATIONS

In applying the results of this pilot study to other reaches of the U.S. Great Lakes coasts, three qualifications need to be stated.

1) The approach in this study was to map one-mile long corridors rather than continuous reaches of the coast as would be done in a regional study. This corridor mapping impacts the time allocations of this study for registration and digitizing of the maps and aerial photographs. The time investment per one-mile corridor is likely greater than the per-mile time investment that would be computed based on the incremental division of time invested for registration and digitizing of several miles of coast.

2) Much of Lake County is downdrift of two total to near-total barriers to littoral transport (*i.e.*, the Waukegan Harbor jetties and the breakwaters forming the harbor at Naval Training Center, Great Lakes). The downdrift starvation of the littoral stream due to entrapment by these structures is a factor that has impacted historical coastal change.

3) Much of the residential coast of Lake County has been engineered for a longer time than most of the rest of the Lake Michigan coast and has been engineered to a greater degree. The higher degree of engineering reflects the economic status of this lakeshore, which includes some of the premier lakeshore residential real estate along the entire Lake Michigan coast.

SUMMARY

The purpose of this pilot study was to document the source materials, equipment, procedures and time allocations necessary to conduct a compilation of historical coastal erosion rates. Two databases were created, a Historical Shoreline Location Database created by digitizing, combining, and storing historical and recent shorelines and blufflines from historical maps and vertical aerial photographs, and a Historical Shoreline Positional Change Database created by measuring spatial differences along transects that intercept the historical and recent shorelines and blufflines. Data from these two databases are included in this report in Appendix I and Appendix K. These data also accompany this report on 3.5-inch diskettes to be used by the contracting agency (FEMA, Office of Risk Assessment) in statistical analysis of erosion rates and for the addition of new shoreline and bluffline data to the database at a later date.

This was the sole FEMA-sponsored pilot study along a Great Lakes coast. It differs from concurrent pilot studies conducted along the U.S. ocean coasts in that its setting and physical processes may not be directly comparable to those along the ocean coasts. In particular, two key factors apply.

1) A large fluctuation in lake level has occurred during historical time. For the data sets used in this study, the range in lake level is 2.8 feet. Shorelines recorded on the historical maps and the aerial photographs are at four different lake levels and thus record differences in shoreline position that are in part independent of any erosion or accretion.
2) No standard datum exists for mapping shorelines along the Illinois coast, and this study did not attempt to adjust shorelines to a common datum. The issue of a shoreline reference will need to be addressed prior to future coastal change mapping of this sort along the Illinois lakeshore.

Applying the results of this study to other reaches of the Lake Michigan coast and to the Great Lakes in general requires recognition of the characteristics specific to this study area that may be less significant elsewhere. In particular, coastal development has had a major impact on the coast of Lake County. Much of the county lakeshore is downdrift of major barriers to littoral transport that have reduced the littoral sediment supply along the downdrift coast. Historical coastal changes downdrift of these barriers (Corridors 3,4, and 5 in this study) are in part directly related to this human influence. In addition, essentially all of the southern half of the Lake County coast is property within affluent municipalities. Most of this property has been engineered to a higher degree than would occur along the majority of residential property along the Lake Michigan coast. In general, because of its proximity to Chicago and the economic status of the majority of the coastal residents, the history of settlement and development and the degree of coastal engineering in Lake County may be different from other comparable reaches of coastal bluffs in the Great Lakes region.

One of the intentions of this study was to compare the use of historical maps to the use of vertical aerial photography as data sources for such studies. The historical maps selected for this study were 1872-73 and 1909-11 field sheets prepared by the U.S. Lake Survey. The spatial inaccuracies in these field sheets required substantial additional work to gain the desired map information as compared to use of the aerial photographs. In particular, a major time investment was necessary in order to achieve acceptable registration of these field sheets. In this study, less time and effort was required to go from data source to digital map using the aerial photographs than using either of the two sets of field sheets.

Future studies should develop a rigorous procedure for selecting and testing the adequacy of ground control points. The importance of ground control for the registration of historical maps or aerial photographs to the base map and for the subsequent rubber sheeting of the digital maps cannot be overstated. A network of adequate ground control points should be established prior to any registration and digitizing of historical maps or aerial photographs. Ground control for mapping is the key to the most efficient and accurate completion of this type of coastal change documentation.

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REFERENCES CITED

American Society for Photogrammetry and Remote Sensing, 1989, ASPRS interim accuracy standards for large-scale maps: Photogrammetric Engineering and Remote Sensing, v. 55, pp. 1038-1040.

Atwood, W. W. and Goldthwait, J. W., 1908, Physical geography of the Evanston-Waukegan region: State of Illinois, Department of Registration and Education, Division of the State Geological Survey, Bull. No. 7, Urbana, Illinois, 102 p.

Barnes, P., Reimnitz. E., McCormick, M., and Kempema, E., 1992a, Coastal profile modifications in winter related to lake ice, southern Lake Michigan: pp. 64-66 in Folger, D. W., Colman, S. M., and Barnes, P. W. (eds.), Southern Lake Michigan Coastal Erosion Study Workshop, February 4-6, 1992, USGS Center for Coastal Geology, St. Petersburg, Florida, U.S. Geological Survey Open File Report 92-324, 116 p.

Barnes, P., Reimnitz, E., and McCormick, M., 1992b, Sediment content of offshore ice in southern Lake Michigan 1991: pp.67-68 in Folger, D. W., Colman, S. M., and Barnes, P. W. (eds.), Southern Lake Michigan Coastal Erosion Study Workshop, February 4-6, 1992, USGS Center for Coastal Geology, St. Petersburg, Florida, U.S. Geological Survey Open File Report 92-324, 116 p.

Berg, R. C. and Collinson, C., 1976, Bluff erosion, recession rates, and volumetric losses on the Lake Michigan shore of Illinois: Environmental Geology Note No. 67, Illinois State Geological Survey, Urbana, Illinois, 33 p.

Bottin, R. R. Jr., 1988, Case histories of Corps breakwater and jetty structures, report 3, North Central Division: Technical Report REMR-CO-3, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, 433 p.

Chicago Shoreline Protection Commission, 1988, Recommendations for shoreline protection and recreational enhancement, final report: City of Chicago, Office of the Mayor, 52 p. plus 7 appendices.

Chrzastowski, M. J. and Read, M. E., 1993, Inventory of federal and state historical maps, charts, and vertical aerial photographs applicable to erosion-rate studies along the Illinois coast of Lake Michigan: Final contract report (Report 2 of 2) for Federal Emergency Management Agency (FEMA), Office of Risk Assessment, FEMA Assistance Award No. EMW-91-K-3575, Illinois State Geological Survey Open-File Series 1993-3, Champaign, Illinois, 115 p.

Chrzastowski, M. J. and Trask, C. B., 1992, Review of the final report for the 1991 beach and nearshore monitoring program at Forest Park Beach, Lake Forest, Illinois: Report submitted to Illinois Department of Transportation, Project No. WR-09118/SRA-190, Illinois State Geological Survey, Champaign, Illinois, 64 p. plus four appendices.

Clark, P. U., and Rudloff, G. A., 1990, Sedimentology and stratigraphy of late Wisconsinan deposits, Lake Michigan bluffs, northern Illinois: pp. 29-41 *in* Schneider, A. F. and Fraser, G. S. (eds.), Late Quaternary History of the Lake Michigan Basin; Geological Society of America Special Paper 251, Boulder, Colorado, 123 p.

Crowell, M., Leatherman, S. P., and Buckley, M. K., 1991, Historical shoreline change: Error analysis and mapping accuracy: Journal of Coastal Research, v. 7, no. 3, pp. 839-852.

DuMontelle, P. B., 1974, Engineering geology of the Lake Michigan bluffs, Wilmette to Waukegan, Illinois: pp. 31-32 *in* Collinson, C. and three others, (eds.), Coastal Geology, Sedimentology, and Management, Chicago and the Northshore; Illinois State Geological Survey Guidebook Series 12, 55 p.

DuMontelle, P.B., Stoffel, K. L., and Brossman, J. J., 1975, Foundation and earth materials of the Lake Michigan till bluffs; preliminary report, Illinois Coastal Zone Management Program: Illinois State Geological Survey, Champaign, Illinois, 37 p.

Ellis, M.Y. (ed.), 1978, Coastal Mapping Handbook: U.S. Department of the Interior, Geological Survey and U.S. Department of Commerce, National Ocean Survey, U.S. Government Printing Office, Washington, D.C., 200 p.

Environmental Systems Research Institute, Inc., 1991, Editing coverages and tables with Arcedit, ARC/INFO users guide rev. 6.0: Environmental Systems Research Institute, Inc. (ESRI), Redlands, California, 272 p. plus three appendices.

Ewing, M., Press, F., and Donn, W. L., 1954, An explanation of the Lake Michigan wave of 26 June 1954: Science, v. 120, pp. 684-686.

Fraser, G. S. and Hester, N. C., 1974, Sediment distribution in a beach ridge complex and its application to artificial beach replenishment: Environmental Geology Notes 67, Illinois State Geological Survey, Urbana, Illinois, 26 p.

Fraser, G. S., Larsen, C. E., and Hester, N. C., 1990, Climatic control of lake levels in the Lake Michigan and Lake Huron basins: pp. 75-89, in Schneider, A. F. and Fraser, G. S. (eds.), Late Quaternary history of the Lake Michigan basin, Geological Society of America Special Paper 251, 123 pp.

Hands, E. B., 1980, Prediction of shore retreat and nearshore profile adjustment to rising water levels on the Great Lakes: Technical Report No 90-7, U. S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Virginia, 119 p.

Hester, N. C. and Fraser, G. S., 1973, Sedimentology of a beach-ridge complex and its significance in land-use planning: Environmental Geology Notes 63, Illinois State Geological Survey, Urbana, Illinois, 24 p.

Illinois State Geological Survey, 1988, Coastal atlas, Illinois shore of Lake Michigan, revised 1987-88: Contract report for Illinois Division of Water Resources Obligation WR08819, Illinois State Geological Survey, Champaign, Illinois, 59 maps, approx. scale 1:4800.

Jennings, J. R., 1990, 150 year erosion history at a beach ridge and dune plain on the Illinois Lake Michigan shore: Programs and Abstracts, International Association of Great Lakes Research, 33rd Conference, p. 67.

Jibson, R. W., Odum, J. K. and Staude, J., 1992, Rates and processes of bluff retreat along the Lake Michigan shoreline in Illinois: pp. 57-59 in Folger, D. W., Colman, S. M. and Barnes, P. W. (eds.), Fourth Annual Southern Lake Michigan Coastal Erosion Workshop, February 4-6, 1992, USGS Center for Coastal Geology, St. Petersburg, Florida, U.S. Geological Survey Open-File Report 92-324, 116 p.

Jibson, R. W. and Staude, J., 1992, Bluff recession rates along the Lake Michigan shoreline in Illinois: Bull. Assoc. of Engineering Geologists, v.29, no. 2, pp. 103-117.

Jibson, R. W., Staude, J. and Reinhardt, J., 1990, Coastal bluff retreat along the Lake Michigan shoreline in Illinois and southern Wisconsin: pp. 32-41 in Barnes, P. W. (ed.), Coastal Sedimentary Processes in Southern Lake Michigan: Their Influence on Coastal Erosion; U.S. Geological Survey Open-File Report 90-295, 55 p.

Kempema, E. W., Barnes, P. W., Haines, J. W., and Reimnitz, E., 1992a, Anchor ice formation and sediment transport in southern Lake Michigan: pp. 69-71 in Folger, D. W., Colman, S. M. and Barnes, P. W. (eds.), Fourth Annual Southern Lake Michigan Coastal Erosion Workshop, February 4-6, 1992, USGS Center for Coastal Geology, St. Petersburg, Florida, U.S. Geological Survey Open-File Report 92-324, 116 p.

Kempema, E. W., Reimnitz, E., and Barnes, P. W., 1992b, Ice drift in southern Lake Michigan based on surface drifter trajectories: pp.72-74 in Folger, D. W., Colman, S. M. and Barnes, P. W. (eds.), Fourth Annual Southern Lake Michigan

Coastal Erosion Workshop, February 4-6, 1992, USGS Center for Coastal Geology, St. Petersburg, Florida, U.S. Geological Survey Open-File Report 92-324, 116 p.

Larsen, C. E., 1973, Prehistoric levels of Lake Michigan-Huron; Their potential in shoreline planning, in Proceedings of 1973 Shoreland Planning Conference, Chicago: Chicago, Lake Michigan Federation, 18 p.

Larsen, C. E., 1973, Variation in bluff recession in relation to lake level fluctuations along the high bluff Illinois shore: Report prepared for the Illinois Institute of Environmental Quality, IIEQ Doc. No. 73-14, Project No. 20.034, Lake Michigan Federation, Chicago, Illinois, 73 p.

Larsen, C. E., 1985, A stratigraphic study of beach features on the southwestern shore of Lake Michigan: new evidence of Holocene lake level fluctuations: Environmental Geology Notes 112, Illinois State Geological Survey, Champaign, Illinois, 31 p.

Lineback, J. A., 1974, Erosion of till bluffs: Wilmette to Waukegan: pp. 37-45 *in* Collinson, C. and three others (eds.), Coastal Geology, Sedimentology, and Management, Chicago and North Shore; Illinois State Geological Survey Guidebook Series 12, Champaign, Illinois, 55 p.

National Ocean Service, undated, Great Lakes water levels, 1860-1985, monthly and annual average elevations: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Rockville, Maryland, 260 p.

Olson, J. S., 1958, Rates of succession and soil development on southern Lake Michigan sand dunes: Botanical Gazette, v. 119, p. 125-170.

Raasveldt, H. C., 1956, The stereomodel, how it is formed and deformed: Photogrammetric Engineering and Remote Sensing, v. 22, pp. 708-726.

Reimnitz, E., Hayden, E., McCormick, M., and Barnes, P., 1991, Preliminary observations on coastal sediment loss through ice rafting in Lake Michigan: Journal of Coastal Research, v. 7, no. 3, pp. 653-664.

Roy, S. D., 1986, Computer simulation model of coastal erosion on Lake Michigan: unpublished Ph.D. thesis, University of Illinois at Chicago, Department of Geology, Chicago, Illinois, 379 p.

Shabica, C. W. and Pranschke, F. A., 1992, Survey of littoral drift sand deposits along the Illinois shore of Lake Michigan: pp. 28-35 in Folger, D. F., Colman, S. M., and Barnes, P. W. (eds.), Fourth Annual Southern Lake Michigan Coastal

Erosion Workshop, February 4-6, 1992, USGS Center for Coastal Geology, St. Petersburg, Florida, U.S. Geological Survey Open-File Report 92-324, 116 p.

Shabica, C. W., Pranschke, F. A., and Chrzastowski, M. J., 1991, Survey of littoral drift sand deposits along the Illinois shore of Lake Michigan from Fort Sheridan to Evanston: Illinois-Indiana Sea Grant Program, Report IL-IN-SG-R-91-3, Cooperative Extension Service, University of Illinois at Urbana-Champaign, 15 p.

Shalowitz, A. L., 1964, Shore and sea boundaries, volume 2, interpretation and use of Coast and Geodetic Survey data: U. S. Department of Commerce, U. S. Coast and Geodetic Survey, Pub. 10-1, U. S. Government Printing Office, Washington, D. C., 749 p.

State of Illinois Division of Waterways, 1958, Interim report for erosion control Illinois shore of Lake Michigan: State of Illinois, Department of Public Works and Buildings, Division of Waterways, Springfield, Illinois, 108 p., 27 plates, 12 exhibits (shoreline and profile changes).

Terpstra, P. D. and Chrzastowski, M. J., 1992, Geometric trends in the evolution of a small log-spiral embayment on the Illinois shore of Lake Michigan: Journal of Coastal Research, v. 8, no. 3, pp. 603-617.

Underwood, S. G. and Anders, F.J., 1991, Evaluation of the coastal features mapping system for shoreline mapping: Technical Report CERC-91-13, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, 41 p. plus one 4 p. appendix.

U.S. Army Corps Engineers, 1953, Illinois shore of Lake Michigan, beach erosion control study: 83rd Congress, 1st Session, House Doc. 28, 137 p., 5 appendices.

U.S. Army Corps of Engineers, 1978, Help yourself, a discussion of erosion problems on the Great Lakes and alternative methods of shore protection: U.S. Army Corps of Engineers North Central Division, Chicago, Illinois, 24 p.

U.S. Congress, 1839, Report on harbor improvements on Lake Michigan (by Captain T. J. Cram, Captain Topographical Engineers): 26th Congress, 1st Session, Senate Doc. No. 140, v. 4, ser. 357, pp. 16-22.

U.S. Deep Waterways Commission, 1897, Report of the U.S. Deep Waterways Commission Prepared at Detroit Michigan, December 19-22, 1896: U.S. Government Printing Office, Washington, D.C., 263 p., 26 pl.

U.S. Engineer Department, 1873, Instructions for chiefs of parties on the United States Lake Survey: U.S. Government Printing Office, Washington, D.C.

U.S. Geological Survey, 1980, Technical Instructions of the National Mapping Division: Accuracy Specifications for Topographic Mapping: Chapter 1B4. 13 p.

U.S. Geological Survey, 1990, Digital line graphs from 1:24,000-scale maps, data users guide 1 (replacement for U.S. Geological Survey Circular 895): U.S. Geological Survey, Reston, Virginia, 107 p.

Willman, H. B. and Lineback, J. A., 1970, Surficial geology of the Chicago region: Illinois State Geological Survey, Urbana, Illinois, (map) 1 sheet, scale 1:250,000.

Woodford, A. M., 1991, Charting the inland seas: A history of the U.S. Lake Survey: U.S. Government Printing Office 1991/544-359, Washington, D.C

APPENDIX A

OFFICES FROM WHICH DATA SOURCES WERE OBTAINED

HISTORICAL MAPS **(U.S. Lake Survey "I" Sheets: bromide copies)**

U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
National Ocean Service (NOS)
Hydrographic Surveys Branch, N/CG243
Data Control Section
6001 Executive Blvd.
Rockville, Maryland 20852

Phone: (301) 443-8408
FAX: (301) 443-8459

Cost: As of October 1992, $48.00 per bromide copy; five to six weeks for delivery.

AERIAL PHOTOGRAPHS **(1947: b&w, 9"x 9")**

Map and Geography Library
418 Library, MC-522
1408 W. Gregory
University of Illinois at Urbana-Champaign
Champaign, Illinois 61820

Phone: (217) 333-0827
FAX: (217) 244-0398

Cost: No cost; photographs on loan under special agreement.

AERIAL PHOTOGRAPHS **(1987: b&w, 9"x 9")**

Illinois Department of Transportation (IDOT)
Aerial Surveys
2300 South Dirksen Parkway
Springfield, Illinois 62764

Phone: (217) 782-7627
FAX: (217) 782-1927

Cost: No cost to sister state agency; present (1992) cost for other government and non-profit institutions is $7.20 per 9"x 9" contact sheet. Approximately one week for delivery.

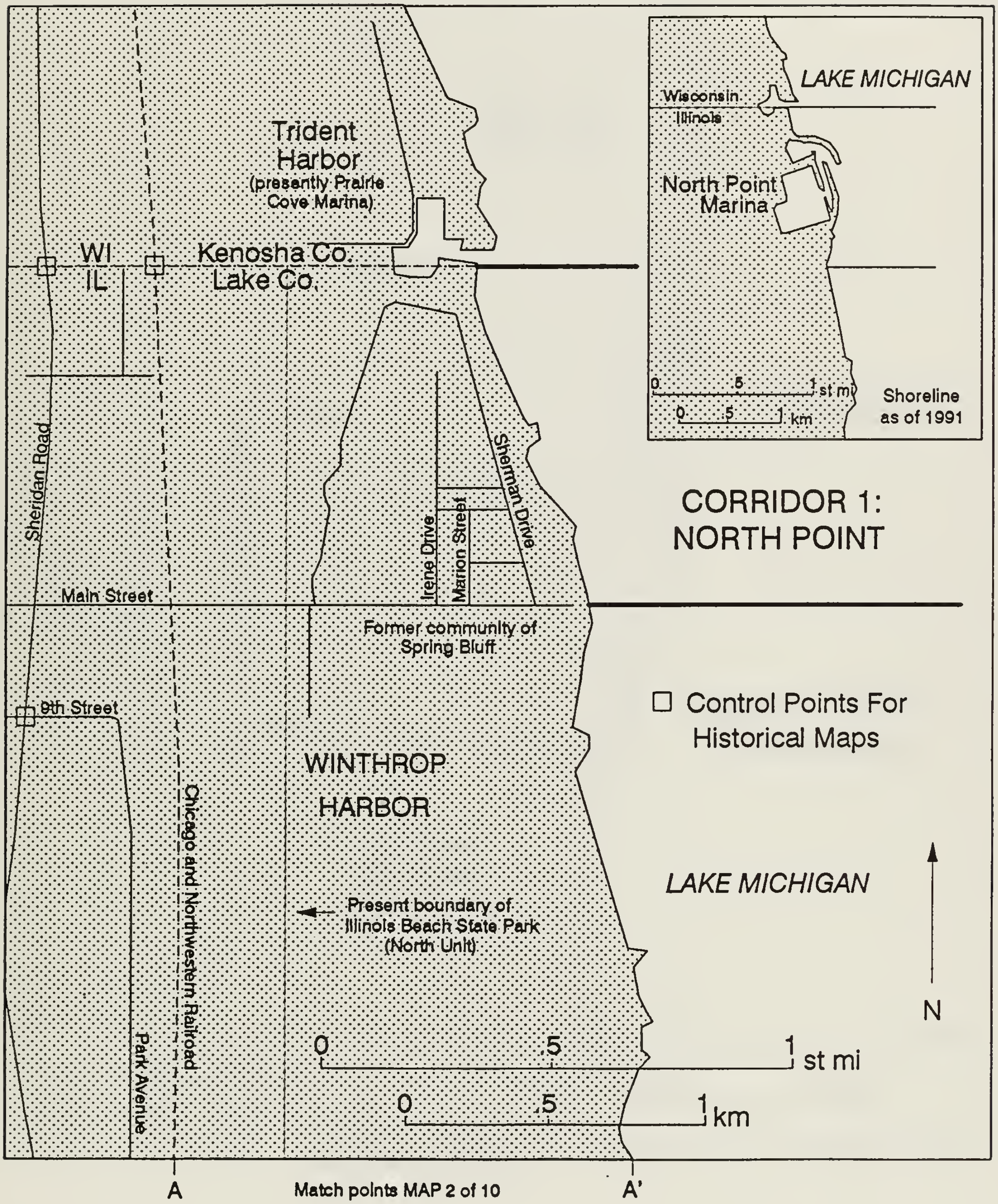
APPENDIX B

GROUND CONTROL POINTS FOR HISTORICAL MAPS

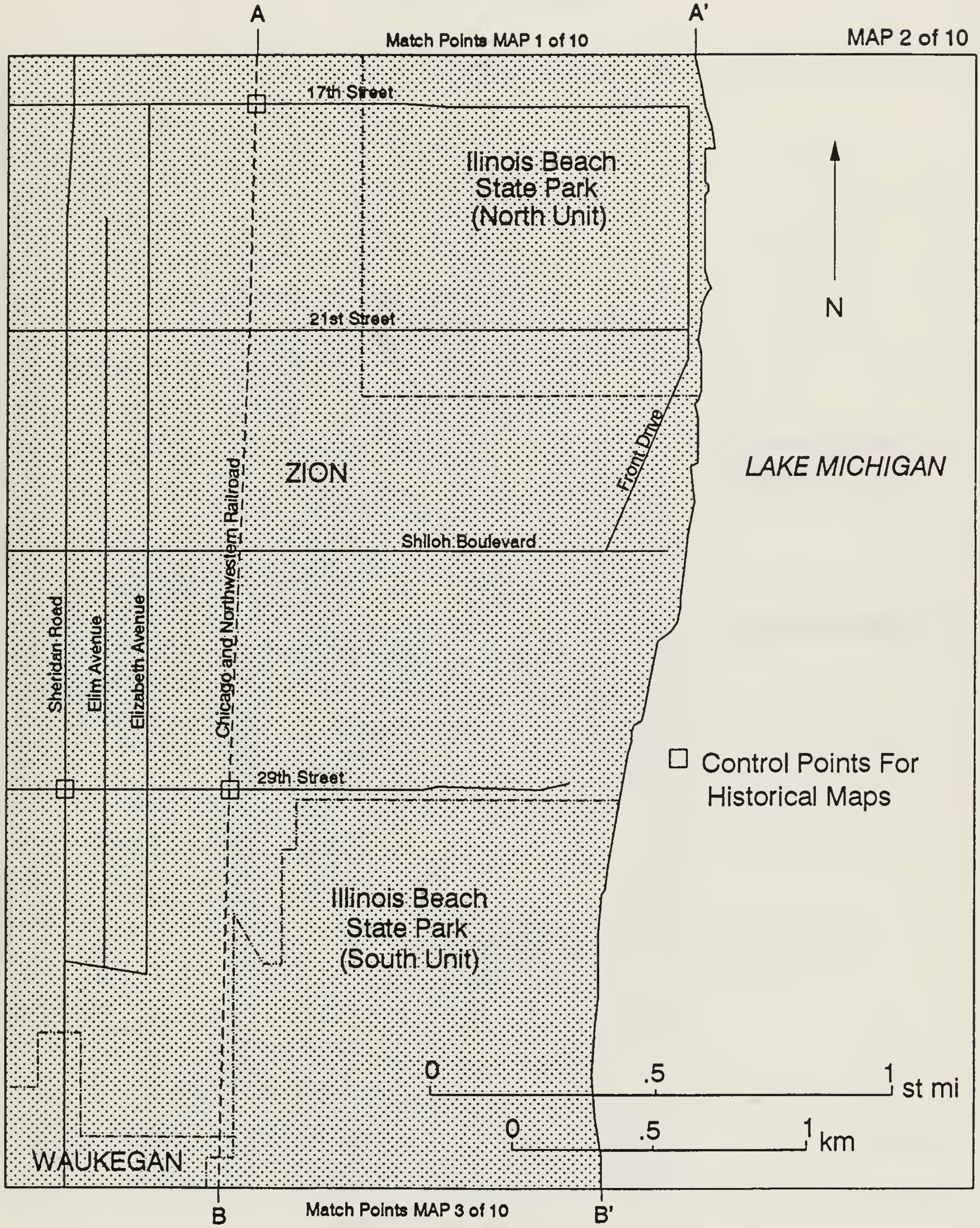
Appendix B Explanation

This appendix is a series of maps showing the ground control points used for registration of the 1872-73 and 1909-1911 U.S. Lake Survey field sheets. Road intersections, railroad crossings, bridges, and other control points are indicated by squares. Appendix E contains a listing of specific points used for each map, and gives the RMS errors associated with each map registration.

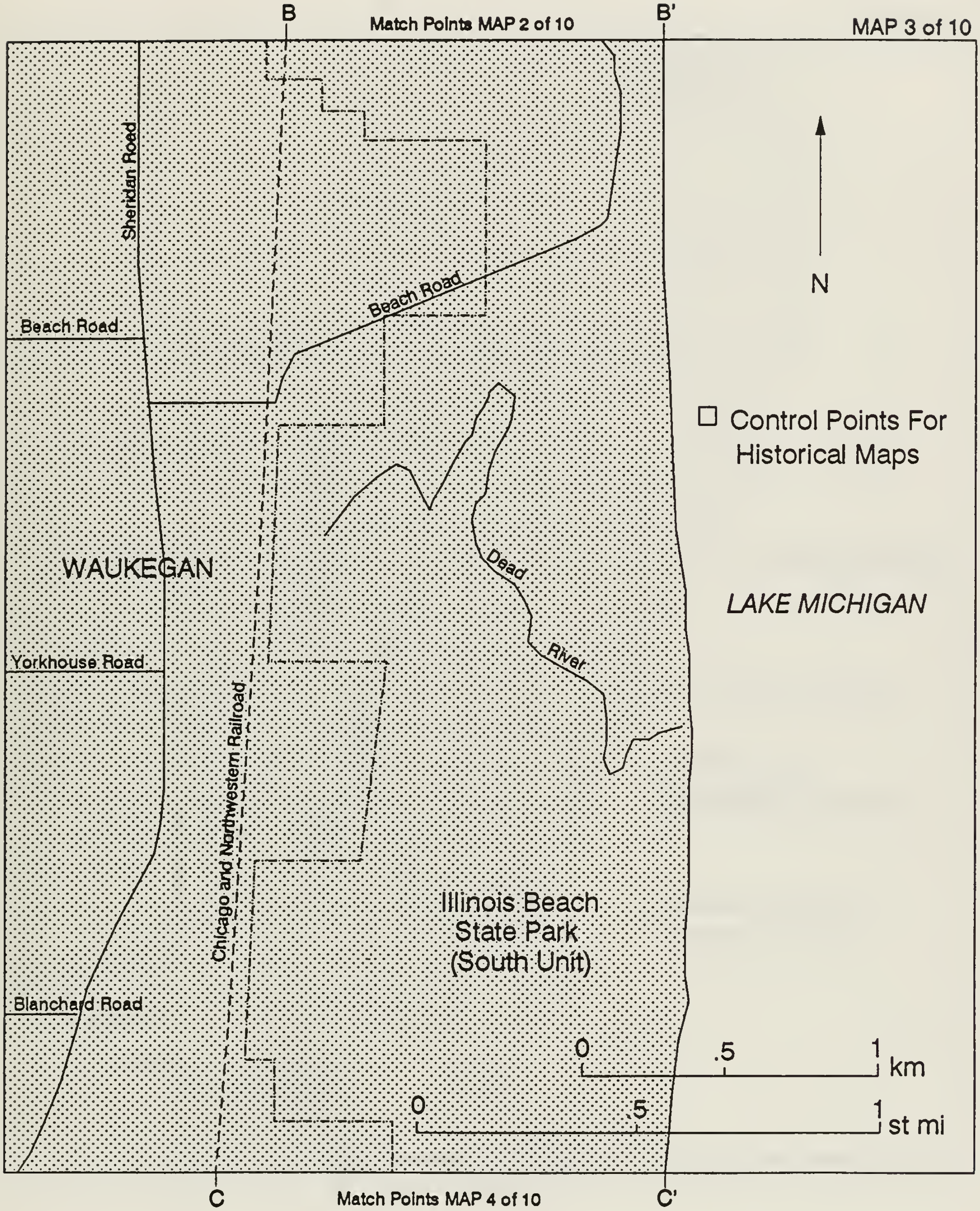
MAP 1 of 10

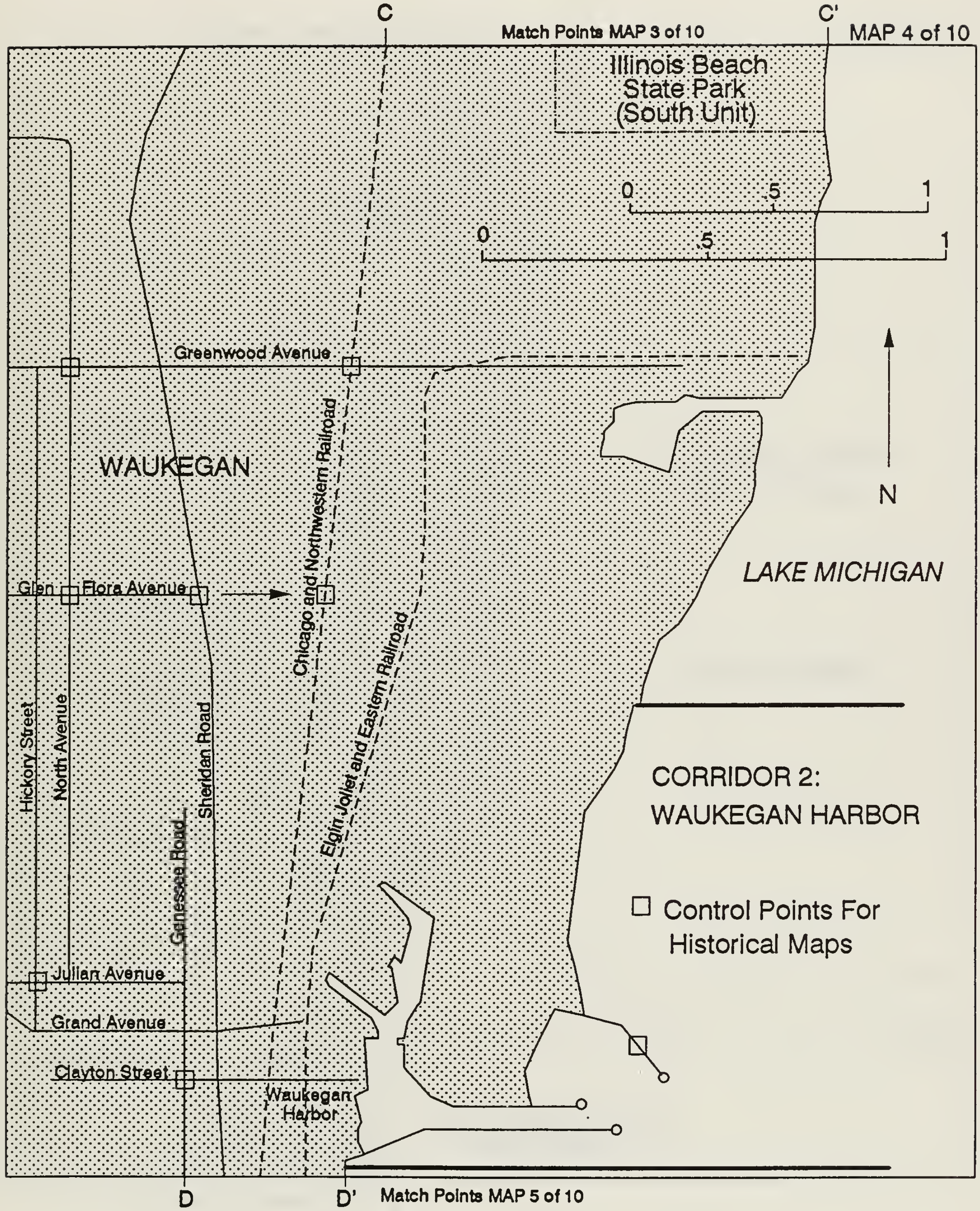


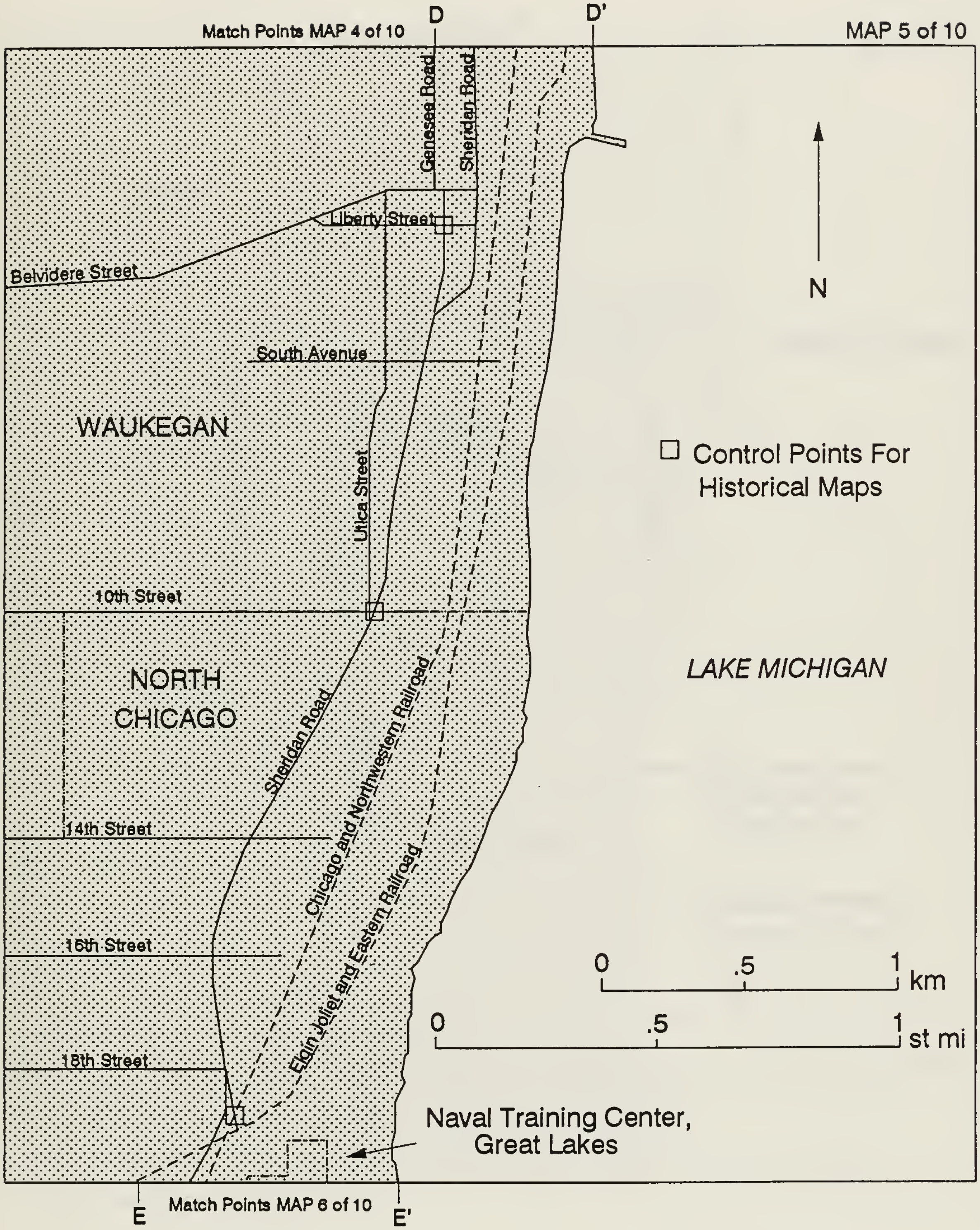
LAKE MICHIGAN
Wisconsin
Illinois
North Point
Marina
0
.5
1 st mi
0
.5
1 km
Shoreline
as of 1991
Trident
Harbor
(presently Prairie
Cove Marina)
WI
IL
Kenosha Co.
Lake Co.
Sheridan Road
Sherman Drive
Irene Drive
Marion Street
Main Street
CORRIDOR 1:
NORTH POINT
Former community of
Spring Bluff
9th Street
Control Points For
Historical Maps
WINTHROP
HARBOR
Chicago and Northwestern Railroad
LAKE MICHIGAN
Present boundary of
Illinois Beach State Park
(North Unit)
N
Park Avenue
0
.5
1 st mi
0
.5
1 km
A
Match points MAP 2 of 10
A'


