Caloosahatchee River West Basin Storage Reservoir: Geographic Information System Applications for Quality Assurance and Quality Control

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The Caloosahatchee River has experienced the consequences of altered flow patterns and degraded water quality as the natural system hydro patterns were affected by development over time. Large influxes of fresh water due to Lake Okeechobee discharges and heavy rainfall during the wet season (and reduction in flows in the dry season) have impacted the delicate balance of salinity levels in the Caloosahatchee Estuary.

The South Florida Water Management District (SFWMD) is responsible for implementing projects for the Comprehensive Everglades Restoration Plan (CERP) to help improve water quality and regulate water flows into the Everglades system. Located on 10,700 acres of former citrus grove in Hendry County, the Caloosahatchee River West Basin Storage Reservoir (C-43 Reservoir) will store approximately 57 bil gal (~170,000 acre ft), for the Congressionally authorized CERP project. The $800 million project, expected to be completed in 2024, will include construction of two 5000-acre reservoir storage cells (cells 1 and 2), three pump stations, a perimeter canal with several water control structures, and required improvements to the State Road 80 Bridge and the Townsend Canal, ultimately connecting to the Caloosahatchee River.

Given the immense effort to construct the project, this article will focus on automated data collection systems using geographic information system (GIS) applications for quality assurance and quality control (QA/QC). The resulting data collection efforts must be efficiently organized and effectively documented in order to produce the final dam completion report in accordance with U.S. Army Corps of Engineers (USACE) guidance for dam safety.

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Project Background

Everglades Restoration Strategies Plan

The Caloosahatchee River and Estuary, shown in Figure 1, includes an important estuarine and marine ecosystem that contains aquatic preserves, along with several other federal, state, and local parks and recreation areas. Restoration of a healthy, productive aquatic ecosystem in the river is essential to maintaining the ecological integrity and associated economic activity in these publicly owned and managed areas.

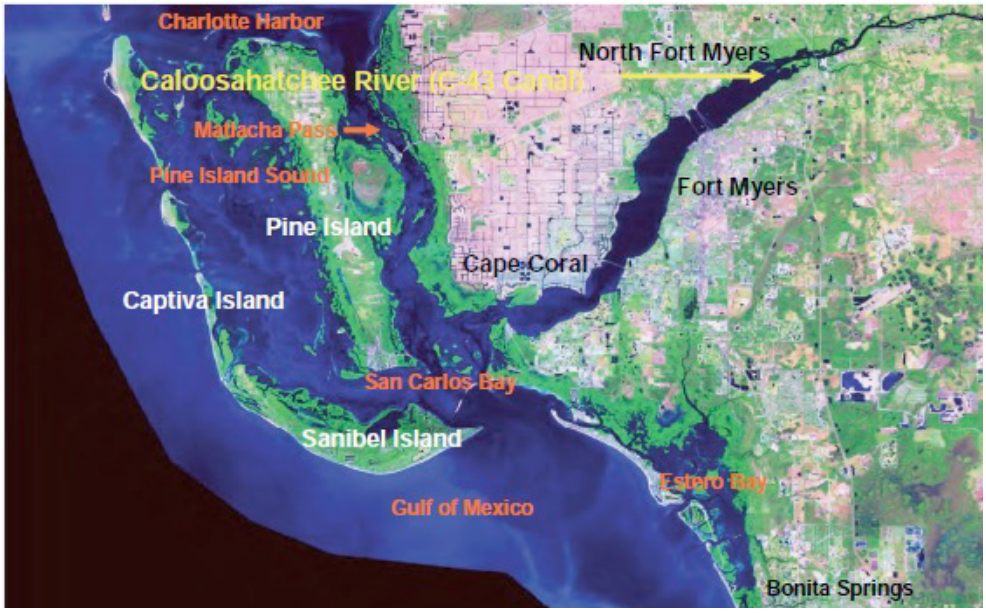

Figure 1. Caloosahatchee Estuary *(source: USACE, Reference 1)*

The C-43 Reservoir, shown in Figure 2, was originally authorized in accordance with the requirements of Section 601(d) of the Water Resources Development Act of 2000 (WRDA, 2000).

In October 2003, SFWMD initiated the Acceler8 Program to move forward with major CERP reservoir projects in parallel with the development of the project implementation report by USACE. The project was shelved in 2008 due to the downturn in the United States economy, and, in 2014, it was resurrected and implemented as part of the SFWMD restoration strategies program to finalize design and initiate construction on the C-43 Reservoir.

