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Project Management GIS Applications and Tools for Coastal-Erosion Mapping in Ohio

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ABSTRACT

A major geologic hazard, coastal erosion along the Lake Erie coastline jeopardizes the properties of Ohio landowners who live along the lake shore; many buildings and infrastructure are lost to coastal erosion. The State of Ohio has a program to map the coastal erosion areas (CEA) of the state every ten years. The mapping of the CEA identifies areas at risk of being lost to coastal erosion within thirty years of the date of mapping. The CEA program informs owners of property that may be at risk and provides information on how to protect their properties from coastal erosion.

A number of geographic information system (GIS) applications and tools were created to assist with the conversion of the older, pre-digital CEA maps to a GIS. New GIS database forms recorded information on scanning of the maps and georeferencing of the scanned maps. An application was built to perform quality control checks of the georeferenced images and record the information into the GIS database. Another application loaded the georeferenced images into the map document, thereby speeding up access to individual images. Finally, an application was created that loads the control points of the georeferenced images into the GIS database. All of these applications have facilitated the task of converting older CEA maps into a GIS.

INTRODUCTION

Erosion along the Lake Erie shoreline of Ohio is a major geologic hazard, which can significantly affects coastal residents. The coastline undergoes very dynamic large- and small-scale changes. Examples of large-scale changes are shown in figures 1 and 2. Figure 1 shows a coastal area near Painesville, Ohio, that has undergone between 34 and 207 feet of recession from 1973 and 1990. Figure 2 shows the Sheldon Marsh barrier beach, which was blown out during the great November 1972 storm (Carter, 1973), and has undergone between 268 and 953 feet of recession during that 17-year period. While these large-scale changes are very dramatic, more normal erosion rates along the coast are also a hazard, eroding bluffs and destroying properties. For example, in Figure 3 a house is in danger of toppling because of erosion at the base of the bluff and rotational landslides that are caused by the unstable bluff slope. As a bluff recedes, buildings can be destroyed from the erosion, torn down before they are destroyed, or moved back from the bluff. Figure 4 shows three examples, including a 3,500 square foot house that was torn down and replaced some distance removed from the bluff.

Figure 1. An area of the coast near Painesville, Ohio, that has undergone up to 207 feet of recession from 1973 to 1990. The figure shows the top of the bluff for 1876 (blue dashed line), 1973 (yellow dashed line), and 1990 (red dashed line), and also shows the parcels that have been lost due to coastal erosion since 1945. The black lines are the outlines of the parcels from the Lake County Auditor's Office. The base map image is from 2004.

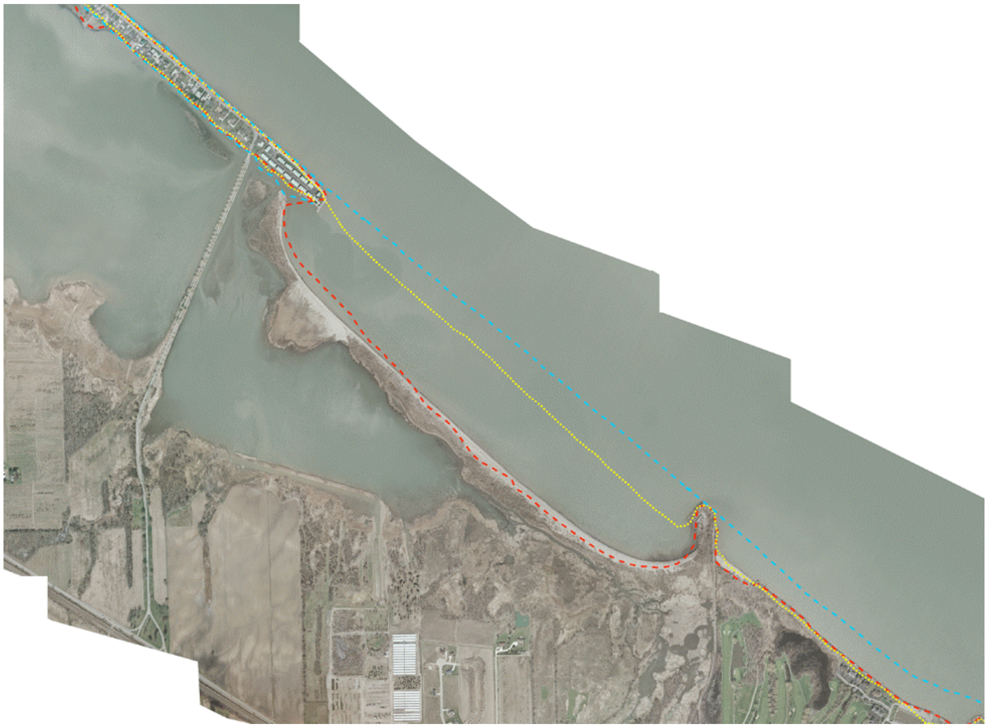

Figure 2. From 1973 to 1990, the Sheldon Marsh barrier island has retreated at a rate between 15 to 56 feet per year (see Figure 1 for explanation of dashed lines).

