Evaluation of Drainage Infrastructure Capacity Under Projected Sea Level and Climate Conditions, Broward County, Florida

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Overview

- Group of projects undertaken by the USGS with cooperation from Broward County Environmental Planning and Community Resilience Division
- Began with saltwater intrusion models
  - Primary objective of studying future sensitivities of saltwater front to pumping and sea-level rise (Northern then Central and Southern Models)
  - Used SEAWAT, historical surface water data for canals, and future sea level projections
- Fueled interest in drainage infrastructure’s response to projected sea-level and potential climate change (rainfall, evaporation)
  - How might system operations and subsequent canal stages and groundwater levels change
  - 2 projects followed – first was a pilot study/proof of concept, second was a county-scale model
Inundation Model (Phase I)

- Look into increased risk of inundation under future conditions (Published 2018)
- Same model boundaries as southern and central Broward saltwater intrusion model
- Modified saltwater intrusion model – removed solute transport, vertically simplified aquifer layering, modified temporal resolution, simulated portions of canal system dynamically (yellow portions in figure)
- Created sub-model with increased resolution
  - Test sensitivity to spatial resolution
- Simulated groundwater levels and structure operations under projected climate and sea level conditions
- Model information
  - 500 ft grid resolution, 167 ft in sub-model
  - Historical simulation period: 1990-1999
  - Future simulation period: 2060-2069
  - Surface-Water Routing process (SWR1) used to simulate canal/drainage network
Inundation Model (Phase I)

- Dynamically simulated canal system:
  - 19 weirs
  - 1 specified inflow (from adjacent water conservation area)
  - 3 gated spillways
  - 9 pumps

- Weirs – flow from drainage area occurs once upstream stage reaches invert elevation (governed by fixed crest weir equation)

- Pumps – flow begins once a control elevation is reached upstream and increases linearly to a maximum rate at a second higher elevation

- Gates – gate begins to open once a higher control elevation is reached and remains open until a lower control elevation is reached
Inundation Model (Phase I)

- Simulated historical period (1990-1999) and future period (2060-2069)
- Southeast Florida Regional Climate Change Compact adopted sea-level rise curves (2011)
  - Low projection - historical linear sea-level rise trend (approx. 6” increase for 2065)
  - Medium projection – modified NRC Curve I (approx. 11” increase for 2065)
  - High projection – modified NRC Curve III (approx. 27” increase for 2065)
- Future precipitation and potential evapotranspiration (PET) from Center for Ocean-Atmospheric Prediction Studies (COAPS)
  - Dynamically downscaled regional climate model (10 km resolution) results using general circulation model output as boundary conditions
  - Daily bias-corrected rainfall with estimates of PET from HadCM3 and CCSM
    - HadCM3 (approx. 8% decrease in rainfall)
    - CCSM (approx. 9% increase in rainfall)
Inundation Model (Phase I)

- West (Water Conservation Area) to East (Tide) groundwater transects for future conditions simulations (2060-2069)
- Show east/west divide of C-11 canal at S-13a structure
- Show increases in groundwater levels in eastern C-11 canal and reduction in groundwater gradient (west to east)
Inundation Model (Phase I)

- S-13 has a gated spillway and a pump used for flood control.
- The target control elevation for the spillway operation is 0.1 ft NAVD.
- Average sea level is projected to top this for the “high” scenario.
- Shift to flood control pump operations raises canal levels (could lower pumping curve).

S-13 Spillway and Pump Flow (CFS)

Shift from spillway…

…to pumping
Inundation Model (Phase II)

- Results of first study identified several needs:
  - Dynamically modeled canals and structures throughout the county
  - Increased drainage feature density
  - Inclusion of northern portion of the county into the study area (from northern saltwater intrusion model)
  - Reduced spatial resolution without the need for a sub-model (more difficult and time consuming)

- Led to Phase II of the Inundation Model Project (June 2018 - June 2021)
  - Northern and central/southern saltwater model boundaries
  - 250 ft grid resolution
  - Dynamically simulated canal/drainage network
Inundation Model (Phase II)

- **Surface-water model construction:**
  - Level-pool routing approach
  - 20 primary drainage areas
  - 55 level pool areas within primary drainage areas
  - 13 gates
  - 32 pumps
  - 41 weirs
  - 3 inflows from WCAs (S39, S38, S34)
  - Leakance coefficients estimated using steady-state wet season average conditions simulation

- **Historical simulation period (2013-2017), currently running**

- **Future period (2065-2070 proposed), next steps**
Inundation Model (Phase II)

- Coastal structure operations
  - Gates with pumping ability available at S-13 structure

- New sea-level rise curves adopted in 2015 (increased), then in 2019 (increased)

### Coastal Structures

<table>
<thead>
<tr>
<th>Name</th>
<th>Canal</th>
<th>Control Elevation ft (NAVD)</th>
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<tbody>
<tr>
<td>G56</td>
<td>Hillsborough Canal</td>
<td>5.5 - 6.5</td>
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<td>G57</td>
<td>Pompano Canal</td>
<td>3.0</td>
</tr>
<tr>
<td>S37A</td>
<td>C-14</td>
<td>2.0</td>
</tr>
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<td>3.0</td>
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<td>0.1</td>
</tr>
<tr>
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<td>C-9</td>
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![map](image-url)
Inundation Model (Phase II)

- Coastal structure operations
  - Gates with pumping ability available at S-13 structure

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2011 vs 2015 Sea-level Rise Curves

G56 CE = 5.99' (Not Shown)

Key West Tidal Gauge

G57/S36 CE
G54 CE
S37A/S33 CE
S29 CE
S13 CE

NOAA High
USACE High
Previous High
IPCC Median
Previous Med
Previous Low

2060-70
Inundation Model (Phase II)

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With 1.1 ft avg tidal range
Future scenario development includes changes to rainfall and potential evapotranspiration (PET) as well as sea level.

- Phase I study suggested primary driver of increases in the likelihood for inundation was due to increased sea level and can be worsened by rainfall events.

- Possible changes in yearly totals, seasonality, and intensity of events.

- Previous study used dynamically downscaled regional climate model projections which is highly uncertain.

- Other approaches use existing rainfall records and projected changes to synthesize future climate.

- Can introduce “design storms” of different return intervals for testing purposes.

### Example Rainfall Events

<table>
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<tr>
<th>Return Period</th>
<th>Range</th>
<th>Total 72 hr Rainfall</th>
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<tbody>
<tr>
<td>5 Year</td>
<td>5-8 in</td>
<td>9.5</td>
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<tr>
<td>10 Year</td>
<td>6-9 in</td>
<td>10.9</td>
</tr>
<tr>
<td>25 Year</td>
<td>8-12 in</td>
<td>12.2</td>
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**Existing Design Storm Rainfall**