A
A'
Match Points MAP 1 of 10
MAP 2 of 10
17th Street
Illinois Beach
State Park
(North Unit)
N
21st Street
Front Drive
ZION
LAKE MICHIGAN
Shiloh Boulevard
Sheridan Road
Elim Avenue
Elizabeth Avenue
Chicago and Northwestern Railroad
29th Street
Control Points For
Historical Maps
Illinois Beach
State Park
(South Unit)
0
.5
1
st mi
0
.5
1
km
WAUKEGAN
B
Match Points MAP 3 of 10
B'

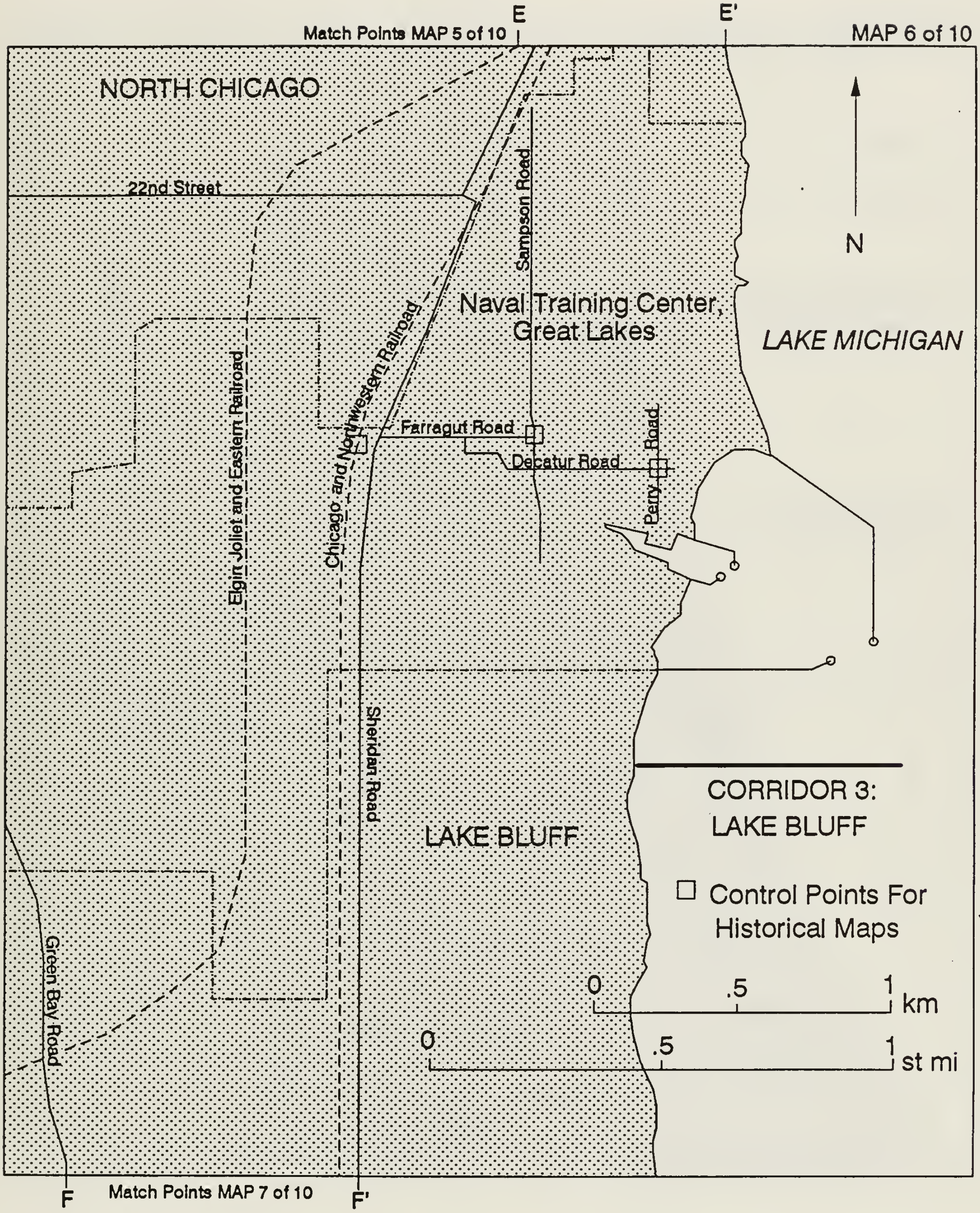
Appendix B (continued)



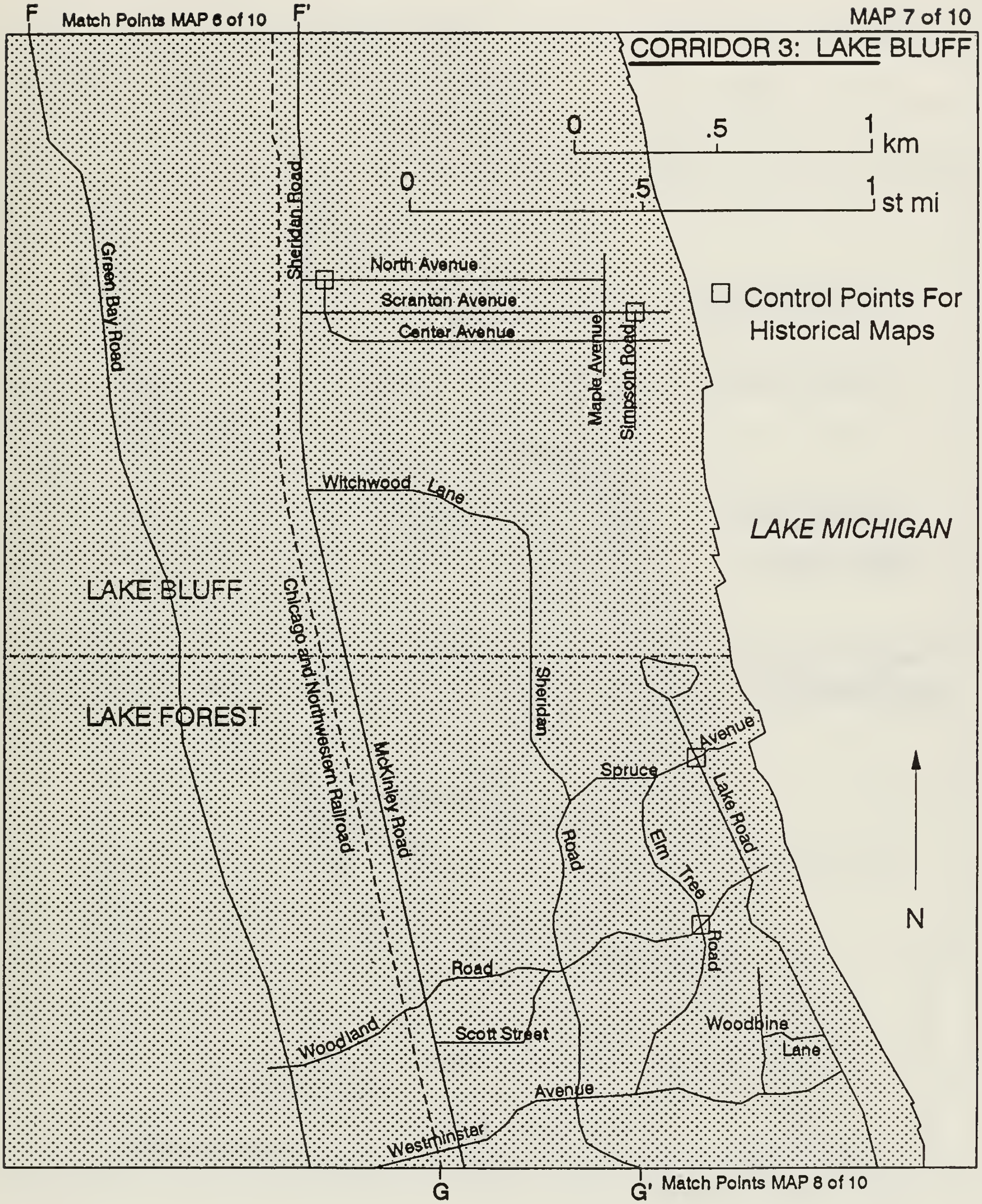

C
C'
Match Points MAP 3 of 10
MAP 4 of 10
Illinois Beach State Park (South Unit)
0 .5 1
0 .5 1
Greenwood Avenue
WAUKEGAN
N
LAKE MICHIGAN
Glen Flora Avenue
Chicago and Northwestern Railroad
Elgin Joliet and Eastern Railroad
Hickory Street
North Avenue
Sheridan Road
Genessee Road
CORRIDOR 2: WAUKEGAN HARBOR
Control Points For Historical Maps
Julian Avenue
Grand Avenue
Clayton Street
Waukegan Harbor
D
D'
Match Points MAP 5 of 10

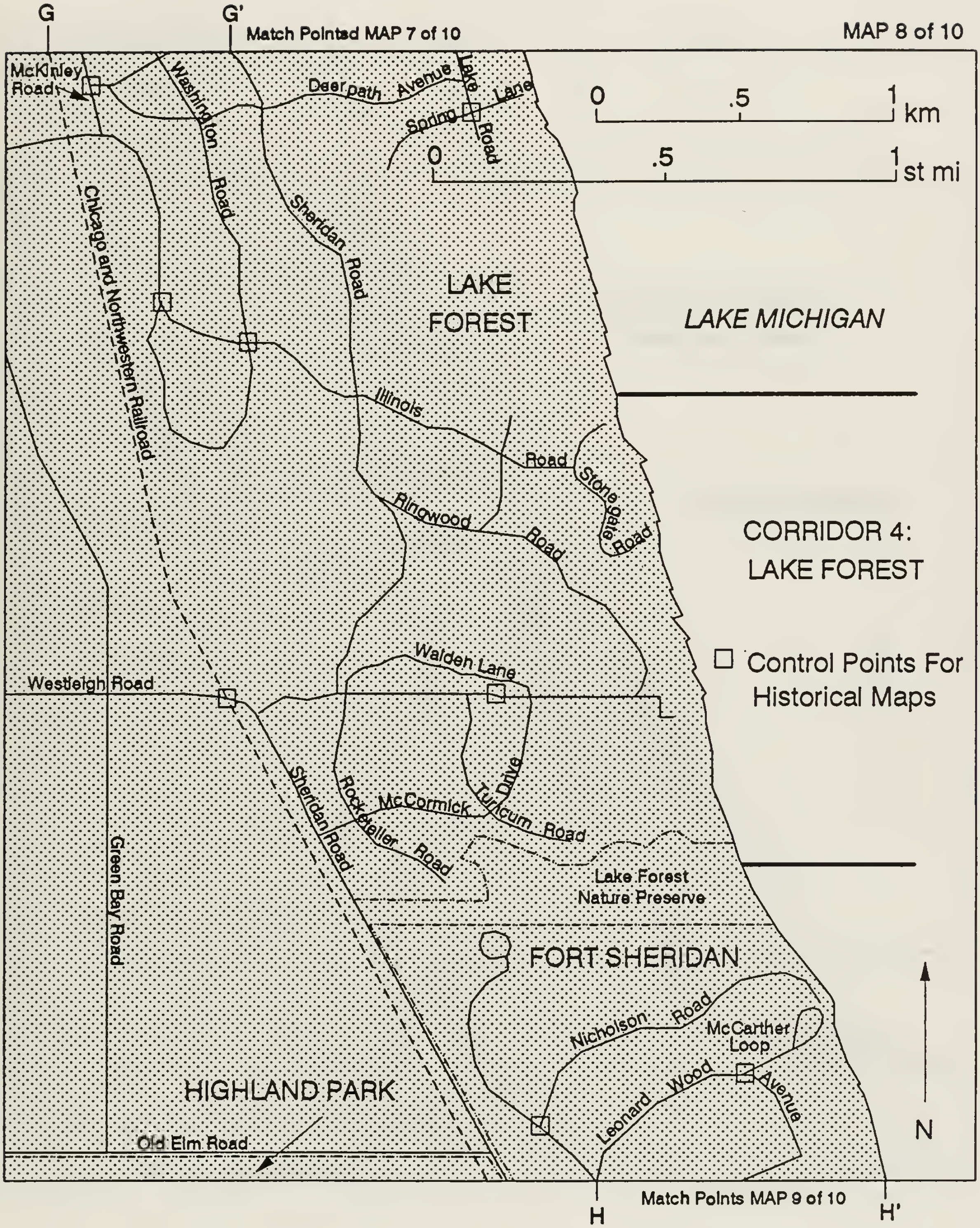

Match Points MAP 4 of 10
D
D'
MAP 5 of 10
Genesee Road
Sheridan Road
Liberty Street
Belvidere Street
N
South Avenue
WAUKEGAN
Control Points For
Historical Maps
Utica Street
10th Street
LAKE MICHIGAN
NORTH
CHICAGO
Sheridan Road
Chicago and Northwestern Railroad
14th Street
Elgin Joliet and Eastern Railroad
16th Street
0
.5
1
km
0
.5
1
st mi
18th Street
Naval Training Center,
Great Lakes
E
Match Points MAP 6 of 10
E'

Appendix B (continued)

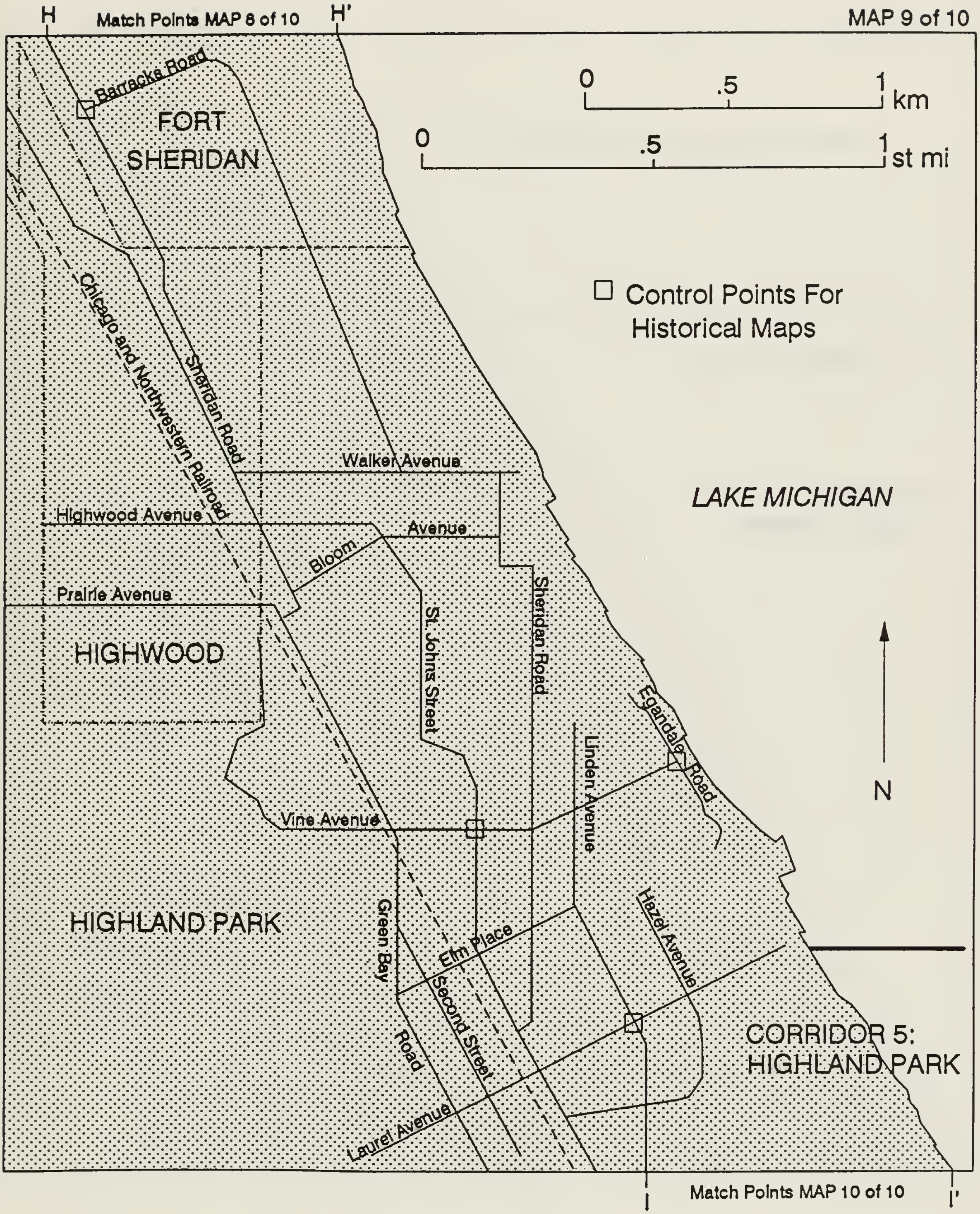


Appendix B (continued)

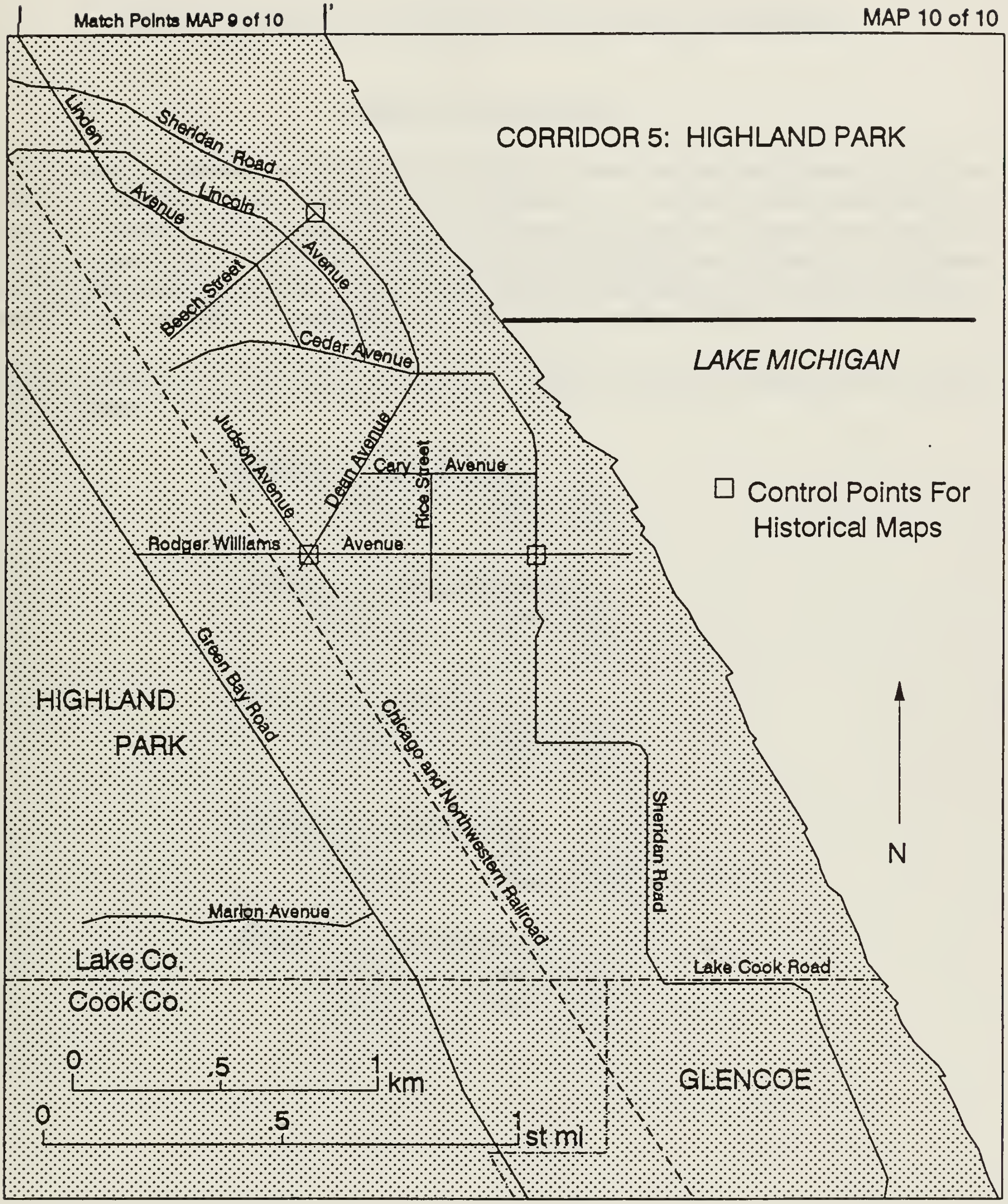



G
G'
Match Points MAP 7 of 10
MAP 8 of 10
McKinley Road
Deerpath Avenue
Lake Road
Spring Lane
Washington Road
Sheridan Road
Chicago and Northwestern Railroad
0 .5 1 km
0 .5 1 st mi
LAKE FOREST
LAKE MICHIGAN
Illinois Road
Stone gate Road
Ringwood Road
CORRIDOR 4: LAKE FOREST
Walden Lane
Control Points For Historical Maps
Westleigh Road
Sheridan Road
Rockefeller Road
McCormick
Tuncum Road
Drive
Lake Forest Nature Preserve
Green Bay Road
FORT SHERIDAN
Nicholson Road
McCarther Loop
Leonard Wood Avenue
HIGHLAND PARK
Old Elm Road
N
H
Match Points MAP 9 of 10
H'

Appendix B (continued)



Appendix B (continued)



APPENDIX C

U.S. LAKE SURVEY MAP COVERAGE FOR EACH CORRIDOR

Appendix C Explanation

This appendix contains reproductions of the U.S. Lake Survey field sheets, with the study corridors indicated. These are 1:1 reproductions made from bromide prints of the field sheets. Handwritten numbers and words on the field sheets are notations made on the bromide prints during this study for registration or reference. Horizontal and vertical ruled lines on the 1909-11 and 1910-11 field sheets are latitude-longitude parallels and meridians corresponding to the U.S. Standard Datum.

The following lists the corridors and the U.S. Lake Survey field sheet numbers for the survey years.

Corridor 1: North Point

1872	Map 1-521
1909-11	Map I-1197

Corridor 2: Waukegan Harbor

1873	Map I-553
1910-11	Map I-1196

Corridor 3: Lake Bluff

1873	Map I-553
1910-11	Map I-1196

Corridor 4: Lake Forest

1873	Map I-553
1910-11	Maps I-1195 and I-1196

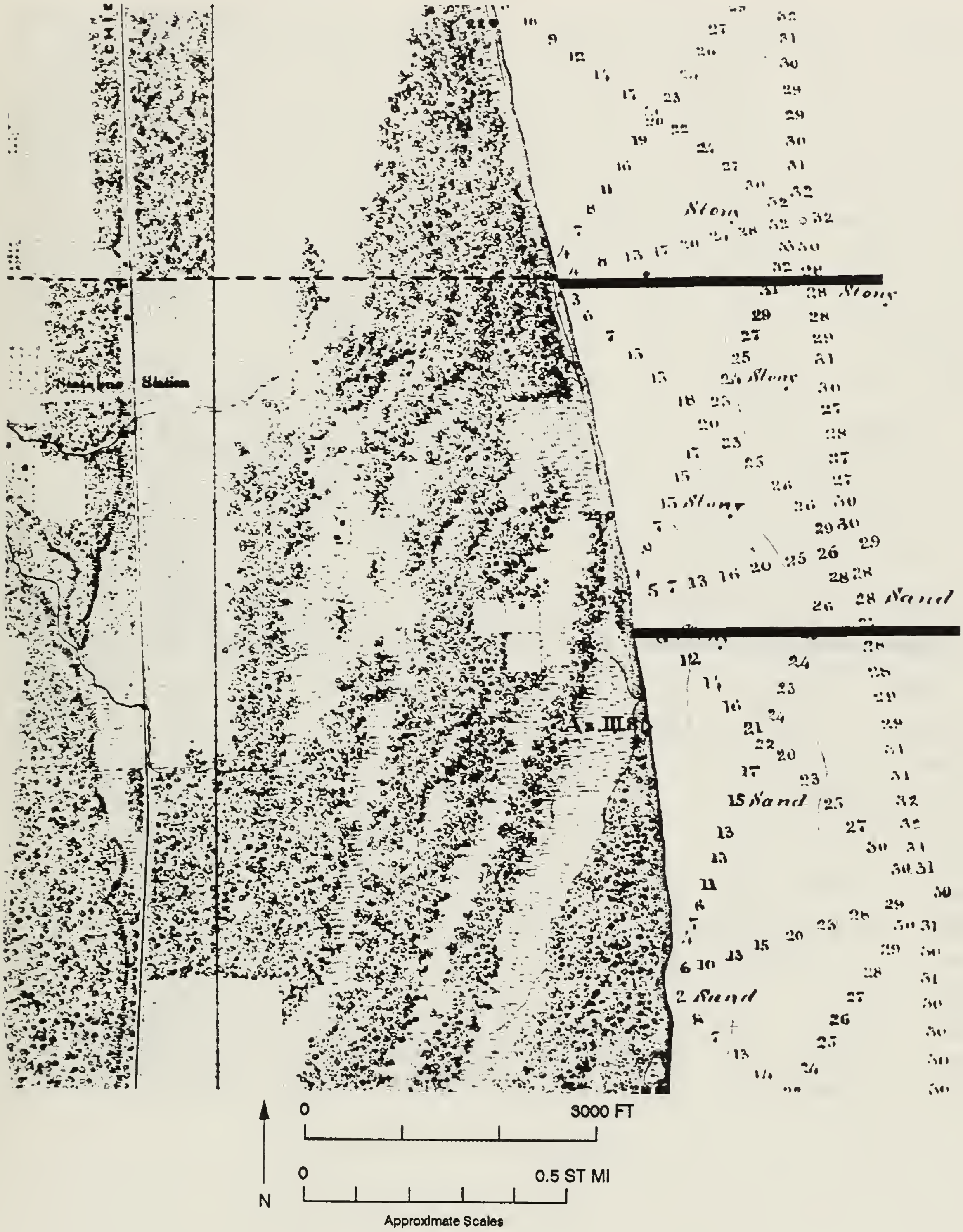
Corridor 5: Highland Park

1873	Map I-552
1910-11	Map I-1195

Appendix C (continued)

Corridor 1 1872

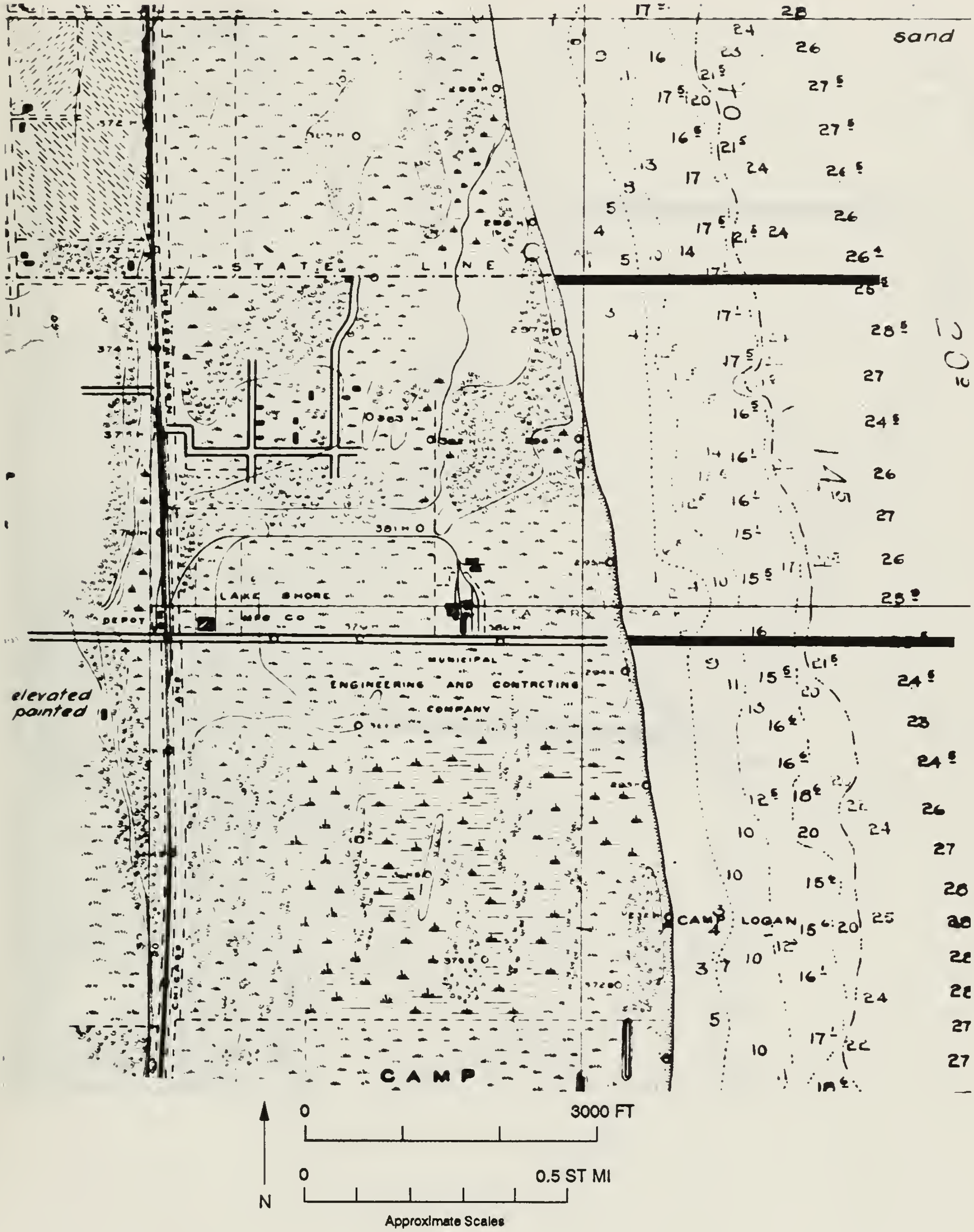
U.S. Lake Survey Map I-521



Appendix C (continued)

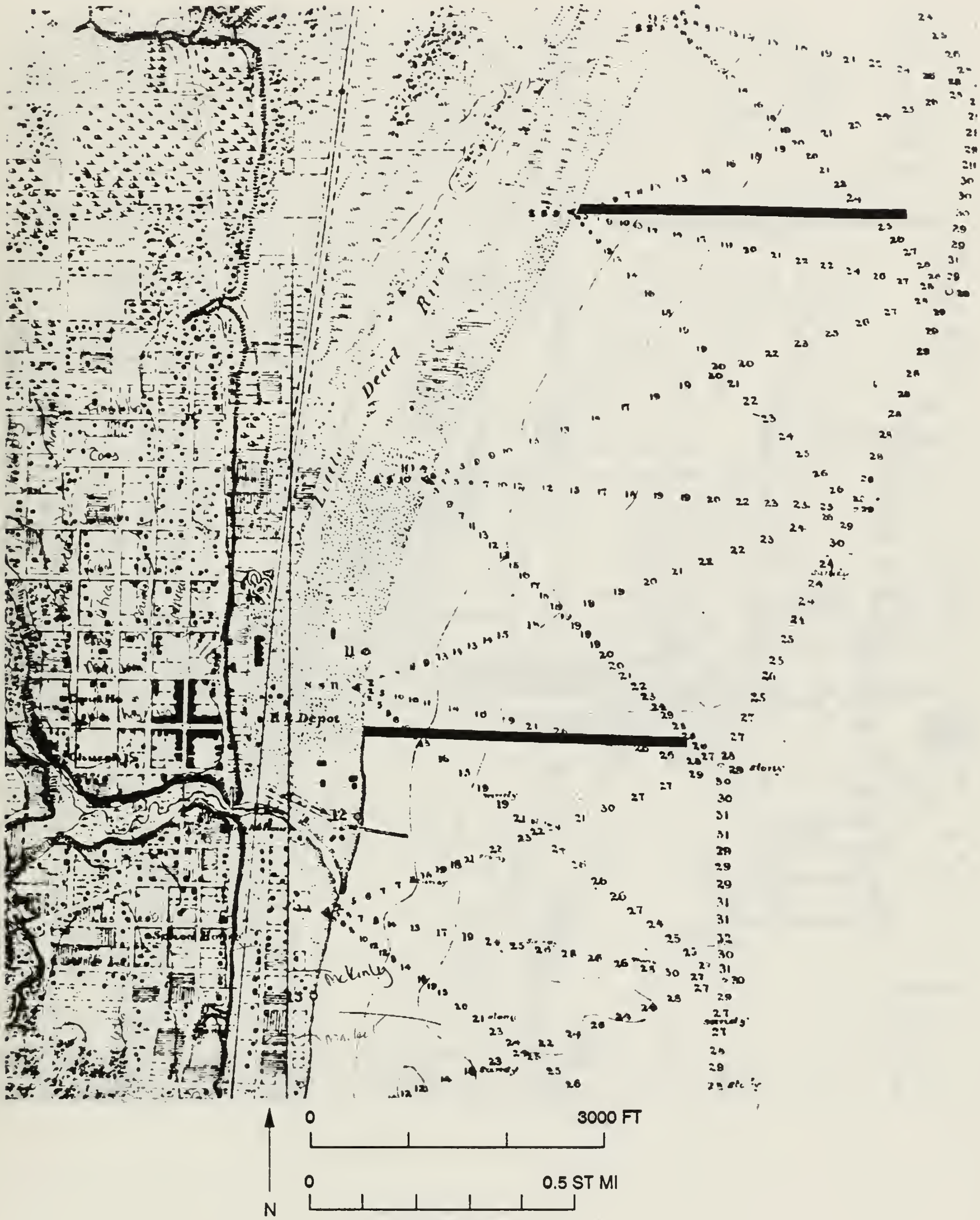
Corridor 1 1909-11

U.S. Lake Survey Map I-1197



Appendix C (continued)

Corridor 2 1873
U.S. Lake Survey Map I-553

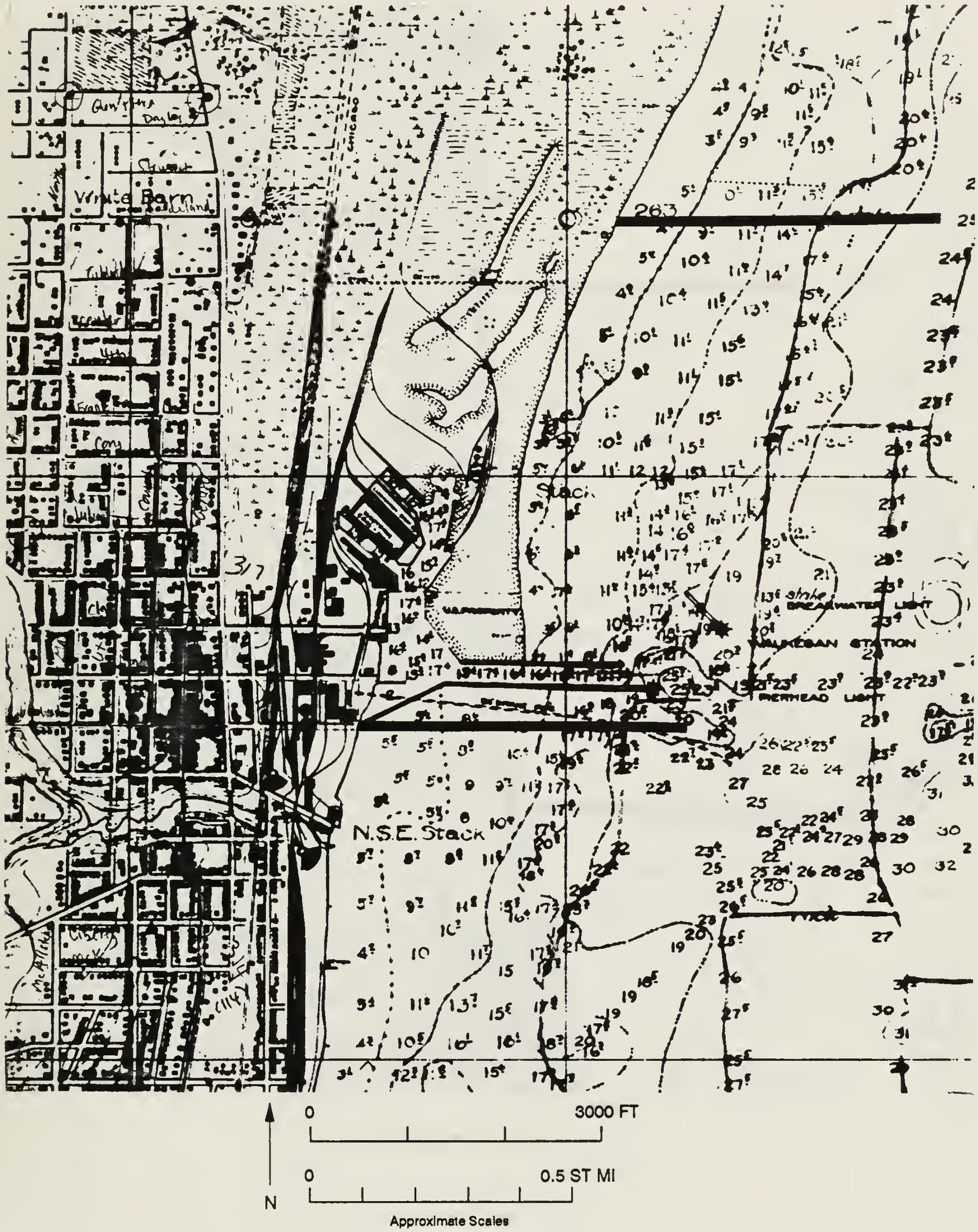


Approximate Scales

Appendix C (continued)

