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Initial Application of a Landscape Evolution Model to a Louisiana Wetland

by Carl F. Cerco

PURPOSE: Corps planning projects encompass a wide variety of restoration goals. These include wetland restoration, island restoration, stream restoration, dam removal, and other projects which result in alteration of the landscape. Planners require tools to help predict potential outcomes of restoration efforts over periods spanning decades. This work unit in "Landscape Evolution Modeling" is intended to acquire, employ, and develop, as necessary, Landscape Evolution Model (LEM) tools that can be used to forecast the evolution of the aquatic-land interface, thereby providing information that can be used to project future impacts and benefits. This technical note reports on the initial application of an LEM to Davis Pond, LA. The application examines the feasibility of transferring an existing LEM from the Florida Everglades, where it was developed, to a distinctly different system.

BACKGROUND: A variety of LEM's exists, one or more of which may fulfill the specified needs as well as serve additional purposes. The three-year planned program will survey a range of existing LEM's for suitability and produce applications and an initial LEM for distribution and employment at the district level. In the first project year, one or more LEM's will be acquired, installed on Corps computing platforms, and then be examined and applied. In the second year, one or more additional models will be acquired and a second, different application area will be selected. Additional models may be acquired and examined in the third project year. A primary product from the third year, however, will be a technical report detailing the potential of LEM's to forecast habitat types and characteristics of evolving landscapes. Recommendations will be made with regard to application of existing technology and/or development of new technology for Corps projects. The present document provides an overview of work completed in the first project year.

SELECTION OF LANDSCAPE MODEL: Corps restoration projects commonly are located at the land-water interface. Although this interface can be distinct (e.g. seawalls), it is often occupied by wetlands subjected to various magnitudes and frequencies of flooding. Wetland physics influence the selection of an LEM and of the processes represented in the LEM. In view of the predominance of wetlands in Corps projects, the Everglades Landscape Model (ELM) was selected for initial examination and application. Despite its name, the ELM (Fitz and Trimble 2006) is a generalized model of wetland processes and evolution and is gradually becoming known as the Ecological Landscape Model to emphasize its generality (Fitz 2008).

Water. Hydrology provides the foundation of the ELM. The region of interest is represented in two dimensions in the surface plane as well as vertically. Surface flows may be overland or

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through defined channels and control structures. Rasters and vectors, as employed in basic Geographic Information Systems, divide the domain into discrete overland and channel elements. Flexibility exists to compute flows internally or to employ linkage to external hydrologic models. The domain is divided vertically into surface water and groundwater with allowance for an unsaturated zone when the water table is below ground surface.

Nutrients. Phosphorus and nitrogen are the two nutrients considered by the ELM as these are the primary nutrients which support and limit plant production in the aquatic environment. Multiple organic and inorganic forms of these nutrients are modeled (as well as salinity and solids). Nutrients follow numerous pathways through the system, as determined by two classes of forcing functions: hydrology and biology. Hydrological processes determine the flux of nutrients into and out of the system as well as the spatial distribution of nutrients within the system. Biological processes determine transformations between different nutrient forms, for example, the uptake of inorganic nutrients and subsequent incorporation into organic plant material. Biological processes also influence nutrient fluxes, however, as when groundwater nutrients are pumped to the surface through macrophyte root uptake.

Habitat. Habitats are considered to be combinations of soil/sediment and plant community characteristics. Habitats are subject to change, either over decades as a result of changes in macrophyte communities and sediment accretion, or swiftly, as a result of infrequent disturbances. ELM considers an arbitrary number of habitats defined by the user and is capable of simulating habitat change. In its present configuration, the ELM employs rule-based algorithms for habitat switching and appears to be most suited to simulate long-term changes.

INITIAL STUDY SYSTEM: Davis Pond, located in southeastern Louisiana, was selected for initial application of the ELM. Factors influencing the selection included:

- The system is distinctly different from the Florida Everglades, providing a test bed to examine the generality of the ELM.
- The system is a Corps project of concern to a Corps District (New Orleans).
- The system presents management issues (e.g. nutrient export to coastal waters downstream) which may be addressed by the ELM following successful model application and examination.