Figure 3. A home, circled in red, that is about to fall off of a bluff because of coastal erosion. Blue lines are shore-normal transects, as described in the text.

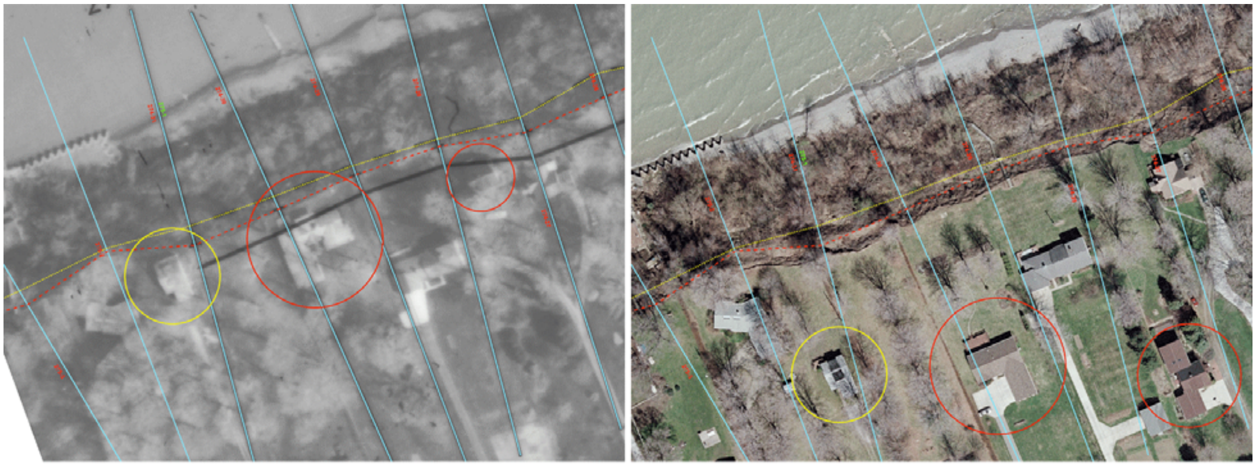

Figure 4. a) 1990 aerial photo. The two homes circled in red will be either torn down or removed. The home circled in yellow will be moved back from the bluff edge. b) 2004 aerial photo. The replacement homes are circled in red, and the home moved back from the bluff edge is circled in yellow.

The geology, lake levels, prevailing winds, and shore protection affect coastal erosion rates. Between 1973 and 1990, the average shoreline recession was 1.41 feet per year, or approximately 23.92 feet over the 17-year time period. Recession rates along the coast range from 0 feet per year to up to 56 feet per year in certain areas of the coastline (see Figure 2).

Historically, erosion has caused a large amount of damage along the coast. Studies performed by the U.S. Army Corps of Engineers (1971) between the spring of 1951 and the spring of 1952 computed erosion damages along Ohio's Lake Erie shoreline to be $11.3 million. The most significant storm of the twentieth century was the storm of November 14, 1972 (Carter, 1973), which caused approximately $22 million in damages (Environmental Data Service, 1972). An economic study of damages caused by coastal erosion shows that even if buildings are not damaged, property values decline rapidly when the home or building is within 25 feet of the bluff or shoreline (Kriesel and Lichtkoppler, 1989; Kriesel and others, 1993). Many of the coastal properties in Ohio have structures close to the bluff edge. A study performed by the Lake Erie Geology Section of the Ohio Department of Natural Resources (ODNR), Division of Geological Survey found that 25 percent of lakefront homes were within 25 feet of the bluff or shoreline, and another 22 percent were between 25 and 50 feet of the bluff or shoreline (Guy, 1999). All of these factors show that monitoring coastal erosion and informing the public about related hazards is an important on-going program.

The State of Ohio mandates that the CEA be designated for the Lake Erie coastline of the state every 10 years (Ohio Revised Code 1506.06). The mapping of the CEA identifies areas at risk of being lost to coastal erosion over a 30-year period. Once CEA areas are designated, the CEA program informs owners of property that may be at risk and provides them with information on how to protect their properties.

