Agenda

- Model objectives and overview
- Model calibration
- Model application
  - 2014 reference condition and 2040 future condition
  - Head difference maps (2014 and 2040)
  - Wetland impact analysis
  - Maximum developable limit (MDL) analysis
  - Velocity vectors analysis
- Conclusions
Model Objectives

- **Primary objective**: Support the Lower West Coast (LWC) water supply plan

- Tool will be used to evaluate if current and future groundwater withdrawals are sustainable
  - Identify areas where there is the potential for cumulative water use withdrawals to cause harm to wetlands and ground water resources
  - Identify potential for saltwater intrusion issues in coastal aquifers
Model Overview

- Includes all of Lee, Collier, and Hendry counties and portions of Charlotte, Glades, and Monroe counties
- **Western boundary** coincides with the Gulf of Mexico and Peace River, including Pine Island and Sanibel Island
- **Eastern boundary** aligned with District’s primary canal (north-south) and Lake Okeechobee
- **Southern boundary** coincides with Lostman’s River and Big Lostman’s Bay tidal boundaries
- **Northern boundary** specified head boundary, reasonable distance away from areas of interest
First SFWMD model for the surficial (SAS) and intermediate (IAS) aquifer systems for LWC planning region

Used updated hydrostratigraphy for model layering
  • Recent SFWMD publication by Geddes et al. (2015)

MODFLOW based, uniform grid size of 1,000 ft × 1,000 ft

Monthly stress periods (time varying data input interval)

Reclaimed water incorporated through golf course and landscape irrigation return flows


Calibrated for surface water flows/levels and groundwater levels

Independent scientific peer review
  • Concurrent with model development
  • Panel: 3 experts in South Florida hydrogeology and groundwater modeling
Model Layers

Cross-Section of Generalized Hydrogeology in LWC

SAS=Surficial Aquifer System; IAS=Intermediate Aquifer System; FAS=Floridan Aquifer System

9 Layer model with 5 productive aquifers

- L1: Water Table Aquifer (WTA)
- L2: Tamiami Confining Unit (TCU)
- L3: Lower Tamiami Aquifer (LTA)
- L4: Upper Hawthorn Confining Unit (H1)
- L5: Sandstone Aquifer – Clastic Zone (S2)
- L6: Sandstone Aquifer – Confining Unit (SC)
- L7: Sandstone Aquifer – Carbonate Zone (S1)
- L8: Mid-Hawthorn Confining Unit (H2)
- L9: Mid-Hawthorn Aquifer (MH)
Surface Water Flow Calibration Summary

- Strong hydraulic connection between surface water and SAS in the LWC
- Ensure surface flows and stages are reasonable as they impact groundwater recharge
- Simple surface water and unsaturated zone model integrated with MODFLOW through evapotranspiration and recharge
- Calibrated simulated flows to observed structure flows at two major watersheds

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Criteria</th>
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<th>West Caloosahatchee</th>
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<td>R Squared (R2)</td>
<td>&gt; 0.5</td>
<td>0.56</td>
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Calibration Criteria Established
- Peer-review recommendation
- Previous models

Green font indicates compliance with all calibration criteria
Surface Water (Wetland) Level Calibration Summary

- Overland flow simulation – wetlands package
  - 60 target wetland gauges

Green font indicates compliance with all calibration criteria

Calibration Period: 1999 - 2012

<table>
<thead>
<tr>
<th>LWCSIM</th>
<th>Criteria</th>
<th>ft or %</th>
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<tr>
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<tr>
<td>Percentage with MAE &lt; 5.0 ft</td>
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<td>Percentage with R2 &gt; 0.4</td>
<td>&gt; 60%</td>
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<tr>
<td>Percentage with TNSE &gt; 0</td>
<td>&gt; 60%</td>
<td>63</td>
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</table>

Calibration criteria was based on previous models and peer-review recommendation.
441 target groundwater monitoring wells

