



# Southeast Coastal Water Quality Monitoring Metadata Tools

## *Database and Web Applications*

Natural Resource Report NPS/SECN/NRR—2009/159



#### ON THE COVER

Top: Cumberland Island National Seashore; Middle: USGS weather and hydrographic monitoring station 022035975 at Hudson Creek in Meridian, Georgia; Bottom: Sapelo Island NERR hydrographic monitoring station at Cabretta Inlet on Sapelo Island, Georgia. Photographs by M. Alber (top) and W. Sheldon (middle and bottom).

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Wade M. Sheldon, Christine Laporte, John Carpenter, and Meryll Alber  
Georgia Coastal Research Council  
Department of Marine Sciences  
University of Georgia  
Athens, GA 30602

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# Acronyms Used in this Report

|            |                                                                                                |
|------------|------------------------------------------------------------------------------------------------|
| ADO        | ActiveX Data Object                                                                            |
| ADP        | Access Data Project                                                                            |
| ANSI       | American National Standards Institute                                                          |
| ASP        | Active Server Page                                                                             |
| DOC        | Dissolved organic carbon                                                                       |
| EDSC       | Environmental Data Standards Council                                                           |
| EIEN       | Environmental Information Exchange Network                                                     |
| EPA        | US Environmental Protection Agency                                                             |
| EPA STORET | US Environmental Protection Agency, Storage and Retrieval                                      |
| GCRC       | Georgia Coastal Research Council                                                               |
| GMOOS      | Gulf of Maine Ocean Observing System                                                           |
| GOMA       | Gulf of Mexico Alliance                                                                        |
| IOOS       | US Integrated Ocean Observing System                                                           |
| KML        | Keyhole Markup Language                                                                        |
| MARRP      | Sea Grant's Mid-Atlantic Regional Research Project                                             |
| NERRS      | National Estuarine Research Reserve System                                                     |
| NERRS CDMO | The National Estuarine Research Reserve System, Centralized Data Management Office             |
| NOAA       | National Oceanic and Atmospheric Agency                                                        |
| NPS        | National Park Service                                                                          |
| NSF LTER   | National Science Foundation, Long Term Ecological Research Network                             |
| OLE-DB     | Object Linking and Embedding Database connection                                               |
| REST       | Representational State Transfer                                                                |
| SAA        | South Atlantic Alliance                                                                        |
| SARP       | Southeast Aquatic Resources Partnership                                                        |
| SARRP      | Sea Grant's South Atlantic Regional Research Project                                           |
| SECART     | Southeast and Caribbean Regional Team                                                          |
| SECOORA    | Southeast Coastal Ocean Observing Regional Association                                         |
| SECN       | Southeast Coast Network (of NPS)                                                               |
| SOAP       | Simple Object Access Protocol                                                                  |
| SQL        | Structured Query Language                                                                      |
| SQLXML     | Structured Query Language eXtensible Markup Language                                           |
| SSH        | Secure Shell                                                                                   |
| SURA SCOOP | Southeastern Universities Research Association, Coastal Ocean Observing and Prediction Program |
| USGS       | US Geological Survey                                                                           |
| USGS NWIS  | US Geological Survey, National Water Information System                                        |
| UGA        | University of Georgia                                                                          |



# Introduction

The National Park Service (NPS) Inventory and Monitoring Program conducts long-term monitoring for key indicators, or “vital signs”. These “vital signs” are measurable, early indicators of changes that could impair the long-term health of natural ecosystems. In the southeast region, the Southeast Coast Network (SECN) has identified “Marine Water Quality” as a key vital sign and begun monitoring water quality in parks within the network. SECN currently monitors water quality at fixed stations in six coastal parks (Cape Hatteras National Seashore, Cape Lookout National Seashore, Fort Pulaski National Monument, Cumberland Island National Seashore, Timucuan Ecological and Historic Preserve and Canaveral National Seashore). To date, the SECN has also established probabilistic surveys in each of these coastal parks, with the exception of Fort Pulaski National Monument.

In addition to the National Park Service, numerous other agencies and institutions collect water quality data in the southeast

coastal region. The SECN identified the need to consolidate this regional information so that coastal managers, researchers and other users can readily identify sampling efforts by location, parameters measured, and methodology. NPS requested the development of a Water Quality Monitoring metadata database for the southeast that would serve as a gateway to this information. The Georgia Coastal Research Council (GCRC), located in the Department of Marine Sciences at the University of Georgia, was funded to develop a database of long-term monitoring program metadata that allows users to query and search for sources of coastal water quality data.

In June, 2008, the GCRC worked with NPS to organize a workshop at the Hollings Marine Laboratory in Charleston, SC that brought together representatives from various agencies and institutions active in coastal water quality monitoring in the southeast. The purpose of the workshop was to introduce the project and solicit feedback on

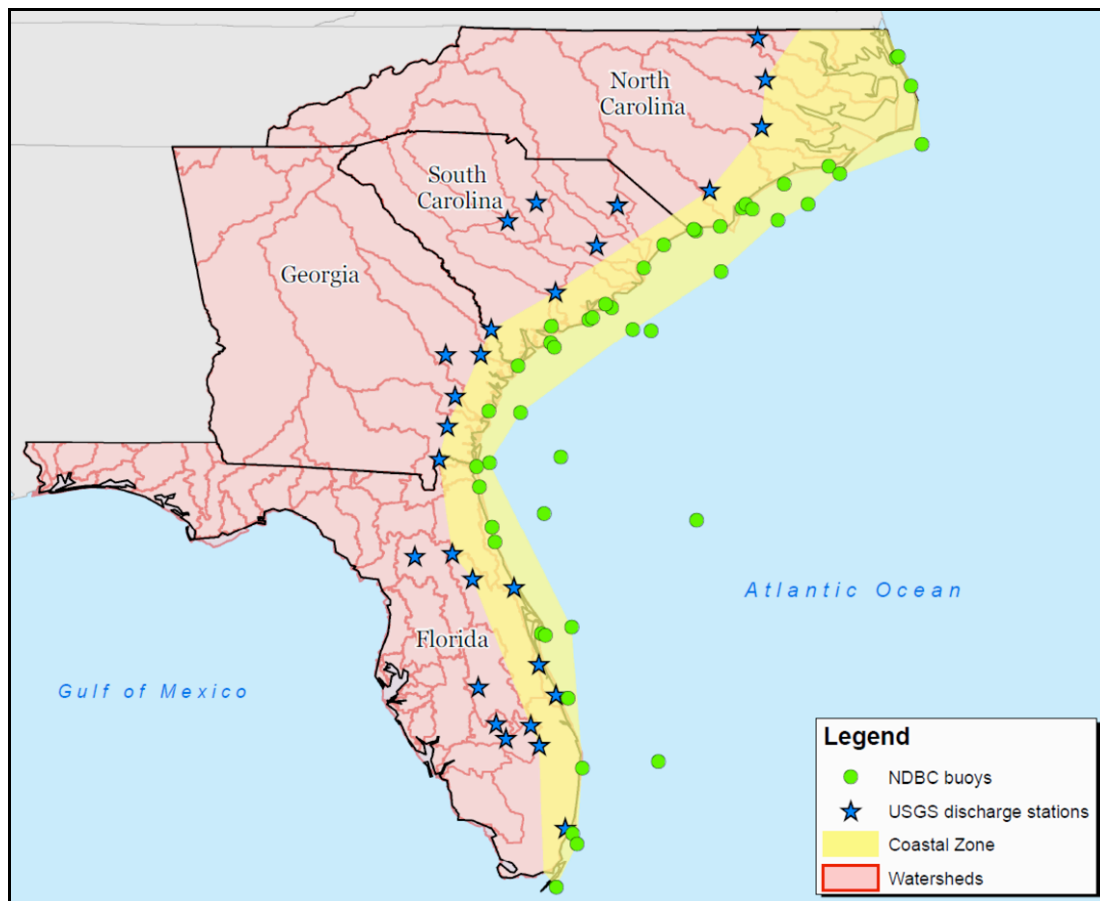


Figure 1. Coastal zone region that defines the geographic scope of the SE Coastal Water Quality Monitoring Metadata database. Locations of the furthest downstream USGS streamflow gages and NOAA NDBC buoys are shown for reference.

ways to optimize the scope and functionality of a metadata database. The workshop also included presentations about the National Park Service SE Coastal Network Monitoring Program and the National Water Quality Council's National Monitoring Network. A total of 28 participants representing 19 programs and organizations from within the geographic scope of the project attended the workshop. (A complete list of participants as well as the workshop summary can be found at <http://www.gcrc.uga.edu/wqmeta/workshop/workshops.htm>.)

This report describes the development of the SE Coastal Water Quality Monitoring Metadata Database and its initial application. Our goal for the database was to develop a tool for storing critical information about water quality monitoring programs, their sponsoring organizations, monitoring locations, and measured parameters. We wanted a flexible design that could accommodate variable types and amounts of information for each resource and support changing the types of metadata stored in the database without changing the underly-

ing database structure and web interfaces. We also wanted to support direct links to data for monitoring stations whenever possible, and include cross-references to EPA STORET codes for parameters to support inclusion of data stored in USGS and USEPA databases. Finally, we wanted the database to provide detailed information on measurements when available (e.g. medium, units, methods).

The geographic scope of the project includes the Coastal Zones of NC, SC, GA and the east coast of FL. We operationally defined a coastal zone polygon using ESRI ArcGIS. The boundaries of the polygon were based on the location of the 5 ft. elevation contour, expanded westward to include the furthest down-river USGS streamflow gauge and eastward to include near-shore NOAA data buoys and other platforms (Fig. 1). The geographic scope of the database is not rigidly defined, and may be expanded in the future based on NPS and user feedback. The database was designed to include information on water quality data collected by federal, state, and municipal agencies as well as by research institutions.

# Methods

## Database Design

Database design was conducted in two phases—development of a prototype database followed by a development of the production database.

### Prototype Database

The process for database design involved conducting a search to identify appropriate metadata standards and database models and then using this information to develop a prototype database. The prototype was presented at the project workshop in June 2008. Feedback from the workshop was used in the development of the final product.

The metadata standards and database designs that we reviewed came from numerous online sources, including the Marine Metadata Interoperability Project (<http://marinemetadata.org/>), the Environmental Information Exchange Network (<http://www.exchangenetwork.net/standards/>), major environmental monitoring programs and networks (IOOS, NOAA NERRS, NSF Long Term Ecological Research Network) and regional consortia (Southeast Coastal Ocean Observations Regional Association, SCOOP - SURA Coastal Ocean Observing and Prediction Program, Gulf of Maine Ocean Observing System). We found that most existing database designs and metadata standards are oriented towards documenting measurement details, primary data collection activities and data set characteristics as opposed to monitoring programs and locations. However, portions of the Environmental Sampling, Analysis and Results Data Standards (2006) from the Environmental Data Standards Council (a collaboration of the USEPA and state and tribal governments) were suitable for this project, particularly the Project (EX000002.1) and Monitoring Location Data (EX000003.1) sub-standards.

Using the EDSC metadata content standards as a guideline, we designed a prototype relational database to store all metadata acquired for the project and to provide interactive access on a web-based portal. The provisional metadata framework was organized hierarchically, with names, brief descriptions and logos of organizations and associated monitoring program(s) at the top. Links to “more

information” below each entry allowed users to view additional details, including program purpose, data website URL, data access information, data access policy, points of contact and other fields. At the project workshop in June 2008, participants were presented with an overview of the prototype database design as well as a spreadsheet containing parameters to stimulate discussion of how they should be stored and searched within this framework. Information from several targeted organizations (e.g. USGS, NOAA NERRS) was entered into the prototype database prior to the meeting to provide working examples for discussion.

Participants were also provided with access to provisional interactive web forms so they could review the web-based metadata entry and display interfaces. They were encouraged to make recommendations regarding the ease of input (getting metadata into the system) and to identify features that would make the portal most useful to users (getting products out of the system). They concurred that the metadata portal should focus on providing basic information about programs and the types of parameters measured, and then direct the user to the monitoring program’s website for more detailed information about sampling details and methodology. Ease of finding specific monitoring locations, along with attendant parameters, was highlighted as an important feature for the project; however, it was noted that sometimes not enough information is provided so parameters can only be associated with monitoring program rather than sampling location. In addition, several participants emphasized that all monitoring data collected by their organizations are entered into the USGS National Water Information System (NWIS) or EPASTORET database, and recommended that information be retrieved from those systems rather than requested by the GCRC or NPS to populate the database.

A specialized group comprised of Informatics professionals provided a detailed list of technical items for consideration. These are included in the complete list of comments and recommendations, found in Appendix B of the Workshop Summary (<http://www.gcrc.uga.edu/wqmeta/workshop/workshops.htm>).

As a result of workshop input we revised the database so that parameters could be organized into groups at multiple levels of detail (from broad to specific) as well as tagged using multiple terms, rather than using a strict hierarchical vocabulary as presented in the prototype. This approach is more flexible, as it allows parameter classifications to be expanded or refined based on user feedback and future needs, and supports searching at varying levels of specificity or with alternative descriptors (e.g. dissolved organic carbon, DOC, organic carbon, carbon). The database was also modified so that it could support linking measurement parameters to programs in addition to monitoring locations to accommodate both reporting practices. Finally, we developed automated data mining programs for the USGS NWIS database and NOAA NERRS database to retrieve information about all registered monitoring stations within the targeted coastal zone along with their respective measurement parameters. This information can then be uploaded to the portal database and incorporated automatically (see Methods for Database Development).