Corridor 2 1910-11

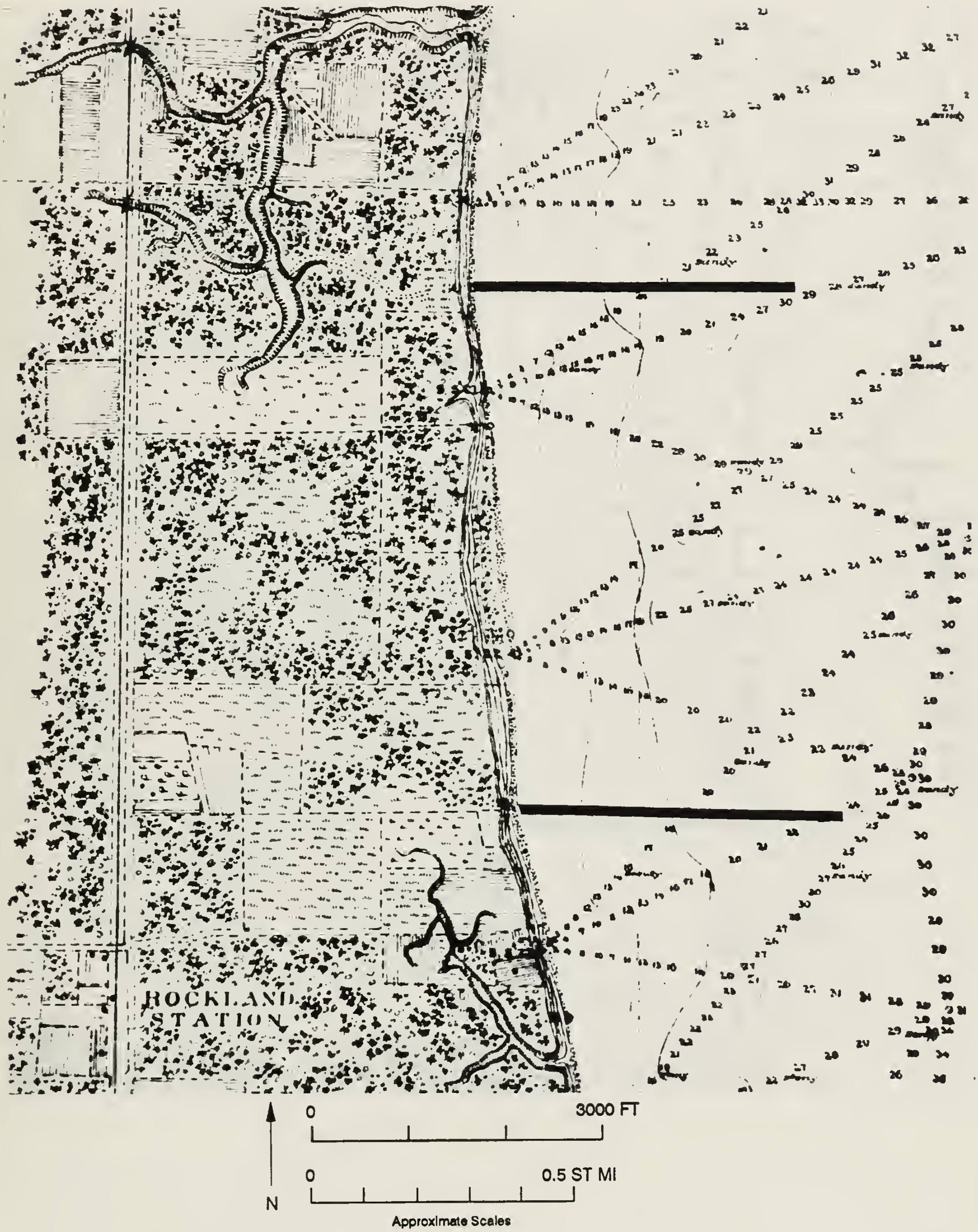
U.S. Lake Survey Map I-1196



Appendix C (continued)

Corridor 3 1873

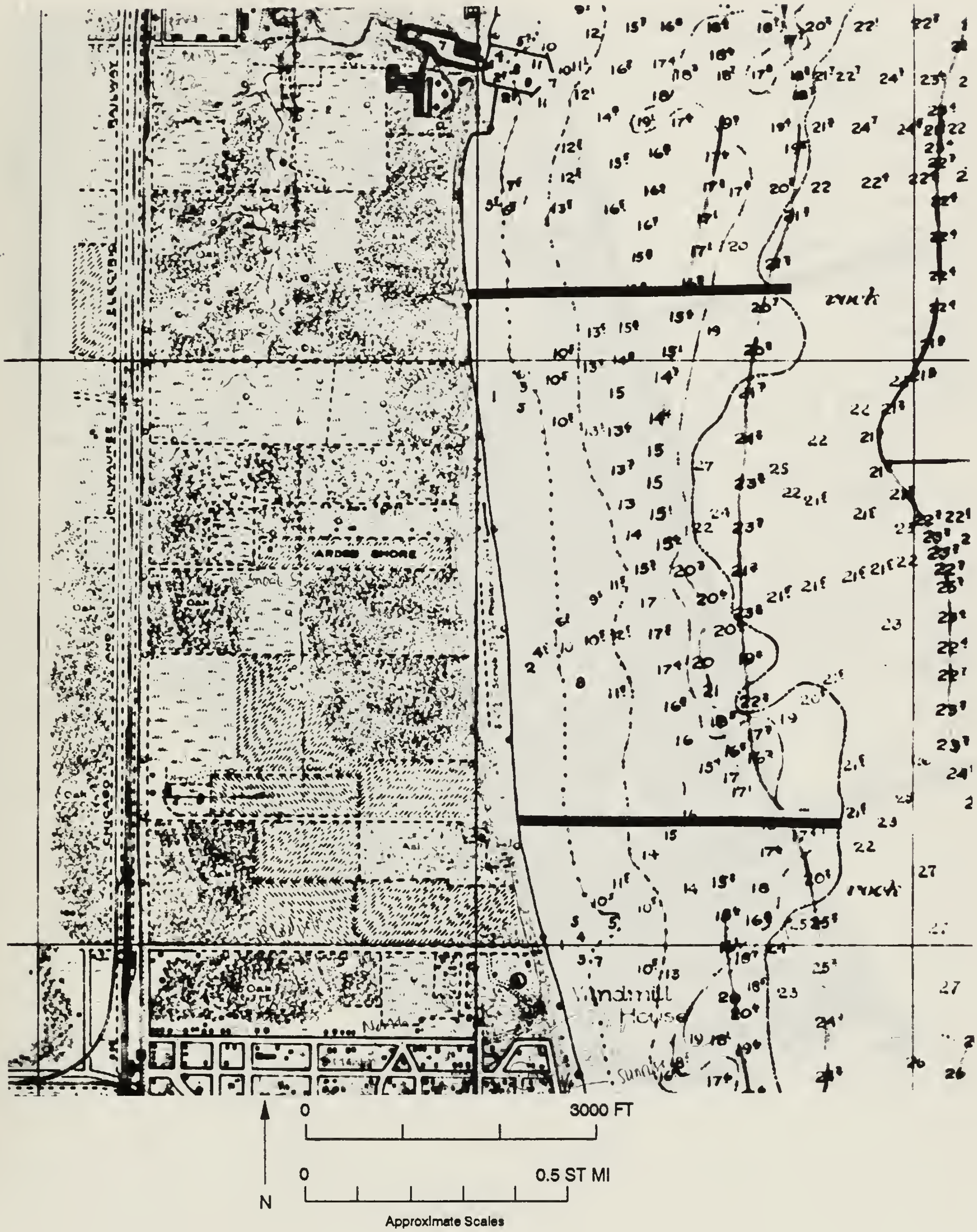
U.S. Lake Survey Map I-553



Appendix C (continued)

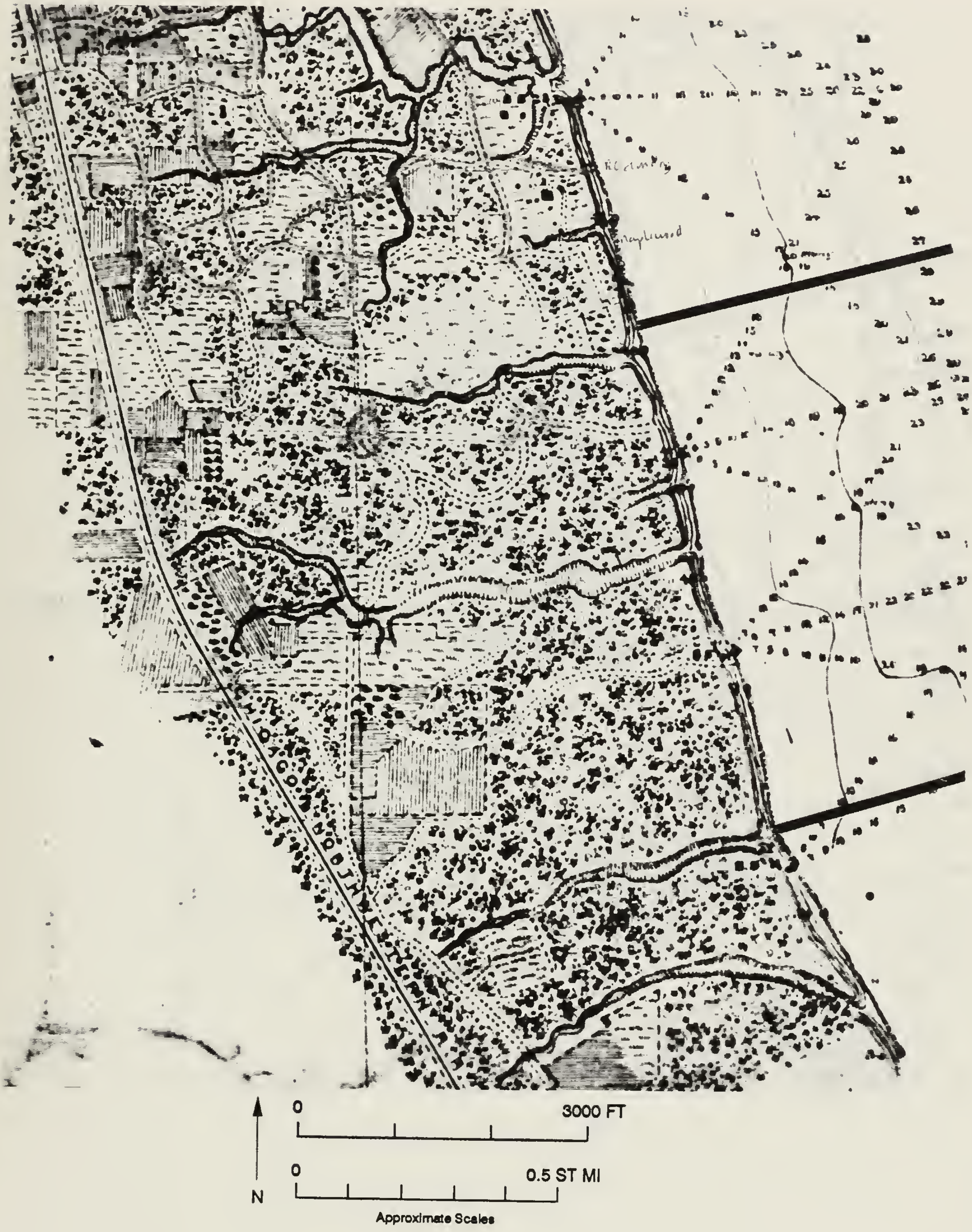
Corridor 3 1910-11

U.S. Lake Survey Map I-1196



Appendix C (continued)

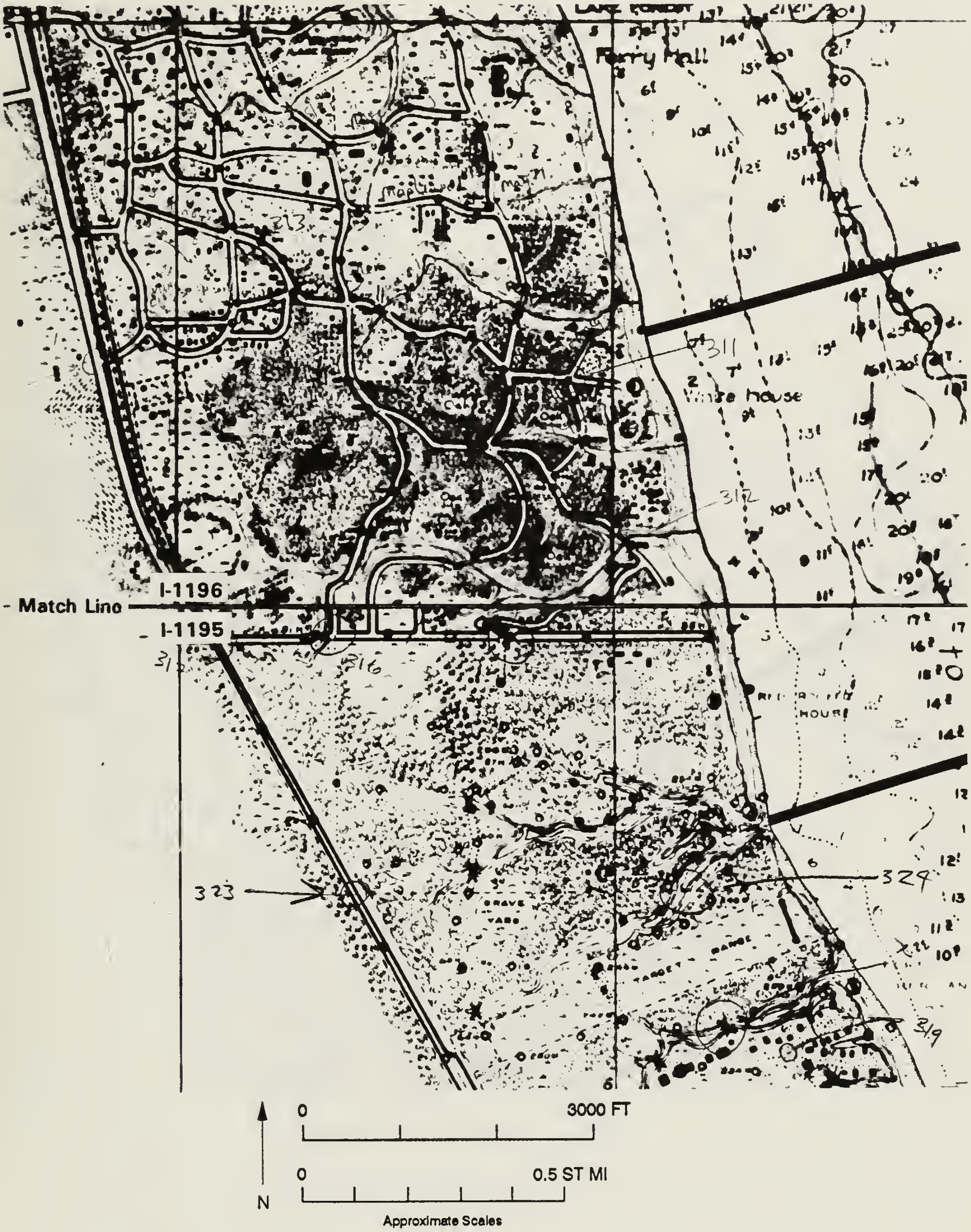
Corridor 4 1873
U.S. Lake Survey Map I-553



Appendix C
(continued)

Corridor 4 1910-11

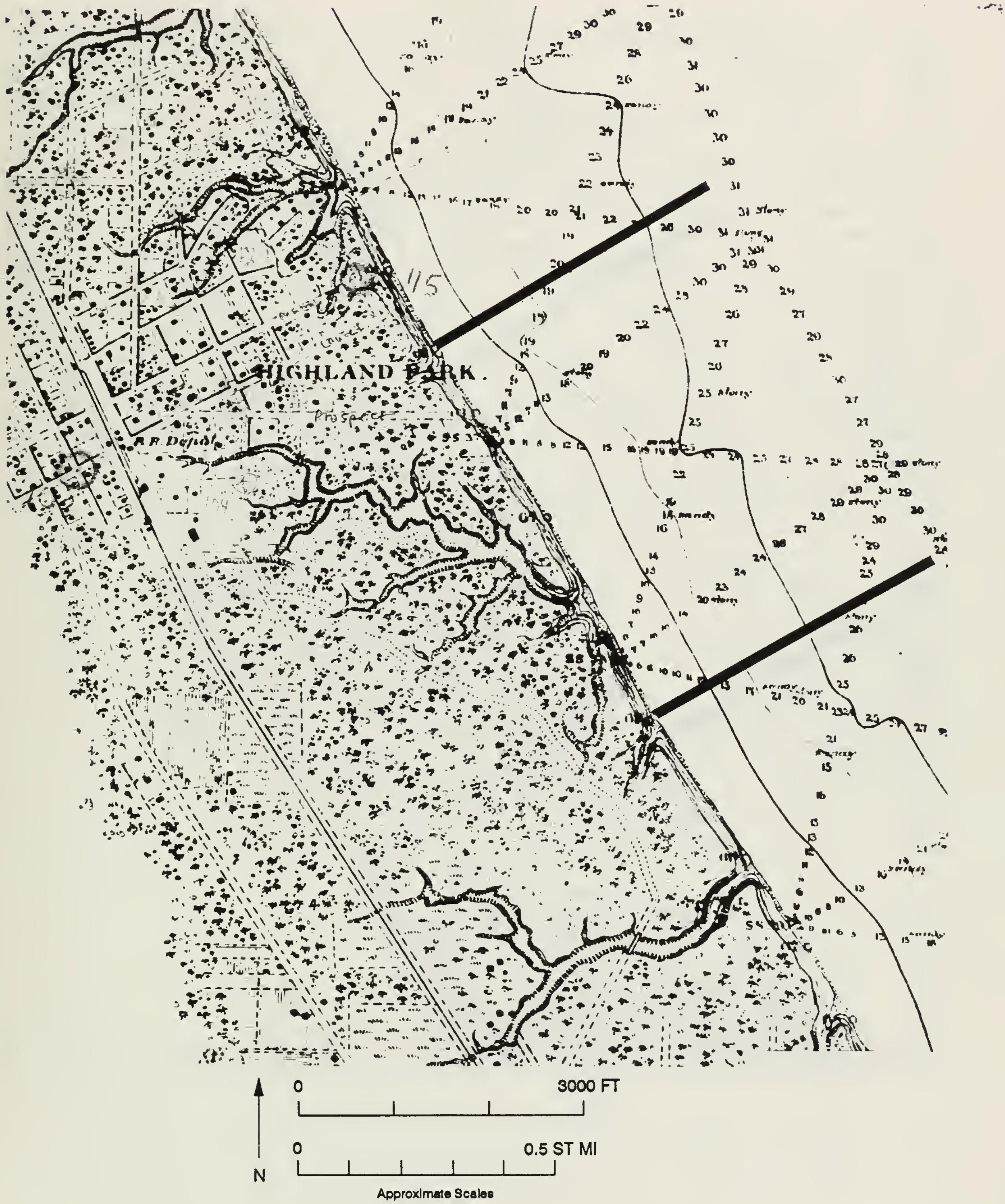
U.S. Lake Survey Maps I-1195 and I-1196



Appendix C (continued)

Corridor 5 1873

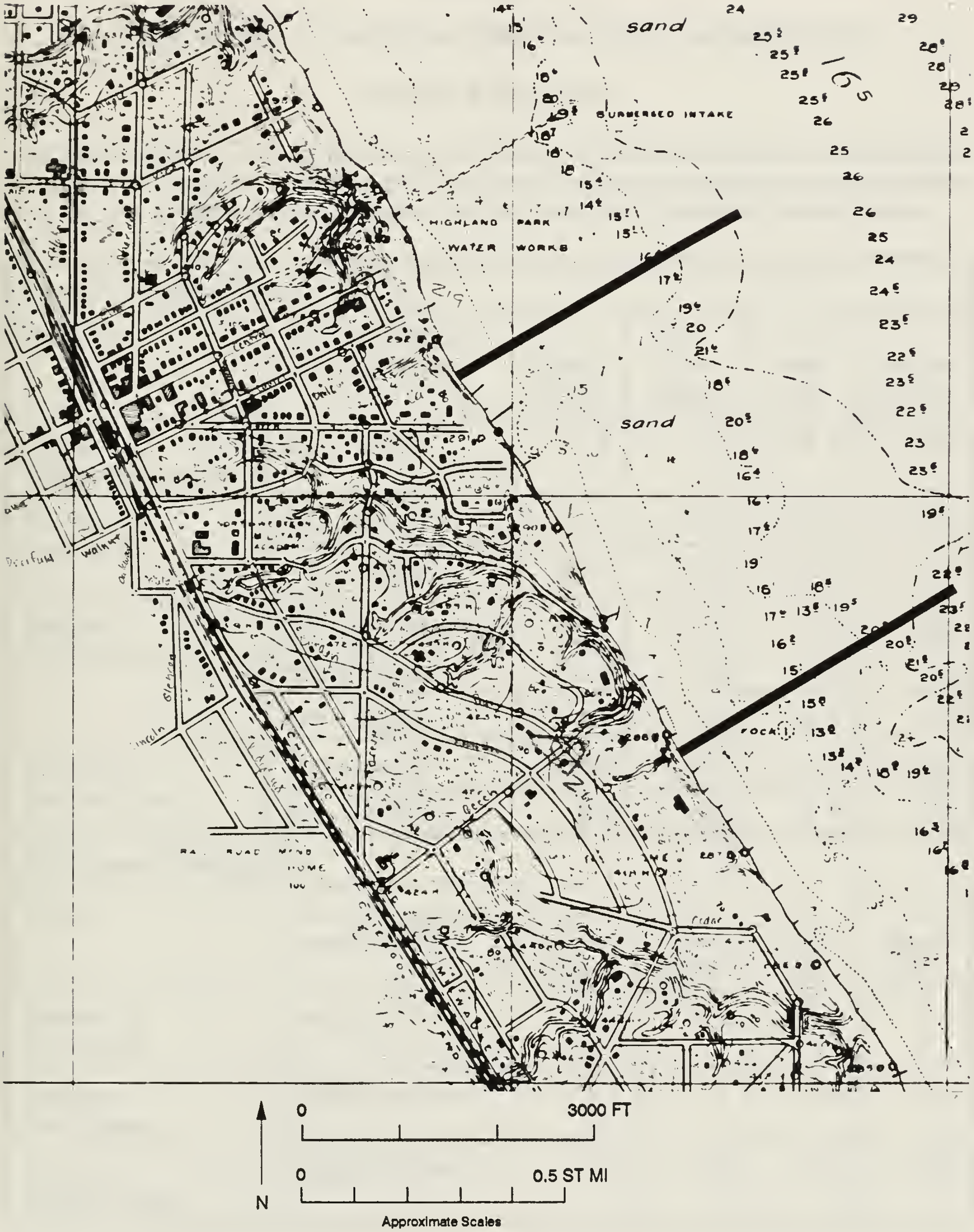
U.S. Lake Survey Map I-552



Appendix C (continued)

Corridor 5 1910-11

U.S. Lake Survey Map I-1195



APPENDIX D

ADJUSTMENTS FOR RELATIVE ORIENTATION OF STEREOMODEL

Appendix D Explanation

This appendix is a listing of adjustments made on the Zeiss Stereotope stereoplotter for internal orientation of each of the 1947 and 1987 aerial photograph stereomodels. A, B, C, and D adjustments relate to the four corners of individual stereomodels.

1947 Aerial Photographs					
Corridor	Aerial Photograph Frame Numbers	A Upper Right	B Lower Right	C Lower Left	D Upper Left
Corridor 2 Waukegan Harbor	BES-1-20/21	11.8	7.9	8.4	12.8
Corridor 3 Lake Bluff	BES-1-28/29	11.3	9.2	10.3	10.0
	BES-1-29/30	19.1	12.0	10.4	11.2
Corridor 4 Lake Forest	BES-1-34/35	10.7	11.5	10.7	8.9
	BES-1-35/36	10.4	6.9	10.8	8.3
	BES-1-36/37	6.6	4.8	6.6	6.2
Corridor 5 Highland Park	BES-1-44/45	9.9	5.7	6.9	6.8
	BES-1-45/46	6.5	5.0	5.4	7.5

1987 Aerial Photographs					
Corridor	Aerial Photograph Frame Numbers	A Upper Right	B Lower Right	C Lower Left	D Upper Left
Corridor 3 Lake Bluff	R3510-427/428	12.2	9.6	11.9	12.3
Corridor 4 Lake Forest	R3510-415/416	10.3	11.1	9.9	12.8
Corridor 5 Highland Park	R3510-406/407	13.8	12.0	9.9	10.0

APPENDIX E

GROUND CONTROL POINTS FOR HISTORICAL MAPS

Appendix E Explanation

This appendix is a listing of the ground control points used for registering the U.S. Lake Survey field sheets, and their associated root-mean-square (RMS) errors. Map scale is given in map feet per digitizing board inch. The locations of these ground control points are shown in Appendix B.

Corridor Year	Intersections or other features used for control points	Map scale (X,Y)	RMS error (board inches)	RMS error (map feet)
Corridor 1 North Point 1872	Sheridan Rd. - Russell Rd. Chicago and North Western Railroad tracks - Russell Rd. Sheridan Rd. - 9th St. 17th St. - Chicago and North Western Railroad tracks	(1686, 1673)	0.009	15
Corridor 2 Waukegan Harbor 1873	North Ave. - Glen Flora Ave. Chicago and North Western Railroad tracks - Greenwood Ave. Utica St. - South Ave. Julian St. - Hickory St.	(1687, 1677)	0.008	13
Corridor 3 Lake Bluff 1873	Lake Rd. - Spruce Ave. 10th St. - Sheridan Rd. Chicago and North Western Railroad tracks extension south of Sheridan Rd. and east of Argonne Dr. Chicago and North Western Railroad bridge west of Clark Ave.	(1642, 1677)	0.007	11

Appendix E (continued)

Corridor Year	Intersections or other features used for control points	Map scale (X,Y)	RMS error (board inches)	RMS error (map feet)
Corridor 4 Lake Forest 1873	Lake Rd. - Spruce Ave. Washington Rd. - Illinois Rd. Westleigh Rd. - Chicago and North Western Railroad tracks Deerpath Ave. - McKinley Rd.	(1683, 1686)	0.010	17
Corridor 5 Highland Park 1873	Sheridan Rd. - Roger Williams Ave. Roger Williams Ave. - Judson Ave. - Dean Ave. Vine Ave. - St. Johns Ave. Vine Ave. - Egandale Rd.	(1674, 1675)	0.013	22
Corridor 1 North Point 1909-11	Sheridan Rd. - Russell Rd. Chicago and North Western Railroad tracks - Russell Rd. Sheridan Rd. - 29th St. Chicago and North Western Railroad tracks - 29th St.	(1640, 1673)	0.007	11
Corridor 2 Waukegan Harbor 1910-11	Genessee St. - Liberty St. North Ave. - Glen Flora Ave. Extension of Glen Flora Ave. - Chicago and North Western Railroad tracks Northeast corner of Waukegan Harbor north breakwater (1904 segment)	(1673, 1667)	0.003	6
Corridor 3 Lake Bluff 1910-11	Walnut Ave. - North Ave. Farragut Ave. - Sampson St. Perry St. - Decatur Ave. Scranton Ave. - Simpson Ave.	(1674, 1666)	0.001	2

Appendix E (continued)

Corridor Year	Intersections or other features used for control points	Map scale (X,Y)	RMS error (board inches)	RMS error (map feet)
Corridor 4 Lake Forest North part 1910-11	Lake Rd. - Spruce Ave. Lake Rd. - Spring Ln. Illinois Rd. - Stonegate Rd. Illinois Rd. - Washington Circle	(1683, 1686)	0.010	17
Corridor 4 Lake Forest South part 1910-11	Westleigh Rd. - Chicago and North Western Railroad tracks Bridge on Westleigh Rd. west of McCormick Dr. McArthur Loop - Leonard Wood Ave. Lyster Rd. - Whistler Rd.	(1660, 1661)	0.006	9
Corridor 5 Highland Park 1910-11	Laurel Ave. - Linden Ave. Beech St. - Sheridan Rd. Vine Ave. - St. Johns Ave. Vine Ave. - Egandale Rd.	(1663, 1663)	0.003	6

APPENDIX F

GROUND CONTROL POINTS FOR AERIAL PHOTOGRAPHS

Appendix F Explanation

This appendix is a listing of the ground control points used for registering aerial photographs, and their associated root-mean-square (RMS) errors in digitizing board inches and map feet. The locations of these points are shown on the maps in Figures 6 through 10.

Corridor Year	Aerial photograph frame numbers	Intersections used for control points	RMS error (board in.)	RMS error (map ft.)
Corridor 1 North Point 1947	BES-1-47	Unnamed intersection approx. 1600′ north of IL-WI state line and 4300′ east of WI Hwy. 32 3rd St. - Sheridan Rd. 3rd St. - Oakdale Ave. Main St. - Laurie Ave.	0.007	7
Corridor 2 Waukegan Harbor 1947	BES-1-20/21	South Ave. - Market St. McKinley St. - Utica St. Belvidere Rd. - County St. Madison St. - Spring St. Madison St. - West St.	0.006	6
Corridor 3 Lake Bluff North part 1947	BES-1-28/29	5th St. - G St. Decatur Ave. - Fisher Rd. Dewey Ave. - Paul Jones St. A St. - 8th St. Shore Acres Rd. - rd. approx. 500′ south of Eastway Rd.	0.022	9
Corridor 3 Lake Bluff South part 1947	BES-1-29/30	Sheridan Rd. - Arden Shore Rd. South Arden Shore Rd. - Arden Shore Rd. South Shore Acres Rd. - rd. approx. 1600′ south of Eastway Rd. Shore Acres Rd. - rd. approx. 500′ south of Eastway Rd.	0.022	9

Appendix F (continued)

Corridor Year	Aerial photograph frame numbers	Intersections used for control points	RMS error (board in.)	RMS error (map ft.)
Corridor 4 Lake Forest 1947	BES-1-36	Northmoor Rd. - Sheridan Rd. McArthur Loop - Leonard Wood Ave. 12th Rd. - Haley Army Heliport access rd. Illinois Rd. - Stonegate Rd.	0.004	4
Corridor 5 Highland Park North part 1947	BES-1-45	Crescent Ct. - Prospect Ave. Laurel Ave. - McGovern St. Homewood Ave. - Midlothian Ave. Linden Ave. - Maple Ave.	0.001	2
Corridor 5 Highland Park South part 1947	BES-1-46	Cedar Ave. - Wildwood Ln. Judson Ave. - Ava St. Beech St. - Sheridan Rd. Lincoln Ave. - Glencoe Ave.	0.010	10
Corridor 1 North Point North part 1987	R3510-456	Unnamed intersection approx. 1600' north of IL-WI state line and 4300' east of WI Hwy. 32 3rd St. - Oakdale Ave. Irene St. - Steven St. Main St. - Rd. approx. 1000' west of Irene St.	0.006	6
Corridor 1 North Point South part 1987	R3510-454	Irene St. - Steven St. Main St. - Rd. approx. 1000' west of Irene St. Vista Rd. bridge over Dead Dog Ditch Lake Shore Rd. bridge over Dead Dog Ditch	0.012	5

Appendix F (continued)

Corridor Year	Aerial photograph frame numbers	Intersections used for control points	RMS error (board in.)	RMS error (map ft.)
Corridor 2 Waukegan Harbor 1987	R3510-435	Unnamed intersection approx. 1000' north of Sea Horse Dr. and 2800' east of Pershing Rd. Cory Ave - Genessee St. Northwest St. - Madison Rd. Liberty St. - Sheridan Rd.	0.006	6
Corridor 3 Lake Bluff 1987	R3510-427/428	Unnamed intersection of two private roads, approx. 2100' east of Sheridan Rd. and 1300' north of Blodgett Ave. Sheridan Rd. - private rd. approx. 1500' north of Blodgett Ave. Sheridan Rd. - Arden Shore Rd. South 4th Ave. - Ohio St. Shore Acres Rd. - rd. approx. 1600' south of Eastway Rd.	0.040	19
Corridor 4 Lake Forest North part 1987	R3510-416	Northmoor Rd. - Sheridan Rd. Maplewood Rd. - Mayflower Rd. McCormick Dr. - Turicum Rd. Westleigh Rd. - Circle Ln.	0.002	2
Corridor 4 Lake Forest South part 1987	R3510-416	Northmoor Rd. - Sheridan Rd. McCormick Dr. - Rockefeller Rd. McCormick Dr. - Turicum Rd. Westleigh Rd. - Circle Ln.	0.011	12
Corridor 5 Highland Park 1987	R3510-407	Linden Ave. - Sheridan Rd. Beech St. - Sheridan Rd. Beech St. - Wade St. Laurel Ave. - Lake Ave. (west intersection)	0.006	7

APPENDIX G

ANNOTATED LIST OF ARC/INFO COMMANDS

Appendix G Explanation

This appendix is an annotated list of the specific ARC/INFO commands that were used to carry out the procedures described in Part 3 of the report text. Unless otherwise indicated, all commands listed are commands used within the Arcedit module of ARC/INFO. Commands used within the Arc module of ARC/INFO are preceded by the notation (Arc). Commands used within the INFO module are preceded by the notation (INFO). Basic commands such as DRAW and MAPEXTENT have not been listed. It should also be noted that although these procedures were carried out for both shorelines and blufflines, for simplicity the term "shoreline" is used in the discussion that follows.

CREATION OF NEW GROUND CONTROL POINTS (page 58)

Commands for adding a tic at the extension of Sheridan Road and the Chicago and North Western Railroad tracks, Corridor 3.

EDITFEATURE ARC	Establishes arcs as the feature to be added.
ADD	Adds the extension.
INTERSECT ALL	Indicates that nodes are to be created wherever arcs cross.
SELECT	Selects either the railroad track arc or the Sheridan Road arc.
MOVE	The arc is not actually going to be moved, but this "pseudo move", in which the arc is selected, creates a node at the intersection.
SELECT	Selects southern arc segment.
SETANGLE -30	Sets the rotation angle to be 30 degrees. The negative sign indicates a clockwise rotation.

ROTATE	Rotates the arc into position coincident with the railroad tracks, with the intersection as the pivot point.

Commands for adding a tic at the intersection of the Chicago and North Western Railroad tracks and the ephemeral stream located west of Sheridan Road and Clark Avenue, Corridor 3.

EDITFEATURE LABEL	Indicates that points, or labels, are the feature to be added.
ADD	Adds points at each of the three intersections. The X-Y coordinates of each point, in feet, were recorded during the add process.
EDITFEATURE LABEL	Establishes that points, or labels, will be added.
COORDINATE KEYBOARD	Adds circumference points at the keyboard using the calculated coordinates.
EDITFEATURE ARC	Indicates that arcs will be added.
ARCTYPE CIRCLE	Indicates that circles will be added.
ADD	Adds circles using the center and circumference points.

RUBBER SHEETING (page 68)

Commands to establish coverage to be rubber sheeted

EDITCOVERAGE coverage	Establishes the coverage to be rubber sheeted (historical map or aerial photograph coverage).
DRAWENVIRONMENT ARC NODE LINK	Draws lines, their intersections, and the link vectors which will be added.
NODESNAP CLOSEST 0	Forces nodes (line intersections) to remain constant in position unless specifically

	moved by the rubber sheeting procedure.
EDITFEATURE LINK	Indicates that links are the feature to be edited or added.

Commands to establish reference coverage

SNAPCOVERAGE dlgcoverage	Establishes the DLG coverage as the digital reference map to which the historical coverage will be rubber sheeted ("snapped").
SNAPPING CLOSEST 50	Searches within a radius of 50 feet for the snapping feature.
BACKCOVERAGE dlgcoverage	Puts the snapping coverage on the screen where it can be seen.
BACKENVIRONMENT ARC	Draws snap coverage lines.
LINKFEATURE NODE NODE	Indicates that nodes (road intersections) on the historical coverage will be linked, or snapped to, nodes (road intersections) on the DLG reference maps.

Commands for adding links

ADD	Allows addition of links. By establishing LINKFEATURE NODE NODE, only vector endpoints coincident with nodes are allowed to be added.

Commands for rubber sheeting

LIMITADJUST BOX	Establishes a zero-adjustment box around those features to be rubber sheeted.
ADJUST	Performs the actual rubber sheeting operations.

GENERATION OF TRANSECTS (page 85)

Commands to establish baseline

EDITFEATURE ARC	Indicates that arcs (lines) are the feature to be edited or added.
ADD	Adds the new arc.