The Davis Pond Freshwater Diversion Structure was authorized by the Flood Control Act of 1965 and modified by the Water Resources Development Acts of 1974, 1986, and 1996. It has been designed to simulate historic spring floods and provide a controlled flow of fresh water and nutrients from the Mississippi River into a target area in the Barataria Bay estuary. Davis Pond is expected to restore former ecological conditions by combating land loss, enhancing vegetation and improving fish and wildlife habitat. The total project area comprises 10,084 acres, including the 9,200-acre ponding area (Figure 1). Davis Pond is able to divert up to 10,650 cfs of fresh water. Diversions through the structure will occur under regulated conditions determined by monitoring basin salinities and fish and wildlife resources. It has been projected that during the next 50 years, Davis Pond will preserve about 33,000 acres of marsh and benefit 777,000 acres of marshes and bays. By improving existing marsh conditions, the project is expected to provide average annual benefits of $15 million for fish and wildlife, plus $300,000 for recreation.

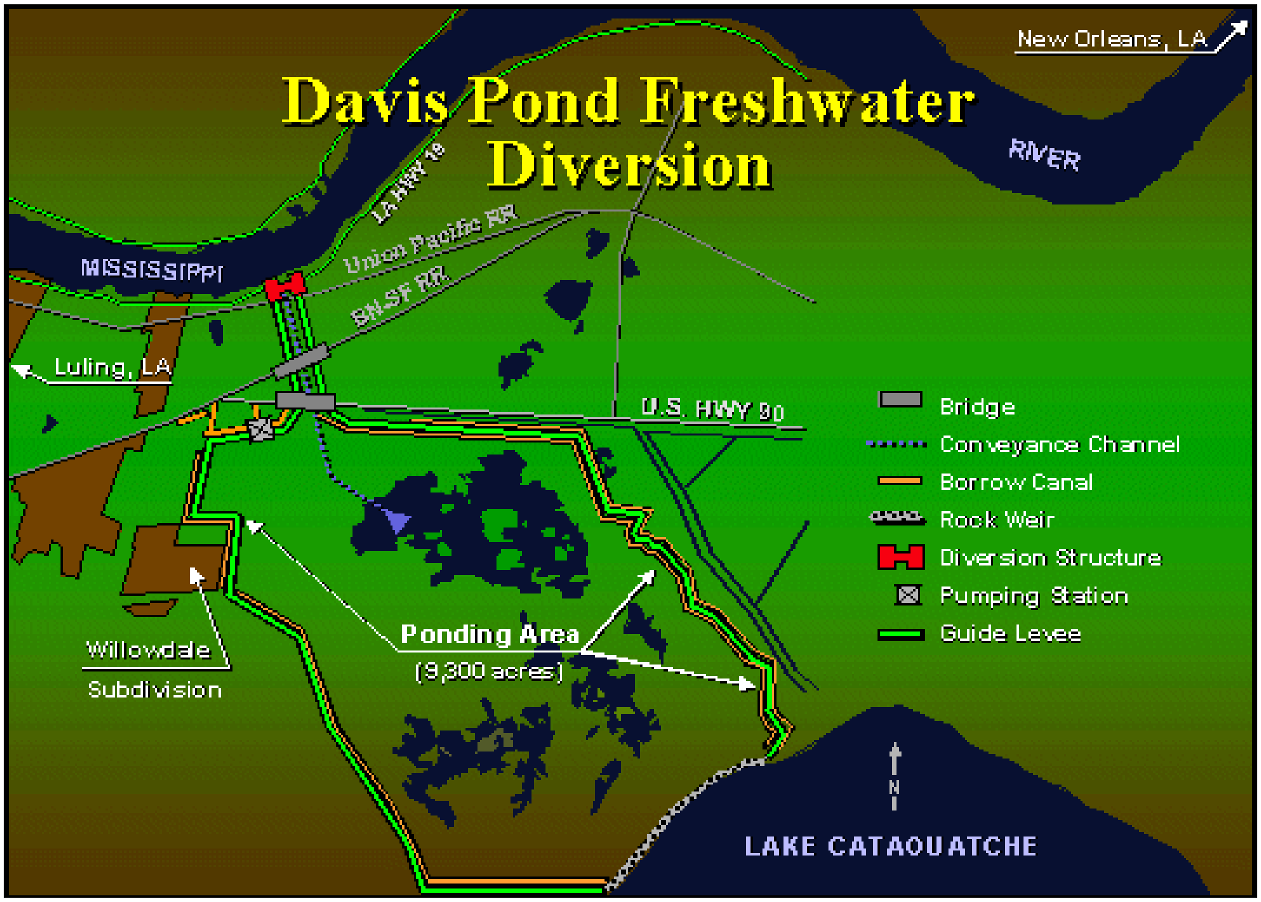

Figure 1. Davis Pond Freshwater Diversion.

