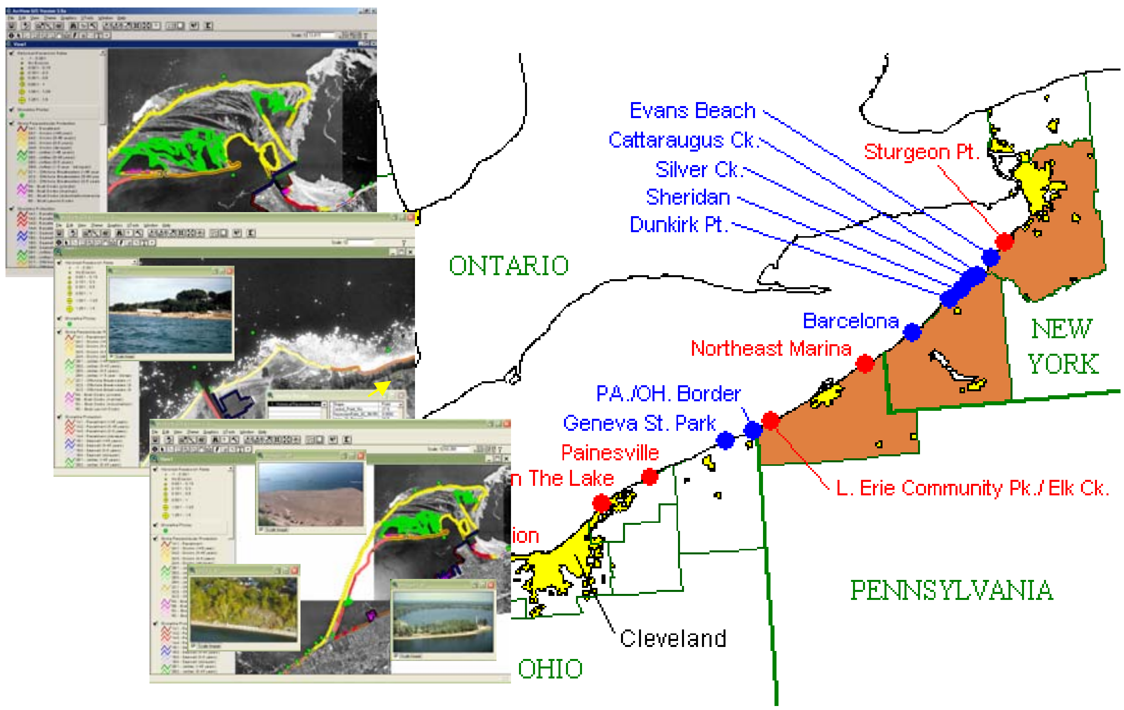
U.S. Army Corps of Engineers - Buffalo District

OPEN COAST REACH DELINEATION AND RE-ATTRIBUTION OF SHORE CLASSIFICATION MAPPING, PENNSYLVANIA AND NEW YORK SHORELINES, LAKE ERIE

LOWER GREAT LAKES EROSION STUDY



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1.0 Introduction

1.1 Background

In 1998, the Buffalo District of the U.S. Army Corps of Engineers (USACE) initiated the Lower Great Lakes Erosion Study (LGLES). The goal of this study is to develop a tool for the assessment of local and regional impacts associated with coastal projects. The tool will be applied to assist a wide range of USACE activities on the St. Lawrence River, Lake Ontario, the Niagara River and Lake Erie including:

- Regional sand management issues
- Maintenance of federal navigation projects
- Federal coastal erosion and flooding projects
- Permitting of activities in the coastal zone
- Technical assistance and advice
- Public education activities
- Lake level regulation responsibilities
- State and local coastal zone management.

A key task in this work is to ultimately determine the relationship between coastal processes and water level change and various physical factors along the shoreline including shoreline type, the extent, type and quality of structural shore protection in place, and the composition of the nearshore portion of the shoreline.

In this regard, and in an effort to further shoreline classification and erosion sensitivity work that was initially conducted by the Erosion Processes Task Group during the IJC Great Lakes Water Level Reference Study in 1993 (Stewart and Pope, 1993), the entire U.S. shoreline of Lake Erie, Lake Ontario and the St. Lawrence River was reclassified in 1999 using a revised three-tiered classification scheme that took into account significant details about shoreline type, the extent and quality of shoreline protection structures, and the nearshore (underwater) geology (see Stewart, 1999). Recession rate data for the entire shoreline was also collected and updated (see Stewart, 1994 and 1999) and along with the three levels of classification information, were summarized over a series of 1 kilometer reach segments that had been ascribed to the shoreline for reference purposes. This kilometer-by-kilometer information was then used as data input to the "Flood and Erosion Prediction System" (FEPS) model that is being utilized in the LGLES for the analysis of coastal processes and other factors in some site specific areas along Lake Erie and Lake Ontario.

As mentioned above, in developing various coastal zone databases for the LGLES, the majority of data (e.g., shoreline classification, recession rates, land use, etc.) have been ascribed to the shoreline using a series of 1 kilometer reach segments. These segments were defined during the IJC Water Level Reference Study in 1993, using what, at that time, were the best available mapping products to "define" the shoreline.

With advances in digital mapping and digital photographic and photogrammetric techniques over the past few years, there was a desire to create a new digital shoreline for these water bodies and then "tie" the related shoreline classification data to this new shoreline. This was required since it was becoming apparent, through other studies that were making use of this original kilometer reach classification (e.g., Lake Michigan Potential Damages Study), that the original 1993 shoreline contained a number of errors, omissions and inaccuracies, that thus called into question (primarily) the spatial accuracy of the classification and recession rate data that had been collected and mapped, and that also resulted in errors in the total lengths of certain shoreline types reported, or in the complete omission of particularly sensitive shoreline areas that were not captured in the 1993 shoreline definition (e.g., embayments). As a result of these errors, the 1 kilometer reach segments that were defined in 1993 were no longer applicable and needed to be revised to reflect any higher resolution mapping or photography that was available.

In addition, data collected for these 1 kilometer reach segments had been summarized (averaged) over this 1 kilometer segment and has been visually represented on various LGLES mapping products using a symbol tied to the center point of each 1 kilometer reach segment. While this presented a general characterization of the reach section for the data in question, it did not accurately reflect variations that might occur within this 1 kilometer stretch.

Given this, there was a need to reinterpret and re-attribute the kilometer-by-kilometer classification data to bring it into consistency with other similar GIS data collection activities and provide a more accurate representation of the open coast classification data.

1.2 Objectives of This Activity

In 2001, USACE Buffalo District began this re-attribution process by contracting with Christian J. Stewart Consulting for the development of new shore classification mapping along the Pennsylvania and New York shorelines of Lake Erie (Figure 1). Mapping and updating of the Ohio portion of Lake Erie is proposed to be conducted at a later date as part of a cooperative program with the Ohio Department of Natural Resources and mapping of Lake Ontario and the St. Lawrence River will likely occur under the auspices of the Lake Ontario – St. Lawrence River Water Level Regulation Study which was initiated by the International Joint Commission in 2001.

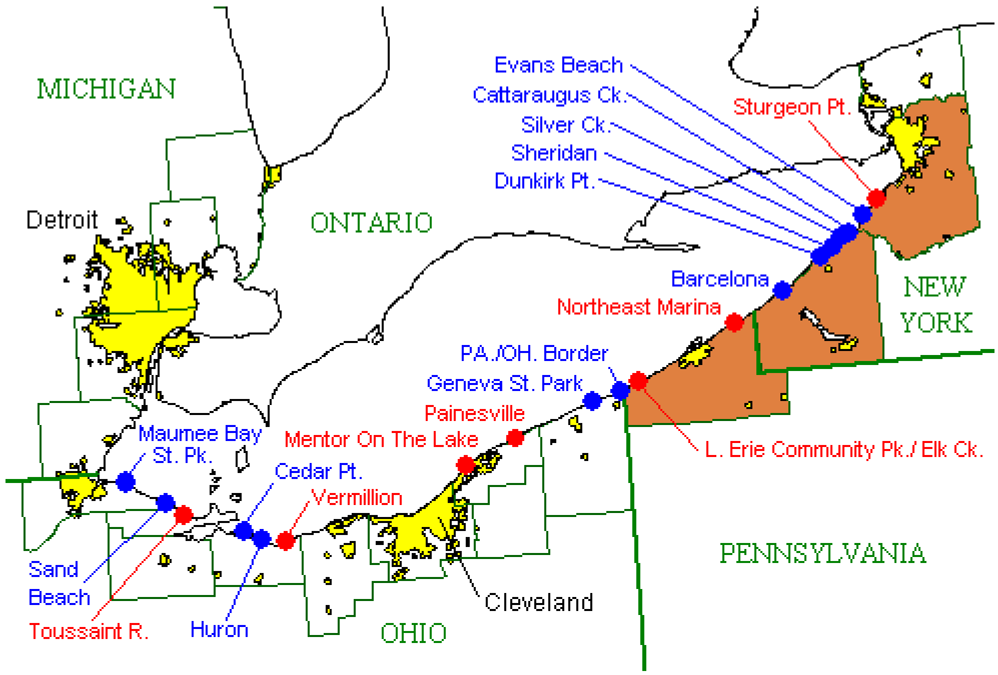


Figure 1 - Lake Erie Shore Classification Mapping Study Area (orange shading) and location of LGLES site specific study areas.