The group also suggested expanding the time-frame, originally proposed by NPS as a 5 year minimum of data collection, to prevent missing potentially useful information from programs that are in their initial phases but plan to sample for at least 5 years. This suggestion was also followed in the final product; for example the Florida Department of Environmental Protection's Coastal Aquatic Managed Areas, Northeast Aquatic Preserves program is now included.

### Production Database Design

The production version of the database ("NPS\_WaterQuality") was developed using Microsoft SQL Server 2000™, a high performance, enterprise-class relational database management system. This software supports all requirements identified during the prototype phase, and standardizing on SQL Server

allowed us to utilize the existing expertise and production servers in the UGA Department of Marine Sciences to host the database and web portal. The database model was implemented using a fully-normalized table design with referential integrity constraints (i.e. foreign key relationships) to prevent entry of incomplete or unlinked information (Riordan, 1999). Indices were created for all database tables to optimize search performance based on empirical testing with representative data. The overall design of the database is illustrated as an entity-relationship diagram (Figure 2) and described in detail below. Complete technical documentation and ANSI SQL scripts to generate the database structure are also available (see Appendix A).

To provide the needed flexibility in the database model, we used a two-table design for both organization and monitoring program metadata. The primary tables (Organizations and MonitoringPrograms) contain fixed fields with appropriate data types for storing information common to all organization and monitoring program entries (i.e. name, acronym, description, web site address, starting date, ending date, record update date). Additional tables are then linked to each of these primary tables (i.e. OrgDescriptors and MonitoringProgramDescriptors) to store varying amounts of metadata for a list of candidate metadata fields defined for each primary table (i.e. OrgDescriptorList and MonitoringDescriptorList). This design allows general metadata fields to be added or removed by authorized database users without any changes to the database schema. In addition, web display information is defined separately for each metadata field (e.g. sort order, field type, field size), and fields can be hidden to suppress web display without removing existing metadata content from the database. Names and descriptions of metadata fields currently defined in the NPS\_WaterQuality database are listed in Tables 1 and 2.

Top-level table listing organizations that sponsor water quality monitoring programs

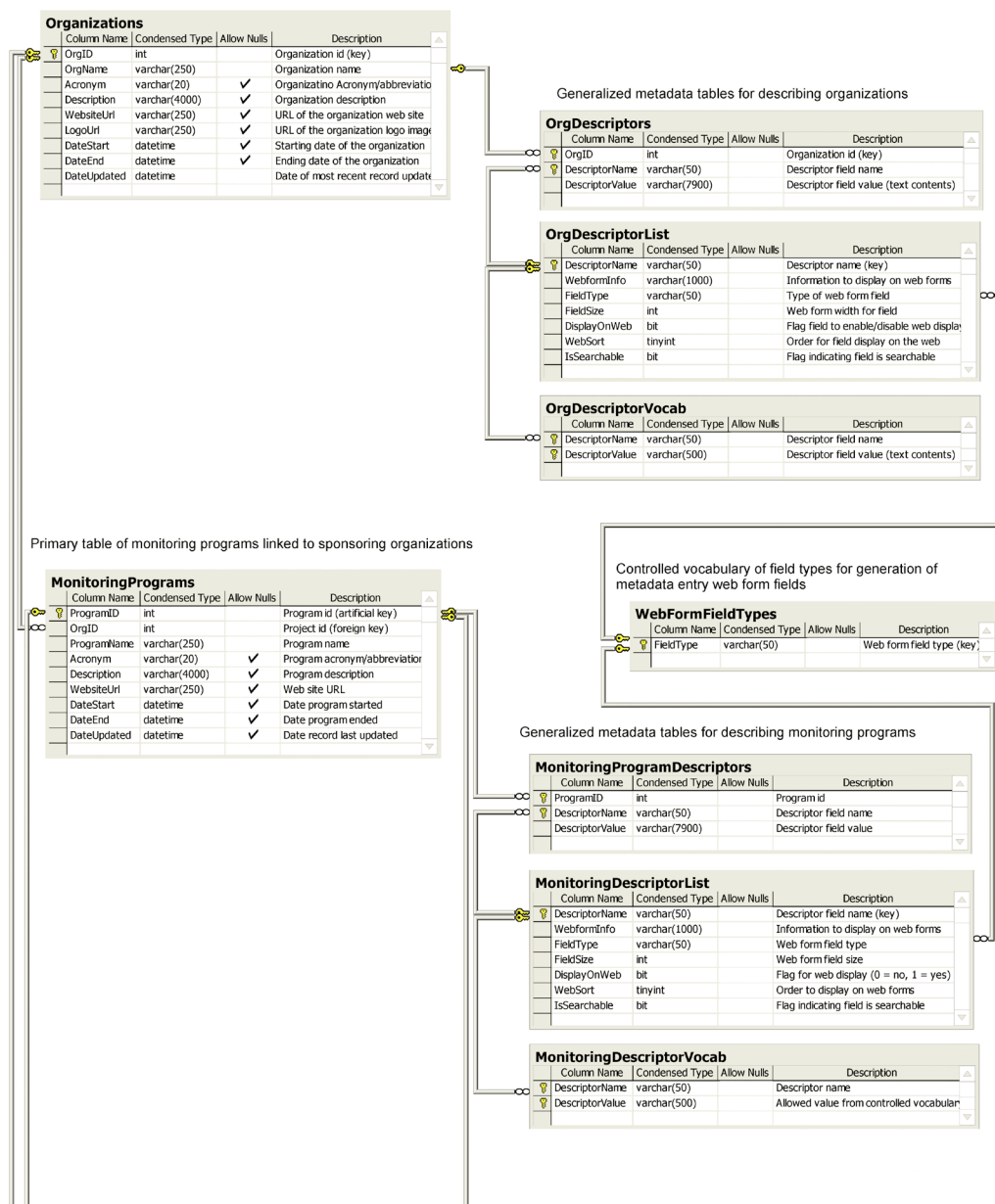
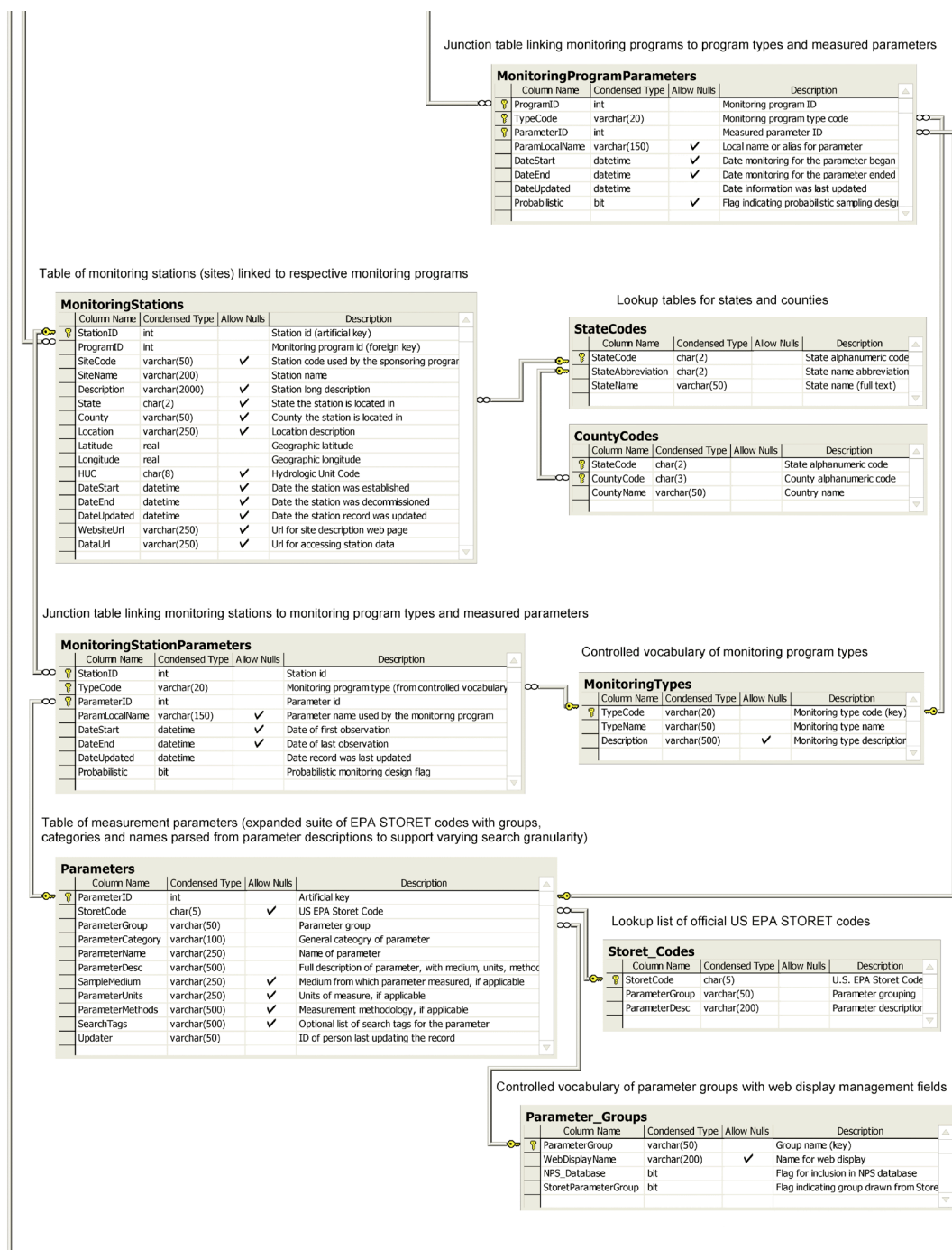


Figure 2. Entity-relationship diagram for the SE Coastal Network Water Quality Inventory & Monitoring program database (NPS\_WaterQuality, version 1.0, 30-Mar-2009). The database model was implemented using Microsoft SQL Server 2000™ on Windows Server 2003™ R2 by Wade Sheldon, Dept. of Marine Sciences, University of Georgia. Note that lines represent relationships between tables, with cardinality indicated by a key symbol for the primary table key and infinity symbol for the foreign table key.

Figure 2b. Entity-relationship diagram for the SE Coastal Network Water Quality Inventory & Monitoring program database (continued).



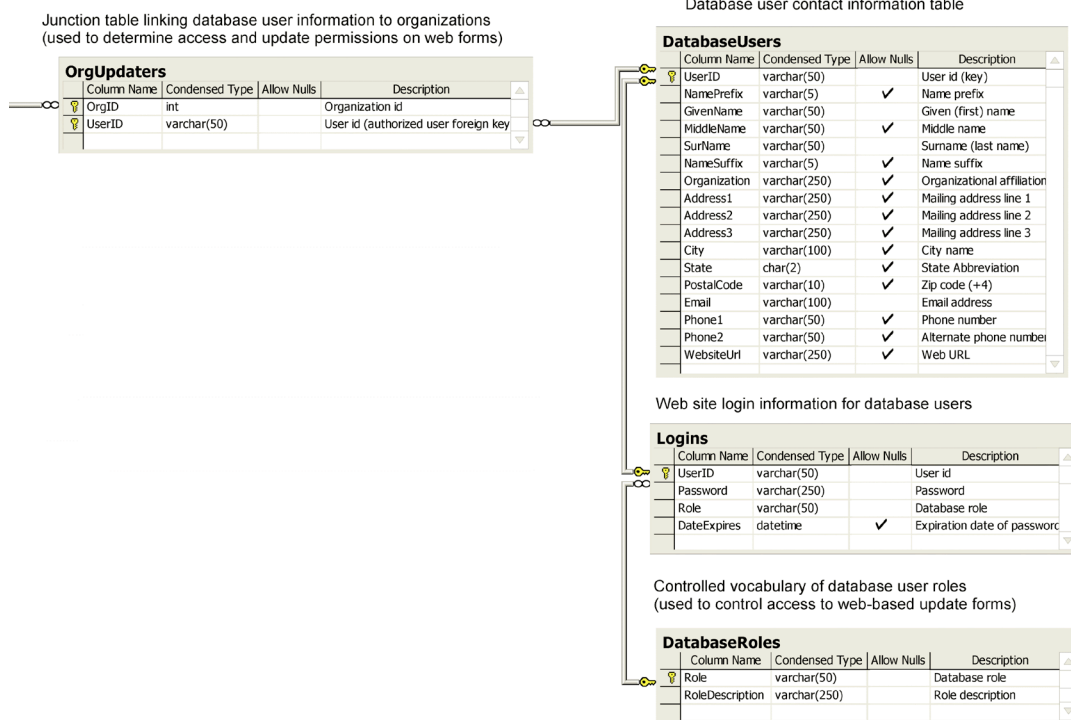


Figure 2c. Entity-relationship diagram for the SE Coastal Network Water Quality Inventory & Monitoring program database (continued).