The first designation of the CEA was finalized in 1998. The 1998 CEA used uncontrolled aerial photography from 1973 and 1990 as the basis for measuring coastal erosion.

The 1990 aerial photographs were enlarged to approximately 1:2,000-scale and printed onto a mylar base. Shore-normal transects were drawn on the 1990 imagery, approximately 100 feet apart. These shore-normal transects serve as reference lines from which recession distances and rates are measured. The 1973 aerial photos were enlarged to the same scale as the 1990 images and the 1973 shoreline was then transferred to the 1990 imagery. Where the 1973 shoreline, 1990 shoreline, and the 1990 toe of the bluff intersected the shore-normal transects, the intersections were mapped on the 1990 imagery. The transects, the 1973 and 1990 shoreline intersections, and the 1990 toe of the bluff were digitized using Sigma Plot software, with each 1990 aerial-photo image having its own relative coordinate system. Once digitized, the vector data was then used as input into a FORTRAN program that calculated the recession distance and recession rate between 1973 and 1990 and also calculated the 30-year average recession distance, i.e., where the shoreline is projected to be in 2020. The 30-year recession distance was then plotted back onto the 1990 imagery (Mackey and others, 1996; Guy, 1999). The preliminary CEA was released to the public in 1996. After public review and modifications to the preliminary CEA were completed, the final CEA was approved by the Director of the Department of Natural Resources in 1998.

GIS PROJECT MANAGEMENT SOFTWARE

The recent remapping of the CEA designation involved many different conversion and mapping steps within a GIS. One of the major steps to remap the CEA was to convert the older mylar photo maps and shoreline data to a GIS. There are 467 photographs from 1990 that cover Ohio's Lake Erie coast. The GIS conversion process of the 1998 CEA mylar images involved several tasks. First, the 1990 mylar aerial photos were scanned. Then, these images were georeferenced to the 2004 digital orthophotos, which are of higher accuracy. Quality control was then performed on the georeferenced images. Finally, the 1990 shore-normal transects, 1973 shoreline intercepts, and the 1990 shoreline intercepts were digitized from the 1990 mylar images.

In order to manage the conversion of the 1998 CEA mylar images to a GIS, a number of applications were created to assist with the project management, including applications for tracking the map-scanning tasks, georeferencing the images, and quality control of the georeferenced images. An attribute table tracked the various GIS tasks performed during the image scanning, georeferencing, and digitizing. Access to the attribute table is done using Visual Basic for Applications (VBA) forms and ESRI's ArcObjects within the ArcMap environment. Other applications were created to speed up the workflow of the GIS users. These applications included automating the loading of georeferenced images into ArcMap and managing the georeferenced control points. All of these applications were accessed by GIS users as buttons on a toolbar, which was named **CEA Tools**. Each of the applications helped track the tasks performed on each image and helped increase productivity, allowing the ODNR Division of Geological Survey to complete the task of converting the 1998 CEA images to a GIS.

CEA Scanning Information Form

The first step in the GIS conversion involved the scanning of the original mylar photos, upon which the shore-normal transects, the 1973 and 1990 shorelines, and the 1998 CEA designations were delineated. A VBA form using ESRI's ArcObjects was created for tracking the progress of scanning the mylar photos (Figure 5). The VBA form allows the recording of important information, namely when the mylar photo was scanned, the operator who did the scanning, and when the image was transferred from the scanning computer to the network for storage. The information is recorded into the attribute table that tracks the various tasks as part of the GIS conversion project. The form in ArcMap is used primarily to view when the scanning took place and who performed the scanning.

To operate the form, the **CEA Scanning Information** application button is selected from the **CEA Tools** toolbar. Once the form has opened up in ArcMap, the user can select the 1990 photo-index name from the drop-down combo box. Once the photo-index name has been selected, information about the scanned image automatically is filled into the appropriate fields. At this point, the user can add or change any of the information associated with the scanned image. The information is recorded back into the database once the user selects the **Update** button.

