



U.S. Army Corps of Engineers - Detroit District

LAKE MICHIGAN POTENTIAL DAMAGES STUDY

PROGRESS REPORT ON ACTIVITIES 1996-1998



U.S. Army Corps of Engineers - Detroit District
477 Michigan Ave., 6th Floor
Detroit, Michigan
48231
Phone: (313) 226-3054
Fax: (313) 226-2398

Progress Report Compiled and Edited By:

VGI VISION GROUP INTERNATIONAL INC.
5325 Cordova Bay Road, Suite 211, Victoria, BC, V8N 5P4
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1.0 Introduction

1.1 Background



Figure 1 - Lake Michigan

international and regional entities (the International Joint Commission (IJC) and Great Lakes Commission) state agencies (including Illinois, Indiana, Michigan and Wisconsin), and academic institutions (Sea Grant Universities, etc.).

1.2 Objectives

The IJC Great Lakes Levels Reference Study recommended that the economic value of all shoreline interests be objectively assessed in terms of "potential damages" (International Joint Commission, 1993). Potential damages were defined as those that may occur under differing hydrologic conditions or alternate management approaches to lake level controls. This approach differs from previous damage surveys conducted in the 1970's that were limited to actual losses under a specific extreme lake level condition. The LMPDS is designed to examine potential damages that may occur if Lake Michigan

The U.S. Army Corps of Engineers (USACE) Detroit District and key cooperators have initiated and are currently conducting a Lake Michigan Potential Damages Study (LMPDS) which will provide an extensive assessment of potential shoreline damages due to changes in Lake Michigan water levels over the next 50 years. Initiated in October of 1996, and expected to be completed in the year 2000, the study ultimately will satisfy several key recommendations of the 1986-1993 International Joint Commission Great Lakes Levels Reference Study (International Joint Commission, 1993).

The LMPDS is potentially the first in a series of similar assessments of potential damages for all US Great Lakes' shorelines. Lake Michigan was chosen as a pilot study because it has severe erosion problems and experienced the most damage during the previous high water periods in the 1970s and 1980s.

LMPDS participants include representatives from USACE, other US federal agencies,

water levels are higher or lower than those recorded over the last 120 years.

The objective of the LMPDS is to create a modeling procedure for estimating economic effects of lake level changes and related social, environmental, and cultural impacts. The LMPDS modeling approaches are expected to be the framework for economic assessments for each of the other Great Lakes. The LMPDS is also intended to be a forum for concerted information system development between international, federal, state, county, township and municipal governance about the resource base that is commonly shared.

The LMPDS will address all economic factors in the coastal zone surrounding Lake Michigan, including coastlines, embayments, interconnected lake bodies and rivers directly affected by the ranges of water levels defined in the study. Economic effects will be assessed for residential, commercial, industrial, institutional uses and will include recreational boating, municipal water supply and wastewater treatment, and navigation within the confines of the coastal zone.

The environmental consequences of extreme lake level fluctuations are also expected to be briefly addressed. These include impacts to fisheries, habitat diversity, endangered and threatened species and archaeological and special natural features.

The IJC study also had several other recommendations that the Lake Michigan Potential Damage Study is attempting to address. These include initiation of coastal erosion monitoring programs, updating of coastal process research, updating of land use information and development of effective public information programs.

It is important to note that a secondary objective of the LMPDS is the development of a state-of-the-art Coastal Zone Management (CZM) tool. The CZM utility of the LMPDS system is a result of the requirements to predict erosion and flooding on a lakewide basis. It is also a necessary utility to assess the potential implication of CZM responses to future "what if" scenarios on potential damages. For example, higher lake levels may trigger increased construction of shoreline protection and this may in turn exacerbate erosion in adjacent unprotected areas. The question is whether CZM policy instruments be able to influence the riparian response to higher lake levels (presumably for the benefit of all). The CZM utility of the LMPDS system includes: automated lakewide assessment of sand supply and sediment budget; automated assessment of the influence of shore protection structures on a local and regional basis; and setback planning for erosion and flooding as they may be related to changing conditions in the future. The development of improved CZM was a key recommendation of the IJC Levels Reference Study.

1.3 The Study Area

The study area for the LMPDS incorporates the entire 2436 kilometers of Lake Michigan shoreline, beginning and ending at the Straits of Mackinaw and the Mackinaw Bridge (Figure 1). Impacts and associated potential damage issues will also be examined for areas extending inland, particularly for some of the larger drowned river mouths along the eastern shoreline of the lake (e.g., Lake Macatawa). Islands will also be examined (e.g., Beaver Island) as many of these are becoming heavily developed with seasonal and year-round residences. For the examination of coastal process issues and shoreline classification, it will also be important to take into account the offshore areas to determine water depths, nearshore composition and the amount of sand cover and sand transport that is occurring.

1.4 Study Scope Limits

The scope of the LMPDS will be decided by a series of factors:

Planning Horizons - Generally speaking, the LMPDS will address impacts and potential damages that may occur over the next 50 year period (i.e. to 2050). Study Team members have discussed extending the analysis further, but have not reached any final decisions on this topic. This is anticipated to be finalized in 1999.

Geologic Perspective on Water Level Fluctuations - Evidence exists that water levels have been much higher and much lower than what has been experienced in the past 140 years since water levels have been recorded. The lakes may actually be at the bottom of a longer duration lower water cycle and could be destined for much higher levels in the next 140 years. Further information on this matter needs to be collected and used in the development of hydrologic scenarios contemplated for evaluation in the LMPDS.

Hydrologic and Water Level Control Scenarios - The number of hydrologic and water level control scenarios that are going to be examined will strongly influence the level of effort and resources required to conduct associated impact analyses. Presently the LMPDS Study Team has made a very preliminary recommendation of 16 different alternative *hydrologic scenarios*. No water level *control scenarios* have been developed yet, but the number here may be restricted given IJC Water Level Reference Study recommendations regarding acceptable control scenarios and structures.

Backwater and Storm Water Rise Determinations - There are many areas that are influenced by the water levels in Lake Michigan and it will be necessary to determine the upstream limits of these impacts, as well as their spatial extent along the rivers. A wide variety of interest groups exist in these areas including, riparian home owners, recreational facilities, industrial facilities and public infrastructure among others. Similarly, the inland extent to which *storm* water levels affect these backwater areas, as well as low-lying shoreline areas, will also need to be determined.

1.5 Format of this Report

This report will provide a concise summary of the key tasks completed over the course of 1996 to 1998, the first two years of the study. Information will also be provided on the key tasks remaining to be completed. A series of items to be considered for the next stages of the study are then presented along with some key preliminary findings.

2.0 Organizational Activities

2.1 Study Objectives and Scoping

Key study objectives were presented in the introduction to this report. Most key facets of the study have been coordinated with and agreed to by the study participants to date. It is recognized that an ongoing review of the scope of work will need to continue throughout the life span of the study. This is necessary since the level of complexity (or detail) of the study is dependant upon the types and extent of the results accomplished for various study tasks. Continual review of the study scope is also necessary since overall limiting forces (available manpower, funding, and time and other mandates) can change over time.

Development of the study objectives and scoping has been predominately accomplished by USACE, Detroit District personnel. Critical input has also been provided from staff of the USACE Great Lakes Regional Office (GLRO) and Waterways Experiment Station (WES), International Joint Commission (IJC), Environment Canada (EC), other U.S. and Canadian federal agencies and, of utmost importance, from input from staff of participating state agencies and academic institutions. Further, the development of a sound economic assessment of the broad impacts of lake level fluctuations will be reliant upon the input of local authorities, whenever possible.

Study objectives have been coordinated with study team and advisory group members at four previous meetings (November 1996, January 1997, September 1997, and October 1998). Coordination activities with the study team and associated advisory members will continue throughout the remainder of the study timeline. It is anticipated that the next periodic meeting will be in the spring or early summer of 1999. The role and utility of the study's products for emerging IJC requirements for review of the Lake Superior regulation plan will likely have direct and material impact on the objectives of study activities.

2.2 Organization of the Study Team

The organization of the study team was completed in early 1997 and consists of key personnel required to make recurring decisions on the scope of study activities and on the allocation of resources. The study team includes key management personnel from the agencies directly responsible for the completion of the study. An advisory body, including staff members from other federal agencies, affected state organizations, and academic institutions has also been established and has provided review and comment on study approaches, activities, results, and recommendations. The study team and advisory group met four times at the Detroit District's offices in November 1996, January 1997, September 1997, and October 1998. Study plans have been reviewed and endorsed, 1998-99 tasks are being determined and corresponding funding is being budgeted. The next periodic broad study meeting will likely be in the spring or early summer of 1999.

2.3 Development of Task Lists and Plan of Study

A series of individual task statements has been prepared by the Study Team to address the multiple activities and components of the study that need to be carried out. Each of these task statements includes assessments of time and cost estimates, and a discussion of the programming and allocation of adequate funding and human resources. The task statements, along with the study objectives have been combined to form a draft Plan of Study for the project. The Plan of Study is a document that will serve as the guiding document over the course of the Study. It is a "living" document in the sense that it is evolving and will be refined as Tasks are completed.

The most recent version of the Plan of Study is dated July 1998. It is available as a downloadable file in Word format, or in HTML version from the LMPDS WWW Page (see below).

2.4 LMPDS World Wide Web Page

A World Wide Web page for the Lake Michigan Potential Damages Study has been developed in order to provide the Great Lakes community and the general public with information on the study. The WWW page may be viewed at:

<http://www.vgivision.com>

Changes to the page are expected to continue as the study proceeds. Comments and suggestions for additional information may be provided to Mr. Chris Stewart via e-mail at **cstewart@vgivision.com**.

3.0 Geographic Information System (GIS) Activities

Geographical Information Systems (GIS) will be a key analysis, and decision making tool in the Potential Damages Study. There are 6 key GIS activities that are being conducted for the LMPDS. These include:

- Design GIS Structure and Great Lakes GIS Strategy
- Coordinate Development of Digital Orthophoto Base
- Develop Historic Digital Orthophotos
- Coordinate Development of Base Maps
- Facilitate Development of Digital Parcel Mapping
- Consolidate Elevation Data

The GIS Structure and Strategy is being developed by PlanGraphics and GRW Engineering for USACE Detroit. The work being performed is summarized here. The latter 5 items highlighted above (Digital Orthophotos, Base Maps, Digital Parcel Mapping and Elevation Data) are partially being addressed through work conducted by the University of Wisconsin under contract to USACE Detroit. A summary of this work is presented here under "Acquisition and Integration of Large Scale Spatial Data." USACE Detroit is also conducting significant components of these tasks using in-house personnel.

In addition to the above, GIS is being used to carry out other analysis and data collection and visualization activities in the project. This includes:

- Development of a Recession Rate and Land Use Analysis System (See Section 5.3)
- Development of GIS Methods for Recession Rate Determination (See Section 4.1)
- An automated system of input and output data management for the lakewide coastal processes model (See Section 4.13)
- Lakewide statistical analysis of coastal processes and quality control/assurance analysis of base data (See Section 4.13)

3.1 Develop a Great Lakes GIS Strategic Plan

The objective of this task is to assess the status and objectives of the USACE Great Lakes Coastal Zone GIS and provide recommendations for successful future expansion, as well as how information and data generated in the LMPDS can be incorporated.

Recommendations are to include strategies to facilitate broad and diverse GIS access and data distribution and design specifications for a GIS configuration that provides maximum efficiency for storage, management and analysis of a wide variety of data types and volumes.

The contractors performing this work - PlanGraphics and GRW Engineering - are presently conducting a systems needs and requirement analysis to evaluate:

- the extent, capacity and shortcomings of the existing USACE GIS including hardware, software and data;
- USACE Staff capacities, technical and administrative controls over available datasets and training needs to support the “target system”; and
- the magnitude and extent of data sets that will need to be incorporated in the future GIS.

They are also conducting a systems design and configuration plan, including:

- database configurations to incorporate shoreline digital orthophotography, terrain data, parcel mapping, coastal geomorphology and structure development data;
- guidelines for the conversion of existing Intergraph MGE-Informix format data to a Oracle-reference base and to incorporate data delivery via Intergraph GeoMedia and ESRI’s ArcView;
- an evaluation of GIS software and hardware requirements; and
- a long-range implementation plan.

3.2 Acquisition and Integration of Large-Scale Spatial Data

There are several initiatives underway to address this particular task:

1. An inventory of available information and data;
2. Acquisition of existing data; and
3. Development of cooperative programs for database generation.

The focus of discussion in this section is inventory work that has been performed within the eleven counties of the State of Wisconsin by the University of Wisconsin. Similar activities are underway in Michigan, Illinois and Indiana, but the results were not available in time to be incorporated into this progress report. Similarly, there has been a significant amount of data compilation by USACE Detroit District staff that is briefly documented here.

3.2.1 USACE Detroit Activities

USACE Detroit District GIS staff have been assembling a range of geospatial data over the course of the LMPDS. This consists primarily of Digital Elevation Model coverage (DEM), Digital Ortho Quarter Quadrangles (DOQQ), Digital Ortho Photos (DOP) and Digital Raster Graphics (DRG). The status of each is described briefly below.

Digital Elevation Model Coverage

Figure 2 presents a representation of the status of DEM coverage for the Lake Michigan

shoreline. DEMs exist for the majority of the shoreline. Level 1 or Level 2 DEMs (Orange) are available for the entire Wisconsin, Illinois and Indiana shoreline. The majority of the Michigan shoreline has Level 2 DEMs available (Yellow), except for the counties of Delta, Manistee, Mason, Oceana and Berrien where Level 1 DEMs (Green) exist. There are only minor portions of Schoolcraft, Mackinaw and Manistee counties where DEMs do not exist but have been authorized (Blue).

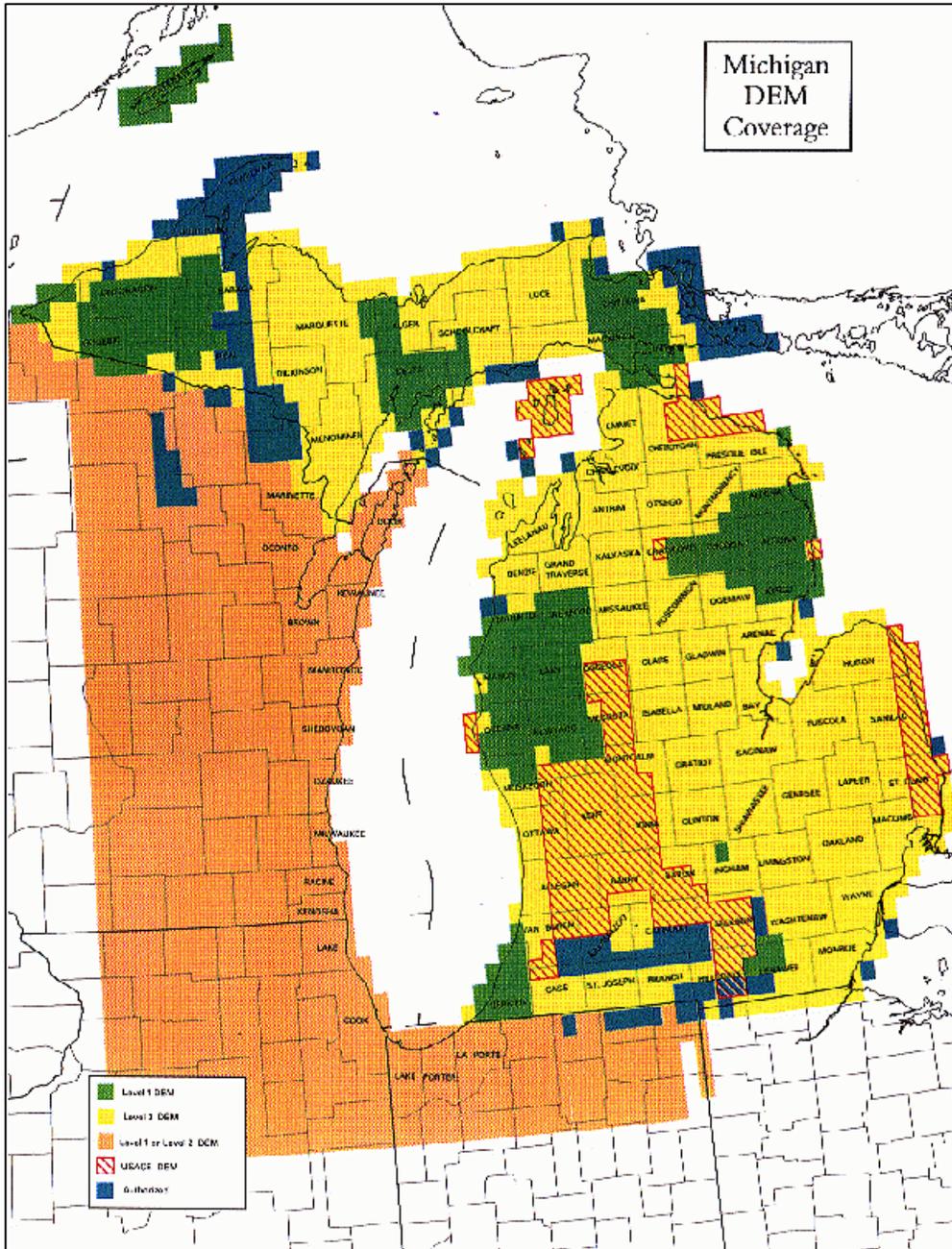


Figure 2 - Lake Michigan DEM Coverage

Digital Ortho Quad and Digital Orthophoto Coverage

Figure 3 presents a representation of the status of DOQQ and DOP coverage for the Lake Michigan shoreline. USGS DOQQs have been completed (Blue) for a number of counties in Wisconsin (Sheboygan, Manitowoc, Door), Illinois (Lake), and Michigan (Manistee, Benzie, Delta (part), Mackinaw (part)). USGS DOQQs are being completed (Green) for Kewaunee County in Wisconsin and Oceana, Mason, Leelanau, Antrim, Charlevoix and Emmet Counties in Michigan. USACE DOQQs are completed (Pink) for Porter and LaPorte Counties in Indiana and VanBuren, Allegan, Ottawa and Muskegon Counties in Michigan and are programmed (Orange) for Oconto and Marinette Counties in Wisconsin and for Menominee, Delta, Schoolcraft and Mackinaw Counties in Michigan. Finally, high resolution DOPs (Brown) exist for Kenosha, Racine, Milwaukee and Ozaukee Counties in Wisconsin and Berrien County in Michigan.