Commands to establish first transect line

SELECT baseline-arc	Selects the digitized baseline arc.
COPY PARALLEL	Generates the first transect in a position coincident with the baseline arc.
SETANGLE -90	Sets the rotation angle at 90 degrees clockwise.
ROTATE	Rotates the first transect 90 degrees into its correct position, using the north end as a pivot point.
SELECT baseline-arc	Selects the baseline arc.
DELETE	Deletes the baseline arc.
(Arc) BUILD <transects> LINE	Renumbers the arcs so that the northernmost transect has $RECNO = 1; creates an arc attribute table (.AAT).
(Arc) BUILD <transects> NODE	Creates a node attribute table (.NAT).

Commands to establish additional transect lines

SELECT first-transect-arc	Selects the first transect.
COPY PARALLEL 150	Makes a copy of the selected transect parallel and 150 feet to the south of the first one; this is the second transect, and it becomes the next selected arc

	automatically.
COPY PARALLEL 150	Creates the third transect 150 feet south of the second transect.

Repeat until all transects are generated (35 transects per one-mile corridor).

<u>Commands for attributing transects</u>

(Arc) ADDITEM transects.AAT transects.AAT CODE 3 3 i	Adds the item CODE to the arc attribute table (AAT) of the transects coverage, with input and output width 3 characters each, and defined as an integer item ("i").
(Arc) ADDITEM transects.AAT transects.AAT YEAR 4 4 i	Adds the item YEAR to the AAT of the transects coverage, with input and output width 4 characters each, and defined as an integer item.
(Arc) ADDITEM transects.NAT transects.NAT CODE 3 3 i	As above, but adds CODE to the node attribute table (.NAT).
(Arc) ADDITEM transects.NAT transects.NAT YEAR 4 4 i	Adds YEAR to the NAT.

<u>Commands to add transects to shoreline/bluffline coverage</u>

EDITCOVERAGE <transects>	Selects transect coverage to edit.
EDITFEATURE ARC	Indicates that arcs will be edited and added.
CALCULATE YEAR = year	Calculates the item YEAR to be equal for the shoreline year being intersected.
INTERSECT ALL	Indicates that the arc that will be added to the transect coverage (the shoreline) will be intersected with pre-existing coverage arcs (the transects).
GET shorelinecover	Brings in the shoreline arc, determining

	each shoreline-transect intersection as the shoreline is copied in.
SELECT BOX	Selects all arcs lying entirely inside a box that is drawn around the arcs to be deleted. (See Figure 12 for a diagram of which arcs are deleted in this step.)
DELETE	Deletes the arcs.
EDITFEATURE NODE	Sets nodes as the feature to be deleted.
SELECT BOX	Selects all nodes lying entirely inside a box that is drawn around the nodes to be deleted. (See Figure 12 for a diagram of which nodes are deleted in this step.)
DELETE	Deletes the nodes.

Commands for attributing transects

EDITCOVERAGE transectcover	Selects transects to edit.
EDITFEATURE ARC	Sets arcs as the feature to attribute.
SELECT ALL	Selects all arcs.
CALCULATE YEAR = year	Calculates the .AAT item YEAR equal to the year of the shoreline.
CALCULATE CODE = $RECNO + 100 (200, 300, 400, 500)	Calculates the .AAT item CODE equal to the $RECNO (which is numbered from 1 to 35) plus the appropriate number for the corridor being edited.
EDITFEATURE NODE	Sets nodes as the feature to attribute.
SELECT BOX	Selects all nodes inside a box that is drawn around the nodes of interest. (In Figure 12, these are the shoreline-transect nodes.)
CALCULATE YEAR = year	Calculates the .NAT item YEAR equal to

	the year of the shoreline.
SELECT ALL	Selects all nodes.
CALCULATE CODE = ARC# + 100 (200, 300, 400, 500)	Calculates the .NAT item CODE equal to the the ARC# (which is numbered from 1 to 35) plus the appropriate number for the corridor being edited.

Preparing the transect coverages and associated files for input into program

(Arc) BUILD transectcover LINE	Builds the coverage as a line coverage.
(Arc) ADDXY transectcover NODE	Adds the X and Y coordinates of each node to the coverage .NAT. These items are named X-COORD and Y-COORD.
(Arc) ADDITEM transectcover.NAT transectcover.NAT RECNO 8 8 i	Adds the item RECNO to the transect coverage .NAT, defined as an 8-character integer item.
(INFO) SELECT transectcover.NAT	Selects the node attribute table.
(INFO) CALCULATE RECNO = $RECNO	Calculates the added .NAT item RECNO to be equal to the internal item $RECNO.
(INFO) OUTPUT transectfile	Opens a new output file, into which the X-Y coordinates of the nodes will be put.
(INFO) PRINT X-COORD, Y-COORD	The values of the X and Y coordinates are output into the transect file.
(Arc) &RUN LAM-GEO.AML transectfile	Runs a small AML (Arc Macro Language) program, given in Appendix J, to convert the X-Y coordinates in Lambert feet to latitude and longitude in degrees-minutes-seconds format. Outputs the file transect.geo.

(INFO) DEFINE file.DEG	Defines a new INFO file to contain the projected coordinates.
(INFO) BLANK, 2, 2, C (INFO) Y, 12, 12, C (INFO) BLANK2, 3, 3, C (INFO) X, 12, 12, C	Sets up the INFO file to contain the X and Y coordinates separated by blank fields. X and Y are switched in this step so that latitude (Y in the Lambert projection) will be presented before longitude.
(INFO) GET transect.geo COPY ASCII	Places the X and Y coordinates, in latitude and longitude, into file.deg.
(Arc) ADDITEM file.DEG file.DEG RECNO 8 8 i	Adds the item RECNO to the latitude-longitude file. This will be the relate item for this file.
(INFO) SELECT file.DEG	Selects the latitude-longitude file.
(INFO) CALCULATE RECNO = $RECNO	Calculates the added item RECNO to be equal to the internal item $RECNO.
CHANGE transectprogram	Enters edit mode to allow insertion of correct filenames. The program was edited and re-run for each shoreline and bluffline coverage.
RUN transectprogram	Runs the transect program with all related datafiles.

APPENDIX H

CONTROL POINTS FOR RUBBER SHEETING

Appendix H Explanation

This appendix lists intersections used as link-vector endpoints for rubber sheeted corridors. All intersections tested for stability are listed. Intersections used for rubber sheeting (links 40 feet or longer) are highlighted. If no intersections are highlighted, rubber sheeting was not performed for that corridor for that year.

Corridor 1: North Point, 1872.	
Link intersection	Link length (feet)
Russell Rd. - Chicago and North Western Railroad tracks	19.1
17th St. - Chicago and North Western Railroad tracks	8.4
Sheridan Rd. - 9th St.	18.7
Russell Rd. - Sheridan Rd.	14.5

Corridor 1: North Point, 1909-11.	
Link intersection	Link length (feet)
Russell Rd. - Chicago and North Western Railroad tracks	11.2
17th St. - Chicago and North Western Railroad tracks	39.0
Russell Rd. - Sheridan Rd.	15.7
Main St. - Chicago and North Western Railroad tracks	**62.9**
Sheridan Rd. - 29th St.	20.8
29th St. - Chicago and North Western Railroad tracks	21.4

Appendix H (continued)

Corridor 1: North Point, 1947	
Link intersection	Link length (feet)
3rd St. - Oakdale Ave.	19.2
3rd St. - Sheridan Rd.	8.9
Main St. - Sheridan Rd.	7.0
Main St. - Franklin Ave.	8.5
Main St. - Lake Shore Rd.	13.5
Sheridan Rd. - Russell Rd.	25.2

Corridor 1: North Point, 1987	
Link intersection	Link length (feet)
Unnamed intersection approx. 1600′ north of IL-WI state line and 4300′ east of WI Hwy. 32	5.5
3rd St. - Oakdale Ave.	25.0
Irene St. - Steven St.	11.1
Main St. - Rd. approx. 1000′ west of Irene St.	27.4

Corridor 2: Waukegan Harbor, 1873.

Link intersection	Link length (feet)
North Ave. - Glen Flora Ave.	23.1
Sheridan Rd. - Glen Flora Ave.	**46.2**
Utica St. - South Ave.	12.2
10th St. - Sheridan Rd.	**85.6**
Genessee St. - Clayton St.	**55.0**
Julian St. - Hickory St.	17.7
Genessee St. - Liberty St.	20.1
Greenwood Ave. - North Ave.	**54.8**
Extension of Greenwood Ave. - Chicago and North Western Railroad tracks	16.3
Northwest St. - Julian St.	14.2
Utica St. - Julian St.	25.0
Franklin St. - County St.	**56.2**
Franklin St. - North Ave. (south intersection)	16.0
Utica St. - Madison St.	27.9
Clayton St. - County St.	25.0
Cory Ave. - Sheridan Rd.	**81.6**
Cory Ave. - North Ave.	32.0
Cory Ave. - County St.	**45.7**
Julian St. - Genessee St.	**59.7**
Porter St. - Ash St.	38.0

Appendix H (continued)

Corridor 2: Waukegan Harbor, 1910-11.	
Link intersection	Link length (feet)
North Ave. - Glen Flora Ave.	23.0
Sheridan Rd. - Glen Flora Ave.	31.9
Utica St. - South Ave.	19.6
Genessee St. - Clayton St.	10.5
Julian St. - Hickory St.	24.4
Genessee St. - Liberty St.	18.5
Greenwood Ave. - Chicago and North Western Railroad tracks	12.7
County St. - Washington St.	29.7

Corridor 2: Waukegan Harbor, 1947. Not enough roads were digitized in the corridor for rubber sheeting. See text, page 81, for discussion.

Corridor 2: Waukegan Harbor, 1987	
Link intersection	Link length (feet)
Ridgeland Ave. - Sheridan Rd.	**62.8**
black intersection on atlas map	12.9
Northwest St. - Madison St.	37.2
Madison St. - Pershing Rd.	**51.1**
Liberty St. - Sheridan Rd.	16.5

Corridor 3: Lake Bluff, 1873.	
Link intersection	Link length (feet)
10th St. - Sheridan Rd.	20.4
Lake Rd. - Spruce Ave.	21.9
Extension of Blodgett Ave. - Chicago and North Western Railroad tracks	**144.4**

Corridor 3: Lake Bluff, 1910-11.	
Link intersection	Link length (feet)
Farragut Ave. - Sampson Rd.	1.3
Perry St. - Decatur Ave.	8.4
Dewey Ave. - Perry St.	14.8
Walnut Ave. - North Ave.	14.9
Maple Ave. - Scranton Ave.	20.4
Lake Rd. - Spruce Ave.	**106.7**
Scranton Ave. - Simpson Ave.	17.4
Scranton Ave. - Sunrise Ave.	11.4
Prospect Ave. - Evanston Ave.	30.0

Corridor 3: Lake Bluff, 1947. No roads were digitized in the corridor, so no rubber sheeting was possible. See text, page 81, for discussion.

Corridor 3: Lake Bluff, 1987. Not enough roads were digitized in the corridor for rubber sheeting. See text, page 81, for discussion.

Appendix H (continued)

Corridor 4: Lake Forest, 1873.	
Link intersection	Link length (feet)
Maplewood Rd. - Sheridan Rd.	**41.5**
Deerpath Ave. - Washington Rd.	**45.5**
Deerpath Ave. - McKinley Rd.	14.3
Westminster Ave. - Woodbine Pl.	25.2
Woodland Rd. - Elm Tree Rd.	25.0
Illinois Rd. - Oakwood Ave.	15.9
Deerpath Ave. - Bank Ln.	16.4
Lake Rd. - Westminster Ave.	36.1
Illinois Rd. - McKinley Rd.	19.8
Illinois Rd. - Washington Circle	28.2
Rosemary Rd. - Washington Rd.	**56.0**
Illinois Rd. - Sheridan Rd.	**45.5**
Sheridan Rd. - Green Briar Ln.	**53.2**
Lake Rd. - Spruce Ave.	11.6

Appendix H (continued)

Corridor 4: Lake Forest, 1910-11	
Link intersection	Link length (feet)
Lake Rd. - Spruce Ave.	13.9
Deerpath Ave. - Chicago and North Western Railroad tracks	**49.6**
Illinois Rd. - Washington Rd.	4.9
Lake Rd. - Spring Ln.	28.9
Illinois Rd. - Stonegate Rd.	17.0
Western Ave. - Ryan Place	**57.5**
Sheridan Rd. - Westleigh Rd.	**48.2**
Westleigh Rd. - Chicago and North Western Railroad tracks	16.4
McArthur Loop - Leonard Wood Ave.	36.1
Whistler Rd. - Lyster Rd.	17.0
Nicholson Rd. - George Bell Rd.	**50.2**

Appendix H (continued)

Corridor 4: Lake Forest, 1947	
Link intersection	Link length (feet)
George Bell Rd. - 12th Rd.	13.2
12th Rd. - Haley Army Heliport access rd.	14.7
George Bell Rd. - Vattman Rd.	16.5
Westleigh Rd. - Walden Ln. (eastern intersection)	22.1
Northmoor Rd. - Sheridan Rd.	11.9
Maywood Rd. - Highview Terrace	27.2
Greenview Place - Winston Rd.	26.0
Wooded Ln. - Green Briar Ln.	15.6
Illinois Rd. - Mayflower Rd.	25.4
McCaskey Rd. - Burkhardt Rd.	25.2
Illinois Rd. - Stonegate Rd.	15.4

Corridor 4: Lake Forest, 1987	
Link intersection	Link length (feet)
Greenview Place - Winston Rd.	26.0
Northmoor Rd. - Sheridan Rd.	11.9
Illinois Rd. - Mayflower Rd.	23.9
McCormick Dr. - Turicum Rd.	9.7
Maplewood Rd. - Mayflower Rd.	36.7
Maplewood Rd. - Sheridan Rd.	36.5
Westleigh Rd. - Circle Ln.	13.1

Appendix H (continued)

Corridor 5: Highland Park, 1873	
Link intersection	Link length (feet)
Roger Williams Ave. - Dean Ave. - Judson Ave.	28.4
St. Johns Ave. - Vine Ave.	23.5
Laurel Ave. - Prospect Ave.	**48.8**
Elm Place - Linden Ave.	**49.5**
Roger Williams Ave. - Sheridan Rd.	25.6
Roger Williams Ave. - Rice St.	3.5
Vine Ave. - Egandale Rd.	**48.2**
Linden Ave. - Ravine Dr.	**49.9**

Appendix H (continued)

Corridor 5: Highland Park, 1910-11	
Link intersection	Link length (feet)
Roger Williams Ave. - Dean Ave. - Judson Ave.	37.2
Laurel Ave. - Linden Ave.	18.5
St. Johns Ave. - Vine Ave.	28.2
Vine Ave. - Sheridan Rd.	**42.8**
Ravine Dr. - Sheridan Rd.	24.1
Lincoln Ave. - Linden Ave.	34.1
Beech St. - Sheridan Rd.	7.7
Beech St. - Wade St.	8.0
Lincoln Ave. - Ridgewood Dr.	28.2
Waverly Rd. - Sheridan Rd. (north intersection)	15.5
Forest Ave. - Sheridan Rd.	28.6
Ravine Dr. - Forest Ave.	27.3
Hazel Ave. - Linden Ave.	20.4
Lake Ave. - Prospect Ave.	28.6
Laurel Ave. - Dale Ave.	6.8
Orchard Ln. - St. Johns Ave.	38.9
Waukegan Ave. - Temple Ave.	32.1
Vine Ave. - Egandale Rd.	18.4

Appendix H (continued)

Corridor 5: Highland Park, 1947 (Northern portion)	
Link intersection	Link length (feet)
Waverly Rd. - Sheridan Rd. (south int.)	31.2
Forest Ave. - Sheridan Rd.	38.6
Forest Ave. - Lincoln Ave.	27.8
Linden Ave. - Sheridan Rd.	24.8
Ravine Dr. - Forest Ave.	14.7
Ravine Dr. - Linden Ave.	11.6
Lake Ave. - Laurel Ave.	16.2
Laurel Ave. - Linden Ave.	5.8

Corridor 5: Highland Park, 1947 (Southern portion)	
Link intersection	Link length (feet)
Forest Ave. - Beech St.	19.0
Roger Williams Ave. - Rice St.	15.9

Corridor 5: Highland Park, 1987	
Link intersection	Link length (feet)
Linden Ave. - Sheridan Rd.	9.2
Forest Ave. - Sheridan Rd.	19.9
Beech St. - Sheridan Rd.	17.4
Beech St. - Wade St.	12.8
Linden Ave. - Cedar Ave.	16.6
Prospect Ave. - Forest Ave.	8.4
Laurel Ave. - Lake Rd.	6.0

APPENDIX I

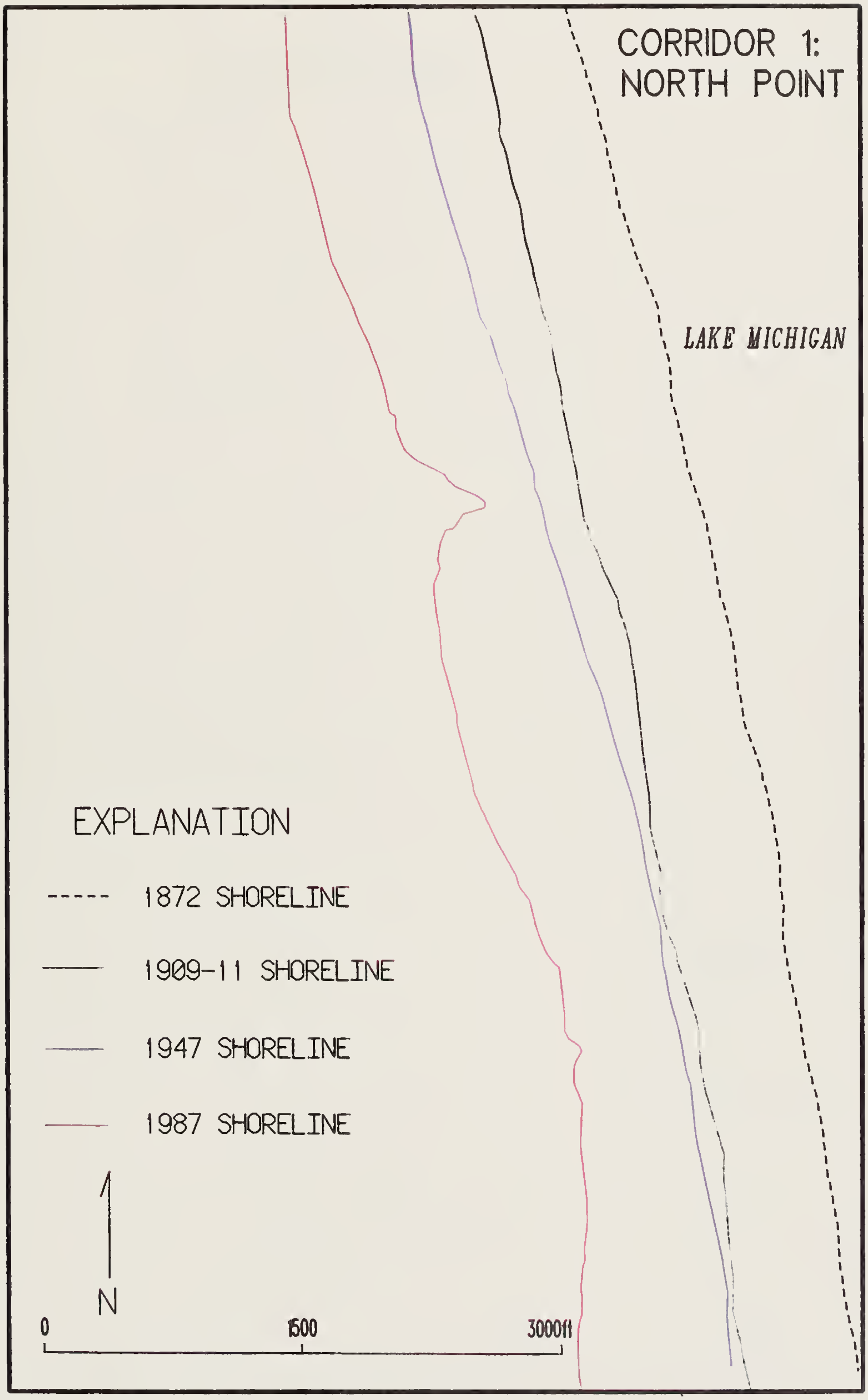
PLOTFILES COMPRISING THE HISTORICAL LOCATION DATABASE

Appendix I Explanation

This appendix contains the plotfiles that comprise the Historical Location Database. The database was generated and stored using the Arcplot module of ARC/INFO Rev. 6.0. These plotfiles are also supplied on a 3.5-inch diskette accompanying this report.

Each of the historical shorelines and blufflines is identified by a unique color and symbol. The oldest and most recent data are shown in black and red respectively as described in the project requirements. The years and corresponding color symbols are:

Year	Color	Symbol
1872, 1873	Black	Dashed Line
1909-11, 1910-11	Green	Solid Line
1947	Blue	Solid Line
1987	Red	Solid Line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NORTH POINT
LAKE MICHIGAN
EXPLANATION
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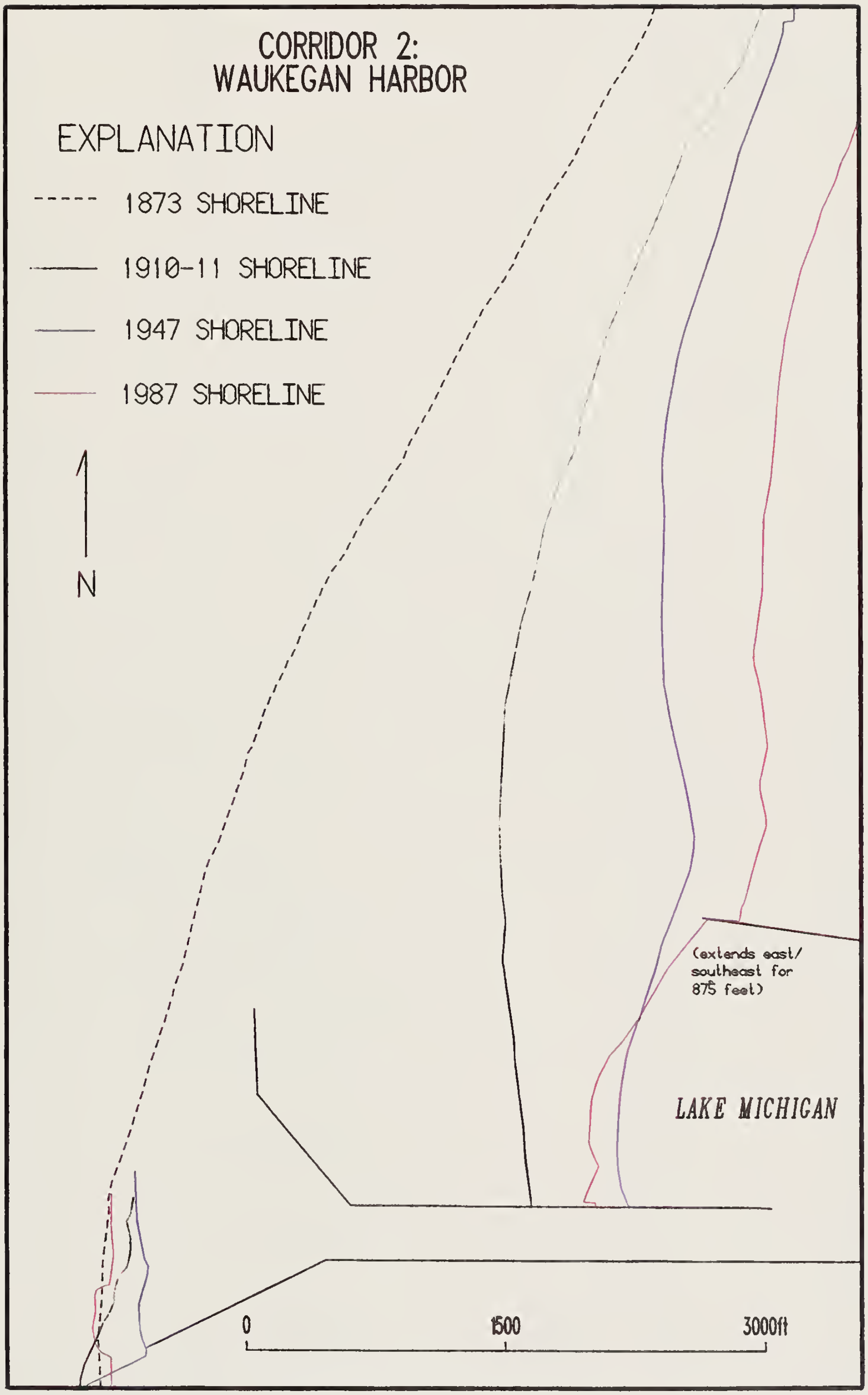
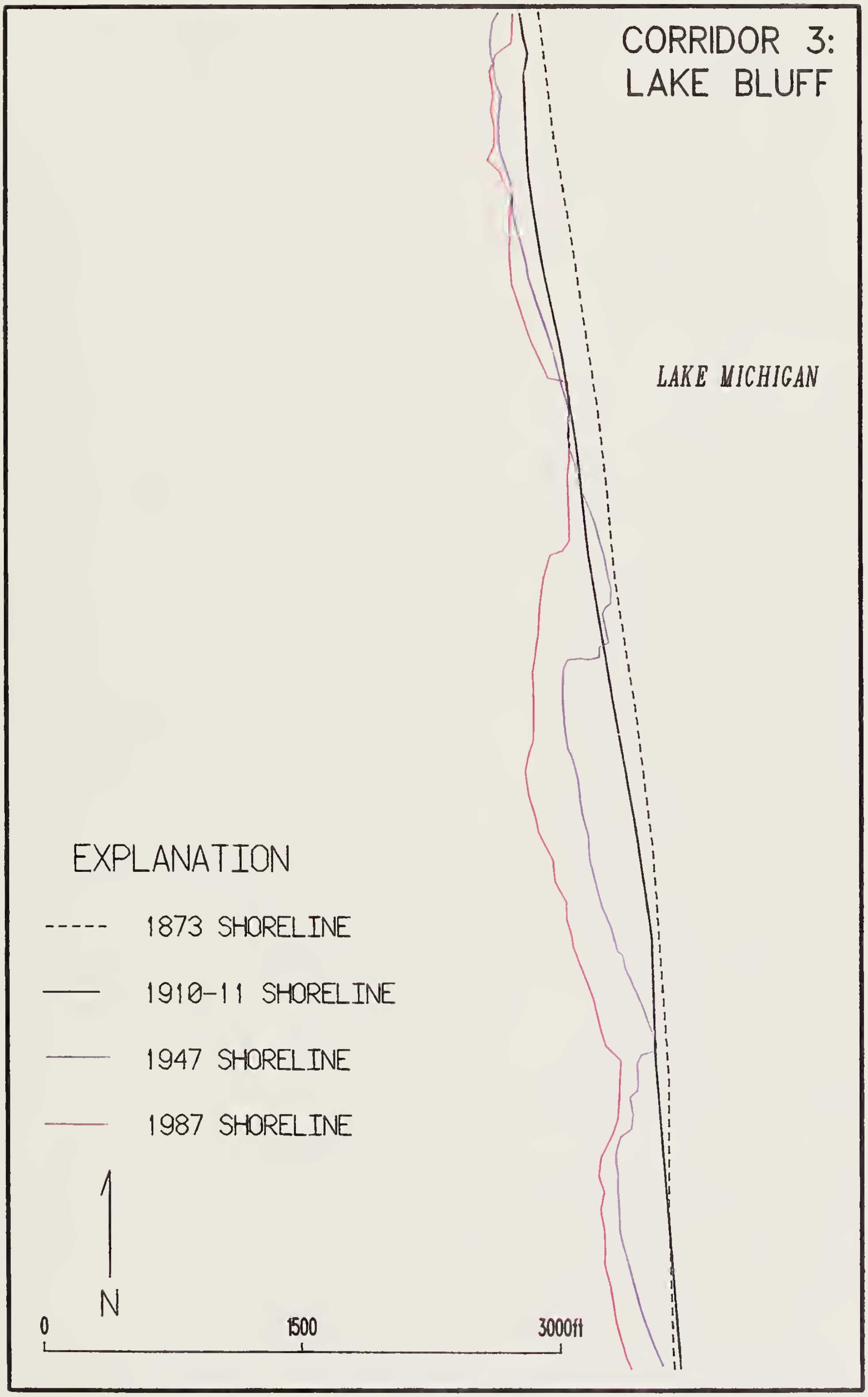
1909-11 SHORELINE
1947 SHORELINE
1987 SHORELINE
N
0
1500
3000ft

Appendix I (continued)




CORRIDOR 3:
LAKE BLUFF
LAKE MICHIGAN
EXPLANATION
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1910-11 SHORELINE
1947 SHORELINE
1987 SHORELINE
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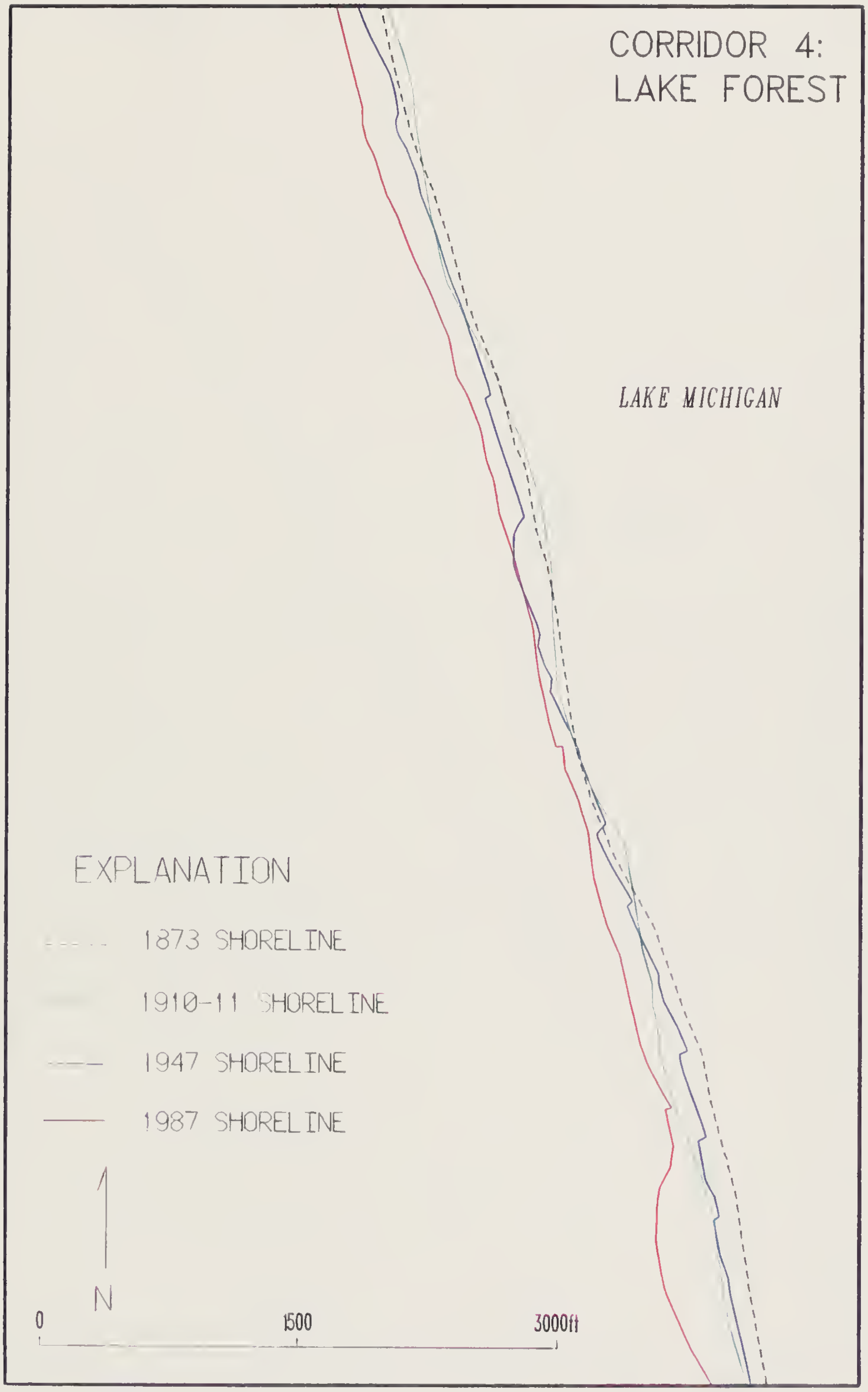
0
1500
3000ft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LAKE FOREST
LAKE MICHIGAN
EXPLANATION
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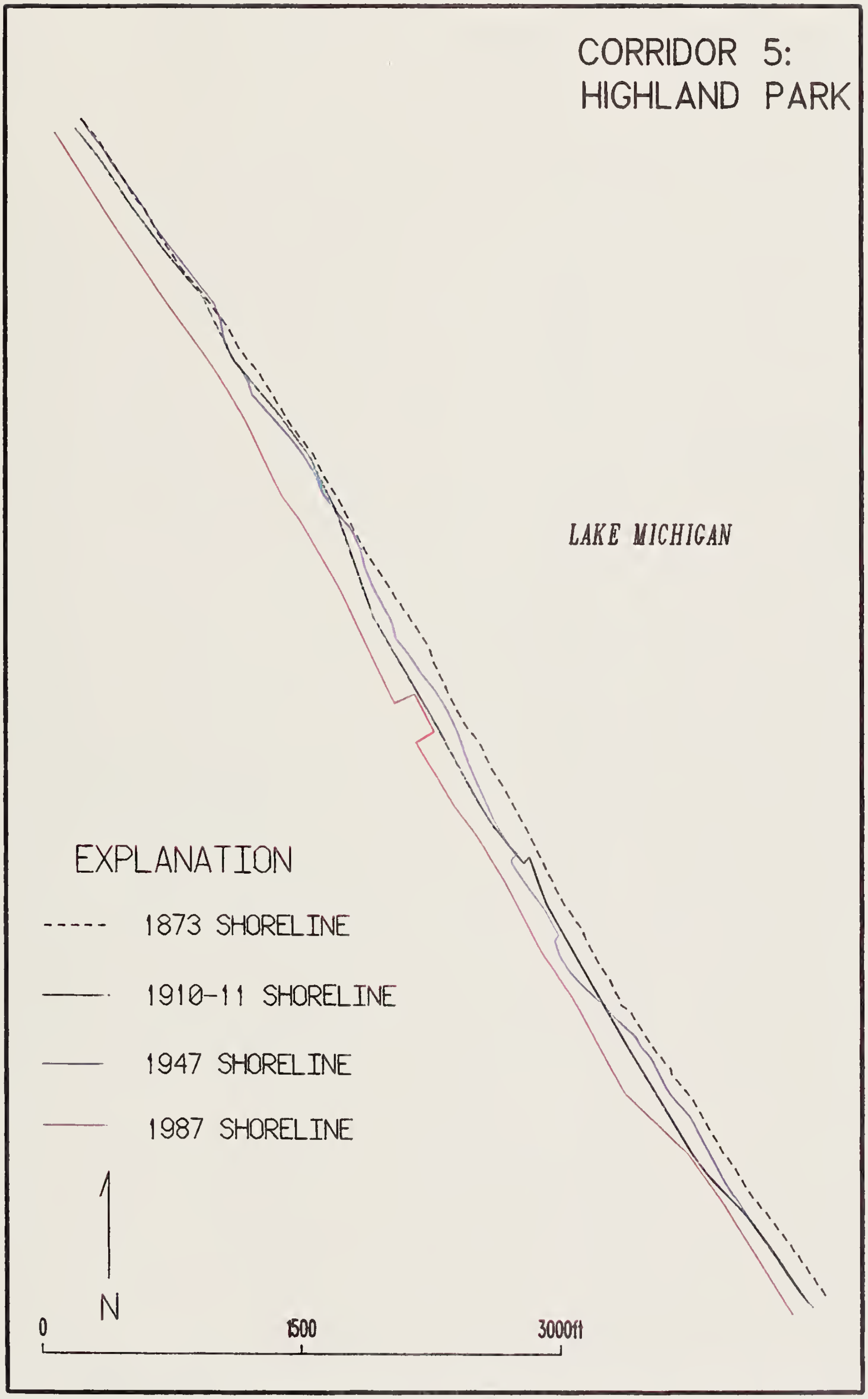
1910-11 SHORELINE
1947 SHORELINE
1987 SHORELINE
N
0
1500
3000ft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HIGHLAND PARK
LAKE MICHIGAN
EXPLANATION
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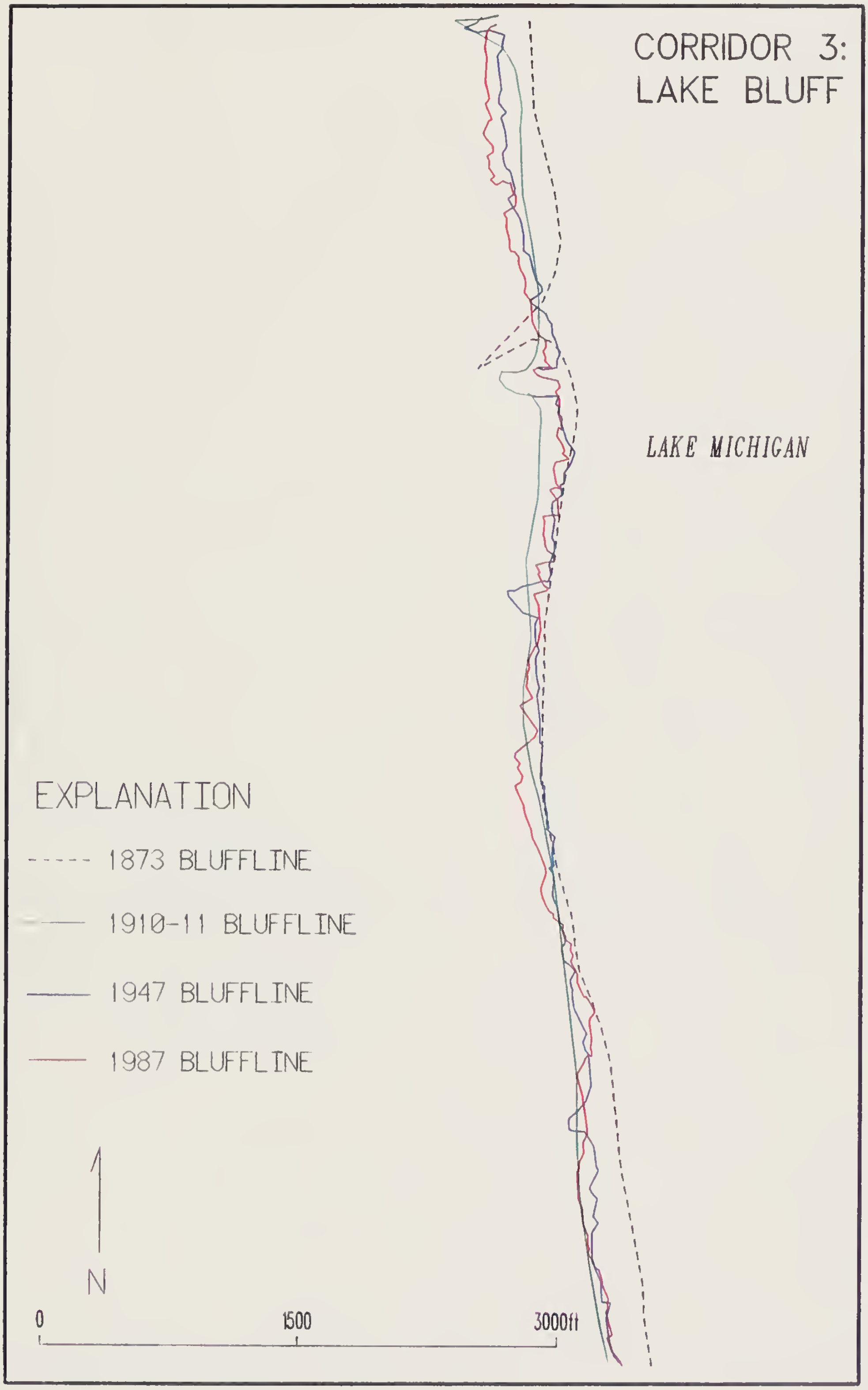
1910-11 SHORELINE
1947 SHORELINE
1987 SHORELINE
N
0
1500
3000ft