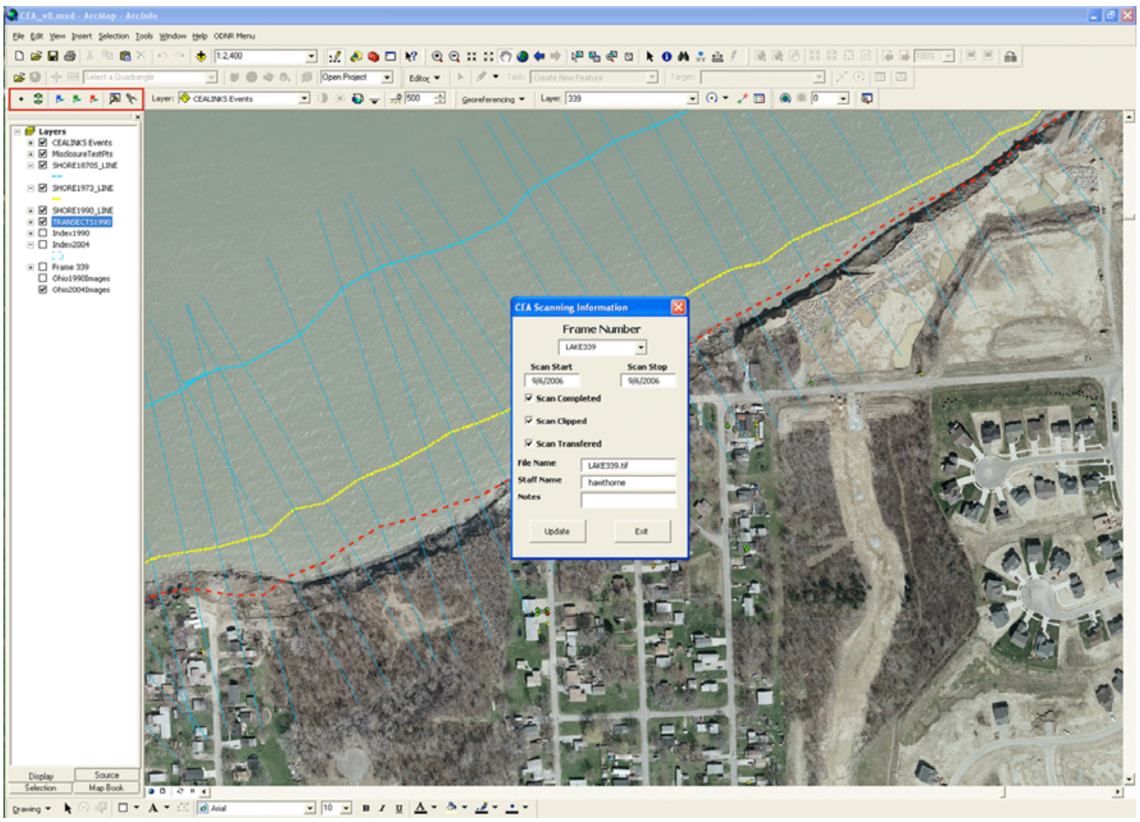

Figure 5. This VBA form tracks the progress of the mylar photo-scanning task. The **CEA Toolbar** is highlighted in red.

CEA Georeferencing Information Form

The next step in the GIS conversion involved georeferencing the raw images into the correct coordinate space. Another new application was created as a VBA form using ArcObjects, to record and track the information associated with georeferencing the raw images (Figure 6). The form allows recording of information such as the date when georeferencing started and stopped; georeferencing parameters including the number of control points, the georeferencing order, and the RMS results; the name of the rectified file and its location; and the staff member who performed the georeferencing. All of this information is recorded in the attribute table that tracks the GIS project tasks.

To operate the form, the **CEA Georeferencing Information** application button is selected from the **CEA Tools** toolbar. Once the form has opened up in ArcMap, the user can select the 1990 photo-index name from the drop-down combo box. Once the photo-index name has been selected, the information about the georeferenced image automatically is filled into the appropriate fields. At this point, the user can add or change any of the information associated with the georeferenced image. The information is recorded back into the database once the user selects the **Update** button.

