South Florida Water Management District
The Lake Okeechobee Stage-Area-Capacity Lookup Application
(2004—Single Process)

System Summary

The Lake Okeechobee Stage-Area-Capacity (LOSAC) Lookup Application is an intuitive, interactive, and dynamic Web application based on HyperGIS. It displays the current, historical, or hypothetical Lake Okeechobee conditions that include lake stage, area, capacity, and depth information as well as their trends.

LOSAC displays the most current Lake Okeechobee conditions obtained from the real-time lake-stage (water-level) reports on the external Web sites operated by the U.S. Army Corps of Engineers (USACE) and the Operations and Maintenance Department at the South Florida Water Management District (SFWMD). The corresponding lake area and capacity are calculated with both geographical information system (GIS) and a mathematical method based on a polynomial stage-storage function. The results are converted to various units to satisfy most users' needs. Based on a digital elevation model (DEM), a bathymetry map illustrates the related depths in the lake at the given stage; while a stage-area-capacity chart presents stage-area and stage-capacity curves that reveal the changing area and capacity along with the corresponding stages. Precise readings to the lake conditions are included in a table. In addition, LOSAC features a dynamic playback of time series of archived data of the lake, and direct retrieval of historical data with a calendar. Using animated buttons, users can browse back and forth through the stage data in the archive and display associated stage, lake-area, capacity, and bathymetry data. A rapid-mode playback shows the changes of the lake over time. The archive is updated regularly. The interactive Web interface of LOSAC also allows users to look up the lake-area and capacity data by entering a hypothetical lake stage or dragging a slider bar.

Prior to its development, the current and historical water-level data were available only in static text format on separate sites. Users had to use half a dozen individual GIS and mathematical tools to build lake-area and capacity information, and manually assemble them from different departments and agencies. LOSAC automates the whole process by integrating Active Server Page (ASP), MS SQL Database, and GIS with a front end built in Dynamic HTML (DHTML), JavaScript, and Visual Basic script, serving as a one-stop source for the current, historical, and hypothetical lake conditions with dynamic contents by an interactive and fun-to-use graphical user interface (GUI) (see Figure 1).

The core of LOSAC is an agent capable of collecting real-time data from partners' Web sites without interfering or burdening the information providers, resulting in a more efficient information flow. It supports multiple modeling methods to calculate the lake conditions in various formats, which is valuable both to the researchers for better understanding of the real-world situation and to the managers for better decision-making processes. LOSAC employs reusable modules, which allow easier function expansion, better background data upgrade, and easier switching between

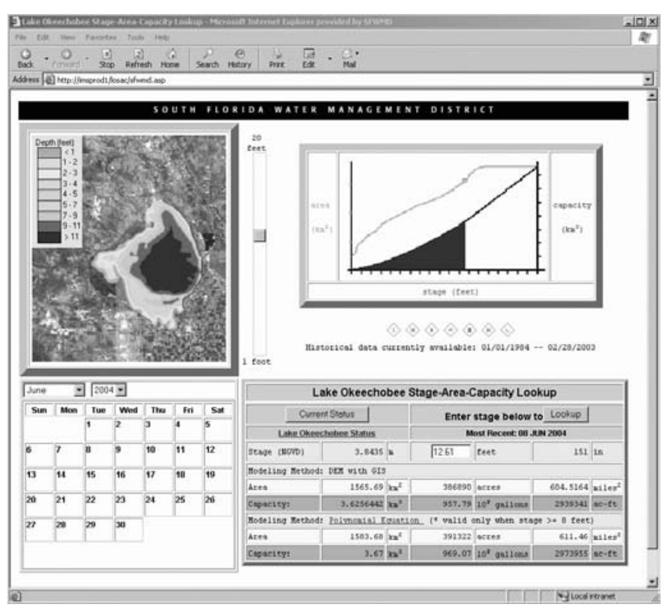

Figure 1. LOSAC GUI

external information providers in case of system downtime or a network outage. Such an object-oriented approach can save time and money in developing, maintaining, and upgrading the system, and in improving the system's reliability. It is also easy to customize information for different users, enrich static contents with multimedia or animation, and expand contents into other formats for mobile devices for more effective communications. The browser-detection technique can serve customized contents tailored for a particular browser. The result is an integrated system that can provide an intuitive, dynamic, and interactive visualization tool for restoration scientists, water-supply planners, emergency managers, and anyone else who needs to access the current, historical, or hypothetical Lake Okeechobee conditions.

Motivation for System Development

LOSAC grew out of popular demand for water-level, lake-area, and potential water-supply-capacity information in Lake Okeechobee during the unusual water shortage period in 2000–2001.