DATA AVAILABILITY: Application of the ELM requires a large body of data, which can be divided into two classes: system description and forcing functions. The system description includes properties such as land surface elevation, channel bathymetry, and habitat types. Forcing functions include water and nutrient fluxes at system boundaries, solar radiation, and evapotranspiration. Data assembled to date are summarized in Table 1.

INITIAL APPLICATION: Available data were assembled into 14 map input files. Data were aggregated into 30-m × 30-m grid elements (Figure 2) on a system grid of 243 rows by 319 columns. Two habitat types, freshwater marsh, dominated by *sagittaria*, and swamp, largely bald cypress, were defined (Figure 3). For some required data (e.g. evapotranspiration, initial macrophyte biomass), typical values were assumed in lieu of observations. The model was run for one year, with 300 time-steps per day, and consumed 4½ hr on a desktop PC running the Linux operating system. Model computations were visualized (Figure 4) by importing into the MATLAB computation package.

Table 1
Data Assembled for ELM Application to Davis Pond

Data	Description	Source
Land surface elevation	LIDAR imagery, 5 x 5 m resolution	John Barras, Environmental Laboratory Baton Rouge Office (personal communication)
Marsh types	Used to delineate habitats in LCA Science Plan	John Barras, Environmental Laboratory Baton Rouge Office (personal communication)
LANDSAT imagery	Basic outline of project area	John Barras, Environmental Laboratory Baton Rouge Office (personal communication)
Bathymetry	Obtained from hydrodynamic model of system	USACE ERDC Coastal and Hydraulics Laboratory
Soil properties	Two sites within Davis Pond region	Louisiana Department of Natural Resources
Accretion data	Two sites within Davis Pond region	Louisiana Department of Natural Resources
Emergent vegetation	Two sites within Davis Pond region	Louisiana Department of Natural Resources
Discrete Hydrographic data	Monthly flows in Davis Pond region	Louisiana Department of Natural Resources