Specifically there were 5 objectives that were to be carried out:

1) **New Shoreline Delineation** – A new digital shoreline needed to be acquired or developed for this section of shoreline, which would serve as a base layer for all other information.

2) **Re-Interpret Geomorphic Classification** - The shoreline type classification was to be re-interpreted and provided as a continuous ArcView coverage on a state-by-state basis;

3) **Re-Interpret Nearshore Geology** - The nearshore geology classification was to be re-interpreted and provided as a continuous ArcView coverage on a state-by-state basis;

4) **Re-Interpret Shore Protection Classification** - The shoreline protection classification was to be re-interpreted and provided as a continuous ArcView coverage on a state-by-state basis;

5) **Re-Interpret Recession Rate Data** - The recession rate data available for these shorelines was to be re-interpreted and provided as a continuous ArcView coverage on a state-by-state basis;

All data were to be mapped in an ArcView GIS format and statistical summaries were to be calculated where appropriate.

1.3 Format of This Report

The approach and methodology used in the re-attribution of these five data sets is presented in Section 2.0. Resulting mapping products and related statistical data are presented in Section 3.0. Recommendations and conclusions are presented in Section 4.0 and hardcopy printouts of the mapping for the study area is presented in an Appendix.

2.0 Methodology

2.1 Data Sources and Limitations

Various data sources were relied upon to develop continuous GIS mapping coverages for each item. A brief description of each source and their limitations is provided below. Further details on the use of each data source are also found in the methodology description for each data layer starting in Section 2.2.

2.1.1 Previous Classification / Coastal Zone Data

The kilometer-by-kilometer classification data that was developed earlier in the LGLES (Stewart, 1999) served as a primary data reference for this activity and provided a coarse delineation of the start and end points of the various levels of information for shoreline type and nearshore geology. This was especially true of the nearshore geology classification as it was anticipated that the existing classification would be the best available reference for this data layer. The existing classification was also used during the detailed mapping process as verification of the classification type where necessary.

2.1.2 Recession Rate Data

Recession rate data used to compile and update the kilometer-by-kilometer historical recession rate database (see Stewart, 1994 and 1999) was re-examined in order to note specific location of recession rate transects or points of measurement along the shoreline.

The original datasets included detailed data from the Pennsylvania Coastal Management Program (Knuth, 1987 and Knuth and Crowe, 1975). For this study, updated information was obtained from the Pennsylvania Department of Environmental Protection (Knuth, 2000) and utilized to map and plot recession rate data points along the shoreline (see Section 2.6 for details).

For the New York shoreline, the original data came from the New York Department of Environmental Conservation and provides long-term recession rates for 1875-1979. Unfortunately, the format of this data was such that mapping of the precise location of a recession rate transect or measurement point could not be completed. The original data was only summarized over a reach of shoreline and thus could not be georeferenced to a single map location in the GIS. As such, to provide some type of representation of recession rate data for the New York shoreline, the kilometer-by-kilometer summary data set (Stewart, 1994 and 1999) was utilized (see Section 2.6 for details).

2.1.3 Aerial Photography

To develop continuous GIS mapping coverages for the various data layers, their specific start and end points had to be determined. This was done in part by examining various air photos, including the air photos used in developing the 1999 shoreline classification. This included 1:4800 scale 1986 aerial photography for the Lake Erie shoreline, which was obtained in photocopy format from USACE Buffalo District.

The photos were used primarily to verify classification decisions or to provide additional detail where information was unavailable or indiscernible on other data products (digital orthophotos, field observation, video). Limitations in the use of these photos were primarily related to the resolution of the photocopied version, as well as shadows and glare obscuring the boundary between two different shore types, or obscuring the type of shore protection present. Given that these photos were used as a secondary data source, these limitations were not critical, and when combined with previous classification data and other data sources, the transitions between two different class types were located with a high degree of certainty.

2.1.4 Digital Orthophotography

Digital orthophotography for the Lake Erie shoreline was downloaded from the Pennsylvania and New York GIS Geospatial Data Clearinghouses:

Pennsylvania Geospatial Data Clearinghouse
http://www.pasda.psu.edu/

New York State
http://www.nysgis.state.ny.us/gateway/mg/cir.htm

The Pennsylvania DOP's consist of 1:12,000 scale, 1993-1994 black and white USGS DOPs based on Digital Ortho Quarter Quads (DOQQ) derived from the National Aerial Photography Program (NAPP). Files are in GeoTIFF format. Each file contains a detailed metadata file. The digital orthophotos and all associated files are included on the data CDs accompanying this report.

DOPs for New York State are 1:12,000 scale color infrared images and are based on Digital Ortho Quarter Quads (DOQQ) derived from the National Aerial Photography Program (NAPP). The digital orthophotos in this series have a 1 meter pixel ground resolution. The data set presents information that represents current conditions for New York State from 1994 - 1998. The DOPs were reprocessed by New York State, Department of State, as part of the New York State Y2K Emergency Preparedness Plan. The orthoimagery was radiometrically balanced (enhanced) to reduce the variability between the DOQQs characteristic of the DOQQ product, and also to improve the feature visibility within individual images. The image format was also changed to GeoTIFF, and then to MrSID formats in a tiled grid structure based on UTM axes. This was done to facilitate internet delivery of the orthoimagery. The Mr.SID images were then converted back to TIFF format for import into ArcView. Further details on the metadata for the New York Digital Orthophotography can be found at:

http://www.nysgis.state.ny.us/gis3/data/dos.doqq_orthos.html.

This file is also provided as a saved data file on the CD that accompanies this report. The digital orthophotos and all associated files are included on the data CDs accompanying this report.

The DOPs were utilized for a number of purposes:

1) They serve as a simple GIS backdrop within ArcView for the presentation of data;
2) They were utilized to create a new "digital" shoreline for the Pennsylvania and New York shorelines (see Section 2.2 below);
3) Printouts of the DOPs were made to use in recording notes while in the field;
4) Features visible on the DOPs (e.g., shore protection structures) were digitized directly from the DOPs in ArcView.

Two minor limitations of the DOPs were noted. The first was the presence of ice. Both shorefast ice and drift ice were visible in the nearshore zone on many of the images. This provided a degree of difficulty in accurately digitizing the waterline/shoreline and also in identifying shore protection structures that might be present. This was overcome as much as possible by using other data sources (video, field notes, and aerial photos) to confirm and verify structures and shoreline position.

A second limitation was related to the quality of the photography, particularly severe glare and severe shadow on some images. Again, this made it difficult in some areas to discern the waterline/shoreline and any features. Again this was overcome through confirmation and verification using other data sources.

2.1.5 Video Tape

Video tape of the Lake Erie shoreline was obtained by USACE staff in April 1999 and was used in the original re-classification of the Lake Erie shoreline. This video tape was re-examined to observe sections of shoreline that could not be seen clearly on the DOPs or during field observations (see below). While it served basically as a confirmation data source, it proved very useful in helping to identify the start and end points of shore protection structures, particularly in some of the well-developed shoreline areas near Buffalo.

2.1.6 Field Survey

In order to assist with the detailed mapping of various classification features, a field survey program was undertaken the week of September 17, 2001. Starting at the Pennsylvania and Ohio border and working east to Buffalo, CJS and USACE staff traveled along the shoreline by boat and observed, mapped and recorded the following where visible:

1) geologic shore type and the start and end points of different shore type classes;
2) start and end points and the type, extent and quality of shoreline protection structures;
3) visual observation and probe samples of nearshore geology;
4) photographs of complex or heavily developed shoreline areas, or specific shore protection structures;
5) any other relevant information.

All data and field observations/notes were recorded on hardcopy printouts of the digital orthophotos. The printed scale of the photos (and corresponding print resolution) were such that features and structures visible on land could be easily discernible on the photo print out. Particular attention was paid to recording and documenting any new shore protection that was not visible in the DOPs or on the older air photography.

Initially it was hoped to get close enough to the shoreline utilize GPS to record the start and end points of both the shore type and shore protection classes. However, due to the lower than average water levels experienced on Lake Erie in September 2001, it was rarely possible to get within 50-100 meters of the shoreline without fear of hitting bottom. As such the start and end points were mapped primarily by "eye" on the digital orthophoto printouts. For reference purposes, an occasional GPS reading was taken a distance offshore, but was never utilized when building the GIS database.