Green font indicates compliance with all calibration criteria

Calibration period: 1999 - 2012

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Criteria</th>
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<tbody>
<tr>
<td></td>
<td>WTA</td>
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<tr>
<td>Residual Mean</td>
<td>+/- 1 foot</td>
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<td>Error Standard Dev</td>
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<tr>
<td>Absolute Residual Mean (MAE)</td>
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<td>RMS Error</td>
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<tr>
<td>Percentage with R2 &gt; 0.4</td>
<td>&gt; 60%</td>
</tr>
<tr>
<td>Percentage with TNSE &gt; 0</td>
<td>&gt; 60%</td>
</tr>
</tbody>
</table>

Calibration criteria was based on previous models and peer-review recommendation.
Model Application
Reference condition (2014) and future condition (2040) runs

- Similar simulation period to calibration run (16 years)
- Similar climatic conditions to calibration run
- New pumping values

<table>
<thead>
<tr>
<th>Type</th>
<th>2014 Method</th>
<th>2040 Method</th>
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<tr>
<td>Public Water Supply (PWS)</td>
<td>Reported</td>
<td>Projected</td>
</tr>
<tr>
<td>Agricultural (AG)</td>
<td>Estimated*</td>
<td>Projected</td>
</tr>
<tr>
<td>Recreational (REC)</td>
<td>Estimated*</td>
<td>Projected</td>
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<tr>
<td>Domestic Self Supplied (DSS)</td>
<td>Estimated**</td>
<td>Projected</td>
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<tr>
<td>Commercial-Industrial (CI)</td>
<td>Permitted</td>
<td>Permitted</td>
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</table>

Increased demands were assigned to existing wells for PWS, added additional wells for AG and REC within the permit boundary, and used locations identified in population projections for DSS.

*AFSIRS = Agricultural Field Scale Irrigation Requirement Simulation
**County Level Per Capita Use
Limitation in 2040 Simulation

- Simulated demands are “instant on”
- Demands do not include annual growth
- Results from the 2040 simulation are considered conservative

Raw water demand shown for all use types
Regional Model Limitations

- Heterogeneity
  - Regional model (1,000 ft × 1,000 ft cell) may not capture local variability in aquifer properties or responses at individual wells

- Multiple wells in a single model cell
  - Model aggregates all withdrawals at the center of the model cell
  - Tends to exaggerate water level drawdowns
  - Results are conservative

- Regional model results from simulations should be used as an overall planning tool and results should not be taken as absolutes
Pumping Wells in Model

Pumped Volumes by Aquifer (2014)

- **WTA**: Water Table aquifer (136 mgd, 22%)
- **LTA**: Lower Tamiami aquifer (241 mgd, 40%)
- **SSA**: Sandstone aquifer (116 mgd, 19%)
- **SSA-Carb**: Sandstone - Clastic (75 mgd, 12%)
- **MHA**: Mid-Hawthorn aquifer (39 mgd, 7%)

Total Pumped = 606 mgd

WTA: Water Table aquifer
LTA: Lower Tamiami aquifer
SSA: Sandstone aquifer
MHA: Mid-Hawthorn aquifer
Largest Public Water Supply Permits in SAS/IAS

* Indicates a modeled demand over the current permitted allocation; however, it is not guaranteed to be permitted by SFWMD Water Use Bureau.
### Largest Agricultural Permits

#### Charlotte

<table>
<thead>
<tr>
<th>Permittee</th>
<th>Allocation mgd</th>
<th>2014 Demand mgd</th>
<th>2040 Demand mgd</th>
<th>Projected DIFF [2040-2014] mgd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Babcock Ranch</td>
<td>8.91</td>
<td>8.07</td>
<td>8.76</td>
<td>0.69</td>
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#### Collier

<table>
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<tr>
<th>Permittee</th>
<th>Allocation mgd</th>
<th>2014 Demand mgd</th>
<th>2040 Demand mgd</th>
<th>Projected DIFF [2040-2014] mgd</th>
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<tbody>
<tr>
<td>Corkscrew Citrus</td>
<td>13.78</td>
<td>12.06</td>
<td>9.33</td>
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<tr>
<td>Silver Strand I I</td>
<td>8.05</td>
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<tr>
<td>Ranch One Coop</td>
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<td>Harker Farm</td>
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<td>Gator Slough</td>
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<td>Shaggy Cypress</td>
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<td>Hogan Island</td>
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<td>5.43</td>
<td>0.34</td>
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<td>Camp Keals Ag Dev</td>
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<td>Gopher Ridge Citrus</td>
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<td>6.89</td>
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#### Hendry