CORRIDOR 3:
LAKE BLUFF
LAKE MICHIGAN
EXPLANATION
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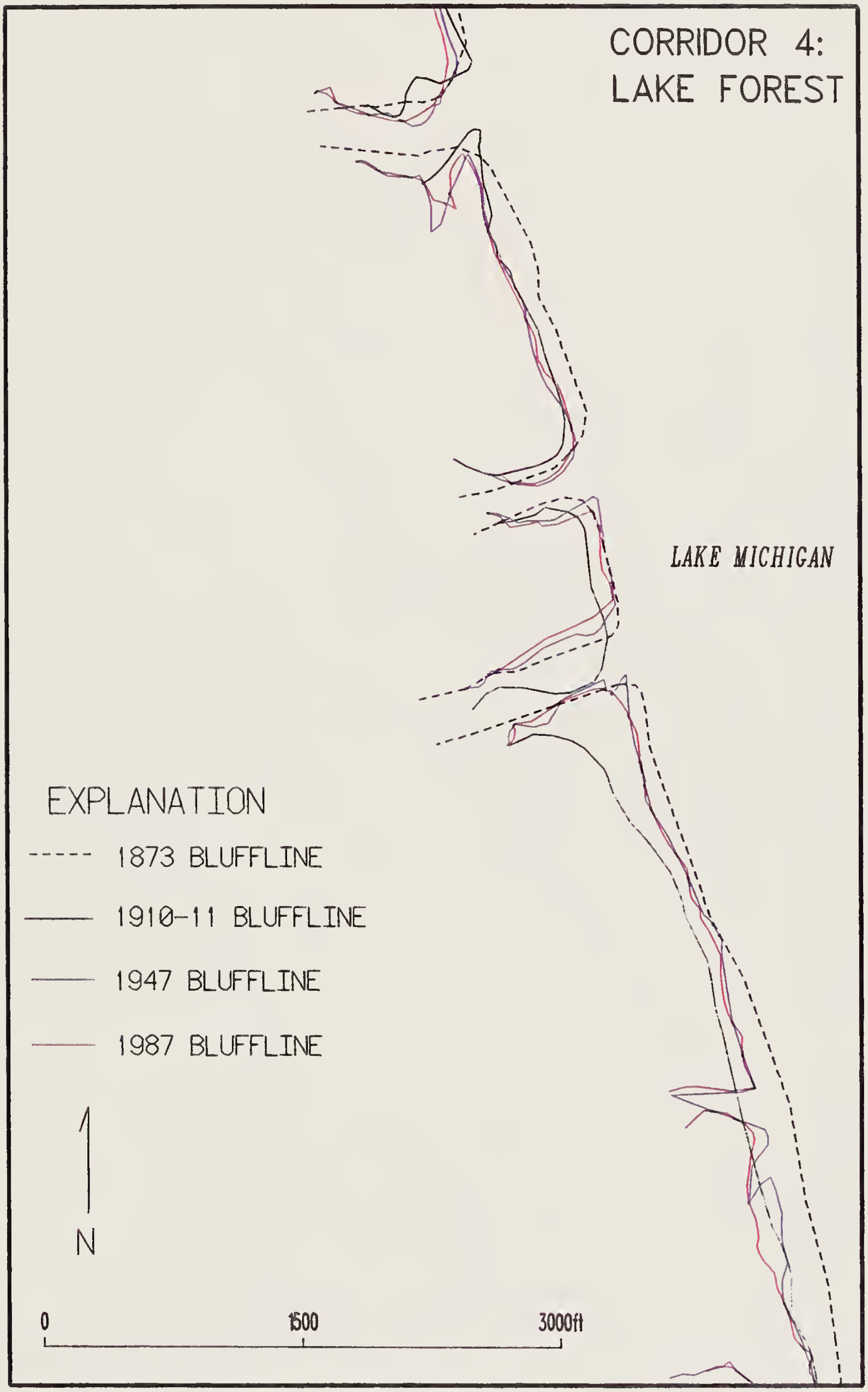
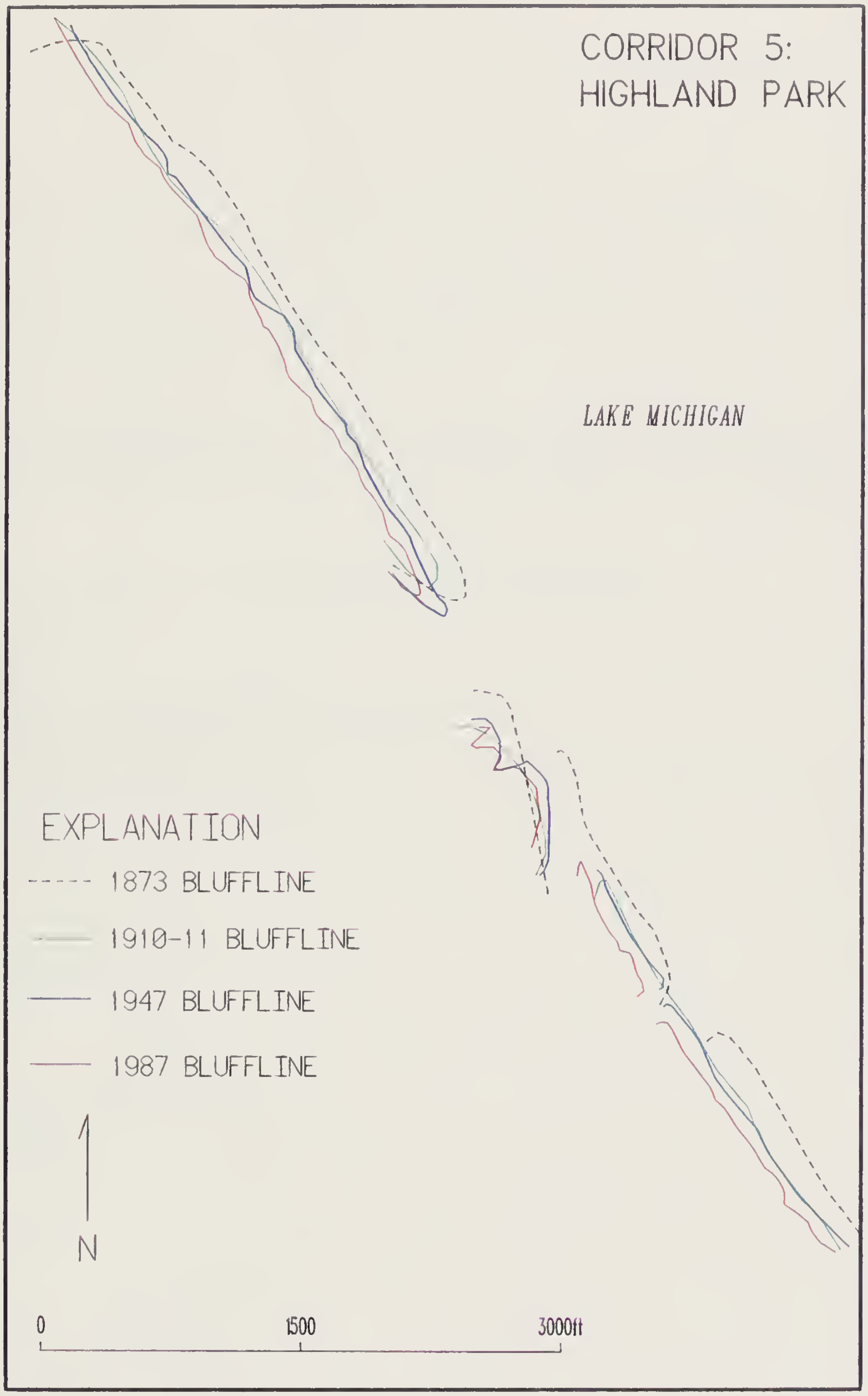
1910-11 BLUFFLINE
1947 BLUFFLINE
1987 BLUFFLINE
N
0
1500
3000ft


CORRIDOR 4:
LAKE FOREST
LAKE MICHIGAN
EXPLANATION
1873 BLUFFLINE
1910-11 BLUFFLINE
1947 BLUFFLINE
1987 BLUFFLINE
N
0
1500
3000ft


CORRIDOR 5:
HIGHLAND PARK
LAKE MICHIGAN
EXPLANATION
1873 BLUFFLINE
1910-11 BLUFFLINE
1947 BLUFFLINE
1987 BLUFFLINE
N
0
1500
3000ft

APPENDIX J

COMPUTER PROGRAMS USED IN DATABASE GENERATION

Appendix J Explanation

This appendix contains the two programs used in generating the Historical Shoreline Positional Change Database. The first program takes a file containing the X-Y coordinates of the shoreline-transect and spine-transect interceptions, in Lambert feet, and converts them to a file containing latitude-longitude coordinates in degrees-minutes-seconds format. The program is written in Arc Macro Language (AML), a programming language specific to ARC/INFO.

The second program relates the arc attribute file, the node attribute file, and the latitude-longitude coordinates of the nodes and outputs the shoreline locational data in the required format. It is written using the INFO programming language.

Conversion program: Lambert feet to latitude and longitude

```
&args FILENAME
&echo &on
&ab &off
PROJECT FILE %FILENAME% %FILENAME%.GEO
INPUT
PROJECTION LAMBERT
UNITS FEET
PARAMETERS
33 00 00
45 00 00
-89 30 00
33 00 00
914400
0
OUTPUT
PROJECTION GEOGRAPHIC
UNITS DMS
PARAMETERS
END
&echo &off
&ab &on
&RETURN
```

Appendix J (continued)

Transect data program: Compilation of transect data in required format

```
10000 PROGRAM SECTION ONE
10001 REM  This program will select an .AAT file, relate the .NAT file to it,
10002 REM  and relate to them a third file which contains the degree values
10003 REM  for the location of the end nodes on the transect arcs.
10004 REM
10005 FORMAT $CHR1,1,C
10006 FORMAT $NUM2,2,I
10007 FORMAT $NUM3,2,I
10008 FORMAT $NUM4,2,I
10009 CALC $NUM4 = 60
10010 MOVE 'Y' TO $CHR1
10011 FC CREATE 2,132
10012 FC INIT 1,2
10013 REM  Select the transect arc attribute file
10014 SEL SH1-1872.AAT
10015 REM  Relate it to the transect node attribute file by CODE
10016 REL SH1-1872.NAT BY CODE
10017 REM Relate both files to the file containing latitude-longitude node coordinates
10018 REM  by the item RECNO
10019 REL SH1-72.DEG 2 BY $1RECNO O RO
10020 OUTPUT /FREE3/FEMA/SH1-72.OUT INIT
20000 PROGRAM SECTION TWO
20001 IF $CHR1 = 'Y' AND $NUM4 GE 60
20002   PRI ''
20003  PRI 'TRAN LATITUDE LONGITUDE YEAR DISTANCE LATITUDE LONGITUDE'
20004   PRI ' '
20005   CALC $NUM4 = 3
20006 ENDIF
20007 IF $CHR1 = 'Y'
20008   FC PUT 1,2,CODE
20009   FC PUT 1,35,YEAR
20010   FC PUT 1,41,LENGTH
20011   MOVE 'N' TO $CHR1
20012   CALC $NUM2 = 7
20013   CALC $NUM3 = 21
20014 ENDIF
20015 FC PUT 1,$NUM2,$2X
20016 FC PUT 1,$NUM3,$2Y
20017 CALC $NUM2 = 55
20018 CALC $NUM3 = 69
20019 NEXT
```

Transect data program, continued

```
20020 CALC $NUM4 = $NUM4 + 2
20021 MOVE 'Y' TO $CHR1
20022 FC DUMP
20023 FC INIT 1,2
30000 PROGRAM END
```

APPENDIX K

HISTORICAL SHORELINE POSITIONAL CHANGE DATABASE

Appendix K Explanation

This appendix is a listing of the Historical Shoreline Positional Change Database. The database has been sorted and edited for clarity of presentation and is not a direct printout of the data on the accompanying 3.5-inch diskette. Shoreline data are presented first for Corridors 1 through 5, followed by bluffline data for Corridors 3 through 5. (Corridors 1 and 2 have no coastal bluffs.) Within each corridor, transects are presented from north to south; within each transect, data are given from earliest to most recent.

Where a transect intersected a bluff that was clearly influenced primarily by fluvial rather than by coastal processes, such as where a transect entered a coast-perpendicular ravine, the distance for that intercept was deleted and replaced by the symbol *** in the bluffline data tables. Where there was some question as to whether the intercepted bluffline was influenced predominantly by fluvial or by coastal processes, the distance presented in the table was not changed.

It should be noted that for the bluffline data, some transects appear to intersect ravines in some years but not in preceding and/or subsequent years. Reasons for this include mismapped and unmapped ravines on the historical maps, and stereoplotter operator interpretation in delineating ravines on the aerial photographs.

Appendix K (continued)

SHORELINES FOR CORRIDOR 1

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
101	42°29'39.90"	-87°46'47.97"	1872	5,410.53	42°29'32.12"	-87°47'59.70"
101	42°29'39.90"	-87°46'47.97"	1909-11	5,748.00	42°29'31.65"	-87°48'04.17"
101	42°29'39.90"	-87°46'47.97"	1947	6,017.21	42°29'31.25"	-87°48'07.73"
101	42°29'39.90"	-87°46'47.97"	1987	6,503.25	42°29'30.56"	-87°48'14.18"
102	42°29'38.43"	-87°46'47.68"	1872	5,383.69	42°29'30.70"	-87°47'59.05"
102	42°29'38.43"	-87°46'47.68"	1909-11	5,735.92	42°29'30.18"	-87°48'03.71"
102	42°29'38.43"	-87°46'47.68"	1947	6,025.80	42°29'29.77"	-87°48'07.55"
102	42°29'38.43"	-87°46'47.68"	1987	6,520.47	42°29'29.06"	-87°48'14.11"
103	42°29'36.96"	-87°46'47.39"	1872	5,362.65	42°29'29.25"	-87°47'58.47"
103	42°29'36.96"	-87°46'47.39"	1909-11	5,730.58	42°29'28.72"	-87°48'03.35"
103	42°29'36.96"	-87°46'47.39"	1947	6,013.38	42°29'28.32"	-87°48'07.09"
103	42°29'36.96"	-87°46'47.39"	1987	6,498.40	42°29'27.62"	-87°48'13.53"
104	42°29'35.48"	-87°46'47.10"	1872	5,347.94	42°29'27.80"	-87°47'57.98"
104	42°29'35.48"	-87°46'47.10"	1909-11	5,728.32	42°29'27.25"	-87°48'03.03"
104	42°29'35.48"	-87°46'47.10"	1947	6,000.97	42°29'26.86"	-87°48'06.65"
104	42°29'35.48"	-87°46'47.10"	1987	6,480.69	42°29'26.17"	-87°48'13.00"
105	42°29'34.01"	-87°46'46.81"	1872	5,341.61	42°29'26.34"	-87°47'57.62"
105	42°29'34.01"	-87°46'46.81"	1909-11	5,718.16	42°29'25.80"	-87°48'02.60"
105	42°29'34.01"	-87°46'46.81"	1947	5,980.46	42°29'25.42"	-87°48'06.08"
105	42°29'34.01"	-87°46'46.81"	1987	6,469.02	42°29'24.71"	-87°48'12.56"
106	42°29'32.54"	-87°46'46.51"	1872	5,329.20	42°29'24.89"	-87°47'57.16"
106	42°29'32.54"	-87°46'46.51"	1909-11	5,709.29	42°29'24.34"	-87°48'02.20"
106	42°29'32.54"	-87°46'46.51"	1947	5,960.45	42°29'23.97"	-87°48'05.53"
106	42°29'32.54"	-87°46'46.51"	1987	6,455.33	42°29'23.27"	-87°48'12.09"
107	42°29'31.07"	-87°46'46.23"	1872	5,307.41	42°29'23.44"	-87°47'56.58"
107	42°29'31.07"	-87°46'46.23"	1909-11	5,700.45	42°29'22.88"	-87°48'01.78"
107	42°29'31.07"	-87°46'46.23"	1947	5,942.94	42°29'22.53"	-87°48'05.00"
107	42°29'31.07"	-87°46'46.23"	1987	6,414.81	42°29'21.85"	-87°48'11.25"
108	42°29'29.60"	-87°46'45.93"	1872	5,275.23	42°29'22.02"	-87°47'55.85"
108	42°29'29.60"	-87°46'45.93"	1909-11	5,692.77	42°29'21.43"	-87°48'01.39"
108	42°29'29.60"	-87°46'45.93"	1947	5,929.25	42°29'21.08"	-87°48'04.53"
108	42°29'29.60"	-87°46'45.93"	1987	6,379.05	42°29'20.43"	-87°48'10.48"
109	42°29'28.13"	-87°46'45.65"	1872	5,257.72	42°29'20.58"	-87°47'55.34"
109	42°29'28.13"	-87°46'45.65"	1909-11	5,675.34	42°29'19.97"	-87°48'00.87"
109	42°29'28.13"	-87°46'45.65"	1947	5,895.06	42°29'19.65"	-87°48'03.78"
109	42°29'28.13"	-87°46'45.65"	1987	6,343.58	42°29'19.01"	-87°48'09.73"

Appendix K (continued)

Shorelines for Corridor 1 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
110	42°29'26.65"	-87°46'45.35"	1872	5,245.56	42°29'19.12"	-87°47'54.88"
110	42°29'26.65"	-87°46'45.35"	1909-11	5,671.56	42°29'18.51"	-87°48'00.52"
110	42°29'26.65"	-87°46'45.35"	1947	5,868.96	42°29'18.23"	-87°48'03.14"
110	42°29'26.65"	-87°46'45.35"	1987	6,332.20	42°29'17.56"	-87°48'09.28"
111	42°29'25.18"	-87°46'45.07"	1872	5,257.48	42°29'17.64"	-87°47'54.74"
111	42°29'25.18"	-87°46'45.07"	1909-11	5,674.06	42°29'17.04"	-87°48'00.26"
111	42°29'25.18"	-87°46'45.07"	1947	5,847.67	42°29'16.78"	-87°48'02.58"
111	42°29'25.18"	-87°46'45.07"	1987	6,304.33	42°29'16.12"	-87°48'08.62"
112	42°29'23.71"	-87°46'44.77"	1872	5,245.81	42°29'16.18"	-87°47'54.30"
112	42°29'23.71"	-87°46'44.77"	1909-11	5,665.72	42°29'15.57"	-87°47'59.87"
112	42°29'23.71"	-87°46'44.77"	1947	5,829.67	42°29'15.34"	-87°48'02.04"
112	42°29'23.71"	-87°46'44.77"	1987	6,158.84	42°29'14.86"	-87°48'06.40"
113	42°29'22.24"	-87°46'44.49"	1872	5,236.68	42°29'14.72"	-87°47'53.89"
113	42°29'22.24"	-87°46'44.49"	1909-11	5,666.21	42°29'14.10"	-87°47'59.59"
113	42°29'22.24"	-87°46'44.49"	1947	5,815.49	42°29'13.88"	-87°48'01.56"
113	42°29'22.24"	-87°46'44.49"	1987	6,096.00	42°29'13.49"	-87°48'05.28"
114	42°29'20.77"	-87°46'44.19"	1872	5,211.12	42°29'13.28"	-87°47'53.26"
114	42°29'20.77"	-87°46'44.19"	1909-11	5,652.28	42°29'12.65"	-87°47'59.10"
114	42°29'20.77"	-87°46'44.19"	1947	5,807.39	42°29'12.43"	-87°48'01.16"
114	42°29'20.77"	-87°46'44.19"	1987	6,241.20	42°29'11.80"	-87°48'06.91"
115	42°29'19.30"	-87°46'43.91"	1872	5,200.23	42°29'11.83"	-87°47'52.83"
115	42°29'19.30"	-87°46'43.91"	1909-11	5,624.42	42°29'11.22"	-87°47'58.44"
115	42°29'19.30"	-87°46'43.91"	1947	5,781.01	42°29'10.99"	-87°48'00.52"
115	42°29'19.30"	-87°46'43.91"	1987	6,279.22	42°29'10.28"	-87°48'07.12"
116	42°29'17.82"	-87°46'43.61"	1872	5,198.17	42°29'10.36"	-87°47'52.50"
116	42°29'17.82"	-87°46'43.61"	1909-11	5,589.69	42°29' 9.79"	-87°47'57.70"
116	42°29'17.82"	-87°46'43.61"	1947	5,761.24	42°29' 9.55"	-87°47'59.97"
116	42°29'17.82"	-87°46'43.61"	1987	6,280.98	42°29' 8.80"	-87°48'06.86"
117	42°29'16.35"	-87°46'43.32"	1872	5,184.48	42°29' 8.91"	-87°47'52.03"
117	42°29'16.35"	-87°46'43.32"	1909-11	5,573.25	42°29' 8.35"	-87°47'57.19"
117	42°29'16.35"	-87°46'43.32"	1947	5,742.74	42°29' 8.10"	-87°47'59.43"
117	42°29'16.35"	-87°46'43.32"	1987	6,282.01	42°29' 7.33"	-87°48'06.58"
118	42°29'14.88"	-87°46'43.03"	1872	5,185.76	42°29' 7.43"	-87°47'51.76"
118	42°29'14.88"	-87°46'43.03"	1909-11	5,573.49	42°29' 6.88"	-87°47'56.89"
118	42°29'14.88"	-87°46'43.03"	1947	5,713.36	42°29' 6.67"	-87°47'58.74"
118	42°29'14.88"	-87°46'43.03"	1987	6,266.81	42°29' 5.88"	-87°48'06.08"
119	42°29'13.41"	-87°46'42.73"	1872	5,187.53	42°29' 5.96"	-87°47'51.49"
119	42°29'13.41"	-87°46'42.73"	1909-11	5,583.11	42°29' 5.39"	-87°47'56.73"
119	42°29'13.41"	-87°46'42.73"	1947	5,696.38	42°29' 5.23"	-87°47'58.23"
119	42°29'13.41"	-87°46'42.73"	1987	6,261.75	42°29' 4.41"	-87°48'05.73"

Appendix K (continued)

Shorelines for Corridor 1 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
120	42°29'11.94"	-87°46'42.45"	1872	5,172.07	42°29' 4.51"	-87°47'50.99"
120	42°29'11.94"	-87°46'42.45"	1909-11	5,590.71	42°29' 3.91"	-87°47'56.54"
120	42°29'11.94"	-87°46'42.45"	1947	5,679.41	42°29' 3.78"	-87°47'57.72"
120	42°29'11.94"	-87°46'42.45"	1987	6,249.34	42°29' 2.96"	-87°48'05.27"
121	42°29'10.46"	-87°46'42.15"	1872	5,149.26	42°29' 3.07"	-87°47'50.40"
121	42°29'10.46"	-87°46'42.15"	1909-11	5,595.03	42°29' 2.43"	-87°47'56.31"
121	42°29'10.46"	-87°46'42.15"	1947	5,655.32	42°29' 2.35"	-87°47'57.11"
121	42°29'10.46"	-87°46'42.15"	1987	6,214.36	42°29' 1.54"	-87°48'04.51"
122	42°29' 8.99"	-87°46'41.87"	1872	5,137.88	42°29' 1.61"	-87°47'49.96"
122	42°29' 8.99"	-87°46'41.87"	1909-11	5,607.93	42°29' 0.95"	-87°47'56.18"
122	42°29' 8.99"	-87°46'41.87"	1947	5,646.45	42°29' 0.88"	-87°47'56.69"
122	42°29' 8.99"	-87°46'41.87"	1987	6,165.70	42°29' 0.14"	-87°48'03.59"
123	42°29' 7.52"	-87°46'41.57"	1872	5,138.12	42°29' 0.14"	-87°47'49.67"
123	42°29' 7.52"	-87°46'41.57"	1909-11	5,596.30	42°28'59.48"	-87°47'55.74"
123	42°29' 7.52"	-87°46'41.57"	1947	5,647.23	42°28'59.41"	-87°47'56.42"
123	42°29' 7.52"	-87°46'41.57"	1987	6,115.27	42°28'58.74"	-87°48'02.62"
124	42°29' 6.05"	-87°46'41.28"	1872	5,152.55	42°28'58.65"	-87°47'49.57"
124	42°29' 6.05"	-87°46'41.28"	1909-11	5,615.05	42°28'57.98"	-87°47'55.70"
124	42°29' 6.05"	-87°46'41.28"	1947	5,635.80	42°28'57.96"	-87°47'55.98"
124	42°29' 6.05"	-87°46'41.28"	1987	6,095.01	42°28'57.30"	-87°48'02.06"
125	42°29' 4.58"	-87°46'40.99"	1872	5,172.61	42°28'57.15"	-87°47'49.54"
125	42°29' 4.58"	-87°46'40.99"	1909-11	5,589.19	42°28'56.56"	-87°47'55.06"
125	42°29' 4.58"	-87°46'40.99"	1947	5,642.42	42°28'56.48"	-87°47'55.77"
125	42°29' 4.58"	-87°46'40.99"	1987	6,039.48	42°28'55.91"	-87°48'01.04"
126	42°29' 3.11"	-87°46'40.70"	1872	5,170.80	42°28'55.68"	-87°47'49.23"
126	42°29' 3.11"	-87°46'40.70"	1909-11	5,569.42	42°28'55.11"	-87°47'54.51"
126	42°29' 3.11"	-87°46'40.70"	1947	5,640.65	42°28'55.01"	-87°47'55.46"
126	42°29' 3.11"	-87°46'40.70"	1987	6,047.33	42°28'54.43"	-87°48'00.85"
127	42°29' 1.63"	-87°46'40.41"	1872	5,159.41	42°28'54.23"	-87°47'48.78"
127	42°29' 1.63"	-87°46'40.41"	1909-11	5,551.96	42°28'53.67"	-87°47'54.00"
127	42°29' 1.63"	-87°46'40.41"	1947	5,625.94	42°28'53.56"	-87°47'54.98"
127	42°29' 1.63"	-87°46'40.41"	1987	6,015.44	42°28'53.00"	-87°48'00.14"
128	42°29' 0.16"	-87°46'40.12"	1872	5,165.25	42°28'52.75"	-87°47'48.58"
128	42°29' 0.16"	-87°46'40.12"	1909-11	5,567.16	42°28'52.17"	-87°47'53.90"
128	42°29' 0.16"	-87°46'40.12"	1947	5,624.17	42°28'52.09"	-87°47'54.65"
128	42°29' 0.16"	-87°46'40.12"	1987	6,055.72	42°28'51.46"	-87°48'00.38"
129	42°28'58.69"	-87°46'39.82"	1872	5,149.51	42°28'51.30"	-87°47'48.08"
129	42°28'58.69"	-87°46'39.82"	1909-11	5,557.51	42°28'50.71"	-87°47'53.48"
129	42°28'58.69"	-87°46'39.82"	1947	5,620.59	42°28'50.63"	-87°47'54.31"
129	42°28'58.69"	-87°46'39.82"	1987	6,050.66	42°28'50.00"	-87°48'00.02"

Appendix K (continued)

Shorelines for Corridor 1 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
130	42°28'57.22"	-87°46'39.54"	1872	5,143.71	42°28'49.83"	-87°47'47.70"
130	42°28'57.22"	-87°46'39.54"	1909-11	5,538.52	42°28'49.27"	-87°47'52.94"
130	42°28'57.22"	-87°46'39.54"	1947	5,627.21	42°28'49.14"	-87°47'54.11"
130	42°28'57.22"	-87°46'39.54"	1987	6,074.99	42°28'48.49"	-87°48'00.05"
131	42°28'55.75"	-87°46'39.24"	1872	5,151.81	42°28'48.35"	-87°47'47.53"
131	42°28'55.75"	-87°46'39.24"	1909-11	5,551.42	42°28'47.78"	-87°47'52.82"
131	42°28'55.75"	-87°46'39.24"	1947	5,620.35	42°28'47.68"	-87°47'53.73"
131	42°28'55.75"	-87°46'39.24"	1987	6,080.58	42°28'47.01"	-87°47'59.83"
132	42°28'54.28"	-87°46'38.96"	1872	5,150.04	42°28'46.88"	-87°47'47.20"
132	42°28'54.28"	-87°46'38.96"	1909-11	5,560.55	42°28'46.29"	-87°47'52.64"
132	42°28'54.28"	-87°46'38.96"	1947	5,612.25	42°28'46.22"	-87°47'53.33"
132	42°28'54.28"	-87°46'38.96"	1987	6,114.49	42°28'45.50"	-87°47'59.99"
133	42°28'52.80"	-87°46'38.66"	1872	5,151.32	42°28'45.41"	-87°47'46.93"
133	42°28'52.80"	-87°46'38.66"	1909-11	5,571.19	42°28'44.81"	-87°47'52.49"
133	42°28'52.80"	-87°46'38.66"	1947	5,604.65	42°28'44.76"	-87°47'52.94"
133	42°28'52.80"	-87°46'38.66"	1987	6,154.03	42°28'43.97"	-87°48'00.22"
134	42°28'51.33"	-87°46'38.38"	1872	5,161.67	42°28'43.93"	-87°47'46.78"
134	42°28'51.33"	-87°46'38.38"	1909-11	5,587.43	42°28'43.31"	-87°47'52.42"
134	42°28'51.33"	-87°46'38.38"	1947	5,607.20	42°28'43.29"	-87°47'52.68"
134	42°28'51.33"	-87°46'38.38"	1987	6,183.41	42°28'42.46"	-87°48'00.32"
135	42°28'49.86"	-87°46'38.08"	1872	5,162.45	42°28'42.45"	-87°47'46.50"
135	42°28'49.86"	-87°46'38.08"	1909-11	5,592.48	42°28'41.83"	-87°47'52.19"
135	42°28'49.86"	-87°46'38.08"	1947	5,628.48	42°28'41.78"	-87°47'52.68"
135	42°28'49.86"	-87°46'38.08"	1987	6,215.10	42°28'40.93"	-87°48'00.45"

Appendix K (continued)

SHORELINES FOR CORRIDOR 2

Transect Code	Latitude and Longitude of Spine-Transect Intersect	Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect
201	42°22'22.45" -87°47'40.95"	1873	5,891.05	42°22'23.79"-87°48'59.71"
201	42°22'22.45" -87°47'40.95"	1910-11	5,452.29	42°22'23.69"-87°48'53.86"
201	42°22'22.45" -87°47'40.95"	1947	5,307.54	42°22'23.65"-87°48'51.92"
201	42°22'22.45" -87°47'40.95"	1987	4,882.79	42°22'23.55"-87°48'46.24"
202	42°22'20.96" -87°47'41.00"	1873	5,975.30	42°22'22.32"-87°49'00.88"
202	42°22'20.96" -87°47'41.00"	1910-11	5,535.79	42°22'22.22"-87°48'55.02"
202	42°22'20.96" -87°47'41.00"	1947	5,363.04	42°22'22.17"-87°48'52.70"
202	42°22'20.96" -87°47'41.00"	1987	4,951.54	42°22'22.09"-87°48'47.21"
203	42°22'19.48" -87°47'41.05"	1873	6,049.30	42°22'20.84"-87°49'01.92"
203	42°22'19.48" -87°47'41.05"	1910-11	5,633.29	42°22'20.75"-87°48'56.36"
203	42°22'19.48" -87°47'41.05"	1947	5,413.29	42°22'20.71"-87°48'53.42"
203	42°22'19.48" -87°47'41.05"	1987	5,010.54	42°22'20.61"-87°48'48.03"
204	42°22'17.99" -87°47'41.09"	1873	6,146.30	42°22'19.38"-87°49'03.27"
204	42°22'17.99" -87°47'41.09"	1910-11	5,693.04	42°22'19.28"-87°48'57.20"
204	42°22'17.99" -87°47'41.09"	1947	5,455.54	42°22'19.23"-87°48'54.03"
204	42°22'17.99" -87°47'41.09"	1987	5,068.04	42°22'19.14"-87°48'48.85"
205	42°22'16.50" -87°47'41.14"	1873	6,223.30	42°22'17.91"-87°49'04.34"
205	42°22'16.50" -87°47'41.14"	1910-11	5,756.30	42°22'17.81"-87°48'58.10"
205	42°22'16.50" -87°47'41.14"	1947	5,493.04	42°22'17.75"-87°48'54.58"
205	42°22'16.50" -87°47'41.14"	1987	5,118.04	42°22'17.66"-87°48'49.57"
206	42°22'15.02" -87°47'41.19"	1873	6,302.55	42°22'16.44"-87°49'05.45"
206	42°22'15.02" -87°47'41.19"	1910-11	5,817.05	42°22'16.33"-87°48'58.96"
206	42°22'15.02" -87°47'41.19"	1947	5,543.29	42°22'16.27"-87°48'55.30"
206	42°22'15.02" -87°47'41.19"	1987	5,172.29	42°22'16.19"-87°48'50.34"
207	42°22'13.53" -87°47'41.23"	1873	6,403.55	42°22'14.97"-87°49'06.83"
207	42°22'13.53" -87°47'41.23"	1910-11	5,881.05	42°22'14.85"-87°48'59.85"
207	42°22'13.53" -87°47'41.23"	1947	5,595.54	42°22'14.79"-87°48'56.03"
207	42°22'13.53" -87°47'41.23"	1987	5,205.54	42°22'14.70"-87°48'50.82"
208	42°22'12.04" -87°47'41.28"	1873	6,487.55	42°22'13.51"-87°49'08.01"
208	42°22'12.04" -87°47'41.28"	1910-11	5,931.80	42°22'13.39"-87°49'00.57"
208	42°22'12.04" -87°47'41.28"	1947	5,636.30	42°22'13.32"-87°48'56.63"
208	42°22'12.04" -87°47'41.28"	1987	5,232.04	42°22'13.23"-87°48'51.23"
209	42°22'10.55" -87°47'41.32"	1873	6,561.55	42°22'12.03"-87°49'09.05"
209	42°22'10.55" -87°47'41.32"	1910-11	5,978.55	42°22'11.91"-87°49'01.25"
209	42°22'10.55" -87°47'41.32"	1947	5,665.80	42°22'11.84"-87°48'57.07"
209	42°22'10.55" -87°47'41.32"	1987	5,252.79	42°22'11.74"-87°48'51.55"

Appendix K (continued)

