Coastal Erosion Hazard Monitoring on the South Shore of Long Island, New York

Joseph J. Tanski[1] and Barry Pendergrass[2]

Abstract

The Atlantic Coast of New York Erosion Monitoring Program (ACNYMP), initiated in 1995, collects information and data on beach changes and coastal processes along the 210-kilometer ocean shoreline of Long Island, New York. To date, the program has collected over 3,400 beach profile surveys at 426 locations and semi-annual aerial photo surveys of the entire shoreline. Data and information such as historical shorelines, topography, locations of structures, flood zone delineations, *etc.* from other coastal projects have also been compiled and digitized as part of this effort. The goal of the ACNYMP is to provide coastal managers, regulators, government officials and the public with information that will allow them to make better decisions regarding coastal erosion hazard management. To encourage use of these data, the project sponsors have developed a quasi GIS viewing software application, known as CoastalView. The software, distributed on CD-ROMs with the program data, allows the user to retrieve, view, and perform simple analyses of all the data on a personal computer. An integrated photo viewer module displays digitized orthogonal aerial photographs, allowing the user to simultaneously view multiple sequential aerial photographs both spatially and temporally. Similarly, multiple profiles can be displayed and manipulated using a special profile-viewing tool. In a separate but related effort, beach profiles were analyzed and characterized using up to 44 parameters per profile. These data are stored in a relational database that allows access and analysis by geographical reach or station(s). Presently, ACNYMP partners are working with NOAA's Coastal Service Center to develop a GIS-based web site to disseminate this information more efficiently to a wider audience.

Introduction

New York has one of the most densely developed and heavily used coastlines in the U.S. The demands placed by the growing population in the New York City/Long Island metropolitan area for recreational, residential and commercial uses are considerable. In 1990, Suffolk County, comprising the eastern half of Long Island, ranked as one of the top ten counties in the country in terms of residential construction growth. Area beaches are a prime recreational resource attracting more

[1] New York Sea Grant Extension Program, 146 Suffolk Hall, Stony Brook University, Stony Brook, NY 11794-5002; PH (631) 632-8730; FAX (631) 632-8216; email: jjt3@cornell.edu.
[2] New York State Department of State, 41 State Street, Albany NY 12231.

than 20 million visitors every year (LIRPB 1989) and serve as the foundation of a multibillion-dollar regional tourism industry. Highly desirable for a variety of uses, these coastal areas are also extremely dynamic and subject to significant changes due to both natural processes associated with wind, waves, and tides and human activities.

The dynamic nature of Long Island's south shore coupled with a large population's desire to live, work and play along this coast presents unique problems and challenges to decision makers, residents and coastal resource users who are concerned with balancing use, conservation and development along this urban and suburban coastal area. To achieve this balance, these audiences need timely, factual information that allows them to better understand the natural and human influenced processes shaping and impacting the coast and the relative role of each, to anticipate shoreline changes and impacts, and to evaluate regional and local mitigation strategies for dealing with coastal erosion. The Atlantic Coast of New York Monitoring Program (ACNYMP) was initiated to help meet these informational needs.

Background

The Long Island Regional Planning Board (LIRPB) originally identified the need for a coastal erosion monitoring program in their proposed coastal hazard management program (LIRPB 1989) for the south shore of Long Island which found existing data on coastal processes were too limited, both spatially and temporally, to make informed management decisions. LIRPB recommended the information base on coastal processes be improved to enable the development and selection of cost effective erosion control projects. The New York Department of State (DOS), Division of Coastal Resources provided funding to develop a model monitoring program. LIRPB worked with New York Sea Grant and the Marine Sciences Research Center (MSRC) at Stony Brook University to compile and synthesize information on existing monitoring programs around the country and work with local, state and federal stakeholders to identify data collection efforts that would be most suitable for meeting New York's needs. This effort resulted in a recommended plan for an erosion monitoring program (Tanski and Bokuniewicz 1992) involving a number of components that included shoreline surveys, aerial photography, wave data, historical data collection, data distribution and predictive numerical modeling.