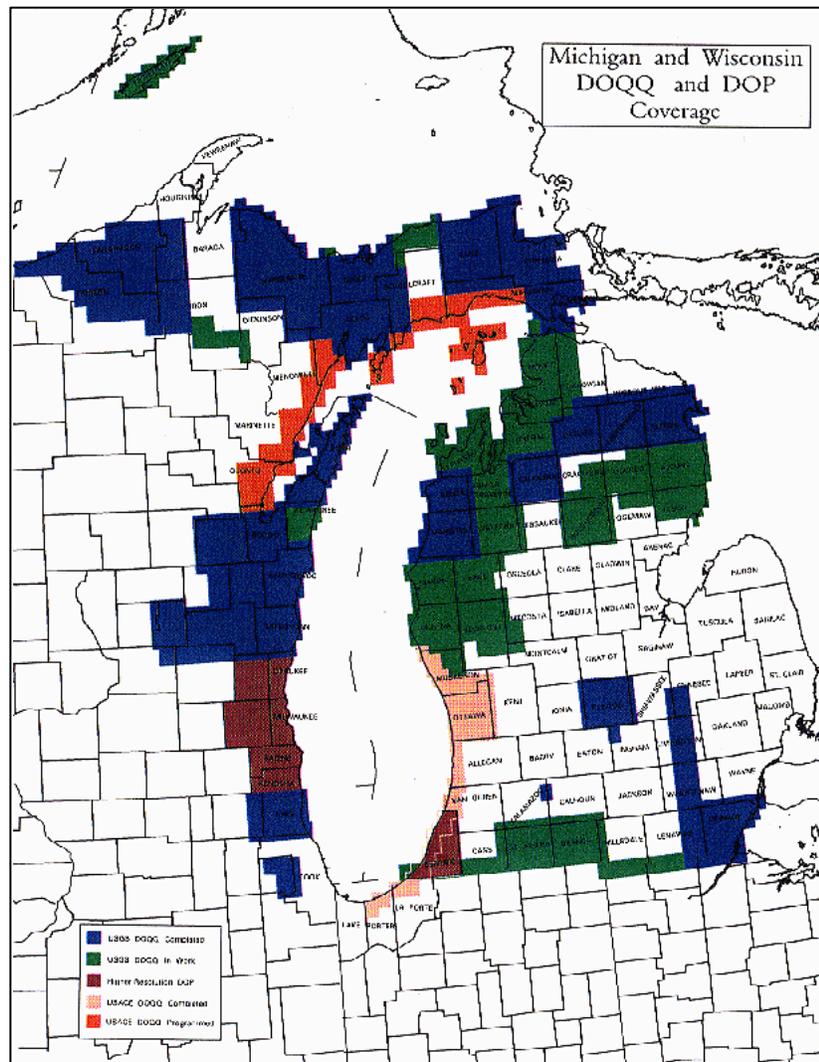


Figure 3 - Lake Michigan DOQQ and DOP Coverage

Digital Raster Graphics

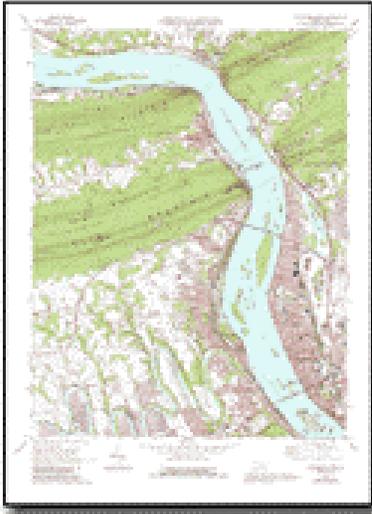


Figure 4 - DRG Example

A digital raster graphic (DRG) is a scanned image of a U.S. Geological Survey (USGS) standard series topographic map (Figure 4), including all map collar information. The image inside the map neatline is georeferenced to the surface of the earth and fit to the Universal Transverse Mercator projection. The horizontal positional accuracy and datum of the DRG matches the accuracy and datum of the source map. The map is scanned at a minimum resolution of 250 dots per inch.

A DRG can be used on-screen to collect, review, and revise other digital data, especially digital line graphs (DLG). When the DRG is combined with other digital products, such as digital orthophoto quadrangles (DOQ) or digital elevation models (DEM), the resulting image provides additional visual information for the extraction and revision of base cartographic information.

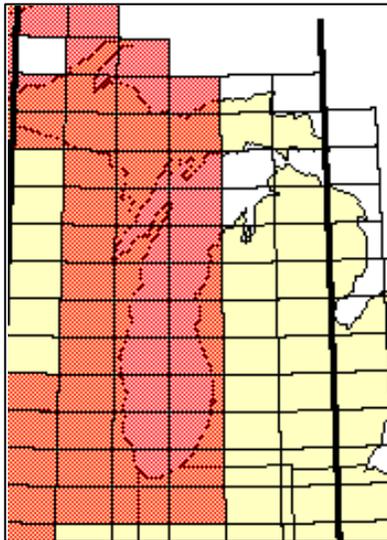


Figure 5 - Lake Michigan DRG Coverage (Red)

DRG's for the majority of the Lake Michigan shoreline (excluding the northeast portion of the Lake) are available online from the USGS-Environmental Management Technical Center (http://www.emtc.nbs.gov/http_data/emtc_spatial/available_data/drg.html). USACE Detroit has downloaded these DRGs with the intent of using them as baseline and backdrop mapping for other mapping initiatives in the LMPDS.

3.2.2. University of Wisconsin Activities

The University of Wisconsin-Madison was retained to research, acquire and integrate existing large scale mapping sources for the Wisconsin coastal zone. The area of study included all of the Wisconsin Lake Michigan shoreline extending 1000 meters inland. Data sources were limited to 1:24,000 or larger scale and public domain data available for the cost of reproduction.

Work under this contract carried out in FY 1998 consisted of:

- an inventory of existing mapping sources, including but not limited to, digital parcel mapping, planimetric mapping, topographic mapping, land use, land cover, soils data, and digital orthophotography;
- a report on the status, accuracy, date, data format, file size and accessibility of all map sources identified;
- identification of gaps in mapping coverage for the 11 counties bordering Lake Michigan in Wisconsin; and
- development of cost estimates for addressing identified data gaps.

To better understand the status of digital geospatial data development at the local government level along the Lake Michigan coast of Wisconsin, the University of Wisconsin-Madison conducted detailed surveys in the 11 counties that border Lake Michigan. These surveys were conducted in person at county offices from January 29 to March 17, 1998. The survey instrument included a total of 70 questions about the completeness, compilation method, format, and documentation of digital mapping of parcels, planimetric and topographic features, zoning, soils, wetlands, land use, natural resources, infrastructure, and digital orthophotos. The survey questions are presented in Appendix A of Hart (1998b).

As a result of the surveys, the University of Wisconsin-Madison has prepared a series of draft reports on the status of large-scale spatial data for the coastal areas of Wisconsin. These reports are organized according to the following subject categories:

- Digital Parcel Mapping;
- Orthophotos;
- Digital Soils Mapping;
- Digital Land Use and Land Cover Mapping; and
- Digital Planimetric and Topographic Mapping.

Digital Parcel Mapping

University of Wisconsin Sea Grant Institute and the University of Wisconsin-Madison Land Information and Computer Graphics Facility have produced a report on the status of digital parcel mapping in Wisconsin's coastal counties. A complete copy of the draft report is available over the internet via the world wide web at <http://www.lic.wisc.edu/>

coastgis/parc-rpt/parc-rpt.htm. The results, summarized from Hart (1998a), are presented in Table 1 and Table 2 and discussed below.

Generally, digital parcel mapping along the Lake Michigan coast in Wisconsin is fairly well advanced (approximately 74% complete), but comes in a wide variety of formats. Pockets of areas are not complete and many areas that are complete have been compiled in a manner to support more efficient drafting of parcel maps rather than spatial analysis of land use, property assessment, and land ownership patterns. Editing of digital parcel mapping from a CAD format to a clean, topologically structured format may potentially require significant staff time or consulting services.

Table 1 Summary of Parcel Mapping Status for Wisconsin Coastal Counties

County	Digital Parcel Mapping Complete	Parcel Mapping for Cities and Villages	Preliminary 1997 DOR Land Parcel Count	Coordinate System	Metadata for Parcels	Data Distribution Policy
Brown	55%	Yes	86,909	County	FGDC	
Door	90%	Yes	37,398	SPCC83-91	Specs, Methods	
Kenosha	100%	Yes	58,291	SPCS27	No	Cost ³
Kewaunee	52%	Yes	18,682	SPCC83	No	Not yet determined ⁴
Manitowoc	100%	No	51,590	County	No	
Marinette	12%	Yes	55,171	County	Methods	
Milwaukee	90%	Yes ¹	259,305	SPCS27	Notes	Cost ⁵
Oconto	10%	Yes	42,267	County	No	
Ozaukee	60%	Yes	33,115	SPCS27	Guidebook, Notes	
Racine	66%	Yes	73,395	SPCS27	Notes	
Sheboygan	100%	Yes ²	53,846	County	Methods	Voluntary License Agreement

1. Except for City of Milwaukee

2. Except for City of Sheboygan

3. \$40 for each PLSS section

4. City of Manitowoc is evaluating a cost schedule and license agreement

5. \$65 for first quarter-section and \$30 for each subsequent quarter-section for MCAMLIS parcel data and \$25 per quarter section for City of Milwaukee parcel data

Table 2 Summary of Parcel Data Formats for Wisconsin Coastal Counties

County	Compilation Method	Format	Topology	Coded with Parcel ID's	Link Between Parcels and Tax Roll Data?
Brown	COGO/GRF	AutoCAD	Yes	Yes	Yes
Door	Variety/GRF	AutoCad and ArcCAD	Yes	Yes	Yes
Kenosha	Digitized/GRF	Genamap and others ¹	Yes	Yes	Yes
Kewaunee	COGO/GRF	AutoCad	Yes	Yes	Yes
Manitowoc	Drawn/ Floating	AutoCad	No	Yes	No
Marinette	COGO/GRF	AutoCad	No	Yes	No
Milwaukee	COGO and Digitized/GRF	Genemap and DXF ²	Yes	Yes	Yes
Oconto	Digitized/PLSS	Arc/Info	Yes	Yes	Yes
Ozaukee	COGO/GRF	AutoCad	Yes	Yes	Yes
Racine	COGO/GRF	Genemap	Yes	Yes	Yes
Sheboygan	COGO and Digitized/GRF	Arc/Info and Shapefiles	Yes	Yes	Yes

1. Kenosha County also provides output in Intergraph .DGN, AutoCAD .DXF, and ArcView Shapefiles
2. Intergraph in the City of Milwaukee

Orthophotos

University of Wisconsin Sea Grant Institute and the University of Wisconsin-Madison Land Information and Computer Graphics Facility have produced a report on the status of orthophotography in Wisconsin's coastal counties. A complete copy of the draft report is available over the internet via the world wide web at <http://www.lic.wisc.edu/coastgis/doq-rpt/doq-rpt.htm>. The results, summarized from Tallman & Hart (1998) are presented in Table 3 and are discussed below.

Large-scale digital orthophoto coverage for Lake Michigan coastal counties exists in two formats: the U.S. Geological Survey's 1:12,000 scale digital orthophoto quarter-quadrangles (DOQQs) and the Southeast Wisconsin Regional Planning Commission's (SEWRPC) 1:4,800 scale orthophoto coverage. Each SEWRPC orthophoto covers a four square mile area comprised of two section-by-two section squares. Lake Michigan coastal counties in the USGS DOQQ coverage include Marinette, Oconto, Brown, Door, Kewaunee, Manitowoc, and Sheboygan counties. Lake Michigan coastal counties covered by SEWRPC include Ozaukee, Milwaukee, Racine and Kenosha counties.

Table 3 Summary of Digital Orthophoto Status for Wisconsin Coastal Counties

County	Source	No. of Orthophotos Required for Coastal Coverage	No. of Orthophotos Currently Available	Original Format	Date Compiled
Brown	USGS	13	13	JPEG	1992
Door	NRCS(USGS)	66	66	.bil	1992
Kenosha	SEWRPC	N/A	N/A	.tif	1995
Kewaunee	N/A	9	4	JPEG, .bil	N/A
Manitowoc	USGS	11	11	JPEG	1992
Marinette	N/A	9	4	N/A	N/A
Milwaukee	SEWRPC	N/A	N/A	.tif	1995
Oconto	N/A	11	2	JPEG, .bil	N/A
Ozaukee	SEWRPC	N/A	N/A	.tif	1995
Racine	SEWRPC	N/A	N/A	.tif	1995
Sheboygan	NRCS(USGS)	8	8	.bil	1992

Digital Soils Mapping

University of Wisconsin Sea Grant Institute and the University of Wisconsin-Madison Land Information and Computer Graphics Facility have produced a report on the status of digital soils mapping in Wisconsin's coastal counties. A complete copy of the draft report is available over the internet via the world wide web at <http://www.lic.wisc.edu/coastgis/soil-rpt/soil-rpt.htm>. The results, summarized from Tallman & Hart (1998b) are discussed below.

Soils data for the Lake Michigan coastal counties are available from both the Southeastern Wisconsin Regional Planning Commission (SEWRPC) and the National Resource Conservation Service (NRCS). Complete coverage is available for the SEWRPC counties. NRCS has large-scale soils information available under the Soil Survey Geographic Database (SSURGO). The program is ongoing and currently Brown County is the only certified SSURGO data set available for the Lake Michigan coastal counties. Two other coastal counties, Sheboygan and Manitowoc, should be completed and certified by the end of 1998. Preliminary data sets for these counties were acquired through an arrangement with the NRCS.

Digital Land Use and Land Cover Mapping

University of Wisconsin Sea Grant Institute and the University of Wisconsin-Madison Land Information and Computer Graphics Facility have produced a report on the status of digital soils mapping in Wisconsin's coastal counties. A complete copy of the draft report is available over the internet via the world wide web at <http://www.lic.wisc.edu/coastgis/lulc-rpt/lulc-rpt.htm>. The results, summarized from Blough & Hart, 1998, are

discussed below.

Land use data for the 11 Lake Michigan Coastal counties is available primarily from two sources:

1. the Bay-Lake Regional Planning Commission (Bay-Lake RPC), encompassing the northeastern coastal counties, and
2. the Southeastern Wisconsin Regional Planning Commission (SEWRPC), encompassing the southeastern coastal counties.

In addition, Brown County has its own land use data available.

Bay-Lake RPC has two sets of land use data. The first is part of a Bluff Stability/Bluff Erosion Study done in cooperation with Dr. David Mickelson of UW-Madison and others. The Bluff Stability study area is 1000 feet inland from the Lake Michigan/Green Bay coastlines, and draws on data from 1996. Other land use data compiled by RPC covers various townships, cities and villages during the period 1995-present.

SEWRPC compiles digital land use data from aerial photos for all counties in its jurisdiction every 5 years. Land use is classified at the parcel level with a 3-digit code into approximately 15 general categories, which are in turn subdivided by specific uses.