Table 1. Metadata fields for describing organizations. Field types listed as “Fixed” are coded as specific fields in the corresponding table in the database (i.e. Organizations or MonitoringPrograms), whereas “User-defined” fields are stored in generalized metadata tables linked to primary tables, allowing authorized database users to rename or define metadata fields at any time without altering the underlying database structure or web portal code. Note that fields described as “(auto)” are automatically assigned by the database system.

| Field Type   | Field              | Description                                             | Required |
|--------------|--------------------|---------------------------------------------------------|----------|
| Fixed (auto) | OrgID              | Organization id (key)                                   | Yes      |
| Fixed        | OrgName            | Organization name                                       | Yes      |
| Fixed        | Acronym            | Organization Acronym/abbreviation                       | no       |
| Fixed        | Description        | Organization description                                | no       |
| Fixed        | WebsiteUrl         | URL of the organization web site                        | no       |
| Fixed        | LogoUrl            | URL of the organization logo image                      | no       |
| Fixed        | DateStart          | Starting date of the organization                       | no       |
| Fixed        | DateEnd            | Ending date of the organization                         | no       |
| Fixed (auto) | DateUpdated        | Date of most recent record update                       | Yes      |
| User-defined | Contact Name       | Name of the primary contact person                      | no       |
| User-defined | Contact Email      | Email address of the primary contact                    | no       |
| User-defined | Contact Web URL    | Web URL for organization contact information            | no       |
| User-defined | Mission Statement  | Statement of the overall mission of the organization    | no       |
| User-defined | InformationWebURL  | Web URL for general organization background information | no       |
| User-defined | Data Access Policy | Data access policy statement                            | no       |
| User-defined | News Web URL       | Web URL of the organization news page                   | no       |

Table 2. Metadata fields for describing monitoring programs. Field types listed as “Fixed” are coded as specific fields in the corresponding table in the database (i.e. Organizations or MonitoringPrograms), whereas “User-defined” fields are stored in generalized metadata tables linked to primary tables, allowing authorized database users to rename or define metadata fields at any time without altering the underlying database structure or web portal code. Note that fields described as “(auto)” are automatically assigned by the database system.

| Field Type   | Field                            | Description                                                                                 | Required |
|--------------|----------------------------------|---------------------------------------------------------------------------------------------|----------|
| Fixed (auto) | ProgramID                        | Program id (key)                                                                            | Yes      |
| Fixed        | OrgID                            | Project id (foreign key)                                                                    | Yes      |
| Fixed        | ProgramName                      | Program name                                                                                | no       |
| Fixed        | Acronym                          | Program acronym/abbreviation                                                                | no       |
| Fixed        | Description                      | Program description                                                                         | no       |
| Fixed        | WebsiteUrl                       | Web site URL                                                                                | no       |
| Fixed        | DateStart                        | Date program started                                                                        | no       |
| Fixed        | DateEnd                          | Date program ended                                                                          | no       |
| Fixed (auto) | DateUpdated                      | Date record last updated                                                                    | Yes      |
| User-defined | Program Contact                  | Name of the program contact                                                                 | no       |
| User-defined | Program Contact Email            | Email address of the primary program contact                                                | no       |
| User-Defined | Program Contact Web URL          | Program Contact Web URL                                                                     | no       |
| User-Defined | Program Purpose                  | Purpose of the monitoring program                                                           | no       |
| User-Defined | Data Access Web URL              | Web address of the main data access or query page                                           | no       |
| User-Defined | Data Access Information          | Data Access Information                                                                     | no       |
| User-Defined | Data Access Policy               | Policy statement for data access and use                                                    | no       |
| User-Defined | Data Access Policy Web URL       | Data Access Policy Web URL                                                                  | no       |
| User-Defined | Sampling Design                  | Description of the overall sampling design, including frequency and site selection criteria | no       |
| User-Defined | Sampling Frequency               | Statement of the nominal sampling frequency for the program                                 | no       |
| User-Defined | Sample Collection                | Description of how samples are collected                                                    | no       |
| User-Defined | Sample Processing                | Description of how samples are processed prior to analysis                                  | no       |
| User-Defined | Data Collection Area Name        | Name of the geographic area in which data collection is performed                           | no       |
| User-Defined | Data Collection Area Description | Textual description of the data collection area                                             | no       |
| User-Defined | Quality Assurance Plan           | Description of the quality assurance plan                                                   | no       |
| User-Defined | Parameters Measured              | Comma-delimited list of monitoring parameters                                               | no       |

## Data Entry and Management

After creating the NPS\_WaterQuality database using SQL Server 2000, we used Microsoft Access™ 2003 to design data entry and management forms, standard queries (i.e. database views), stored procedures to support web-based data entry and update forms, and reports (Chipman and Baron, 2000). The forms and reports are stored in an Access Data Project (ADP) file along with database connection information, while the database objects (i.e. tables, views, stored procedures, functions, diagrams) are stored on the centralized server. This client-server approach allows multiple users to work with the NPS\_WaterQuality database simultaneously without causing version-control issues or risking database file corruption, as commonly occurs with file-based databases. Fixed database roles (database owner, database writer, database reader) are currently used to control access to the database, but more

application-specific roles or fine-grained security restrictions can be added as necessary to manage permissions in the future.

## Access Data Entry Forms

Screen captures and descriptions of the primary Access data entry and management forms are provided below (Figures 3-7). The forms are all based on ActiveX Data Object (ADO) data-bound user interface controls, which automatically retrieve values from look-up tables and synchronize entered data to the server while minimizing network utilization. Note that the Access forms require direct communication with the SQL Server database, which is currently restricted to designated computers in the UGA Marine Sciences Department; however, remote access can be provided to designated users outside of UGA by tunneling database connections over Secure Shell (SSH).

Figure 3. Access form for updating information about organizations that operate or sponsor water quality monitoring programs. Sub-forms are included for managing user permissions for revising content on the web portal and for defining general metadata descriptors based on a controlled vocabulary of targeted information.

The screenshot shows the 'Organizations' form in Microsoft Access. The form is titled 'Organizations' and contains the following fields and sections:

- OrgID:** 11
- Org. Name:** National Park Service: Southeast Coast Network (SECN)
- Acronym:** SECN
- Description:** The Southeast Coast Network (SECN) is one of 32 National Park Service (NPS) Networks established to implement an integrated monitoring program under the Natural Resource Challenge. The SECN contains twenty parks, seventeen of which contain significant and diverse natural resources. In total, SECN parks encompass more than 184,000 acres of federally-managed land across North Carolina, South Carolina, Georgia, Alabama and Florida. The
- Website Url:** <http://science.nature.nps.gov/im/units/SECN/aboutus.cfm>
- Logo Url:** <http://science.nature.nps.gov/im/images/arrowhead.gif>
- Date Start:** 1/1/2006
- Date End:** (empty)
- Updated:** 3/23/2009 10:51:43
- Allowed Updaters (in addition to Administrators):**
  - UserID:** Christine Laporte (Georgia Coastal Research Council)
  - \*** (empty)
- Descriptors:**

| Descriptor Field    | Descriptor Text                                                                                                                         |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Contact Email       | joe_devivo@nps.gov                                                                                                                      |
| Contact Name        | Joe DeVivo                                                                                                                              |
| Contact Web Url     | <a href="http://science.nature.nps.gov/im/units/SECN/networkstaff.cfm">http://science.nature.nps.gov/im/units/SECN/networkstaff.cfm</a> |
| Information Web Url | <a href="http://science.nature.nps.gov/im/units/SECN/index.cfm">http://science.nature.nps.gov/im/units/SECN/index.cfm</a>               |

At the bottom of the form, there is a record navigation bar showing 'Record: 11 of 21'.

**Monitoring Programs**

ProgramID: 16 Look up record

Program Name: National Park Service: Inventory & Monitoring Vital Signs Monitoring: Marine Water Quality Program

Acronym: NPS MWQP

ProjectID: National Park Service: Southeast Coast Network (SECN)

Description: Estuaries are semi-enclosed coastal bodies of water that have free connection with the open sea and within which sea water mixes with fresh water. The key feature of an estuary is that it is an interface between sea water and fresh water and there is an influence of the ocean tide creating a dynamic relationship between the two waters. Estuaries contain critical habitat for a variety of fish, and wildlife species. They serve as nursery habitats for fish, crustaceans, and shellfish and foraging habitat for birds and mammals while providing a multitude of recreational opportunities including boating,

WebsiteUrl: <http://science.nature.nps.gov/im/units/SECN/marinewq.cfm>

Date Start: 1/1/2006 Date End: Updated: 3/23/2009 5:00:09 PM

**Program Descriptors**

| Descriptor Field                 | Descriptor Text                                                                                                               |
|----------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| Data Collection Area Description | Cape Hatteras National Seashore (CAHA)<br>Cape Lookout National Seashore (CALO)<br>Cumberland Island National Seashore (CUIS) |
| Program Contact                  | Christina Wright                                                                                                              |
| Program Contact Email            | Christina_Wright@nps.gov                                                                                                      |

**Program Parameters (use if not assigned by station)**

| Monitoring Type | Parameter | Local Name | Date Start | Date End | Date Updated  | Probabilistic            |
|-----------------|-----------|------------|------------|----------|---------------|--------------------------|
|                 |           |            |            |          | 3/31/2009 10: | <input type="checkbox"/> |

Record: 15 of 41

Figure 4. Access form used to add and update monitoring program entries, linked to sponsoring organizations. Sub-forms are included to manage general metadata descriptors and measured parameters (i.e. for monitoring programs that do not report parameters for individual sites or stations).

Figure 5. Access form used to add and update station entries for a research program. Sub-forms are included to define parameters measured at the station (grouped by type of monitoring effort), including starting and ending dates of measurement and a flag field to indicate whether the station was used as part of a probabilistic sampling event. Station location information is stored at several levels of granularity (i.e. state, county, location name, hydrologic unit code, latitude and longitude) to support a broad range of search and display options.

Figure 6. Access form used to manage measurement parameters associated with monitoring programs and stations. Parameter IDs are linked to US EPA STORET codes, when applicable, and are classified into parameter groups and categories to support searches at varying levels of specificity. Optional fields for defining relevant sample media, units, methods and additional search tags are also provided for use where applicable.

| Descriptor Name                | Webform Info                                               | Field Type | Field Size | Web Sort | Display                             | Search                              |
|--------------------------------|------------------------------------------------------------|------------|------------|----------|-------------------------------------|-------------------------------------|
| Program Contact                | Name of the program contact                                | text       | 200        | 1        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Program Contact Email          | Email address of the primary program contact               | text       | 200        | 2        | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| Program Contact Web Url        | Program Contact Web Url                                    | text       | 200        | 3        | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| Program Purpose                | Purpose of the monitoring program                          | textarea   | 1000       | 4        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Data Access Web Url            | Web address of the main data access or query page          | text       | 200        | 5        | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| Data Access Information        | Data Access Information                                    | textarea   | 1000       | 6        | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| Data Access Policy             | Policy statement for data access and use                   | textarea   | 1000       | 7        | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| Data Access Policy Web Url     | Data Access Policy Web Url                                 | text       | 200        | 8        | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| Sampling Design                | Description of the overall sampling design, including freq | textarea   | 4000       | 9        | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Sampling Frequency             | Statement of the nominal sampling frequency for the p      | text       | 200        | 10       | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Sample Collection              | Description of how samples are collected                   | textarea   | 4000       | 11       | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Sample Processing              | Description of how samples are processed prior to analy    | textarea   | 4000       | 12       | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Data Collection Area Name      | Name of the geographic area in which data collection is    | text       | 200        | 13       | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Data Collection Area Descripti | Textual description of the data collection area            | textarea   | 1000       | 14       | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| Quality Assurance Plan         | Description of the quality assurance plan                  | textarea   | 4000       | 15       | <input checked="" type="checkbox"/> | <input type="checkbox"/>            |
| List Test                      | Test field for select list testing                         | list       | 200        | 17       | <input type="checkbox"/>            | <input type="checkbox"/>            |
| Parameters Measured            | Comma-delimited list of monitoring parameters              | textarea   | 1000       | 18       | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| *                              |                                                            | text       | 200        | 255      | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |

Record: 1 of 17

Figure 7. Access form used to manage metadata fields for describing monitoring programs. Fields are included to control the display of fields on web portal data entry forms, including field type, allowed size, and sort order. Individual descriptor fields can be hidden by unchecking the “Display” field, allowing unneeded content fields to be removed from the web site without deleting legacy content in the database. Descriptors can also be omitted from program searches by unchecking the “Search” field, excluding inappropriate content (e.g. web URLs, email addresses) from search results. An identical form is also available for managing metadata fields for describing organizations.

