Integrated Hydrologic Modeling for Wetland Restoration - Lessons from the Picayune Strand Project

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Overview

The Picayune Strand Restoration Project (PSRP) is the first Comprehensive Everglades Restoration Plan (CERP) project under construction. The project involves the restoration of natural water flow across a 55,000 acres area in western Collier County in southwest Florida. The project area was drained in the 1960s in anticipation of extensive residential development. The canal and road infrastructures associated with the development drastically altered the natural landscape, changing a healthy mosaic of upland and wetland ecosystem into a distressed environment. Wetlands and historic sheet-flows in Picayune Strand and in adjacent public lands will be restored by plugging of canals and removal of roads, while maintaining the existing level of flood protection by a network of pump stations and levees (Fig. 1).

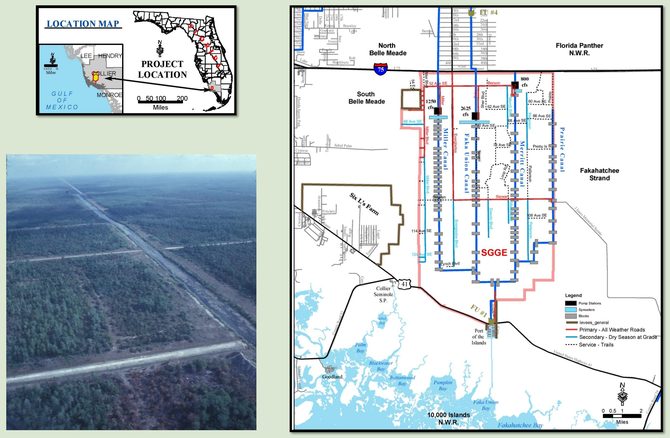

Fig. 1. Location of the Picayune Strand Project Area

Hydrology in Project Area and Intricacies of Modeling

The project area is typical of humid subtropical climate. Annual rainfall averages 53 inches and varies from a low of 30 inches to a high of 105 inches. Nearly 80 percent of the annual rainfall occurs during May through October. Most of the rainfall is returned to the atmosphere by evaporation from soil and free water surfaces, as well as transpiration through plants. Under natural conditions, the combined process of evapotranspiration accounts for an approximate loss of 45 inches of water per year, making only about 8 inches of average annual precipitation available for surface runoff and groundwater recharge.

The flat topography, very porous marly soils and seasonal rainfall cycle dominates the surface and groundwater hydrology of the area. The flat topography with very minor gradients result in a gentle, broad, slow-moving overland sheet flow a few inches to a few feet deep across the landscape during much of the wet season. Water flows in a general southerly direction, curving slightly to the south-southwest as it approaches the coast. The range of annual fluctuation in water levels above and below ground and the duration of inundation are the primary factors influencing plant communities. There is a strong interconnection between surface water and ground water (Fig.2). The traditional hydrologic-hydraulic modeling methods of representing the physical and climatic characteristics of the area was found unsatisfactory. Hence, coupling the surface and subsurface flow phenomena in an integrated fashion had to be applied to represent the unique hydrology of Picayune Strand.

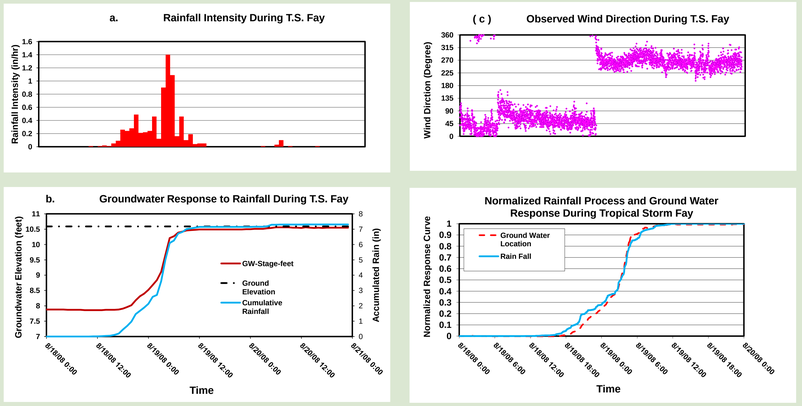

Fig. 2. Interaction between surface water and groundwater - observed rainfall and groundwater table response during Tropical Storm Fay (August 18 – 21, 2006.)

Major Hydrologic Modeling Efforts

From the early 1990s there has been numerous hydrological-hydraulic modeling efforts to investigate the best way to evaluate the restoration measures of Picayune Strand. These efforts have evolved through continual refinement, testing of the different available modeling tools; recalibration with newly procured data on topography, land use, soils, vegetation, canal-floodplain cross-sections, water use and related hydrogeological property, and monitored data, and most importantly, the improved understanding of the restoration targets.