Through the efforts of DOS, the monitoring program gained support of local, state and federal governments. Authorized under the federal Water Resources Development Act of 1992, the ACNYMP received additional support from New York State. The ACNYMP is a cooperative effort between the U.S. Army Corps of Engineers New York District (USACE), DOS, NYSG and the New York State Department of Environmental Conservation (DEC). A Study Team comprised of representatives from each of these organizations provides overall program guidance. Three major objectives of the ACNYMP are to collect and analyze data on coastal processes and responses, organize and package new and historical data in a form usable by managers and planners, and make this information available to managers, agency representatives, consultants, scientists, decision makers and the public. This paper describes monitoring program efforts focusing primarily on the latter two objectives.

Study Area

The area covered by the ACNYMP is a 210-kilometer reach of Atlantic Ocean shoreline of Long Island, New York stretching between Coney Island in New York City east to Montauk Point (Figure 1). The coast can be divided into two physiographic provinces; a barrier island and spit section extending 160 km from Coney Island to the barrier spit east of Shinnecock Inlet, and a 50 km headland section between Southampton and Montauk Point (Taney 1961). The barrier section is composed of 6 islands and a peninsula (from west to east: Coney Island, Rockaway Peninsula, Long Beach, Jones Beach, Fire Island, and Westhampton separated by six stabilized inlets. The headland section is comprised primarily of beaches cut into glacial outwash deposits. Along the western portion of the headlands section, beaches front a relatively flat outwash plain with shallow coastal ponds that are the remnants of glacial drainage channels. Glacial bluffs 12 to 18 m high back the beaches along the easternmost16 km of the shore.

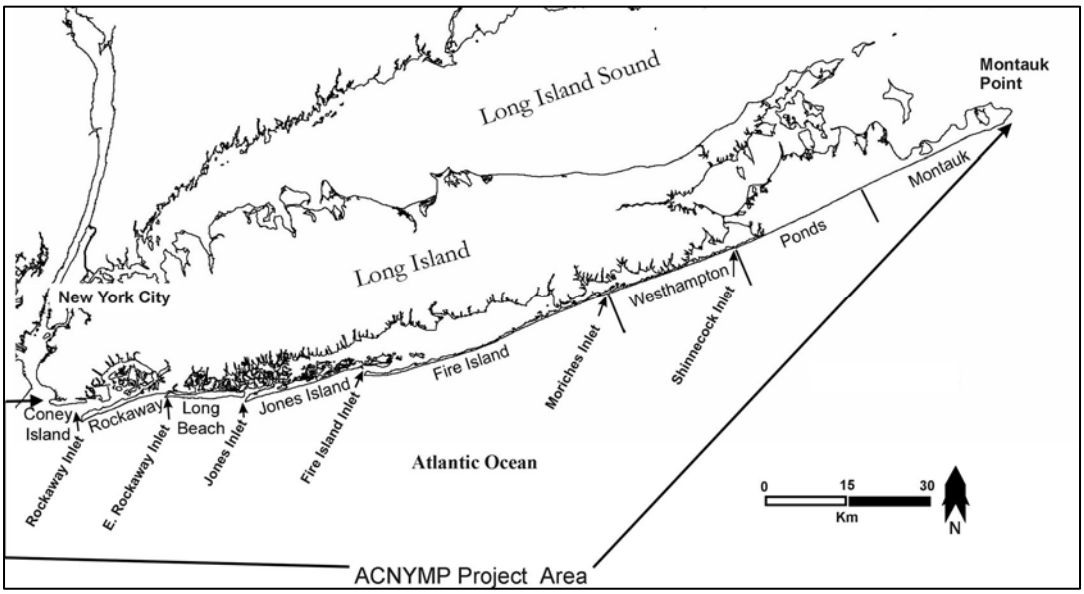


Figure 1. Location map showing area covered by ACNYMP monitoring program.