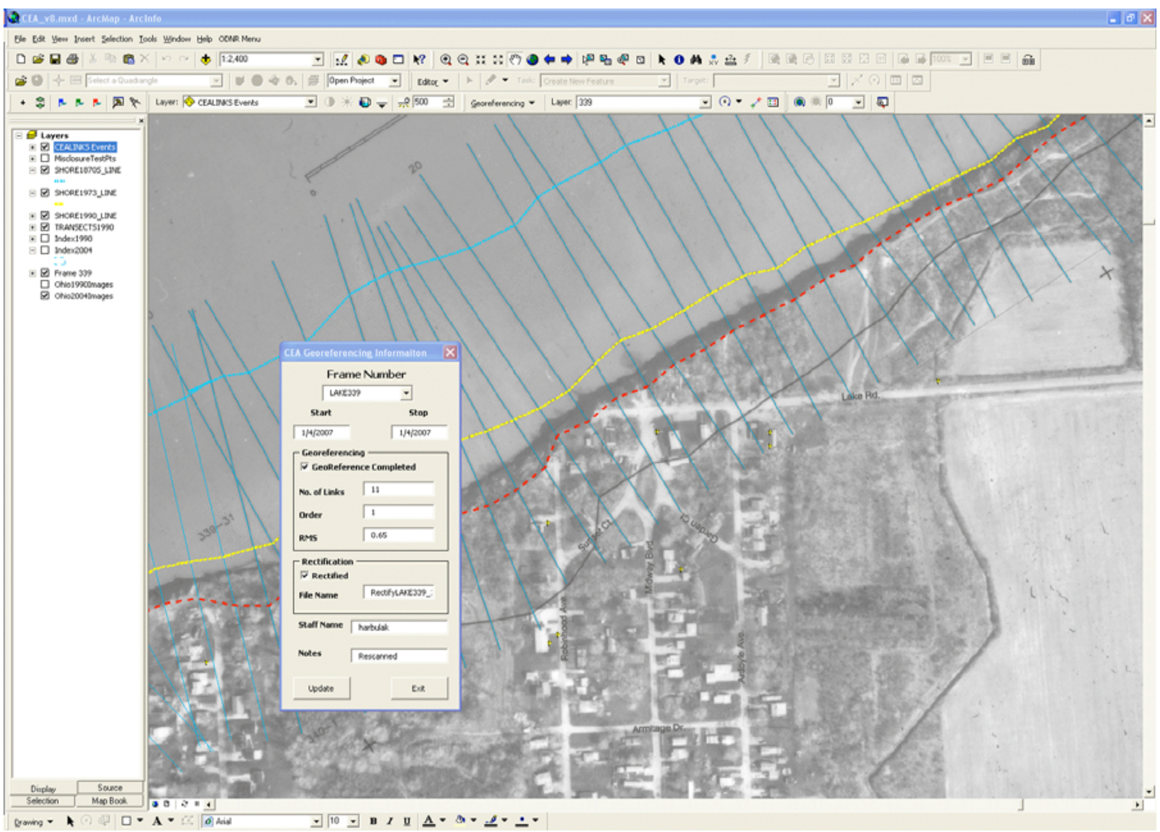

Figure 6. This VBA form tracks the progress of the mylar image-georeferencing task.

CEA Test Points Application

The standard technique for assessing the accuracy of an image involves measuring the misclosure distance of control points between a map or an image whose accuracy is being assessed and a map or an image of higher accuracy (Subcommittee for Base Cartographic Data, 1998). To perform this type of accuracy assessment on the georeferenced imagery, a tool was created that would allow accuracy points to be digitized and saved as a feature class in the geodatabase (Figure 7). The tool's main function is to calculate the misclosure distance between a test point on the newly-created georeferenced image and a higher-accuracy reference point. The misclosure is calculated and recorded as an attribute in the feature-class attribute table and the points are symbolized as to whether they pass or fail the quality control check.