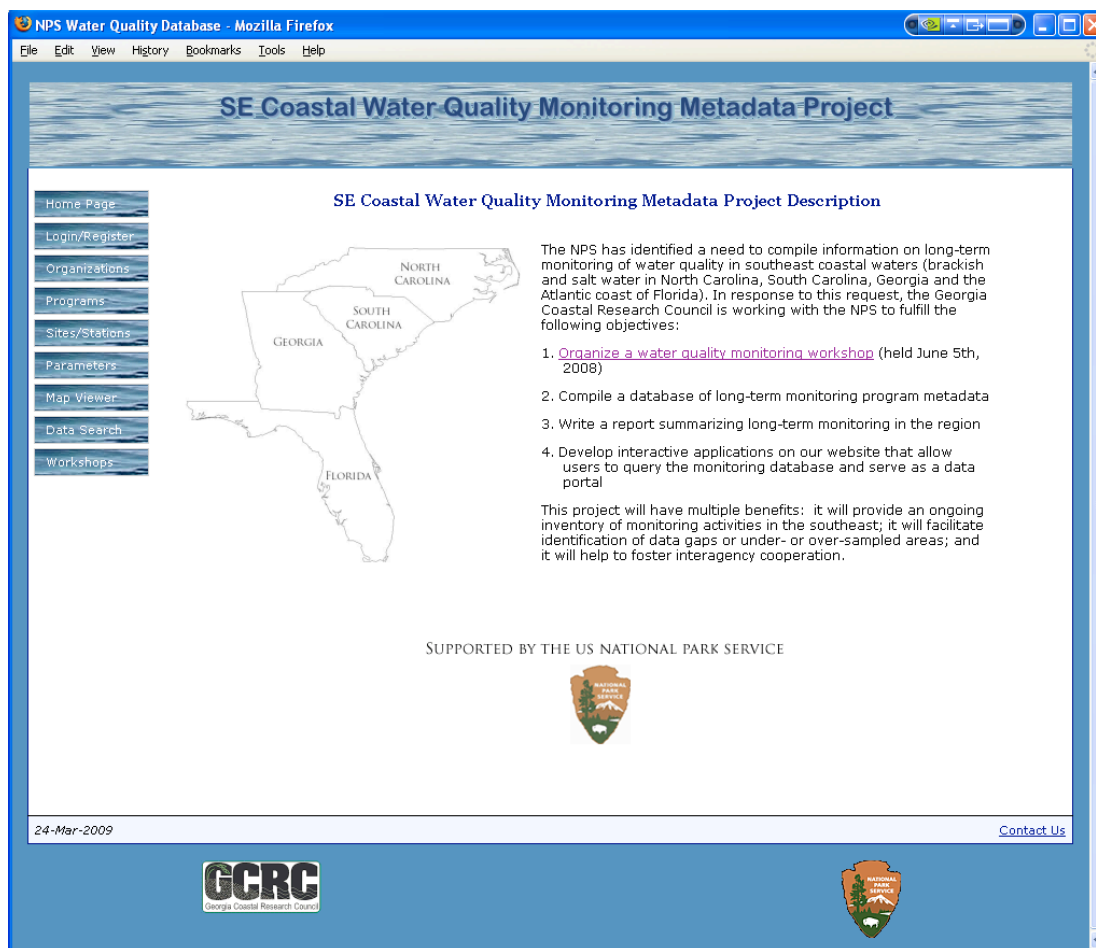
### Web-based Data Entry

In addition to the Microsoft Access forms, web-based data entry forms were also developed for the database. The portal is currently part of the Georgia Coastal Research Council web site (<http://www.gcrc.uga.edu/wqmeta/>), which is hosted on a web server in the UGA Department of Marine Sciences running Windows Server 2003 R2 and Internet Information Server 6 (IIS). Web pages were developed using HTML templates and Active Server Page (ASP) server-side scripting technology to dynamically retrieve information from the SQL Server database and format it for web display and downloading.

Web-based forms for data entry and management are illustrated in Figures 8-12, along with additional pages that allow users to browse summaries and detailed metadata describing registered organizations and monitoring programs. Dynamically-generated hyperlinks are provided to navigate to related information in the portal as well as to leave the portal to view external web links for the organization, program, or station (e.g. view the monitoring program’s web site or access the data retrieval page).

Web-based data entry forms are currently limited to user registration and entering and updating metadata for monitoring programs and sponsoring organizations, but additional forms may be added as portal development continues. Unlike the Access ADP forms, web portal forms connect to the database through a web application layer (i.e. ADO/OLE-DB commands issued by scripts on Active Server Pages, or mediated through SQLXML templates and web services hosted on the IIS 6 web server). Instead of general database roles, web portal permissions are based on more specific roles and authorization stored in the database itself (i.e. DatabaseUsers, DatabaseRoles, Logins and OrgUpdaters tables). General users are able to register information about new organizations and respective monitoring programs, but cannot update information for organizations entered by others, whereas Administrators and “SuperUsers” (e.g. GCRC staff) can update information for any organization. This management role and “information ownership” permission scheme allows a broad spectrum of users to safely enter and update information for monitoring programs they represent over the Internet without requiring administrative oversight.

Figure 8. Provisional home page of the web portal developed for accessing the NPS\_WaterQuality database, with links to data search and display pages and database update forms (URL: <http://www.gcrc.uga.edu/wqmeta/>).



NPS Water Quality Database :: Organizations - Mozilla Firefox

File Edit View History Bookmarks Tools Help

You are logged on as Wade Sheldon

## SE Coastal Water Quality Monitoring Metadata Project

Home > Organizations > Add Organization

Home Page

Login/Register

Organizations

Programs

Sites/Stations

Parameters

Map Viewer

Data Search

Workshops

### Registered Organizations

---

**Florida Department of Environmental Protection: Coastal and Aquatic Managed Areas (CAMA) Northeast**



**Description:** The Florida Department of Environmental Protection's (DEP) Office of Coastal and Aquatic Managed Areas oversees the management of Florida's 41 aquatic preserves, three National Estuarine Research Reserves (NERR), one National Marine Sanctuary and the Coral Reef Conservation Program. These protected areas comprise more than 4 million acres of the most valuable submerged lands and select coastal uplands in Florida.

**Web Site:** <http://www.dep.state.fl.us/coastal/>

**Registered Monitoring Programs:**  
[Florida DEP CAMA NE: Mosquito Lagoon Aquatic Preserve](#)  
[Florida DEP CAMA, NE: Guana Tolomato-Matanzas National Estuarine Research Reserve / Aquatic Preserve](#)  
[Florida DEP CAMA, NE: Nassau River-St. Johns River Marshes -Fort Clinch State Park Aquatic Preserve](#)

**More Information:** [View/update all organization information](#)

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**Florida Department of Environmental Protection: Coastal and Aquatic Managed Areas (CAMA): Southeast**



**Description:** The Florida Department of Environmental Protection's (DEP) Office of Coastal and Aquatic Managed Areas oversees the management of Florida's 41 aquatic preserves, three National Estuarine Research Reserves (NERR), one National Marine Sanctuary and the Coral Reef Conservation Program. These protected areas comprise more than 4 million acres of the most valuable submerged lands and select coastal uplands in Florida.

**Web Site:** <http://www.dep.state.fl.us/coastal/>

**Registered Monitoring Programs:** [Florida DEP CAMA, SE: North Fork, St. Lucie Aquatic Preserve](#)

**More Information:** [View/update all organization information](#)

---

**Florida Department of Environmental Protection: Coastal and Aquatic Managed Areas (CAMA): Southern portion of FL**

Figure 9. Organizations page, listing the titles, logos, web site home pages, and brief descriptions of all registered organizations, along with links to view additional information and links to display information about associated monitoring programs.

Figure 10. Detail page for an organization, displaying all available metadata information. Note that only meta-data fields with content are displayed, and that hyperlinks are automatically added for web and email addresses. Links to pages for all associated monitoring programs are listed below the metadata information, and a link to update the content is included at the bottom of the page (requires authentication and update permissions for the respective organization).

**NPS Water Quality Database :: Organization Details - Mozilla Firefox**

You are logged on as Wade Sheldon

## SE Coastal Water Quality Monitoring Metadata Project

Home > Organizations > Organization Details

**NOAA National Estuarine Research Reserve System (NERRS)**

**Organization Logo:**

**Acronym:** NERRS

**Description:** The National Estuarine Research Reserves System is a network of 27 areas representing different biogeographic regions of the United States that are protected for long-term research, water-quality monitoring, education and coastal stewardship. Established by the Coastal Zone Management Act of 1972, as amended, the reserve system is a partnership program between the National Oceanic and Atmospheric Administration and the coastal states. NOAA provides funding, national guidance and technical assistance. Each reserve is managed on daily basis by a lead state agency or university, with input from local partners. Reserve staff work with local communities and regional groups to address natural resource management issues, such as non-point source pollution, habitat restoration and invasive species. Through integrated research and education, the reserves help communities develop strategies to deal successfully with these coastal resource issues. Reserves provide adult audiences with training on estuarine issues of concern in their local communities. They offer field classes for K-12 students and support teachers through professional development programs in marine education. Reserves also provide long-term water quality monitoring as well as opportunities for both scientists and graduate students to conduct research in a "living laboratory."

**Web Site:** <http://nerrs.noaa.gov/>

**Duration:** 01/01/1972 to present (as of 03/11/2009)

**Contact Name:** Susan N. White

**Contact Email:** [Susan.White@noaa.gov](mailto:Susan.White@noaa.gov)

**Contact Web URL:** <http://nerrs.noaa.gov/contactus.html>

**Mission Statement:** To practice and promote coastal and estuarine stewardship through innovative research and education, using a system of protected areas.

**News Web URL:** <http://www8.nps.noaa.gov/publicnerrs/newshome.aspx>

**Monitoring Programs:**

- [Ace Basin NERR Monitoring Program](#)
- [Guana Tolomato Matanzas NERR Monitoring Program](#)
- [North Carolina NERR Monitoring Program](#)
- [North Inlet Winyah Bay Monitoring Program](#)
- [Sapelo Island NERR Monitoring Program](#)

» [Update information for this organization](#)

NPS Water Quality Database :: Program Details - Mozilla Firefox

You are logged on as Wade Sheldon

## SE Coastal Water Quality Monitoring Metadata Project

Home > Organizations > Monitoring Programs > Program Details

### North Carolina NERR Monitoring Program

**Sponsoring Organization:** [NOAA National Estuarine Research Reserve System \(NERRS\)](#)

**Description:** North Carolina's estuarine system is the third largest in the country, encompassing more the two million acres. This system is of prime economic importance to the coastal area -- 90 percent of the commercial seafood species caught in the state spends at least part of their lives in an estuary. The North Carolina National Estuarine Research Reserve was established to preserve these fragile natural areas and the variety of life they support. The state is representative of two major biogeographic regions located north (Virginian) and south (Carolinian) of Cape Hatteras. Therefore, NOAA and the state of North Carolina created a multi-component reserve with the following sites: Currituck Banks (960 acres near Corolla), Rachel Carson (2,625 acres near Beaufort), Masonboro Island (5,097 acres near Wrightsville Beach) and Zeke's Island (1,165 acres near Kure Beach).

**Web Site:** <http://www.nccoastalreserve.net/>

**Duration:** 01/01/1995 to present (as of 03/26/2009)

**Program Contact:** Rebecca Ellin

**Program Contact Email:** [Rebecca.ellin@ncmail.net](mailto:Rebecca.ellin@ncmail.net)

**Program Contact Web Url:** <http://www.nccoastalreserve.net/Resources/Contact-Us/43.aspx>

**Program Purpose:** The North Carolina Coastal Reserve (NCCR) & National Estuarine Research Reserve System (NCNERR) is a network of ten protected sites established for long-term research, education and stewardship. This program protects more than 41,000 acres of estuarine land and water, which provides essential habitat for wildlife; offers educational opportunities for students, teachers and the public; and serves as living laboratories for scientists. Four of the Reserve components are designated as NCNERR sites: Currituck Banks, Rachel Carson, Masonboro Island, and Zeke's Island. The state supported sites in the NCCR are Kitty Hawk Woods, Emily and Richardson Preyer Buckridge, Buxton Woods, Permuda Island, Bald Head Woods, and Bird Island.

**Data Access Web Url:** [http://cdmo.baruch.sc.edu/QueryPages/csv\\_export.cfm](http://cdmo.baruch.sc.edu/QueryPages/csv_export.cfm)

**Data Access Information:** Data is available from the NERR Centralized Data Management Office

**Data Access Policy Web Url:** <http://cdmo.baruch.sc.edu/aboutdata.cfm>

**Sampling Design:** The research sector of NCNERR is managed according to the Reserve management plan, the NERRS strategic plan, and the NERRS Research and Monitoring Plan (2006-2011, [http://nerrs.noaa.gov/pdf/Research\\_Monitoring.pdf](http://nerrs.noaa.gov/pdf/Research_Monitoring.pdf)). The NERRS Research and Monitoring Plan (2006-2011) provides four goals that direct the system-wide research and monitoring efforts.

**Sampling Frequency:** Continuous water quality and weather monitoring, with near-real-time data access

Figure 11. Detail page for a registered monitoring program, displaying all available metadata information. Note that only metadata fields with content are displayed, and that hyperlinks are automatically added for web and email addresses. A link to display all associated monitoring stations is listed below the metadata information, and a link to update the content is included at the bottom of the page (requires authentication and update permissions for the respective organization).

Figure 12. Web form for entering or updating information about a monitoring program. Note that fields are provided for all metadata descriptors defined in the database, with field types and lengths as specified. Support for drop-down menu entry for terms from a controlled vocabulary associated with a descriptor field is also supported.