Tide range increases from 0.6 m at Montauk to approximately 1.4 m at Coney Island. Waves are generally less than 1 m but may reach 4 to 5 m during storm conditions. Net longshore transport is from east to west with estimated long-term rates increasing from 75,000 to 230,000 m^3/yr in the east to over 400,000 m^3/yr near Fire Island Inlet (RPI 1985).

Development along the shoreline is varied. The westernmost barriers (Coney Island, Rockaway and Long Beach) are heavily urbanized with high density year round communities (Figure 2). Barriers to the east are less densely populated and are primarily used for recreation with seasonal beach communities. Fire Island contains New York's only designated wilderness area, an 8-mile stretch of barrier island in the Fire Island National Seashore. The headland portion is the Hamptons, a resort community known for its large waterfront estates.

Figure 2. Coney Island, an urbanized barrier in the western portion of the study area.

Monitoring Program Elements

The major components of the ACNYMP program are based on the model program developed for DOS by the LIRPB and NYSG (Tanski and Bokuniewicz 1992) and include beach profile surveys, aerial photographs, collection and analysis of historical data, development of a computer database for data, storage and dissemination and predictive numerical modeling. The last component has not yet been implemented and will not be discussed here.

Profile Surveys: The original ACNYMP plan called for beach profile surveys to be taken at selected locations on a seasonal basis (spring and fall) to quantitatively measure the condition of the beach and dune and assess shoreline change. Under the program, a system of 348 monuments spaced at approximately 600 m intervals from Coney Island to Montauk Point was established (Figure 3). Starting in 1995, profile data was collected on a biannual to annual basis depending on funding. Licensed surveyors collected the profiles using a digital total station with a rodman for the subaerial beach and a sea sled for the subtidal beach. Survey data collected as part of several other on-going federal storm damage reduction projects with monitoring components in the area were also incorporated into the ACNYMP database. Presently, the database contains some 3,406 profiles collected at 426 stations. These profiles include 1,275 subaerial, or "short", profiles and 2131"long" profiles measured to a distance 760 m offshore or a depth of 9 m (approximate depth of closure). An analysis by the USACE Engineer Research and Development Center laboratory (Morang 2002) found less than 3 percent of the profiles failed to meet quality control criteria. These data provide a detailed, quantitative picture of shoreline change previously not available (Figure 4).

Aerial Photography: Vertical color aerial photography of the entire reach has been taken twice a year at a scale of 1:9,600 starting in 1995. Flights were scheduled for the spring and fall to coincide with the profile surveys. The photographs provide a qualitative measure of the condition beach between survey stations.

Historical Data: Historical data collection and analysis has focused primarily on documenting and archiving historical plan view shoreline positions and older beach profiles survey data. DOS conducted a shoreline analysis of Jones Island from 1880 to the present using aerial photographs and NOS T-sheets. The state has also contracted with a consultant to identify, document and compile profile data collected in the past by local, state and federal agencies in this area. These data are being digitized and will be added to the database. The historical shoreline and profile data will help extend the period of record and be used to provide a more accurate understanding of long-term trends in shoreline migration and beach changes. The