During this water shortage period, water managers in charge of the water supply needed to know the water-supply capacity of the lake. By calculating the volume between the current water level and the bottom of the irrigation gates, and comparing it with the current water usage, water managers would know how long the outflow by gravity could last, and how soon and how many pumps would be needed to boost water supply. For the general public, a major interest was the information on accessibility to the lake. Some docks and ramps were located on dry lake beds for quite a few months, which made launching a boat for bass fishing impossible. Meanwhile, researchers were busy feeding data to their models simulating various lake-management scenarios to predict future water conditions. At the time, the task of providing lake information was less coordinated and usually resulted in redundancy and inconsistency. Many departments relied on static maps to respond to public inquiry. Exchanging data between models was a highly specialized chore because of the variety of data formats involved in the models and the lack of a method to describe data meaningfully. The field data were heterogeneous and distributed in nature, owned and managed by different departments or even different agencies.

Given the competing demands and the complexity involved, a more efficient and effective GIS approach, which would result in reducing redundant development efforts, reusing resources, simplifying maintenance efforts, and functioning dynamically in real time, was urgently needed.

System Benefits Achieved

LOSAC brought the following major system benefits:

1. Improved the decision-making process by reducing the delay in accessing information, by making otherwise unavailable information accessible, by making information more comprehensible and thus more effective, and by providing information in alternative methods and units.
2. Improved productivity by eliminating the needs to visit multiple sites and send requests to multiple departments to get all the information, by eliminating the redundancy of re-creating similar information by multiple departments, by providing users with instant results rather than taking days to produce similar information with traditional methods, and by requiring less staff time and resources to develop and maintain such a system.
3. Potentially increased user base by more than a thousand times without incurring additional costs to the SFWMD and the users.

Some unexpected benefits also occurred. First, because reusable modules and objects were employed, we were able to easily add a second modeling method of polynomial equation in addition to the original GIS method by DEM. Next, with the existing data in the SQL server, it was very easy to add extra queries to answer additional questions about the historical lake conditions such as the highest, lowest, and average lake levels during a given time period. Moreover, we were able to reuse those modules later in a new geographical region—Lake Istokpoga—for a study of potential restorable wetlands.

Overall, LOSAC showcased an integrated GIS method that can save time and money, improve the effectiveness and the efficiency of information flows, and consequently improve the decision-making process.

System Design Issues Encountered and Overcome

Developing LOSAC involved four phases: inception, elaboration, construction, and transition. The inception phase was directly motivated by the needs to respond to the distinctive requests for the basic lake conditions about Lake Okeechobee during the water shortage period. The objectives were to present the current lake status including water level, lake area, and potential capacity of water supply in a timely manner, and to provide a more efficient and effective way in delivering such spatial information. Elaboration led to a better understanding of the problems. After analyzing the system requirements, case diagrams were used to sort out all required system functions so that all the potential scenarios for the system uses were discovered and documented. During the elaboration, we kept a conceptual perspective in outlining the domain analysis of the lake conditions. Understanding the interaction between the objects such as controls, bathymetry map, and stage-level-capacity chart was beneficial in exploring how various system components would interact within the system. Further elaboration, investigating the resources and constrains in technology, skills, and time, paved the way for an iterative construction, which was a series of iterations for construction, defining the functionality to be delivered in each of the iterations. Compared to a one-time release near the delivery date, which may pose a risk should there be a failure, an iterative construction has frequent and smaller releases that are based on previous successful releases. Thus, its incremental implementation is more predictable and manageable with more control of risks. For example, we built a GIS method for calculating the lake area and capacity first, then added polynomial function in the next iteration. In the transition phase, there was no development to add functionality but to fix bugs and optimize performances.

In particular, the system was at first designed as a desktop application that was built with ArcObjects and relied on a full ArcGIS license for each desktop client. Thus, it limited the user base because of the cost and complexity in deployment. Later, a modified desktop application was developed using a GIS agent to generate maps and output data in XML, thus requiring no ArcGIS license to run. It expanded the user base because of its reduced cost. However, it still inherited complexity from the desktop application deployment. We redesigned the system as a Web-based application so that more users can be served. The new design uses an ASP-based Web agent to process information from external http servers and an internal SQL server to produce dynamic and interactive presentation, with an ArcObjects-based desktop application as an additional agent for back-end support and update of base maps.