The screenshot shows a web browser window titled 'NPS Water Quality Database :: Update Program Details - Mozilla Firefox'. The user is logged in as 'Wade Sheldon'. The page has a navigation menu on the left with links: Home Page, Login/Register, Organizations, Programs, Sites/Stations, Parameters, Map Viewer, Data Search, and Workshops. The main content area is titled 'Update Monitoring Program Information' and contains the following fields:

- Program Name:** North Carolina NERR Monitoring Program
- Program Acronym:** (empty text box)
- Parent Organization:** NOAA National Estuarine Research Reserve System (NERRS) (dropdown menu)
- Description:** North Carolina's estuarine system is the third largest in the country, encompassing more than two million acres. This system is of prime economic importance to the coastal area -- 90 percent of the commercial seafood species caught in the state spends at least part of their lives in an estuary. The North Carolina National Estuarine Research Reserve was established to preserve these fragile natural areas and the variety of life they support. The state is representative of two major biogeographic regions located north (Virginian) and south (Carolinian) of Cape Hatteras. Therefore, NOAA and the state of (dropdown menu)
- Main Web Url:** http://www.nccoastalreserve.net/
- Program Dates:** Start: 01/01/1995 End: (empty text box)
- Program Contact:** Rebecca Elin
- Program Contact Email:** Rebecca.elin@ncmail.net
- Program Contact Web Url:** http://www.nccoastalreserve.net/Resources/Contact-Us/43.aspx
- Program Purpose:** The North Carolina Coastal Reserve (NCCR) & National Estuarine Research Reserve System (NERRS) is a network of ten protected sites established for long-term research, education and stewardship. This program protects more than 41,000 acres of estuarine land and water, which (dropdown menu)
- Data Access Web Url:** http://cdmo.baruch.sc.edu/QueryPages/csv\_export.cfm
- Data Access Information:** Data is available from the NERR Centralized Data Management Office
- Data Access Policy:** (empty text box)
- Data Access Policy Web Url:** http://cdmo.baruch.sc.edu/aboutdata.cfm
- Sampling Design:** The research sector of NCNERR is managed according to the Reserve management plan, the NERRS strategic plan, and the NERRS Research and Monitoring Plan (2006-2011)

### Database Querying

The large disparities in quantity of information available for each program, as well as variations in reporting practices for associating measured parameters with programs and locations, significantly complicated query design and logic. We designed a series of basic queries that are stored as database “views” for displaying information on the portal website and populating data entry and management forms (Henderson, 2000). These views provide “virtual tables” that can be searched and displayed using simpler logic than that required to query the underlying database structure. They also support interactive queries to generate database products (e.g. reports, Keyhole Markup Language files for mapping, and tabular lists of stations and parameters matching search criteria). A list of views and their respective parameters is provided in the technical database documentation (see Appendix A).

To augment the interactive web portal, REST and SOAP web service interfaces were also developed using Microsoft SQLXML 3.0 (Henderson, 2002). These web services accept various search parameters and return structured information (i.e. XML text) to support mining information from the NPS\_WaterQuality database over the Internet. The XML text returned by the query can be transformed to standard HTML for web display or incorporated in other portals, databases, or applications. For example, the following URL retrieves a list of stations at which salinity is measured in a region of the Georgia coast using the REST web service interface:

URL: [http://www.gcrc.uga.edu/wqmeta\\_xml/rest/findSites.xml?Parameter=salinity&North=32&South=31.5&West=-83&East=-80](http://www.gcrc.uga.edu/wqmeta_xml/rest/findSites.xml?Parameter=salinity&North=32&South=31.5&West=-83&East=-80)

Results (abbreviated):

```
<Sites>
  <Site siteId="45" programId="37" organizationId="2">
    <Name>Crab Creek water quality station</Name>
    <Program>Sapelo Island NERR Monitoring Program</Program>
    <Organization>NOAA National Estuarine Research Reserve System
      (NERRS)</Organization>
    <OrganizationAcronym>NERRS</OrganizationAcronym>
    <State>Georgia</State>
    <County>McIntosh</County>
    <Latitude>31.51230</Latitude>
    <Longitude>-80.25420</Longitude>
    <DateStart>2004-01-01T00:00:00</DateStart>
    <DateEnd>2004-01-01T00:00:00</DateEnd>
    <DateUpdated>2009-03-26T00:00:00</DateUpdated>
    <WebsiteURL><![CDATA[http://www.sapelonerr.org/]]></WebsiteURL>
    <DataURL/>
  </Site>
  <Site siteId="60" programId="5" organizationId="3">
    <Name>Hydrographic mooring in the Sapelo River near Eulonia</Name>
    <Program>GCE LTER Continuous Salinity, Temperature and Water Level
      Monitoring</Program>
    <Organization>Georgia Coastal Ecosystems Long Term Ecological
      Research (GCE LTER)</Organization>
    <OrganizationAcronym>GCE-LTER</OrganizationAcronym>
    <State>Georgia</State>
    <County>McIntosh</County>
    <Latitude>31.53748</Latitude>
    <Longitude>-81.42398</Longitude>
    <HUC>03060204</HUC>
    <DateStart>2001-09-13T00:00:00</DateStart>
    <DateUpdated>2009-03-26T21:39:02</DateUpdated>
    <WebsiteURL><![CDATA[http://gce-lter.marsci.uga.edu/public/research/
      mon/sounds_creeks.htm]]></WebsiteURL>
    <DataURL><![CDATA[http://gce-lter.marsci.uga.edu/portal/
      gce_hydro.htm]]></DataURL>
  </Site>
  ...
</Sites>
```

After testing is finished, complete syntax and instructions will be provided on the web portal to support metadata retrieval via web services.

A series of parameterized stored procedures were also developed to support querying database views using web-based forms. In addition to standardizing the query logic and improving performance, stored procedures provide excellent protection against malicious users in a web environment (e.g. SQL injection attacks), significantly enhancing da-

tabase security. Each procedure is optimized for a different range of search parameters to maximize efficiency and performance, but all return the same fields in the query results. For example, “procSearchStationsAll” supports searching by site name, range of observation dates (start date, end date), Hydrologic Unit Code, and geographic boundaries (north, south, east, west). In contrast, “procSearchStationsByProgramByParameter” supports searching by the above parameters plus four additional parameters: monitoring programs (delimited list of Program IDs),

monitoring types (delimited list of monitoring activity types), parameter measured, and probabilistic sampling design.

Several versions of each procedure are provided to support multiple output formats. For example, “procSearchStationsAll” returns an SQL resultset (table), “procSearchStationsAll\_XML” returns an XML document, and “procSearchStationsAll\_KML” returns a Google Earth™ Keyhole Markup Language file. Despite this apparent complexity, interactive web applications and web service search interfaces call the appropriate

procedure automatically based on which query parameters are entered. This provides users with a seamless interface for searching the database by program, site name, monitoring type, measured parameter, date range, hydrologic unit code, and geographic bounding box (Figures 13-15).

Refinements to the web portal are ongoing, and other pages will be added as user interest and future funding permit.

Figure 13. Web form for searching the NPS\_WaterQuality database to locate sites and stations by monitoring program, site name, monitoring type, parameter, date range, hydrologic unit code and geographic bounding box. All criteria other than program and site type are optional, and multiple program and site types can be specified to narrow or broaden searches. Results can be returned as a web table, spreadsheet file, Google Earth KML file, or general XML file.

**NPS Water Quality Database - Mozilla Firefox**

File Edit View History Bookmarks Tools Help

NPS Water Quality Database

You are logged on as Wade Sheldon

### SE Coastal Water Quality Monitoring Metadata Project

Home > Search Sites/Stations

#### Search for Monitoring Sites and Stations

**Program:** [\(select all\)](#)

- CAMA NE: Florida DEP CAMA, NE: Nassau River-St. Johns River Marshes -Fort Clinch State Park Aquatic Preserve
- CAMA SE: Florida DEP CAMA, SE: North Fork, St. Lucie Aquatic Preserve
- GCE-LTER: GCE LTER Climate Monitoring
- GCE-LTER: GCE LTER Continuous Salinity, Temperature and Water Level Monitoring
- GCE-LTER: GCE LTER Water Quality Monitoring
- GCRD: Georgia DNR Nutrient Monitoring in Coastal Rivers, Sounds and Estuaries
- GCRD: Georgia DNR Shellfish Water Quality
- MAREX: University of Georgia's MAREX Altamaha River Monitoring Program

*(hold down the control, command or shift key to select multiple programs)*

**Site Name:**  *(partial string match, case-insensitive)*

**Site Type:**

- ☒ Ground Water Station
- ☒ Meteorological Station
- ☒ Nutrient Sampling Station
- ☒ Shellfish Contaminants
- ☒ Streamflow Station
- ☒ Water Quality Station

☐ fixed site ☐ probabilistic site ☒ either fixed or probabilistic

**Parameter:**  *(parameter measured at the site/station, case-insensitive)*

**Date Range:**  to  *(mm/dd/yyyy)*

**Hydrologic Unit:**  *(8-digit HUC)*

**Geographic Bounding Box:** *(decimal degrees)*

Zoom in to the region you would like to search  
(click on the magnifying glass to drag a bounding box)

North   
West   East  
South

**Display Options:** Format:  Sort by:  *(Web page and Spreadsheet only)*

Done

NPS Water Quality Database - Mozilla Firefox

File Edit View History Bookmarks Tools Help

NPS Water Quality Database

You are logged on as Wade Sheldon

## SE Coastal Water-Quality Monitoring Metadata Project

Home > Search Sites/Stations > Results > Spreadsheet > Google Earth > XML

Home Page  
Login/Register  
Organizations  
Programs  
Site Search  
Workshops  
Web Services

### Search for Monitoring Sites and Stations

| Organization          | Site Code                | Site Name                                | State          | County | Latitude | Longitude |
|-----------------------|--------------------------|------------------------------------------|----------------|--------|----------|-----------|
| <a href="#">NERRS</a> | <a href="#">acespnut</a> | St. Pierre nutrient sampling station     | South Carolina |        | 32.52330 | -80.35680 |
| <a href="#">NERRS</a> | <a href="#">acespwq</a>  | St. Pierre water quality station         | South Carolina |        | 32.52330 | -80.35680 |
| <a href="#">NERRS</a> | <a href="#">acebbnut</a> | Big Bay nutrient sampling station        | South Carolina |        | 32.48970 | -80.32020 |
| <a href="#">NERRS</a> | <a href="#">acebbwq</a>  | Big Bay water quality station            | South Carolina |        | 32.48970 | -80.32020 |
| <a href="#">NERRS</a> | <a href="#">acebpmet</a> | Bennett's Point meteorological station   | South Carolina |        | 32.55870 | -80.45370 |
| <a href="#">NERRS</a> | <a href="#">acefcnut</a> | Fishing Creek nutrient sampling station  | South Carolina |        | 32.63580 | -80.36550 |
| <a href="#">NERRS</a> | <a href="#">acefcwq</a>  | Fishing Creek water quality station      | South Carolina |        | 32.63580 | -80.36550 |
| <a href="#">NERRS</a> | <a href="#">acemcnut</a> | Mosquito Creek nutrient sampling station | South Carolina |        | 32.55580 | -80.43800 |
| <a href="#">NERRS</a> | <a href="#">acemcwq</a>  | Mosquito Creek water quality station     | South Carolina |        | 32.55580 | -80.43800 |
| <a href="#">NERRS</a> | <a href="#">acercwq</a>  | Rock Creek water quality station         | South Carolina |        | 32.54850 | -80.50360 |

10 Records

NPS Water Quality Database - Mozilla Firefox

File Edit View History Bookmarks Tools Help

NPS Water Quality Database

## SE Coastal Water-Quality Monitoring Metadata Project

Home > Search Sites/Stations > Site/Station Details

Home Page  
Login/Register  
Organizations  
Programs  
Site Search  
Workshops  
Web Services

### Site or Station Details

**Site/Station** acemcnut - Mosquito Creek nutrient sampling station

**Organization** [NERRS](#) - NOAA National Estuarine Research Reserve System (NERRS)

**Program** [Ace Basin NERR Monitoring Program](#)

**Location** ACE Basin National Estuarine Research Reserve, South Carolina

**Coordinates** 32.55580° N, -80.43800° W

**Date Range** Mar 01, 2002 to the present (last updated Mar 26, 2009)

**Web Links** Web Page: <http://www.dnr.sc.gov/marine/NERR/index.html>

**Site Map**

Map data ©2009 Tele Atlas - [Terms of Use](#)

| Parameters | Type                 | Name       | Category | Alias | Tags | Probabilistic | Storet Code |
|------------|----------------------|------------|----------|-------|------|---------------|-------------|
| nutrients  | Ammonia              | Nitrogen   | NH4F     |       |      | no            | 71846       |
| nutrients  | Chlorophyll a        | Pigments   | CHLA_N   |       |      | no            | 32217       |
| nutrients  | Inorganic nitrogen   | Nitrogen   | DIN      |       |      | no            |             |
| nutrients  | Nitrate              | Nitrogen   | NO3F     |       |      | no            | 71850       |
| nutrients  | Nitrite              | Nitrogen   | NO2F     |       |      | no            | 71855       |
| nutrients  | Nitrite plus nitrate | Nitrogen   | NO23F    |       |      | no            | 00630       |
| nutrients  | Orthophosphate       | Phosphorus | PO4F     |       |      | no            | 00660       |

Figure 14. Site search results displayed as a web table (top), and Site details page (bottom) reached by clicking on the "Site Code" link on the search results table or "view site metadata" link in the Google Earth placemark balloon. Note the links at the top of the search results page, which allow users to download their search results in spreadsheet, Google Earth or XML format directly without returning to the search form.