In areas where the distance offshore precluded an accurate field mapping of the start and end points (particularly of shore protection structures), a review of the "on-screen" DOPs (better resolution), combined with a close review of the video tape, air photos and whatever information *was* recorded in the field, did allow for an accurate mapping of the classification units to take place.

For the nearshore geology classification, two simple methods were utilized in the field to record bottom type. The first was visual observation. For most of the shoreline, water depths were shallow enough to allow observation of the bottom type and record this as appropriate on the field sheets. A second method made use of a sediment probe – simply a long, pointed iron rod - which allowed us to physically probe the bottom and discern (by sound and touch) whether it was composed of bedrock, sands, or clays/muds.

It should be noted that the previous classification efforts identified that most of the Pennsylvania and New York nearshore areas consisted of bedrock. As such, our field investigation of this classification level was focused more on finding any evidence to refute this, rather than to provide a detailed mapping of the nearshore geology (given that we were confident the previous classification data was perhaps the best we could get). Given that our visual observations when in the field confirmed that the majority of the nearshore was bedrock, we made only sporadic use of the sediment probe

2.2 Develop Digital Shoreline

A new digital shoreline was developed for this project and was created by digitizing directly from the DOPs that were obtained. The DOPs were first imported into ArcView 3.0. In some cases (New York DOPs) it was necessary to convert the MR. SID Images to GeoTIFF format before bringing into ArcView. Once in ArcView the shoreline coverage was digitized on-screen.

DOP coverage was incomplete for only one small portion of the shoreline, on the neck of the Presque Isle peninsula. Coverage here was completed by using a Digital Raster Graphic (DRG) USGS topographic map, as well as air photos and other data sources (maps, field notes, video) to best estimate the shoreline position.

Rivermouths were digitized as far up as deemed appropriate or to a point that was visible from the boat while conducting field activities.

Two minor limitations of the DOPs were noted. The first was the presence of ice. Both shorefast ice and drift ice were visible in the nearshore zone on many of the images. This provided a degree of difficulty in accurately digitizing the waterline/shoreline. This was overcome as much as possible by using other data sources (video, field notes, and aerial photos) to confirm and verify shoreline position.

A second limitation was related to the quality of the photography, particularly severe glare and severe shadow on some images. Again, this made it difficult in some areas to discern the waterline/shoreline from other physical features, particularly buildings and dock structures.   Again this was overcome through confirmation and verification using other data sources.

An example of the digital shoreline coverage for a portion of the New York shoreline is presented in Figure 2 below. Note the presence of drift ice just offshore.

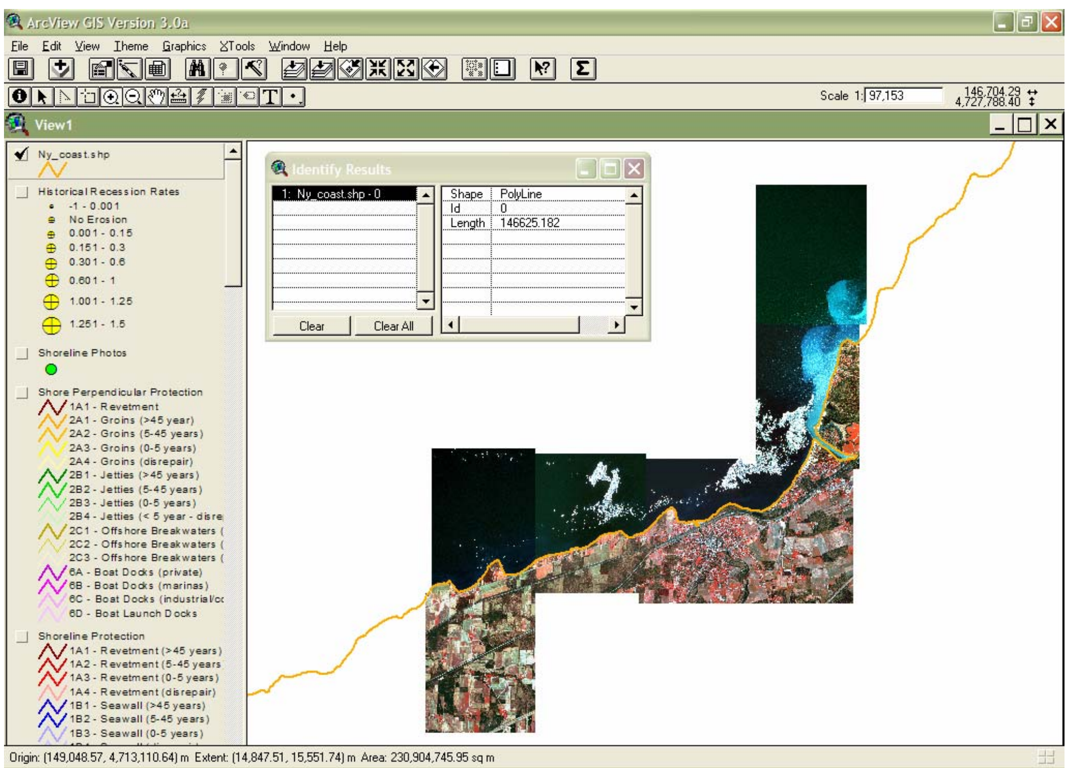


Figure 2 – Example of Digital Shoreline Coverage (Orange Line) for Lake Erie Shoreline.

2.3 Geologic Shoreline Type Re-Attribution

The re-attribution and re-mapping of the shoreline type classification was completed directly in ArcView GIS. First, the new digital shoreline was plotted and the associated digital orthophotos were brought in to serve as a backdrop for reference purposes and to assist where needed in determining the transitions between shore types.

Second, the original kilometer-by-kilometer shoreline classification data (Stewart, 1999) was imported into ArcView and displayed on screen in order to provide a general reference as to where major changes in shore types occurred and as to what these sections of shoreline had been previously classified as. Using the information from the detailed field notes, in combination with the original classification (as a guideline), and examination of other data sources as necessary (aerial photography, video tape). The start and end point of each distinct geologic shore type were then plotted on the new digital shoreline by bi-secting the shoreline line string in the appropriate spot. This created a distinct line segment in ArcView which was then classified using the geologic shoreline type classification scheme developed for both the Lake Michigan Potential Damages Study (LMPDS) and the LGLES (Stewart, 1999) (Table 1). This segment was saved as a separate coverage in ArcView.

Table 1 - Shoreline Type Classification (Stewart, 1999)

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

An example of the shore type mapping can be found in Figure 3.

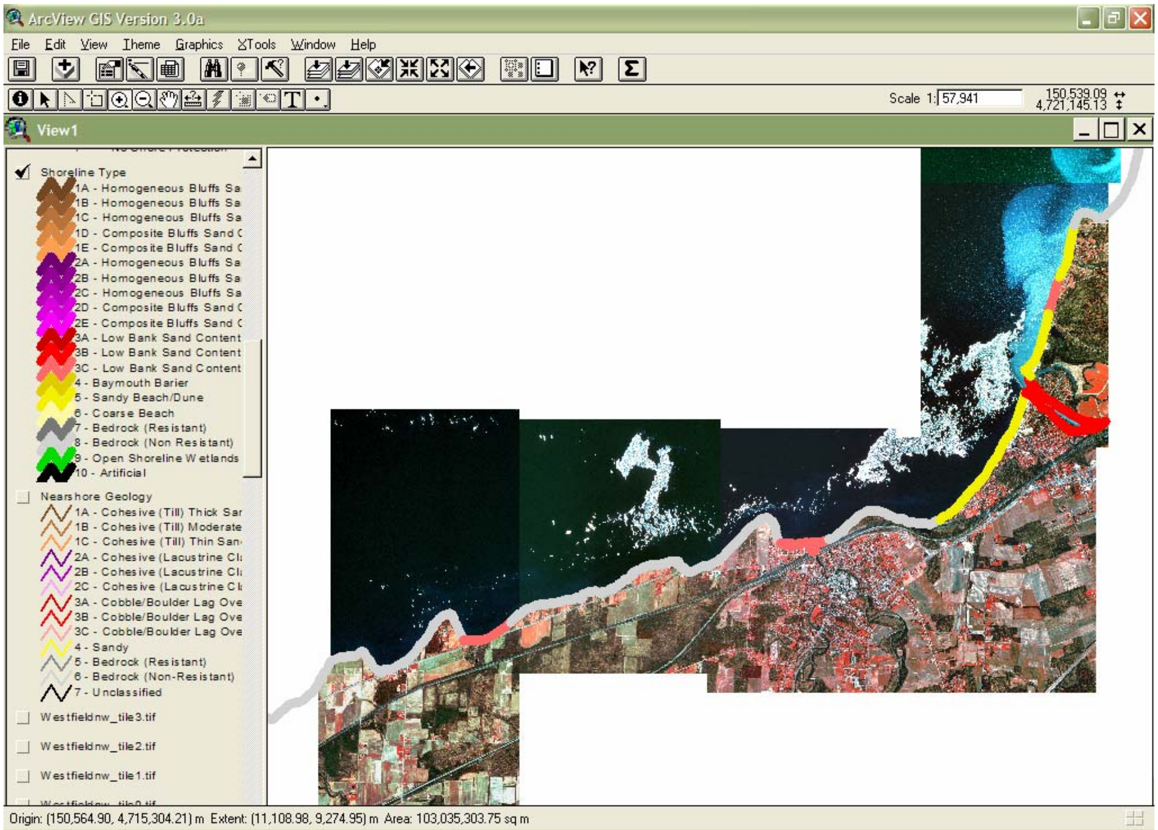


Figure 3 – Example of Geologic Shore Type Mapping for a portion of the Lake Erie Shoreline, New York State.