Brown County has countywide land use, vintage 1990 for the county and 1994 for the City of Green Bay. Land use was compiled at the parcel level, but aggregated where there are contiguous land uses. There are some subparcel designations. Brown County Land Use Codes (R1,RA, R2, ...MF, C50, C60, C70,...I20, I40, I72...) are the classification system, a hybrid land use/land cover system.

A variety of digital land cover data is available through Wisconsin's Department of Natural Resources (WIDNR), but little is usable at scales larger than 1:24,000 for the counties bordering Lake Michigan. Resources which come close to the scale requirement are:

1. Wetlands data from 1:24,000 rectified photo base maps, begun 1990.
2. Hydrography from USGS 7.5' quad separates, currently in progress.
3. DEMs from USGS 7.5' quads, at 30 meter resolution.
4. DLGs from USGS 7.5' quads for various themes such as Boundaries, Hydrography, Transportation Status, and Manmade Features.
5. Rural Land Cover Vegetation Mapping from Landsat Thematic Mapper satellite images taken primarily in 1992, minimum mapping unit of 5 acres, usable at 1:40,000 to 1:500,000.

Of the above list, the Rural Land Cover Vegetation Mapping data, commonly referred to as the WISCLAND dataset, is the most unique and current source of land cover data for the state of Wisconsin, despite its small scale.

Digital Planimetric and Topographic Mapping

University of Wisconsin Sea Grant Institute and the University of Wisconsin-Madison Land Information and Computer Graphics Facility have produced a report on the status of digital soils mapping in Wisconsin's coastal counties. A complete copy of the draft report is available over the internet via the world wide web at <http://www.lic.wisc.edu/coastgis/plan-rpt/plan-rpt.htm>. The results, summarized from Hart (1998b) are discussed below.

Large-scale mapping of planimetric and topographic features is common at the local level of government in Wisconsin. The status of large-scale digital planimetric and topographic mapping in the Lake Michigan coastal counties can be broken into the following four categories:

Counties where large-scale, digital planimetric mapping only is complete:

- Door County (based on 1994 aerials - hydrography and road centerlines)
- Kewaunee County (based on 1993 aerials - buildings, hydrography, and roads)
- Sheboygan County (based on 1995 aerials - buildings, hydrography, and roads)

Counties in the Southeastern Wisconsin Regional Planning Commission (SEWRPC) where detailed digital planimetric and topographic mapping is either complete or underway. Mapping scales are either 1"=100' or 1"=200' and contours are at 2 foot intervals:

- Ozaukee County (75% complete)
- Milwaukee County (100% complete)
- Racine County (20% complete)
- Kenosha County (100% complete)

Coastal cities with detailed planimetric and topographic mapping, typically 1"=100' or 1"=200' scale with two foot contours:

- City of Manitowoc
- City of Sheboygan
- City of Racine

Counties where some planimetric features (typically hydrography and road centerlines) are represented on digital parcel mapping:

- Marinette County (digital parcel mapping 12% complete)
- Oconto County (digital parcel mapping 10% complete)
- Brown County (digital parcel mapping 55% complete)
- Manitowoc County (digital parcel mapping 100% complete)

4.0 Coastal Process Investigations

There are a range of coastal investigations being carried out as part of the LMPDS. Many of these follow directly from work undertaken and recommendations made during the 1986-1993 IJC Great Lakes Water Level Reference Study. Tasks include:

1. Recession Rate Updates, Analysis and Generation of New Data
2. Revision of the Great Lakes Shoreline Classification Scheme
3. Collection of Coastal Processes Field Data
4. Development of a Coastal Processes Model
5. Analysis of Lakewide Bluff Stability Factors
6. Analysis of Structural Shore Protection Impacts
7. Analysis of Lakewide Sediment Budgets
8. Estimation of Nearshore Wave Climate for Water Level Scenarios
9. Development of an Erosion Prediction System
10. Development of a Wave Runup Prediction System

Work to date has included substantial completion of all of the above tasks with the exception of the last item. Brief summaries are provided for all coastal activities.

4.1 Recession Rate Updates, Analyses and Generation of New Data

4.1.1 Collection of New Recession Rate Data

In 1994 the U.S. Army Corps of Engineers - Detroit District prepared a comprehensive kilometer-by-kilometer database of recession rate data for all of the U.S. Great Lakes shorelines including Lake Michigan (Stewart, 1994). This database provides mean, median, maximum and minimum recession rates for each kilometer reach and was based on all available shoreline recession rate data as of March 1994.

In order to utilize this as a baseline recession rate database for the 1997 Lake Michigan Potential Damages Study, any new recession rate data (i.e., anything updated, calculated or created subsequent to the 1994 database) for the Lake Michigan shoreline needed to be incorporated to this database.

To acquire this new data, inquiries were made with various individuals and State agencies. New recession rate data was acquired primarily for the Michigan and Wisconsin shorelines through the following data sources:

- **State of Michigan, Department of Environmental Quality:** New or updated data was obtained for the majority of counties (excluding Berrien), along the eastern shoreline of Lake Michigan;
- **Wisconsin Recession Rate Study** - The State of Wisconsin contracted S.E.H. and Baker Engineering to develop a new recession rate methodology for the Wisconsin coast. Three 10-mile test sites in three counties (Manitowoc, Ozaukee, Racine) were

completed and "new" recession rate data was determined for these sites;

- **SEWRPC Lake Michigan Recession and Bluff Stability in Southeastern Wisconsin** - This 1997 report by SEWRPC provides updated recession rate data for Kenosha, Racine, Milwaukee, and Ozaukee Counties. Calculations are provided for the periods 1963-1995, 1970-1995 and 1975-1995.
- **Bay/Lakes Regional Planning Commission, Lake Michigan Recession and Bluff Stability in Southeastern Wisconsin** - This is a report similar in nature to the above and covers some of the northeastern counties including Sheboygan, Manitowoc, Kewaunee and Door. Calculations are provided for the period 1978-1992.

Detailed descriptions of the new data sets are found in Stewart (1997). The comprehensive updated database is also available as an Appendix to the Stewart (1997) report. These may both be obtained from USACE Detroit District.

4.1.2 Creation Of A Single-Value Recession Rate Database, Lake Michigan Shoreline

As a first step in the analysis of recession rates and land use for the Lake Michigan Potential damages study, the revised recession rate database created above had to be reviewed in order to select a single, most appropriate recession rate value for each kilometer reach along the shoreline¹.

To a degree, this exercise was performed during the creation of a recession rate data set that was prepared for the USGS and University of Virginia during the creation of a yet unpublished map of Great Lakes erosion and accretion (Stewart et al., 1997). However, the logic and assumptions used in creating this data set were never explicitly recorded, and since then, changes in our understanding of recession and the use of recession rate data in the establishment of hazard lands along the shoreline have occurred. As such, a review of the data was again necessary to establish the best value of recession for each reach.

For the USGS exercise described above a number of general assumptions were used in selecting the best value of recession for each reach. Generally speaking, the best value of recession was that which:

- Had the longest period of record;
- Was the most accurate in terms of its "Confidence" ranking (this usually correlated to the method of calculation used);
- Had a fair number of data records within the reach;
- Was used by the State in the determination of formal erosion hazard setbacks; and

¹ This was done primarily out of a "database convenience" point of view in that it provides a single, reliable value of recession for the reach that can then be assessed in terms of accuracy relative to land use and other issues. In the event that more detailed recession data is required for future modeling purposes, it is available through the comprehensive recession rate database.

- Was the only estimate of recession available for the reach

In re-visiting the database for this project, we had to consider a number of other issues. For example, many agencies (State of Ohio for example, Mr. Scudder Mackey, personal communication) are beginning to use shorter term recession rate information to establish setbacks as they feel it is more representative of coastal and development conditions that have existed in the recent past. Historic data (e.g., comparing circa 1800 shorelines to 1990s shorelines) may be less representative of reality than comparing 1960s or 1970s shorelines with 1990s shorelines. Given this, we looked for such short-term data and where appropriate given other factors such as its confidence, number of data points, etc., selected it for use here.

Second, some of the State CZM recession rate data used in determining single value recession rates for the USGS project were fairly low in the confidence ranking. Where these occurred and where other more confident data existed, the more confident data was substituted.

Third, an assumption was made in the original database that recession rates of all bedrock shorelines was zero, even if the shoreline was classified as “non-resistant” bedrock. Recent discussions as part of the shoreline classification exercise have indicated that the erosion of soft bedrock areas can be a critical component of profile retreat in these areas. In light of this, the classification information for the Lake Michigan shoreline was consulted and where “non-resistant” bedrock was identified, the recession rate was changed from “0.00” to “no data.” This occurred primarily in portions of Emmett County as well as in areas of the Upper Peninsula.

Fourth, the new data sets entered into the master database (described above) were used in many places as new "best" values for many reaches. This is particularly true of the new Michigan DNR and SEWRPC (1997) data in Michigan and Wisconsin respectively. Despite its lower confidence, some of the SEH and Baker (1997) values were used for some reaches, as they replaced data that was of an even lower confidence, or where data was based on only a single data point.

Once all data had been selected, a single value recession rate database was created. A hardcopy of this database is presented in Appendix 2 of Stewart (1997). Unlike the master database, only mean recession rate values are listed, along with the period of record, source and comments where available.

4.1.3 Short-Term Trends in Water Levels and Recession Rates

This task involved a closer examination of all known recession rate data for Lake Michigan in an attempt to determine relationships between water level trends and recession rates (i.e., can we establish with any accuracy, recession rates during high water periods?, low water periods?, falling water level periods?, rising water level periods?), as well as to determine if recent recession rates have been significantly changed (relative to long-term historic rates), as a result of shoreline modification, development, changes in

sediment supply, etc.

Existing recession rate data was examined with reference to periods of higher or lower water levels on the Great Lakes in order to determine if there were any data sets that were calculated over a high water, or low water level period. The theory here was that by pulling these data sets out, we might be able to get a better handle on whether or not the data reflects increases in erosion rates during high water and decreases in erosion rates during low water, a case commonly observed by shore property owners.

In reviewing the data it became apparent that there were generally 2 high water periods that could be extracted. These are loosely defined as the 1970s high water period and the 1980s high water period. No data records existed that were suitable to cover the 1950s high water period. Periods of record within each of these vary, and in some cases cover the time when levels were rising to the peak levels, or only the very short period when levels were at their peak.

Data covering low water level periods is scarce. Only one data set was available covering the 1960s low water period (1955-1967) and it is of low confidence. Other data sets tended to cover the "low" water period between the 1970 peak and the 1980s peaks. Data sets used here have periods of record of: 1973-1984, 1978-1984, and 1975-1980.

For both high water recession and low water recession, available data sets were found for the eastern shoreline of Lake Michigan from about Reach 695 - 940 (Michigan and Indiana shoreline), and for the Wisconsin shoreline from about Reach 1073-1340. This was to be expected, as these are areas that have traditionally had erosion problems, and thus areas where researchers have focussed their efforts.

In order to better visualize the relationship between long term recession rates and short-term trends, a series of simple graphs were created with the data. An example is found on the following page for the section of shoreline between St. Joseph and New Buffalo, Michigan.

Examination of these graphs shows some simple but interesting relationships. In the majority of cases, recession rate data calculated over the high water level periods is significantly higher than the long-term average rate of recession utilized. There are a few cases where this does not hold, and a few others where data calculated by Wood in the mid-80's shows significant increases in accretion during the high water level period. This occurs along portions of the Indiana shoreline and bears further investigation to determine if it is a measurement error, or due to some other factor (e.g., nourishment?).

Where data for both the 1970s and the 1980s is available, 1980s high water recession rates tend to be higher than the 1970s high water recession rates. This may indicate a direct correlation between water level height and erosion rate, however, there does not appear to be enough data available to really verify this any further.

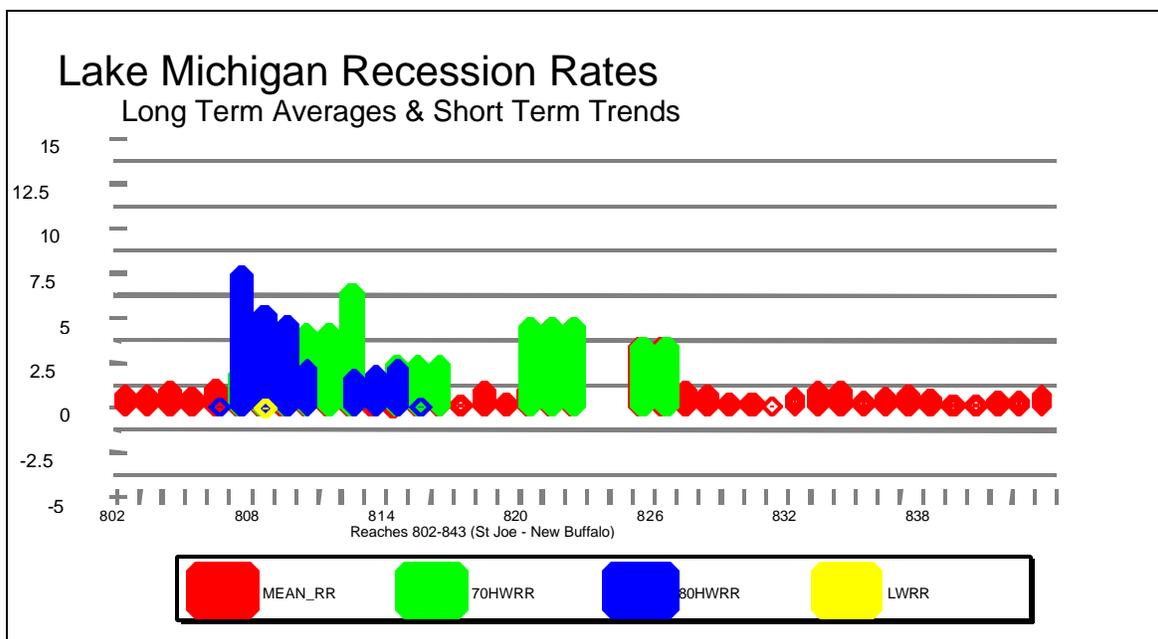


Figure 6 - Comparison of Lake Michigan Short-Term Trend Recession Rate Data

Where "Low Water" recession rate data is available, it was found to be significantly lower in all cases versus both long-term data and 1970s or 1980s high water data.

A graphical representation of this nature makes it easy to identify recession "hot spots", whether one is looking at the long-term data or the short-term trend information. It certainly seems to raise a red flag as to those areas that may experience severe problems during a high water period. Granted, the data is a bit biased based on where researchers have conducted studies, but it seems to serve as a good starting point for hazard identification.

4.1.4 Generation of New Recession Rate Data

The objectives of this work include enhancing the completeness of existing recession rate data contained in the Detroit District, USACE databases. This task is focused on filling data gaps in the current record that were identified in the above tasks. New short-term recession rate data is also being generated for critically sensitive shorelines (primarily a series of 8 detailed study sites) for recent periods of high (1970s, 1980s, and 1990s) or low (1960s) Great Lakes water levels. Long-term average annual rates will also be generated for shorelines which were either recently developed or are expected to be developed over the study period. Data from previously undeveloped areas will be important where the erosion contributes significantly to sediment budget in downdrift developed areas.

There are three key activities currently underway for the collection of new recession rate data.

First, Stewart (1997) identified that there is a general lack of recession rate data for the Green Bay portion of the Lake Michigan shoreline (Marinette, Oconto, Brown and Door counties) in Wisconsin. To rectify this and also to develop a GIS methodology for use in conducting future calculations and determinations of recession rates along the Great Lakes, VGI Vision Group International Inc. has been retained to provide the Lake Michigan Potential Damages Study with recession rates for this section of Lake Michigan shoreline and conduct a proof of concept study to demonstrate the applicability of GIS and viewer technology in automating the calculation of recession rates in these areas. To accomplish this, shoreline positions for two different time periods are being digitized from available digital raster topographic files and digital orthophoto files. An application is being developed using ArcView and AVENUE scripting to compute shoreline recession rates from digitized shoreline data. In general, the GIS will allow users to select a reach of shoreline and period of record for which recession rates will be calculated. The selected reach will then be displayed and shore normal (orthogonal) transects will automatically be added at 50 meter intervals. The user may then query the GIS to calculate the annual rate of recession for any of the displayed transects. An additional function will allow users to calculate the mean annual recession rate for an entire reach.