Lessons learned from the levee failures after Hurricane Katrina resulted in the project being redesigned to incorporate the updated engineering standards from USACE. The project is being incrementally delivered as each of the contracts are redesigned and moved forward into construction.

The purpose of the C-43 Reservoir project is to assist in the restoration of the Caloosahatchee Estuary as part of CERP for restoring the south Florida ecosystem. The volume in the two-cell

reservoir includes normal pool depths (when the reservoir is full), varying from 15 ft at the southeast corner to 25 ft at the northwest corner. Major features of the project include external and internal embankments, canals, pump stations, water control structures, and environmentally responsible design features. Some water quality benefits may be realized in the Caloosahatchee Estuary, since some of the nutrient-laden runoff and lake water will be stored in the reservoir, allowing for the settling of nutrients within the reservoir cells prior to delivery to the estuary.

C-43 Reservoir Project Site Location and Conditions

The C43 Reservoir project site is located west of the City of LaBelle in Hendry County, south of SR 80 and along the C-43 Canal, and approximately 30 mi east of Fort Myers. The reservoir is about 6 mi long and approximately 3 mi wide and averages approximately 17 ft deep. The top of the perimeter dam is at an elevation higher than 54.5 ft North American Vertical Datum (NAVD). The bottom of the reservoir varies from approximately 16 to 26 ft in elevation.

Most south Florida water storage facilities experience excessive seepage flows. The C-43 Reservoir site geology consists, primarily, of a thin and variable surface layer of top soils, underlain by sands and clayey sands down to a deposit of clays of marine origin. This formation, which comprises the bottom impermeable layer, generally extends from about 0 to -20 ft. The formation is an area of unique geological character in south Florida, and when combined with a soil bentonite cut-off wall, the reservoir will efficiently "hold" water.

The project will help to reduce the frequency and intensity of harmful freshwater discharges into the Caloosahatchee Estuary. Once completed, the project will provide immediate environmental restoration benefits by:

- Capturing and storing stormwater runoff from the C-43 Basin and regulatory discharges from Lake Okeechobee, thus reducing excess freshwater flows to the estuary.
- Helping to maintain a desirable salinity balance by controlling peak flows during the wet season and providing essential freshwater flows during the dry season.
- Helping to sustain a healthy estuarine nursery that supports recreational and commercial fisheries.
- Reducing nutrient loading to the Caloosahatchee Estuary, an incidental benefit resulting from settling of nutrient-rich particulate matter in the reservoir.

The SFWMD is currently collaborating with USACE to build the reservoir project to current state and federal dam safety standards.

Figure 2. Caloosahatchee Watershed *(source: USACE, Reference 1)*

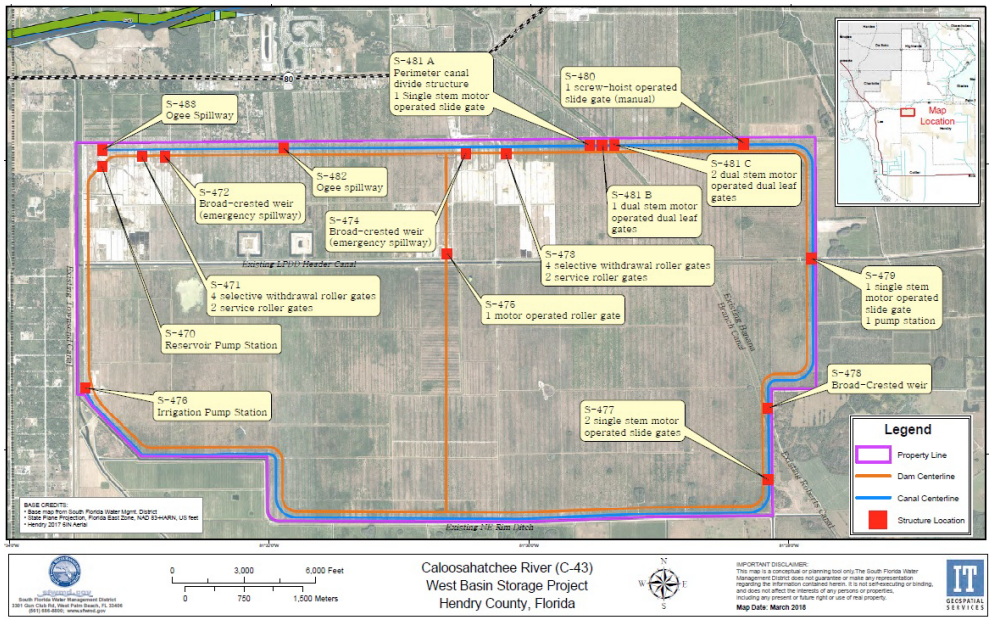

Figure 3. C43 Reservoir Project Site Plan

The project will be executed in four construction packages, which are currently underway:

- Package 1 – Preloading and Demolition: Construction complete
- Package 2 – Bypass Pumping Station S-476 (195 cu ft per second [cfs]): Construction complete
- Package 3 – Inflow Pump Station S-470 (1500 cfs): Construction underway
- Package 4 – Reservoir and Water Control Structures: Construction underway

Design and Construction Overview

The design and construction of the project includes improvements to the existing Townsend Canal and serves as a direct connection from the reservoir to the Caloosahatchee River. An improvement to the level of flood protection and preservation of water supply for the surrounding agriculture is an added requirement of the project. An overall site plan of the project is shown in Figure 3.

Project Design and Construction

C-43 Reservoir: Construction Package 4

Designed to contain an average depth of approximately 17 to 18 ft, the reservoir is expected to store more than 170,000 acre ft of water. The water will be captured during wet season releases and released during dry season demand.

Characteristics of the site include:

Continued on page 36

Continued from page 35

1. It's a large, rectangular, contiguous piece of land close to the Caloosahatchee River (C-43 Canal).
2. A connection to the C43 Canal exists through the Townsend Canal under SR 80 and to the C-43 Reservoir (within approximately 1 mi).
3. Townsend Canal, with some improvements, has the required conveyance capacity to operate the reservoir.
4. It's in the approximate middle of the C43 Canal drainage basin.
5. The geologic formation beneath the reservoir footprint contains a clay (relatively impermeable) layer within 20 ft of the surface and runs relatively consistently across the entire site (see the general soil profile in Figure 4).
6. The dam is classified as a high hazard above ground impoundment and is surrounded by sparse development to date. Impacts to the local community were minimized during the design of this project.

The dam's typical cross section is shown in Figure 4. As noted, the majority of the embankment materials will be excavated and reused onsite. The soil cement drainage, chimney, and blanket drains will be constructed of imported materials produced at a nearby aggregate pit determined to be suitable for the project. The soil bentonite cut-off wall extends from EL +47 (the top of the red bar, within the top one-third of the dam embankment) and 5 ft into the clay layer below the reservoir. The soil cement is proposed to be 12 in. thick and will be batched onsite utilizing existing surficial sandy materials determined to be sufficient for design.

The C-43 Reservoir is surrounded by a perimeter canal, tow roads, and maintenance roads. There are over a dozen water control structures in the perimeter canal, and in the dam itself, to regulate discharges and manage water supply and stormwater from the adjacent properites. These structures include numerous gated culverts, gated spillways, uncontrolled emergency spillways and wiers, ogee weir discharge structures, and bridges.