2.4 Shore Protection Classification Re-Attribution

The re-attribution and re-mapping of the shore protection classification was completed directly in ArcView GIS. First, the new digital shoreline was plotted and the associated digital orthophotos were brought in to serve as a backdrop for reference purposes and to assist in determining the transitions between shore protection types.

Using the detailed field notes in combination with the on-screen DOPs, the aerial photography and the shoreline video, the start and end point of the structures were accurately confirmed. These were then plotted on the new digital shoreline by bi-secting the shoreline line string in the appropriate spot. This created a distinct line segment in ArcView which was then classified using the shore protection classification scheme previously developed (Stewart, 1999) (Table 2). This line segment was saved as a separate coverage in ArcView.

It should be noted that in areas where more than one shore protection structure was present along a length of shoreline (e.g., a seawall with a rip rap revetment fronting it, or a seawall with groins), only the primary mode of protection that was in place was included in the continuous GIS coverage that was developed. For this purpose, primary shore protection was defined as that which would bear the initial brunt of any wave activity or other coastal processes. Secondary shore protection structures were then noted in the "Comments" column of the attribute table associated with the line segment.

Table 2: Shore Protection Type Classification (Stewart, 1998)

1. Coastal Armoring

1A1 - Revetments >45 year lifespan
1A2 - Revetments 5-45 year lifespan
1A3 - Revetments 0-5 year lifespan
1A4 - Revetments 0 year lifespan (disrepair)

1B1 - Seawalls/Bulkheads >45 year lifespan
1B2 - Seawalls/Bulkheads 5-45 year lifespan
1B3 - Seawalls/Bulkheads 0-5 year lifespan
1B4 - Seawalls/Bulkheads 0 year lifespan (disrepair)

2. Beach Erosion Control Devices

2A1 - Groins >45 year lifespan
2A2 - Groins 5-45 year lifespan
2A3 - Groins 0-5 year lifespan
2A4 - Groins 0 year lifespan (disrepair)

2B1 - Jetties >45 year lifespan
2B2 - Jetties 5-45 year lifespan
2B3 - Jetties 0-5 year lifespan
2B4 - Jetties 0 year lifespan (disrepair)

2C1 - Offshore Breakwaters >45 year lifespan
2C2 - Offshore Breakwaters 5-45 year lifespan
2C3 - Offshore Breakwaters 0-5 year lifespan
2C4 - Offshore Breakwaters 0 year lifespan (disrepair)

3. Non-Structural

3A1 - Beach Nourishment >45 year lifespan
3A2 - Beach Nourishment 5-45 year lifespan
3A3 - Beach Nourishment 0-5 year lifespan
3A4 - Beach Nourishment 0 year lifespan (disrepair)

3B1 - Vegetation Planting >45 year lifespan
3B2 - Vegetation Planting 5-45 year lifespan
3B3 - Vegetation Planting 0-5 year lifespan
3B4 - Vegetation Planting 0 year lifespan (disrepair)

3C1 - Slope/Bluff Stabilization >45 year lifespan
3C2 - Slope/Bluff Stabilization 5-45 year lifespan
3C3 - Slope/Bluff Stabilization 0-5 year lifespan
3C4 - Slope/Bluff Stabilization 0 year lifespan (disrepair)

4. Protected Wetlands

5. Ad-Hoc Structures

5A1 - Concrete Rubble >45 year lifespan
5A2 - Concrete Rubble 5-45 year lifespan
5A3 - Concrete Rubble 0-5 year lifespan
5A4 - Concrete Rubble 0 year lifespan (disrepair)

5B1 - Other Materials >45 year lifespan
5B2 - Other Materials 5-45 year lifespan
5B3 - Other Materials 0-5 year lifespan
5B4 - Other Materials 0 year lifespan (disrepair)

6 – Boat Launch Ramps

7 - No Protection

In addition to capturing shore *parallel* protection, there was a desire to capture shore *perpendicular* protection structures (e.g., groins, jetties, offshore breakwaters) as well as those structures related to recreational boating (e.g., boat docks, launch ramps). As such, additional classification categories were created to capture these and included changing Category 6 in the Shore Protection Class to "Boat Launch Ramps" (Table 2)(in order to capture the alongshore length of such structures), as well as the addition of the following shore perpendicular categories:

Boat Docks (Private) – any boat dock associated with a private residence;

Boat Docks (Marinas) – any boat dock or group of docks associated with a private or public marina;

Boat Docks (Commercial/Industrial) – Docks and piers associated with commercial and industrial businesses (other than marinas); and

Boat Launch Docks – any boat dock associated with public or private boat launch ramps.

Where these structures were visible on the digital orthophotos, they were digitized on-screen, classified accordingly and saved as a separate ArcView coverage. In some cases, objects were not visible on the DOPs but were noted in the field, or alternatively (in the case of some marina docks) were in different locations or configured differently in 2001, than what was shown in the DOPs. Where this occurred, these structures were digitized as accurately as possible using the more recent field mapping information.

An example of the shore protection mapping showing both shore parallel and shore perpendicular structures is found in Figure 4.

Figure 4 – Example of Shore Protection Mapping, Dunkirk Harbor, Lake Erie.

2.5 Nearshore Geology Re-Attribution

Re-attribution of the nearshore geology classification data was conducted primarily by using the previous classification data and then best estimating the start and end points of where the geology changed, given the limited data collected in the field as well as the information from previous geologic reports and mapping. Recall that the previous classification efforts identified that most of the Pennsylvania and New York nearshore areas (other than around Presque Isle) consisted of bedrock. As such, our field investigation of this classification level focused more on finding any evidence to refute this, rather than to provide a detailed mapping of the nearshore geology (given that we were confident the previous classification data was perhaps the best we could get).

The re-attribution and re-mapping of the nearshore type classification was completed directly in ArcView GIS. First, the new digital shoreline was plotted and the associated digital orthophotos were brought in to serve as a backdrop for reference purposes.

Second, the original kilometer-by-kilometer nearshore classification data (Stewart, 1999) was imported into ArcView and displayed on screen in order to provide a general reference as to where major changes in nearshore types occurred and as to what these sections of nearshore had been previously classified as. Using this information, as well as the limited information from the field notes, start and end points of changes in the nearshore geology were plotted as accurately as possible on the new digital shoreline by bi-secting the shoreline line string in the appropriate spot. This created a distinct line segment in ArcView which was then classified using the nearshore geology classification scheme previously developed (Stewart, 1999) (Table 3). This was saved as a separate coverage in ArcView.

An example of the nearshore geology mapping for the Presque Isle, PA area can be seen in Figure 5.