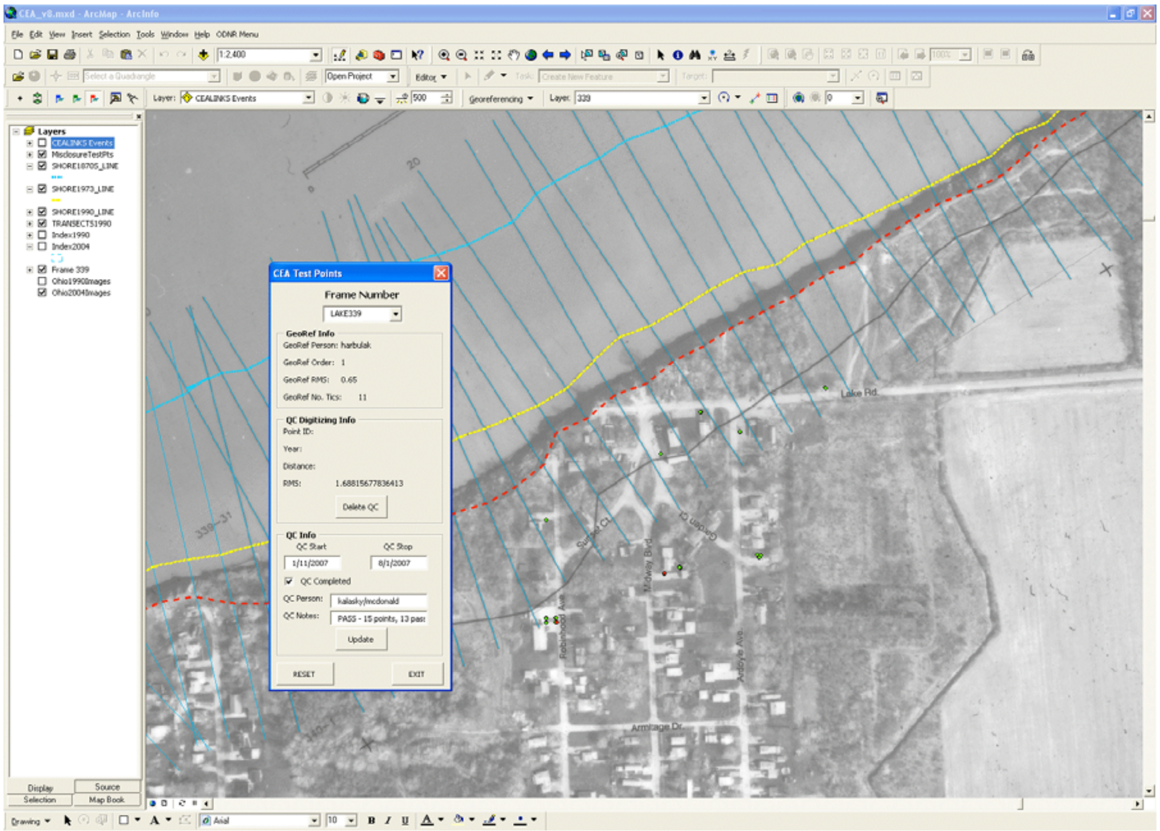

Figure 7. The **CEA Test Points** application provides a tool that allows test points to be digitized to check the accuracy of georeferencing.

To operate the application, the user first activates the **CEA Test Points** button on the **CEA Tools** toolbar. Once activated, a form opens within ArcMap. This form records and presents information about the quality control points that are digitized and presents a statistical summary of the overall accuracy of the georeferenced image. Next, the GIS user locates a well-defined feature that can be identified on both the 1990 and 2004 imagery. The user digitizes a point at the location of the well-defined feature on the 1990 imagery, turns off the display of the

1990 imagery, and then digitizes a point on the 2004 image. The application creates the two different points in the **MisclosureTestPts** feature class, calculates the distance, and calculates the summary statistics for the 1990 image. Using the summary statistics, the GIS user then can input comments about the relative accuracy of the georeferenced image. The GIS user performing the quality control assessment was also required to input their name in the **QC Person** input box to track the staff members that did the quality control on any particular image.

Load 1990 Imagery Application

An application was written to automatically load the desired 1990 and 2004 images into the GIS software (Figure 8). The application saves time because GIS users do not need to know the file names for the imagery nor the location of the imagery on the PC or the network. This particular application uses the index polygon feature classes for the 1990 imagery and the 2004 imagery to facilitate loading the imagery into ArcMap. When activated, the application searches for the selected polygon in the 1990-imagery index polygons and reads the 1990 photo-index name for the selected polygon from the attribute table. The application then performs an intersection of the selected 1990-imagery index polygon with the 2004-imagery index polygons. The application then reads and generates a list of 2004 photo-index names from the intersected polygons. The 1990 photo-index name and the list of the intersected 2004 photo-index names are then passed to Microsoft Scripting Runtime procedures that will search directories and subdirectories, find the 1990 and 2004 imagery associated with the index names, and load the imagery into ArcMap.

For the GIS user, the **Load 1990 Imagery** application is very easy to use. To operate the application, a GIS user selects the 1990 photo-index polygon, activates the application button on a toolbar, and then all of the images are loaded for that area. In addition, all of the images are grouped together in the ArcMap Table of Contents, and the group layer is placed at the bottom of the Table of Contents.