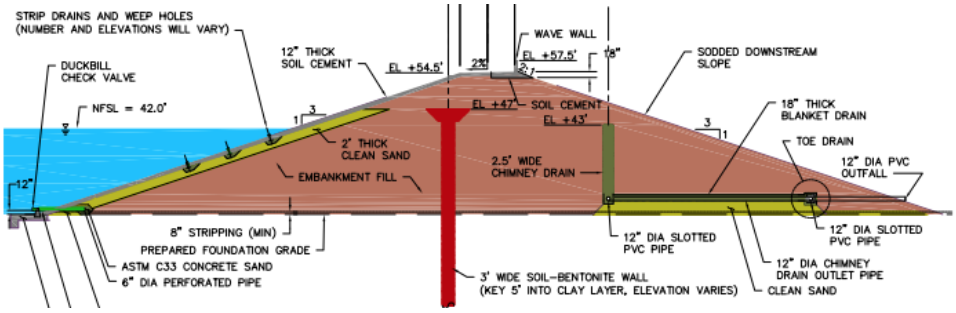

Figure 4. Typical Cross Section of the Dam at the C-43 Reservoir

Quality Assurance and Quality Control

The reservoir dam embankment is classified as a high-hazard embankment, and early in the redesign phases of the project, SFWMD recognized the need for a robust QA/QC program. As the project is federally cost-shared, the project design was conducted in accordance with the USACE dam safety policy and procedures outlined in ER 1110-2-1156, along with other applicable USACE design guidelines. The contract documents included a detailed and comprehensive QA/QC plan as part of the specifications that followed the USACE three-phase control system. Definable features of work (DFOW) were pre-established in the contract to clearly identify individual activities and specific locations of work to be entered into the quality process. Each DFOW represents a specific feature of work as generally identified by the contract specification work items. There were over 100 DFOW identified in the design and they included all aspects of the project's construction activities, including foundation, embankment, soil bentonite, concrete, and electrical and mechanical features. The DFOW checklists were preprepared to serve as inspection sign offs for each feature as the project is completed.

Due to the sheer size of the project, the reservoir was divided into segments and individual structures (Figure 5). The DFOW checklists were then assigned to each specific segment of the dam and each structure.

As a result, the data collection and data management efforts are anticipated to be very