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<th>Projected DIFF [2040-2014] mgd</th>
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<tr>
<td>Ico Hill Grade Combin</td>
<td>10.45</td>
<td>5.25</td>
<td>5.63</td>
<td>0.38</td>
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<tr>
<td>McDaniel Ranch</td>
<td>28.25</td>
<td>22.60</td>
<td>22.83</td>
<td>0.23</td>
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<tr>
<td>Devil’s Garden South</td>
<td>7.64</td>
<td>6.01</td>
<td>6.07</td>
<td>0.06</td>
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#### Lee

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<th>Permittee</th>
<th>Allocation mgd</th>
<th>2014 Demand mgd</th>
<th>2040 Demand mgd</th>
<th>Projected DIFF [2040-2014] mgd</th>
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<tbody>
<tr>
<td>Cooperative Three Inc</td>
<td>7.54</td>
<td>1.81</td>
<td>1.69</td>
<td>-0.12</td>
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</table>
Model Results:
Simulated Head (Water Level) Differences

2040 Future Average – 2014 Reference Condition Average
Rebound up to 1 ft
Due to decline in 2040
DSS pumping in MHA. LTA and SSA are absent

Drawdown up to 3 ft
Due to increase in AGR pumping in LTA and SSA

Rebound up to 1 ft
Due to decrease in LTA AGR pumping in 2040

2040 Future Average – 2014 Reference Condition Average
Head Difference: Lower Tamiami Aquifer

2040 Future Average – 2014 Reference Condition Average

- Drawdown up to 3 ft
- Aquifer absent
- Drawdown
- Rebound

Rebound up to 1 ft
Due to decrease in LTA AGR pumping in 2040
Head Difference: Sandstone-Clastic Aquifer

2040 Future Average – 2014 Reference Condition Average

Aquifer absent

Drawdown up to 12 ft
Due to increased PWS and AGR pumping

Drawdown

Rebound
Drawdown up to 15 ft
Due to increased PWS, DSS, and AGR

Significant increase in projected DSS demand in Lehigh Acres
Head Difference: Mid-Hawthorn Aquifer
2040 Future Average – 2014 Reference Condition Average

- **Rebound** up to 30 ft
  - DSS use declines due to expansion of PWS service area and increased reclaimed water use

- **Drawdown** up to 12 ft
  - Due to increase in REC and PWS pumping in MHA

- **Drawdown** up to 12 ft
  - Due to increase in Collier Co. pumping in MHA

- MHA is not a very productive aquifer
- Higher drawdown responses even for smaller pumping
Wetland Impact Analysis (Pumps Off Scenario)
Purpose

• To identify potential wetland areas that can be adversely affected by cumulative water use withdrawals

Limitations

• Model calibrated to boundary conditions with pumping occurring, not to extreme condition of no pumps
• Effects of drainage and developments also negatively impact wetlands, but that is not part of this analysis
Wetland Impact Analysis

- **Method**
  - Use pumps off runs for 2014 reference condition and 2040 future condition and overlay the 2014 wetland land use
  - Identify wetland areas with a potential 1 ft or greater of additional drawdown in Water Table Aquifer
  - Note: Red areas are areas with 1 ft or greater of additional drawdown underlain by wetlands
Maximum Developable Limit Analysis
MDLs are part of Minimum Flow Level (MFL) prevention strategy that prevent harmful withdrawals from the following aquifers:

- Lower Tamiami
- Sandstone
- Mid-Hawthorn

MDLs prohibit water withdrawals that lower the water levels less than 20 ft above the top of the uppermost geologic strata of the aquifer at any point during a 1-in-10 year* drought condition

*1-in-10 drought year for LWC Planning Area for the period 1999-2012: 2007
Procedure

1. Create raster surfaces of LTA top and simulated 1-in-10 condition LTA head (May 2007)
2. Remove areas where LTA is absent or very thin
3. Get the difference raster (LTA simulated head minus LTA top)
4. Determine the area of potential violation (LTA simulated head – LTA top) < 20 ft

Model indicated the MDL was violated in May 2007 (head in LTA above the strata top < 20 ft)

