Broward/USGS Modeling Projects Summary

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Description of Problem, Need or Value

Climate change and sea level rise pose significant threats to water supplies and flood protection impacting the resilience of Broward County. Non-climate stressors, including low land elevations, flat topography, karst geology and dense coastal development contribute to the region's physical and economic vulnerabilities. Local impacts are accelerated by urban growth and historical drainage of the Everglades that add additional pressures on our highly valued water resources. Today, municipalities, water utilities and individual communities are grappling with balancing the planning and financial challenges of necessary infrastructure improvements. Informed decisions and wise investments will be essential to building resilience throughout the Broward community and must reflect comprehensive and integrated water resource management strategies. The numerical models being developed will provide the necessary tools to make informed decisions on how best to protect our water resources and provide the County with resilience strategies. The models will first demonstrate future conditions with no action taken and then simulate predictive scenarios for evaluation purposes.

Objectives

North, Central and Southern Broward County Saltwater Intrusion Models:

In 2006 the Broward County's Natural Resources Planning and Management Division contracted with the USGS to develop a numerical model tracking the movement of saltwater intrusion in the northern third of the county. The model used the USGS's SEAWAT variable modeling code to density-dependent flow and transport of chlorides due to the intrusion of saline water. The initial results verified the model's ability to track the historical movement of the saltwater front and through sensitivity analysis influences, the important factors contributing to movement of the saltwater front was also evaluated. It was shown that this tool could aid in planning for future water resources projects and for the development of resilience strategies.

The current modeling effort has been expanded to the central and southern portions of the County and provides a link to the previous northern model, thereby giving a full coverage of the County. The outcome of this expanded effort will; 1) simulate historical saltwater intrusion from predevelopment conditions (1950s) through periods of Everglades drainage, agricultural use, and most recent urbanization, 2) quantify effects of stresses through sensitivity analysis intended to isolate various anthropogenic stresses (i.e., municipal groundwater withdrawals, changing canal water elevations and land-use changes) and natural stresses (i.e., drought conditions and sea level rise) to evaluate the greatest influences on the movement of the saltwater front, and 3) to provide a useful tool for future water management and resource planning:

Climate/Inundation Model:

Broward County in cooperation with USGS, is building upon on-going saltwater intrusion modeling to assess the influence of changing climatic conditions on the urban water resources and infrastructure. The current effort integrates bias-corrected, dynamically-downscaled data from Global Circulation Models, prepared by Florida State University's Center for Ocean-Atmospheric Prediction Studies (COAPS), into the updated surface/groundwater model that will be used for predictions county-wide.

Two (2) representative land areas within the county have been selected as focused areas to test potential adaptation strategies from the effects of climate change and non-climatic stressors. The first area, Fort Lauderdale, represents a tidally influenced community and contains important infrastructure such as Fort Lauderdale-Hollywood International Airport and the Port Everglades. The second focus area encompasses portions of the Town of Davie representing an inland community dependent on gravity drainage.

The existing 3-D MODFLOW model is integrated with surface-water routing component and a variable density component to offer a more detailed conceptualization of the surface-water/groundwater interactions between interception storage, overland flow, depression storage, and unsaturated zone storage. Once the models are calibrated to the historical data sets, future conditions for both sea level and precipitation patterns will be applied to create the future baselines. With respect to sea level rise, the projections agreed upon by the partner counties to the Southeast Florida Regional Climate Change Compact of 9 to 24 inches by 2060. This is consistent with 2011 USACE guidance for incorporating sea level change in civil works projects.

These 'no action' conditions will then be assessed and several infrastructure enhancements (new pumps or increased pump capacity, seaward movement of water control structures, drainage well systems, etc.) will be incorporated to explore cost-effective strategies for flood protection. The predictive scenarios will also incorporate additional synthesized datasets including evapotranspiration, rainfall, ocean/canal stage, etc. to assess the current infrastructures' ability to adequately mitigate the adverse effects of variable climate changes. Using the calibrated results of this modeling will allow comparison of alternative strategies against the 'no-action' scenario in the face of climate change. The ultimate goal is to determine planning level costs (i.e. coupled property appraiser data with capital infrastructure costs) for assessing long-term, cost-effective strategies that may be pursued in the future.

