

## **Streamlining Coastal Monitoring Programs with GIS in Martin County, Florida**

Alexandra Carvalho, Ph.D. - Taylor Engineering, Inc.; Kathy Fitzpatrick, P.E. - Martin County, FL Engineering Department; Heather Kostura, Northstar Geomatics

The Coastal Division in Martin County's Engineering Department maintains data covering 21 miles of beach coastline and 114 miles of inland waterways. The Coastal Division also houses data from its extensive offshore artificial reef, beach nourishment, and water quality monitoring programs. Effective management requires rapid access to this information coupled with the capability for rapid analysis. This paper gives an overview of the structure and organization of the Martin County coastal geodatabase and the data handling and analysis tools developed to help the county with its coastal management and monitoring programs.

### **INTRODUCTION**

Martin County is located on the central Atlantic coast of Florida. The St. Lucie Inlet intersects the county shoreline — 21 miles of oceanfront. The inlet serves as a conduit between the Atlantic Ocean and the Intracoastal and Okeechobee Waterways.

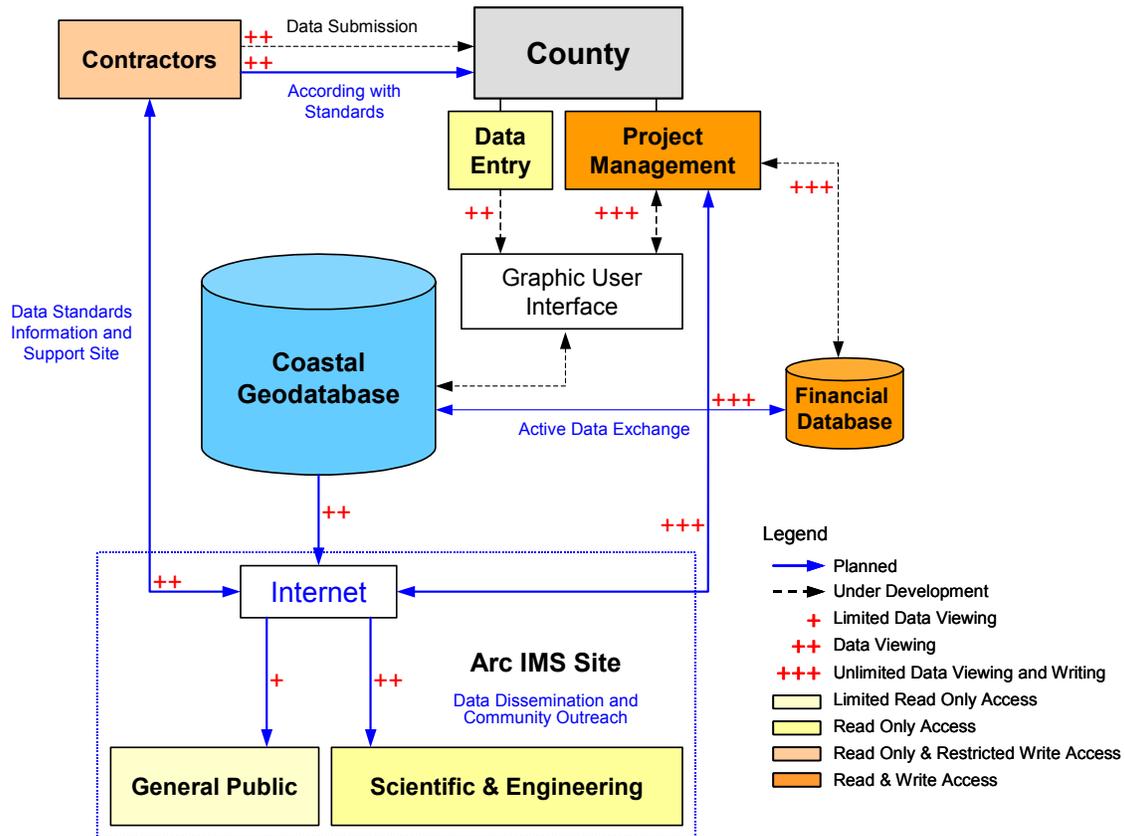
The Coastal Division of the Martin County Engineering Department manages and maintains data for several coastal programs. The artificial reef program includes three nearshore and three offshore reef sites. Two of the three offshore sites are located in federal waters; one is located in state and federal waters; all nearshore reef sites are located in state waters. The beach program includes two long-term beach restoration projects. One beach project, federally funded, is located along the northern shores of the county (Hutchinson Island), the other beach project, locally funded, is located along the Town of Jupiter Island. The waterway maintenance program includes the St. Lucie Inlet Federal Navigation Project and other navigation and dredging projects along the County's 114 miles of inland waterways and tidal areas. Each program represents an ongoing long-term commitment from the County and a substantial financial investment in the planning, permitting, construction and monitoring phases of each program's projects.