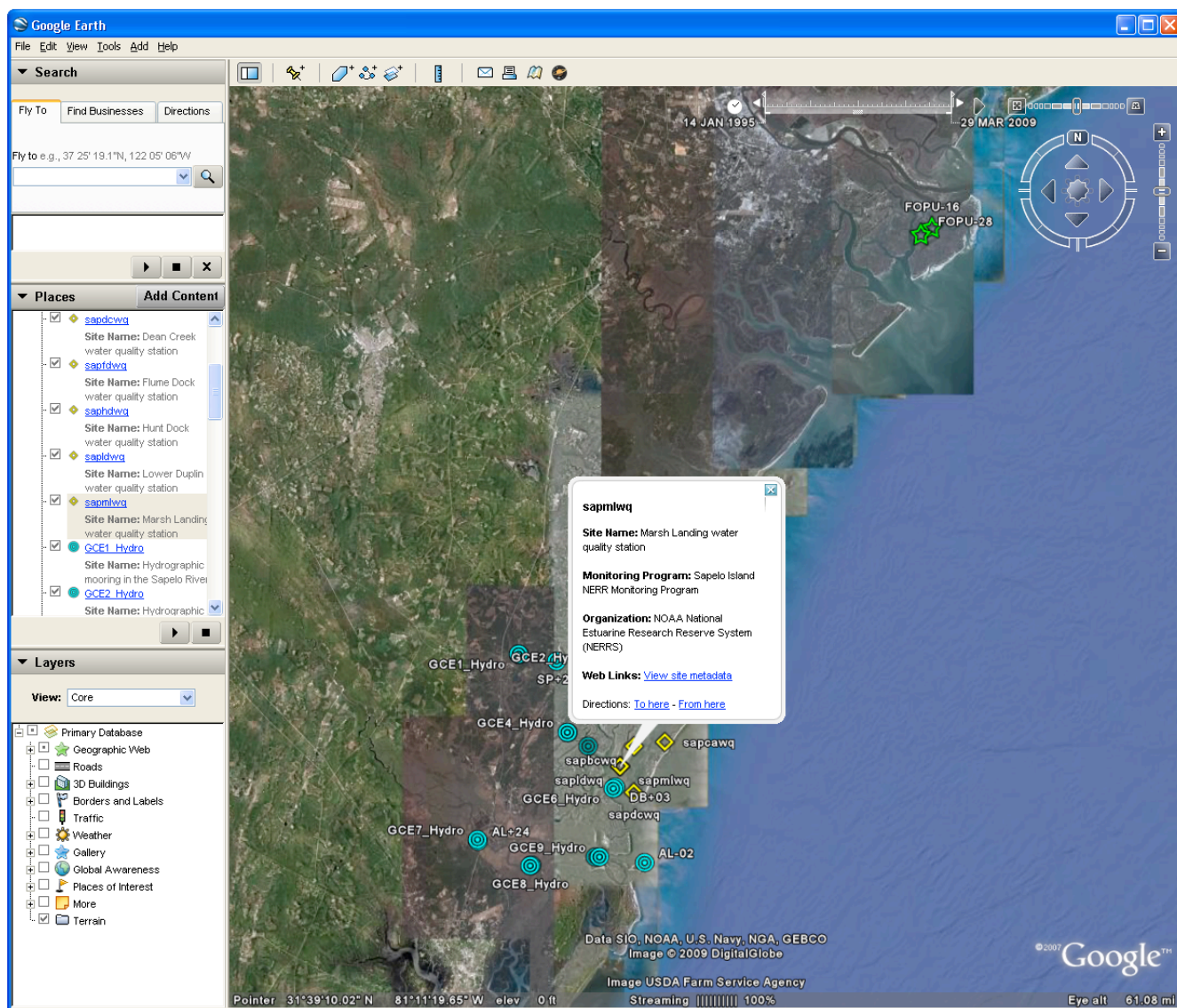


Figure 15. Google Earth™ display of NPS\_WaterQuality search results returned in KML format. Note that placemark icons are keyed to Organizations, and that links are provided in the placemark balloon to view all available metadata on the SE Coastal Water Quality Monitoring Metadata Project website. Also note that temporal information is included in the KML file, when available, so that the time slider on the upper right of the screen can be used to view stations that were active during a particular period of time.

# Results

## Initial Data Entry

After the database design was finalized, GCRC staff entered the information for those organizations whose coastal water quality monitoring programs met our selection criteria. The criteria included: geographically located along the SE coast between the northern border of NC and the southern tip of Florida's east coast; occurring within the Coastal Zone demarcation

for each state; having an existing or planned long-term data collection program (either periodic or episodic) and existing or planned data access. Metadata content was manually extracted from program web sites (e.g. program titles, descriptions, policy website links) or obtained from agency representatives. Project partners (see Appendix B) were then asked to review the draft entries online to ensure accuracy. These efforts resulted

|                                                                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|-----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Federal Agencies                                                                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| National Park Service: Southeast Coast Network (SECN)                                   | NPS Inventory & Monitoring Vital Signs Monitoring: Marine Water Quality Program                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| NOAA Centers for Coastal Ocean Science, (NCCOS)                                         | NCCOS Georgia Coastal Analysis Partnership<br>NCCOS National Benthic Inventory Program                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| NOAA National Estuarine Research Reserve System (NERRS)                                 | Ace Basin NERR Monitoring Program<br>Guana Tolomato Matanzas NERR Monitoring Program<br>North Carolina NERR Monitoring Program<br>North Inlet Winyah Bay Monitoring Program<br>Sapelo Island NERR Monitoring Program                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| U.S. Geological Survey (USGS)                                                           | USGS Water Resources of the United States: Ground Water<br>USGS Water Resources of the United States: Surface Water<br>USGS Water Resources of the United States: Water Quality                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| State Agencies                                                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Florida Department of Environmental Protection Coastal and Aquatic Managed Areas (CAMA) | Northeast<br>CAMA Mosquito Lagoon Aquatic Preserve<br>CAMA Guana Tolomato-Matanzas National Estuarine Research Reserve /Aquatic Preserve<br>CAMA Nassau River-St. Johns River Marshes -Fort Clinch State Park Aquatic Preserve<br>Southeast<br>CAMA North Fork, St. Lucie Aquatic Preserve<br>Southern<br>CAMA Biscayne Bay Aquatic Preserve<br>CAMA Florida Keys National Marine Sanctuary Water Quality<br>Northeast District (FLDEP: NE)<br>Florida DEP Integrated Water Resource Monitoring Network<br>Florida DEP Integrated Water Resource Monitoring Network: Duval Tributary<br>Florida DEP Integrated Water Resource Monitoring Network: St. Johns River |
| Florida Water Management Districts                                                      | South Florida Water Management District (SFWMD)<br>SFWMD Biscayne Bay Monitoring<br>St. Johns River Water Management District (SJRWMD)<br>SJRWMD Surface Water Quality Monitoring                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Georgia Department of Natural Resources: Coastal Resources Division (GADNR: CRD)        | Georgia DNR: CRD Nutrient Monitoring in Coastal Rivers, Sounds and Estuaries<br>Georgia DNR: CRD Shellfish Water Quality                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| North Carolina Department of Environment and Natural Resources (NCDENR)                 | Division of Water Quality (DWQ)<br>NCDENR: DWQ Ambient Monitoring System<br>Division of Environmental Health (DEH)<br>NCDNR: DEH Recreational Water Quality and Shellfish Sanitation Monitoring                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

Box 1. Monitoring Organizations and Programs included in SE Coastal Water Quality Monitoring Metadata Project

Box 1. (Continued).

|                                                                                                                                                                                                                                                  |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>South Carolina Department of Health and Environmental Control (SC DHEC)</p> <p>SC DHEC Ambient Surface Physical and Chemical Water Monitoring Network</p> <p>SC DHEC Beach Monitoring Program</p> <p>SC DHEC Shellfish Sanitation Program</p> |
| <p>South Carolina Department of Natural Resources: Marine Division (SCDNR)</p> <p>SC Estuarine and Coastal Assessment Program (SCECAP) * joint program with SCDHEC</p>                                                                           |
| <p>Municipalities</p>                                                                                                                                                                                                                            |
| <p>Florida: City of Jacksonville</p> <p>JAX: Surface Water Quality: Timucuan Preserve (NPS)</p>                                                                                                                                                  |
| <p>Research Programs</p>                                                                                                                                                                                                                         |
| <p>Florida International University: Southeast Environmental Research Center (SERC)</p> <p>Water Quality Monitoring Network: Florida Bay District</p> <p>Water Quality Monitoring Network: Florida Keys National Marine Sanctuary</p>            |
| <p>Georgia Coastal Ecosystems Long Term Ecological Research (GCE LTER)</p> <p>GCE LTER Climate Monitoring</p> <p>GCE LTER Continuous Salinity, Temperature and Water Level Monitoring</p> <p>GCE LTER Water Quality Monitoring</p>               |
| <p>University of Georgia Marine Extension Service: MAREX Marine Advisory Services</p> <p>Altamaha River Monitoring Program</p> <p>Ogeechee River Monitoring Program</p> <p>Satilla River Monitoring Program</p>                                  |
| <p>University of North Carolina FerryMon (UNCFerryMon)</p> <p>FerryMon</p>                                                                                                                                                                       |
| <p>Regional Associations</p>                                                                                                                                                                                                                     |
| <p>Southeast Coastal Ocean Observing Regional Association (SECOORA)</p> <p>SE component, national Integrated Ocean Observing System (IOOS); Metadata only.</p>                                                                                   |

in a total of 41 programs registered in the database.

In addition, we retrieved monitoring location and parameter information from national databases (i.e. USGS NWIS, NERRS CDMO, LTER Data Catalog) by programmatically mining web applications and web services using custom MATLAB® programs and XSLT stylesheets (see Appendix C) and uploading parsed information directly into the database. We also requested and received information in spreadsheet form for programs that do not operate web-based information systems. Data describing 16,182 stations and 286,042 parameters were uploaded to the database following this initial effort. We also retrieved descriptions and geographic coordinates for over 15,000 additional aquatic and groundwater stations from the US EPA STORET database. However,

the only way to retrieve information about what parameters are measured at these locations is by requesting a separate data set for each station via web form and email reply, so these stations have not yet been added to the database.

A list of organizations and programs currently included in the database can be found in Box 1. GCRC will continue to solicit and follow up with programs or individuals who have professional interest in this metadata. Figure 16 shows the coverage of monitoring sites and programs registered in the metadata database as of June 2009. Similar maps can be generated dynamically on the web portal to display locations of monitoring activities of interest to database users. For example, Figure 17 shows the illustrating locations of monitoring locations in the vicinity of Jacksonville, FL.

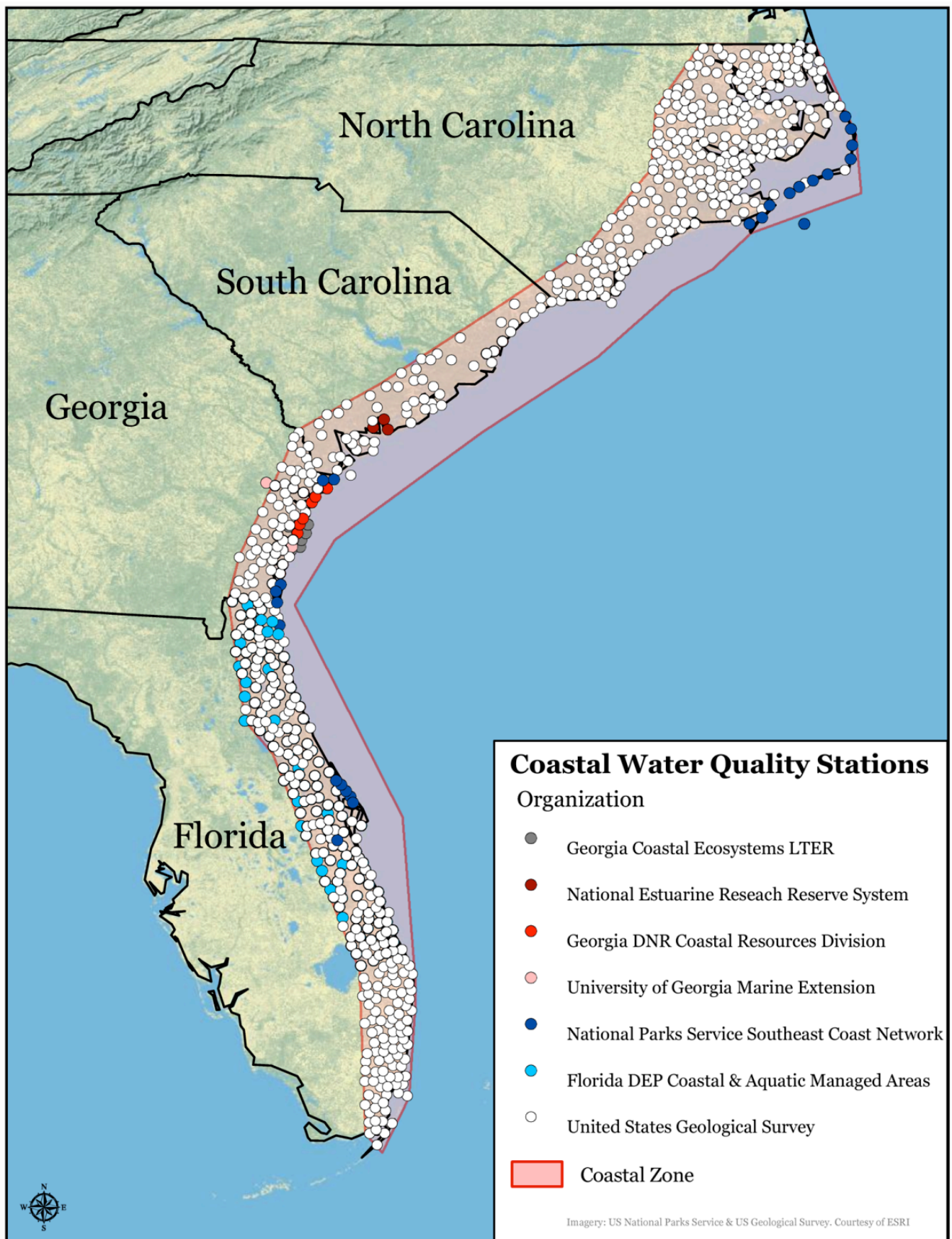


Figure 16. Map depicting locations of 16,182 monitoring sites registered in the NPS\_WaterQuality database as of June 2009 by sponsoring organization.