Model Domain and Discretization:

The Central and Southern Saltwater Intrusion Models, coupled with the previously developed northern variable density model, will give a County-wide representation of saltwater intrusion. The SEAWAT modeling platform, which is being utilized for these models, includes many of the standard packages such as General Head Boundary (GHB), Well (WEL), Recharge (RCH), and Evapotranspiration (ETS). The recently released Surface Water Routing Package (SWR1) will allow for the dynamic control of canal water levels based on current structural operation criteria. Broward County has a total of 122 structures that are used in the models.

The Inundation Model focus areas will use outputs from the Saltwater Intrusion Models to obtain boundary conditions to be used for the more finely discretized simulations. See Figures 1a, 1b, and 1c for model extents. Grid size will be reduced from 500 ft. to 165 ft. and the stress periods will be

modified from monthly to daily for groundwater and from monthly to hourly for surface water. See Table 1: Model details and Figure 2 for grid size comparison. This finer temporal and spatial discretization is necessary to more effectively simulate certain situations (i.e. to evaluate short term design storms within neighborhood scale events). In addition to the finer discretization, specialized Urban Runoff (URO) processes have been implemented to help capture previously generalized surface water/groundwater interactions. These URO processes include Interception Storage, Surface Water Storage (Overland flow & Depression Storage), and Unsaturated Zone Storage (Sub-surface & Infiltration).

Table 1. Model details

	Saltwater Intrusion Models	**Inundation Model**
Domains	See Figure 1.a	See Figures 1.b, 1.c
Grid Sizes	500 ft. X 500 ft. See Fig,2	165 ft. x 165 ft. (50m. x 50 m.)
Calibration Time Periods	1/1/1950 - 5/31/2012	1970 -2000
Predictive Time Periods	6/1/2012 - 12/31/2062	2038-2068
Stress Periods	Monthly	Groundwater - Daily Surface Water-Hourly