Second, the University of Wisconsin is utilizing softcopy photogrammetric methods to calculate bluff recession rates for two sites along the Lake Michigan shoreline, the first, a two mile stretch of Lake Michigan coastline near Two Rivers, Wisconsin and the second, a two mile stretch of Lake Michigan coastline near St. Joseph, Michigan. The objective of this task is to generate accuracy and cost comparisons of softcopy photogrammetric methods with those of LIDAR and standard photogrammetric analytical stereo plotter techniques for bluff mapping and recession rate calculations. Part of this work will also include researching DEM differencing methods to include development of specifications that address resolution differences, resampling techniques, accuracy estimates and error propagation, metadata, file structures, file formats, and file compression. The Contractor will also produce DEM's of the Michigan site using the Government supplied data and scanned images. An accuracy study of these data will not be made. Using similar data (scanned photographs and control with the same approximate accuracy as supplied for the Michigan site), DEM's will be produced for the Wisconsin site. An accuracy assessment of these data will be made comparing the results from the "Low Cost Alternative" to the results of the main study. The accuracy of the DEM at the Michigan site will be inferred from this study.

Third, detailed calculations of short-term recession rates were carried out at each of the 8 detailed site studies (see Section 4.3) that have been selected for detailed analysis. This work is being conducted by Baird & Associates and the results will feed directly into the detailed Coastal Process Model that is being developed (see Section 4.4). A key product of this Phase 2 investigation by Baird was the development of a new approach for projecting future recession which incorporates an uncertainty band around the projected future shoreline. The basis of this approach stems from the fact that the calculated spatial

variability in recession rate (based on two snap shots of bluff crest position in time) is related to the spatial variability in geologic conditions and to a temporal factor associated with the evolution cycle of bluff failure. Therefore, it is important to utilize this information to create bands of uncertainty around future shoreline positions projected either by conventional extrapolation of historic recession rates or by predictions of future shoreline position using the deterministic coastal processes model COSMOS (see Section 4.4). Baird are working closely with Dave Mickelson of the University of Wisconsin to further develop, test and refine this hypothesis. This key finding has two important implications for the LMPDS system: 1) the projected future shoreline position will have a band of uncertainty which will have a significant influence on damage potential projections; and 2) modifications may be required to the shoreline classification system based on the findings of Mickelson to allow lakewide estimates of the uncertainty band width around future projections of shoreline (or bluff crest) position based on bluff type classification.

It is anticipated that the generation of all new recession rate data as described above will be completed by the end of 1998.

4.2 Revision of the Great Lakes Shoreline Classification Scheme

4.2.1 Original Classification

In March of 1993, the International Joint Commission completed the 1986-1993 Reference Study of Water Level Fluctuations in the Great Lakes - St. Lawrence River basin. As part of this work, the Erosion Processes Task Group (Stewart and Pope, 1993) had developed a three-tiered shoreline classification scheme for the Great Lakes that took into account factors related to the overall erodibility of the shoreline. These included the geomorphic shore type present, the level of shoreline protection present, and the geological composition of the nearshore zone. This original classification was applied to all of the Great Lakes shoreline, including Lake Michigan, and associated statistics on the various shoreline types were generated.

4.2.2 Limitations of Original Scheme

While the shore classification scheme and the resulting database of classification information provided a comprehensive attempt to recognize and quantify the complex nature of the Great Lakes shoreline, there were some limitations that arose, primarily due to time and budget constraints associated with the Reference Study:

- 1) The United States shoreline was classified using various published and unpublished data sources, photographs, and personal knowledge. The mappers proceeded by reviewing their materials and writing the shore type, protection level, and offshore type on U.S Geological Survey topographic quadrangles. The quadrangles were then sent to USACE Detroit District, where the classifications were entered into a Geographical Information System (GIS) database. Note that the quadrangles were

used merely as a convenient base upon which the mappers could write their classifications and notes. The shorelines in the GIS database are not based on the quadrangles but rather on recent aerial photographs. Many portions of the shore, especially along barrier spits and sandy coasts, have changed significantly since the maps were printed. In addition, man-made structures have caused major changes in some areas. This resulted in inaccuracies in shore type boundaries or misclassification of shore types.

- 2) Although the classification of several shore sections were re-evaluated to cross-check the initial classification, there was insufficient time to conduct a broad ranging quality control check. Therefore there are undoubtedly some sections of the shoreline which were mis-classified and cases where similar shores may have been interpreted into different classes.
- 3) The limited time and budget allocated to the study did not allow for additional data collection or for field verification of the classification. In addition, several different coastal geological experts were used to apply the classification scheme across the basin. This resulted in some variability in interpretation, particularly between the U.S. and Canada, and between different lakes on the U.S. side.
- 4) The variability in descriptive data throughout the literature, between states and across Canada, the limited availability of recent good-quality aerial photography and/or oblique video tapes, the lack of information on nearshore geology and bathymetry, and the generality of the classification scheme, made it impossible to assure an equal level of quality and detail in the classification across the basin.
- 5) The protection classification scheme developed for the Reference Study did not recognize the quality of the protection, only the percentage of shoreline covered. To be true to the purposes of the classification scheme, verification is needed that a "heavily protected shore" is engineered to provide a predictable design life and level of protection.
- 6) Additional data is needed on nearshore geology and bathymetry (including nearshore slope). The six classes utilized were fairly basic. Further refinements based on a better knowledge of offshore stratigraphy and lithology, as well as the degree of sand cover are required.

A number of other issues and limitations were identified in the Erosion Processes Task Group Report (Stewart and Pope, 1993).

4.2.3 Opportunities For Improvement / Revision

With renewed interest in the classification scheme through the Lake Michigan Potential Damages Study, there was an opportunity to revise and improve the classification scheme so that the above limitations could be removed, or at least significantly reduced.

In undertaking the revision of the classification scheme, a number of activities were undertaken. First, detailed discussions were held with LMPDS Study Team members (primarily staff of USACE Detroit District and CHL, and other consultants) who provided a number of alternatives and possibilities relative to the existing limitations and relative to how the scheme was to mesh with the potential damages “model” that was to be developed in the LMPDS. This resulted in the development of a “Strawman” Classification that was then distributed to the Study Team as well as to other interested parties.

Comments on the Strawman Classification were compiled and used as a focus of discussion at a Shoreline Classification Revision Meeting that was held in Chicago in June of 1997. This meeting included staff of various USACE offices, other consultants involved in the Study, as well as interests from other state agencies (e.g., State of Ohio, State of Illinois). A thorough discussion of all issues was held and an attempt at consensus was made in order to reach decisions on any classification issues.

A Draft Revised Shoreline Classification Scheme was prepared following the above meeting and was circulated to Study Team Members as well as to members of the LMPDS Advisory Committee that was established in January of 1997. This revised scheme was then presented to the Advisory Committee at a Study Update meeting in September of 1997. Comments received at this meeting were incorporated and a final revised classification scheme was prepared (see Stewart, 1997b).

The final revised classification scheme for use in the Lake Michigan Potential Damage Study is presented below:

Geomorphic Classification

1. Sand or Cohesive Bluffs (define heights and other information as separate attributes)
 - 1a. Homogeneous Bluffs (sand content 0-20%)
 - 1b. Homogeneous Bluffs (sand content 20-50%)
 - 1c. Homogeneous Bluffs (sand content >50%)
 - 1d. Composite Bluffs (sand content 0-20%)
 - 1e. Composite Bluffs (sand content 20-50%)
 - 1f. Composite Bluffs (sand content >50%)
2. Sand or Cohesive Bluffs With Beach (define heights and other information as separate attributes)
 - 2a. Homogeneous Bluffs (sand content 0-20%)
 - 2b. Homogeneous Bluffs (sand content 20-50%)
 - 2c. Homogeneous Bluffs (sand content >50%)
 - 2d. Composite Bluffs (sand content 0-20%)
 - 2e. Composite Bluffs (sand content 20-50%)
 - 2f. Composite Bluffs (sand content >50%)
3. Low Bank
 - 3a. (Sand content 0-20%)
 - 3b. (Sand content 20-50%)

- 3c. (Sand content >50%)
- 4. Baymouth Barrier
- 5. Sandy Beach / Dune
- 6. Coarse Beaches
- 7. Bedrock (Resistant)
- 8. Bedrock (Non-Resistant)
- 9. Open Shoreline Wetlands
- 10. Artificial
- 11. Unclassified

Shore Protection Classification

- 1. Coastal Armoring
 - 1a. Revetments
 - 1b. Seawalls / Bulkheads
- 2. Beach Erosion Control Devices
 - 2a. Groins
 - 2b. Jetties (littoral barriers?)
 - 2c. Offshore Breakwaters
 - 2d. Perched Beaches
- 3. Non-Structural
 - 3a. Beach Nourishment
 - 3b. Vegetation Planting / Bioengineering
 - 3c. Slope Grading / Bluff Stabilization
- 4. Protected Wetlands
- 5. Ad-Hoc
 - 5a. Concrete Rubble
 - 5b. Other Materials
- 6. Unclassified
- 7. No Shore Protection

Quality Qualifier

- 1 - Full Effect - >45 year predicted lifespan
- 2 - Some Effect - 5 - 45 year predicted lifespan
- 3 - No Effect - 0-5 year predicted lifespan
- 4 - Unprotected - 0 years

All would be +/- 5 years

Nearshore Subaqueous Classification

- 1. Cohesive (Till)
 - 1a. Thick Sand Cover (>200 m³/m)
 - 1b. Moderate Sand Cover (50-200 m³/m)
 - 1c. Thin Sand Cover (<50 m³/m)

2. Cohesive (Lacustrine Clay)
 - 2a. Thick Sand Cover (>200 m³/m)
 - 2b. Moderate Sand Cover (50-200 m³/m)
 - 2c. Thin Sand Cover (<50 m³/m)
3. Cobble / Boulder Lag Over Cohesive
 - 3a. Thick Sand Cover (>200 m³/m)
 - 3b. Moderate Sand Cover (50-200 m³/m)
 - 3c. Thin Sand Cover (<50 m³/m)
4. Sandy
5. Bedrock (Resistant)
6. Bedrock (Non-Resistant)
7. Unclassified

4.2.4 Reclassification Activities

A number of activities took place in late 1997 and early 1998 to facilitate the re-classification of the Lake Michigan shoreline using the new shoreline classification scheme. First, in November 1997, staff of USACE Detroit District conducted a helicopter survey of the shoreline and obtained new video-tape coverage the majority of the shoreline.

Second, all associated background data was collected and reviewed for key classification information. This included lithology data, bore hole data, profiles, SHOALS data and GPR data where available.

Third, a one week "shirtsleeve" classification session was held in March of 1998 with key members of the Study Team (Chris Stewart - VGI, Rob Nairn-Baird, Joan Pope - USACE, CERC, Charles Thompson - USACE, Detroit, and Rob Ferguson - USACE, Detroit). At the workshop, all available materials including the video tapes, recent color aerial photography, topographic maps, land use maps, reports and other data were made available. Proceeding kilometer-by-kilometer along the shoreline, the reclassification team examined all the data and recorded new classification information on hardcopy maps with reach boundaries noted on them.

Following the workshop, the hardcopy information was converted into a kilometer-by-kilometer spreadsheet and associated statistics on shore type, shore protection level and nearshore type were generated. Detailed statistics have been prepared by VGI Vision Group International Inc. and have been provided to USACE Detroit. Summary statistics are presented on the following pages (Tables 4-6).

Table 4 - Shore Type Classification	Km's of Coast
1. Sand or Cohesive Homogeneous Bluffs	
1A - Homogeneous Bluffs Sand Content 0-20%	79
1B - Homogeneous Bluffs Sand Content 20-50%	41
1C - Homogeneous Bluffs Sand Content >50%	16
1D - Composite Bluffs Sand Content 0-20%	4
1E - Composite Bluffs Sand Content 20-50%	131
1F - Composite Bluffs Sand Content >50%	5
2. Sand or Cohesive Bluffs With Beach	
2A - Homogeneous Bluffs Sand Content 0-20%	11
2B - Homogeneous Bluffs Sand Content 20-50%	30
2C - Homogeneous Bluffs Sand Content >50%	77
2D - Composite Bluffs Sand Content 0-20%	0
2E - Composite Bluffs Sand Content 20-50%	4
2F - Composite Bluffs Sand Content >50%	0
3. Low Bank	
3A - Sand Content 0-20%	102
3B - Sand Content 20-50%	152
3C - Sand Content >50%	111
4 - Baymouth Barrier	90
5 - Sandy Beach / Dune	606
6 - Coarse Beaches	297
7 - Bedrock (Resistant)	0
8 - Bedrock (Non-Resistant)	376
9 - Open Shoreline Wetlands	105
10 - Artificial	199
11 - Unclassified	0
Total	2436

Table 5 - Shore Protection Classification	KMs of Coast
1. Coastal Armoring	
1A - Revetments - Unknown Quality	1
1A1 - Revetments >45 year lifespan	208
1A2 - Revetments 5-45 year lifespan	192
1A3 - Revetments 0-5 year lifespan	88
1A4 - Revetments 0 year lifespan (disrepair)	0
1B1 - Seawalls/Bulkheads >45 year lifespan	84
1B2 - Seawalls/Bulkheads 5-45 year lifespan	18
1B3 - Seawalls/Bulkheads 0-5 year lifespan	67
1B4 - Seawalls/Bulkheads 0 year lifespan (disrepair)	2

Continued...

2. Beach Erosion Control Devices	
2A1 - Groins >45 year lifespan	6
2A2 - Groins 5-45 year lifespan	17
2A3 - Groins 0-5 year lifespan	71
2A4 - Groins 0 year lifespan (disrepair)	7
2B - Jetties - Unknown Quality	1
2B1 - Jetties >45 year lifespan	57
2B2 - Jetties 5-45 year lifespan	13
2B3 - Jetties 0-5 year lifespan	30
2B4 - Jetties 0 year lifespan (disrepair)	1
2C - Offshore Breakwaters - Unknown Quality	3
2C1 - Offshore Breakwaters >45 year lifespan	16
2C2 - Offshore Breakwaters 5-45 year lifespan	0
2C3 - Offshore Breakwaters 0-5 year lifespan	0
2C4 - Offshore Breakwaters 0 year lifespan (disrepair)	0
3. Non-Structural	
3A1 - Beach Nourishment >45 year lifespan	7
3A2 - Beach Nourishment 5-45 year lifespan	4
3A3 - Beach Nourishment 0-5 year lifespan	0
3A4 - Beach Nourishment 0 year lifespan (disrepair)	0
3B1 - Vegetation Planting >45 year lifespan	1
3B2 - Vegetation Planting 5-45 year lifespan	0
3B3 - Vegetation Planting 0-5 year lifespan	0
3B4 - Vegetation Planting 0 year lifespan (disrepair)	1
3C1 - Slope/Bluff Stabilization >45 year lifespan	0
3C2 - Slope/Bluff Stabilization 5-45 year lifespan	0
3C3 - Slope/Bluff Stabilization 0-5 year lifespan	1
3C4 - Slope/Bluff Stabilization 0 year lifespan (disrepair)	0
4. Protected Wetlands	
0	
5. Ad-Hoc Structures	
5A1 - Concrete Rubble >45 year lifespan	0
5A2 - Concrete Rubble 5-45 year lifespan	2
5A3 - Concrete Rubble 0-5 year lifespan	14
5A4 - Concrete Rubble 0 year lifespan (disrepair)	0
5B1 - Other Materials >45 year lifespan	0
5B2 - Other Materials 5-45 year lifespan	0
5B3 - Other Materials 0-5 year lifespan	1
5B4 - Other Materials 0 year lifespan (disrepair)	0
6 - Unclassified	
4	
7 - No Protection	
1566	
Grand Total	2483

Table 6 - Nearshore Classification	Kms of Coast
1. Cohesive (Till)	
1A - Thick Sand Cover (>200m ³ /m)	125
1B - Moderate Sand Cover (50-200 m ³ /m)	224
1C - Thin Sand Cover (<50 m ³ /m)	7
2. Cohesive (Lacustrine Clay)	
2A - Thick Sand Cover (>200m ³ /m)	21
2B - Moderate Sand Cover (50-200 m ³ /m)	46
2C - Thin Sand Cover (<50 m ³ /m)	3
3. Cobble/Boulder Lag Over Cohesive	
3A - Thick Sand Cover (>200m ³ /m)	188
3B - Moderate Sand Cover (50-200 m ³ /m)	233
3C - Thin Sand Cover (<50 m ³ /m)	202
4 - Sandy	518
5 - Bedrock (Resistant)	0
6 - Bedrock (Non-Resistant)	861
7 - Unclassified	8
Total	2436

4.2.5 Future Refinements to the Shoreline Classification System

Refinements to the Shoreline Classification system will be required in FY1999 to address one or both of the following issues:

- Quality control / assurance review of the lakewide data base will be required as part of the lakewide application of the Flood and Erosion Prediction System. There are certain to be areas which have been incorrectly classified and these will be highlighted in both statistical and deterministic approaches to assessing lakewide predictive capabilities of the system (See Section 4.13).
- Depending on the outcome of the work by Baird and Mickelson at U. of Wisconsin on bluff failure types and the implication for an uncertainty band around projected shoreline position, modification of the system may be required to allow for lakewide classification of bluff failure modes.
- A decision may be made to include islands (e.g., Beaver Island) in the LMPDS analyses. If so, these islands will need to be classified and included in the database.