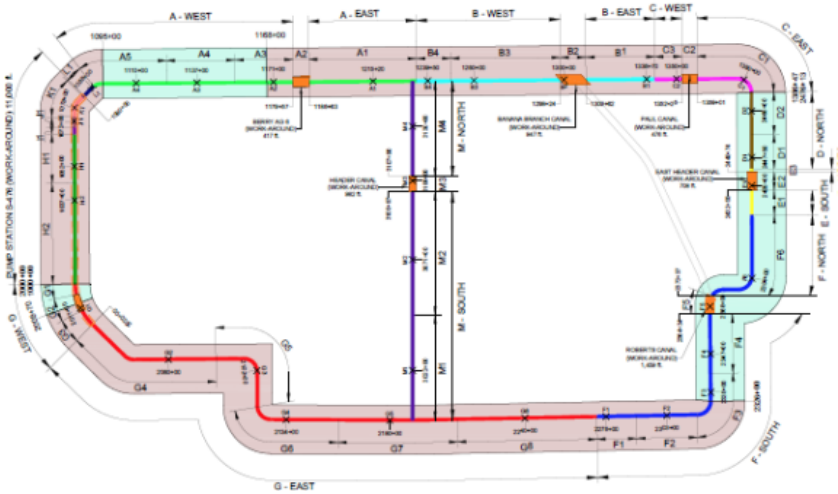

Figure 5. Dam Segments

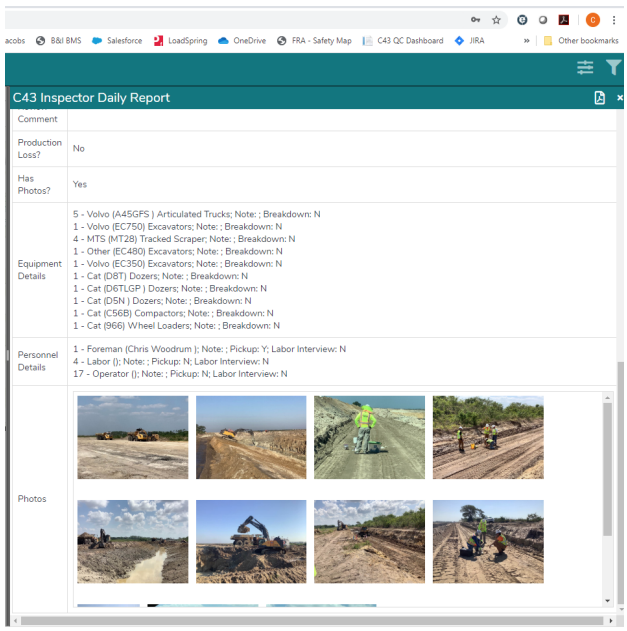

Figure 6. Inspector Daily Reports

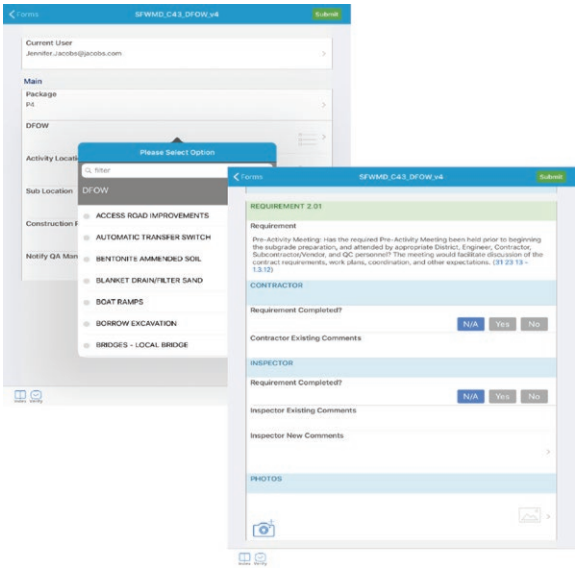

Figure 7. Definable Features of Work Checklists

Figure 8. Drone Photography for Foundation Preparation

significant. It's expected that the project will generate over 100,000 data records to properly document construction. The project requires that a completion report be developed consistent with the requirements of ER 1110-1-1901, "Project Geotechnical and Concrete Materials Completion Reports for Major USACE Projects." This completion report will serve as a record of the quality activities associated with the construction of the project and will be used as future reference for dam safety inspections and evaluations for the reservoir.

Efficient and effective project completion report development requires an automated system of data collection, sampling, testing, reporting, and display. The intent is to have all of the inspector daily reports, inspection test plans (ITPs), quality management systems (QMS) data, and inspection/DFOW checklists consistent with the three-phase process and integrated into an automated data collection system.

During contract document development, the SFWMD worked with USACE to develop a data management specification requirement to effectively manage the vast amounts of data expected to be generated by the QA/QC teams. The USACE developed SIMDAMS®, a GIS database system to store and display data associated with construction and maintenance of USACE dam projects. The SFWMD developed its own GIS-based platform that included significant enhancements to capture and display a wider array of data and make it user friendly for the construction and QA management teams. Data will be extracted from the SFWMD site and translated to the SIMDAMS format for delivery to USACE.

Geographic Information System Applications for Data Collection and Display

The SFWMD platform is composed of a comprehensive and cutting-edge set of technology solutions that support field data collection and multi-user editing, as well as QC. Ultimately, these data are consolidated into a Microsoft SQL Server-based QA dashboard that's accessible to the team via a password-protected, role-based website.

The platform integrates the various records and data collected from the project site and displays real-time data in a format easily viewed and analyzed by the project team, including the engineer of record, construction management teams, QA/QC teams, and inspectors. The reports that feed into the QA dashboard include:

- Inspection Daily Reports
- DFOW Checklist
- Foundation Preparation and Mapping
- Proof of Concepts
- Materials Testing (QMS)

Inspector Daily Reports

The inspector daily reports (IDRs) are collected in the field using tablet devices with digital forms that can be populated offline and later synchronized to the QA dashboard when a Wi-Fi network is available. Forms automatically track the data and user names are based on preset variables to the degree possible in order to maintain QC for data entry. Photos associated with forms are also tagged with location details for display in the QA dashboard (Figure 6).

Definable Features of Work Checklists

The DFOW checklists consist of a list of critical requirements associated with a particular feature of work on the site. These checklists are also collected in the field and have the same basic functionality as the IDRs; however, these forms are available to both contractors and inspectors and are password-protected and role-based. A contractor can update the status of a particular requirement and provide a description and photos of the work being completed. Upon syncing these forms with the QA dashboard, inspectors can view contractor comments on tablets or the QA dashboard and provide their own comments and photos. A DFOW requirement is not considered to be complete until QA/QC is marked as complete in the form (Figure 7).

Foundation Preparation and Mapping

The initial application of the dashboard has been the foundation preparation and mapping DFOW. Data collected during the foundation preparation and mapping phase of the project are transmitted for storage in the SQL database, and some are linked to the QA dashboard through the document library on the SFWMD SharePoint site. These files include location details used to link to the QA dashboard map. Users can identify a location of interest and link back to the SharePoint repository to retrieve associated documents, including drone imagery and documents provided by the engineer of record (Figure 8).

Proof of Concepts

In addition to foundation preparation and mapping, there are several proof of concepts activities to verify construction means and methods results in the intended engineered quality.