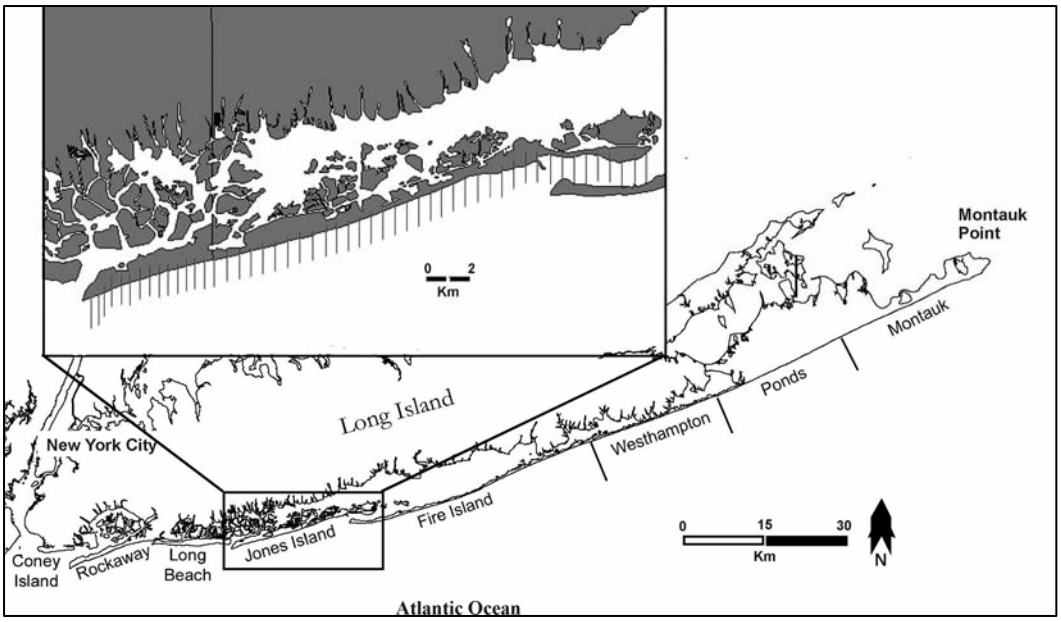


Figure 3. Profile lines on Jones Beach showing typical ACNYMP survey monument spacing.

USACE has also contributed similar information for other areas collected in conjunction with their investigations for storm damage reduction and navigation projects at Coney Island, Rockaway, Fire Island Inlet, Shinnecock Inlet and Fire Island to Montauk Point. In addition to historical shoreline positions and profiles, these data include topography, building footprints, and location of waterfront structures for selected areas.

Data Storage and Dissemination: The ACNYMP has amassed a great deal of data. The sheer volume of these data pose challenges in making the information available to a wide range of audiences in a usable form, a primary objective of the program. Initially, profile data were stored electronically in the USACE's Beach Morphology and Analysis Package format (Summerfeld et al. 1994). Hard copies of the aerial photographs were scanned and stored on CD's. The profile data and both hard copies and digital versions of the aerial photographs were housed at USACE district offices in New York City, DOS offices in Albany and NYSG offices in Stony Brook on Long Island. While multiple repositories increased access and use, this format proved cumbersome in terms of disseminating the information, training potential users and maintaining the data sets. To help overcome some of these limitations, two separate computerized databases were developed to facilitate data

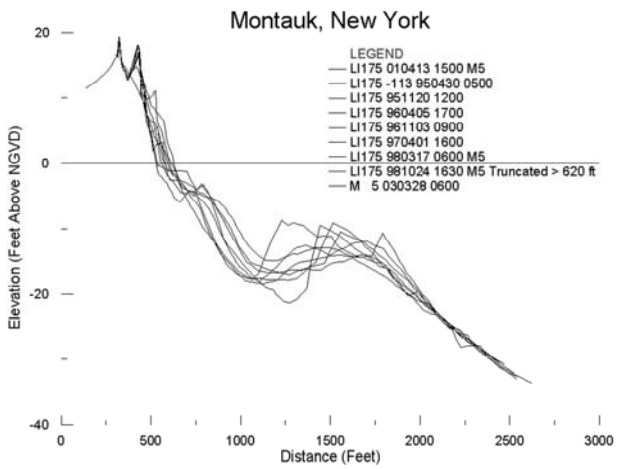


Figure 4. Example of ACNYMP profile data.

storage and use. The first was a GIS-based system designed to assemble and store ACNYMP and related coastal data and to allow users to easily retrieve, view and perform simple analyses on different data sets. The second was a relational database designed specifically to analyze profile data for selected parameters and provide quantitative information on beach characteristics and changes. These databases are described below.

GIS Database

Development: Development of the GIS database was a collaborative process between the USACE, DOS and NYSG. The partners conducted a user needs survey of the primary ACNYMP audiences sending a questionnaire to 293 coastal managers, planners and regulators, consultants, engineers, researchers, and property owners, to identify key data requirements and information gaps, functional responsibilities, and computer and data handling capabilities (Tanski 1997). The results of the user needs survey formed the basis of the design of a GIS-based database for the monitoring program data. SAIC, Inc., under contract to the USACE, constructed the system under the direction of the ACNYMP study team.