Each project has multiple grants and permits associated with it. These grants and permits have phases with conditions that require tracking. The difficulty of managing and tracking these requirements and the data they generate has increased greatly with the growing number of permits governing coastal projects. As in many other public entities, budgets and staff in the Coastal Division are limited. Also, the different agencies or contractors that require or provide project data use different formats and datums. Very often, these data are provided without metadata. To address these issues and to streamline the management of its coastal programs, the Coastal Division decided to contract out the development of a customized GIS-based Coastal Information Management System (CIMS),

This paper begins by giving a general overview of each component of the Martin County CIMS. It then describes the system's main component — the Martin County Coastal Geodatabase — and focuses on the design process behind the current geodatabase structure. Next, it briefly describes the Coastal Division's current program management practices, its data needs, and the steps taken to reach a CIMS compatible data organization level. Finally, it addresses some of the validation rules implemented and the design options built into the Graphic User Interface (GUI).

## MARTIN COUNTY COASTAL INFORMATION MANAGEMENT SYSTEM (CIMS) OVERVIEW

The goals of the Martin County CIMS (Figure 1) are to create a GIS-based framework to provide the Coastal Division with an efficient way to manage its coastal programs, and to provide the general public, and the scientific and engineering community access to the information stored in the coastal geodatabase.



**Figure 1** – Martin County Coastal Information Management System components and potential users.

The Martin County CIMS includes two databases and an Arc IMS Site. The “Financial Database,” an Access™ database, stores the financial data related to coastal programs and projects. The “Coastal Geodatabase,” discussed in detail in this paper, is an Arc SDE geodatabase, which stores most of the Coastal Division data. A friendly, customized, graphic user interface, developed in Visual Basic™, facilitates the rapid and efficient access to the information stored in the geodatabase.

The planned Arc IMS site, will address community outreach and coastal data dissemination. The site will include an Arc IMS shell to query and display the data stored in the geodatabase. Three access levels are planned for three specific audience types: the general public; the scientific and engineering community, including contractors; and project managers in Martin County. The most restricted level makes available to the general public basemap and basic coastal and project information. The second level, directed towards the scientific and engineering community, will provide access to larger amounts of information. This level will most likely require a user registration and password. Finally, the least restricted level will allow full write

and read access to the county's project managers and contractors involved in the geodatabase maintenance and design.

Parallel to the development of the databases, the Coastal Division is putting together mandatory data submittal standards for its contractors. By taking these steps, the Coastal Division hopes to transfer some of the burden of data formatting to the contractors and focus its efforts on the quality control and data analysis of multiple projects. This task may require the design of additional tools made available to contractors through the Internet.

## **THE MARTIN COUNTY COASTAL GEODATABASE**

### **Data Needs Assessment**

Early in this project, Taylor Engineering, Inc. held several meetings with the Martin County Engineering Department Coastal Division and with fellow contractors to present the CIMS concept, and to discuss its coastal geodatabase component. The meetings addressed issues such as the county's data management needs, contractors and agencies data submission practices, and the mandatory data submittal standards.

Understanding the Coastal Division data needs required knowledge of the geographic area covered by the county coastal programs and the types of projects in each program. It also required understanding the Coastal Division's program and project management and administration practices. Currently the Coastal Division has only two administrative levels: programs and projects. A program, a broader category, includes many projects types. For example, the Artificial Reef Program includes nearshore, offshore, and inland waters reef projects. The Waterway Maintenance Program includes navigation, dredging and inlet projects, and so forth.

The addition of GIS to the current program and project management practices introduced a new organizational level — the program site. Program sites represent the geographic boundaries where project activities can occur. All projects that involve some type of engineering activity within a physical geographical location require a permit. Since the permits set the site's geographic boundaries, if the permit expires, the program sites may cease to exist. However, exceptions to this rule exist. In some cases, project activities occur outside the physical boundaries of its program sites.