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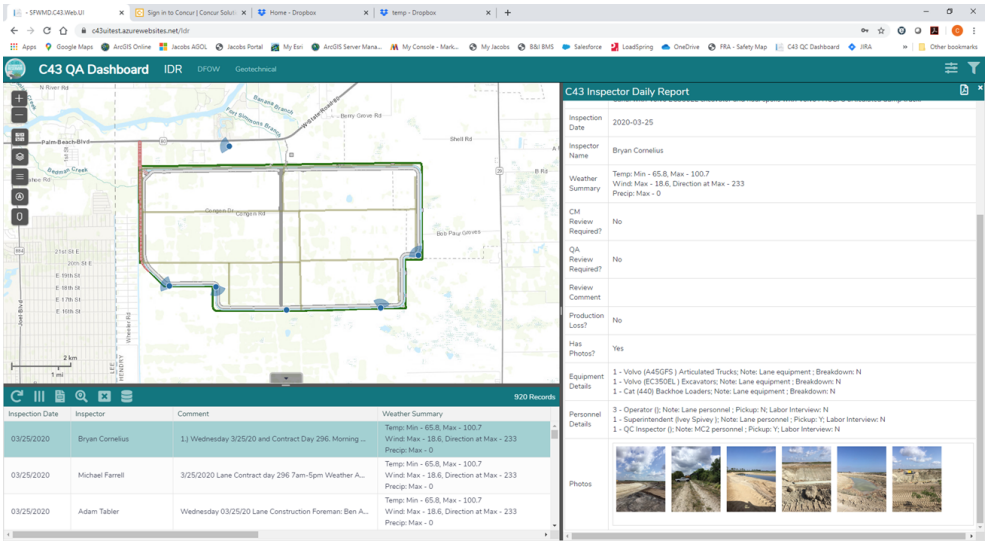

Figure 9. C-43 Quality Assurance Dashboard

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These activities precede the full production construction of features in order to gain insight into how the finished product will be built and make adjustments to construction and QA/QC procedures, if required. The proof of concepts will be shown separately in the QA dashboard and are available for reference to the team.

These proof of concepts include:

- Foundation Preparation and Mapping (described)
- Soil Bentonite Cut-Off Wall Construction
- Drains and Filters
- Embankment Construction
- Sand Relief Columns
- Soil Cement Slope Protection

Materials Testing and Quality Management System

The QMS is a proprietary system developed for field and laboratory test data management, which allows for electronic review, acceptance, and reporting. It plays a significant role in data management.

The SFWMD and the contractor have constructed QA and QA materials testing laboratories on the project site, which are USACE-validated materials labs and will handle sampling and testing anticipated during the course of construction. The labs are equipped with state-of-the-art materials testing equipment for soils, slurry walls, and concrete. Both the SFWMD QA and contractor QC will have access to the QMS, designed to schedule, track, and record/report all materials testing collected onsite. Data collected in the QMS system are posted to the SFWMD SharePoint site daily and published on the QA dashboard using a scheduled automated process. The test results are associated with the map locations and can be searched, filtered, and queried by a number of attributes. The site also provides sliders to select specific ranges for date and elevation of tests to be displayed.

C-43 Quality Assurance Dashboard

All data collected in the field forms or QMS system and posted to the SFWMD SharePoint site are consolidated into the QA dashboard. This website is password-protected and role-based, and users can view IDRs, DFOW checklists, or geotechnical testing results (Figure 9). The summary data are displayed in a tabular grid and are associated with locations on a map; more-detailed views of the data can also be displayed in a details pane. Photos collected during inspections are published with locations and bearing details on a map. The site also allows users to filter, sort, and query the data to find specific information. Additional functionality is available to the construction and quality managers that allows for review and approval of submitted forms.

Completion Report

The completion report will be generated based on USACE requirements in ER 1110-1110-1-1901, "Project Geotechnical and Concrete Materials Completion Reports for Major USACE Projects."

The data will be pulled from the QA dashboard using the history and attributes from GIS and SharePoint document libraries in order to efficiently generate this document and maintain a high level of quality, given the anticipated size of the data repository. This completion report will serve as a record of the quality activities associated with the construction of the project and will be used as future reference for dam safety inspections and evaluations for the reservoir.

Summary and Conclusions

This article presented the C43 Reservoir project and reviewed the project design and construction features to help restore America's Everglades. Sustainable project features include capture of stormwater flows and storage for use in dry season flows to the Caloosahatchee Estuary. Given the size of the project and the vast volumes of data to be collected, organized, reviewed, and documented, a custom automated data collection system was established. Integrated with GIS tools developed by Jacobs, the project can effectively and efficiently collect and store the mountains of data for visual display in the C43 dashboard created specifically for this project. The data will then be converted to the USACE SIMDAMS model for record of construction on this very important project.

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- Terracon Inc. (geotechnical engineering lead)

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