SEEPAGE MODELING IN SUPPORT OF WATER RESOURCES DEVEOPMENT

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In south Florida there is a growing and competing demand for the existing water resources. To address this need methods to harness as much available fresh water are being considered, including rainfall runoff. Earth Tech was selected by the South Florida Water Management District (District) to provide engineering, surveying, geotechnical, planning, preliminary and final design services for the C-9 Impoundment Project, which is a feature of the Comprehensive Everglades Restoration Plan.

The Project is planned to have a total storage capacity of approximately 6,600 acre-feet with a storage depth of water to be approximately four feet. The Project encompasses water supply, seepage control, ecosystem restoration, water quality and incidental flood protection characteristics. The impoundment pool will assist in reducing seepage from Water Conservation Area 3B and the Water Conservation Area 3A/3B Seepage Management Area, thereby increasing groundwater recharge in the vicinity of the impoundment, and provide an additional source of water for meeting the municipal and agricultural water supply demands and for preventing saltwater intrusion into drinking water aquifers.

The C-9 Impoundment is located in southwestern Broward County, adjacent to and east of US-27 on the north bank of the west to east flowing C-9 Canal. The northern boundary of the project is approximately 10.7 miles south of the I-75/US-27 Interchange. The impoundment is approximately 1.9 miles in length south to north and approximately 1.4 miles in width from east to west. The Impoundment is situated on a 1,800 acre existing mixed used area (wetlands, agricultural, and others).

The hydrogeologic conceptual model was developed using data from regional geologic reports and site-specific data including: geologic sections D-D' (Figure 18, Fish, 1988) and F-F' (Figure 20, Fish & Stewart, 1991) which cross the model domain, the land surface, the top of model layer 1, was based on site survey data and USGS Topographic Map elevations; geologic, hydrologic, and geophysical data gathered during the site geotechnical investigation which helped define the thickness of the surface muck and the low permeability cap rock.

A site-wide groundwater flow model was constructed with the most recent data at the C-9 Impoundment site. A number of sources of hydrogeologic information were reviewed prior to the construction of this MODFLOW model. Since the model domain straddles the southern Broward County and northern Dade County line both reports by Fish (Fish & Stewart, 1991 and Fish 1988) were some of the principal sources of hydrogeologic data for the deeper portion of the site. The information for shallow portion of the site was also obtained from the Fish reports and supplemented with the hydrogeologic data gathered at the site (Earth Tech, 2006). *The Draft Lower East Coast subReginal (LECsR)*

MODFLOW Model Documentation report, SFWMD, March 2006, was used as guidance for model parameter selection. The Broward County groundwater model (BC MODFLOW) was review by means of the draft report *Flood Protection Analysis for Broward County Water Preserve Areas C-11 and C- 9 Impoundments* (Burns & McDonnell, June 2005).

The Modular Three Dimensional Finite Difference Flow Model (MODFLOW) (McDonald and Harbaugh, 1988) modeling software was selected to model the aquifers underlying the C-9 Impoundment site. The model simulates the Fort Thompson Formation, which contains the Biscayne aquifer system, and the overlying sediments and top of the underlying Tamiami Formation. The model domain grid covers an area 53,725 feet (10.175 miles) west to east and 38,975 feet (7.38 miles) south to north, covering an area of 75.1 mi2. . The model domain extends beyond the impoundment a sufficient distance to minimize boundary impacts on the area around the C-9 Impoundment. An iterative process was followed to arrive at a model domain size where mounding impacts from a flooded C-9 Impoundment were insignificant at the domain edge.

The water levels for the model boundaries were based on stages measured in surface water canals whose water levels are largely regulated with control structures. Average and maximum water levels from the recorded water levels database at each structure were used to set water elevations in the various boundaries across the model domain. Water levels were extrapolated between gauge locations based on the assumption that this would reflect actual conditions.