### **Data Organization**

With the Coastal Division spatial data management needs established, data organization consisted of:

- ❑ Identifying and categorizing existing and future data needs and organizing that data into subject-specific stand-alone tables;
- ❑ Breaking down these data categories into subtypes and domains and assigning them to the table's attribute fields;
- ❑ Identifying and characterizing the relationships between stand-alone tables and between these and feature classes;
- ❑ Creating the geodatabase schema.

In this project, stand-alone tables store non-spatial data and spatial feature attributes. Feature classes contain the geometry type field, the foreign key fields, and the labels field. Project files such as data text files, reports, drawings, photos, and videos require an external data storage directory. The Documents table's "Link" attribute field stores the path to these files.

Third party data feature classes in the geodatabase serve mostly as basemap data. Plans call for limited editing to these feature classes. This process will consist of limited QA/QC of the data and limited attribute formatting to meet the spatial data standards (SDS).

The Martin County Coastal Division is making a concerted effort to secure Federal Geographic Data Committee (FGDC) compliant metadata for all its GIS data. A member of the project team is gathering and compiling existing metadata and coordinating with consultants to include FGDC compliant metadata in their data submissions to the Coastal Division. Required and recommended fields, defined specifically for the Geodatabase, help maintain compliance and data integrity. When completed, the Arc SDE geodatabase will store the metadata.

### Design Issues

Several issues identified during the design process influenced the structure of the geodatabase. These issues are particularly important considering that the objectives of this project are to increase the efficiency of data entry, to implement quality assurance/quality control (QA/QC) procedures, to reduce the potential for faulty data entry into the geodatabase, and to design a permit and grant condition-tracking system.

The general characteristics of the coastal zone directly affect geodatabase design. The coastal zone, a very dynamic and diverse environment, contains sensitive environments and habitats influenced daily by natural forces (winds, tides, waves) and human activities. The physical characteristics of the coastal zone vary greatly as one travels from offshore toward land. Figure 2 shows some of the different environments found in the coastal zone.