The resulting product was a CD-ROM based system that contained ACNYMP and other data along with a custom built data viewing application called CoastalView. CoastalView, based on Blue Marble Geographic's GeoView ActiveX object mapping software, provides a convenient way to access the three categories of data assembled under the ACNYMP. These data are the aerial photographs, beach profile surveys and various coastal datasets obtained from other projects or sources, termed "basefile" data. The CoastalView application consisted of three major components for handling the datasets: a main user interface, a profile viewer, and an aerial photo viewer.

Main Interface: All the data are accessed through CoastalView's main interface. The interface graphically presents data in a map view and can display different types of data, adjusting the projection so that all data layers are displayed in a common coordinate system. The internal data manipulation and graphic presentation procedures are very similar to those performed by other GIS packages, such as ESRI's ArcView. The display is also similar in appearance and functionality to ArcView (Figure 5). Menu tool bars across the top of the screen allow the user to pan, zoom, add and manipulate data layers, change attributes' display characteristics, measure distances, print and perform other functions similar to ArcView. Opened data layers are displayed in a table of contents vertically along the right hand side of the screen. The basefile data used by CoastalView is actually stored in ESRI's shapefile format and can be directly incorporated into an ArcView project. These shapefiles contain: political boundaries, spot elevations, coastal protection structures, streets, floodplain delineations, building footprints, topographical contour lines, locations of profile monuments and lines, and historical shorelines. Available data files also include orthophotos for portions of the shoreline and georeferenced aerial photographs covering the entire shoreline that can be used as base layers or maps for the different datasets.

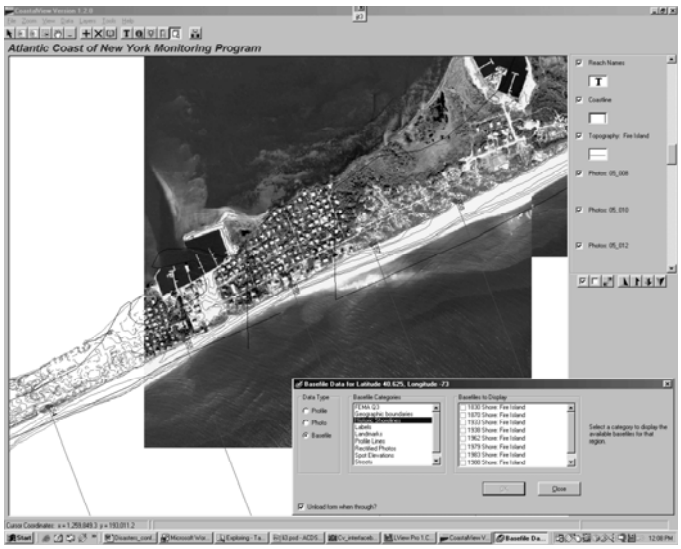


Figure 5. Main interface of CoastalView showing rectified photo, topography and profile locations for a selected reach along with data selection menu.

CoastalView's map interface allows the user to access the profile data and digital aerial images using two specialized applications known as the Profile Viewer and the Aerial Photograph Viewer. These applications were necessary because the historical profile and aerial photographs data are not georeferenced and have special display and presentation requirements. These specialized applications are used in conjunction with an extensive relational database that was created as part of CoastalView. This database is a Microsoft Access database that contains tables with information on basefile, profile, aerial image data, as well as their spatial and temporal aspects in terms of shoreline location and, in the case of the photos and beach profiles, dates of surveys. Other information, such as related metadata files and file locations, is also included.

Profile Viewer: When a profile location is selected through the main interface, the Profile Viewer (Figure 6) queries a table in the database that contains data regarding the profile survey identification, geographic location of the profile monument, date of survey and measurements of distance from the profile monument, and the corresponding elevation with respect to sea level. The measurements of distance and elevation are used to construct a graph representing a cross section of the beach and nearshore. The Profile Viewer can display multiple surveys taken at a single location and allows the user to perform a variety of manipulations including zooming, stacking or overlaying profiles, displaying sequential pairs of profiles and changing graphical display characteristics as well as exporting and importing files.