Shorelines for Corridor 2 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect	Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect
210	42°22'09.07" -87°47'41.37"	1873	6,643.05	42°22'10.57"-87°49'10.18"
210	42°22'09.07" -87°47'41.37"	1910-11	6,015.80	42°22'10.43"-87°49'01.80"
210	42°22'09.07" -87°47'41.37"	1947	5,687.80	42°22'10.36"-87°48'57.41"
210	42°22'09.07" -87°47'41.37"	1987	5,262.29	42°22'10.26"-87°48'51.72"
211	42°22'07.58" -87°47'41.42"	1873	6,721.56	42°22'09.10"-87°49'11.27"
211	42°22'07.58" -87°47'41.42"	1910-11	6,066.80	42°22'08.95"-87°49'02.52"
211	42°22'07.58" -87°47'41.42"	1947	5,699.55	42°22'08.87"-87°48'57.61"
211	42°22'07.58" -87°47'41.42"	1987	5,275.29	42°22'08.77"-87°48'51.94"
212	42°22'06.09" -87°47'41.46"	1873	6,815.06	42°22'07.63"-87°49'12.57"
212	42°22'06.09" -87°47'41.46"	1910-11	6,124.05	42°22'07.48"-87°49'03.33"
212	42°22'06.09" -87°47'41.46"	1947	5,689.30	42°22'07.38"-87°48'57.51"
212	42°22'06.09" -87°47'41.46"	1987	5,300.04	42°22'07.29"-87°48'52.31"
213	42°22'04.61" -87°47'41.51"	1873	6,908.81	42°22'06.17"-87°49'13.87"
213	42°22'04.61" -87°47'41.51"	1910-11	6,163.30	42°22'06.00"-87°49'03.90"
213	42°22'04.61" -87°47'41.51"	1947	5,688.80	42°22'05.90"-87°48'57.56"
213	42°22'04.61" -87°47'41.51"	1987	5,305.04	42°22'05.81"-87°48'52.43"
214	42°22'03.12" -87°47'41.55"	1873	7,000.06	42°22'04.70"-87°49'15.13"
214	42°22'03.12" -87°47'41.55"	1910-11	6,196.05	42°22'04.52"-87°49'04.38"
214	42°22'03.12" -87°47'41.55"	1947	5,696.80	42°22'04.41"-87°48'57.71"
214	42°22'03.12" -87°47'41.55"	1987	5,310.54	42°22'04.32"-87°48'52.55"
215	42°22'01.63" -87°47'41.60"	1873	7,070.81	42°22'03.24"-87°49'16.13"
215	42°22'01.63" -87°47'41.60"	1910-11	6,237.30	42°22'03.04"-87°49'04.98"
215	42°22'01.63" -87°47'41.60"	1947	5,696.05	42°22'02.92"-87°48'57.74"
215	42°22'01.63" -87°47'41.60"	1987	5,329.79	42°22'02.84"-87°48'52.85"
216	42°22'00.15" -87°47'41.65"	1873	7,139.81	42°22'01.76"-87°49'17.10"
216	42°22'00.15" -87°47'41.65"	1910-11	6,269.30	42°22'01.56"-87°49'05.46"
216	42°22'00.15" -87°47'41.65"	1947	5,690.55	42°22'01.44"-87°48'57.72"
216	42°22'00.15" -87°47'41.65"	1987	5,339.79	42°22'01.35"-87°48'53.04"
217	42°21'58.66" -87°47'41.69"	1873	7,208.31	42°22'00.29"-87°49'18.06"
217	42°21'58.66" -87°47'41.69"	1910-11	6,295.55	42°22'00.08"-87°49'05.85"
217	42°21'58.66" -87°47'41.69"	1947	5,677.05	42°21'59.95"-87°48'57.58"
217	42°21'58.66" -87°47'41.69"	1987	5,307.54	42°21'59.86"-87°48'52.65"
218	42°21'57.17" -87°47'41.74"	1873	7,266.81	42°21'58.81"-87°49'18.88"
218	42°21'57.17" -87°47'41.74"	1910-11	6,305.30	42°21'58.59"-87°49'06.02"
218	42°21'57.17" -87°47'41.74"	1947	5,645.05	42°21'58.45"-87°48'57.20"
218	42°21'57.17" -87°47'41.74"	1987	5,287.04	42°21'58.37"-87°48'52.42"
219	42°21'55.68" -87°47'41.78"	1873	7,319.56	42°21'57.34"-87°49'19.63"
219	42°21'55.68" -87°47'41.78"	1910-11	6,313.05	42°21'57.11"-87°49'06.17"
219	42°21'55.68" -87°47'41.78"	1947	5,608.04	42°21'56.95"-87°48'56.74"
219	42°21'55.68" -87°47'41.78"	1987	5,316.04	42°21'56.89"-87°48'52.84"

Appendix K (continued)

Shorelines for Corridor 2 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect	Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect
220	42°21'54.20" -87°47'41.83"	1873	7,373.81	42°21'55.87"-87°49'20.40"
220	42°21'54.20" -87°47'41.83"	1910-11	6,318.05	42°21'55.62"-87°49'06.29"
220	42°21'54.20" -87°47'41.83"	1947	5,578.79	42°21'55.46"-87°48'56.41"
220	42°21'54.20" -87°47'41.83"	1987	5,290.54	42°21'55.39"-87°48'52.56"
221	42°21'52.71" -87°47'41.88"	1873	7,430.06	42°21'54.39"-87°49'21.20"
221	42°21'52.71" -87°47'41.88"	1910-11	6,310.80	42°21'54.13"-87°49'06.24"
221	42°21'52.71" -87°47'41.88"	1947	5,573.79	42°21'53.97"-87°48'56.39"
221	42°21'52.71" -87°47'41.88"	1987	5,328.04	42°21'53.91"-87°48'53.10"
222	42°21'51.22" -87°47'41.92"	1873	7,479.56	42°21'52.91"-87°49'21.91"
222	42°21'51.22" -87°47'41.92"	1910-11	6,305.55	42°21'52.65"-87°49'06.21"
222	42°21'51.22" -87°47'41.92"	1947	5,621.79	42°21'52.49"-87°48'57.07"
222	42°21'51.22" -87°47'41.92"	1987	5,368.29	42°21'52.43"-87°48'53.69"
223	42°21'49.74" -87°47'41.97"	1873	7,512.81	42°21'51.43"-87°49'22.40"
223	42°21'49.74" -87°47'41.97"	1910-11	6,294.80	42°21'51.16"-87°49'06.12"
223	42°21'49.74" -87°47'41.97"	1947	5,677.30	42°21'51.02"-87°48'57.86"
223	42°21'49.74" -87°47'41.97"	1987	5,563.79	42°21'50.99"-87°48'56.34"
224	42°21'48.25" -87°47'42.02"	1873	7,551.06	42°21'49.96"-87°49'22.96"
224	42°21'48.25" -87°47'42.02"	1910-11	6,295.55	42°21'49.67"-87°49'06.17"
224	42°21'48.25" -87°47'42.02"	1947	5,719.30	42°21'49.54"-87°48'58.47"
224	42°21'48.25" -87°47'42.02"	1987	5,675.80	42°21'49.54"-87°48'57.89"
225	42°21'46.76" -87°47'42.07"	1873	7,599.06	42°21'48.48"-87°49'23.65"
225	42°21'46.76" -87°47'42.07"	1910-11	6,275.55	42°21'48.18"-87°49'05.95"
225	42°21'46.76" -87°47'42.07"	1947	5,770.05	42°21'48.07"-87°48'59.20"
225	42°21'46.76" -87°47'42.07"	1987	5,762.55	42°21'48.07"-87°48'59.09"
226	42°21'45.27" -87°47'42.11"	1873	7,647.81	42°21'47.00"-87°49'24.34"
226	42°21'45.27" -87°47'42.11"	1910-11	6,256.55	42°21'46.69"-87°49'05.75"
226	42°21'45.27" -87°47'42.11"	1947	5,819.80	42°21'46.59"-87°48'59.90"
226	42°21'45.27" -87°47'42.11"	1987	5,871.80	42°21'46.60"-87°49'00.60"
227	42°21'43.79" -87°47'42.16"	1873	7,690.31	42°21'45.52"-87°49'24.95"
227	42°21'43.79" -87°47'42.16"	1910-11	6,238.05	42°21'45.20"-87°49'05.54"
227	42°21'43.79" -87°47'42.16"	1947	5,844.05	42°21'45.11"-87°49'00.28"
227	42°21'43.79" -87°47'42.16"	1987	5,945.05	42°21'45.13"-87°49'01.63"
228	42°21'42.30" -87°47'42.20"	1873	7,738.31	42°21'44.05"-87°49'25.64"
228	42°21'42.30" -87°47'42.20"	1910-11	6,219.05	42°21'43.71"-87°49'05.33"
228	42°21'42.30" -87°47'42.20"	1947	5,853.05	42°21'43.62"-87°49'00.43"
228	42°21'42.30" -87°47'42.20"	1987	5,960.80	42°21'43.65"-87°49'01.88"
229	42°21'40.81" -87°47'42.25"	1873	7,790.56	42°21'42.58"-87°49'26.39"
229	42°21'40.81" -87°47'42.25"	1910-11	6,205.30	42°21'42.22"-87°49'05.19"
229	42°21'40.81" -87°47'42.25"	1947	5,838.80	42°21'42.13"-87°49'00.30"
229	42°21'40.81" -87°47'42.25"	1987	5,927.30	42°21'42.16"-87°49'01.47"

Appendix K (continued)

Shorelines for Corridor 2 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect	Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect
230	42°21'39.33" -87°47'42.30"	1873	7,825.56	42°21'41.10"-87°49'26.89"
230	42°21'39.33" -87°47'42.30"	1910-11	7,728.31	42°21'41.07"-87°49'25.60"
230	42°21'39.33" -87°47'42.30"	1947	7,713.56	42°21'41.07"-87°49'25.40"
230	42°21'39.33" -87°47'42.30"	1987	7,810.31	42°21'41.09"-87°49'26.69"
231	42°21'37.84" -87°47'42.34"	1873	7,837.56	42°21'39.61"-87°49'27.11"
231	42°21'37.84" -87°47'42.34"	1910-11	7,735.56	42°21'39.58"-87°49'25.74"
231	42°21'37.84" -87°47'42.34"	1947	7,692.31	42°21'39.58"-87°49'25.15"
231	42°21'37.84" -87°47'42.34"	1987	7,804.56	42°21'39.61"-87°49'26.66"
232	42°21'36.35" -87°47'42.39"	1873	7,850.06	42°21'38.13"-87°49'27.32"
232	42°21'36.35" -87°47'42.39"	1910-11	7,786.31	42°21'38.12"-87°49'26.46"
232	42°21'36.35" -87°47'42.39"	1947	7,674.81	42°21'38.09"-87°49'24.98"
232	42°21'36.35" -87°47'42.39"	1987	7,814.31	42°21'38.12"-87°49'26.83"
233	42°21'34.87" -87°47'42.42"	1873	7,855.56	42°21'36.64"-87°49'27.43"
233	42°21'34.87" -87°47'42.42"	1910-11	7,832.06	42°21'36.64"-87°49'27.11"
233	42°21'34.87" -87°47'42.42"	1947	7,700.56	42°21'36.60"-87°49'25.36"
233	42°21'34.87" -87°47'42.42"	1987	7,873.81	42°21'36.64"-87°49'27.67"
234	42°21'33.38" -87°47'42.48"	1873	7,858.56	42°21'35.16"-87°49'27.52"
234	42°21'33.38" -87°47'42.48"	1910-11	7,900.06	42°21'35.16"-87°49'28.07"
234	42°21'33.38" -87°47'42.48"	1947	7,687.06	42°21'35.11"-87°49'25.22"
234	42°21'33.38" -87°47'42.48"	1987	7,807.56	42°21'35.15"-87°49'26.84"
235	42°21'31.89" -87°47'42.53"	1873	7,853.56	42°21'33.67"-87°49'27.49"
235	42°21'31.89" -87°47'42.53"	1910-11	7,931.57	42°21'33.68"-87°49'28.54"
235	42°21'31.89" -87°47'42.53"	1947	7,909.31	42°21'33.68"-87°49'28.24"
235	42°21'31.89" -87°47'42.53"	1987	7,806.31	42°21'33.66"-87°49'26.87"

SHORELINES FOR CORRIDOR 3

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
301	42°18'06.39"	-87°48'45.57"	1873	5,624.35	42°18'06.19"	-87°50'00.71"
301	42°18'06.39"	-87°48'45.57"	1910-11	5,694.87	42°18'06.19"	-87°50'01.64"
301	42°18'06.39"	-87°48'45.57"	1947	5,803.90	42°18'06.19"	-87°50'03.10"
301	42°18'06.39"	-87°48'45.57"	1987	5,723.88	42°18'06.19"	-87°50'02.03"
302	42°18'04.91"	-87°48'45.56"	1873	5,609.36	42°18'04.70"	-87°50'00.49"
302	42°18'04.91"	-87°48'45.56"	1910-11	5,681.37	42°18'04.71"	-87°50'01.45"
302	42°18'04.91"	-87°48'45.56"	1947	5,802.65	42°18'04.70"	-87°50'03.08"
302	42°18'04.91"	-87°48'45.56"	1987	5,804.40	42°18'04.70"	-87°50'03.09"
303	42°18'03.42"	-87°48'45.55"	1873	5,594.85	42°18'03.22"	-87°50'00.28"
303	42°18'03.42"	-87°48'45.55"	1910-11	5,689.12	42°18'03.22"	-87°50'01.55"
303	42°18'03.42"	-87°48'45.55"	1947	5,777.40	42°18'03.22"	-87°50'02.73"
303	42°18'03.42"	-87°48'45.55"	1987	5,809.40	42°18'03.21"	-87°50'03.16"
304	42°18'01.93"	-87°48'45.55"	1873	5,577.09	42°18'01.73"	-87°50'00.05"
304	42°18'01.93"	-87°48'45.55"	1910-11	5,686.37	42°18'01.73"	-87°50'01.51"
304	42°18'01.93"	-87°48'45.55"	1947	5,786.64	42°18'01.73"	-87°50'02.85"
304	42°18'01.93"	-87°48'45.55"	1987	5,802.90	42°18'01.72"	-87°50'03.06"
305	42°18'00.44"	-87°48'45.53"	1873	5,554.34	42°18'00.25"	-87°49'59.73"
305	42°18'00.44"	-87°48'45.53"	1910-11	5,677.37	42°18'00.24"	-87°50'01.37"
305	42°18'00.44"	-87°48'45.53"	1947	5,750.39	42°18'00.24"	-87°50'02.35"
305	42°18'00.44"	-87°48'45.53"	1987	5,773.64	42°18'00.24"	-87°50'02.67"
306	42°17'58.95"	-87°48'45.53"	1873	5,531.33	42°17'58.76"	-87°49'59.42"
306	42°17'58.95"	-87°48'45.53"	1910-11	5,657.86	42°17'58.76"	-87°50'01.12"
306	42°17'58.95"	-87°48'45.53"	1947	5,733.63	42°17'58.75"	-87°50'02.12"
306	42°17'58.95"	-87°48'45.53"	1987	5,745.88	42°17'58.76"	-87°50'02.29"
307	42°17'57.47"	-87°48'45.52"	1873	5,512.83	42°17'57.27"	-87°49'59.16"
307	42°17'57.47"	-87°48'45.52"	1910-11	5,637.61	42°17'57.27"	-87°50'00.83"
307	42°17'57.47"	-87°48'45.52"	1947	5,698.12	42°17'57.26"	-87°50'01.63"
307	42°17'57.47"	-87°48'45.52"	1987	5,754.89	42°17'57.26"	-87°50'02.40"
308	42°17'55.98"	-87°48'45.51"	1873	5,493.57	42°17'55.78"	-87°49'58.91"
308	42°17'55.98"	-87°48'45.51"	1910-11	5,610.10	42°17'55.79"	-87°50'00.45"
308	42°17'55.98"	-87°48'45.51"	1947	5,663.86	42°17'55.78"	-87°50'01.18"
308	42°17'55.98"	-87°48'45.51"	1987	5,734.38	42°17'55.78"	-87°50'02.11"
309	42°17'54.49"	-87°48'45.51"	1873	5,474.32	42°17'54.30"	-87°49'58.63"
309	42°17'54.49"	-87°48'45.51"	1910-11	5,579.85	42°17'54.29"	-87°50'00.05"
309	42°17'54.49"	-87°48'45.51"	1947	5,616.60	42°17'54.30"	-87°50'00.53"
309	42°17'54.49"	-87°48'45.51"	1987	5,687.37	42°17'54.29"	-87°50'01.48"

Appendix K (continued)

Shorelines for Corridor 3 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
310	42°17'53.00"	-87°48'45.51"	1873	5,454.07	42°17'52.81"	-87°49'58.35"
310	42°17'53.00"	-87°48'45.51"	1910-11	5,555.59	42°17'52.81"	-87°49'59.71"
310	42°17'53.00"	-87°48'45.51"	1947	5,575.60	42°17'52.80"	-87°49'59.98"
310	42°17'53.00"	-87°48'45.51"	1987	5,624.86	42°17'52.80"	-87°50'00.64"
311	42°17'51.52"	-87°48'45.50"	1873	5,433.31	42°17'51.33"	-87°49'58.08"
311	42°17'51.52"	-87°48'45.50"	1910-11	5,535.08	42°17'51.32"	-87°49'59.43"
311	42°17'51.52"	-87°48'45.50"	1947	5,541.08	42°17'51.32"	-87°49'59.51"
311	42°17'51.52"	-87°48'45.50"	1987	5,543.58	42°17'51.32"	-87°49'59.55"
312	42°17'50.03"	-87°48'45.49"	1873	5,420.05	42°17'49.84"	-87°49'57.89"
312	42°17'50.03"	-87°48'45.49"	1910-11	5,515.58	42°17'49.84"	-87°49'59.16"
312	42°17'50.03"	-87°48'45.49"	1947	5,539.08	42°17'49.83"	-87°49'59.48"
312	42°17'50.03"	-87°48'45.49"	1987	5,543.08	42°17'49.83"	-87°49'59.53"
313	42°17'48.54"	-87°48'45.48"	1873	5,407.05	42°17'48.35"	-87°49'57.71"
313	42°17'48.54"	-87°48'45.48"	1910-11	5,503.08	42°17'48.35"	-87°49'59.00"
313	42°17'48.54"	-87°48'45.48"	1947	5,499.82	42°17'48.35"	-87°49'58.94"
313	42°17'48.54"	-87°48'45.48"	1987	5,550.59	42°17'48.35"	-87°49'59.62"
314	42°17'47.05"	-87°48'45.47"	1873	5,397.05	42°17'46.87"	-87°49'57.56"
314	42°17'47.05"	-87°48'45.47"	1910-11	5,490.57	42°17'46.86"	-87°49'58.82"
314	42°17'47.05"	-87°48'45.47"	1947	5,447.31	42°17'46.86"	-87°49'58.23"
314	42°17'47.05"	-87°48'45.47"	1987	5,547.34	42°17'46.86"	-87°49'59.57"
315	42°17'45.56"	-87°48'45.47"	1873	5,386.55	42°17'45.38"	-87°49'57.43"
315	42°17'45.56"	-87°48'45.47"	1910-11	5,474.07	42°17'45.38"	-87°49'58.59"
315	42°17'45.56"	-87°48'45.47"	1947	5,412.30	42°17'45.37"	-87°49'57.76"
315	42°17'45.56"	-87°48'45.47"	1987	5,636.86	42°17'45.37"	-87°50'00.77"
316	42°17'44.08"	-87°48'45.46"	1873	5,369.80	42°17'43.89"	-87°49'57.20"
316	42°17'44.08"	-87°48'45.46"	1910-11	5,452.57	42°17'43.88"	-87°49'58.29"
316	42°17'44.08"	-87°48'45.46"	1947	5,405.81	42°17'43.89"	-87°49'57.68"
316	42°17'44.08"	-87°48'45.46"	1987	5,666.37	42°17'43.88"	-87°50'01.15"
317	42°17'42.59"	-87°48'45.46"	1873	5,349.79	42°17'42.41"	-87°49'56.91"
317	42°17'42.59"	-87°48'45.46"	1910-11	5,431.31	42°17'42.40"	-87°49'58.01"
317	42°17'42.59"	-87°48'45.46"	1947	5,420.31	42°17'42.40"	-87°49'57.86"
317	42°17'42.59"	-87°48'45.46"	1987	5,681.37	42°17'42.39"	-87°50'01.35"
318	42°17'41.10"	-87°48'45.44"	1873	5,329.54	42°17'40.92"	-87°49'56.64"
318	42°17'41.10"	-87°48'45.44"	1910-11	5,409.80	42°17'40.91"	-87°49'57.71"
318	42°17'41.10"	-87°48'45.44"	1947	5,588.09	42°17'40.91"	-87°50'00.09"
318	42°17'41.10"	-87°48'45.44"	1987	5,698.12	42°17'40.90"	-87°50'01.56"
319	42°17'39.61"	-87°48'45.44"	1873	5,311.28	42°17'39.43"	-87°49'56.38"
319	42°17'39.61"	-87°48'45.44"	1910-11	5,387.80	42°17'39.43"	-87°49'57.40"
319	42°17'39.61"	-87°48'45.44"	1947	5,585.09	42°17'39.42"	-87°50'00.04"
319	42°17'39.61"	-87°48'45.44"	1987	5,701.12	42°17'39.42"	-87°50'01.59"

Appendix K (continued)

Shorelines for Corridor 3 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
320	42°17'38.12"	-87°48'45.44"	1873	5,296.03	42°17'37.94"	-87°49'56.17"
320	42°17'38.12"	-87°48'45.44"	1910-11	5,364.79	42°17'37.94"	-87°49'57.09"
320	42°17'38.12"	-87°48'45.44"	1947	5,551.59	42°17'37.93"	-87°49'59.59"
320	42°17'38.12"	-87°48'45.44"	1987	5,729.63	42°17'37.92"	-87°50'01.96"
321	42°17'36.64"	-87°48'45.44"	1873	5,280.52	42°17'36.45"	-87°49'55.96"
321	42°17'36.64"	-87°48'45.44"	1910-11	5,340.78	42°17'36.45"	-87°49'56.76"
321	42°17'36.64"	-87°48'45.44"	1947	5,529.58	42°17'36.45"	-87°49'59.29"
321	42°17'36.64"	-87°48'45.44"	1987	5,719.37	42°17'36.44"	-87°50'01.83"
322	42°17'35.15"	-87°48'45.42"	1873	5,265.52	42°17'34.97"	-87°49'55.75"
322	42°17'35.15"	-87°48'45.42"	1910-11	5,318.53	42°17'34.96"	-87°49'56.45"
322	42°17'35.15"	-87°48'45.42"	1947	5,501.83	42°17'34.96"	-87°49'58.91"
322	42°17'35.15"	-87°48'45.42"	1987	5,676.87	42°17'34.96"	-87°50'01.25"
323	42°17'33.67"	-87°48'45.42"	1873	5,255.02	42°17'33.48"	-87°49'55.61"
323	42°17'33.67"	-87°48'45.42"	1910-11	5,300.78	42°17'33.48"	-87°49'56.21"
323	42°17'33.67"	-87°48'45.42"	1947	5,483.33	42°17'33.47"	-87°49'58.65"
323	42°17'33.67"	-87°48'45.42"	1987	5,633.11	42°17'33.47"	-87°50'00.66"
324	42°17'32.18"	-87°48'45.41"	1873	5,246.77	42°17'31.99"	-87°49'55.49"
324	42°17'32.18"	-87°48'45.41"	1910-11	5,281.77	42°17'31.99"	-87°49'55.95"
324	42°17'32.18"	-87°48'45.41"	1947	5,441.06	42°17'31.99"	-87°49'58.08"
324	42°17'32.18"	-87°48'45.41"	1987	5,590.85	42°17'31.99"	-87°50'00.08"
325	42°17'30.69"	-87°48'45.41"	1873	5,239.01	42°17'30.50"	-87°49'55.38"
325	42°17'30.69"	-87°48'45.41"	1910-11	5,270.27	42°17'30.51"	-87°49'55.80"
325	42°17'30.69"	-87°48'45.41"	1947	5,380.54	42°17'30.51"	-87°49'57.27"
325	42°17'30.69"	-87°48'45.41"	1987	5,557.84	42°17'30.49"	-87°49'59.64"
326	42°17'29.21"	-87°48'45.39"	1873	5,232.26	42°17'29.02"	-87°49'55.28"
326	42°17'29.21"	-87°48'45.39"	1910-11	5,269.27	42°17'29.02"	-87°49'55.77"
326	42°17'29.21"	-87°48'45.39"	1947	5,332.03	42°17'29.01"	-87°49'56.61"
326	42°17'29.21"	-87°48'45.39"	1987	5,501.33	42°17'29.01"	-87°49'58.87"
327	42°17'27.72"	-87°48'45.39"	1873	5,225.51	42°17'27.53"	-87°49'55.18"
327	42°17'27.72"	-87°48'45.39"	1910-11	5,267.77	42°17'27.53"	-87°49'55.74"
327	42°17'27.72"	-87°48'45.39"	1947	5,274.52	42°17'27.53"	-87°49'55.84"
327	42°17'27.72"	-87°48'45.39"	1987	5,469.07	42°17'27.52"	-87°49'58.44"
328	42°17'26.23"	-87°48'45.39"	1873	5,218.51	42°17'26.05"	-87°49'55.08"
328	42°17'26.23"	-87°48'45.39"	1910-11	5,264.27	42°17'26.04"	-87°49'55.70"
328	42°17'26.23"	-87°48'45.39"	1947	5,335.03	42°17'26.04"	-87°49'56.63"
328	42°17'26.23"	-87°48'45.39"	1987	5,396.30	42°17'26.04"	-87°49'57.46"
329	42°17'24.74"	-87°48'45.37"	1873	5,219.26	42°17'24.56"	-87°49'55.08"
329	42°17'24.74"	-87°48'45.37"	1910-11	5,255.52	42°17'24.55"	-87°49'55.58"
329	42°17'24.74"	-87°48'45.37"	1947	5,356.54	42°17'24.55"	-87°49'56.92"
329	42°17'24.74"	-87°48'45.37"	1987	5,408.05	42°17'24.55"	-87°49'57.61"

Appendix K (continued)

Shorelines for Corridor 3 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
330	42°17'23.25"	-87°48'45.37"	1873	5,222.26	42°17'23.07"	-87°49'55.12"
330	42°17'23.25"	-87°48'45.37"	1910-11	5,247.27	42°17'23.07"	-87°49'55.45"
330	42°17'23.25"	-87°48'45.37"	1947	5,420.31	42°17'23.07"	-87°49'57.76"
330	42°17'23.25"	-87°48'45.37"	1987	5,461.82	42°17'23.06"	-87°49'58.31"
331	42°17'21.77"	-87°48'45.35"	1873	5,225.51	42°17'21.58"	-87°49'55.15"
331	42°17'21.77"	-87°48'45.35"	1910-11	5,238.51	42°17'21.59"	-87°49'55.33"
331	42°17'21.77"	-87°48'45.35"	1947	5,419.56	42°17'21.58"	-87°49'57.75"
331	42°17'21.77"	-87°48'45.35"	1987	5,476.32	42°17'21.57"	-87°49'58.49"
332	42°17'20.28"	-87°48'45.35"	1873	5,227.01	42°17'20.10"	-87°49'55.17"
332	42°17'20.28"	-87°48'45.35"	1910-11	5,228.51	42°17'20.10"	-87°49'55.19"
332	42°17'20.28"	-87°48'45.35"	1947	5,415.30	42°17'20.09"	-87°49'57.68"
332	42°17'20.28"	-87°48'45.35"	1987	5,474.57	42°17'20.09"	-87°49'58.48"
333	42°17'18.79"	-87°48'45.35"	1873	5,225.76	42°17'18.61"	-87°49'55.14"
333	42°17'18.79"	-87°48'45.35"	1910-11	5,218.76	42°17'18.61"	-87°49'55.04"
333	42°17'18.79"	-87°48'45.35"	1947	5,381.54	42°17'18.61"	-87°49'57.22"
333	42°17'18.79"	-87°48'45.35"	1987	5,474.07	42°17'18.60"	-87°49'58.46"
334	42°17'17.30"	-87°48'45.34"	1873	5,224.01	42°17'17.12"	-87°49'55.11"
334	42°17'17.30"	-87°48'45.34"	1910-11	5,207.75	42°17'17.12"	-87°49'54.89"
334	42°17'17.30"	-87°48'45.34"	1947	5,345.04	42°17'17.11"	-87°49'56.72"
334	42°17'17.30"	-87°48'45.34"	1987	5,446.06	42°17'17.11"	-87°49'58.07"
335	42°17'15.82"	-87°48'45.33"	1873	5,222.51	42°17'15.63"	-87°49'55.09"
335	42°17'15.82"	-87°48'45.33"	1910-11	5,198.50	42°17'15.64"	-87°49'54.77"
335	42°17'15.82"	-87°48'45.33"	1947	5,296.53	42°17'15.62"	-87°49'56.08"
335	42°17'15.82"	-87°48'45.33"	1987	5,412.55	42°17'15.63"	-87°49'57.63"

Appendix K (continued)

SHORELINES FOR CORRIDOR 4

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
401	42°14'50.17"	-87°47'46.29"	1873	5,555.35	42°14'35.08"	-87°48'57.61"
401	42°14'50.17"	-87°47'46.29"	1910-11	5,527.36	42°14'35.16"	-87°48'57.25"
401	42°14'50.17"	-87°47'46.29"	1947	5,638.70	42°14'34.85"	-87°48'58.67"
401	42°14'50.17"	-87°47'46.29"	1987	5,722.37	42°14'34.63"	-87°48'59.74"
402	42°14'48.73"	-87°47'45.74"	1873	5,565.79	42°14'33.62"	-87°48'57.19"
402	42°14'48.73"	-87°47'45.74"	1910-11	5,523.96	42°14'33.74"	-87°48'56.65"
402	42°14'48.73"	-87°47'45.74"	1947	5,617.82	42°14'33.48"	-87°48'57.86"
402	42°14'48.73"	-87°47'45.74"	1987	5,728.38	42°14'33.18"	-87°48'59.27"
403	42°14'47.31"	-87°47'45.19"	1873	5,575.99	42°14'32.16"	-87°48'56.77"
403	42°14'47.31"	-87°47'45.19"	1910-11	5,523.72	42°14'32.31"	-87°48'56.10"
403	42°14'47.31"	-87°47'45.19"	1947	5,599.00	42°14'32.10"	-87°48'57.07"
403	42°14'47.31"	-87°47'45.19"	1987	5,734.08	42°14'31.73"	-87°48'58.80"
404	42°14'45.87"	-87°47'44.65"	1873	5,581.76	42°14'30.71"	-87°48'56.30"
404	42°14'45.87"	-87°47'44.65"	1910-11	5,548.00	42°14'30.81"	-87°48'55.86"
404	42°14'45.87"	-87°47'44.65"	1947	5,627.24	42°14'30.59"	-87°48'56.88"
404	42°14'45.87"	-87°47'44.65"	1987	5,755.51	42°14'30.25"	-87°48'58.53"
405	42°14'44.44"	-87°47'44.10"	1873	5,579.15	42°14'29.29"	-87°48'55.71"
405	42°14'44.44"	-87°47'44.10"	1910-11	5,568.88	42°14'29.33"	-87°48'55.59"
405	42°14'44.44"	-87°47'44.10"	1947	5,615.21	42°14'29.20"	-87°48'56.18"
405	42°14'44.44"	-87°47'44.10"	1987	5,743.01	42°14'28.85"	-87°48'57.82"
406	42°14'43.01"	-87°47'43.55"	1873	5,568.16	42°14'27.89"	-87°48'55.02"
406	42°14'43.01"	-87°47'43.55"	1910-11	5,589.28	42°14'27.83"	-87°48'55.29"
406	42°14'43.01"	-87°47'43.55"	1947	5,615.93	42°14'27.76"	-87°48'55.64"
406	42°14'43.01"	-87°47'43.55"	1987	5,736.21	42°14'27.43"	-87°48'57.19"
407	42°14'41.58"	-87°47'43.00"	1873	5,563.42	42°14'26.47"	-87°48'54.41"
407	42°14'41.58"	-87°47'43.00"	1910-11	5,604.94	42°14'26.36"	-87°48'54.94"
407	42°14'41.58"	-87°47'43.00"	1947	5,604.94	42°14'26.36"	-87°48'54.94"
407	42°14'41.58"	-87°47'43.00"	1987	5,721.27	42°14'26.04"	-87°48'56.43"
408	42°14'40.16"	-87°47'42.44"	1873	5,562.39	42°14'25.05"	-87°48'53.85"
408	42°14'40.16"	-87°47'42.44"	1910-11	5,614.90	42°14'24.91"	-87°48'54.53"
408	42°14'40.16"	-87°47'42.44"	1947	5,603.43	42°14'24.94"	-87°48'54.38"
408	42°14'40.16"	-87°47'42.44"	1987	5,703.00	42°14'24.67"	-87°48'55.65"
409	42°14'38.72"	-87°47'41.91"	1873	5,563.42	42°14'23.61"	-87°48'53.32"
409	42°14'38.72"	-87°47'41.91"	1910-11	5,595.05	42°14'23.53"	-87°48'53.73"
409	42°14'38.72"	-87°47'41.91"	1947	5,590.38	42°14'23.54"	-87°48'53.67"
409	42°14'38.72"	-87°47'41.91"	1987	5,682.60	42°14'23.30"	-87°48'54.85"

Appendix K (continued)

Shorelines for Corridor 4 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
410	42°14'37.29"	-87°47'41.36"	1873	5,548.86	42°14'22.22"	-87°48'52.58"
410	42°14'37.29"	-87°47'41.36"	1910-11	5,561.67	42°14'22.18"	-87°48'52.75"
410	42°14'37.29"	-87°47'41.36"	1947	5,587.77	42°14'22.12"	-87°48'53.09"
410	42°14'37.29"	-87°47'41.36"	1987	5,676.11	42°14'21.88"	-87°48'54.21"
411	42°14'35.86"	-87°47'40.80"	1873	5,533.92	42°14'20.83"	-87°48'51.84"
411	42°14'35.86"	-87°47'40.80"	1910-11	5,535.98	42°14'20.82"	-87°48'51.86"
411	42°14'35.86"	-87°47'40.80"	1947	5,581.76	42°14'20.70"	-87°48'52.45"
411	42°14'35.86"	-87°47'40.80"	1987	5,676.11	42°14'20.44"	-87°48'53.66"
412	42°14'34.43"	-87°47'40.25"	1873	5,537.63	42°14'19.39"	-87°48'51.34"
412	42°14'34.43"	-87°47'40.25"	1910-11	5,527.12	42°14'19.43"	-87°48'51.20"
412	42°14'34.43"	-87°47'40.25"	1947	5,602.72	42°14'19.21"	-87°48'52.17"
412	42°14'34.43"	-87°47'40.25"	1987	5,656.81	42°14'19.07"	-87°48'52.87"
413	42°14'33.00"	-87°47'39.72"	1873	5,540.17	42°14'17.95"	-87°48'50.83"
413	42°14'33.00"	-87°47'39.72"	1910-11	5,510.59	42°14'18.04"	-87°48'50.45"
413	42°14'33.00"	-87°47'39.72"	1947	5,598.69	42°14'17.79"	-87°48'51.58"
413	42°14'33.00"	-87°47'39.72"	1987	5,667.42	42°14'17.61"	-87°48'52.46"
414	42°14'31.57"	-87°47'39.16"	1873	5,539.21	42°14'16.53"	-87°48'50.26"
414	42°14'31.57"	-87°47'39.16"	1910-11	5,511.22	42°14'16.60"	-87°48'49.90"
414	42°14'31.57"	-87°47'39.16"	1947	5,594.33	42°14'16.38"	-87°48'50.97"
414	42°14'31.57"	-87°47'39.16"	1987	5,670.41	42°14'16.17"	-87°48'51.95"
415	42°14'30.13"	-87°47'38.61"	1873	5,557.41	42°14'15.04"	-87°48'49.95"
415	42°14'30.13"	-87°47'38.61"	1910-11	5,517.16	42°14'15.16"	-87°48'49.43"
415	42°14'30.13"	-87°47'38.61"	1947	5,637.12	42°14'14.83"	-87°48'50.97"
415	42°14'30.13"	-87°47'38.61"	1987	5,677.38	42°14'14.72"	-87°48'51.50"
416	42°14'28.71"	-87°47'38.07"	1873	5,558.44	42°14'13.61"	-87°48'49.41"
416	42°14'28.71"	-87°47'38.07"	1910-11	5,538.35	42°14'13.66"	-87°48'49.16"
416	42°14'28.71"	-87°47'38.07"	1947	5,682.12	42°14'13.27"	-87°48'51.01"
416	42°14'28.71"	-87°47'38.07"	1987	5,674.29	42°14'13.29"	-87°48'50.90"
417	42°14'27.27"	-87°47'37.52"	1873	5,572.35	42°14'12.15"	-87°48'49.05"
417	42°14'27.27"	-87°47'37.52"	1910-11	5,575.99	42°14'12.14"	-87°48'49.09"
417	42°14'27.27"	-87°47'37.52"	1947	5,669.31	42°14'11.88"	-87°48'50.29"
417	42°14'27.27"	-87°47'37.52"	1987	5,678.96	42°14'11.86"	-87°48'50.42"
418	42°14'25.85"	-87°47'36.97"	1873	5,590.69	42°14'10.66"	-87°48'48.73"
418	42°14'25.85"	-87°47'36.97"	1910-11	5,613.39	42°14'10.60"	-87°48'49.02"
418	42°14'25.85"	-87°47'36.97"	1947	5,680.06	42°14'10.42"	-87°48'49.88"
418	42°14'25.85"	-87°47'36.97"	1987	5,693.11	42°14'10.38"	-87°48'50.04"
419	42°14'24.41"	-87°47'36.42"	1873	5,613.39	42°14'09.17"	-87°48'48.47"
419	42°14'24.41"	-87°47'36.42"	1910-11	5,646.06	42°14'09.08"	-87°48'48.89"
419	42°14'24.41"	-87°47'36.42"	1947	5,670.89	42°14'09.01"	-87°48'49.21"
419	42°14'24.41"	-87°47'36.42"	1987	5,716.60	42°14'08.89"	-87°48'49.80"

Appendix K (continued)