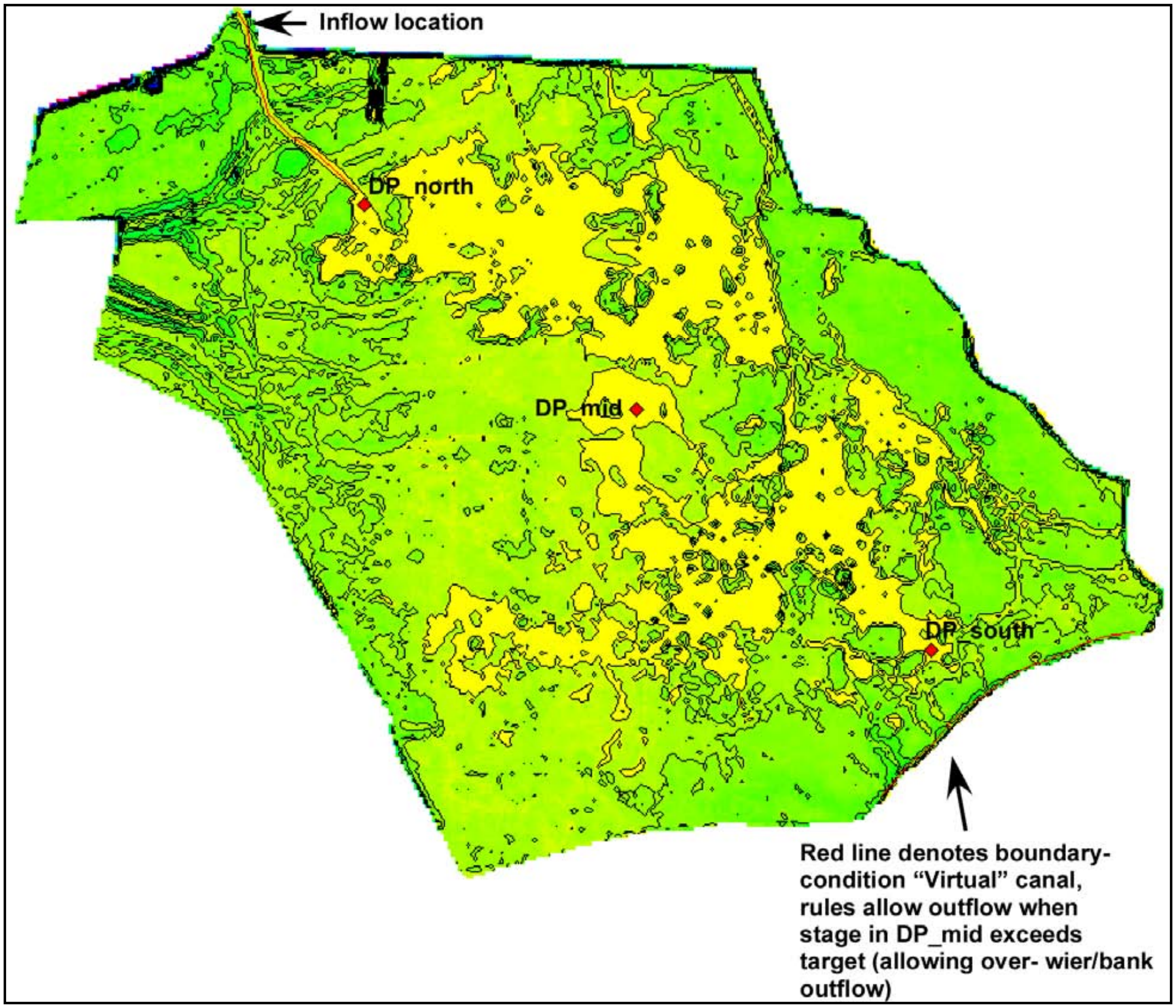

Figure 2. Land surface elevation as rendered on a 30-m x 30-m grid.

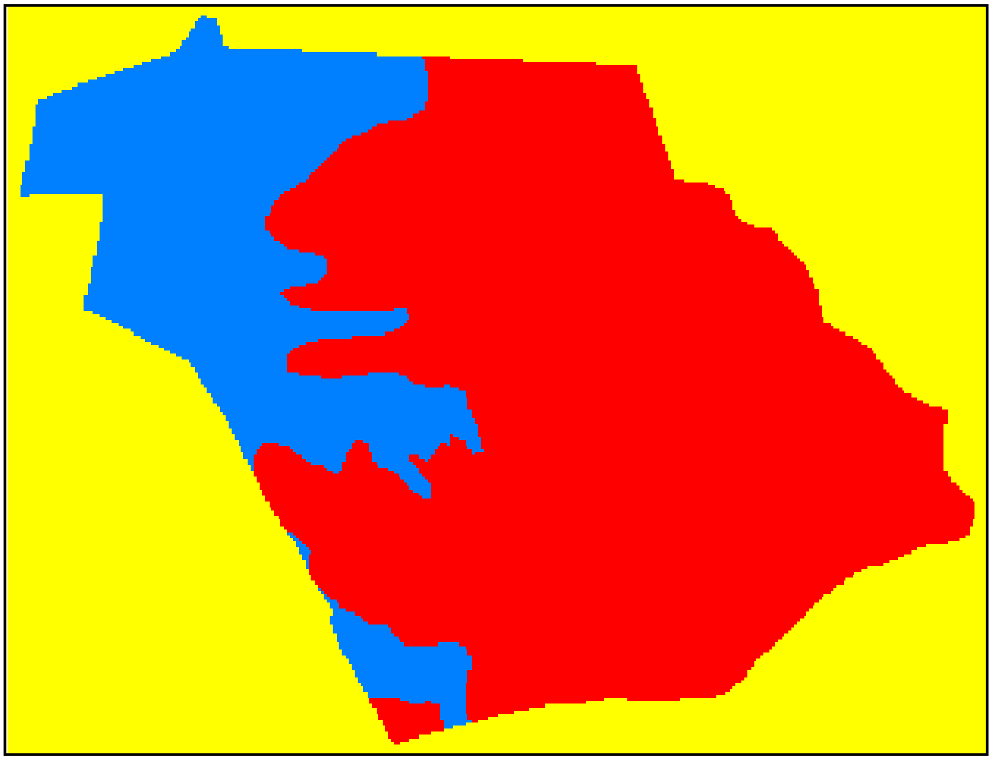

Figure 3. Habitat types: freshwater marsh (red) and swamp (blue).