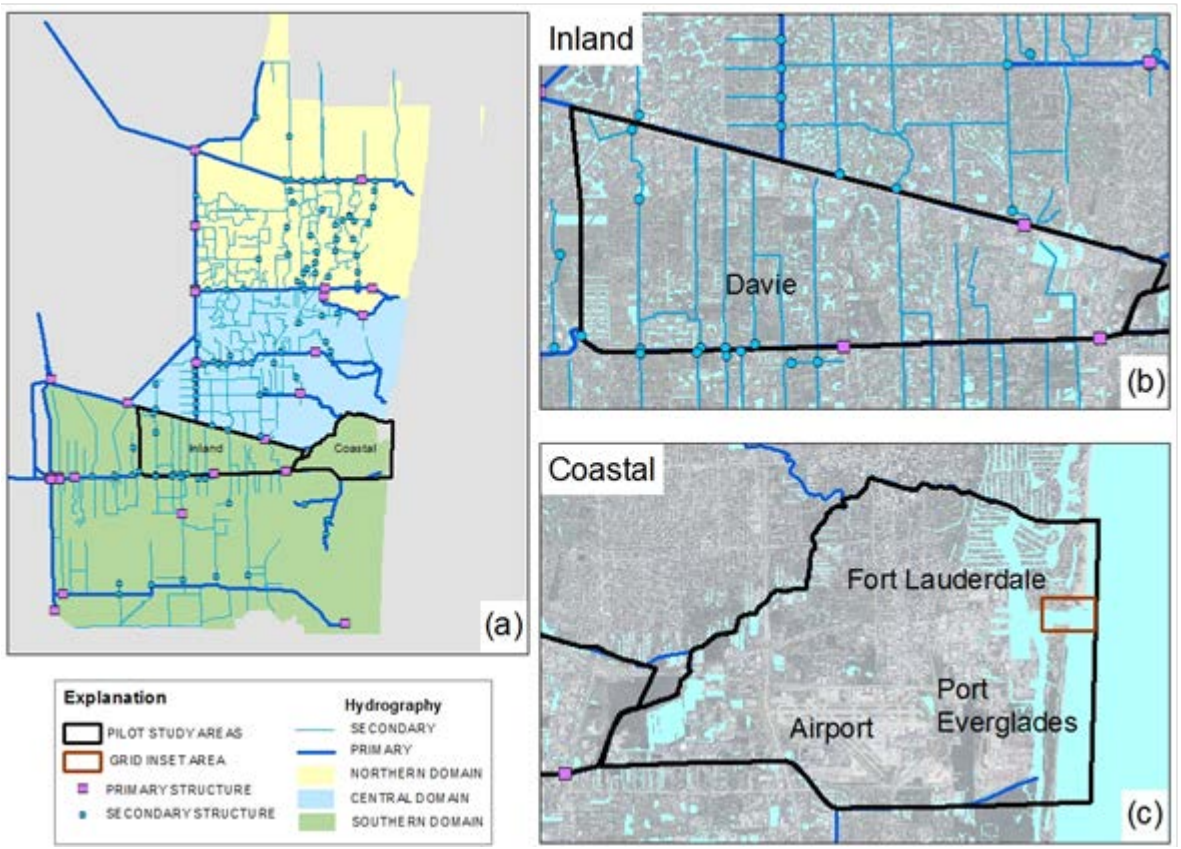

Figure 1. a) Model Domains of Northern, Central, and Southern Variable Density Models, b) Domain for the Inland focal area and, c) Coastal focal area in the Inundation Model

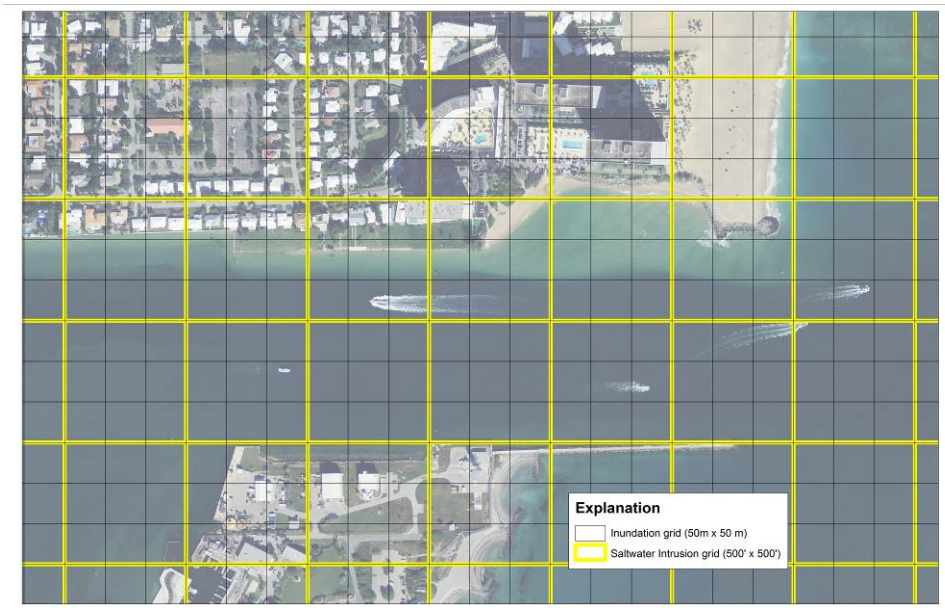

Figure 2. Grid discretization used in Inundation focal areas (50x50m =165x165ft) vs. the larger grid used in the Variable Density Models (500x500ft).

Project Activities

Central and Southern Saltwater Intrusion Models:

The proposed study involves the development of a variable-density ground-water flow and solute transport model for central and southern Broward County, Florida. The objectives of the model development are to; (1) determine how well the model represents the historical saltwater intrusion patterns, (2) determine the types of field data and model parameters that are most important for simulating saltwater intrusion, and (3) quantify the relative importance of the various hydrologic stresses (i.e. rainfall, ground-water withdrawals, canal stage, etc.) influencing saltwater intrusion.