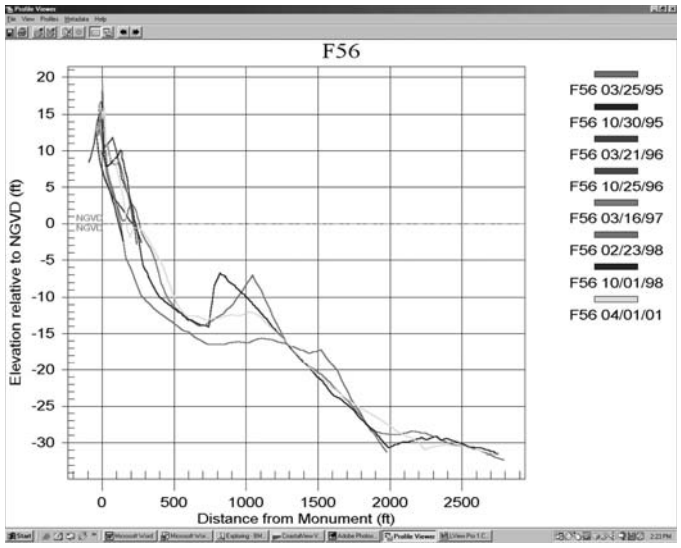


Figure 6. Profile Viewer interface.

Aerial Photograph Viewer: The Aerial Photograph Viewer is designed

to display non-georeferenced vertical aerial images. Presently, the database contains some 1,600 images scanned at a resolution of 150 dpi and stored as jpeg files. This application allows the user to view spatially and temporally sequential aerial photographs on the same screen. As seen in Figure 7, the images are displayed in groups: the user chooses the central image. The image above the center photo is a photograph taken on a previous survey date, the image below the center is from the next survey date. Images to the right and left are photos of the area east and west of the central image, respectively. Buttons are provided to browse the photos along the coastline, or to view previous or next survey dates. The display is automatically updated to include the proper photos in each of the windows. Reduced metadata for the central image, a photo index and a location map for the photos being shown are also displayed. Again, this is accomplished by means of a query to the main CoastalView database, which includes tables containing information regarding photo identification and number, survey date, location, the image's file name, and location.

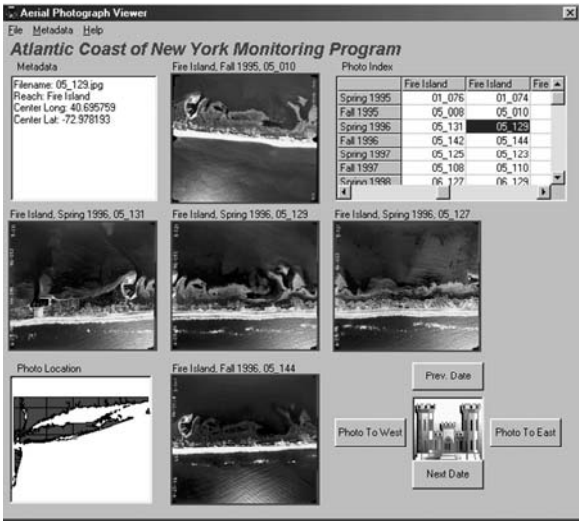


Figure 7. Aerial Photograph Viewer interface.

Profile Analysis Database

The Long Island South Shore Database was developed by MSRC with funding from DOS to facilitate analysis and interpretation of the extensive ACNYMP profile data (Batten et al. 2002). The database was designed to allow users with little or no database experience to quickly quantify selected beach characteristics at single locations or over geographic reaches, and generate graphic and numerical summaries of basic statistics, absolute values and seasonal differences of key beach features. This was accomplished by evaluating each profile for 44 different parameters, such as berm width, beach volume, dune height, dune volume, bar position, bar volume, etc. The data from this analysis (more than 100,000 data points) were entered into the Long Island South Shore Database, a Microsoft Access relational database with a graphical interface that allows the user to select pre-defined queries to evaluate seasonal differences in beach and dune parameters and calculate summary statistics by individual station, multiple stations or geographic reach (Figure 8) by pressing a button and entering the station numbers or reach names. The output is provided both in numerical reports and graphical representations of the values of the parameters of interest (Figure 9).

