A GIS MAPPING TOOL FOR THE PRESENTATION AND ANALYSIS OF COASTAL DATA ALONG THE SHORELINES OF THE NORTH AMERICAN GREAT LAKES

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ABSTRACT

In 1997 and 1998, the U.S. Army Corps of Engineers initiated an intensive coastal data collection and modeling activity of Great Lakes shorelines, beginning with Lakes Michigan, Erie and Ontario. A wealth of information is being collected including kilometer-by-kilometer data on recession rates, land use, land use trends, shore type (geology), type and quality of shore protection, offshore geology, and bluff characteristics. To manage and analyze this data, a Recession Rate Analysis System (RRA) was developed. The RRA is a flexible and customizable program that integrates a relational database management system with a dedicated GIS package that allows basic mapping and visualization of all query results. Initial versions of the RRA have utilized MS FoxPro as the database tool and QuikMap as the GIS viewing package. Subsequent versions are intended to be developed for all the Great Lakes and will be referenced to U.S. Army Corps MicroStation graphic files and be directly supportable by industry standard GIS viewing software including both ArcView and GeoMedia. We are also examining the possibility of developing the RRA as a GIS web query tool to provide the same functional capabilities as the CD version (or greater) across the Internet to any user, including shoreline property owners.

INTRODUCTION

In 1997, the Detroit District of the U.S. Army Corps of Engineers initiated an extensive and long-term assessment of potential shoreline flood and erosion damages over the next 50 years due to fluctuating lake levels along the Lake Michigan shoreline.   The study, known as the Lake Michigan Potential Damages Study (LMPDS), is dedicated to meeting several of the recommendations that came out of the 1986-1993 IJC Great Lakes Levels Reference Study (International Joint Commission, 1993), in particular to "objectively assess the economic value of all shoreline interests in terms of "potential damages" that could occur under differing hydrologic conditions, or alternate management approaches to lake level controls." The first two years of this study (1996-1998) focused on developing the Study Plan, collecting coastal erosion data and the design of computer models and associated input databases for coastal processes and economic assessments.

In 1998, taking their cue from work carried out in the LMPDS, the Buffalo District of the U.S. Army Corps of Engineers began the Lower Great Lakes Erosion Study, with the key first-year

objective of developing shoreline classification, recession rate, land use and land use trend databases for the U.S. shorelines of Lake Ontario and Lake Erie. These databases are proposed to be the foundation for a lake-wide shoreline erosion modeling system that will be used to anticipate future shoreline erosion potential based on given future climate and water level scenarios. The system may ultimately be used to address issues related to lake level control, coastal zone management (CZM), and site specific designs.

KEY DATA INPUTS

Key data inputs to the models being developed above are both long-term and short-term recession rate data. A direct economic evaluation of potential erosion damages can be made through the use of shoreline recession rates, or more specifically the horizontal extent of bluff crest or dune scarp retreat over time. Land values of area lost and the value of damage to buildings or structures associated with the shoreline recession provide an estimate of potential damage. Thus it becomes important to have accurate and reliable shoreline recession rate data for as much of the shoreline as possible.

Another key input related to recession rates 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. If we have sound databases of both land use and land use trends, we can input these into the models being developed to help predict possible future damages along the shoreline.

DATABASE DEVELOPMENT

Objectives

There were three general objectives to the work carried out in this activity:

1)   Assemble and assess all available recession rate data for the Lake Michigan. Lake Erie and Lake Ontario shorelines;
2)   Assess data gaps in recession rate data relative to other factors such as land use, shore type, land use trends; and
3)   Identify areas where new recession rate or other data needs to be calculated or areas where existing recession rate or other data needs to be refined or revised and provide recommendations on how to accomplish this.