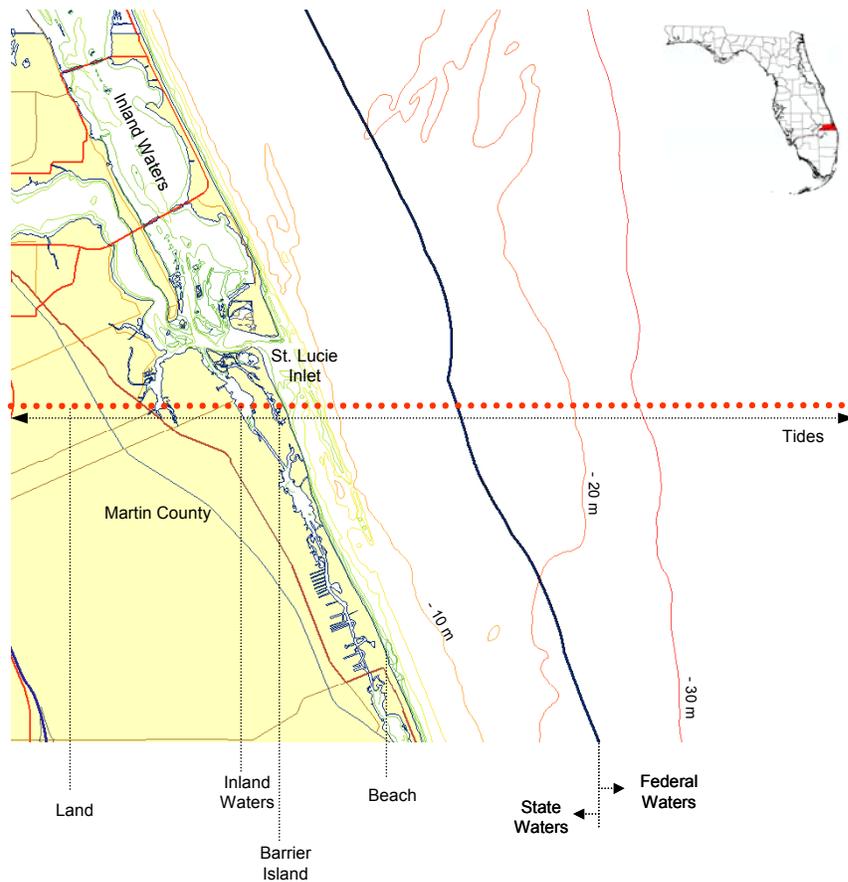
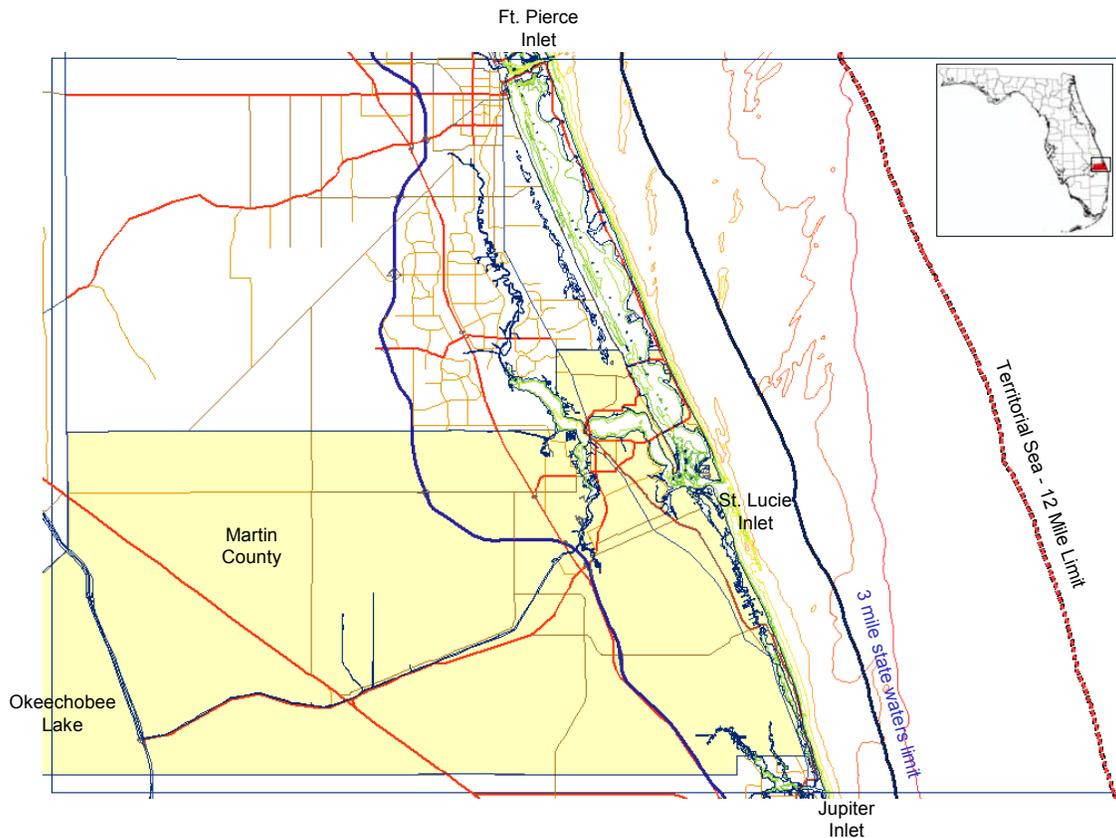


Figure 2 – Coastal zone variability along a cross-shore profile.

The Martin County Coastal Division's programs encompass all the environments shown in Figure 2. Its coastal programs include projects in water, on land, or both. For example, the waterway maintenance program includes navigation channels, dredged material maintenance areas and navigation channel easements.

### Validation Rules

Figure 3 shows the geodatabase geographic boundaries. The boundaries establish preliminary QA/QC procedures and limit data entry to county related data. Its limits extend eastward to the Territorial Sea (12 nautical miles), westward past the county coastal and inland waters to the eastern limit of Okeechobee Lake, northward to Ft. Pierce Inlet, and southward to Jupiter Inlet. Although these boundaries encompass more than the county waters, they are logical given the physical characteristics of the Martin County coastal zone, and the types of projects under the responsibility of the Coastal Division.



**Figure 3 – Martin County Coastal Geodatabase boundaries**

In addition to the geodatabase extent setup, program site boundaries restrict the addition of projects to permitted sites only. To overcome the exceptions to the rules, escape paths that allow the user to add a project outside a program site boundary are also available.