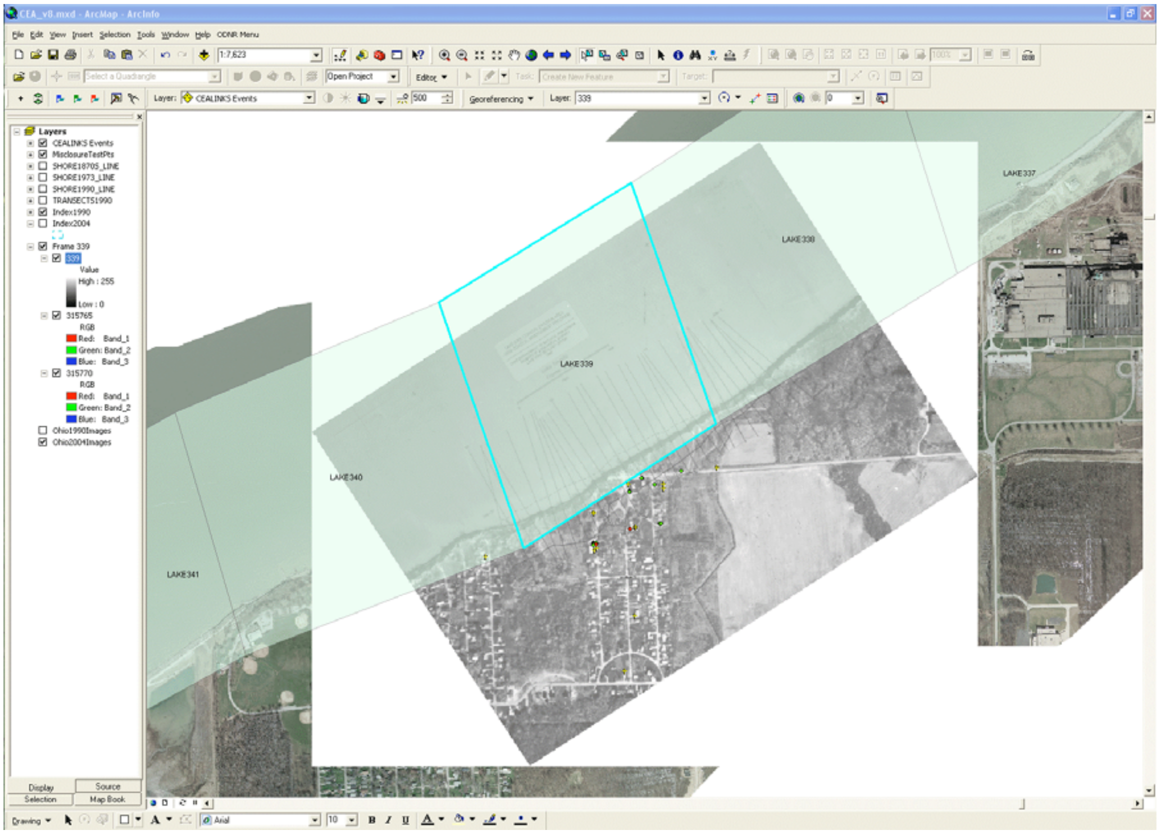

Figure 8. The **Load 1990 Imagery** application loads all of the 2004 images associated with the corresponding 1990 images. The figure shows the end result of loading the 1990 imagery to the ArcMap. The 1990 aerial-photo index polygon used to locate the 1990 image is highlighted in light blue; the 1990 aerial-photo image (grey-scale image) is loaded beneath the 1990-index polygon, and beneath the 1990 aerial photo image is the 2004 color imagery.

CEA Control Points Application

One of the project requirements was to save the georeferenced control points for each image as a text file. For the entire 1998 CEA conversion project, over 500 text files were created. The georeferenced control points files are managed using a new application (Figure 9). A VBA form was created that provides access to four different applications. The two buttons grouped together on the bottom of the form, **Load Frame** and **Load All**, will load the georeferenced control point text files into an attribute table in the GIS database. The attribute table is shown on the right side of Figure 9. Either a single text file can be loaded, or an entire directory of georeferenced control point text files. Once loaded, the georeferenced control points can be displayed as an event feature class. Two other buttons, at the top of the VBA form, control the display of the georeferenced control points and the misclosure test points. When a 1990 photo-index frame is selected from the combo box and the **Frame** button is selected, ArcMap will zoom into the location of the selected 1990 image and hide all of the control points and misclosure points not associated with the selected image. The application applies a definition query to both the georeferenced control points and the misclosure points, which allows the GIS user to only examine the georeferenced control points and misclosure points for a single image. The other button, **Display All**, will zoom out to the entire extent of the data and display all the points by removing the definition query.