Specific Tasks

In meeting these general objectives, a number of specific tasks were carried out. These include:

a)   the updating of a Lake Michigan, Lake Erie and Lake Ontario kilometer-by-kilometer

       Great Lakes Shoreline Recession Rate Database (Stewart, 1994) with new (i.e., 1994-present) data;

b)   the development of a single "best" value per kilometer recession rate database for the Lakes Michigan, Erie and Ontario shorelines;

c)   the analysis and assessment of short-term recession rates and their correlation to periods of lower or higher water levels;

d)   the development of a kilometer-by-kilometer existing land use database;

e)   the development of a kilometer-by-kilometer land use trend database;

f)   the development of a kilometer-by-kilometer shoreline classification database;

g)   the development of a relational database system to assist in the identification of priority areas for recession rate data collection or revision, and recession rate data "gap analysis"; and

h)   the application of this database system to the Lakes Michigan, Erie and Ontario shoreline data set.

Data Inputs

Data inputs to the RRA included the following:

REACH - Each lake was divided into kilometer-by-kilometer segments along the U.S. shoreline beginning in the east and extending clockwise around the lake. In total, Lake Michigan had 2,436 reaches, Lake Erie had 834 reaches and Lake Ontario had 514 reaches.

LATITUDE AND LONGITUDE - For mapping purposes, the latitude and longitude of the center point of each kilometer reach was recorded.

GEOMORPHIC SHORE TYPE - A definition of the predominant shore type for the particular reach (e.g., cohesive bluff, sandy beach/dune, bedrock).

SHORE PROTECTION TYPE - A noting of the types, extent and quality of shoreline protection structures found within the kilometer reach.

NEARSHORE TYPE - A definition of the predominant geology found in the nearshore zone (i.e., under the water)(e.g., bedrock, sand over clay).

BLUFF HEIGHT - For those areas defined as bluff shorelines, estimates were made of the average height of the bluff within the kilometer reach.

BLUFF SLOPE - For those areas defined as bluff shorelines, estimates were made of the average slope of the bluff within the kilometer reach.

GULLIES - For those areas defined as bluff shorelines, the number of gullies occurring within the kilometer reach were counted.

MEAN RECESSION RATE - All existing recession rate data was reviewed in order to select a

single, most appropriate recession rate value for each kilometer reach along the shoreline. Generally speaking, the best value of recession was that which had the longest period of record, was the most accurate in terms of it's "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, or was the only estimate of recession available for the reach.

HIGH WATER RECESSION RATES - All recession rate data was examined to determine if there were data sets that could be extracted that covered periods in the 1970s and 1980s when water level on the Great Lakes were at record high levels. Where found these data were incorporated to the database.

LOW WATER RECESSION RATES - All recession rate data was examined to determine if there were data sets that could be extracted that covered periods in the mid 1960s when water level on the Great Lakes were at record low levels. Where found these data were incorporated to the database.

RECESSION RATE SOURCE - This simply identified the particular reference or study associated with any of the recession rate data selected for the kilometer reach.

EXISTING LAND_USE - 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.

LAND USE TRENDS - Estimates were made for each reach on the degree to which development would increase or decrease over the next 50 years. A series of Land Use Trend Indices were developed with 1 being a decrease in development and 5 being increases of greater than 10% in development.

OWNERSHIP - An ownership category was added to identify whether the reach was privately or publicly owned. This basically identified those reaches within National or State parks, National Lakeshores, Township Parks, State Forests, National Forests, Large Scale Developments, City / Town Boundaries, Nuclear Plants (Some), Large Industry or Utilities (Some) and Harbors.

COMMENTS - An additional column was added to the database to reflect any additional comments noted about that particular reach.

THE RECESSION RATE ANALYSIS (RRA) SYSTEM

To manage the wealth of data collected through the above activities and to be able to conduct some preliminary analyses of recession rate, land use and other data, we have created a

Recession Rate Analysis System (RRA), which is an expert system designed to undertake 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 is provided to the client along with any associated reports and "hard copy" data appendices. This can then be used by the client 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).