Table 3: Nearshore Geology Classification (Stewart, 1998)

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 (Laccustrine 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**

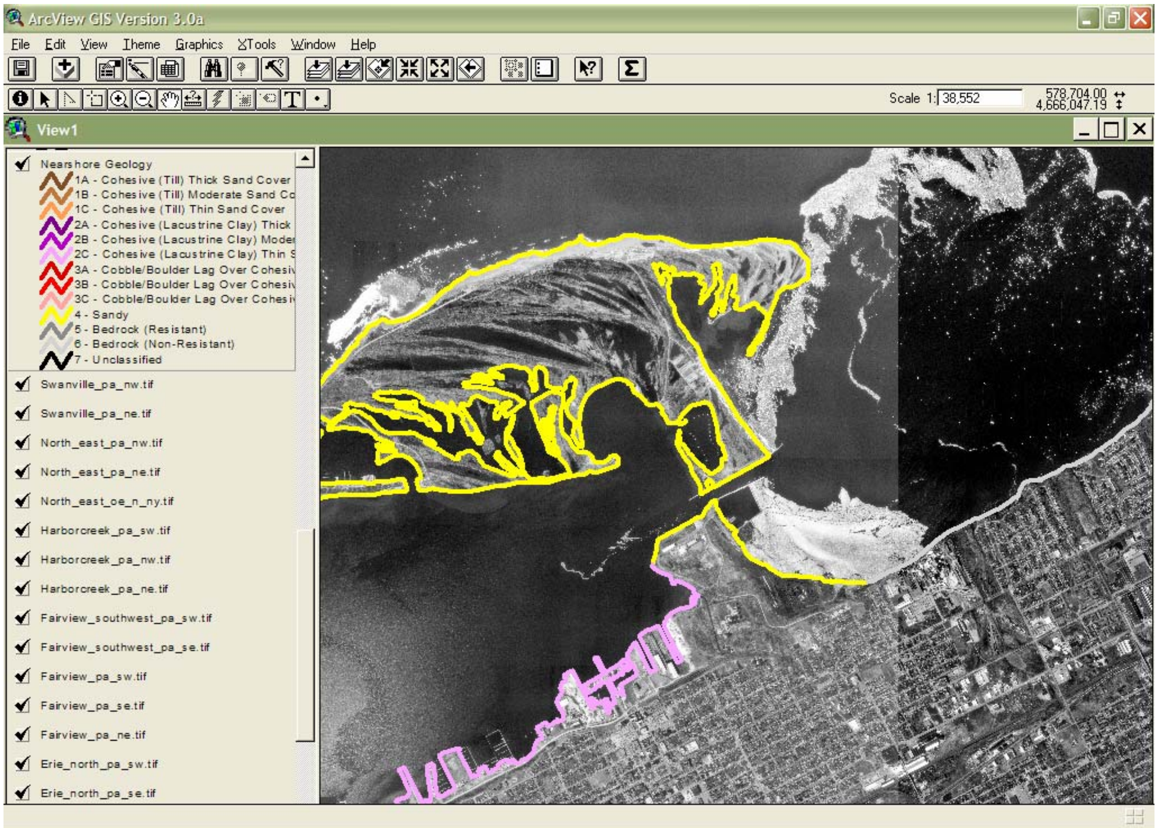


Figure 5 – Example of Nearshore Geology Mapping, Presque Isle, PA.

2.6 Recession Rate Data Re-Attribution

2.6.1 Introduction

A wealth of recession rate data has been collected for the Lake Erie shoreline by various interests, including State natural resource agencies, academics, consulting companies, local municipalities and shoreline stakeholder groups. Much of this data has been compiled in a recession rate database for the Lake Erie shoreline (Stewart, 1994) and provides a comprehensive listing of all data on a kilometer-by-kilometer basis, as well as brief descriptions of the nature of the data, its accuracy, confidence, etc.

In the early part of the LGLES, this 1994 database was updated (Stewart, 1999) with new or updated recession rate data, and for LGLES modeling purposes, a representative value of recession was selected from the available data to provide a single recession rate value for each kilometer reach that was defined along the Lake Erie shoreline.

Similar to the shore type classification, questions arose as to whether a single value of recession adequately represented the true erosion rates occurring in a one-kilometer segment, particularly when local variations in recession rate within that kilometer could be quite different. Also, with the redefinition of the shoreline using new and improved digital mapping products, uncertainty again arose as to how representative the erosion rates were, given the errors and inaccuracies that were contained in the original (1993-1994) shoreline. Given this, there was a need to re-examine the recession rate data and determine if there was a more suitable way of representing the data as a continuous GIS mapping coverage - one that was tied to the new digital shoreline developed for the study.

2.6.2 Data Selection

A first step in this activity was to re-examine the original data and determine which data would be suitable for plotting in a continuous GIS mapping format. Such data would consist primarily of those data sets that were "point location - discrete value" data sets, i.e., there was a specific point along the shoreline where the recession rate was measured (which could then be plotted as a point on the new shoreline), and there is a specific, or discrete, value of recession that has been calculated for that point. Point location data sets where a range of recession rates were provided, as opposed to a discrete value, could also be mapped in a similar fashion. Data sets that included a value of recession over a distance, or linear zone, of shoreline were not included.

The end result of this is that only a few of the many recession rate data sets included in the comprehensive recession rate database were selected for inclusion in the continuous mapping coverages for the five counties. These include:

Pennsylvania

The original datasets included detailed data from the Pennsylvania Coastal Management Program (Knuth, 1987 and Knuth and Crowe, 1975). For this 2001 study, updated information was obtained from the Pennsylvania Department of Environmental Protection (Knuth, 2000) and utilized to map and plot recession rate data points along the shoreline.

Data Description

The Commonwealth of Pennsylvania began a shoreline bluff recession monitoring program in 1982. At that time sixty-four monitoring stations were placed at approximately one-kilometer intervals. The monitoring stations, or control points were numbered 0.0 beginning at the Ohio-Pennsylvania State Boundary to number 33.0 in Millcreek Township. No control points were established on Presque Isle peninsula or on the shoreline of Presque Isle Bay. Control point 44.0 (approximately forty-four kilometers from the Ohio boundary) was originally established at International Paper Company, Inc. in the City of Erie. The last control point near the Pennsylvania-New York boundary was numbered 73.0.

Sixty-four additional stations were established in 1986. The additional stations are numbered beginning with 0.5 located between Control Points 0.0 and 1.0 and thence every kilometer to Control Point 33.5 one-half kilometer east of Control Point 33.0. The control points east of the City of Erie resume at Control Point 44.5 and thence to Control Point 73.5 at the Pennsylvania-New York border.

A few Control Points are established as map locations only. Having been developed on a one-half kilometer grid it was inevitable that some locations would fall in areas where there was no bluff.

The Control Points have been monitored since the base line data was collected in 1982 and 1986. Monitoring programs in 1986 (for the 1982 Control Points), 1989, 1994, and 1998-1999 have resulted in eighteen years of data on approximately five year intervals.

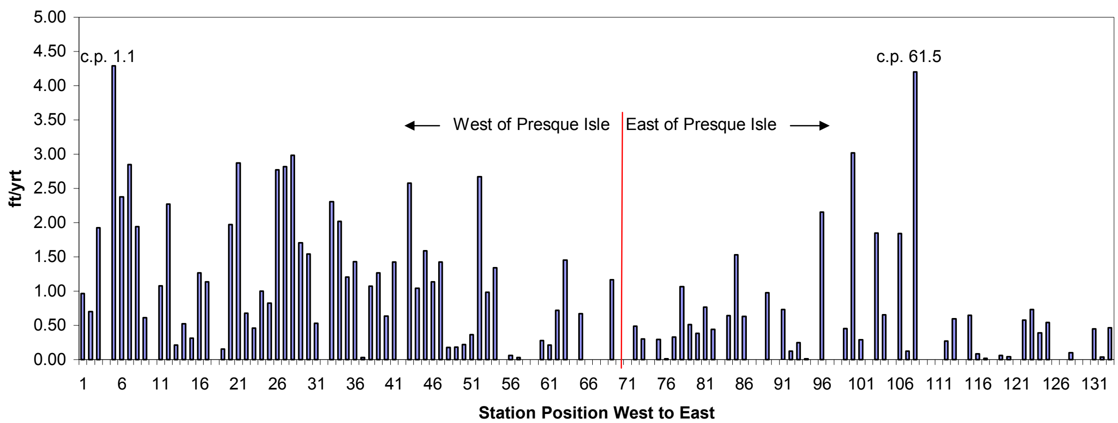
The updated Pennsylvania recession rate data was calculated at a series of points spaced approximately every 500 meters along the shoreline (excluding the Presque Isle peninsula and Presque Isle Bay. Table 4 is a sample of the recession rate data all monitoring activity since 1982 for the first few control points. The full data table can be found on the data CD that accompanies this report. For each station the date of monitoring activity is given along with a distance in decimal feet recorded between the control point at the station and the edge of the bluff. The table shows the recessional loss for the time period monitored for each station in feet per year and also in meters per year. The average recession rate for the reach is also shown. Average recession for the reach from Ohio to the proximal end of Presque Isle peninsula is 1.12 feet per yr. For the reach from Presque Isle Bay to New York to average recession rate is 0.57 feet per year.

Figure 6 is a graph of recession rate averages along the shoreline by station number.