4.3 Coastal Field Data Collection and Site Studies

The objective of this task were to collect extensive field data at selected study sites, representative of larger areas of similar sandy or cohesive shore types in both developed and undeveloped areas. The data collected at these sites is being used to provide critical

information to test and refine analytical procedures being developed in the *Coastal Processes Model / Flood and Erosion Prediction System* (see section 4.3).

Data have been collected during the summer of 1997 and 1998 at the following study sites:

- Two Creeks, WI;
- Fisher Creek, WI;
- New Buffalo, MI;
- Warren Dunes, MI;
- Shoreham, MI;
- Miami Park, MI;
- Muskegon, MI; and
- Little Sable Point, MI.

These sites were chosen since they are fairly representative of various shore types and levels of development. Some of these detailed study sites were also chosen because other data collection efforts took place there in the past, which can provide a better understanding of temporal changes.

The types of data collected at each site have included:

- hydrographic and topographic survey lines (one primary line with two parallel secondary lines on either side locating the top and toe of the bluff, shoreline, and profile of offshore bottom elevations to the 20 foot contour);
- soil borings, elevation of glacial till and its contact with overlying sand deposits, and laboratory tests for engineering properties;
- geophysical surveys (generally ground penetrating radar) to determine the thickness of sand deposits; and
- SHOALS (Scanning Hydrographic Operational Airborne LIDAR System) bathymetric surveys from the bluff edge to the 20 foot contour, for a distance of approximately one mile at each study site, centered around the survey lines.

These tasks were completed during 1997 and 1998. Coleman Engineering performed the Wisconsin field surveys; Toltest, Inc. performed the Michigan field surveys; and, John Chance & Associates, under contract to WES, performed the SHOALS surveys. USACE (Detroit District and WES) staff also assisted in portions of the field data collection and in contract administration and documentation of results.

Detailed field work was also supplemented by observations of key study team members and consultants during a one week field trip in the summer of 1997 along the Michigan shoreline. This included a boat tour of the shoreline along a portion of shoreline in Shoreham and stops at all of the key study areas along the Michigan shoreline. All scheduled FY 1997 coastal field data has been collected. The SHOALS data sets have been reduced and reported. The remaining data sets are currently being analyzed and reported.

Expected outputs from this task will be: collection, reduction, and reporting of digital data for the SHOALS surveys, and for the topographic, hydrographic and geophysical

surveys; digital profiles and contour maps; boring logs; and lab test results.

4.4 Coastal Process Modeling

Numerical modeling of shoreline processes is an integral component of the Lake Michigan Potential Damages study. The objective is to develop a defensible deterministic analytical model for predicting erosion at a range of spatial and temporal scales for the Lake Michigan shoreline. The Flood and Erosion Prediction System that has been developed as part of FY1998 activities by Baird::

- Accounts for changes in forcing (wave and water level conditions);
- Accounts for changes in resisting factors (sand supply, sand cover and shore protection);
- Describes erosion on a temporal scale (several months to 30 years or more) that captures bluff stability detail;
- Relies on the wealth of existing recession rate data for model calibration and verification; and
- Is coupled with a ArcView GIS (through the use of tools created through Avenue scripting) to assess economic and environmental implications of “what-if” scenarios.

The GIS based Flood and Erosion Prediction System that has been developed by Baird & Associates recognizes and accounts for the inherent differences between erosion dynamics at sandy shores and cohesive shores.

The Flood and Erosion Prediction System includes links between existing numerical models (wave climate, wave propagation, COSMOS nearshore coastal processes and bluff failure) and modifications to produce a versatile model for describing and predicting erosion for short to long term time scales. The model has been successfully tested at the eight study sites where detailed data have been collected (see 4.3 above). The model will then be applied basin wide across the Lake Michigan shoreline to estimate the degree that beach erosion and bluff recession would be expected to take place in response to various hydrologic/control scenarios over the planning horizon of the study. A schematic of the model is found in Figure 7.

An example of the model calibration is presented in Figure 8. At the Two Creeks, Wisconsin cohesive shore site, the COSMOS model has been successfully calibrated to predict the historic recession rates. In Figure 9, the future bluff crest position is predicted with the model, assuming similar wave and water level conditions.

The development of the coastal process model / Flood and Erosion Prediction System is expected to be continual over the course of the Study. Work to date has included refining prior modeling approaches, the development of a new conceptual model, and the development and testing of an updated model using field data collected at the Lake Michigan study sites. Anticipated work for FY 1999 and beyond will include basin-wide model application to the alternative hydrologic/control scenarios, and linkages of the GIS - Based Flood and Erosion Prediction System a comprehensive GIS context (including

land based economic attributes).

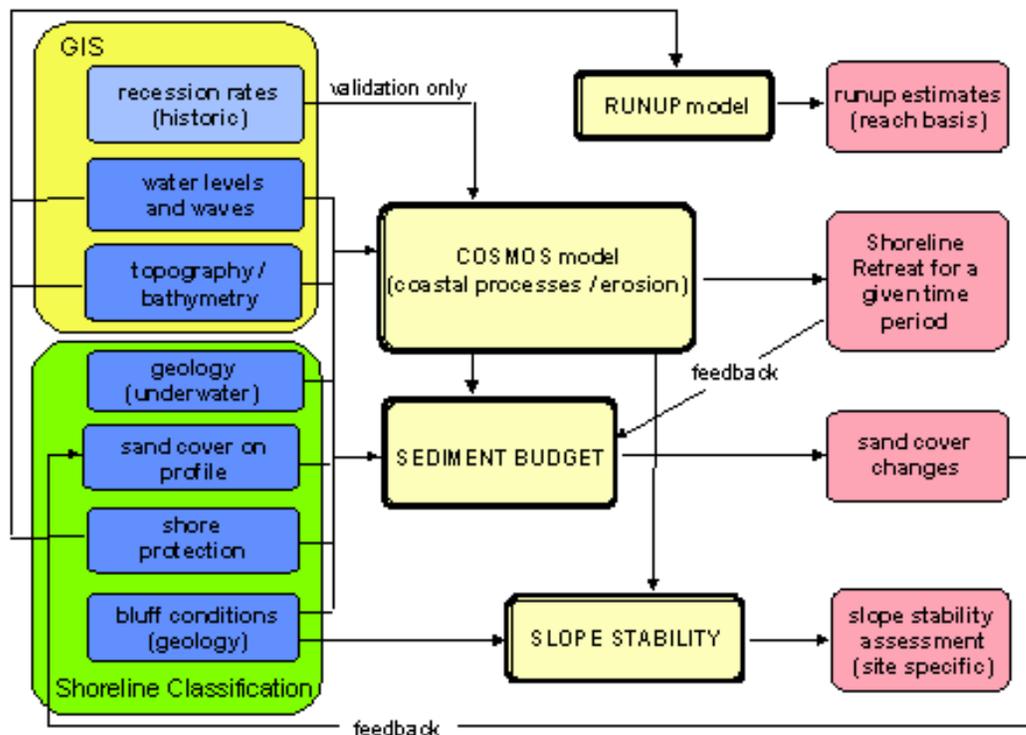


Figure 7 - Flood and Erosion Prediction System Flow Diagram (Baird and Associates, 1998)

The GIS-Based Flood and Erosion Prediction System has several applications as a coastal zone management tool, following the LMPDS including:

- The ability to determine 30 and 60 year setbacks under “what if” scenarios, relying on predictive rather than extrapolated recession rates;
- Application as a management tool to assess the impacts of shore protection, jetties, breakwaters, and other shore structures;
- The ability to provide a scientifically defensible planning tool that will be accessible to the public and other stakeholders; and,
- The capability to prioritize and justify public funding of shoreline projects.

4.5 Analysis of Bluff Stability Factors on a Local / Short Term Basis

The objective of this task is to determine the interdependence between coastal processes and bluff stability. Many coastal processes may influence the stability of bluffs, such as the removal of beach surcharge at the toe of a bluff, notching at the toe of a bluff, and

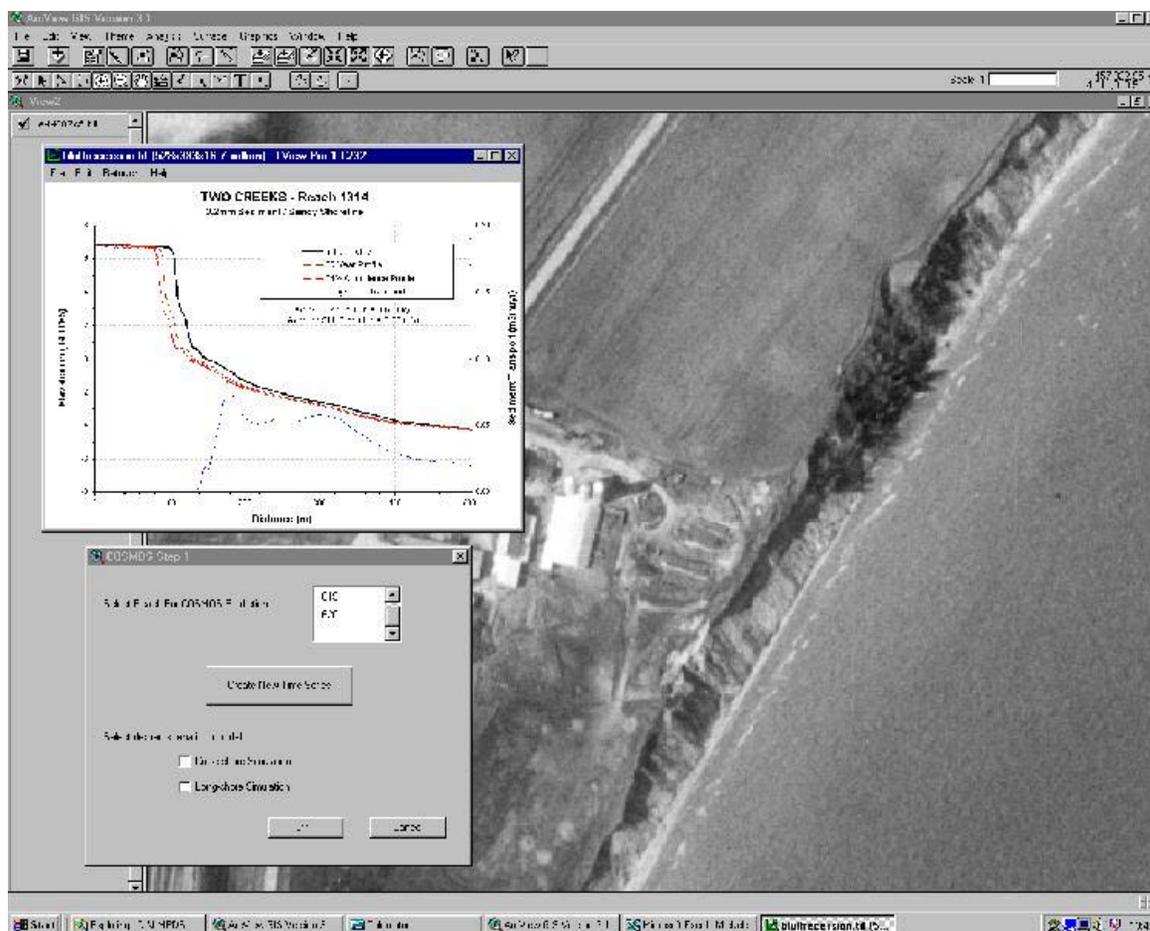


Figure 8 - Calibration of Historic Profile Change and Bluff Retreat at Two Creeks, Wisconsin

wave impact on the bluff face. Alternatively, bluff stability and ultimately failure can influence coastal processes by obstructing sand transport or protecting the erodible section of a lake bed. Further analysis on these issues is taking place to ensure the linkages between bluff stability and coastal processes are incorporated into the coastal process model being developed. This study task will draw upon field observations, research and publications conducted by others outside the scope of this overall study. This will not be a lakewide function of the model and in most cases will require additional site specific data to apply this procedure. Nevertheless, it is a critical task as it will help explain the short term increases in bluff failures during periods of high lake levels - the key area of concern for riparians. Dr. Chase of Western Michigan University has obtained a comprehensive data base for several sites in Allegan County which will allow quantitative assessment of these local and short term bluff stability issues. Chase has also initiated a preliminary assessment of the link between coastal processes and bluff failure.

The lakewide assessment of the influence of bluff stability on future projections of shoreline or bluff crest position has been analyzed by Baird & Associates and the University of Wisconsin and is described in Section 4.1.4. The result of this assessment is the application of an uncertainty band on either side of the shoreline position (Figure 9).

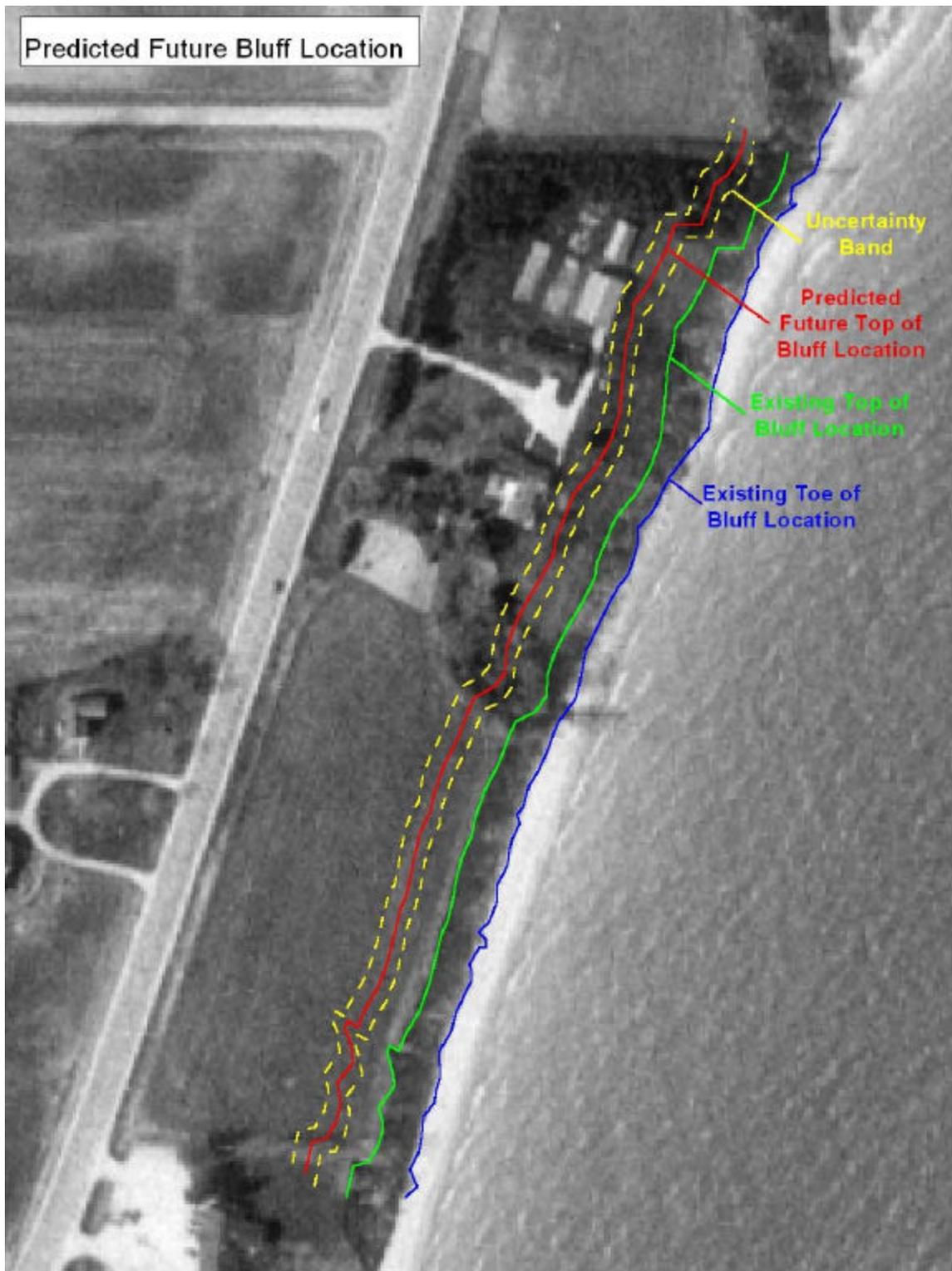


Figure 9 - Predicted Future Bluff Locations at Two Creeks, Wisconsin

In addition to the lakewide work described in Section 4.1.4, work to date within the LMPDS has been relatively limited and has focused on initial review and analysis of the above data. Bluff height, slope and gully information have been recorded on a kilometer-by-kilometer basis for input into the coastal processes model and incorporation into the GIS database. This information was simply extracted and measured from topographic maps for those areas of shoreline classified as bluff shoreline in the classification exercise. This data will form part of the kilometer-by-kilometer coastal zone database and be incorporated into a database analysis system for future use. Bluff height data will also be utilized in the calculation of sediment budget information for each reach within the coastal processes model.