KEY RRA MENUS AND INTERFACE

RRA Main Menu
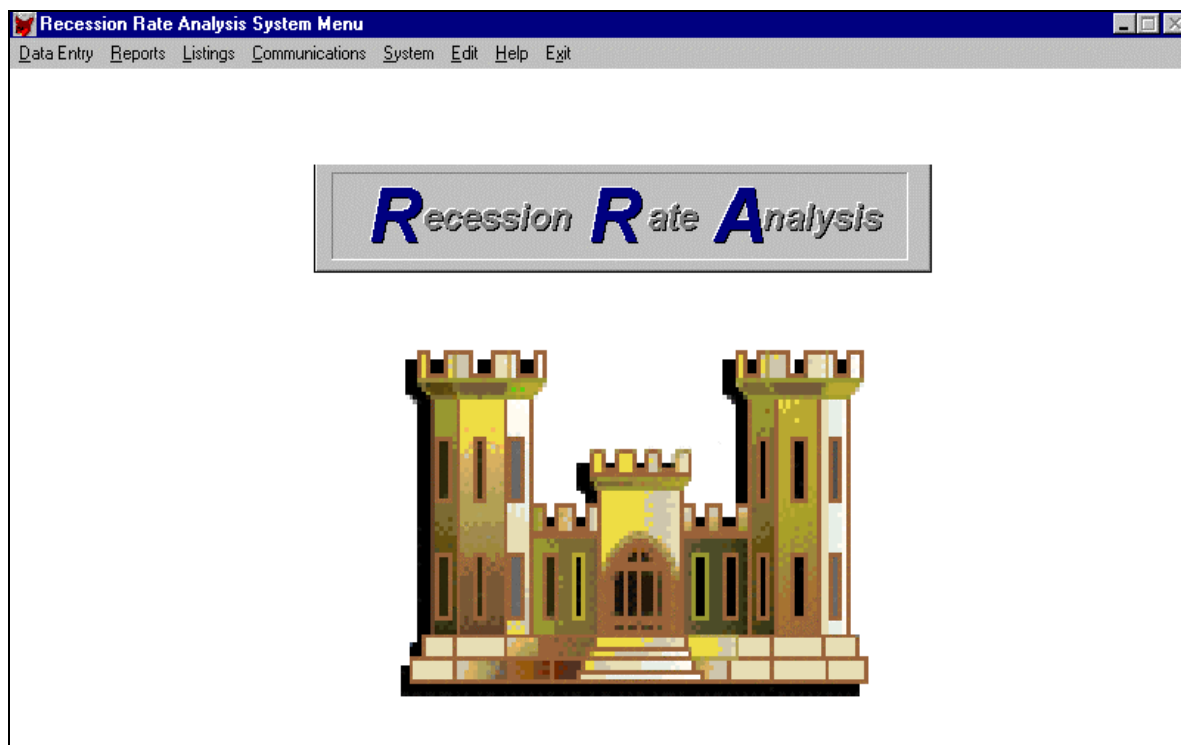
Figure 1 - RRA Main Screen

The RRA has been designed with ease of use in mind. The User Interface is relatively simple and un-cluttered (**Figure 1**). The main menu bar includes items for "Data Entry", "Reports",

"Listings", "Communications", "System", "Edit", "Help" and "Exit".

The Data Entry Menu

The Data Entry menu provides users with the ability to update the database for a range of data categories including recession rates, land use, land use trend, latitude, longitude, shore type, bluff attributes, shore protection and nearshore classification. The **"Site Location Update"** command (**Figure 2**) is of particular importance and allows the update of any of the data fields for a reach of interest. This window also provides a glance at all data associated with a reach without using the Reports function of the program.

Figure 2 - Site Location Update Window

The Reports Menu

Site Location Summary and Detail Reports

There are three types of query reports that can be generated from the RRA. The "Site Location Summary Report" will provide a query result listing by appropriate reach and will also provide information for that reach on shore classification data and mean recession rate data.   The " Site

Location Detail Report" will provide a query result listing by reach along with *all* available data for that reach.

Figure 3 - Site Location Detail Report Query Window

The query window for both the detail and summary reports is the same (**Figure 3**) and is structured so that a full range of query possibilities can be undertaken. "Site Range" allows the user to choose all reaches for analysis, or a selection of reaches for more site specific analysis. "Rate Range" allows users to query any range of recession rate data. Users may query up to 8 types of "Land Use" in a single query. Users may also "include" or "exclude" up to three data types on "Land Use Trend", "Geomorphic Shore Type", "Shore Protection" and "Nearshore Class." The "Select" buttons refer to recession rate data and allows the user to query all recession rate data and reaches, only those reaches where data is available, or only those reaches where no recession data is available. The "Sort" button allows the query results to be sorted by reach number or by recession rate.