Table 4 – Sample of Recession Rate Data for Pennsylvania Shoreline

Stat	1982	Dist (ft)	1986/87	Dist (ft)	1989	Dist (ft)	1994	Dist (ft)	1998/99	Dist (ft)	Dist (a-k)	Years	Recess (ft/yr	Recess (m/yr)
0.0	12-Oct-82	178.00	01-Nov-86	171.50	17-May-89	168.25	26-Jul-94	168.00	01-Jun-98	163.00	15.00	15.58	0.9628	0.2935
0.1		0.00		0.00		0.00	26-Jul-94	71.75	01-Jun-98	69.00	2.75	3.92	0.7015	0.2138
0.5		0.00	01-Nov-86	98.00	17-May-89	89.75	26-Jul-94	86.00	02-Jun-98	77.00	22.00	11.42	1.9264	0.5872
1.0														
1.1		0.00	08-Nov-86	292.00	18-May-89	266.75	26-Jul-94	247.00	02-Jun-98	243.00	49.00	11.42	4.2907	1.3078
1.5		0.00	08-Nov-86	144.67	18-May-89	132.50	29-Jul-94	125.33	02-Jun-98	117.50	27.17	11.42	2.3792	0.7252
2.0	23-Mar-82	74.50	08-Nov-86	57.58	18-May-89	45.50			02-Jun-98	28.50	46.00	16.17	2.8448	0.8671
2.5	12-Oct-82	329.00	01-Nov-86	320.00	18-May-89	306.42	26-Jul-94	306.42	02-Jun-98	298.60	30.40	15.67	1.94	0.5913
3.0	23-Mar-82	29.00	01-Nov-86	24.83	18-May-89	22.00	29-Jul-94	20.75	02-Jun-98	19.10	9.90	16.17	0.6122	0.1866
3.5		0.00	01-Nov-86	19.75	19-May-89	19.75	29-Jul-94	19.75	02-Jun-98	19.75	0.00	11.42	0	0
4.0	23-Mar-82	50.00	01-Nov-86	45.17	19-May-89	40.50	01-Aug-94	37.83	08-Jun-98	32.50	17.41	16.17	1.0767	0.3282
4.5		0.00	01-Nov-86	271.92	19-May-89	267.00	29-Jul-94	253.50	08-Jun-98	246.00	25.92	11.42	2.2697	0.6918
5.0	24-Mar-82	45.00	08-Nov-86	45.00	19-May-89	45.00	01-Aug-94	43.00	08-Jun-98	41.58	3.42	16.17	0.2115	0.0645
5.5		0.00	08-Nov-86	118.50	19-May-89	105.75	01-Aug-94	105.75	08-Jun-98	112.50	6.00	11.42	0.5254	0.1601

Figure 6 – Graph of Average Annual Recession Rates, Pennsylvania Shoreline



Data Mapping

Data provided by the State of Pennsylvania included detailed geographic coordinates for the location of the recession rate control points, but these were not readily extractable from the data CDs obtained as they were provided on a series of maps in .psp format which we could not open. Also provided however, were PowerPoint files that provided a survey sketch of the control point, as well as an oblique aerial photograph of the control point location taken from just offshore. This, used in concert with the DOPs and other air photo information allowed us to plot the location of the control points relatively accurately within the GIS. These are represented by a yellow symbol with crosshairs as shown in Figure 7. These symbols are also sized according to recession rate range – the larger the symbol, the larger the long-term recession rate calculated. Control point photos were also imported as a separate coverage within the GIS and can be viewed along with the recession rate data for the point. These points are represented by the green symbols in the GIS. When queried, a small version of the photo pops up in a new window (see Figure 7). This window can be expanded if required.

Figure 7 – Recession Rate Control Points (Yellow Symbols) and Oblique Air Photo Points (Green Symbols), Pennsylvania Shoreline

Data provided for the PA recession rate control points included measurements taken over four different periods (see Table 4). For the purposes of this study, only the longest term recession rate for the control point was displayed in the GIS attribute table (Table 5). This is found in the "RecessionRate_82_98/99" field in the table.

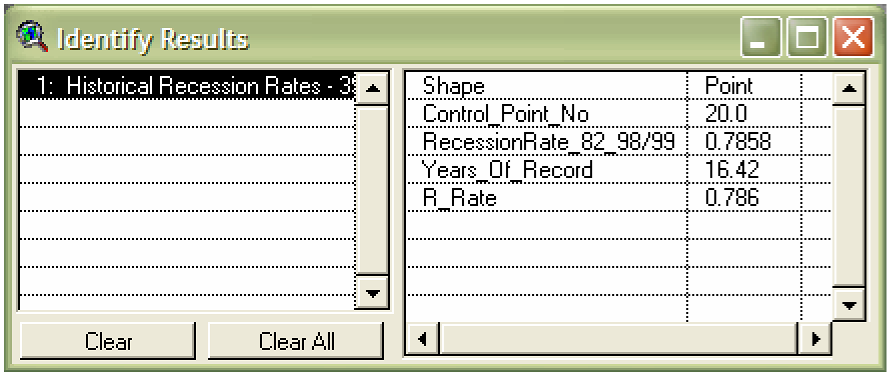


Table 5 – Recession Rate Attribute Table, Pennsylvania Shoreline

New York

Data Description

For the New York shoreline, the original data came from the New York Department of Environmental Conservation and provides long-term recession rates for 1875-1979. For this original data set, comparisons were made between shoreline positions on 1875 Hydrographic Survey maps with the shoreline position on 1979 aerial photographs. Baselines were established on the 1875 maps using road intersections and other landmarks that also exist on the 1979 air photos. Transects were established approximately every 244 meters along the baseline and baseline to bluff-crest measurements were made for each. Similar measurements were made along the same transects on the 1979 photos, and the net shoreline change was calculated by subtracting the two values. Appropriate scale adjustments were made in order to allow accurate comparisons between the maps and the air photos, and average annual recession rates were calculated simply by dividing the total shoreline change by the 104 year period of record. In some areas of Lake Erie, 1875 hydrographic charts were not available and 1938 air photos were utilized and compared with the 1979 maps, producing a 40 year period of record.

In addition to the NY DEC data, the recession rate database also contains data from a study conducted by Geier and Calkin (1983). This data set involved the calculation of short-term (1938-1974) and long-term (1875-1974) bluff recession rates along the New York Lake Erie coast at 116 locations between Buffalo and the Pennsylvania State Line. Recession measurements were made on 1:10,000 scale 1875 Lake Survey maps, and 1:4,800 scale 1938 and 1974 aerial photographs.

Data Mapping

Unfortunately, when attempting to re-establish the point locations for both the NY DEC and Geier and Calkin transects, we were unable to obtain the topographic maps that indicated the exact profile positions. As such, mapping of the precise location of a recession rate transect or measurement point could not be completed. In order to provide some type of representation of recession rate data for the New York shoreline, the representative kilometer-by-kilometer summary data set for the NY shoreline (Stewart, 1994 and 1999) was utilized.

Using maps showing the boundaries of the kilometer reach segments, the centre points of each reach segment were plotted as accurately as possible and shifted slightly landward so as to be visible in the GIS. These are represented by a yellow symbol with crosshairs as shown in Figure 8. These symbols are also sized according to recession rate range – the larger the symbol, the larger the long-term recession rate calculated.

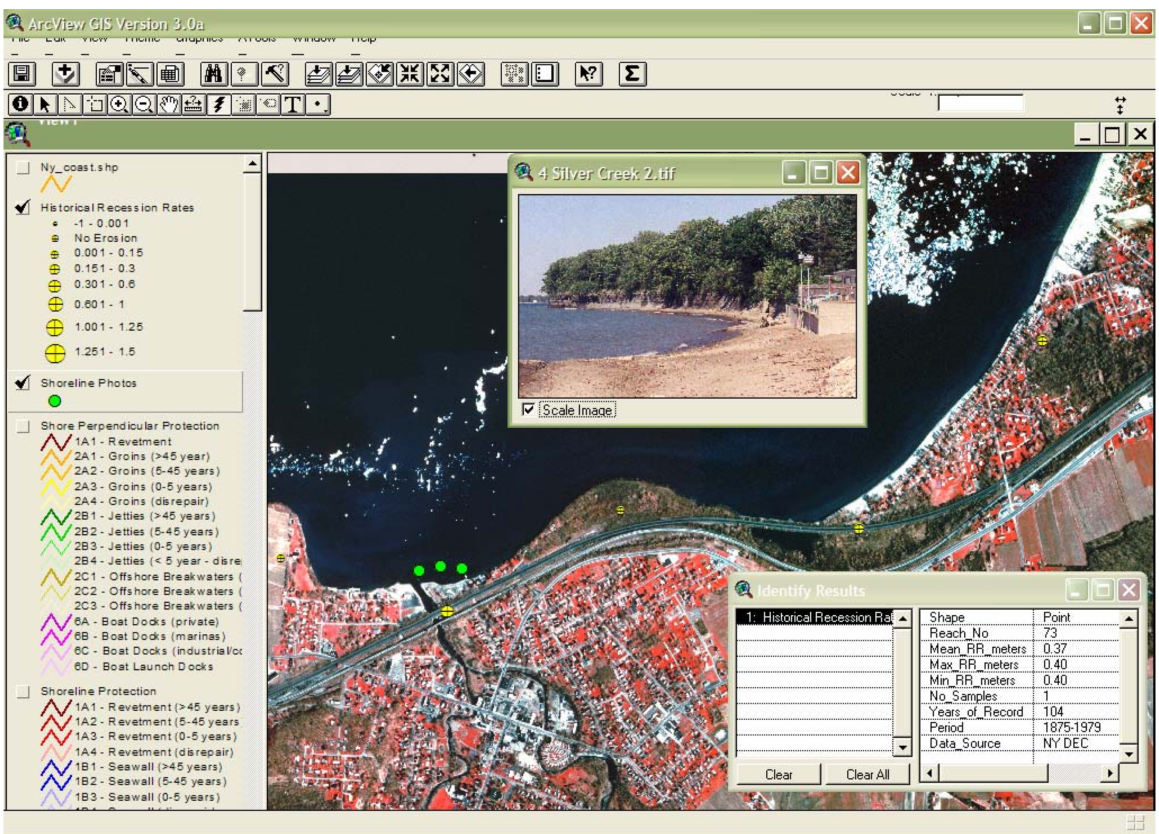
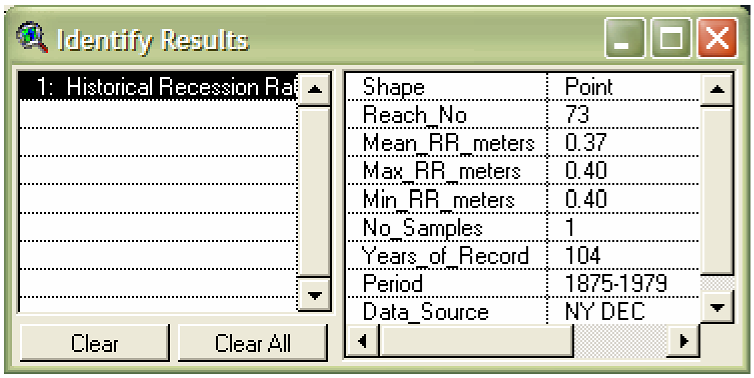