Web Migration

To further facilitate dissemination and use of the ACNYMP data, program partners are working with NOAA's Coastal Services Center to develop a GIS-based website. Following recommendations contained in a conceptual design study (Iroku, et al. 2003), the website will incorporate the look and functionality of CoastalView but will

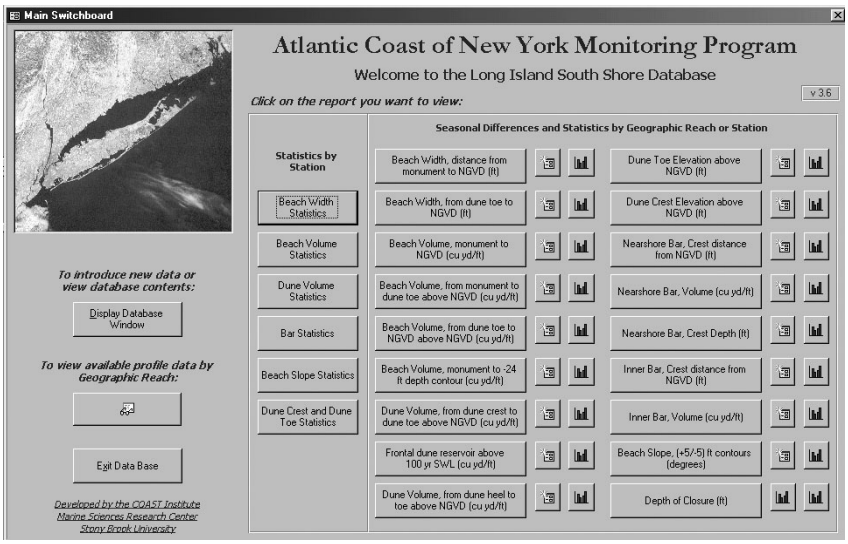
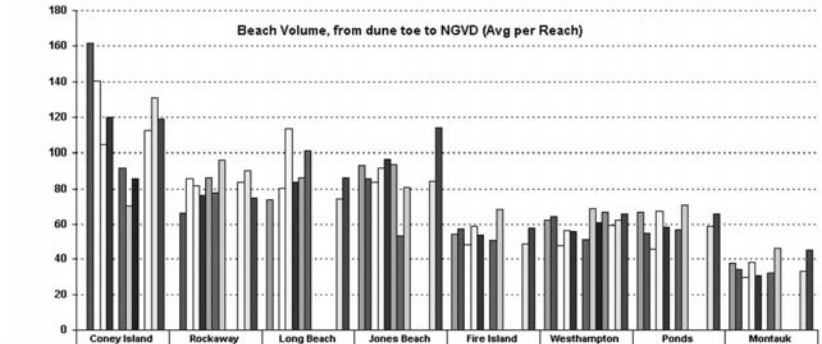


Figure 8. Profile database user interface.

take advantage of broadband internet capabilities and advances in internet map serving software that were not readily available when CoastalView was first being implemented. The site will use ESRI's ArcIMS and ArcGIS for processing, storing and displaying geographic data. Special tools will be developed for viewing and displaying the profile and aerial photo datasets. All required processing for accessing, viewing and manipulating the data will be done on the server-side and not on the user's machine. As a result, users will need no additional hardware or software other than an Internet-enabled computer and capable Internet browser such as Netscape or Internet Explorer. Transferring the data to Internet based distribution will not only allow the information generated by the ACNYMP to reach the widest possible audience, it will also facilitate maintaining and updating these datasets.