Non-spatial data entry QA/QC is provided mostly through domains. These restrict faulty data entry to the geodatabase and implement some of the naming conventions that are part of the data submission standards.

## **Data Handling Tools**

The data handling tools require flexibility to accommodate continuous and discrete events and preconditioned or sequential events. For example, a survey or dredging event may require only a day of work, but it may take a week to complete due to poor weather or rough seas. Also, poor weather conditions may lead to the suspension of an artificial reef deployment. As a result, all the monitoring events dependent on the completion of the reef construction (example, a 30 day post-construction survey) need to remain on hold until construction is completed.

These tools also need to implement QA/QC procedures to the data imported into the geodatabase. For example, the Survey Import Tool checks the survey's elevation values for each incoming data file. The tool flags the positive depth values in open water surveys data files and negative depth in land survey data files. It skips this process for beach profiles, where both negative and positive elevation values are possible. After the survey is imported, the user must verify the data entry and make sure that the flagged values are effectively wrong.

## **Feature Representation**

The type of feature data types, symbols, and scale that best represent the data needs of the user must receive scrutiny. For example, for planning purposes, a polygon feature class showing the survey boundary and date, will allow the user to identify areas that need surveying services. However, if the user wants to conduct a detailed bathymetric analysis, a line or point feature class, or tin surface may become the best display option to view the area's detailed bathymetry.

As the project evolves, the project team will develop a series of Arc Map templates to support the permit and grant application processes. In these templates, symbol type and size are issues that will require some thought. For example, one can represent a sea turtle nest in a sea turtle nest survey with a point feature class. In this case, each point feature will represent the sea turtle nest's approximate location. However, turtle nests are small compared with an artificial reef. Artificial reefs are usually also represented by point feature classes, but artificial reefs may spread more than 100 feet. In order to display both features in the same map, one would have to choose larger symbols for the artificial reef deployments or not display at all the turtle nests in the less detailed maps.