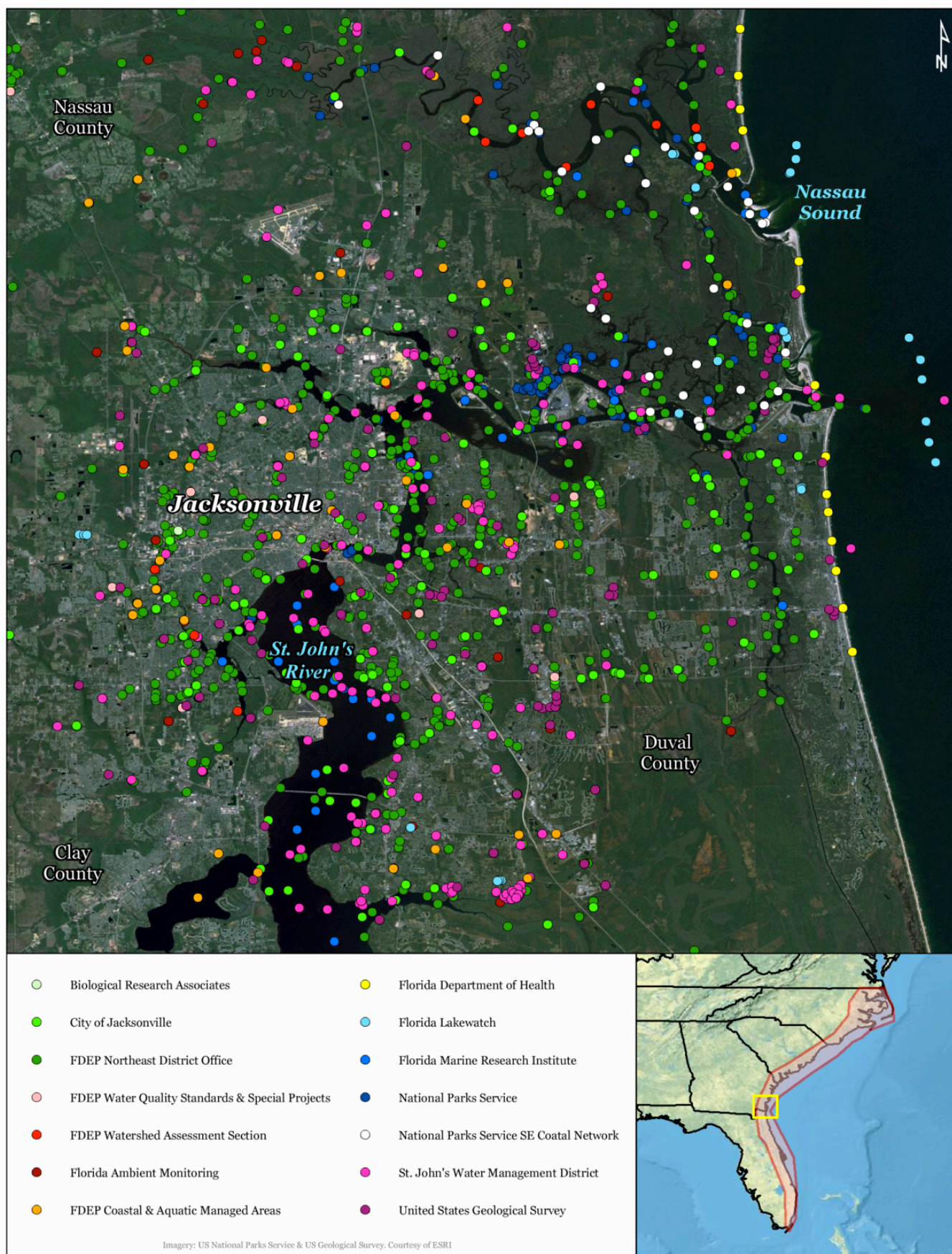


Figure 17. Map illustrating locations of monitoring locations in the vicinity of Jacksonville, FL as of June 2009.

## Portal Use Examples

Several examples are briefly described below to illustrate how water quality monitoring information can be discovered on the metadata portal.

### Case 1: Search by Organization and Program.

A user browses the portal looking for information about estuarine research programs operating in the southeastern U.S. They start by browsing the “Organizations” page (<http://www.gcrc.uga.edu/wqmeta/app/organizations.asp>), and discover the entry

for the NOAA National Estuarine Research Reserve System (NERRS) (Figure 18). After reading the description for this organization, they click on the “More Information” link to view all available metadata. They then view details for the Ace Basin NERR Monitoring Program by clicking on the respective link under “Monitoring Programs”. After viewing the complete description of this program, they use the “Web Site” link to visit the ACE Basin home page on the South Carolina DNR web site, or click on the “Data Access Web URL” link to view all available data for this program on the NERR Centralized Data Management web site.

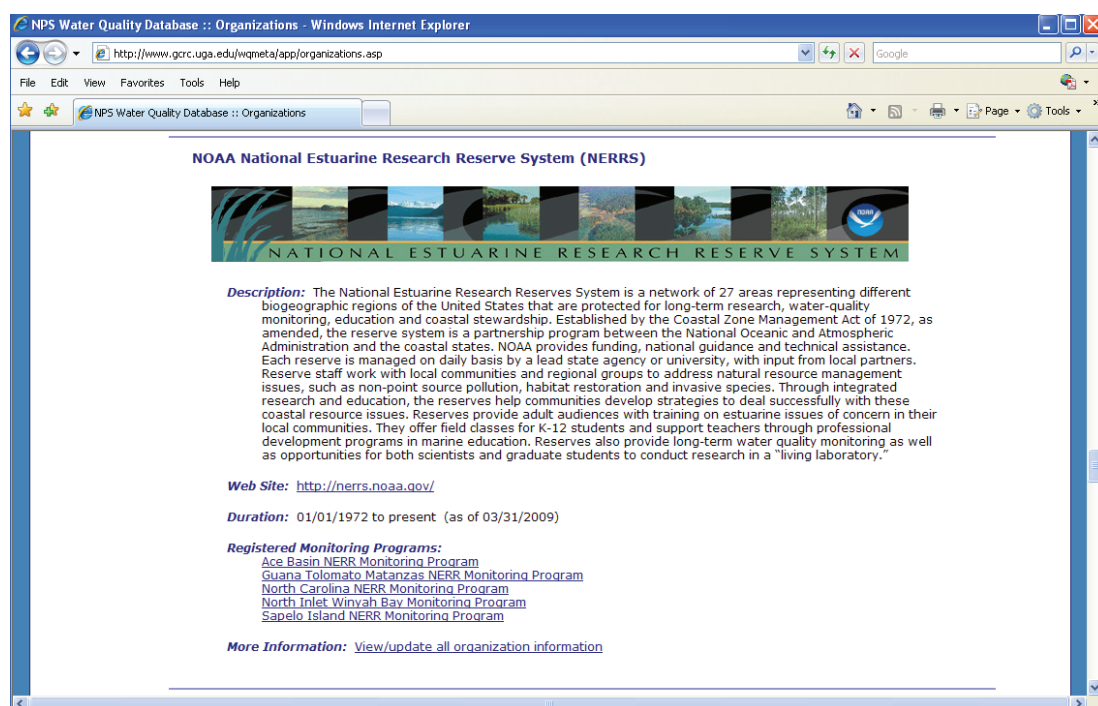


Figure 18. Screen capture of the NOAA National Estuarine Research Reserve System program description.

## Case 2. Search by Area and Partnerships

A user visits the portal looking for information about Water Quality monitoring in Florida's Timucuan Ecological and Historical Preserve, which is conducted as a cooperative project between the City of Jacksonville, the State of Florida and National Park Services. They begin by clicking on the "Site Search" link, select the "SECN: National Park Service: Inventory & Monitoring Vital Signs Monitoring: Marine Water Quality Program" from the list of monitoring programs, and zoom the Google Map to include the vicinity of Jacksonville, Florida (Figure

19). They select the "Web Table" format option, press the "Perform Search" button, and retrieve a list of TIMU water quality monitoring sites and Timucuan Ecological and Historic Preserve sites within the search area. They then click on "Site Code" links to view detailed information about each site, including description, location details, dates of operation, links to the information and data from the sponsoring organization's web site, an interactive map of the site location, and a list of the parameters measured (see Figure 19).

Figure 19. Screen capture of the monitoring site search form with NPS Inventory and Monitoring Program selected. Geographic boundaries set by zooming in on the map (<http://www.gcrc.uga.edu/wqmeta/app/search.asp>).

**NPS Water Quality Database - Mozilla Firefox**

**SE Coastal Water Quality-Monitoring-Metadata Project**

**Search for Monitoring Sites and Stations**

**Program:** (select all)  
 NERRS: Guana Tolomato Matanzas NERR Monitoring Program  
 NERRS: North Carolina NERR Monitoring Program  
 NERRS: North Inlet Winyah Bay Monitoring Program  
 NERRS: Sapelo Island NERR Monitoring Program  
**SECN: National Park Service: Inventory & Monitoring Vital Signs Monitoring: Marine Water Quality Program**  
 USGS: USGS Water Resources of the United States: Ground Water  
 USGS: USGS Water Resources of the United States: Surface Water  
 USGS: USGS Water Resources of the United States: Water Quality  
 (hold down the control, command or shift key to select multiple programs)

**Site Name:** (partial string match, case-insensitive)

**Site Type:**  
☒ Ground Water Station  
☒ Meteorological Station  
☒ Nutrient Sampling Station  
☒ Shellfish Contaminants  
☒ Streamflow Station  
☒ Water Quality Station  
☐ fixed site ☐ probabilistic site ☒ either fixed or probabilistic

**Parameter:** (parameter measured at the site/station, case-insensitive)

**Date Range:** to (mm/dd/yyyy)

**Hydrologic Unit:** (8-digit HUC)

**Geographic Bounding Box:** (decimal degrees)  
 Zoom in to the region you would like to search (click on the magnifying glass to drag a bounding box)

North: 30.8645102262  
 West: -82.331542968 East: -80.793457031  
 South: 29.4395975666

### Case 3: Search by Parameter and Location.

A user browses the portal looking for information about programs measuring oxygen in the vicinity of Beaufort, SC. They begin by clicking on the “Site Search” link to bring up the monitoring sites and stations search page (<http://www.gcrc.uga.edu/wqmeta/app/search.asp>). They enter “oxygen” in the “Parameter” field, drag a box around the SC coast in the Beaufort vicinity using the Google Map on the search form, select the Google Earth KML file option, and hit the “Perform Search” button. They are prompted whether to open the file in Google Earth on their desktop or save the file, and they choose to open the file. After Google

Earth loads the KML file, they drag the time slider to display stations active during the period of interest. In this case, the time slider covers the period from February 1980 through March 2009. They then click on a place marker on the map to view station information (Figure 20), and decide that the ACE Basin NERR St. Pierre water quality station is of interest. They click on the “View station metadata” link in the marker balloon, and detailed station metadata is displayed from the web portal. They then click on the “Data Access Web URL” link and reach the NERR CDMO web site to request data for this station.