Summary

The ACNYMP provides a spatially and temporally rich data set documenting changes along Long Island's populated ocean coast. This information can be used by managers, planners, engineers, scientists and the public to make better decisions regarding coastal management, development, and erosion control strategies. The CoastalView GIS-based data viewing system and the Long Island South Shore Database are two tools designed to help these audiences access and utilize these data. Development of a web-based GIS to disseminate the data collected under the program should encourage greater use.



	Coney Island	Rockaway	Long Beach	Jones Beach	Fire Island	Westhampton	Ponds	Montauk
1995 Spring			73.83678049	93.04132558	54.33046154	62.31584211	66.9795	37.64830769
1995 Fall	161.8093333	66.438		85.71637209	57.40144595	64.275125	55.23121951	34.10892857
1996 Spring	140.08615	85.73714286	80.504	83.65842222	48.39632468	47.42386486	45.78415	29.71707143
1996 Fall	104.5758387	81.8098	113.5248571	91.92178378	58.88141892	56.57924242	67.53551429	38.27697561
1997 Spring	120.1440952	76.31533333	83.78755556	96.79725926	54.06827184	56.27702326	58.38525581	30.51139024
1997 Fall		86.29766667	86.35490909	93.49585106				
1998 Spring	91.78533333	77.79133333	101.0906667	53.56035714	51.03096104	51.79173438	56.94054762	32.43286047
1998 Fall	78.37077778	96.30925		81.04572727	68.58251613	69.11560606	70.82957143	45.96823077
1999 Spring	85.64777778					60.86790909		
1999 Fall						67.15771053		
2000 Spring	112.4695833	83.71840741				59.5191		
2001 Spring	130.9786	90.1785	74.3314375	84.16444444	48.99410811	62.48450943	59.03203704	33.0258
2002 Spring	119.1245185	74.91115385	86.20335294	114.0928529	58.0421	66.15317391	65.71210714	45.2282

Figure 9. Example of profile database numerical report and chart output

References

Batten, B., G. Salgado, E. McLaughlin, and H. Bokuniewicz. 2002. Beach profile analysis and database development. Report to New York Department of State. Working Paper 1232. Marines Sciences Research Center. Stony Brook University. Stony Brook, NY. 35 pp.

Iroku, B., A. Magri, S. Smith and J. Tanski. 2003. Conceptual design of a web based GIS for dissemination of Atlantic Coast of New York monitoring program data. Final Report to the Atlantic Coast of New York Monitoring Program. Cornell University Center for the Environment. Ithaca, NY. 61 pp.

Long Island Regional Planning Board. 1989. Proposed Long Island South Shore Hazard Management Plan. Final Report. Long Island Regional Planning Board, Hauppauge, NY 102 pp. + app.

Morang, A. 2002. Atlantic Coast of New York monitoring program: Cross-shore profiles, quality-control procedures, monumentation and data archiving. TR-02-16. U.S. Army Corps of Engineers Coastal Hydraulics Laboratory, Vicksburg, MS. 65 pp + app.

RPI. 1985. Fire Island to Montauk Point, Long Island, NY: sediment budget analysis. Summary Report for New York District, USACE; Research Planning Institute, Inc., Columbia, SC. 85 pp. + app.

Sommerfeld, B.G. J.M. Mason, N.C. Kraus, and M. Larsen. 1994. Beach fill module, Rept. 1, beach morphology and analysis package (BMAP) users guide. Instruction Rept. CERC 94-1, U.S. Army Engineers Waterways Experiment Station, Vicksburg MS.

Taney, N.E. 1961. Geomorphology of the south shore of Long Island, New York. TM No. 128. U.S. Army Corps of Engineers. Beach Erosion Board, Washington, DC. 50 pp.

Tanski, J. 1997. Atlantic coast of New York erosion monitoring program user needs analysis survey results. Report to Atlantic Coast of New York Monitoring Program. 7 pp + app.

Tanski, J. and H. Bokuniewicz. 1992. Development of a coastal erosion monitoring program for the south shore of Long Island, New York. New York Sea Grant Special Report No. 106. New York Sea Grant Institute, Stony Brook, NY. 56 pp.