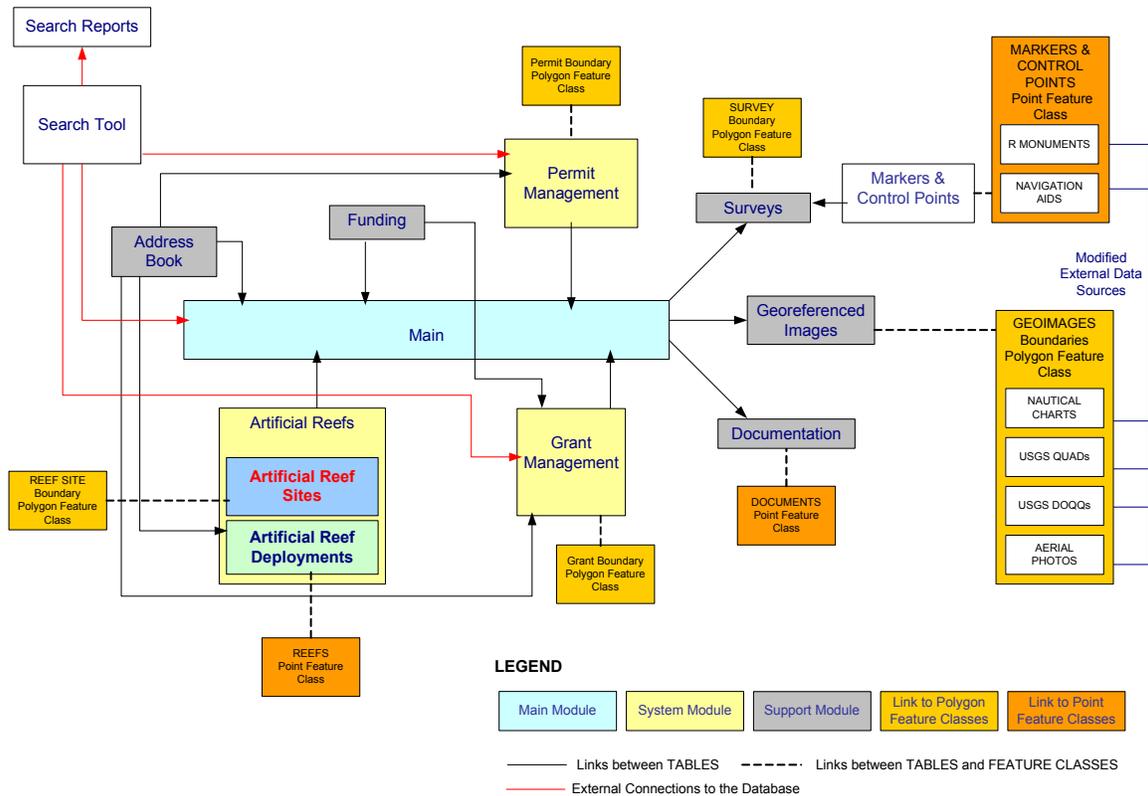
## **Geodatabase Structure**

Figure 4 shows the geodatabase GUI modular system components developed to date: Main Module, Support Modules and System Modules.

The Main Module contains the core of the geodatabase. It allows the county to organize its projects from beginning to end. The main module mimics the Coastal Division project management practice, starting at the program level and ending with the deliverables that result from its project activities.

The Support Modules play an active role in storing the data common to many projects. The information they store ranges from project manager contacts (Address book) and project funding sources (Funding Module), to aerial photographs of the project areas (Georeferenced Images Module), project reports (Documentation Module), pre- and post-construction surveys (Survey Module), and so forth.

The System Modules store information related to specific programs (Artificial Reefs Module) or to grants and permits. The complexity and the amount of information that permits and grants generate require independent modules to store all the information.



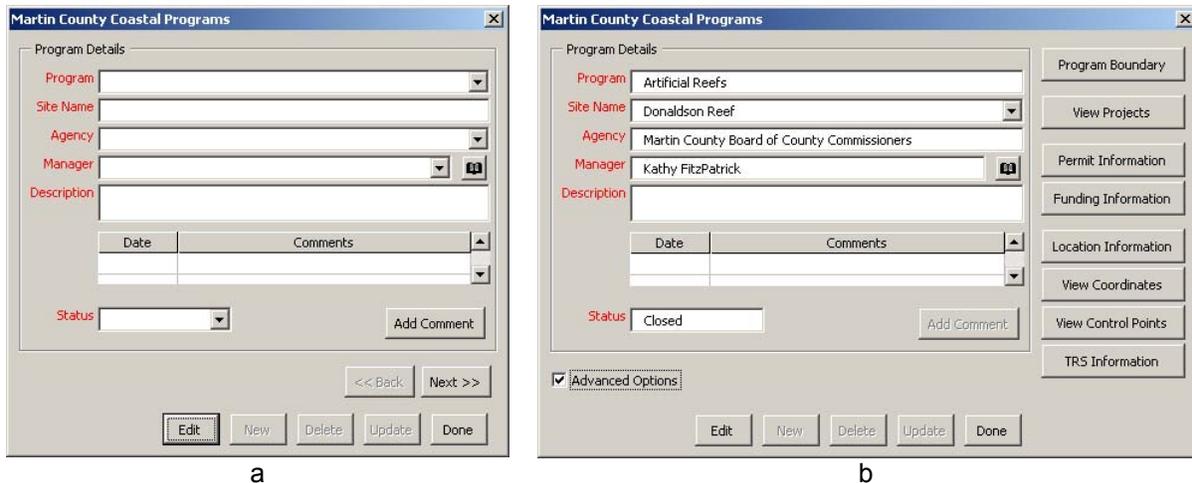
**Figure 4 – Martin County Coastal Geodatabase module diagram**

A hypothetical case — adding a new reef to a reef site — illustrates the interaction among modules. In this case, the geodatabase already included program and project details (Main Module) as well as the permit information (Permit Module) and the details on the grant that funds the project (Grant and Funding Modules). When the project manager adds a new project to the geodatabase, the GUI takes the manager through a checklist of the most common project activities for that particular project type. In the current example, one of the required activities is a reef pre-construction bathymetric survey. The Address Book Module provides the manager with information regarding survey companies. With the survey complete, the surveyor delivers the data to the Coastal Division. The Survey Import Tool in the Survey Module helps the manager QA/QC the information and stores it in the geodatabase. The project manager enters other project activity deliverables such as side scan images and reports, into the geodatabase through the Georeferenced Images Module and the Documentation Module.

### Data Entry and Editing Forms

The CIMS graphic user interfaces (GUI) are developed in Visual Basic™. These GUIs support non-spatial data entry and editing into the geodatabase. In some cases, they contain links to GIS tools for spatial data handling and analysis. The forms in the GUI load from Arc Map toolbars designed specifically for the CIMS project.