Figure 8 – Recession Rate Control Points (Yellow Symbols) and Ground Photo Points (Green Symbols), New York Shoreline

Data provided for the NY recession rate points (center points of the reaches) includes the mean recession rate for the kilometer (calculated from the original data sets) as well as the maximum and minimum recession rates for the reach, the number of samples (original measurement points) that the summary data is based upon, the period and years of record of measurement and the data source (usually NY DEC or Geier and Calkin, 1983)(see Table 6).



Shape	Point
Reach_No	73
Mean_RR_meters	0.37
Max_RR_meters	0.40
Min_RR_meters	0.40
No_Samples	1
Years_of_Record	104
Period	1875-1979
Data_Source	NY DEC

Table 6 – Recession Rate Attribute Table, New York Shoreline

Unlike the Pennsylvania shoreline, there were no oblique air photos available for the center points of each reach. However, at some points along the shore, ground photos were available. The locations of these photos are represented by the green symbols in the GIS. When queried, a small version of the photo pops up in a new window (see Figure 8). This window can be expanded if required.

3.0 Data Presentation and Analysis

3.1 ArcView Project Files

Two separate ArcView project files were created for this activity, one for the Pennsylvania shoreline and one for the New York shoreline and are available on the data CD accompanying this report. Details on how to install and access these project files and associated coverages are found in an Appendix to this report.

3.2 ArcView Coverages

Within each project file there are ArcView coverages set up for the following data:

1) the digitized coastline (ny_coast.shp, penn_coast.shp)
2) the digital orthophotos (*.tif files)
3) shore type data (ny_shoretype.shp; penn_shoretype.sh)
4) parallel shore protection data (ny_shoreprotection.shp; penn_shoreprotection.shp)
5) perpendicular shore protection (ny_offshore.shp; penn_offshore.shp)
6) nearshore geology (ny_nearshoretype.shp; penn_nearshoretype.shp)
7) recession rate data (recession.shp)
8) photo locations (photos.shp)

Details on the locations of these coverages and how to access them are found in an Appendix to this report.

3.3 Data Attributes

All classification data was entered directly into attribute tables within ArcView GIS. These tables contained the following key information:

3.3.1 Shore Type Classification

Length - This provided the length of the particular shore type segment (and classification type) in meters based on the start and end points that were mapped.

Shore_type - The shore type classification as assigned.

Notes - Any relevant additional information regarding the classified segment. In this case this usually included additional detail regarding the shore type classification.

X_start; Y_start - longitude and latitude coordinates of the start point of the classified segment.

X_end; Y_end – longitude and latitude coordinates of the end point of the classified segment.

3.3.2 Parallel Shore Protection Classification

Length - This provided the length of the particular parallel shoreline protection segment (and classification type) in meters based on the start and end points that were mapped.

SP_Type - The shore protection classification as assigned.

Notes - Any relevant additional information regarding the classified segment. In this case this usually included additional detail regarding the primary and any secondary shore protection structures that were present.

X_start; Y_start - longitude and latitude coordinates of the start point of the classified segment.

X_end; Y_end – longitude and latitude coordinates of the end point of the classified segment.

3.3.3 Nearshore Geology

Length - This provided the length of the particular nearshore geology segment (and classification type) in meters based on the start and end points that were mapped.

Ns_type - The nearshore geology classification as assigned.

Notes - any relevant additional information regarding the classified segment. In this case this usually included additional detail regarding the nearshore type classification.

X_start; Y_start - longitude and latitude coordinates of the start point of the classified segment.

X_end; Y_end – longitude and latitude coordinates of the end point of the classified segment.

3.3.4 Perpendicular Shore Protection

OffshoreSP_type - the shore protection, or shore perpendicular structure classification code as assigned.

Notes - any relevant additional information.

Length - the total length of the line segment that defines the structure.

3.3.5 Recession Rate Data

Recession rate data attribute tables were discussed previously in Section 2.6.

3.3.6 Photographs

Data attribute tables for the photographs simply have one field in them listing the file name of each photograph as a separate record.

3.4 Combined Data Presentation

The shore type, shore protection, nearshore geology, offshore structure and recession rate data were all mapped in ArcView GIS and provided as separate data coverages (Arc shape files) which were delivered electronically to USACE Buffalo. While each data layer could be mapped individually (see Figures 2-8 for example), for presentation purposes in this activity, there was also a desire to display all data layers at the same time. Given that all the data layers (except the offshore structures) were tied to the new digital shoreline, this required slight adjustments in the line widths of and style of each coverage so as to be clearly visible.

Figure 9 presents an example of the combined mapping for a section of New York shoreline. Hardcopy printouts for the entire Pennsylvania and New York shoreline are found in an Appendix to this report. In this example, the nearshore geology layer is not displayed as it is consistent along most of the shoreline. The thicker colored line running along the shoreline represents the geologic shore type classification. Within this line is a narrower line which represents the parallel shore protection classification. Perpendicular shore protection structures displayed as another coverage (in this case the marina breakwaters and marina docks). Recession data points (yellow symbols) and ground photos (green symbols) are also shown.