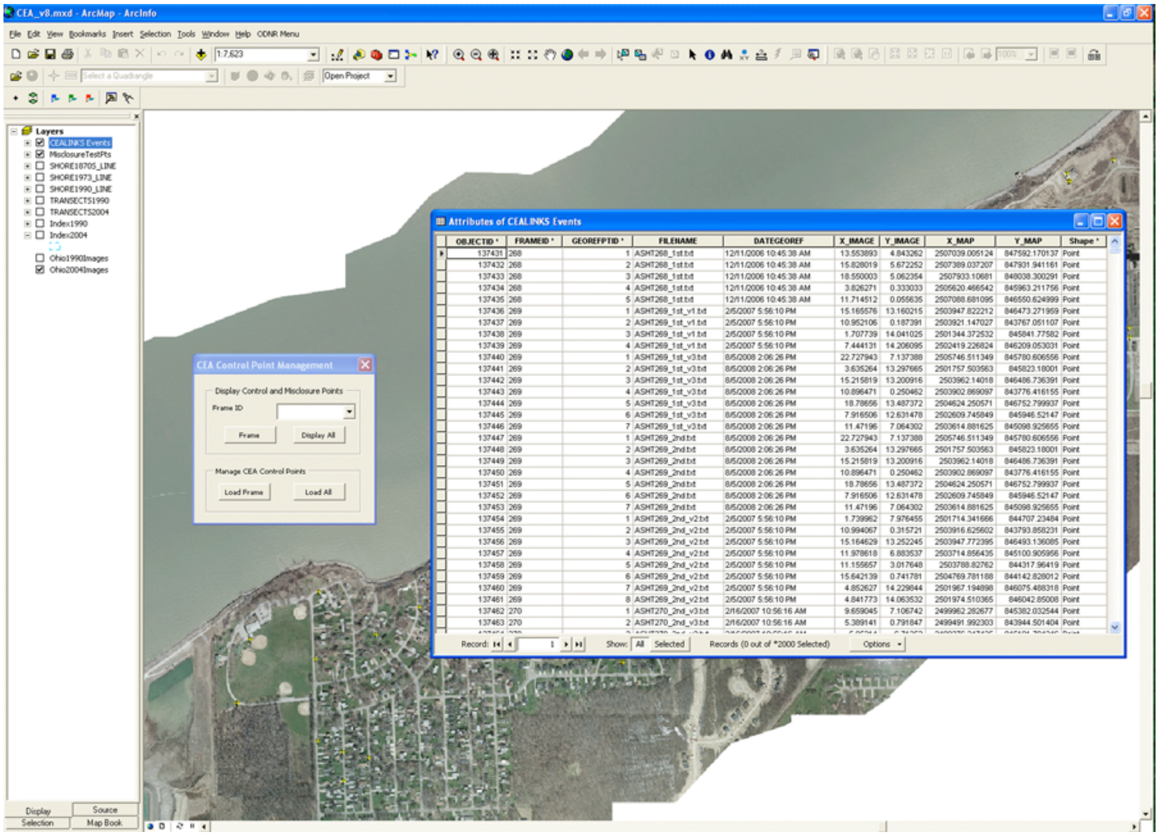

Figure 9. The CEA Control Points application manages the georeferenced control points in the GIS.

CONCLUSIONS

Each of these new tools allowed for better project management during the course of the 1990 CEA conversion project. The ODNR Division of Geological Survey had two separate offices working on georeferencing the mylar images. While five student interns and two staff members worked in the Columbus office, two staff members were located in the Sandusky, Ohio, office, more than 100 miles away. Consequently, managing the work load, assigning tasks and data to people, and tracking the disposition of the data and the progress of the tasks was a challenging endeavor. Only by using these tools were we able to track all the images, files, and tasks without losing data or losing track of the assigned tasks.

ACKNOWLEDGEMENTS

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REFERENCES

Carter, C.H., 1973, The November 1972 Storm on Lake Erie: Ohio Deparment of Natural Resources, Division of Geological Survey Information Circular 39, 12 p.

Environmental Data Service, 1972, Storm Data: U.S. Department of Commerce, NOAA, v. 14, no. 11, p. 178–185.

Guy, D.E., Jr., 1999, Erosion Hazard Area Mapping, Lake County, Ohio: Journal of Coastal Research, Special issue 28, p. 185–196.

Kriesel, Warren, and Lichtkoppler, Frank, 1989, Coastal Erosion and the Residential Property Market: Columbus, Ohio, Ohio Sea Grant Fact Sheet 044 and appendix, 6 p.

Kriesel, Warren, Randall, Alan, and Lichtkoppler, Frank, 1993, Estimating the Benefits of Shore Erosion Protection in Ohio's Lake Erie Housing Market: Water Resources Research, v. 29, p. 795–801.

Mackey, S.D., Foye, D.A., and Guy, D.E., 1996, Lake Erie Recession-Line Mapping—An Update, *in* Folger, D.W., ed., Lake Erie Coastal Erosion Study Workshop, 4th annual, St. Petersburg, Fla, April 16–18, 1996, Proceedings: U.S. Geological Survey Open-File Report 96-507, p. 37–39.

Subcommittee for Base Cartographic Data, 1998, Geospatial Positioning Accuracy Standards, Part 3—National Standard for Spatial Data Accuracy: Federal Geographic Data Committee, 28 p., accessed at http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3.

U.S. Army Corp of Engineers, 1971, National Shoreline Study—Great Lakes Inventory Report: Chicago, Department of the Army, 221 p.