The potential County users of the system include administrative staff that only enter data and project managers. For this reason the GUI provides two ways to enter and edit data into the geodatabase — data entry wizards and data viewers. Figures 5a and 5b show examples of the data entry wizard and a data viewer GUIs to enter Program information into the geodatabase.



**Figure 5** – Program data entry wizard (a) and data viewer (b) GUI.

Data entry wizards guide the user through the data entry process (Figure 5a). In most cases, the initial form locks the user into the data entry path, making sure that all required information is entered. This option targets users that know very little about the project, but must still enter non-spatial data into the geodatabase.

Project managers may employ these wizards or the data viewers. The data viewers access the same information as the data entry wizards, but this information is displayed only at the user's request, by checking the "advanced options" check box (Figure 5b). Checking this box activates the buttons "Program Boundary" through "TRS Information" on the right of the form. These buttons, give the user the opportunity to view additional information and to edit or add new information to the geodatabase.

### Search Tool

The search tool keeps project managers up to date on the project's activities. Tool functions include keeping track of project activity and tracking of permit and grant condition requirements. Managers set the search frequency that best fits their needs. The tool "reports" the search results (example, condition requirements due dates) in a message box and gives users the option to view/print a report with the search results.

### FINAL CONSIDERATIONS

The Martin County Coastal Information Management System is in its infancy. The pilot coastal geodatabase, a personal geodatabase, and the graphic user interface are currently undergoing modifications and adjustments. Many of the planned tools are incomplete. Plans call for intensive tests of the tools and of the GUI interface in the pilot project before their implementation on the ARC SDE platform. The financial database is also incomplete, and the development of the Arc IMS site will not start until the Arc SDE Geodatabase becomes functional.

The potential benefits of the CIMS framework are evident to the Martin County Coastal Division. Future plans call for development of several planning tools for placement of artificial reefs. These tools will address the location issues behind siting and permitting a new artificial reef site. Determining the best location for a site and the potential conflicts it generates require spatial data handling tools. Some of these tools, such as an area calculator, are very simple. Others require detailed spatial analysis and acquisition of third party information.

Martin County has also identified the need for two more system modules: a beach management module and a waterway maintenance module. The first includes projects related to beach and dune restoration, sediment search, and shore protection structures. The second includes projects related to dredging, navigation, and the St. Lucie Inlet. However, the completion of this work pivots on the positive resolution of two key issues.

The first issue concerns funding. As mentioned, budgets and staff in the Coastal Division are limited.

The second issue relates directly to the physical placement of the CIMS components. Currently the Martin County Coastal Division has neither the storage capacity required to host the geodatabase nor the capability to host an internet site that provides the type of community outreach services described earlier. For these reasons, the County is currently negotiating an agreement with Indian River Community College (IRCC) to act as the official host for the geodatabase and Arc IMS site. This type of collaboration would provide the IRCC with an opportunity to participate actively in some of the county's projects.

Given the positive resolution of these two key issues, adequate funding and storage site, the County will complete and implement the system. However, as with any dynamic system, the Martin County Coastal Information Management System will require further refinements and adjustments as it responds to the demands of policy makers. These include the Florida Department of Environmental Protection (FDEP), the agency that has awarded many of the grants and permits for the County's coastal projects. Only through close communication with FDEP and similar agencies, can this project meet the ever-changing grant and permit condition requirements.

#### **AUTHOR INFORMATION**

Alexandra Carvalho, Ph.D.  
Project Scientist  
Taylor Engineering, Inc.  
9000 Cypress Green Dr. Suite 200  
Jacksonville, FL 32256  
Phone:(904) 731-7040 office  
Fax:(904) 731-9847  
Email: acarvalho@taylorengeering.com

Kathy Fitzpatrick, P.E.  
Martin County Engineering Department  
Coastal Division  
2401 SE Monterey Road  
Stuart, FL 34996  
Phone: (772) 288-5429  
Fax: (772) 288-5955  
Email: kfitzpat@martin.fl.us

Heather Kostura  
Northstar Geomatics  
P.O. Box 2371  
Stuart, FL 34995  
Phone: (561) 781-6400  
Fax: (561) 781-6462  
Email: hkostura@sfwmd.gov