4.6 Analysis of Structural Shore Protection Impacts

The objective of this task is to determine the interdependence between coastal processes and the extent, type and quality of structural shore protection put in place along the Lake Michigan shoreline. Many coastal processes influence the effectiveness of shore protection structures over their design life. Alternatively, structural shore protection has a direct and measurable effect upon alongshore sediment transport interfering with natural processes of beach accretion and erosion.

This study task has included a combination of qualitative and quantitative techniques drawing upon field observations, research and publications conducted by others outside the scope of the overall study. The geotechnical information being gathered at the site study areas may also prove useful in further defining these interactions. Further analysis on these issues must take place to ensure that the coastal process model being developed provides reliable estimates of future erosion and recession. This is especially important for areas where greater capital investment in structural shore protection is expected to occur over the study planning horizon.

The results of this task will be used to define the role of the different types of shore protection structures on erosion processes for the lakewide predictions. It will also be important to evaluate the accelerated erosion that would occur if existing structures were to fail (particularly those that have been subject to considerable nearshore downcutting). In addition to contributing to the assessment of potential damages, another intention of this task would be to develop general guidance on the efficacy of different types of shore protection in different physical settings.

Work to date on this task has consisted of incorporating the effects of shore protection within the lakewide Flood and Erosion Prediction System that has been developed by Baird. FY1998 tasks will include further testing of these effects and assessment of potential damage issues such as future costs of replacing and maintaining shore protection and assessing shore protection where shore protection structures are not maintained.

4.7 Analysis of Lakewide Sediment Budgets

The objective of this task is to determine a sediment budget, on a lakewide basis, which can be updated to keep track of sediment supply to various reaches around the Lake Michigan shoreline. This analysis includes information for various reaches, such as: potential alongshore transport rates; fraction of beach size sediment made available through erosion; other sources of sediment; and, sinks of sediment. This analysis provides important information for predicting the sand cover on cohesive shores, and changes, which may effect future recession rates. Essentially, a predictive system will be developed to evaluate changes to sand cover on cohesive shores (or erosion of sandy beaches) where the sediment budget has been influenced by natural or human factors. This will introduce a feedback mechanism in to the modeling system as changes to sand cover may influence recession rates which in turn will influence yield of eroded sand (and sand cover), which in turn effects recession rates. This feedback mechanism will be addressed in the overall Flood and Erosion Prediction System through iterative model runs. It is likely that the fully interactive predictive system involving both sediment budget and coastal process modules (i.e. complete with feedback) would only be applied on a littoral cell basis (i.e. not on a lakewide basis). The sediment budget system for predicting changes to sand cover is currently being checked against the recent changes that have been experienced downdrift of New Buffalo.

An important task in the development of the sediment budget aspect of the Flood and Erosion Prediction System by Baird has been creating an automated approach for assessing bypassing at all partial and full littoral barriers around the lake. The influence of dredging operations the sediment budget has also been incorporated. The system will therefore be ideally suited to the estimation of the cost (potential damages) of increased dredging requirements under low water scenarios.

Baird & Associates have completed the development of the sediment budget module of the Flood and Erosion Prediction System. Testing of the system has been completed at some of the eight study sites and required information to implement the model on a lakewide basis has been obtained and included in the system. FY1999 work will include the testing of the system on a lakewide basis and filling remaining data gaps.

Examples of output from the sediment budget component of the system are shown in Figures 10 and 11. Figure 10 shows the lake bed change in plan and profile between 1945 and 1997 updrift of New Buffalo, Michigan. Figure 11 shows the sediment budget output for the system from New Buffalo. The system successfully predicted the loss of sand from the downdrift shoreline and accelerated lake bed downcutting.

4.8 Estimation of Deepwater Wave Climate for Water Level Scenarios

The objective of this task is to develop site specific deepwater wave climates all around the Lake Michigan shoreline. This information is required as input for the coastal

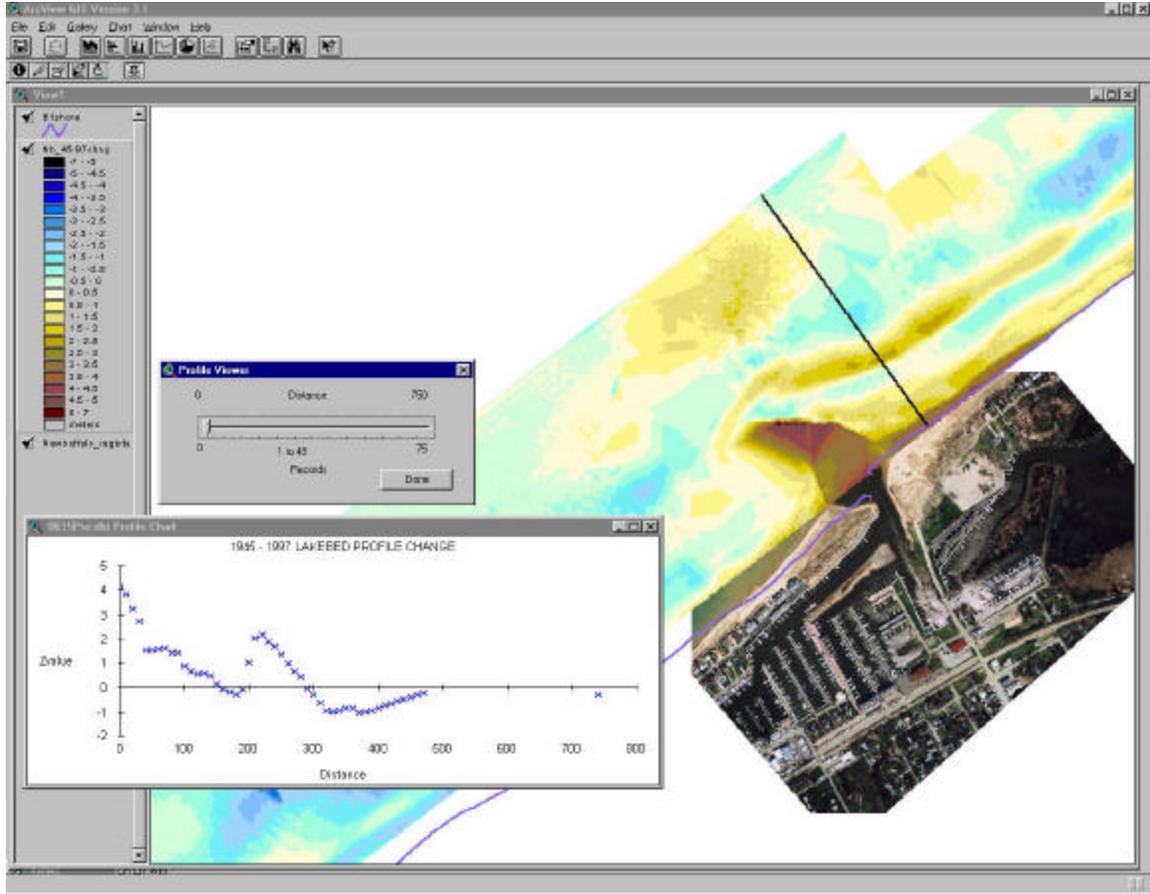


Figure 10 - Lake Bed Change at New Buffalo, Michigan



Figure 11 - Sediment Budget, Existing Conditions at New Buffalo, Michigan

process modeling of shore erosion. The WIS hindcast deepwater wave database completed by the USACE Waterways Experiment Station covers the period from 1956 to 1987 for the entire lake. An additional period of coverage (1991 to 1993) was completed for the St. Joseph Harbor MCCC project. Additional modeling is currently being conducted to develop a complete database from 1956 to 1997, and possibly through to the end of 1998. Baird & Associates have completed site specific hindcast to fill gaps in the spatial coverage of the WIS stations. Baird have also incorporated the influence of ice conditions on the wave predictions as part of the Flood and Erosion Prediction System, and particularly the issue of shore ice protecting the nearshore and backshore zones. Also, the wave, water level (monthly and surge) information will have to be combined to develop a single input file of hourly waves and water levels. For future wave conditions, information on wind climate scenarios from Global Climate Models (GCM's) will be required.

To date, the complete historic data base (up to September 1997) has been completed and input to the coastal process model for initial analysis at the study sites. Baird & Associates have developed a module for the Flood and Erosion Prediction System which allows for consideration of ice influence on wave generation and shoreline protection. The future wave condition scenarios are currently being completed and will be input to the FY99 lake-wide application of the potential damages system.

4.9 Determine Nearshore Waves and Surge Characteristics for Each Scenario

The objective of this task is to apply a nearshore wave transformation procedure to determine local wave condition input to the coastal process model using the deepwater WIS data for various scenarios as input. In many open coast locations this transformation procedure will be straightforward and will incorporate application of the TMA spectral similarity concept in addition to linear wave refraction. Baird & Associates have completed the development of a module within the GIS Linked Flood and Erosion Prediction System for prediction of nearshore wave conditions on a 1 km reach resolution. In addition, Baird have created a utility with the ArcView based Flood and Erosion Prediction System using Avenue scripting to interpolate lakewide surge conditions on a 1 km reach resolution based on interpretation of analyzed water level gage data at the available stations on Lake Michigan.

Figure 12 provides a screen capture from the Flood and Erosion Prediction System showing the nearshore wave rose for Reach 841 at New Buffalo, Michigan. The system can automatically produce this output for any reach around the lake.

4.10 Determine Storm Water Level Coincident Frequencies by Scenario

The objective of this task is to estimate storm surge and wave run-up characteristics for each water level scenario for each reach of the Lake Michigan shoreline. This

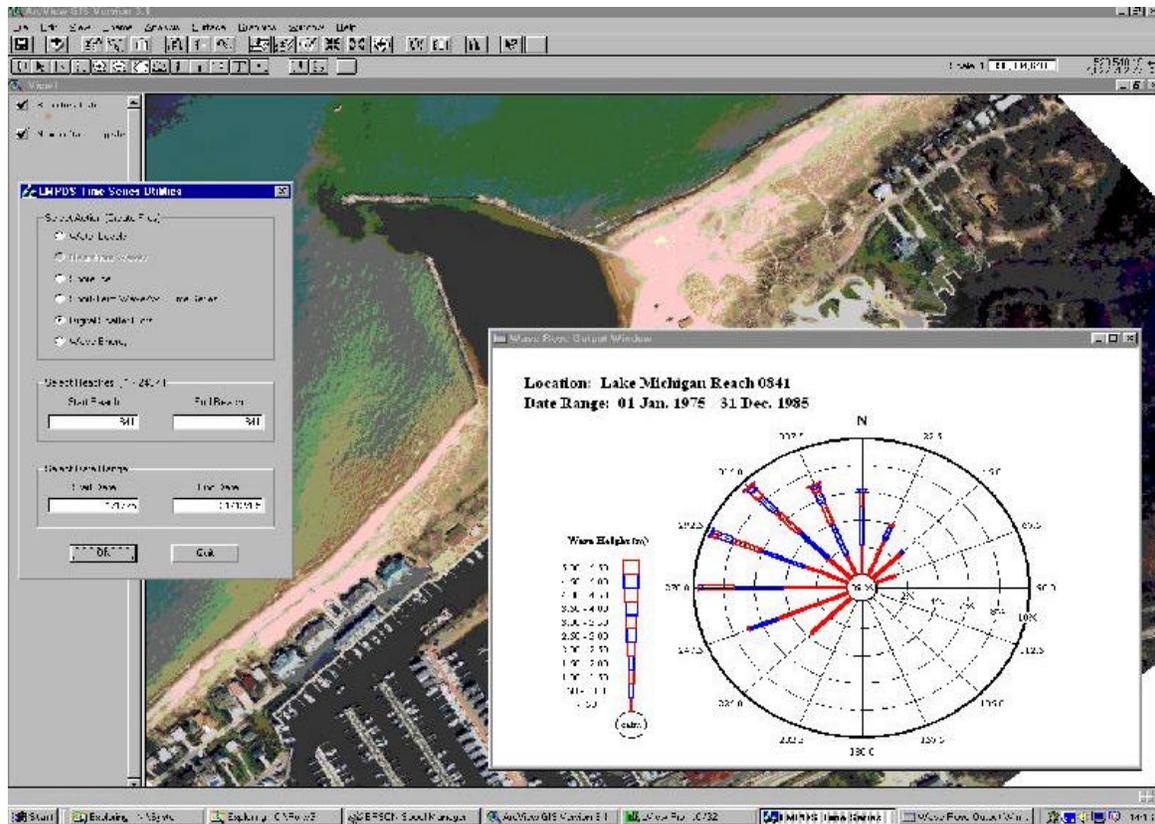


Figure 12 - Nearshore Wave Output for Reach 841, New Buffalo, Michigan

information is required as input for the erosion processes modeling to estimate potential damages under differing water level regimes.

For historic conditions, measured surge levels have been derived by Baird through analysis of water level gage records (as noted in Section 4.9, these have been interpolated to all 1 km reaches within the Flood and Erosion Prediction System. These analyses typically look at the maximum difference between an instantaneous reading at a particular gage and the monthly mean water level (stillwater) for the lake. For alternative scenarios developed, wave climate and storm surge predictions generated under other tasks will need to be applied to estimate frequencies and magnitudes of storm surges in the nearshore zone. Alternative surge scenarios can be automatically interpolated lakewide on a 1 km resolution with the newly developed system.

Wave runup characteristics are exceedingly site specific, since they are affected primarily by profile characteristics, substrates, and deepwater wave climate which vary considerably along the shoreline. Several studies have been conducted under the auspices of FEMA in the past on wave runup methodologies and coastal flood inundation probabilities. These studies will also be evaluated as to their detail, coverage, and utility for application for the wave runup prediction system that is proposed to be developed.

To date, the historic surge level data has been interpolated on a lakewide basis. It is anticipated that surge level estimates for the alternate water level scenarios will be

completed by April 1999 for input to the Flood and Erosion Prediction System. A thorough review of the utility of existing wave runup analyses for predicting wave forces under the alternate water level scenarios should also be completed by December 1998. If further work is warranted, this work will need to be conducted in 1999.

4.11 Determine Estuarine Backwater Effects

This task is designed to assess the backwater effects associated with high and low hydrologic scenarios for the drowned river mouth/estuarine systems on Lake Michigan. There are many areas which are influenced by the water levels on Lake Michigan and it is the intent of this task to determine the upstream limits of these impacts, as well as their spatial extent along the rivers. A wide variety of interest groups exist in this area such as, riparian home owners, recreational facilities, industrial facilities, public infrastructure, among others. There are a variety of methods that may be used for this task. Cross-section data needed to generate the hydraulic backwater models can be very extensive and expensive to collect. Options will be evaluated to use DEM data to extract cross-section information as input to HEC-2. Alternatively, the use of the MIKE11 model and its ability to use either scanned contours or information directly from a GIS will be investigated.

Baird have completed an initial scoping of the efforts required to incorporate backwater effects within the Flood and Flood and Erosion Prediction System that has been developed by Baird in FY1998.

4.12 Estimate Recession Rates for Each Water Level Scenario

The objective of this task is to generate estimates of future average annual recession rates for each and every kilometer along the Lake Michigan shoreline for each and every one of the hydrologic / control scenarios being evaluated under the overall study. This work is the culmination of most of the coastal investigations being conducted under this study. An initial sub-task will be to check the predicted recession rates for a historic period (covering all or part of the 1956-1996 updated WIS database) against the estimated rates for all reaches. Refinements to the classification system, the wave input and/or the coastal process modeling system may be required to ensure that the model is capable of representing, to a reasonable degree of accuracy, the existing conditions. Once satisfactory results are achieved for all reaches, the system will be applied to predict recession rates for all reaches under the various hydrologic scenarios.

Initial tests have been completed with the Flood and Erosion Prediction System on areas outside the detailed study sites between August 1998 and September 1998 to assess the level of work that will be required to refine the lakewide system. Work on lakewide predictions will commence on this task in October 1998 and are anticipated to be complete by March 1999.

4.13 Development of a Flood and Erosion Prediction System

The development of the Flood and Erosion Prediction System is essentially the culmination of many of the coastal process investigations being carried out in the LMPDS. The objective is to develop a system for the prediction of shoreline recession (or accretion) on a lakewide basis at a 1 kilometer resolution.

Baird have completed development of the core of a GIS linked Flood and Erosion Prediction System (Figure 7) incorporating the work described in Sections 4.1-4.12 above. A summary of progress by Baird & Associates and is presented here.