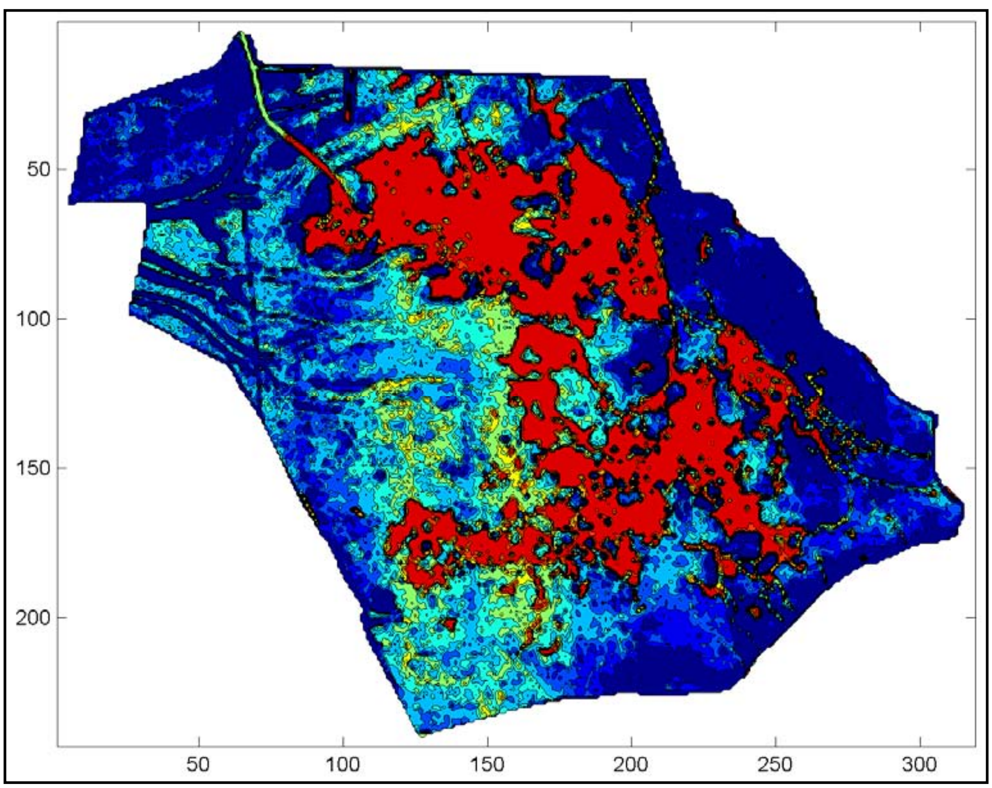

Figure 4. Water surface elevation as computed by ELM.

NEXT STEPS: The goals of the initial project year were successfully fulfilled. An LEM was obtained, examined, installed on a Corps' computing platform, and applied to a test system. The examination determined that nitrogen and suspended solids algorithms were coded into the ELM but not activated. Only phosphorus was a concern in Florida. The immediate next step for the ELM is to activate and examine these algorithms. The Davis Pond application is presently in the "proof of concept" stage. It was determined that ELM can be applied to a system distinctly different from the original Florida Everglades application. Next steps are to accomplish realistic Davis Pond simulations. These will require searching for currently unavailable data and additional development of the data already in hand. Multi-year simulations will be completed and computed habitat will be compared to LANDSAT photos to determine the predictability of habitat change. Exploratory scenarios to test the response of the ELM to events (e.g. flooding) and long-term change (e.g. land subsidence) will be conducted.

ADDITIONAL INFORMATION: This technical note was prepared by Carl F. Cerco, Research Hydrologist, Environmental Laboratory, U.S. Army Engineer Research and Development Center. The study was conducted as an activity of the Ecosystem Management and Restoration Research Program (EMRRP). For information on EMRRP, please consult *http://el.erdc.usace.army.mil/emrrp/emrrp.html* or contact the Program Manager, Glenn Rhett, at *Glenn.G.Rhett@usace.army.mil*. This technical note should be cited as follows:

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