What Differentiates This System from Other Similar Systems

1. Real-time capacity and balanced client-server function loads. The core of LOSAC is a HyperGIS agent capable of collecting real-time data from partners' Web sites without interfering or burdening the information providers, resulting in a more efficient information flow. LOSAC used optimized function allocation between the server side and the client side. While the server side provides up-to-date information, the client side handles local interactivity with users. This approach results in a system that runs very fast with full interactivity.
2. Multiple modeling methods. LOSAC supports multiple modeling methods to calculate the lake conditions in various formats, which is valuable both to the researchers for better understanding the real-world situation and to the managers for making better decisions.
3. Reusable modules and objects. LOSAC employs reusable modules, which allow easier function expansion, better background data upgrade, and easier switching between external information providers in case of system downtime or network outage. Such an object-oriented approach saves time and money in developing, maintaining, upgrading, and expanding the system, and improving system reliability. Also it can be configured for use in another geographical region.
4. Customizable and expandable interface. It is also easy to customize information for different users, enrich static contents with multimedia or animation, and expand contents into other formats for mobile devices for more effective communications. The browser-detection technique can serve customized contents tailored for a particular browser.
5. Improved user-friendly interface and greater error tolerance. LOSAC uses smart browser-type and screen-resolution detection techniques to maximize users' online experiences. When an incompatible browser or screen resolution is used, warning messages will be displayed and corrective actions are suggested. LOSAC implements extensive DHTML controls to aid user navigation. In addition to traditional command buttons and an input box, a slider bar and a set of animated buttons provide users with total control and make the application fun to use. LOSAC also uses extensive tool tips to give users additional information when they move the cursor over to an object such as a control button or a map. Users will be given correct ranges if their inputs are out of boundary.
6. Expanded user base. LOSAC fundamentally changed how the information on Lake Okeechobee conditions was delivered. Because of staff and resources limitation, only a tiny portion of potential users could be supported by making paper maps and reports. The original desktop version by ArcObjects automated the process, but it still limited the user base to those who were proficient in GIS use and had the luxury of accessing expansive GIS software. The modified desktop version helped increase the user base by reducing the reliance on the special GIS software. However, only the Web-based LOSAC enables the user base to expand exponentially without incurring additional costs to the SFWMD or to the taxpayers. Also, the visual-pleasing interface helps attract new users as well as old users who were discouraged by previous hard-to-use interfaces.

System Hardware, Software, and Data

Hardware:

Hardware configuration supporting the system includes: a Windows Server to host MSSQL and IIS Web Server with ASP agent, a Windows workstation to host the VB/ArcObjects desktop agent, and external HTTP servers from other departments or outside agencies.

Software:

Primary software components include: ASP 3.0, MS SQL Server 2000, IIS Web Server 5.0, VB/ArcObjects, andXML/DHTML.

Data:

Databases used by the system include:real-time lake-stage data from external http servers, lake-bottom elevation data in shapefile, stage-area-capacity table derived from elevation data in XML/SQL, SPOT image as background, bathymetry maps generated by the VB/ArcObjects desktop agent, and stage-area-capacity charts generated by the VB/ArcObjects desktop agent.

Where Are We Now?/Future Directions

Modularized development used in LOSAC allows easy expansion of the data and functions, even porting the whole application to a new geographical region with minimal modifications. Since LOSAC was submitted to the ESIG award review in 2004, it had been successfully modified and reconfigured for use in another geographical region as the Lake Istokpoga Stage-Area-Capacity (LISAC) Lookup Application for a study of potential restorable wetlands, because of the reusable modules and objects. Also notable was that LOSAC had been online and performed well during the 2004 hurricane season when three major hurricanes directly impacted the Lake Okeechobee watershed.

The current update is due to the vertical datum conversion from the National Geodetic Vertical Datum 1929 (NGVD 29) to the North American Vertical Datum 1988 (NAVD 88) at SFWMD. We currently register water elevations including lake stages relative to NGVD 29. The conversion to NAVD 88 will allow us to align our data standard with other federal agencies and provide a consistent vertical elevation base for scientific data analysis and modeling. Background data in LOSAC can be easily upgraded to NAVD 88 after applying an offset grid onto the original grid in NGVD 29. The VB/ArcObjects desktop agent will then generate a new set of XML data and maps for use in LOSAC. While the upgrading process is transparent to users and requires no users' action, users will notice and appreciate the immediate improvement. To ease the transition for users, we plan to add a dual-view panel that displays bathymetry maps and related vertical data in both NGVD 29 and NAVD 88.

The other updates under consideration are based on survey feedback from users on what additional features they wish to have. Among them are: support for more browsers such as Firefox; function to plot time series of water level, lake area, and capacity; zoom and pan functions to the bathymetry map; output in PDF; direct download of time series data and GIS data; selectable background thematic layers such as roads, county boundaries, public-use facilities, etc.

Another exciting feature would be implementing Really Simple Syndication (RSS) feed. Until now, uses of RSS are limited to news organizations and Web blogs for syndication where a portion of their contents are made available for others to use. An RSS feed is a set of XML files that provides a short summary along with a universal resource locator (URL) to the full contents. An RSS feed reader or aggregator can check RSS-enabled Web pages on behalf of a user and display any updated contents that it finds. Thus, by providing an RSS feed, LOSAC allows users to set up certain criteria for notification of the updates of the lake conditions via e-mail or mobile device when certain user-specified thresholds are exceeded, thereby saving users from having to repeatedly visit LOSAC to check for new updates. Users can also take the RSS feed from LOSAC as an input for building their own models or customized Web pages.

Future integration to real-time rainfall radar NEXRAD data and ArcHydro watershed models will truly open the door for a realistic lake dynamic simulation under various given water-management scenarios.

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