A Flood and Erosion Prediction System has been developed to provide a graphical, geographically referenced database of information required to predict future shoreline position. To date, the system the following key components: ArcView GIS, Nearshore wave transformation, coastal process, flood and erosion predictions (the latter with the COSMOS model). Linkages, Graphical User Interfaces and data analysis requirements have been addressed through the development of tools using Avenue scripting to enhance the ArcView GIS. The system allows users to create “projects” for studying any specified section of shoreline using the built-in data and coastal process modeling tools. Projects for eight detailed study sites around Lake Michigan have been created and the coastal process tools have been used to simulate the historical trends at these sites.

Base data that has been integrated to form part of the system includes:

- shoreline classification data (geomorphic, nearshore subaqueous, and structural classifications);
- “single value” shoreline recession rates;
- more detailed estimates of shoreline recession rates at study sites;
- lakewide digital bathymetry from NOAA;
- base map information and topography for study sites (lakewide pending);
- SHOALS bathymetry for 7 of 8 study sites (Fischer Creek, WI is not available);
- hourly WIS hindcast data for the period 1957-1987 (1987 to 1997 is pending);
- hourly water levels at 8 gauge stations for varying periods;
- weekly ice cover data for the period 1972-1995;
- ground penetrating radar at study sites (pending);
- grain size information at study sites;
- boreholes and stratigraphy at study sites; and
- available dredging records;

Added data analysis functionality has been incorporated into the GIS with the development of automated procedures to:

- extract cross-shore profiles from bathymetric and topographic data;

- conduct surface and volume comparisons of bathymetric data;
- create digital scatter plots of wave and water level data for any reach (both nearshore and offshore information), with the option of omitting periods when shore ice is present; and
- generate historical hourly water level files for any reach based on the water levels measured at the 8 available gauges.

The COSMOS coastal process model has been linked to LMPDS GIS system. The model link provides the ability to:

- automatically create the COSMOS model input file using reach-specific data and profiles;
- automatically create a cohesive profile at each reach based on the shoreline classification (sand cover);
- estimate the longshore transport at each reach which is used in the sediment budget calculations;
- estimate profile change in response to storm conditions;
- estimates long-term bluff recession rates (and confidence intervals on rates); and
- manually edit model parameters to provide flexible input for modelling “what” if scenarios;

The system as described above has been applied to the study sites to model historical shoreline trends. Analysis completed to date includes:

- surface comparisons of offshore bathymetry for the New Buffalo, Warren Dunes, and Shoreham study sites for the period from 1945 to 1997;
- generation of historical wave/water level/ice data for each reach at each study site;
- estimation of longshore transport rates and shoreline change at each study site using the COSMOS model and developed tools;
- calibration of the newly-revised bluff recession capability of COSMOS using erodibility factors derived from physical model tests (performed during FY98) and recession rates measured from historical aerial photos; and
- development of a sediment budget for each study site.

Planned FY99 activities include:

- lakewide testing of the system and required refinements to the system and base data set to achieve acceptable predictions (compared to historic rates);
- improved incorporation of bluff type influence on confidence interval for shoreline position projections;
- investigation of short term links between coastal process and bluff failures to allow assessment of short term risk;
- refinements to the system to allow predictions and graphical presentation of flooding related damages;
- integration of GIS-Based Flood and Erosion Prediction System with potential damage

assessment system and data base.

The first activity is a critical quality control/quality assurance task. A preliminary assessment of lakewide testing procedures has been completed using a statistical analysis technique referred to as Classification and Regression Tree Analysis (CART). The CART package has been linked to the GIS data base of the Flood and Erosion Prediction System in order to assist with discriminating between errors related to base data versus process representation.

4.14 Development of a Wave Run-Up Prediction System

The objective of this task is to develop a fourth module for the shore erosion prediction system which will provide an estimate of wave runup (extreme value analysis) on a kilometer reach basis. One option includes using existing software that could be integrated to produce a predictive system for estimating runup using the range of techniques presently available in the literature. A lakewide definition of wave runup statistics on a kilometer definition for both historic and future scenarios would be a unique tool and one which state and other federal agencies may have great interest.

To date, there has been no activity on this task aside from the initial scoping in FY1997.

5.0 Land Use Investigations

Recall that a key input to the coastal process model and erosion prediction models being developed is accurate recession rate data (Section 4.1). Another key input related to the recession rate information is the existing land use along the shoreline, as well as the possible trend in land use into the future. From a potential damage point of view, it is important to know the relationship between the recession rate of a particular stretch of shoreline and the land use or possible land use that is occurring on it. For example, a highly erosive, developed shoreline will have greater "potential damage" than a highly erosive undeveloped shoreline. As such, it became necessary to develop sound databases of both land use and land use trends along the Lake Michigan shoreline for input to the models being developed to help predict possible future damages along the shoreline.

5.1 Update Current Land Use Conditions

In order to be able to correlate recession rates with existing land use along the shoreline, it was necessary to establish the existing land use associated with each 1 km reach segment, as this level of detail in the data had never yet been derived. This data was not easily extractable from the USACE GIS database electronically and thus was done manually.

Land use maps (plots) and USGS topographic maps of the Lake Michigan shoreline with 1km tick marks on them were obtained from USACE and used in this exercise. Proceeding linearly along the shoreline, all land use classes occurring in each reach were recorded in a column in the database. Only land use classes within a maximum of 0.5 km of the shoreline were recorded. In many cases, particularly where residential development was present, only the most adjacent land use to the waterline was recorded. Where residential development occurred along with other land uses, estimates of the linear percent of the reach occupied by the residential categories were made.

The land use data compiled in this exercise is circa 1978. Land use updates are currently underway within Detroit District, however the data was not yet available for this exercise.

Land use by reach data is presented in Appendix 4 of Stewart (1997) submitted to USACE Detroit District in December of 1997.

5.2 Land Use Trend Information

Land use trend information was available from the following three key data sources:

5.2.1 Land Use and Land Use Trend Data Collected During the IJC Reference Study

Past and future land use trend information for Lake Michigan was collected as part of Phase II of the IJC Water Levels Reference Study (Taylor and Gauthier, 1993). The data was based primarily upon responses provided from questionnaires that were distributed to regional planning entities along the shoreline. Questions were posed that requested their best estimations of current development percentages (circa 1990), past development percentages (circa 1980) and anticipated development percentages (circa 2000).

Land use trends generated in this study refer exclusively to new development in the residential, commercial / industrial and public infrastructure categories. Ten-year development trends that were generated represent the increase in percentage of the shoreline that is expected to be developed into any of these three categories.

5.2.2 State of Wisconsin Land Use Trend Data, 1978-1992

Subsequent to the work completed during the IJC Reference Study, the State of Wisconsin initiated a comprehensive review of land use change in the Lake Michigan coastal zone between 1978-1992. This work (see Niedzwiedz, 1995a-k) utilized 1978 and 1992 color aerial photographs to map and delineate land use areas and numbers of structures in each area for each county along the Lake Michigan shoreline.

5.2.3 Site Visits and Related Reports

Site visits along the eastern shoreline of Lake Michigan were carried out in the summer of 1997 on two occasions. The first of these occurred near the end of June 1997 and focussed on the Michigan counties of Berrien, Van Buren, Allegan, Ottawa and Muskegon (Nick Raphael and Roger Gauthier, personal communication). The second of these occurred between July 26th and August 9th, 1997 and focused on the northern Michigan counties of Emmet, Charlevoix, Antrim, Grand Traverse, Leelanau, Benzie, Manistee, Mason, and Oceana (Stewart, 1997). Visits to these areas focused on discussion with local planning officials. Questions on existing land use and future land use trends were asked during all interviews. Information was also obtained through field observation and notes / photos where possible. In addition to this anecdotal data, various land use plans and Master Plans from a number of county officials were obtained during these visits. This material was reviewed to determine the availability and usability of any "Land Use Trend" information for entry into the database.

5.2.4 Development of Land Use Trend Indices

One of the primary goals in this overall recession rate - land use analysis exercise is to determine recession rate data gaps relative to changes in land use that are anticipated to occur. For example, if we estimate that a particular reach is going to show an increase in development, and there is presently no recession data available for that reach, it becomes important to collect or develop recession rate data for that reach. If we keep things at this simplistic level, our primary concern with regard to land use trends is whether or not there is going to be a simple increase in development, a decrease in development or no change, for each reach under consideration.

The land use trend data obtained from the IJC study, from the Wisconsin studies and from the anecdotal information derived from interviews with planning officials, generally provides us with specific percentages of development increase expected. While it would be simple enough to use this data as developed, there are a number of issues that arise that we feel prevent this from occurring. These include differences in the way the data were collected, lack of confidence in the data generated in the IJC study, differing time periods over which trends were estimated (e.g., 1991-2000, 1978-1992), and inclusion of slightly different land uses in the "developed" categories in the IJC and Wisconsin studies.

Given these concerns, we felt that instead of using the data directly, we would use it as a starting point to develop a series of "Land Use Indices" that provide a more consistent, lakewide assessment of the potential land use trend in each reach. In developing these indices, our primary concern was whether there would simply be an increase in "development", a decrease in development or no change. Reaches with an increase would be targeted or "ranked" as of a higher concern than those with a decrease in development or no change. As such, we have developed a simple 5 step index:

- 1 = reaches where there is an estimated decrease in developed area
- 2 = reaches where there will be no change in the level of development
- 3 = reaches where there is an estimated 1-3% increase in developed area
- 4 = reaches where there is an estimated 4-10% increase in developed area
- 5 = reaches where there is an estimated >10% increase in developed area

In assigning an index value to each reach, a number of assumptions were made:

- 1) It was generally assumed that data generated from any of the studies listed above would be representative of future change in shoreline development over the next 50 years.
- 2) Any level of development estimated at greater than 10% of a reach would be ranked as the highest level of concern (index value of 5).
- 3) Areas encompassed by State Parks, National Parks, State or National Forests and large urban centers or areas of harbor structures will not have any change in their status, i.e., their land uses are essentially fixed and will not change (index value of 2).

- 4) Despite concerns about the quality of the data, IJC land use trend data developed for the State of Michigan were used to develop indices for these areas, except in those areas where interviews with local planning officials or personal field observation necessitated adjustments, or where Assumption #1 applied.
- 5) IJC data for Indiana and Illinois was also utilized. For both states, the level of development was not expected to change.
- 6) Indices for Wisconsin were generated from the combined percentage change values generated from the detailed data (Section 3.2.2 above). IJC data was not utilized for the Wisconsin shoreline.

In applying the indices, we proceeded in the following manner:

- 1) Reviewed and utilized IJC data for Michigan, Indiana and Illinois shoreline
- 2) Reviewed and utilized Wisconsin data
- 3) Adjusted reaches accordingly based on assumptions above
- 4) Adjusted any Michigan reaches based on information obtained from planning officials or personal observations

Land use trend indices for each reach are presented in Appendix 4 of Stewart (1997).

5.3 Development of a Recession Rate - Land Use Analysis System

To allow an analysis of recession rates and land use to be conducted for the LMPDS, a Recession Rate Analysis System (RRA) was developed by VGI Vision Group International Inc. The RRA is an expert system designed to undertake the priority determinations for recession rate data and to serve as a vehicle for cataloguing, monitoring and updating the entire database of related information (e.g., reach, land use, land use trend, etc.).

The RRA is a flexible and customizable system that integrates a powerful relational database management system (MS FoxPro) with a dedicated Geographic Information System mapping and visualization package (QuikMap) that will allow basic mapping and visualization of all query results.

The RRA system is a “living system” in that, a complete copy of it, with the data collected for the project was provided to USACE Detroit. This can then be used to run additional queries, and undertake additional recession rate assessments as new data becomes available, or as various data sets become revised (e.g., land use, shoreline classification).

It should be noted that Version 1.0 of the RRA designed for Phase I of the LMPDS provided a basic level of functionality in order to address the query needs of the recession rate and land use analyses being conducted. While it was an excellent tool for doing this, there were some components of the program that needed further refinement.

These were addressed during FY98 and have been incorporated into Version 2.0 of the software which was provided to USACE Detroit in October of 1998. The most notable change in Version 2.0 is the inclusion of the updated shoreline classification data for Lake Michigan and a refined and more robust query capability based on the new classification data. Further refinement of the RRA envisioned over the course of FY99 will include incorporation with ArcView and GeoMedia GIS viewers, as well as incorporation to the LMPDS models and GIS systems being developed. RRA databases are also being developed for the Lake Erie and Ontario shorelines under a separate initiative for USACE Buffalo District and are anticipated for the Lake Huron and Superior shorelines in the near future.

A complete description of the RRA and examples of specific analyses conducted for the LMPDS are can be found in Stewart (1997).

6.0 Economic Approaches

There are a series of economic approaches and considerations that will be required for adequate damage estimations to be made within the model.

6.1 Estimate Future Structural Protection Trends

A large majority of "damages" along the shoreline are those caused to shore protection structures during large storms. The level of this damage will vary depending on the type of structure that is in place and the quality of the structure. To be able to adequately assess these damages 50 years into the future, it will be necessary to estimate the types and quality of shore protection structures that may be in place over that time period and the types of changes or trends that might occur. For example, if there is a trend from low quality, concrete rubble structures, to the installation of well engineered (and well maintained) revetments or breakwaters, we would expect that the damage level to such a structure would decrease. Also, we would expect that the damages to any land or buildings behind that structure would also decrease. Similarly, if significant amounts of shore protection structures are removed, or left un-maintained, this may have a significant impact on the level and types of damages that might occur to the shoreline in these areas (e.g., accelerated erosion, flooding at high water).

It is anticipated that the work conducted on this task will consist of a review of Great Lakes coastal engineering literature as well as previous information on shore protection gathered in the IJC Levels Reference Study and other previous studies where shore protection structures were examined. Past information can be compared with the types, quality and extent of structures identified in the recent classification of Lake Michigan conducted for the LMPDS. This task will also build on the work completed by Baird & Associates in FY98 on shore protection issues as described in Section 4.6.

This task has not yet been initiated. It is expected that it will be addressed over the course of the FY99 fiscal year.

6.2 Determine Avoided Cost Considerations

Avoided costs are those costs of damage or potential damage that are avoided or eliminated through the construction of well-engineered shoreline protection. For example, if a property owner builds a \$100,000 seawall and over the course of time, prevents his \$500,000 home from being destroyed or damaged by wave activity, flooding, etc., then his initial \$100,000 investment has helped him "avoid" a potential \$500,000 loss. Related closely to the structural shoreline protection trend issue, an estimate of these avoided costs will be key to an accurate prediction of potential damages into the future. As another example, if the entire shoreline were to be adequately

protected, then our potential damages would end up being zero. In reality of course, this is not so simple, and a methodology will need to be developed for ascertaining these costs.

It is expected that this task will draw heavily upon work conducted by Baird & Associates (1993) on Avoided Costs that was completed for the Potential Damages Task Group (1993) of the IJC Levels Reference Study. In this work, Baird looked at avoided costs resulting from the construction of a range of well engineered structures. Their approach was developed for examining the entire Great Lakes shoreline and will likely need to be refined to be applicable to Lake Michigan. In addition, the more recent work of Baird & Associates will also be used to assess the potential increases in the cost of constructing and maintaining shore protection with the effects of ongoing nearshore downcutting (see Section 4.6).

This task has not yet been initiated. It is expected that it will be addressed over the course of the FY99 fiscal year.

6.3 Develop Assessed vs Market Value Protocol

There are usually significant differences between the assessed value and the market value of a particular parcel of land. Often the only value that is readily available to us for the purposes of property valuation is the assessed value (through tax assessor records). The market value of the home then needs to be established through some multiplier (sometimes referred to as the "mill" rate). As these mill rates may vary from township to township, a consistent method needs to be developed within the LMPDS for translating the assessed value into a reasonable market value for the purposes of potential damage evaluation.

This task has not yet been initiated. It is expected that it will be addressed over the course of the FY99 fiscal year.

6.4 Develop Future Model Update Procedures

Once a basin-wide potential damage model is developed, it will need to be continually updated to reflect changes in economic conditions (e.g., increases or decreases in housing values), changes in land use or land use trends, etc. A specific procedure or method for accomplishing this update needs to be developed.

This task has not yet been initiated. It is expected that it will be addressed over the course of the FY99 fiscal year.

7.0 Impact Assessments

A critical component of the Lake Michigan Potential Damages Study will be an assessment of the social, environmental and economic impacts that could potentially occur along the shoreline under different water level scenarios.

7.1 Social Impacts

Investigation of **social impacts** will focus primarily on:

- An update of current land use management and shoreline management practices along the shoreline; and
- An assessment of alternative land use and shoreline management options that may be available.