Table 1. Summary of Major Modeling Efforts in the Picayune Strand Project Area

Modeling Phase	Modeling Tool	Time Conducted	Model	Major Results
Pre-CERP I	HSPF, MODFLOW	1994-1996	1D	Hydrologic Restoration of Southern Golden Gate Plan, 1996
Pre-CERP II -A	SWMM & UNET	1998-1999	1D	Flood Hydrology
-B	WETFLOW	1999	2D	Memo: Hydrodynamic Simulation of flow patterns for SGGE, 1999.
-C	MIKESHE/MIKE11	2000-June, 2002	Integrated Model 3D	Integrated Surface and Groundwater Hydrologic-Hydraulic Modeling Report
CERP - PIR	MIKESHE\MIKE11	June, 2002 - 2004	Integrated Model 3D	Final Integrated Project Implementation Report and Environmental Impact Analysis (PSRP PIR Report)
CERP - Accelerat8 Phase 1	MIKESHE\MIKE11	2006 - 2008	2D	Hydraulic Design Tool – Basis of Design Report for Pump Stations, Levels, Canal and Roads
Phase 2	MIKESHE\MIKE11	2008-2010	Integrated 3D	Preliminary Hydraulic Design Tool for Protection Features
CERP – Protection Features	GSSHA	2010-Date	2D	PSRP protection feature design (continuing)

The Role of Hydrologic Modeling in PSRP

- Formulate the best way to restore the pre-development hydrology without adverse social, economical and environmental impact to the upstream, downstream and adjacent landowners and ecosystems.
- Due to very close interaction of surface and groundwater flows in the region, evaluation of pre-development, existing and restored hydrologic conditions involved dynamic simulation of the surface and ground water flow characteristics in an integrated fashion
- The integrated surface water and groundwater modeling tool MIKESHE\MIKE 11 was selected as the tool to evaluate effectiveness of restoration measures
- More than 20 alternatives initially formulated and simulated, three alternatives warranted further modeling investigations before the final plan selected
- Supported the efforts on PIR report, Basis of Design Report, and Water Reservation Rule making documents.

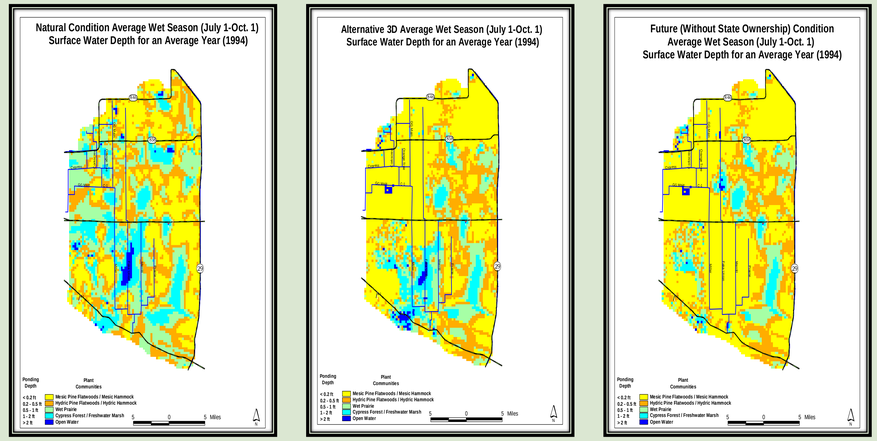

Fig. 3. The simulated average wet season water depth used to evaluate the vegetation communities

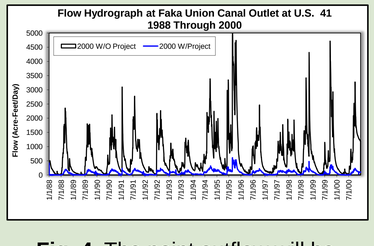

Fig. 4. The point outflow will be reduced to less than 12% of current flow

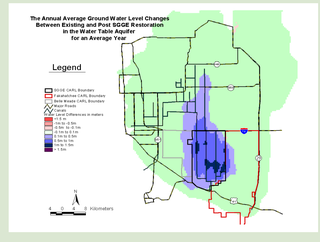

Fig. 5. The PSRP will increase groundwater recharge and storage

Summary

- Two decades of strenuous hydrologic-hydraulic modeling had proved to be critical in developing the project from initial plan formulation to project implementation.
- Due to very close interaction of surface and groundwater flows in the region, evaluation of pre-development, existing and restored hydrologic conditions involved dynamic simulation of the surface and groundwater flow characteristics in an integrated fashion. The application of modeling tool MIKESHE \ MIKE11 proved to be a very effective in representing the unique hydrologic process of PSRP.
- Models are the theoretical formulation of a landscape and the mathematical representation of the hydrologic processes. In spite of reasonable calibration verification, they will always have inherent uncertainty and limitations.

References

SFWMD, 1996. Hydrologic Restoration of Southern Golden Gate Estates – Conceptual Plan

USACE and SFWMD, 2004. Picayune Strand Restoration Final Integrated Project Implementation Report and Environmental Impact Statement

SFWMD, 2009. Technical Document to Support a Water Reservation Rule for Picayune Strand and Downstream Estuaries

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