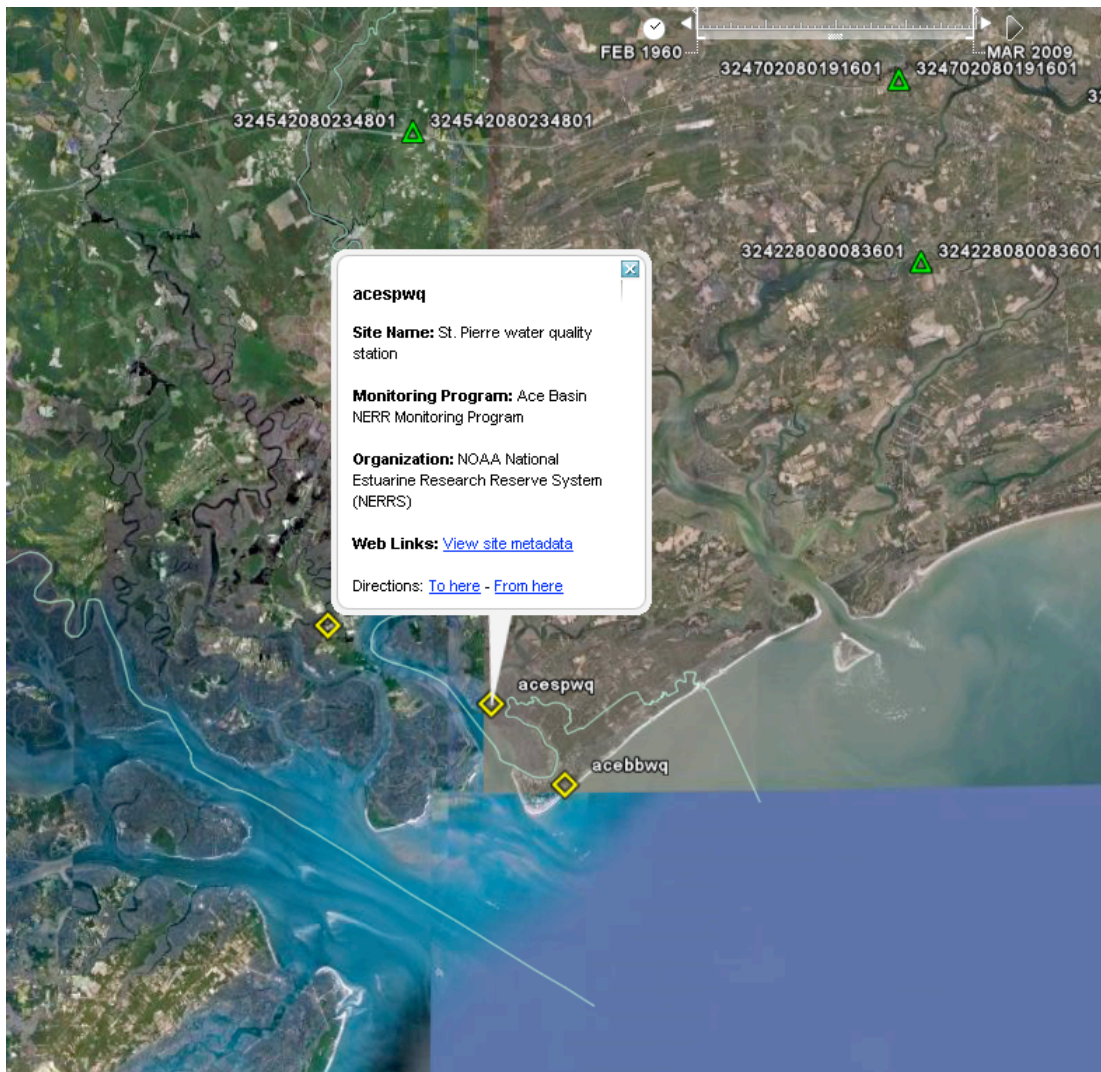


Figure 20. Partial screen capture of a Google Earth™ file dynamically generated by querying the NPS\_WaterQuality database. Note that the information balloon opened by clicking on a place marker contains a summary describing the location and a hyperlink to the complete station description web page on the portal.



## Discussion

The SE Coastal Water Quality Monitoring Metadata Database provides a set of valuable tools and several applications to a range of potential users. Now that the database has been developed, the National Park Service will be able to use it for improved coordination with its water quality monitoring partners at its Coastal Parks in the SECN Program, addressing the initial need identified as impetus for the project.

Federal, local and state agencies as well as municipalities and non-government organizations involved in coastal water quality monitoring could utilize the tools to identify programs already in place and gaps in monitoring to better target limited monitoring resources.

On a regional scale, the project's water quality database and the portal have timely relevance to the broad community of southeast coastal managers, researchers, planners and constituents as they make significant progress in leveraging and focusing regional associations and partnerships.

Regional and neighboring networks and partnerships that have expressed support and interest in the practical outcomes of the

project include Sea Grant's South Atlantic Regional Research project (SARRP), South Atlantic Marine Fisheries Council (SAFMC), Southeast Coastal Ocean Observing Regional Association (SECOORA), the Gulf of Mexico Alliance (GOMA) and Sea Grant's Mid-Atlantic Regional Research Project (MARRP).

There are additional potential regional partnerships whose participation will enhance the project's utility and viability; these include Southeast Aquatic Resources Partnership (SARP), Southeast and Caribbean Regional Team (SECART) and the South Atlantic Alliance (SAA).

Finally, on the national level, this project provides a solid foundation for the Southeast region to address a nationwide imperative for cost-effectiveness and improved resource management by providing information that will help programs to prevent monitoring duplication and identify data gaps. The projects' tools can play a critical role in regional coordination and sharing of limited resources.



## Literature Cited

- Chipman, M. and Baron, A. 2000. Microsoft Access Developer's Guide to SQL Server. Macmillan Computer Publishing, 864pp.
- Henderson, K. 2000. The Guru's Guide to Transact-SQL. Addison-Wesley Professional Press, 592pp.
- Henderson, K. 2002. The Guru's Guide to SQL Server Stored Procedures, XML, and HTML. Addison-Wesley Professional Press, 800pp.
- Riordan, R. 1999. Designing Relational Database Systems. Microsoft Press, 293pp.



## Appendix A: Technical documentation for the NPS\_WaterQuality database implementation

Complete technical documentation for the NPS\_WaterQuality database version 1.0 (30-Mar-2009) was generated using DBScribe for SQL Server version 1.2 from Leadum Software (<http://www.leadum.com/>). Detailed descriptions of all database objects (i.e. tables, views, stored procedures, functions) are provided, including the SQL Data Definition Language code for each object, as well as all relationships, indices and object dependencies. For security reasons, minimal information is included about database logins, object-level permissions, and server configuration.

The text of the technical documentation is not included in this report due to excessive length (324pp). A printed copy will be provided separately to the National Park Service, and digital versions can be downloaded from the SE Coastal Water Quality Monitoring Metadata Project website in several formats at the URLs below. Note that the Microsoft Word and Portable Document Format versions include hyperlinks and bookmarks to support document navigation.

Microsoft Word 2003: [http://www.gcrc.uga.edu/wqmeta/nps\\_report/NPS\\_WaterQuality\\_Technical\\_Docs\\_v3.doc](http://www.gcrc.uga.edu/wqmeta/nps_report/NPS_WaterQuality_Technical_Docs_v3.doc)

Rich Text Format:

[http://www.gcrc.uga.edu/wqmeta/nps\\_report/NPS\\_WaterQuality\\_Technical\\_Docs\\_v3.rtf](http://www.gcrc.uga.edu/wqmeta/nps_report/NPS_WaterQuality_Technical_Docs_v3.rtf)

Portable Document Format:

[http://www.gcrc.uga.edu/wqmeta/nps\\_report/NPS\\_WaterQuality\\_Technical\\_Docs\\_v3.pdf](http://www.gcrc.uga.edu/wqmeta/nps_report/NPS_WaterQuality_Technical_Docs_v3.pdf)



## Appendix B: Project Partners

Wendy Allen, University of South Carolina  
 William Bailey, United States Army Corps of Engineers  
 Lee Banks, Florida Department of Environmental Protection  
 Shannon Berry, South Carolina Department of Health and Environmental Control  
 David Bosch, United States Department of Agriculture  
 Joseph Boyer, SE Environmental Research Center, Florida International University  
 Marie Bundy, National Estuarine Research Reserves  
 Aisa Ceric, St. Johns River Water Management District, Florida  
 Changsheng Chen, University of Massachusetts Dartmouth  
 Elizabeth Cheney, Georgia Department of Natural Resources  
 David Chestnut, South Carolina Department of Health and Environmental Control  
 Marsha Colbert, Florida Department of Environmental Protection  
 Chantal Collier, Florida Department of Environmental Protection  
 Mary Conley, The Nature Conservancy  
 Jeremy Cothran, Southeast Coastal Ocean Observing Regional Association  
 Linda Crean, South Florida Water Management District, Florida  
 Scott Cross, National Oceanic and Atmospheric Administration  
 Joe DeVivo, National Park Service  
 Eva DiDonato, National Park Service  
 Carl Friedrichs, Virginia Institute of Marine Sciences  
 Janice Flory, Georgia Coastal Research Council  
 Keith Gates, University of Georgia Marine Extension Service  
 Dominic Guadagnoli, Georgia Department of Natural Resources  
 Rodney Guajardo, University of North Carolina FerryMon  
 George Haden, Florida Department of Environmental Protection  
 Patrick Hagan, Sapelo Island National Estuarine Research Reserve  
 Linda Harwell, Environmental Protection Agency  
 Laura Herrin, Florida Department of Environmental Protection  
 Daniel Hitchcock, Clemson University  
 Dorset Hurley, Sapelo Island National Estuarine Research Reserve  
 Jeff Hyland, National Oceanic and Atmospheric Administration  
 Amy Kalmbacher, Florida Department of Environmental Protection  
 Margie Lasi, St. Johns River Water Management District, Florida  
 Brian McCallum, United States Geological Survey  
 Ellen McCarron, Florida Department of Environmental Protection  
 Mike McManus, The Nature Conservancy  
 Jan Miller, St. Johns River Water Management District, Florida  
 Dana Morton, City of Jacksonville, Florida  
 George Myers, Florida Department of Environmental Protection  
 Michael P. O'Neil, United States Department of Agriculture  
 Callie Oblinger, United States Geological Survey  
 Mike Pearson, South Carolina Department of Health and Environmental Control  
 Dwayne Porter, University of South Carolina  
 J.D. Potts, North Carolina Department of Health and Natural Resources  
 Dianne Reid, North Carolina Department of Health and Natural Resources  
 William Richardson, Florida Fish and Wildlife Commission  
 Jay Sauber, North Carolina Department of Health and Natural Resources  
 Doug Scheidt, DYNAMAC Corporation  
 Joan Sheldon, Georgia Coastal Research Council

Mike Shirley, Florida Department of Environmental Protection  
Gail M. Sloane, Florida Department of Environmental Protection  
Tammy Small, Baruch Institute for Marine and Coastal Sciences  
Katy Smith, University of Georgia Marine Extension Service  
Vembu Subramanian, University of South Florida  
Eileen Szuchy, Florida Department of Environmental Protection  
Emma Thompson, National Park Service  
Wendy Tweedale, St. Johns River Water Management District, Florida  
Bon Van Dolah, South Carolina Department of Natural Resources  
George Vellidis, University of Georgia  
Eric Vowinkel, United States Geological Survey  
Steven Wolfe, Florida Department of Environmental Protection  
Susan White, National Oceanic and Atmospheric Administration  
Christina Wright, National Park Service

## Appendix C: Supporting technology developed to populate the NPS\_Water-Quality database

A Zip archive containing all the files can be downloaded from the SE Coastal Water Quality Monitoring Metadata Project web site ([http://www.gcrc.uga.edu/wqmeta/nps\\_report/NPS\\_WaterQuality\\_utilities.zip](http://www.gcrc.uga.edu/wqmeta/nps_report/NPS_WaterQuality_utilities.zip)).

1. MATLAB functions for programmatically mining information from the USGS National Water Information System (NWIS).
  - a. “fetch\_usgs\_inventory.m” – Fetches the USGS monitoring site inventory report for a given state and set of station types in XML format
  - b. “harvest\_usgs\_wq\_parms.m” – Retrieves water quality parameter information for USGS sites and generates a delimited text table for uploading to the NPS\_WaterQuality database
  - c. “parse\_usgs\_eq\_parms.m” – Function called by harvest\_usgs\_eq\_parms.m to parse parameter information from a USGS water quality data inventory web page
2. XSLT 2.0 style sheets for parsing XML station inventory reports from the USGS NWIS to generate tabular data for uploading to NPS\_WaterQuality.
  - a. “usgs\_site\_descriptions.xsl” – Stylesheet for transforming USGS site descriptions to tab-delimited text
  - b. “usgs\_site\_monitoring\_dates.xsl” – Stylesheet for transforming USGS site monitoring date information to tab-delimited text
3. XSLT 2.0 style sheet for parsing NOAA NERR station and parameter information retrieved via web services (see <http://cdmo.baruch.sc.edu/webservices/index.cfm>).
  - a. “exportStationCodesXML.xsl” – Transforms the raw row and column data in the SOAP message to a tab-delimited table
4. GIS data describing the nominal coastal zone polygon used to restrict the scope of the NPS\_WaterQuality database, in ArcGIS, KML and MATLAB file formats.
  - a. “CoastalZone.zip” – ArcGIS shapefile and KML formats in a Zip archive
  - b. “CoastalZone.mat” – MATLAB data structure parsed from the ArcGIS shapefile



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 910/100604, October 2009

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**U.S. Department of the Interior**



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**Natural Resource Program Center**

1201 Oak Ridge Drive, Suite 150  
Fort Collins, Colorado 80525

[www.nature.nps.gov](http://www.nature.nps.gov)