Shorelines for Corridor 4 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
420	42°14'22.98"	-87°47'35.87"	1873	5,637.36	42°14'07.68"	-87°48'48.24"
420	42°14'22.98"	-87°47'35.87"	1910-11	5,654.13	42°14'07.63"	-87°48'48.46"
420	42°14'22.98"	-87°47'35.87"	1947	5,668.21	42°14'07.60"	-87°48'48.63"
420	42°14'22.98"	-87°47'35.87"	1987	5,726.25	42°14'07.44"	-87°48'49.38"
421	42°14'21.55"	-87°47'35.33"	1873	5,655.63	42°14'06.20"	-87°48'47.92"
421	42°14'21.55"	-87°47'35.33"	1910-11	5,649.62	42°14'06.21"	-87°48'47.85"
421	42°14'21.55"	-87°47'35.33"	1947	5,648.83	42°14'06.22"	-87°48'47.84"
421	42°14'21.55"	-87°47'35.33"	1987	5,711.62	42°14'06.04"	-87°48'48.64"
422	42°14'20.12"	-87°47'34.78"	1873	5,655.47	42°14'04.76"	-87°48'47.37"
422	42°14'20.12"	-87°47'34.78"	1910-11	5,638.23	42°14'04.81"	-87°48'47.15"
422	42°14'20.12"	-87°47'34.78"	1947	5,640.60	42°14'04.81"	-87°48'47.18"
422	42°14'20.12"	-87°47'34.78"	1987	5,706.40	42°14'04.63"	-87°48'48.02"
423	42°14'18.70"	-87°47'34.23"	1873	5,645.03	42°14'03.36"	-87°48'46.69"
423	42°14'18.70"	-87°47'34.23"	1910-11	5,597.73	42°14'03.49"	-87°48'46.08"
423	42°14'18.70"	-87°47'34.23"	1947	5,643.21	42°14'03.36"	-87°48'46.67"
423	42°14'18.70"	-87°47'34.23"	1987	5,704.34	42°14'03.21"	-87°48'47.45"
424	42°14'17.26"	-87°47'33.68"	1873	5,626.45	42°14'01.98"	-87°48'45.90"
424	42°14'17.26"	-87°47'33.68"	1910-11	5,584.61	42°14'02.10"	-87°48'45.36"
424	42°14'17.26"	-87°47'33.68"	1947	5,655.39	42°14'01.90"	-87°48'46.28"
424	42°14'17.26"	-87°47'33.68"	1987	5,728.62	42°14'01.70"	-87°48'47.22"
425	42°14'15.82"	-87°47'33.14"	1873	5,592.99	42°14'00.64"	-87°48'44.93"
425	42°14'15.82"	-87°47'33.14"	1910-11	5,603.43	42°14'00.61"	-87°48'45.07"
425	42°14'15.82"	-87°47'33.14"	1947	5,617.51	42°14'00.58"	-87°48'45.24"
425	42°14'15.82"	-87°47'33.14"	1987	5,736.45	42°14'00.25"	-87°48'46.77"
426	42°14'14.40"	-87°47'32.59"	1873	5,564.76	42°13'59.29"	-87°48'44.02"
426	42°14'14.40"	-87°47'32.59"	1910-11	5,622.02	42°13'59.13"	-87°48'44.74"
426	42°14'14.40"	-87°47'32.59"	1947	5,625.97	42°13'59.12"	-87°48'44.80"
426	42°14'14.40"	-87°47'32.59"	1987	5,728.38	42°13'58.84"	-87°48'46.11"
427	42°14'12.96"	-87°47'32.04"	1873	5,557.65	42°13'57.87"	-87°48'43.37"
427	42°14'12.96"	-87°47'32.04"	1910-11	5,632.22	42°13'57.67"	-87°48'44.34"
427	42°14'12.96"	-87°47'32.04"	1947	5,600.82	42°13'57.76"	-87°48'43.94"
427	42°14'12.96"	-87°47'32.04"	1987	5,728.07	42°13'57.42"	-87°48'45.56"
428	42°14'11.53"	-87°47'31.49"	1873	5,547.76	42°13'56.47"	-87°48'42.70"
428	42°14'11.53"	-87°47'31.49"	1910-11	5,654.68	42°13'56.19"	-87°48'44.07"
428	42°14'11.53"	-87°47'31.49"	1947	5,607.62	42°13'56.31"	-87°48'43.47"
428	42°14'11.53"	-87°47'31.49"	1987	5,738.82	42°13'55.95"	-87°48'45.16"
429	42°14'10.10"	-87°47'30.95"	1873	5,532.58	42°13'55.09"	-87°48'41.96"
429	42°14'10.10"	-87°47'30.95"	1910-11	5,678.48	42°13'54.68"	-87°48'43.83"
429	42°14'10.10"	-87°47'30.95"	1947	5,581.45	42°13'54.95"	-87°48'42.59"
429	42°14'10.10"	-87°47'30.95"	1987	5,743.01	42°13'54.51"	-87°48'44.66"

Appendix K (continued)

Shorelines for Corridor 4 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
430	42°14'08.67"	-87°47'30.40"	1873	5,539.93	42°13'53.63"	-87°48'41.50"
430	42°14'08.67"	-87°47'30.40"	1910-11	5,681.64	42°13'53.25"	-87°48'43.32"
430	42°14'08.67"	-87°47'30.40"	1947	5,616.32	42°13'53.43"	-87°48'42.48"
430	42°14'08.67"	-87°47'30.40"	1987	5,716.36	42°13'53.16"	-87°48'43.77"
431	42°14'07.25"	-87°47'29.85"	1873	5,550.92	42°13'52.17"	-87°48'41.10"
431	42°14'07.25"	-87°47'29.85"	1910-11	5,673.74	42°13'51.84"	-87°48'42.67"
431	42°14'07.25"	-87°47'29.85"	1947	5,608.41	42°13'52.02"	-87°48'41.84"
431	42°14'07.25"	-87°47'29.85"	1987	5,734.39	42°13'51.67"	-87°48'43.45"
432	42°14'05.81"	-87°47'29.30"	1873	5,554.63	42°13'50.73"	-87°48'40.59"
432	42°14'05.81"	-87°47'29.30"	1910-11	5,664.16	42°13'50.43"	-87°48'42.00"
432	42°14'05.81"	-87°47'29.30"	1947	5,649.46	42°13'50.47"	-87°48'41.81"
432	42°14'05.81"	-87°47'29.30"	1987	5,785.16	42°13'50.10"	-87°48'43.56"
433	42°14'04.38"	-87°47'28.76"	1873	5,559.23	42°13'49.29"	-87°48'40.11"
433	42°14'04.38"	-87°47'28.76"	1910-11	5,665.60	42°13'49.00"	-87°48'41.47"
433	42°14'04.38"	-87°47'28.76"	1947	5,642.66	42°13'49.06"	-87°48'41.18"
433	42°14'04.38"	-87°47'28.76"	1987	5,875.79	42°13'48.43"	-87°48'44.17"
434	42°14'02.95"	-87°47'28.21"	1873	5,583.58	42°13'47.79"	-87°48'39.88"
434	42°14'02.95"	-87°47'28.21"	1910-11	5,677.14	42°13'47.53"	-87°48'41.07"
434	42°14'02.95"	-87°47'28.21"	1947	5,678.72	42°13'47.53"	-87°48'41.10"
434	42°14'02.95"	-87°47'28.21"	1987	5,914.47	42°13'46.89"	-87°48'44.12"
435	42°14'01.52"	-87°47'27.66"	1873	5,604.77	42°13'46.30"	-87°48'39.59"
435	42°14'01.52"	-87°47'27.66"	1910-11	5,698.64	42°13'46.04"	-87°48'40.80"
435	42°14'01.52"	-87°47'27.66"	1947	5,681.64	42°13'46.09"	-87°48'40.59"
435	42°14'01.52"	-87°47'27.66"	1987	5,928.86	42°13'45.42"	-87°48'43.75"

Appendix K (continued)

SHORELINES FOR CORRIDOR 5

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
501	42°11'36.35"	-87°46'01.47"	1873	5,404.57	42°11'09.09"	-87°47'03.54"
501	42°11'36.35"	-87°46'01.47"	1910-11	5,441.28	42°11'08.90"	-87°47'03.96"
501	42°11'36.35"	-87°46'01.47"	1947	5,407.83	42°11'09.07"	-87°47'03.57"
501	42°11'36.35"	-87°46'01.47"	1987	5,526.13	42°11'08.47"	-87°47'04.93"
502	42°11'35.07"	-87°46'00.47"	1873	5,402.43	42°11'07.81"	-87°47'02.49"
502	42°11'35.07"	-87°46'00.47"	1910-11	5,431.50	42°11'07.67"	-87°47'02.83"
502	42°11'35.07"	-87°46'00.47"	1947	5,398.40	42°11'07.83"	-87°47'02.45"
502	42°11'35.07"	-87°46'00.47"	1987	5,522.53	42°11'07.21"	-87°47'03.88"
503	42°11'33.79"	-87°45'59.45"	1873	5,391.67	42°11'06.59"	-87°47'01.35"
503	42°11'33.79"	-87°45'59.45"	1910-11	5,423.87	42°11'06.43"	-87°47'01.73"
503	42°11'33.79"	-87°45'59.45"	1947	5,389.31	42°11'06.61"	-87°47'01.32"
503	42°11'33.79"	-87°45'59.45"	1987	5,519.40	42°11'05.94"	-87°47'02.82"
504	42°11'32.51"	-87°45'58.42"	1873	5,393.12	42°11'05.30"	-87°47'00.36"
504	42°11'32.51"	-87°45'58.42"	1910-11	5,410.53	42°11'05.22"	-87°47'00.56"
504	42°11'32.51"	-87°45'58.42"	1947	5,382.58	42°11'05.35"	-87°47'00.23"
504	42°11'32.51"	-87°45'58.42"	1987	5,512.45	42°11'04.70"	-87°47'01.72"
505	42°11'31.23"	-87°45'57.40"	1873	5,384.93	42°11'04.06"	-87°46'59.24"
505	42°11'31.23"	-87°45'57.40"	1910-11	5,390.42	42°11'04.04"	-87°46'59.31"
505	42°11'31.23"	-87°45'57.40"	1947	5,364.95	42°11'04.16"	-87°46'59.01"
505	42°11'31.23"	-87°45'57.40"	1987	5,505.04	42°11'03.45"	-87°47'0.62"
506	42°11'29.94"	-87°45'56.40"	1873	5,365.72	42°11'02.88"	-87°46'58.00"
506	42°11'29.94"	-87°45'56.40"	1910-11	5,378.07	42°11'02.81"	-87°46'58.15"
506	42°11'29.94"	-87°45'56.40"	1947	5,346.99	42°11'02.97"	-87°46'57.79"
506	42°11'29.94"	-87°45'56.40"	1987	5,493.03	42°11'02.23"	-87°46'59.46"
507	42°11'28.66"	-87°45'55.37"	1873	5,355.52	42°11'01.64"	-87°46'56.86"
507	42°11'28.66"	-87°45'55.37"	1910-11	5,394.58	42°11'01.45"	-87°46'57.31"
507	42°11'28.66"	-87°45'55.37"	1947	5,387.51	42°11'01.49"	-87°46'57.22"
507	42°11'28.66"	-87°45'55.37"	1987	5,480.89	42°11'01.02"	-87°46'58.30"
508	42°11'27.38"	-87°45'54.35"	1873	5,349.00	42°11'00.40"	-87°46'55.77"
508	42°11'27.38"	-87°45'54.35"	1910-11	5,392.01	42°11'00.19"	-87°46'56.27"
508	42°11'27.38"	-87°45'54.35"	1947	5,394.24	42°11'00.18"	-87°46'56.30"
508	42°11'27.38"	-87°45'54.35"	1987	5,475.41	42°10'59.76"	-87°46'57.23"
509	42°11'26.10"	-87°45'53.33"	1873	5,343.94	42°10'59.14"	-87°46'54.70"
509	42°11'26.10"	-87°45'53.33"	1910-11	5,370.44	42°10'59.01"	-87°46'55.01"
509	42°11'26.10"	-87°45'53.33"	1947	5,398.82	42°10'58.87"	-87°46'55.33"
509	42°11'26.10"	-87°45'53.33"	1987	5,478.19	42°10'58.47"	-87°46'56.23"

Appendix K (continued)

Shorelines for Corridor 5 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
510	42°11'24.83"	-87°45'52.33"	1873	5,343.52	42°10'57.87"	-87°46'53.68"
510	42°11'24.83"	-87°45'52.33"	1910-11	5,354.06	42°10'57.81"	-87°46'53.80"
510	42°11'24.83"	-87°45'52.33"	1947	5,369.67	42°10'57.73"	-87°46'53.97"
510	42°11'24.83"	-87°45'52.33"	1987	5,492.13	42°10'57.12"	-87°46'55.38"
511	42°11'23.54"	-87°45'51.30"	1873	5,336.65	42°10'56.62"	-87°46'52.59"
511	42°11'23.54"	-87°45'51.30"	1910-11	5,351.57	42°10'56.54"	-87°46'52.75"
511	42°11'23.54"	-87°45'51.30"	1947	5,361.14	42°10'56.50"	-87°46'52.86"
511	42°11'23.54"	-87°45'51.30"	1987	5,508.51	42°10'55.76"	-87°46'54.56"
512	42°11'22.26"	-87°45'50.28"	1873	5,341.58	42°10'55.32"	-87°46'51.62"
512	42°11'22.26"	-87°45'50.28"	1910-11	5,366.62	42°10'55.18"	-87°46'51.90"
512	42°11'22.26"	-87°45'50.28"	1947	5,368.29	42°10'55.18"	-87°46'51.93"
512	42°11'22.26"	-87°45'50.28"	1987	5,500.88	42°10'54.51"	-87°46'53.44"
513	42°11'20.98"	-87°45'49.28"	1873	5,353.72	42°10'53.98"	-87°46'50.75"
513	42°11'20.98"	-87°45'49.28"	1910-11	5,394.24	42°10'53.77"	-87°46'51.21"
513	42°11'20.98"	-87°45'49.28"	1947	5,353.72	42°10'53.98"	-87°46'50.75"
513	42°11'20.98"	-87°45'49.28"	1987	5,504.69	42°10'53.21"	-87°46'52.47"
514	42°11'19.70"	-87°45'48.26"	1873	5,353.72	42°10'52.69"	-87°46'49.73"
514	42°11'19.70"	-87°45'48.26"	1910-11	5,426.36	42°10'52.33"	-87°46'50.55"
514	42°11'19.70"	-87°45'48.26"	1947	5,388.96	42°10'52.51"	-87°46'50.13"
514	42°11'19.70"	-87°45'48.26"	1987	5,508.85	42°10'51.90"	-87°46'51.51"
515	42°11'18.41"	-87°45'47.23"	1873	5,349.90	42°10'51.43"	-87°46'48.66"
515	42°11'18.41"	-87°45'47.23"	1910-11	5,458.90	42°10'50.88"	-87°46'49.92"
515	42°11'18.41"	-87°45'47.23"	1947	5,404.79	42°10'51.15"	-87°46'49.30"
515	42°11'18.41"	-87°45'47.23"	1987	5,526.13	42°10'50.54"	-87°46'50.69"
516	42°11'17.13"	-87°45'46.21"	1873	5,343.73	42°10'50.18"	-87°46'47.58"
516	42°11'17.13"	-87°45'46.21"	1910-11	5,465.63	42°10'49.57"	-87°46'48.98"
516	42°11'17.13"	-87°45'46.21"	1947	5,425.67	42°10'49.77"	-87°46'48.52"
516	42°11'17.13"	-87°45'46.21"	1987	5,543.75	42°10'49.17"	-87°46'49.87"
517	42°11'15.86"	-87°45'45.21"	1873	5,360.79	42°10'48.81"	-87°46'46.76"
517	42°11'15.86"	-87°45'45.21"	1910-11	5,470.35	42°10'48.26"	-87°46'48.01"
517	42°11'15.86"	-87°45'45.21"	1947	5,416.36	42°10'48.53"	-87°46'47.39"
517	42°11'15.86"	-87°45'45.21"	1987	5,557.90	42°10'47.82"	-87°46'49.01"
518	42°11'14.57"	-87°45'44.19"	1873	5,372.59	42°10'47.47"	-87°46'45.87"
518	42°11'14.57"	-87°45'44.19"	1910-11	5,473.95	42°10'46.96"	-87°46'47.03"
518	42°11'14.57"	-87°45'44.19"	1947	5,403.67	42°10'47.32"	-87°46'46.22"
518	42°11'14.57"	-87°45'44.19"	1987	5,484.15	42°10'46.91"	-87°46'47.15"
519	42°11'13.30"	-87°45'43.16"	1873	5,372.24	42°10'46.20"	-87°46'44.85"
519	42°11'13.30"	-87°45'43.16"	1910-11	5,479.78	42°10'45.65"	-87°46'46.08"
519	42°11'13.30"	-87°45'43.16"	1947	5,421.64	42°10'45.95"	-87°46'45.42"
519	42°11'13.30"	-87°45'43.16"	1987	5,573.17	42°10'45.18"	-87°46'47.16"

Appendix K (continued)

Shorelines for Corridor 5 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
520	42°11'12.01"	-87°45'42.14"	1873	5,380.77	42°10'44.87"	-87°46'43.92"
520	42°11'12.01"	-87°45'42.14"	1910-11	5,487.41	42°10'44.34"	-87°46'45.15"
520	42°11'12.01"	-87°45'42.14"	1947	5,448.01	42°10'44.53"	-87°46'44.71"
520	42°11'12.01"	-87°45'42.14"	1987	5,572.05	42°10'43.90"	-87°46'46.12"
521	42°11'10.73"	-87°45'41.14"	1873	5,382.66	42°10'43.58"	-87°46'42.93"
521	42°11'10.73"	-87°45'41.14"	1910-11	5,490.75	42°10'43.03"	-87°46'44.17"
521	42°11'10.73"	-87°45'41.14"	1947	5,466.40	42°10'43.16"	-87°46'43.90"
521	42°11'10.73"	-87°45'41.14"	1987	5,561.59	42°10'42.68"	-87°46'44.99"
522	42°11'09.44"	-87°45'40.12"	1873	5,390.98	42°10'42.26"	-87°46'42.02"
522	42°11'09.44"	-87°45'40.12"	1910-11	5,474.72	42°10'41.83"	-87°46'42.97"
522	42°11'09.44"	-87°45'40.12"	1947	5,472.02	42°10'41.84"	-87°46'42.95"
522	42°11'09.44"	-87°45'40.12"	1987	5,557.90	42°10'41.41"	-87°46'43.93"
523	42°11'08.17"	-87°45'39.09"	1873	5,403.33	42°10'40.92"	-87°46'41.13"
523	42°11'08.17"	-87°45'39.09"	1910-11	5,451.14	42°10'40.68"	-87°46'41.68"
523	42°11'08.17"	-87°45'39.09"	1947	5,497.48	42°10'40.44"	-87°46'42.22"
523	42°11'08.17"	-87°45'39.09"	1987	5,561.59	42°10'40.12"	-87°46'42.95"
524	42°11'06.89"	-87°45'38.09"	1873	5,413.32	42°10'39.58"	-87°46'40.23"
524	42°11'06.89"	-87°45'38.09"	1910-11	5,473.61	42°10'39.28"	-87°46'40.93"
524	42°11'06.89"	-87°45'38.09"	1947	5,487.97	42°10'39.21"	-87°46'41.09"
524	42°11'06.89"	-87°45'38.09"	1987	5,573.17	42°10'38.78"	-87°46'42.07"
525	42°11'05.60"	-87°45'37.07"	1873	5,417.48	42°10'38.28"	-87°46'39.26"
525	42°11'05.60"	-87°45'37.07"	1910-11	5,478.88	42°10'37.97"	-87°46'39.97"
525	42°11'05.60"	-87°45'37.07"	1947	5,529.73	42°10'37.71"	-87°46'40.56"
525	42°11'05.60"	-87°45'37.07"	1987	5,579.13	42°10'37.46"	-87°46'41.13"
526	42°11'04.33"	-87°45'36.05"	1873	5,420.18	42°10'36.99"	-87°46'38.28"
526	42°11'04.33"	-87°45'36.05"	1910-11	5,483.25	42°10'36.67"	-87°46'39.00"
526	42°11'04.33"	-87°45'36.05"	1947	5,515.93	42°10'36.50"	-87°46'39.38"
526	42°11'04.33"	-87°45'36.05"	1987	5,572.61	42°10'36.22"	-87°46'40.02"
527	42°11'03.04"	-87°45'35.03"	1873	5,426.91	42°10'35.66"	-87°46'37.34"
527	42°11'03.04"	-87°45'35.03"	1910-11	5,490.33	42°10'35.35"	-87°46'38.07"
527	42°11'03.04"	-87°45'35.03"	1947	5,477.98	42°10'35.41"	-87°46'37.92"
527	42°11'03.04"	-87°45'35.03"	1987	5,581.01	42°10'34.90"	-87°46'39.11"
528	42°11'01.76"	-87°45'34.02"	1873	5,416.92	42°10'34.44"	-87°46'36.20"
528	42°11'01.76"	-87°45'34.02"	1910-11	5,496.16	42°10'34.04"	-87°46'37.12"
528	42°11'01.76"	-87°45'34.02"	1947	5,448.01	42°10'34.28"	-87°46'36.57"
528	42°11'01.76"	-87°45'34.02"	1987	5,590.45	42°10'33.56"	-87°46'38.20"
529	42°11'00.48"	-87°45'33.00"	1873	5,403.11	42°10'33.23"	-87°46'35.03"
529	42°11'00.48"	-87°45'33.00"	1910-11	5,498.86	42°10'32.74"	-87°46'36.14"
529	42°11'00.48"	-87°45'33.00"	1947	5,447.45	42°10'33.00"	-87°46'35.54"
529	42°11'00.48"	-87°45'33.00"	1987	5,591.13	42°10'32.28"	-87°46'37.19"

Appendix K (continued)

Shorelines for Corridor 5 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
530	42°10'59.20"	-87°45'31.98"	1873	5,390.77	42°10'32.00"	-87°46'33.88"
530	42°10'59.20"	-87°45'31.98"	1910-11	5,499.07	42°10'31.47"	-87°46'35.12"
530	42°10'59.20"	-87°45'31.98"	1947	5,436.21	42°10'31.78"	-87°46'34.39"
530	42°10'59.20"	-87°45'31.98"	1987	5,554.64	42°10'31.18"	-87°46'35.75"
531	42°10'57.92"	-87°45'30.96"	1873	5,396.38	42°10'30.70"	-87°46'32.92"
531	42°10'57.92"	-87°45'30.96"	1910-11	5,499.97	42°10'30.18"	-87°46'34.11"
531	42°10'57.92"	-87°45'30.96"	1947	5,435.10	42°10'30.51"	-87°46'33.37"
531	42°10'57.92"	-87°45'30.96"	1987	5,514.34	42°10'30.11"	-87°46'34.27"
532	42°10'56.64"	-87°45'29.95"	1873	5,387.29	42°10'29.47"	-87°46'31.79"
532	42°10'56.64"	-87°45'29.95"	1910-11	5,485.40	42°10'28.97"	-87°46'32.93"
532	42°10'56.64"	-87°45'29.95"	1947	5,445.44	42°10'29.17"	-87°46'32.47"
532	42°10'56.64"	-87°45'29.95"	1987	5,501.01	42°10'28.89"	-87°46'33.10"
533	42°10'55.36"	-87°45'28.93"	1873	5,385.15	42°10'28.19"	-87°46'30.76"
533	42°10'55.36"	-87°45'28.93"	1910-11	5,450.23	42°10'27.86"	-87°46'31.50"
533	42°10'55.36"	-87°45'28.93"	1947	5,441.83	42°10'27.91"	-87°46'31.41"
533	42°10'55.36"	-87°45'28.93"	1987	5,494.36	42°10'27.64"	-87°46'32.01"
534	42°10'54.07"	-87°45'27.91"	1873	5,368.98	42°10'26.99"	-87°46'29.55"
534	42°10'54.07"	-87°45'27.91"	1910-11	5,433.86	42°10'26.67"	-87°46'30.29"
534	42°10'54.07"	-87°45'27.91"	1947	5,434.20	42°10'26.67"	-87°46'30.30"
534	42°10'54.07"	-87°45'27.91"	1987	5,494.36	42°10'26.36"	-87°46'30.99"
535	42°10'52.80"	-87°45'26.89"	1873	5,354.06	42°10'25.79"	-87°46'28.37"
535	42°10'52.80"	-87°45'26.89"	1910-11	5,428.03	42°10'25.42"	-87°46'29.22"
535	42°10'52.80"	-87°45'26.89"	1947	5,428.93	42°10'25.41"	-87°46'29.22"
535	42°10'52.80"	-87°45'26.89"	1987	5,493.93	42°10'25.08"	-87°46'29.97"

Appendix K (continued)

BLUFFLINES FOR CORRIDOR 3

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
301	42°18'06.39"	-87°48'45.57"	1873	5,776.39	42°18'06.19"	-87°50'02.74"
301	42°18'06.39"	-87°48'45.57"	1910-11	***	42°18'06.18"	-87°50'05.70"
301	42°18'06.39"	-87°48'45.57"	1947	***	42°18'06.18"	-87°50'05.85"
301	42°18'06.39"	-87°48'45.57"	1987	5,935.68	42°18'06.18"	-87°50'04.86"
302	42°18'04.91"	-87°48'45.56"	1873	5,770.64	42°18'04.70"	-87°50'02.65"
302	42°18'04.91"	-87°48'45.56"	1910-11	5,835.41	42°18'04.69"	-87°50'03.51"
302	42°18'04.91"	-87°48'45.56"	1947	5,896.42	42°18'04.70"	-87°50'04.32"
302	42°18'04.91"	-87°48'45.56"	1987	5,943.93	42°18'04.69"	-87°50'04.96"
303	42°18'03.42"	-87°48'45.55"	1873	5,767.39	42°18'03.21"	-87°50'02.60"
303	42°18'03.42"	-87°48'45.55"	1910-11	5,808.65	42°18'03.21"	-87°50'03.14"
303	42°18'03.42"	-87°48'45.55"	1947	5,888.67	42°18'03.21"	-87°50'04.21"
303	42°18'03.42"	-87°48'45.55"	1987	5,944.18	42°18'03.21"	-87°50'04.96"
304	42°18'01.93"	-87°48'45.55"	1873	5,733.88	42°18'01.73"	-87°50'02.14"
304	42°18'01.93"	-87°48'45.55"	1910-11	5,814.65	42°18'01.72"	-87°50'03.22"
304	42°18'01.93"	-87°48'45.55"	1947	5,870.66	42°18'01.73"	-87°50'03.97"
304	42°18'01.93"	-87°48'45.55"	1987	5,923.93	42°18'01.72"	-87°50'04.68"
305	42°18'00.44"	-87°48'45.53"	1873	5,698.87	42°18'00.25"	-87°50'01.67"
305	42°18'00.44"	-87°48'45.53"	1910-11	5,811.40	42°18'00.24"	-87°50'03.16"
305	42°18'00.44"	-87°48'45.53"	1947	5,846.16	42°18'00.23"	-87°50'03.63"
305	42°18'00.44"	-87°48'45.53"	1987	5,857.66	42°18'00.23"	-87°50'03.79"
306	42°17'58.95"	-87°48'45.53"	1873	5,677.87	42°17'58.75"	-87°50'01.38"
306	42°17'58.95"	-87°48'45.53"	1910-11	5,791.64	42°17'58.75"	-87°50'02.89"
306	42°17'58.95"	-87°48'45.53"	1947	5,819.65	42°17'58.75"	-87°50'03.27"
306	42°17'58.95"	-87°48'45.53"	1987	5,873.91	42°17'58.75"	-87°50'04.00"
307	42°17'57.47"	-87°48'45.52"	1873	5,685.37	42°17'57.27"	-87°50'01.46"
307	42°17'57.47"	-87°48'45.52"	1910-11	5,769.39	42°17'57.26"	-87°50'02.58"
307	42°17'57.47"	-87°48'45.52"	1947	5,787.89	42°17'57.26"	-87°50'02.84"
307	42°17'57.47"	-87°48'45.52"	1987	5,833.90	42°17'57.26"	-87°50'03.45"
308	42°17'55.98"	-87°48'45.51"	1873	5,739.63	42°17'55.78"	-87°50'02.19"
308	42°17'55.98"	-87°48'45.51"	1910-11	5,753.14	42°17'55.77"	-87°50'02.37"
308	42°17'55.98"	-87°48'45.51"	1947	5,785.15	42°17'55.78"	-87°50'02.79"
308	42°17'55.98"	-87°48'45.51"	1987	5,790.14	42°17'55.78"	-87°50'02.86"
309	42°17'54.49"	-87°48'45.51"	1873	***	42°17'54.29"	-87°50'04.13"
309	42°17'54.49"	-87°48'45.51"	1910-11	5,755.64	42°17'54.28"	-87°50'02.39"
309	42°17'54.49"	-87°48'45.51"	1947	5,700.63	42°17'54.29"	-87°50'01.65"
309	42°17'54.49"	-87°48'45.51"	1987	5,739.63	42°17'54.29"	-87°50'02.18"

Appendix K (continued)

Blufflines for Corridor 3 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
310	42°17'53.00"	-87°48'45.51"	1873	5,640.36	42°17'52.81"	-87°50'00.85"
310	42°17'53.00"	-87°48'45.51"	1910-11	***	42°17'52.79"	-87°50'04.43"
310	42°17'53.00"	-87°48'45.51"	1947	***	42°17'52.79"	-87°50'04.94"
310	42°17'53.00"	-87°48'45.51"	1987	***	42°17'52.81"	-87°50'02.29"
311	42°17'51.52"	-87°48'45.50"	1873	5,617.85	42°17'51.32"	-87°50'00.54"
311	42°17'51.52"	-87°48'45.50"	1910-11	5,752.64	42°17'51.32"	-87°50'02.34"
311	42°17'51.52"	-87°48'45.50"	1947	5,682.87	42°17'51.32"	-87°50'01.41"
311	42°17'51.52"	-87°48'45.50"	1987	5,685.12	42°17'51.32"	-87°50'01.43"
312	42°17'50.03"	-87°48'45.49"	1873	5,646.86	42°17'49.83"	-87°50'00.92"
312	42°17'50.03"	-87°48'45.49"	1910-11	5,760.63	42°17'49.83"	-87°50'02.43"
312	42°17'50.03"	-87°48'45.49"	1947	5,628.36	42°17'49.83"	-87°50'00.67"
312	42°17'50.03"	-87°48'45.49"	1987	5,669.86	42°17'49.84"	-87°50'01.23"
313	42°17'48.54"	-87°48'45.48"	1873	5,678.12	42°17'48.34"	-87°50'01.33"
313	42°17'48.54"	-87°48'45.48"	1910-11	5,767.64	42°17'48.34"	-87°50'02.52"
313	42°17'48.54"	-87°48'45.48"	1947	5,681.87	42°17'48.34"	-87°50'01.37"
313	42°17'48.54"	-87°48'45.48"	1987	5,714.62	42°17'48.35"	-87°50'01.81"
314	42°17'47.05"	-87°48'45.47"	1873	5,701.12	42°17'46.85"	-87°50'01.62"
314	42°17'47.05"	-87°48'45.47"	1910-11	5,793.89	42°17'46.85"	-87°50'02.87"
314	42°17'47.05"	-87°48'45.47"	1947	5,718.38	42°17'46.85"	-87°50'01.85"
314	42°17'47.05"	-87°48'45.47"	1987	5,749.13	42°17'46.85"	-87°50'02.27"
315	42°17'45.56"	-87°48'45.47"	1873	5,721.63	42°17'45.36"	-87°50'01.90"
315	42°17'45.56"	-87°48'45.47"	1910-11	5,818.40	42°17'45.36"	-87°50'03.18"
315	42°17'45.56"	-87°48'45.47"	1947	5,730.88	42°17'45.36"	-87°50'02.02"
315	42°17'45.56"	-87°48'45.47"	1987	5,771.64	42°17'45.36"	-87°50'02.57"
316	42°17'44.08"	-87°48'45.46"	1873	5,745.64	42°17'43.88"	-87°50'02.21"
316	42°17'44.08"	-87°48'45.46"	1910-11	5,807.90	42°17'43.88"	-87°50'03.05"
316	42°17'44.08"	-87°48'45.46"	1947	***	42°17'43.88"	-87°50'03.58"
316	42°17'44.08"	-87°48'45.46"	1987	5,775.89	42°17'43.87"	-87°50'02.62"
317	42°17'42.59"	-87°48'45.46"	1873	5,760.14	42°17'42.39"	-87°50'02.39"
317	42°17'42.59"	-87°48'45.46"	1910-11	5,810.40	42°17'42.39"	-87°50'03.07"
317	42°17'42.59"	-87°48'45.46"	1947	5,781.40	42°17'42.39"	-87°50'02.68"
317	42°17'42.59"	-87°48'45.46"	1987	5,791.90	42°17'42.39"	-87°50'02.82"
318	42°17'41.10"	-87°48'45.44"	1873	5,767.39	42°17'40.91"	-87°50'02.48"
318	42°17'41.10"	-87°48'45.44"	1910-11	5,834.91	42°17'40.90"	-87°50'03.39"
318	42°17'41.10"	-87°48'45.44"	1947	5,780.14	42°17'40.90"	-87°50'02.65"
318	42°17'41.10"	-87°48'45.44"	1987	5,827.91	42°17'40.90"	-87°50'03.29"
319	42°17'39.61"	-87°48'45.44"	1873	5,770.14	42°17'39.42"	-87°50'02.52"
319	42°17'39.61"	-87°48'45.44"	1910-11	5,840.15	42°17'39.41"	-87°50'03.45"
319	42°17'39.61"	-87°48'45.44"	1947	5,777.14	42°17'39.41"	-87°50'02.61"
319	42°17'39.61"	-87°48'45.44"	1987	5,802.65	42°17'39.41"	-87°50'02.94"

Appendix K (continued)

Blufflines for Corridor 3 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
320	42°17'38.12"	-87°48'45.44"	1873	5,777.14	42°17'37.92"	-87°50'02.59"
320	42°17'38.12"	-87°48'45.44"	1910-11	5,817.90	42°17'37.93"	-87°50'03.14"
320	42°17'38.12"	-87°48'45.44"	1947	5,775.14	42°17'37.92"	-87°50'02.57"
320	42°17'38.12"	-87°48'45.44"	1987	5,856.66	42°17'37.93"	-87°50'03.66"
321	42°17'36.64"	-87°48'45.44"	1873	5,771.64	42°17'36.43"	-87°50'02.52"
321	42°17'36.64"	-87°48'45.44"	1910-11	5,781.64	42°17'36.43"	-87°50'02.66"
321	42°17'36.64"	-87°48'45.44"	1947	5,761.63	42°17'36.44"	-87°50'02.39"
321	42°17'36.64"	-87°48'45.44"	1987	5,850.41	42°17'36.44"	-87°50'03.58"
322	42°17'35.15"	-87°48'45.42"	1873	5,746.13	42°17'34.95"	-87°50'02.17"
322	42°17'35.15"	-87°48'45.42"	1910-11	5,755.14	42°17'34.95"	-87°50'02.29"
322	42°17'35.15"	-87°48'45.42"	1947	5,730.63	42°17'34.95"	-87°50'01.96"
322	42°17'35.15"	-87°48'45.42"	1987	5,809.40	42°17'34.95"	-87°50'03.01"
323	42°17'33.67"	-87°48'45.42"	1873	5,711.63	42°17'33.47"	-87°50'01.70"
323	42°17'33.67"	-87°48'45.42"	1910-11	5,730.38	42°17'33.47"	-87°50'01.95"
323	42°17'33.67"	-87°48'45.42"	1947	5,734.89	42°17'33.46"	-87°50'02.01"
323	42°17'33.67"	-87°48'45.42"	1987	5,772.89	42°17'33.47"	-87°50'02.52"
324	42°17'32.18"	-87°48'45.41"	1873	5,670.12	42°17'31.98"	-87°50'01.14"
324	42°17'32.18"	-87°48'45.41"	1910-11	5,716.88	42°17'31.98"	-87°50'01.76"
324	42°17'32.18"	-87°48'45.41"	1947	5,718.13	42°17'31.98"	-87°50'01.78"
324	42°17'32.18"	-87°48'45.41"	1987	5,736.63	42°17'31.97"	-87°50'02.03"
325	42°17'30.69"	-87°48'45.41"	1873	5,653.36	42°17'30.49"	-87°50'00.92"
325	42°17'30.69"	-87°48'45.41"	1910-11	5,701.62	42°17'30.49"	-87°50'01.56"
325	42°17'30.69"	-87°48'45.41"	1947	5,703.62	42°17'30.49"	-87°50'01.59"
325	42°17'30.69"	-87°48'45.41"	1987	5,664.36	42°17'30.49"	-87°50'01.07"
326	42°17'29.21"	-87°48'45.39"	1873	5,606.60	42°17'29.00"	-87°50'00.27"
326	42°17'29.21"	-87°48'45.39"	1910-11	5,685.62	42°17'29.01"	-87°50'01.33"
326	42°17'29.21"	-87°48'45.39"	1947	5,671.12	42°17'29.00"	-87°50'01.14"
326	42°17'29.21"	-87°48'45.39"	1987	5,626.86	42°17'29.01"	-87°50'00.56"
327	42°17'27.72"	-87°48'45.39"	1873	5,558.34	42°17'27.52"	-87°49'59.63"
327	42°17'27.72"	-87°48'45.39"	1910-11	5,670.61	42°17'27.52"	-87°50'01.13"
327	42°17'27.72"	-87°48'45.39"	1947	5,617.60	42°17'27.52"	-87°50'00.42"
327	42°17'27.72"	-87°48'45.39"	1987	5,600.60	42°17'27.52"	-87°50'00.19"
328	42°17'26.23"	-87°48'45.39"	1873	5,526.83	42°17'26.03"	-87°49'59.20"
328	42°17'26.23"	-87°48'45.39"	1910-11	5,656.61	42°17'26.03"	-87°50'00.94"
328	42°17'26.23"	-87°48'45.39"	1947	5,606.35	42°17'26.03"	-87°50'00.27"
328	42°17'26.23"	-87°48'45.39"	1987	5,651.86	42°17'26.03"	-87°50'00.87"
329	42°17'24.74"	-87°48'45.37"	1873	5,512.83	42°17'24.54"	-87°49'59.01"
329	42°17'24.74"	-87°48'45.37"	1910-11	5,656.36	42°17'24.54"	-87°50'00.92"
329	42°17'24.74"	-87°48'45.37"	1947	5,655.36	42°17'24.54"	-87°50'00.91"
329	42°17'24.74"	-87°48'45.37"	1987	5,628.61	42°17'24.54"	-87°50'00.56"