While a formal definition of this task has not yet been developed, preliminary discussion among the Study Team members during an early meeting focused on gaining a better understanding of the impacts that specific land use and shoreline management practices have had on reducing damages along the shoreline, and to what extent these programs may reduce potential damages in the future. Particular reference was made to the State of Michigan Coastal Zone Management Program. A report on shoreline management practices carried out in the IJC Study (Ecologistics, 1992?) does not apparently contain detailed information of this type (i.e., a comprehensive analysis of one particular program). In light of this, it is felt that such a review could be undertaken by conducting the following basic steps:

1. Conduct a comprehensive review of the Michigan CZM program and its impact on damage/hazard reduction;
2. Conduct a comprehensive review of municipal/county zoning and planning ordinances and by-laws and their impact on damage/hazard reduction;
3. Evaluate the likely future impacts of the above practices on damage/hazard reduction;
4. Prepare a Summary Report on the above findings.

The Flood and Erosion Prediction System developed in FY1998 by Baird could be used to assess the implications of CZM policy instruments on riparian response to different “what if” scenarios (such as high lake levels). In addition, it is expected that a great deal of data and information may be gleaned from work conducted by the Social Impacts Task Group during the IJC Levels Reference Study. This will also be supplemented by anecdotal and in-person interview data collected through discussions with county, municipal and other government agency personnel during the summers of 1997 and 1998.

This task has not yet been initiated. It is expected that it will be addressed over the course of the FY99 fiscal year.

7.2 Environmental Impacts

Investigation of **environmental impacts** will focus on:

- Impacts to archaeological and special natural features;
- Impacts to habitat biodiversity;
- Impacts to fisheries;
- Impacts to threatened and endangered species.

Again, no specific tasks have yet been defined. It is anticipated however that there will not be the time nor the budget to conduct detailed environmental impact assessments for the entire shoreline. As such, it is expected that many of the resources developed on this topic during the IJC Reference Study and elsewhere in the literature, will need to be reviewed and synthesized for use in the LMPDS. This will also be supplemented by anecdotal and in-person interview data collected through discussions with county, municipal and other government agency personnel during the summers of 1997 and 1998. A mechanism for incorporation of environmental impact data to the Potential Damages model will also need to be developed.

This task has not yet been initiated. It is expected that it will be addressed over the course of the FY99 fiscal year.

7.3 Economic Impacts

Investigation of **economic impacts** will focus on:

- Estimates of residential property losses by water level scenario;
- Estimates of commercial-industrial-institutional losses by water level scenario;
- Estimates of community-based property losses by water level scenario;
- Estimates of recreational boating and sports fishery losses by water level scenario;
- Estimates of the impacts and costs of dredging and channel maintenance;
- Estimates of future structural shoreline protection trends and costs;
- Estimates of the future damage costs avoided through construction of shore protection structures.

This step is essentially the culmination of many of the above described tasks and represents the final output of the Potential Damages model (see Section 8.0 below). Key economic impact data for initial input to the model will likely be drawn from the previous IJC Reference study, but will be revised to reflect the analyses being conducted here in the LMPDS.

This task has not yet been initiated. It is expected that it will be addressed over the course of the FY99 fiscal year.

8.0 Potential Damage Investigations

A critical component of the Lake Michigan Potential Damages Study will be an assessment of the potential damages that could potentially occur along the shoreline under different water level scenarios.

Potential damage assessments will ultimately be conducted in 5 key areas:

8.1 Residential Property Losses

Residential property losses will be estimated for each water level scenario on a lakewide basis. For residential damages due to **erosion**, damage estimates are proposed to be calculated via a number of steps including:

- Map the current bluff line
- Model recession rates
- Map the future bluff line
- Identify impacted parcels
- Query assessor records
- Apply market projections
- Generate preliminary damage estimates
- Apply anticipated land use adaption adjustment and
- Finalize damage estimates by township by scenario.

For residential damages due to **flooding**, damage estimates are proposed to be calculated via a number of steps including:

- Identify parcels in hazard zones per scenario
- Identify base elevations of structures
- Generate the number of incidences of instantaneous highs
- Generate depth-damage curves by township (adjusted for projected market value increases)
- Apply projected depth-damage curves per township
- Generate preliminary damage estimates
- Apply anticipated land use adaption adjustment and
- Finalize damage estimates by township by scenario.

To account for damages to shoreline protection structures, damage estimates are proposed to be calculated via a number of steps including:

- Generate average loss estimates by structure type by township per each scenario
- Apply loss estimates to percentages of the shoreline as categorized in shore protection GIS layer
- Adjust estimates by derived avoided cost factors (high water level scenarios only)

- Finalize estimates by scenario by township.

8.2 Commercial-Industrial-Institutional Damages

Commercial-Industrial-Institutional damages will be estimated for a number of key sectors. **Manufacturing and Shipping** losses will be calculated via a number of steps including:

- Conducting a 100% census of all facilities
- Assessing structural protection losses by scenario
- Assessing increasing dredging costs for low scenarios
- Coordinating estimates with plant managers
- Developing assumptions of future conditions
- Assessing lost revenue, profit, income, taxes, etc., ??
- Assessing anticipated adaptations to each scenario

Retail and Other Commerce losses will be calculated via a number of steps including:

- Conducting a 100% census of all facilities
- Assessing direct losses to facilities by scenario
- Assessing structural protection losses by scenario
- Developing assumptions of future conditions
- Assessing lost revenue, profit, income, taxes, etc., ??
- Assessing anticipated adaptations to each scenario

Parks and Recreational Facilities losses will be calculated via a number of steps including:

- Conducting a 100% census of all facilities
- Assessing structural protection losses by scenario
- Assessing "loss of use" by scenario
- Developing assumptions of future conditions
- Coordinating estimates with facility managers

Commercial Fishery losses will be calculated via a number of steps including:

- Conducting a 100% census of all facilities
- Assessing structural protection losses by scenario
- Assessing increasing dredging costs for low scenarios
- Developing assumptions of future conditions

Recreational Boating and Fishery Damages will focus on losses to these sectors including marinas, recreational boaters and sport and commercial fisheries (as noted above).

8.3 Community Based Damages

Community-Based Damages will focus on damages associated with a number of categories. **Roads and Infrastructure** losses will be calculated via a number of steps including:

- Conducting a 100% census of all networks within hazard zones derived from each scenario
- Assessing structural protection losses by scenario
- Developing assumptions of future conditions and increases in economic development based on community master plans
- Coordinating estimates with state, county, utility and private interests.

Water Supply and Wastewater Treatment losses will be calculated via a number of steps including:

- Conducting a 100% census of all facilities
- Assessing structural protection losses by scenario
- Assessing increased pumping costs for low scenarios
- Developing assumptions of future conditions based upon municipal and county master plans
- Coordinating estimates with municipal and county managers.

Finally, **Dredging and Channel Maintenance Damages** will focus on those costs associated with additional dredging required as a result of significantly lower water levels, or associated with excessive sedimentation of channels in high water periods or during altered current conditions. A number of steps are proposed including:

- Conducting a 100% census of all harbors and channelways
- Assessing increased costs for low scenarios
- Assessing increased facility maintenance costs for high scenarios
- Developing assumptions of future conditions based upon O & M program schedules.

Damage assessments in all areas will draw heavily upon the impact assessments conducted above and will be calculated through the potential damages model developed for the LMPDS.

These tasks have not yet been initiated and are expected to begin in 1999.

9.0 Things to Consider For Next Steps

The following are a series of items that are presented (in no particular order) for the purposes of getting Study Team, Advisory Committee, and other LMPDS participants to begin thinking about what activities need to be undertaken in the coming year and to think about the decisions and other factors that go along with these activities. These items formed part of the discussion during a Study Update meeting held in Detroit on October 14-16, 1998. While some of the issues identified below were addressed during the course of that meeting, other will need to be resolved over the course of 1999.

9.1 Damage, Impact and Economic Assessments

A significant amount of work has been completed and is well underway on developing a coastal processes model and "refining" the "state-of -the art" relative to coastal process and research. If the study is to progress toward completion by the year 2000, then the damage, impact and economic assessment tasks that have been defined need to begin immediately.

Decisions need to be made as to the level of impact and damage assessment to be made. Will there be resources to collect, synthesize and analyze data on a basin-wide basis, or will the analysis need to focus on the site specific areas with "extrapolation" to the entire shoreline?

Decisions need to be made early in 1999 of how to conduct the tasks listed in Section 6, those related to structural protection trends, avoided costs of protection, market versus assessed values and how the potential damage model can be updated in the future. These tasks also may need to be completed prior to any further model development.

9.2 Low Water Impacts

Decisions need to be made upon mechanisms for not only collecting information on low water damages, but incorporating this information into the potential damage model so that the economic impacts of low water levels can be produced for those low water scenarios that will be evaluated. "Impact" discussions should include a good description of low water issues like interruption to navigation, increased dredging needs, contaminated material placement and containment, recreational boating & facilities losses, infrastructure development, value of pre-dredging in anticipation of low water.

There is a real concern that there may not be the time nor budget to explicitly consider such impacts, particularly given the focus on flooding and erosion issues and coastal processes that has taken place to date. Whether this is the case or not, there is a good deal of information out there on the potential impacts of such events. Much of this was collected in Phase I and II of the 1986-1993 Reference Study, much of it has come from

previous investigations of water levels and damages along the shoreline. Some of this information has come from interviews we are conducting with local planning officials.

This information could be easily synthesized and compiled into a specific report on low water impacts and issues. This can always be supplemented later by any specific or quantifiable data that might be collected at a later date.

9.3 Alternative Water Level and Control Scenarios

The specific scenarios that the LMPDS Study Team plans to analyze need to be developed promptly. They are key items that will drive all of the impact assessment and the damage investigations. While 16 or so alternative water level scenarios have been suggested, they have not been finalized nor has any work begun on their definition. Similarly, there have not yet been any alternative control scenarios proposed or defined.

Another decision to be made here is how many scenarios can be evaluated? Will there be enough resources to examine 20, 30, 40 scenarios? Not likely. Will there only be enough resources to examine 2 or 3? This will be a critical decision, as there is a need to evaluate enough scenarios so that there is a good representation of conditions that may occur, but not so many as to overburden and overtax the resources that are available.

9.4 Basin Wide or Site Specific

The coastal processes model and potential damages model being developed are complex and require significant resources to develop fully. Similar resources will be required to apply these models to the entire shoreline. Presently, initial applications are proposed for the 8 site study areas. Will the resources be available to carry these analyses beyond the study areas and to the entire shoreline? At a minimum, the models, for each of the study sites, should demonstrate the model's ability to predict long-term lakewide shoreline change for the purposes of economic assessment and coastal zone management. It should accurately predict shoreline recession observed at the study sites over the period of record available. If the model is at least proved accurately for the site study areas, it may be easier to seek additional funding for basin-wide application with a proven model in hand.

9.5 Public Information and Involvement

The IJC Levels Reference Study (particularly Phase II) had unprecedented public involvement with a Citizen's Advisory Committee, interest group representatives sitting on task group and working groups, and a comprehensive series of public meetings, progress meetings and open houses. In addition, a regular newsletter was circulated.

To date, formal public involvement on the LMPDS has been rather limited. Representatives of the riparian interest group have attended a few of the LMPDS Study meetings and there is very little information being circulated regarding the scope or

objectives of the study. A World Wide Web page has been developed, but has not yet been fully advertised to the Great Lakes community.

On the plus side, the series of interviews conducted with county, township and municipal planning agencies has brought the study to the attention of the people at the local level. The challenge here will be to keep these individuals and agencies up-to-date with the Study and to make it clear how the study results can be of benefit to them in their future shoreline planning initiatives.

A second challenge is whether there is a risk of not involving the public, and specifically, interest group representatives, more formally in the LMPDS work? Will the public be receptive of our work if they have not been involved in it? How can we better inform the public as to the objectives of the study?

9.6 GIS Integration

There are a range of GIS activities taking place and a range of GIS applications being developed as part of the LMPDS. These include but are not limited to:

- Development of a GIS strategy
- GIS base mapping, digital orthophotos, etc.
- Development of the Recession Rate Analysis System
- GIS recession rate determinations (3 different contractors)
- Development of an Erosion Prediction System

It is also anticipated as well that GIS will be used heavily in other tasks still to be completed.

The integration of all these GIS activities will be critical to the success of the LMPDS. All applications being developed must fit in to the overall corporate GIS structure being developed and must integrate with the coastal process model and potential damage model being developed and vice versa. It is anticipated that much of this coordination will be exercised through Detroit District and through their contractor conducting the development of the GIS strategy.

9.7 Defining the End-User for the Study and the Final Products

Who will be the end user of this study and the various applications that come out of it? Efforts should be made to clearly determine all of the possible uses of the system for each of the groups, agencies, organizations, etc, that are thought to have an interest in the system. While there is a general knowledge of the broad uses of economic assessment of future lake level and wave trends, structure/shoreline response studies, and coastal zone management, there is still a need to define exactly how the results of the system would be used in these areas. It will help in developing priorities for areas in the system that

require improvement.

There is a need to determine the products/scenarios/evaluations that will provide the biggest impact at the end of the study. This will help in setting priorities and determining time requirements for conducting the necessary scenarios. Efforts should be made to clearly identify who will run the system and design it for their use. Define who will use the output from the system (in detail) and elicit their support and/or assistance.

Given the variety of potential applications for the integrated system and potential users of the results, consideration should be given to creating a fairly general name for the system. Previously, Jack Davis (personal communication, October 1997) suggested calling it the SHORES system, from SHOReline Evaluation System. It could be referred to as the Lake Michigan SHORES system (or ultimately Great Lakes SHORES system) for economic analysis, or coastal zone management, or erosion prediction, or bluff stability analysis, etc. The study is still the Lake Michigan Potential Damages Study, but the tool being developed will have application beyond economic assessment. The system name will help sell its capabilities. (The SHORES suggestion is just a suggestion, but finding a name for the system should be given consideration.)

Finally, efforts at listing all the groups and organizations that we think will have an interest in the system should continue as well as the active and aggressive pursuit of their participation. A list might include FEMA, NOAA, GLERL, UM, UW, Sea Grant for MI, WI, IN, and IL, USFWS, USGS, state GS's, LRB, and LRC.

9.8 Islands

Interviews with planning officials around the lake have brought to light that significant development is occurring on many of the islands in the northern part of the lake (e.g., Beaver Island). None of these islands are included in the present kilometer-by-kilometer database and the potential for damages on them is increasing. Should these islands be incorporated to the study? Is the value of development on them significant in lakewide considerations?

9.10 Updating the Data

This most likely falls into the category of "Developing Future Model Update Procedures" but the key data inputs that are feeding into the coastal process model (e.g., recession rates, land use, land use trends, type and extent of shore protection) will continually change. Thought needs to be given to a regular schedule of updating (or monitoring) this information so that 5, 10, 15, or 20 years from now, the new data can be fed into the models and accurate predictions can be made beyond 2050. Examples of this may include:

- Recession rate updates every 5 years

- Land Use updates every 5 years
- Shoreline structure inventories every 5 years

The State of Ohio as an example, has made significant progress in establishing such a program of continued monitoring and coastal data update for their shoreline. Similar programs should be put in place for the Lake Michigan shoreline.

10.0 Preliminary Findings

The following (in no particular order) are brief descriptions of some of the initial and preliminary findings that have come out of the first two years work on the LMPDS. The intent here is not to go into extreme detail on these, but to provide a context for the next phases of the study.

- There is a significant lack of recession rate data for the entire Green Bay shoreline including counties of Door, Brown, Oconto and Marinette. Analyses conducted have found these shorelines to be subject to existing and potential future development pressures, and they are of a shore type that can be subject to erosion activity.
- Related to the above, in attempting to address the above data gap, it was found that there is a significant lack of adequate air photo or other mapping data to accurately develop recession rate data for entire Green Bay shoreline including counties of Door, Brown, Oconto and Marinette.
- Interviews with planning officials identified that a major low water problem in many areas will be those associated with disposal of contaminated sediments if additional dredging is required.
- Development on islands in Lake Michigan, especially Beaver Island in Charlevoix county is increasing rapidly. Potential damages to such areas could be substantial and they need to be considered.
- Backwater effects, especially those related to extreme low water level scenarios, could have a major impact on many of the drowned river mouths along the Michigan shoreline (e.g., Lake Macatawa, Lake Charlevoix). These areas have not been included in any of the coastal zone databases (e.g., recession rate, land use) and will need to be explicitly considered in any potential damage analyses.

11.0 Summary

This report has summarized the status of a range of tasks being conducted for the Lake Michigan Potential Damages Study. Significant work has been accomplished in the first two years of the study. Significant work remains to be completed over the next two years to bring the study to completion. Key decisions need to be made regarding the next steps. A number of discussion items have been proposed for consideration over FY99 and a number of preliminary findings have been identified and will undergo further investigation over the remainder of the study.

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