Constant Head boundaries were used to simulate the heads in the western, northern, and eastern model boundaries. Constant heads allow sufficient water to recharge or discharge from the aquifer to maintain the specified head. The C-9 and C-6 canals were simulated using the River Package. River nodes incorporate the geometry of the surface water feature to be simulated (similar to drain nodes) but may either remove or recharge water, depending upon the head relationships. The western canal and the borrow canal, located west of the Project and Highway US-27, and the deep canal located on the eastern side of the Project, were simulated using the drain cells. Drain cells incorporate the geometry of the surface water feature to be simulated (similar to river nodes) but may only remove water, depending upon the head relationships.

Horizontal hydraulic conductivity (Kh) values were obtained from aquifer tests completed either at the C-9 Impoundment site or in comparable units. Vertical hydraulic conductivity values (Kv) values were estimated based on similar studies performed in South Florida and laboratory vertical permeability tests that were performed during the Geotechnical Services investigation.

There are numerous lakes throughout the model domain and are represented with very high K and storage zones in the model. This very high K zone is used for the entire lake depth and extends down to layers 5 or 6, depending on the lake bottom elevation. Recharge was not used in this model. The region surrounding the planned C-9 Impoundment has highly regulated surface water levels in the canals which control the water surface elevation across the area. The rainfall that does occur, and the recharge that follows, is largely reflected by the stage levels in the canals and behind the levees. The highly managed nature of the surface water system results in fairly stable stages in the canals.

Two values of storativity (S) were used in the model, with the value for sediments obtained from South Florida Water Management District, March 2006. A second value of approximately one was used for the lakes and water bodies to simulate the absence of sediments. An assumed porosity of 30 percent was used in the model, also based on values listed South Florida Water Management District, March 2006.

Model calibration involved the flow model being run under steady-state conditions. Two simulations were made, one each with the average and maximum stage settings with best estimate site K settings. Since there are very few groundwater wells in the model domain with water levels measured for the specific model layers, a calibration based on head matching was not pursued. A qualitative calibration was made based on comparison of the simulated heads with published water table map for Broward County. Two such maps are presented in Fish, 1988; Figure 40 is a wet season map and Figure 41 is a dry season map. Both maps show the groundwater flow direction being generally to the east with significant flow components towards the west to east oriented C-9 and C-11 canals.

A Model Sensitivity Analysis was pursued to evaluate the sensitivity of the system to increased subsurface permeability. Seven simulations were run for each set of stage water levels (average and maximum). In general, as the K_h and K_v values increased for layers 4, 5, and 6 (the main portions of the Biscayne Aquifer) flows out of the WCA 3B and the C-9 impoundment increased and seepage into the down-gradient canals also increased.

Five MODFLOW simulations were made with canal and surface water body stage elevations identical to selected SEEP2D simulations. The results of the first two show that the WCA 3B and the C-9 impoundment are the water supply sources to the local flow system and the canals and downgradient lakes the water seepage out locations. The first two simulations also show the C-9 canal to be a major discharge point. The next three simulations with the Impoundment include the C-9 Impoundment at normal pool elevation with seepage canals added around three sides of the impoundment. The three simulations, A, B, and C, represent simulations with only the C-509W canal (A), with the C-509W and C-509N canals (B), and all three canals (C), respectively. With all three simulations the downgradient lakes intercept the majority of the seepage.

Simulated groundwater mounding was also evaluated. The model output heads from the existing conditions model setup was the basis of comparison. Mounding is the difference between simulated heads for the existing conditions and the Impoundment at “normal pool” elevation. Four observation points were established, one outside of each corner of the impoundment, which provided consistent observation locations. The head increases ranged from approximately one-half foot at the northeast corner (upgradient side) to 1.8 feet rise at the south east corner (down gradient side). Any mounding remaining outside of the C-509 seepage canals is captured by the downgradient subdivision lakes.

The final step was to convert the seepage rates into seepage coefficients, or seepage per foot of canal or per square foot of water body area. These seepage coefficients were used in the following surface water modeling task.