Appendix K (continued)

Blufflines for Corridor 3 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
330	42°17′23.25"	-87°48′45.37"	1873	5,501.83	42°17′23.06"	-87°49′58.85"
330	42°17′23.25"	-87°48′45.37"	1910-11	5,656.62	42°17′23.05"	-87°50′00.92"
330	42°17′23.25"	-87°48′45.37"	1947	5,593.85	42°17′23.06"	-87°50′00.07"
330	42°17′23.25"	-87°48′45.37"	1987	5,633.36	42°17′23.06"	-87°50′00.61"
331	42°17′21.77"	-87°48′45.35"	1873	5,482.58	42°17′21.57"	-87°49′58.59"
331	42°17′21.77"	-87°48′45.35"	1910-11	5,652.87	42°17′21.56"	-87°50′00.86"
331	42°17′21.77"	-87°48′45.35"	1947	5,616.35	42°17′21.56"	-87°50′00.37"
331	42°17′21.77"	-87°48′45.35"	1987	5,659.37	42°17′21.56"	-87°50′00.94"
332	42°17′20.28"	-87°48′45.35"	1873	5,456.07	42°17′20.09"	-87°49′58.22"
332	42°17′20.28"	-87°48′45.35"	1910-11	5,637.11	42°17′20.08"	-87°50′00.64"
332	42°17′20.28"	-87°48′45.35"	1947	5,592.35	42°17′20.08"	-87°50′00.04"
332	42°17′20.28"	-87°48′45.35"	1987	5,637.61	42°17′20.08"	-87°50′00.66"
333	42°17′18.79"	-87°48′45.35"	1873	5,431.81	42°17′18.60"	-87°49′57.89"
333	42°17′18.79"	-87°48′45.35"	1910-11	5,618.60	42°17′18.59"	-87°50′00.39"
333	42°17′18.79"	-87°48′45.35"	1947	5,606.60	42°17′18.60"	-87°50′00.22"
333	42°17′18.79"	-87°48′45.35"	1987	5,600.85	42°17′18.60"	-87°50′00.14"
334	42°17′17.30"	-87°48′45.34"	1873	5,416.80	42°17′17.11"	-87°49′57.68"
334	42°17′17.30"	-87°48′45.34"	1910-11	5,596.35	42°17′17.11"	-87°50′00.09"
334	42°17′17.30"	-87°48′45.34"	1947	5,540.33	42°17′17.11"	-87°49′59.34"
334	42°17′17.30"	-87°48′45.34"	1987	5,553.09	42°17′17.11"	-87°49′59.50"
335	42°17′15.82"	-87°48′45.33"	1873	5,403.55	42°17′15.62"	-87°49′57.51"
335	42°17′15.82"	-87°48′45.33"	1910-11	5,568.59	42°17′15.61"	-87°49′59.71"
335	42°17′15.82"	-87°48′45.33"	1947	5,546.59	42°17′15.62"	-87°49′59.42"
335	42°17′15.82"	-87°48′45.33"	1987	5,550.09	42°17′15.62"	-87°49′59.46"

Appendix K (continued)

BLUFFLINES FOR CORRIDOR 4

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
401	42°14'50.17"	-87°47'46.29"	1873	5,712.17	42°14'34.66"	-87°48'59.62"
401	42°14'50.17"	-87°47'46.29"	1910-11	5,763.42	42°14'34.52"	-87°49'00.28"
401	42°14'50.17"	-87°47'46.29"	1947	5,790.07	42°14'34.44"	-87°49'00.61"
401	42°14'50.17"	-87°47'46.29"	1987	5,812.22	42°14'34.39"	-87°49'00.90"
402	42°14'48.73"	-87°47'45.74"	1873	5,719.76	42°14'33.20"	-87°48'59.16"
402	42°14'48.73"	-87°47'45.74"	1910-11	5,742.22	42°14'33.14"	-87°48'59.46"
402	42°14'48.73"	-87°47'45.74"	1947	5,791.10	42°14'33.01"	-87°49'00.08"
402	42°14'48.73"	-87°47'45.74"	1987	5,811.19	42°14'32.95"	-87°49'00.34"
403	42°14'47.31"	-87°47'45.19"	1873	5,806.52	42°14'31.54"	-87°48'59.73"
403	42°14'47.31"	-87°47'45.19"	1910-11	5,760.25	42°14'31.67"	-87°48'59.14"
403	42°14'47.31"	-87°47'45.19"	1947	5,798.69	42°14'31.55"	-87°48'59.63"
403	42°14'47.31"	-87°47'45.19"	1987	5,849.38	42°14'31.42"	-87°49'00.28"
404	42°14'45.87"	-87°47'44.65"	1873	***	42°14'28.77"	-87°49'05.51"
404	42°14'45.87"	-87°47'44.65"	1910-11	***	42°14'28.86"	-87°49'05.05"
404	42°14'45.87"	-87°47'44.65"	1947	***	42°14'29.66"	-87°49'01.28"
404	42°14'45.87"	-87°47'44.65"	1987	***	42°14'28.90"	-87°49'04.90"
405	42°14'44.44"	-87°47'44.10"	1873	5,840.21	42°14'28.58"	-87°48'59.07"
405	42°14'44.44"	-87°47'44.10"	1910-11	5,793.47	42°14'28.71"	-87°48'58.46"
405	42°14'44.44"	-87°47'44.10"	1947	***	42°14'27.65"	-87°49'03.48"
405	42°14'44.44"	-87°47'44.10"	1987	***	42°14'27.73"	-87°49'03.08"
406	42°14'43.01"	-87°47'43.55"	1873	5,763.10	42°14'27.36"	-87°48'57.53"
406	42°14'43.01"	-87°47'43.55"	1910-11	5,817.20	42°14'27.22"	-87°48'58.22"
406	42°14'43.01"	-87°47'43.55"	1947	5,835.78	42°14'27.16"	-87°48'58.46"
406	42°14'43.01"	-87°47'43.55"	1987	5,842.03	42°14'27.15"	-87°48'58.54"
407	42°14'41.58"	-87°47'43.00"	1873	5,734.32	42°14'26.01"	-87°48'56.61"
407	42°14'41.58"	-87°47'43.00"	1910-11	5,843.85	42°14'25.71"	-87°48'58.02"
407	42°14'41.58"	-87°47'43.00"	1947	5,859.27	42°14'25.67"	-87°48'58.20"
407	42°14'41.58"	-87°47'43.00"	1987	5,861.64	42°14'25.66"	-87°48'58.24"
408	42°14'40.16"	-87°47'42.44"	1873	5,710.59	42°14'24.65"	-87°48'55.76"
408	42°14'40.16"	-87°47'42.44"	1910-11	5,837.36	42°14'24.30"	-87°48'57.38"
408	42°14'40.16"	-87°47'42.44"	1947	5,847.01	42°14'24.27"	-87°48'57.50"
408	42°14'40.16"	-87°47'42.44"	1987	5,856.97	42°14'24.25"	-87°48'57.64"
409	42°14'38.72"	-87°47'41.91"	1873	5,736.21	42°14'23.15"	-87°48'55.54"
409	42°14'38.72"	-87°47'41.91"	1910-11	5,806.52	42°14'22.95"	-87°48'56.44"
409	42°14'38.72"	-87°47'41.91"	1947	5,814.97	42°14'22.93"	-87°48'56.55"
409	42°14'38.72"	-87°47'41.91"	1987	5,831.11	42°14'22.88"	-87°48'56.75"

Appendix K (continued)

Blufflines for Corridor 4 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
410	42°14'37.29"	-87°47'41.36"	1873	5,717.39	42°14'21.77"	-87°48'54.75"
410	42°14'37.29"	-87°47'41.36"	1910-11	5,779.87	42°14'21.60"	-87°48'55.54"
410	42°14'37.29"	-87°47'41.36"	1947	5,826.92	42°14'21.47"	-87°48'56.15"
410	42°14'37.29"	-87°47'41.36"	1987	5,809.99	42°14'21.51"	-87°48'55.93"
411	42°14'35.86"	-87°47'40.80"	1873	5,703.79	42°14'20.37"	-87°48'54.02"
411	42°14'35.86"	-87°47'40.80"	1910-11	5,779.32	42°14'20.16"	-87°48'54.99"
411	42°14'35.86"	-87°47'40.80"	1947	5,831.59	42°14'20.02"	-87°48'55.66"
411	42°14'35.86"	-87°47'40.80"	1987	5,813.32	42°14'20.07"	-87°48'55.43"
412	42°14'34.43"	-87°47'40.25"	1873	5,695.24	42°14'18.96"	-87°48'53.37"
412	42°14'34.43"	-87°47'40.25"	1910-11	5,773.86	42°14'18.76"	-87°48'54.37"
412	42°14'34.43"	-87°47'40.25"	1947	5,792.20	42°14'18.70"	-87°48'54.61"
412	42°14'34.43"	-87°47'40.25"	1987	5,770.22	42°14'18.76"	-87°48'54.33"
413	42°14'33.00"	-87°47'39.72"	1873	5,754.72	42°14'17.38"	-87°48'53.58"
413	42°14'33.00"	-87°47'39.72"	1910-11	5,821.15	42°14'17.19"	-87°48'54.44"
413	42°14'33.00"	-87°47'39.72"	1947	5,774.89	42°14'17.32"	-87°48'53.83"
413	42°14'33.00"	-87°47'39.72"	1987	5,784.30	42°14'17.29"	-87°48'53.95"
414	42°14'31.57"	-87°47'39.16"	1873	***	42°14'14.20"	-87°49'01.28"
414	42°14'31.57"	-87°47'39.16"	1910-11	***	42°14'14.36"	-87°49'00.50"
414	42°14'31.57"	-87°47'39.16"	1947	***	42°14'14.37"	-87°49'00.46"
414	42°14'31.57"	-87°47'39.16"	1987	***	42°14'14.59"	-87°48'59.43"
415	42°14'30.13"	-87°47'38.61"	1873	5,782.16	42°14'14.44"	-87°48'52.84"
415	42°14'30.13"	-87°47'38.61"	1910-11	5,838.87	42°14'14.28"	-87°48'53.56"
415	42°14'30.13"	-87°47'38.61"	1947	5,767.53	42°14'14.48"	-87°48'52.65"
415	42°14'30.13"	-87°47'38.61"	1987	5,786.12	42°14'14.42"	-87°48'52.89"
416	42°14'28.71"	-87°47'38.07"	1873	5,785.56	42°14'12.99"	-87°48'52.34"
416	42°14'28.71"	-87°47'38.07"	1910-11	5,852.78	42°14'12.81"	-87°48'53.20"
416	42°14'28.71"	-87°47'38.07"	1947	5,786.67	42°14'12.99"	-87°48'52.35"
416	42°14'28.71"	-87°47'38.07"	1987	5,815.14	42°14'12.91"	-87°48'52.72"
417	42°14'27.27"	-87°47'37.52"	1873	5,792.37	42°14'11.55"	-87°48'51.87"
417	42°14'27.27"	-87°47'37.52"	1910-11	5,870.02	42°14'11.33"	-87°48'52.86"
417	42°14'27.27"	-87°47'37.52"	1947	5,803.67	42°14'11.51"	-87°48'52.02"
417	42°14'27.27"	-87°47'37.52"	1987	5,810.16	42°14'11.50"	-87°48'52.10"
418	42°14'25.85"	-87°47'36.97"	1873	5,841.55	42°14'09.98"	-87°48'51.95"
418	42°14'25.85"	-87°47'36.97"	1910-11	5,869.31	42°14'09.91"	-87°48'52.31"
418	42°14'25.85"	-87°47'36.97"	1947	***	42°14'09.11"	-87°48'56.08"
418	42°14'25.85"	-87°47'36.97"	1987	***	42°14'08.86"	-87°48'57.25"
419	42°14'24.41"	-87°47'36.42"	1873	***	42°14'06.95"	-87°48'58.95"
419	42°14'24.41"	-87°47'36.42"	1910-11	***	42°14'08.23"	-87°48'52.93"
419	42°14'24.41"	-87°47'36.42"	1947	***	42°14'07.08"	-87°48'58.39"
419	42°14'24.41"	-87°47'36.42"	1987	***	42°14'07.43"	-87°48'56.70"

Appendix K (continued)

Blufflines for Corridor 4 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
420	42°14'22.98"	-87°47'35.87"	1873	5,811.74	42°14'07.21"	-87°48'50.47"
420	42°14'22.98"	-87°47'35.87"	1910-11	***	42°14'06.12"	-87°48'55.62"
420	42°14'22.98"	-87°47'35.87"	1947	5,879.67	42°14'07.02"	-87°48'51.34"
420	42°14'22.98"	-87°47'35.87"	1987	5,890.35	42°14'06.99"	-87°48'51.49"
421	42°14'21.55"	-87°47'35.33"	1873	5,840.45	42°14'05.69"	-87°48'50.29"
421	42°14'21.55"	-87°47'35.33"	1910-11	6,053.18	42°14'05.12"	-87°48'53.03"
421	42°14'21.55"	-87°47'35.33"	1947	5,898.73	42°14'05.54"	-87°48'51.04"
421	42°14'21.55"	-87°47'35.33"	1987	5,882.21	42°14'05.58"	-87°48'50.83"
422	42°14'20.12"	-87°47'34.78"	1873	5,836.88	42°14'04.27"	-87°48'49.70"
422	42°14'20.12"	-87°47'34.78"	1910-11	6,025.17	42°14'03.76"	-87°48'52.12"
422	42°14'20.12"	-87°47'34.78"	1947	5,901.18	42°14'04.10"	-87°48'50.52"
422	42°14'20.12"	-87°47'34.78"	1987	5,905.06	42°14'04.09"	-87°48'50.57"
423	42°14'18.70"	-87°47'34.23"	1873	5,828.26	42°14'02.86"	-87°48'49.04"
423	42°14'18.70"	-87°47'34.23"	1910-11	5,980.89	42°14'02.45"	-87°48'51.00"
423	42°14'18.70"	-87°47'34.23"	1947	5,896.75	42°14'02.67"	-87°48'49.91"
423	42°14'18.70"	-87°47'34.23"	1987	5,901.66	42°14'02.67"	-87°48'49.98"
424	42°14'17.26"	-87°47'33.68"	1873	5,818.78	42°14'01.46"	-87°48'48.37"
424	42°14'17.26"	-87°47'33.68"	1910-11	5,920.40	42°14'01.18"	-87°48'49.67"
424	42°14'17.26"	-87°47'33.68"	1947	5,868.99	42°14'01.32"	-87°48'49.01"
424	42°14'17.26"	-87°47'33.68"	1987	5,860.06	42°14'01.35"	-87°48'48.91"
425	42°14'15.82"	-87°47'33.14"	1873	5,811.19	42°14'00.05"	-87°48'47.72"
425	42°14'15.82"	-87°47'33.14"	1910-11	5,892.56	42°13'59.82"	-87°48'48.77"
425	42°14'15.82"	-87°47'33.14"	1947	5,845.19	42°13'59.95"	-87°48'48.17"
425	42°14'15.82"	-87°47'33.14"	1987	5,859.03	42°13'59.91"	-87°48'48.34"
426	42°14'14.40"	-87°47'32.59"	1873	5,801.85	42°13'58.65"	-87°48'47.05"
426	42°14'14.40"	-87°47'32.59"	1910-11	5,887.58	42°13'58.41"	-87°48'48.15"
426	42°14'14.40"	-87°47'32.59"	1947	5,812.53	42°13'58.62"	-87°48'47.20"
426	42°14'14.40"	-87°47'32.59"	1987	5,835.54	42°13'58.55"	-87°48'47.49"
427	42°14'12.96"	-87°47'32.04"	1873	5,769.67	42°13'57.29"	-87°48'46.10"
427	42°14'12.96"	-87°47'32.04"	1910-11	5,866.86	42°13'57.03"	-87°48'47.35"
427	42°14'12.96"	-87°47'32.04"	1947	5,816.41	42°13'57.17"	-87°48'46.70"
427	42°14'12.96"	-87°47'32.04"	1987	5,822.18	42°13'57.16"	-87°48'46.77"
428	42°14'11.53"	-87°47'31.49"	1873	5,750.37	42°13'55.92"	-87°48'45.30"
428	42°14'11.53"	-87°47'31.49"	1910-11	5,888.84	42°13'55.54"	-87°48'47.08"
428	42°14'11.53"	-87°47'31.49"	1947	5,839.49	42°13'55.68"	-87°48'46.45"
428	42°14'11.53"	-87°47'31.49"	1987	5,855.70	42°13'55.64"	-87°48'46.65"
429	42°14'10.10"	-87°47'30.95"	1873	5,741.43	42°13'54.52"	-87°48'44.65"
429	42°14'10.10"	-87°47'30.95"	1910-11	5,893.83	42°13'54.10"	-87°48'46.59"
429	42°14'10.10"	-87°47'30.95"	1947	5,851.99	42°13'54.21"	-87°48'46.06"
429	42°14'10.10"	-87°47'30.95"	1987	5,830.32	42°13'54.27"	-87°48'45.79"

Appendix K (continued)

Blufflines for Corridor 4 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
430	42°14'08.67"	-87°47'30.40"	1873	5,734.39	42°13'53.10"	-87°48'44.00"
430	42°14'08.67"	-87°47'30.40"	1910-11	5,905.06	42°13'52.64"	-87°48'46.19"
430	42°14'08.67"	-87°47'30.40"	1947	5,844.16	42°13'52.80"	-87°48'45.41"
430	42°14'08.67"	-87°47'30.40"	1987	5,845.26	42°13'52.80"	-87°48'45.42"
431	42°14'07.25"	-87°47'29.85"	1873	5,728.14	42°13'51.69"	-87°48'43.37"
431	42°14'07.25"	-87°47'29.85"	1910-11	5,916.05	42°13'51.18"	-87°48'45.78"
431	42°14'07.25"	-87°47'29.85"	1947	***	42°13'51.09"	-87°48'46.21"
431	42°14'07.25"	-87°47'29.85"	1987	***	42°13'51.12"	-87°48'46.03"
432	42°14'05.81"	-87°47'29.30"	1873	5,749.10	42°13'50.20"	-87°48'43.09"
432	42°14'05.81"	-87°47'29.30"	1910-11	5,921.34	42°13'49.74"	-87°48'45.30"
432	42°14'05.81"	-87°47'29.30"	1947	5,878.72	42°13'49.85"	-87°48'44.75"
432	42°14'05.81"	-87°47'29.30"	1987	5,935.18	42°13'49.70"	-87°48'45.47"
433	42°14'04.38"	-87°47'28.76"	1873	5,769.67	42°13'48.72"	-87°48'42.80"
433	42°14'04.38"	-87°47'28.76"	1910-11	5,927.52	42°13'48.29"	-87°48'44.83"
433	42°14'04.38"	-87°47'28.76"	1947	5,881.25	42°13'48.41"	-87°48'44.24"
433	42°14'04.38"	-87°47'28.76"	1987	5,989.99	42°13'48.11"	-87°48'45.63"
434	42°14'02.95"	-87°47'28.21"	1873	5,781.69	42°13'47.25"	-87°48'42.41"
434	42°14'02.95"	-87°47'28.21"	1910-11	5,926.73	42°13'46.85"	-87°48'44.28"
434	42°14'02.95"	-87°47'28.21"	1947	5,900.63	42°13'46.93"	-87°48'43.94"
434	42°14'02.95"	-87°47'28.21"	1987	5,993.63	42°13'46.68"	-87°48'45.14"
435	42°14'01.52"	-87°47'27.66"	1873	5,786.43	42°13'45.81"	-87°48'41.93"
435	42°14'01.52"	-87°47'27.66"	1910-11	5,910.73	42°13'45.46"	-87°48'43.52"
435	42°14'01.52"	-87°47'27.66"	1947	5,922.61	42°13'45.44"	-87°48'43.67"
435	42°14'01.52"	-87°47'27.66"	1987	5,979.31	42°13'45.29"	-87°48'44.40"

Appendix K (continued)

BLUFFLINES FOR CORRIDOR 5

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
501	42°11'36.35"	-87°46'01.47"	1873	5,581.14	42°11'08.19"	-87°47'05.56"
501	42°11'36.35"	-87°46'01.47"	1910-11	5,649.15	42°11'07.86"	-87°47'06.35"
501	42°11'36.35"	-87°46'01.47"	1947	5,656.56	42°11'07.82"	-87°47'06.43"
501	42°11'36.35"	-87°46'01.47"	1987	5,682.72	42°11'07.68"	-87°47'06.72"
502	42°11'35.07"	-87°46'00.47"	1873	5,567.21	42°11'06.99"	-87°47'04.39"
502	42°11'35.07"	-87°46'00.47"	1910-11	5,658.58	42°11'06.52"	-87°47'05.43"
502	42°11'35.07"	-87°46'00.47"	1947	5,626.59	42°11'06.69"	-87°47'05.07"
502	42°11'35.07"	-87°46'00.47"	1987	5,685.85	42°11'06.39"	-87°47'05.76"
503	42°11'33.79"	-87°45'59.45"	1873	5,514.68	42°11'05.97"	-87°47'02.77"
503	42°11'33.79"	-87°45'59.45"	1910-11	5,651.29	42°11'05.28"	-87°47'04.33"
503	42°11'33.79"	-87°45'59.45"	1947	5,630.75	42°11'05.38"	-87°47'04.10"
503	42°11'33.79"	-87°45'59.45"	1987	5,669.47	42°11'05.19"	-87°47'04.55"
504	42°11'32.51"	-87°45'58.42"	1873	5,501.56	42°11'04.75"	-87°47'01.60"
504	42°11'32.51"	-87°45'58.42"	1910-11	5,614.03	42°11'04.19"	-87°47'02.89"
504	42°11'32.51"	-87°45'58.42"	1947	5,621.11	42°11'04.15"	-87°47'02.97"
504	42°11'32.51"	-87°45'58.42"	1987	5,646.02	42°11'04.02"	-87°47'03.26"
505	42°11'31.23"	-87°45'57.40"	1873	5,505.81	42°11'03.45"	-87°47'00.63"
505	42°11'31.23"	-87°45'57.40"	1910-11	5,571.92	42°11'03.11"	-87°47'01.39"
505	42°11'31.23"	-87°45'57.40"	1947	5,605.15	42°11'02.95"	-87°47'01.76"
505	42°11'31.23"	-87°45'57.40"	1987	5,666.90	42°11'02.63"	-87°47'02.48"
506	42°11'29.94"	-87°45'56.40"	1873	5,513.57	42°11'02.13"	-87°46'59.70"
506	42°11'29.94"	-87°45'56.40"	1910-11	5,559.02	42°11'01.90"	-87°47'00.23"
506	42°11'29.94"	-87°45'56.40"	1947	5,602.24	42°11'01.69"	-87°47'00.71"
506	42°11'29.94"	-87°45'56.40"	1987	5,614.80	42°11'01.62"	-87°47'00.86"
507	42°11'28.66"	-87°45'55.37"	1873	5,516.83	42°11'00.83"	-87°46'58.71"
507	42°11'28.66"	-87°45'55.37"	1910-11	5,557.00	42°11'00.63"	-87°46'59.18"
507	42°11'28.66"	-87°45'55.37"	1947	5,581.91	42°11'00.51"	-87°46'59.46"
507	42°11'28.66"	-87°45'55.37"	1987	5,640.40	42°11'00.21"	-87°47'00.14"
508	42°11'27.38"	-87°45'54.35"	1873	5,512.67	42°10'59.57"	-87°46'57.65"
508	42°11'27.38"	-87°45'54.35"	1910-11	5,572.27	42°10'59.27"	-87°46'58.33"
508	42°11'27.38"	-87°45'54.35"	1947	5,578.79	42°10'59.24"	-87°46'58.42"
508	42°11'27.38"	-87°45'54.35"	1987	5,641.30	42°10'58.93"	-87°46'59.13"
509	42°11'26.10"	-87°45'53.33"	1873	5,497.27	42°10'58.37"	-87°46'56.46"
509	42°11'26.10"	-87°45'53.33"	1910-11	5,574.28	42°10'57.98"	-87°46'57.34"
509	42°11'26.10"	-87°45'53.33"	1947	5,591.56	42°10'57.89"	-87°46'57.54"
509	42°11'26.10"	-87°45'53.33"	1987	5,656.43	42°10'57.56"	-87°46'58.28"

Appendix K (continued)

Blufflines for Corridor 5 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
510	42°11'24.83"	-87°45'52.33"	1873	5,486.51	42°10'57.15"	-87°46'55.32"
510	42°11'24.83"	-87°45'52.33"	1910-11	5,569.70	42°10'56.72"	-87°46'56.27"
510	42°11'24.83"	-87°45'52.33"	1947	5,582.26	42°10'56.67"	-87°46'56.41"
510	42°11'24.83"	-87°45'52.33"	1987	5,649.28	42°10'56.32"	-87°46'57.18"
511	42°11'23.54"	-87°45'51.30"	1873	5,486.51	42°10'55.86"	-87°46'54.30"
511	42°11'23.54"	-87°45'51.30"	1910-11	5,568.32	42°10'55.45"	-87°46'55.24"
511	42°11'23.54"	-87°45'51.30"	1947	5,579.56	42°10'55.39"	-87°46'55.37"
511	42°11'23.54"	-87°45'51.30"	1987	5,637.14	42°10'55.10"	-87°46'56.03"
512	42°11'22.26"	-87°45'50.28"	1873	5,495.55	42°10'54.54"	-87°46'53.39"
512	42°11'22.26"	-87°45'50.28"	1910-11	5,568.11	42°10'54.17"	-87°46'54.22"
512	42°11'22.26"	-87°45'50.28"	1947	5,598.98	42°10'54.01"	-87°46'54.57"
512	42°11'22.26"	-87°45'50.28"	1987	5,637.14	42°10'53.82"	-87°46'55.01"
513	42°11'20.98"	-87°45'49.28"	1873	5,499.07	42°10'53.24"	-87°46'52.41"
513	42°11'20.98"	-87°45'49.28"	1910-11	5,568.80	42°10'52.89"	-87°46'53.22"
513	42°11'20.98"	-87°45'49.28"	1947	5,602.80	42°10'52.72"	-87°46'53.61"
513	42°11'20.98"	-87°45'49.28"	1987	5,633.32	42°10'52.56"	-87°46'53.96"
514	42°11'19.70"	-87°45'48.26"	1873	5,489.43	42°10'52.01"	-87°46'51.28"
514	42°11'19.70"	-87°45'48.26"	1910-11	5,555.55	42°10'51.67"	-87°46'52.03"
514	42°11'19.70"	-87°45'48.26"	1947	5,598.42	42°10'51.45"	-87°46'52.53"
514	42°11'19.70"	-87°45'48.26"	1987	5,634.23	42°10'51.28"	-87°46'52.94"
515	42°11'18.41"	-87°45'47.23"	1873	5,485.05	42°10'50.75"	-87°46'50.22"
515	42°11'18.41"	-87°45'47.23"	1910-11	5,574.28	42°10'50.29"	-87°46'51.24"
515	42°11'18.41"	-87°45'47.23"	1947	5,616.95	42°10'50.08"	-87°46'51.73"
515	42°11'18.41"	-87°45'47.23"	1987	5,658.58	42°10'49.87"	-87°46'52.21"
516	42°11'17.13"	-87°45'46.21"	1873	***	42°10'46.71"	-87°46'55.47"
516	42°11'17.13"	-87°45'46.21"	1910-11	***	42°10'45.95"	-87°46'57.19"
516	42°11'17.13"	-87°45'46.21"	1947	5,620.76	42°10'48.78"	-87°46'50.76"
516	42°11'17.13"	-87°45'46.21"	1987	***	42°10'45.17"	-87°46'58.96"
517	42°11'15.86"	-87°45'45.21"	1873	***	42°10'45.48"	-87°46'54.35"
517	42°11'15.86"	-87°45'45.21"	1910-11	***	42°10'44.71"	-87°46'56.09"
517	42°11'15.86"	-87°45'45.21"	1947	***	42°10'44.47"	-87°46'56.63"
517	42°11'15.86"	-87°45'45.21"	1987	***	42°10'43.89"	-87°46'57.97"
518	42°11'14.57"	-87°45'44.19"	1873	***	42°10'44.24"	-87°46'53.24"
518	42°11'14.57"	-87°45'44.19"	1910-11	***	42°10'43.47"	-87°46'54.98"
518	42°11'14.57"	-87°45'44.19"	1947	***	42°10'43.19"	-87°46'55.61"
518	42°11'14.57"	-87°45'44.19"	1987	***	42°10'42.60"	-87°46'56.96"
519	42°11'13.30"	-87°45'43.16"	1873	5,614.03	42°10'44.98"	-87°46'47.62"
519	42°11'13.30"	-87°45'43.16"	1910-11	5,753.56	42°10'44.27"	-87°46'49.22"
519	42°11'13.30"	-87°45'43.16"	1947	5,701.59	42°10'44.53"	-87°46'48.63"
519	42°11'13.30"	-87°45'43.16"	1987	5,731.77	42°10'44.38"	-87°46'48.98"

Appendix K (continued)

Blufflines for Corridor 5 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
520	42°11'12.01"	-87°45'42.14"	1873	5,660.64	42°10'43.45"	-87°46'47.13"
520	42°11'12.01"	-87°45'42.14"	1910-11	5,702.36	42°10'43.25"	-87°46'47.62"
520	42°11'12.01"	-87°45'42.14"	1947	5,765.56	42°10'42.93"	-87°46'48.35"
520	42°11'12.01"	-87°45'42.14"	1987	5,762.30	42°10'42.94"	-87°46'48.31"
521	42°11'10.73"	-87°45'41.14"	1873	5,523.21	42°10'42.87"	-87°46'44.55"
521	42°11'10.73"	-87°45'41.14"	1910-11	5,700.56	42°10'41.97"	-87°46'46.58"
521	42°11'10.73"	-87°45'41.14"	1947	5,635.34	42°10'42.30"	-87°46'45.83"
521	42°11'10.73"	-87°45'41.14"	1987	5,682.59	42°10'42.06"	-87°46'46.38"
522	42°11'09.44"	-87°45'40.12"	1873	5,570.81	42°10'41.34"	-87°46'44.08"
522	42°11'09.44"	-87°45'40.12"	1910-11	5,739.06	42°10'40.50"	-87°46'46.01"
522	42°11'09.44"	-87°45'40.12"	1947	5,709.09	42°10'40.65"	-87°46'45.66"
522	42°11'09.44"	-87°45'40.12"	1987	5,768.90	42°10'40.35"	-87°46'46.35"
523	42°11'08.17"	-87°45'39.09"	1873	5,603.35	42°10'39.91"	-87°46'43.44"
523	42°11'08.17"	-87°45'39.09"	1910-11	***	42°10'37.39"	-87°46'49.17"
523	42°11'08.17"	-87°45'39.09"	1947	***	42°10'38.75"	-87°46'46.04"
523	42°11'08.17"	-87°45'39.09"	1987	***	42°10'36.76"	-87°46'50.58"
524	42°11'06.89"	-87°45'38.09"	1873	5,602.24	42°10'38.63"	-87°46'42.40"
524	42°11'06.89"	-87°45'38.09"	1910-11	5,644.22	42°10'38.42"	-87°46'42.89"
524	42°11'06.89"	-87°45'38.09"	1947	5,644.90	42°10'38.41"	-87°46'42.89"
524	42°11'06.89"	-87°45'38.09"	1987	5,699.44	42°10'38.14"	-87°46'43.52"
525	42°11'05.60"	-87°45'37.07"	1873	5,598.77	42°10'37.37"	-87°46'41.34"
525	42°11'05.60"	-87°45'37.07"	1910-11	5,649.28	42°10'37.11"	-87°46'41.92"
525	42°11'05.60"	-87°45'37.07"	1947	5,663.98	42°10'37.03"	-87°46'42.10"
525	42°11'05.60"	-87°45'37.07"	1987	5,729.20	42°10'36.70"	-87°46'42.84"
526	42°11'04.33"	-87°45'36.05"	1873	5,590.23	42°10'36.12"	-87°46'40.23"
526	42°11'04.33"	-87°45'36.05"	1910-11	5,662.40	42°10'35.77"	-87°46'41.06"
526	42°11'04.33"	-87°45'36.05"	1947	5,663.98	42°10'35.76"	-87°46'41.08"
526	42°11'04.33"	-87°45'36.05"	1987	5,705.96	42°10'35.54"	-87°46'41.56"
527	42°11'03.04"	-87°45'35.03"	1873	5,626.04	42°10'34.66"	-87°46'39.62"
527	42°11'03.04"	-87°45'35.03"	1910-11	5,666.56	42°10'34.46"	-87°46'40.09"
527	42°11'03.04"	-87°45'35.03"	1947	5,650.05	42°10'34.54"	-87°46'39.91"
527	42°11'03.04"	-87°45'35.03"	1987	***	42°10'33.30"	-87°46'42.74"
528	42°11'01.76"	-87°45'34.02"	1873	***	42°10'31.69"	-87°46'42.46"
528	42°11'01.76"	-87°45'34.02"	1910-11	5,651.85	42°10'33.26"	-87°46'38.90"
528	42°11'01.76"	-87°45'34.02"	1947	5,669.47	42°10'33.17"	-87°46'39.10"
528	42°11'01.76"	-87°45'34.02"	1987	5,721.78	42°10'32.90"	-87°46'39.71"
529	42°11'00.48"	-87°45'33.00"	1873	5,561.72	42°10'32.42"	-87°46'36.85"
529	42°11'00.48"	-87°45'33.00"	1910-11	5,650.73	42°10'31.98"	-87°46'37.88"
529	42°11'00.48"	-87°45'33.00"	1947	5,655.80	42°10'31.95"	-87°46'37.93"
529	42°11'00.48"	-87°45'33.00"	1987	5,726.84	42°10'31.60"	-87°46'38.75"

Appendix K (continued)

Blufflines for Corridor 5 (continued)

Transect Code	Latitude and Longitude of Spine-Transect Intersect		Year(s)	Distance (feet)	Latitude and Longitude of Transect-Shoreline Intersect	
530	42°10'59.20"	-87°45'31.98"	1873	5,527.80	42°10'31.32"	-87°46'35.44"
530	42°10'59.20"	-87°45'31.98"	1910-11	5,646.79	42°10'30.72"	-87°46'36.82"
530	42°10'59.20"	-87°45'31.98"	1947	5,674.40	42°10'30.58"	-87°46'37.13"
530	42°10'59.20"	-87°45'31.98"	1987	5,710.89	42°10'30.39"	-87°46'37.54"
531	42°10'57.92"	-87°45'30.96"	1873	5,528.49	42°10'30.04"	-87°46'34.43"
531	42°10'57.92"	-87°45'30.96"	1910-11	5,628.95	42°10'29.53"	-87°46'35.59"
531	42°10'57.92"	-87°45'30.96"	1947	5,651.29	42°10'29.41"	-87°46'35.85"
531	42°10'57.92"	-87°45'30.96"	1987	5,703.95	42°10'29.14"	-87°46'36.44"
532	42°10'56.64"	-87°45'29.95"	1873	5,532.99	42°10'28.72"	-87°46'33.47"
532	42°10'56.64"	-87°45'29.95"	1910-11	5,648.38	42°10'28.15"	-87°46'34.79"
532	42°10'56.64"	-87°45'29.95"	1947	5,645.25	42°10'28.16"	-87°46'34.76"
532	42°10'56.64"	-87°45'29.95"	1987	5,690.14	42°10'27.94"	-87°46'35.27"
533	42°10'55.36"	-87°45'28.93"	1873	5,534.32	42°10'27.44"	-87°46'32.47"
533	42°10'55.36"	-87°45'28.93"	1910-11	5,638.81	42°10'26.91"	-87°46'33.67"
533	42°10'55.36"	-87°45'28.93"	1947	5,640.83	42°10'26.90"	-87°46'33.69"
533	42°10'55.36"	-87°45'28.93"	1987	5,671.49	42°10'26.75"	-87°46'34.04"
534	42°10'54.07"	-87°45'27.91"	1873	5,531.06	42°10'26.18"	-87°46'31.41"
534	42°10'54.07"	-87°45'27.91"	1910-11	5,618.62	42°10'25.73"	-87°46'32.42"
534	42°10'54.07"	-87°45'27.91"	1947	5,620.63	42°10'25.72"	-87°46'32.44"
534	42°10'54.07"	-87°45'27.91"	1987	5,669.68	42°10'25.47"	-87°46'33.00"
535	42°10'52.80"	-87°45'26.89"	1873	5,514.34	42°10'24.98"	-87°46'30.20"
535	42°10'52.80"	-87°45'26.89"	1910-11	5,606.06	42°10'24.52"	-87°46'31.25"
535	42°10'52.80"	-87°45'26.89"	1947	5,582.81	42°10'24.63"	-87°46'30.98"
535	42°10'52.80"	-87°45'26.89"	1987	5,649.49	42°10'24.30"	-87°46'31.75"