Finally, the icons at the bottom of the window allow the results to be output to the screen, or to the default printer.

A category has been added for querying "Bluff Height Range" which allows the user to query by bluff height to obtain all reaches where a particular bluff height or range of bluff heights occur (note this is limited to those reaches where the data was recorded).

Map Site Locations

The "Map Site Locations" window (**Figure 4**) provides the same query capabilities as the reporting screens, along with the ability to export the query results to the QuikMap GIS Viewer for mapping and visualization. Query results can be mapped by recession rate, geomorphic shore type, shore protection, or nearshore type.

RRA ANALYSIS EXAMPLE

To provide a simple example of how the RRA can be used to conduct analysis of the various data sets, we wanted to identify particular reaches along the Lake Michigan shoreline where erosion

Figure 4 - Map Site Locations Query Window

damage hazards might exist. To do this we queried the system for all "developed" reaches where recession rates are greater than 1.0 meter per year and where there were no shoreline protection structures recorded.   Results of this query (**Figure 5**) are mapped by recession rate and identify those reaches that may be considered as priority for construction of shore protection structures, or alternatively where other actions may be necessary to remove the erosion damage potential to buildings or other structures present.

FUTURE REFINEMENTS TO THE RRA

The Recession Rate Analysis System was found to be an extremely useful tool for assisting in the various analyses performed. It combined a powerful and quick relational database with a simple mapping tool for visualization of the results. There are a number of areas where the system could be refined however so as to make future analysis much simpler.

New Base Map

A new base map is required that consists only of the Great Lakes basin shoreline. While the North American Digital Chart of the World (the current base map) is adequate for mapping and
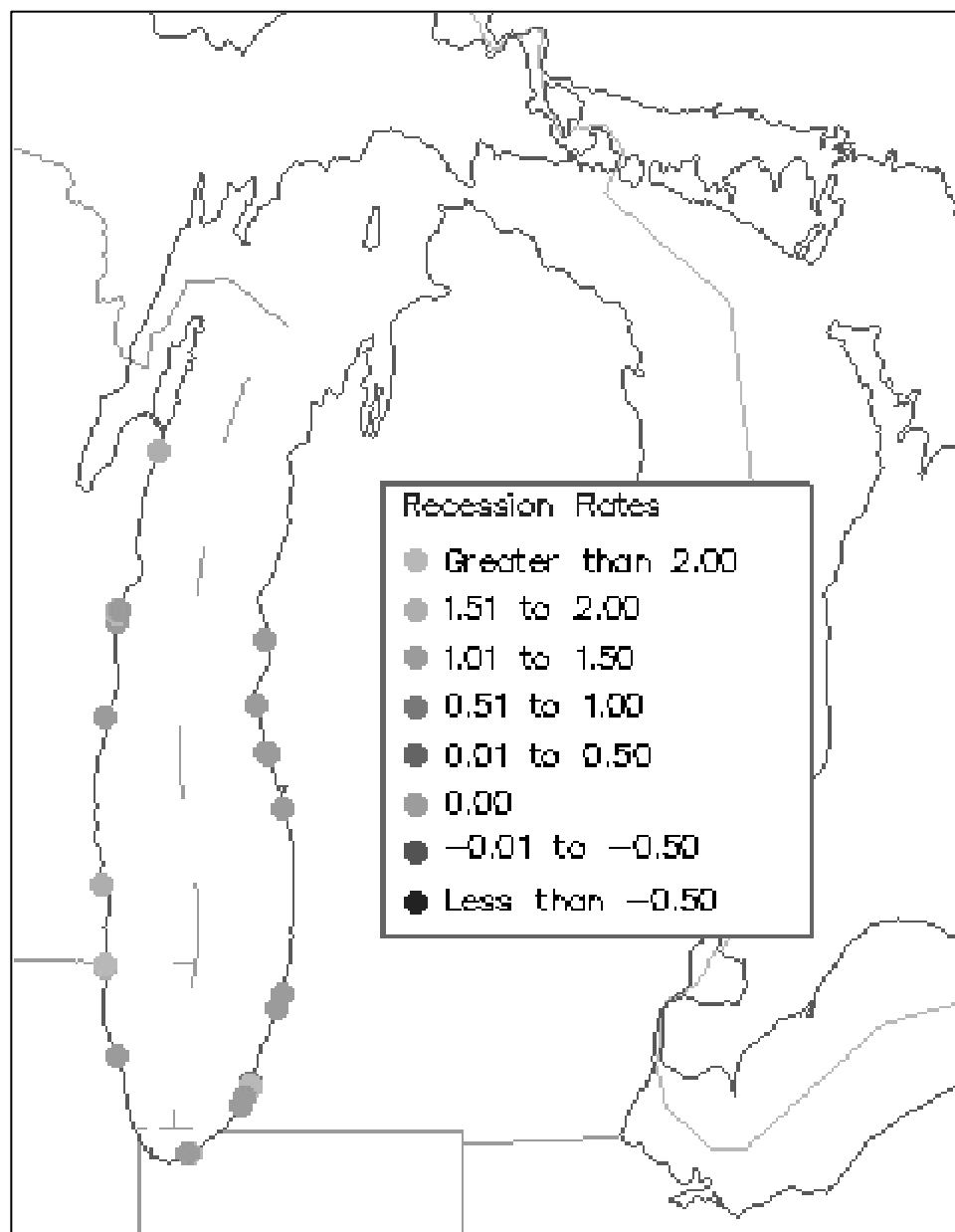
**Figure 5 - RRA Mapping Example , Reaches Where Erosion Damage Potential
Exists**