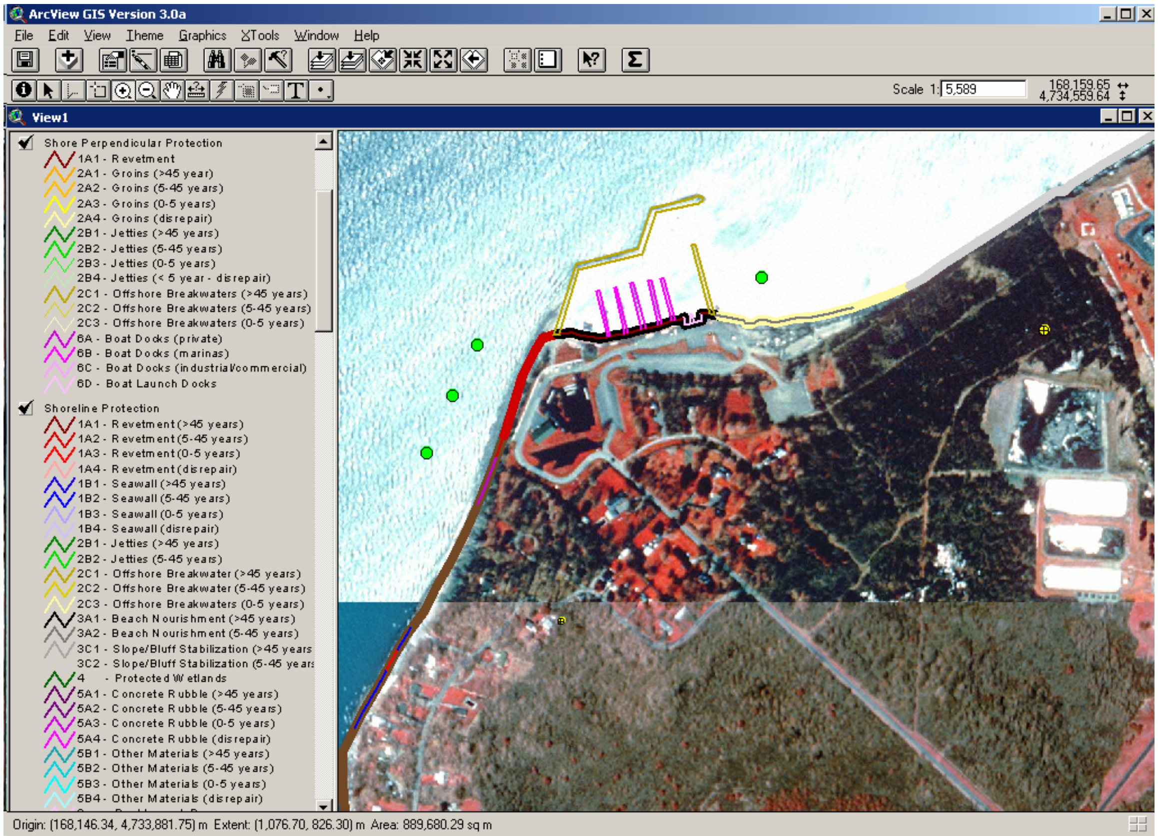


Figure 9 - Example of Combined Mapping, Sturgeon Point Marina, NY

Within the GIS, layers can be turned off and on as required and additional layers (e.g., nearshore geology) can be added if required. Similarly, the DOPs can be turned off if they are not required as backdrop images.

3.5 Data Analysis

For analysis purposes, data was exported from the ArcView GIS program into MS-Excel in order to compute overall statistics on the total lengths of the different classification types along the open coast of Lake Erie for each state. Analysis of the data is presented below.

3.5.1 Pennsylvania

Shore Type

Summary statistics on the lengths of different shore types found along the open coast of Pennsylvania are provided in Table 7.

Table 7 – Pennsylvania Shore Type Statistics

Type	Description	Length (km)
1B	Homogenous Bluff 20-50% sand	8.3
1C	Homogenous Bluff >50% sand	0.3
1D	Composite Bluff (0-20% sand)	22.4
1E	Composite Bluff (20-50% sand)	12.7
2D	Composite Bluff With Beach (0-20% sand)	1.9
2E	Composite Bluff with Beach (20-50% sand)	2.8
3A	Low Bank 0-20% sand	0.3
3B	Low Bank 20-50% sand	2.7
3C	Low Bank >50% sand	6.8
4	Baymouth Barrier	5.5
5	Sandy Beach / Dune	19.8
6	Coarse Beaches	4.9
8	Non-Resistant Bedrock	8.8
9	Wetlands	26.7
10	Artificial	17.2
	TOTAL:	**141.1**

Shore Protection

Summary statistics on the type and extent of shore protection structures found along the open coast of Pennsylvania are provided in Table 8.

Table 8 – Pennsylvania Parallel Shore Protection Statistics

Type	Description	Length (km)
1A1	Revetments >45 year lifespan	4.3
1A2	Revetments 5-45 year lifespan	5.5

1A3	Revetments 0-5 year lifespan	0.4
1A4	Revetments 0 year lifespan (disrepair)	0.1
1B1	Seawalls >45 year lifespan	11.9
1B2	Seawalls 5-45 year lifespan	5.4
1B3	Seawalls 0-5 year lifespan	2.6
1B4	Seawalls 0 year lifespan (disrepair)	0.1
2C1	Offshore Breakwaters >45 year lifespan	0.1
3C2	Slope / Bluff Stabilization 0-45 year lifespan	0.0
5A2	Ad Hoc Concrete Rubble 0-45 year lifespan	1.1
5A3	Ad Hoc Concrete Rubble 0-5 year lifespan	0.2
5A4	Ad Hoc Concrete Rubble 0 year lifespan (disrepair)	1.1
5B2	Ad Hoc Other Materials 0-45 year lifespan	0.2
5B4	Ad Hoc Other Materials 0 year lifespan (disrepair)	0.1
6D	Boat Launch Ramps / Areas	0.3
7	No Protection	107.7
	Total:	**141.1**

Nearshore Geology

Summary statistics on the type of nearshore geology found along the open coast of Pennsylvania are provided in Table 9.

Table 9 – Pennsylvania Nearshore Geology Summary Statistics

Type	Description	Length (km)
2C	Cohesive Lacustrine Clay Thin Sand Cover (<50m3/m)	17.4
4	Sand	59.0
6	Non-Resistant Bedrock	64.7
	TOTAL:	**141.1**

3.5.2 New York

Shore Type

Summary statistics on the lengths of different shore types found along the open coast of New York are provided in Table 10.

Table 10 – New York Shore Type Statistics

Type	Description		Length (km)
1A	Homogenous Bluff 0-20% sand		3.0
1E	Composite Bluff (20-50% sand)		6.8
2C	Homogeneous Bluff with Beach (>50% sand)		1.2
2E	Composite Bluff with Beach (20-50% sand)		5.6
3A	Low Bank 0-20% sand		2.0
3B	Low Bank 20-50% sand		6.9
3C	Low Bank >50% sand		3.7
5	Sandy Beach / Dune		17.9
6	Coarse Beaches		1.1
8	Non-Resistant Bedrock		61.8
10	Artificial		35.1
		TOTAL:	**145.1**

Shore Protection

Summary statistics on the type and extent of shore protection structures found along the open coast of New York are provided in Table 11.

Table 11 – New York Parallel Shore Protection Statistics

Type	Description	Length (km)
1A1	Revetments >45 year lifespan	9.9
1A2	Revetments 5-45 year lifespan	4.4
1A3	Revetments 0-5 year lifespan	1.1
1B1	Seawalls >45 year lifespan	20.7
1B2	Seawalls 5-45 year lifespan	15.4
1B3	Seawalls 0-5 year lifespan	0.5
1B4	Seawalls 0 year lifespan (disrepair)	0.1

2B1	Jetties >45 year lifespan	0.2
2C1	Offshore Breakwaters >45 year lifespan	0.1
2C3	Offshore Breakwaters 0-5 year lifespan	0.1
3A2	Beach Nourishment 5-45 year lifespan	0.2
3C1	Slope / Bluff Stabilization >45 year lifespan	0.1
5A2	Ad Hoc Concrete Rubble 0-45 year lifespan	0.4
5A3	Ad Hoc Concrete Rubble 0-5 year lifespan	0.7
5A4	Ad Hoc Concrete Rubble 0 year lifespan (disrepair)	0.7
5B4	Ad Hoc Other Materials 0 year lifespan (disrepair)	0.2
6D	Boat Launch Ramps / Areas	0.6
7	No Protection	89.8
	TOTAL:	**145.1**

Nearshore Geology

The nearshore geology of the New York Lake Erie shoreline consisted entirely of Class 6, Non-Resistant Bedrock (145.1km).

4.0 Summary and Conclusions

The open coast reach delineation and re-attribution of shoreline classification exercise carried out in this task has resulted in the development of continuous GIS mapping coverages for key coastal zone data sets along the New York and Pennsylvania Lake Erie shoreline. Newly mapped data includes shoreline type, shore protection, nearshore geology and recession rate data. In addition, a new digital shoreline was created. As a result of this exercise, there are a number of conclusions and recommendations that should be considered during future exercises of this nature:

1) The creation of individual mapping coverages for each data layer provides a degree of flexibility in the display and visualization of the information. Each layer can be mapped or presented individually, or they can be presented at the same time, with a slight offset from each other so that they are easily visible.

2) The newly created digital shoreline provides a much more accurate "baseline" on which to map the related information and provides for an ability to conduct future modeling exercises and analyses at a greater level of detail than at the 1 kilometer scale previously in place.

3) The shore protection mapping that has been developed in this activity only maps the primary shore protection that is in place. Secondary shore protection structures are then referenced in the attribute table, or else captured in the "offshore" mapping coverage that has been developed. This needs to be kept in mind during any future examination of related costs/impacts to shore protection structures and those conducting such an analysis may wish to use the continuous mapping data in conjunction with field observations or any other detailed mapping that may be available in the future.

4) In developing the nearshore geology mapping coverage, it is important to note that there was no solid evidence of the exact delineation (boundary) between different nearshore geologic types. The boundaries were largely determined using the previous classification information, with limited help from field study results. For future exercises of this nature, it would be helpful to have more accurate nearshore mapping information, so that this delineation could be done with more confidence.

5) Continuous GIS mapping coverages for the remainder of the Lake Erie shoreline should be considered in order to develop consistent data sets for the Lake and to conduct more detailed potential damages modeling and FEPS modeling for the

whole lake. As such, USACE should continue, as budget permits, with an extension of this mapping for the remaining Lake Erie shoreline.

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APPENDIX I – Map Printouts (Under Separate Cover)

APPENDIX II – ArcView 3.0 Project Installation Guidelines (Under Separate Cover)