Approach

1. Develop a three-dimensional dispersive saltwater intrusion model for central and southern Broward County to simulate hydrologic conditions for the period from the 1950's to the present.
2. Use the historical data record (groundwater heads and salinities) to calibrate aquifer flow and transport parameters to verify that a parsimonious numerical model is representative of observed saltwater intrusion patterns.
3. Conduct a formalized sensitivity analysis to determine the; (i) optimal field data for calibration, and (ii) optimal model parameters to simulated saltwater intrusion patterns.
4. Quantify the relative importance of various hydrologic mechanisms influencing the transition zone between freshwater and saltwater.
5. Perform at least 6 predictive scenarios involving sea-level rise and/or drought conditions

Evaluations:

Initially, several predictive scenarios will assess the impacts of future sea level rise and seasonal changes in precipitation on regional hydrologic conditions. These will be consistent with the U.S. Army Corps of Engineers guidelines for public works projects and with the SLR planning projections recommended by the Southeast Florida Regional Climate Compact. Areas that show increased flooding for prolong duration will be identified as areas at risk. Once areas of risk are identified, additional scenarios will assess the efficacy of mitigating for increased flooding by evaluating across different adaptive strategies.

County-wide Assessments:

1. Sea level rise projections with seasonal changes in precipitation
2. Impacts on wet season/dry season groundwater levels
3. Changes in groundwater chlorides
4. Impacts on surface water/flooding (limited by 500 ft. grid size)
5. Develop and test adaptive scenarios

Potential Adaptation Scenarios:

- Current pumping rates with projected sea level rise to determine future viability of coastal well fields
- Use of drainage wells for mitigating/managing coastal saltwater intrusion interface
- Moving of G-54 Structure eastward
- Deepening or construction of new canals west of wellfields to increase recharge
- Exploring relationship of rainfall and saltwater front movement
- Performing a data worth analysis for optimizing the saltwater monitoring network

Climate/Inundation Modeling

The proposed study will evaluate the effects of predicted climate and sea-level changes on drainage, flooding, and saltwater intrusion. Approaches to mitigate reductions in the efficiency of the surface-water management system will be evaluated.

Approach

1. Develop a methodology for representing sub-basin scale urban recharge, evapotranspiration, and runoff to secondary and primary canal systems.
2. Evaluate two representative areas (coastal and inland) for detailed flood simulation and identify data gaps that may require additional data collection activities for successful model application.
3. Convert existing surface water model datasets for Broward County into equivalent Surface Water Routing Package MODFLOW-2005 datasets.
4. Calibrate an integrated surface water and groundwater model for two representative areas.
5. Develop a method for downsizing simulated results of one or more global climate models into a form suitable for hydrologic simulation within Broward County.
6. Perform model scenarios to evaluate the effect of climate change on drainage efficiency and evaluate possible adaptation strategies for improving flood prevention.

Evaluations:

Several predictive scenarios will be run to determine the extent of impacts of climate change conditions (precipitation, evapotranspiration, and SLR) will have on surface water management systems with respect to drainage and flood control operations. These scenarios will include various iterations of downscaled Global Climate Model data from Florida State University's Center for Ocean-Atmospheric Studies (COAPS) which include bias corrected 20th and 21st century data from the Community Climate System Model (CCSM), Hadley Centre Coupled Model, V3 (HadCM3), and Geophysical Fluid Dynamics Laboratory (GFDL) model. Sea level rise predictive scenarios are proposed to include current rate (2.24mm/yr.), low, median, and high SLR projections to be consistent with U.S. Army Corps of Engineers guidelines as adopted by the Southeast Florida Regional Climate Compact. Different combinations of sea level rise and precipitation scenarios will be run to identify land areas that may be prone to increased flooding in the future. Once these areas of concern are identified additional scenarios will include adaptive measures such as installing pump assisted drainage infrastructure.

Focal Area Assessments:

1. Inundation responses to various SLR rates
2. Three Design Storm Events
3. Observed High Tide Events
4. Combined SLR, storms events and high tide
5. Inland and coastal groundwater and surface water levels
6. Develop and test adaptation strategies

Potential Adaptation Scenarios:

- Replacement of gravity drainage infrastructure with pumps
- Movement of control structures
- Retrofitting current control structures(adding or increasing pump capacity)
- Increasing coastal sea wall heights