display purposes, the scale of it necessitated an extra step in order to "zoom" in to the area in
order to see the data results.   In addition, while the resolution and accuracy of the position of our
data points was suitable at a larger scale, zooming in on select points found them to be displaced
somewhat from the shoreline shown on the map.

"Blank" and "0.00" Recession Rate Values

The RRA is limited in that blank values for recession rate data are shown as zero values in the Data Entry portions of the program. To keep these zero values from being plotted or reported as true zeros, the program was coded so that only those recession values that also had a source identified would be reported or mapped. This took care of many of these situations, however in some instances where a shoreline was a harbor structure or was classed as artificial (and hence given a "true" recession value of zero) there was no source data listed. As such these values did not get mapped. This will need to be corrected in future versions of the program.

Percentage of Development in Each Reach

When entering land use data into the database, if a single family residential category was encountered, a rough estimate of the percentage of the reach occupied by this category was made and also included in the database. The RRA presently has no way of utilizing this percentage in the formulation of any queries. For example, in those reaches where both a residential and a forested land use occur, and where the residential land use already occupies 80% of the reach, it may be a reasonable assumption that the forested area of that reach may be subject to development or redevelopment pressure. The ability to specifically query this information would simplify the selection of such reaches and help identify site specific areas that may see increased development.

Ownership

The RRA also does not presently include any means of performing a query on ownership data. In addition, the ownership database does not include a great deal of specifics on public versus private ownership, only whether it is a State or National Park, etc. A more comprehensive database on this item and a better ability to query this information would likely be a useful analysis tool in future analyses.

Integration With Industry Standard GIS Viewers and Client Graphics

Initial versions of the RRAS developed for Lakes Michigan, Erie and Ontario used MS FoxPro as the database tool and QuikMap as the GIS viewing package. Subsequent versions are intended to be developed on CD-ROM for all of the lakes that will be referenced to U.S. Army Corps MicroStation graphic files and be directly supportable by industry standard GIS viewing software including both ArcView and GeoMedia. We are also examining the possibility of developing the RRA as a GIS web query tool to provide the same functional capabilities as the CD version (or greater) across the Internet to any user, including shoreline property owners.

ACKNOWLEDGEMENTS

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