Blue areas meet MDL criteria (water level in LTA above LTA top > 20 ft)

Black areas indicate LTA is absent or thin
Model simulated impacted areas have no confinement between Lower Tamiami and Water Table aquifers

- Defining aquifer and MDL is difficult

Monitor well data indicate that MDL was not violated during this period

Associated with agricultural withdrawals

Agricultural demands simulated with AFSIRS estimated due to absence of metered data

What was actually pumped may differ from AFSIRS

<table>
<thead>
<tr>
<th>LTA MDL-Impacted AG Permits</th>
<th>From Permit</th>
<th>From Model</th>
<th>From Model</th>
<th>Model Layer</th>
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<tbody>
<tr>
<td>Permit ID</td>
<td>Name</td>
<td>Permitted Allocation MGD</td>
<td>2014 Demand MGD</td>
<td>2040 Demand MGD</td>
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<tr>
<td>11-00094-W</td>
<td>Highlands Citrus Grove</td>
<td>7.70</td>
<td>4.32</td>
<td>3.74</td>
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<td>36-00167-W</td>
<td>Coop Three Inc</td>
<td>7.54</td>
<td>1.81</td>
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<td>36-00077-W</td>
<td>Corkscrew Grove</td>
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<td>Coral Creek Grove</td>
<td>0.80</td>
<td>0.21</td>
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AFSIRS = Agricultural Field Scale Irrigation Requirement Simulation
### 2014 RC Sandstone Aquifer MDL Analysis

#### SSA MDL-Impacted AG Permits

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<tr>
<th>Permit ID</th>
<th>Name</th>
<th>Permitted Allocation MGD</th>
<th>2014 Demand MGD</th>
<th>2040 Demand MGD</th>
<th>Model Layer</th>
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<tbody>
<tr>
<td>11-00094-W</td>
<td>Highlands Citrus Grove</td>
<td>7.70</td>
<td>4.32</td>
<td>3.74</td>
<td>1,3,5,7</td>
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<tr>
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<td>Doke/Edwards Grove</td>
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<td>11-00091-W</td>
<td>Peacock Citrus</td>
<td>0.52</td>
<td>0.19</td>
<td>0.19</td>
<td>5</td>
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</table>

- Area has no confinement between SSA and LTA
- Decline in future demands
- No potential growth expected
Velocity Vector Analysis
Velocity Vector Analysis

- LWCSIM is not a density-dependent model
  - it cannot model saltwater intrusion
  - it cannot simulate salinity effects of sea level rise

- Velocity vector direction can be an indication of movement of the saltwater interface
  - Interface positions are plotted as a reference to the wellfield locations only
Focus on public water supply utilities vulnerable to saltwater intrusion due to close proximity to the saltwater interface.
Bonita Springs – Lower Tamiami Aquifer

- 2014: Direction of velocity vectors: towards the saltwater interface
- 2040: Conditions are almost the same

<table>
<thead>
<tr>
<th>Permittee</th>
<th>Aquifer</th>
<th>2014 (MGD)</th>
<th>2040 (MGD)</th>
<th>Increase</th>
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</thead>
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<td>Bonita Springs</td>
<td>Lower Tamiami Aquifer</td>
<td>3.53</td>
<td>5.48</td>
<td>1.95</td>
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<table>
<thead>
<tr>
<th>Saltwater Interface (LTA)</th>
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<tr>
<td>2009</td>
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<tr>
<td>2014</td>
</tr>
<tr>
<td>2019</td>
</tr>
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Velocity vectors in every model cell
Vector size proportional to velocity
Golden Gate – Lower Tamiami Aquifer

- 2014: Direction of velocity vectors: towards the saltwater interface
- 2040: Conditions are almost the same

<table>
<thead>
<tr>
<th>Permittee</th>
<th>Aquifer</th>
<th>2014 (MGD)</th>
<th>2040 (MGD)</th>
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<td>Golden Gate</td>
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<td>16.06</td>
<td>16.80</td>
<td>0.74</td>
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Saltwater Interface (LTA)
- 2009
- 2014
- 2019

Velocity vectors in every model cell
Vector size proportional to velocity
City of Naples (Coastal) – Lower Tamiami Aquifer

- 2014: Direction of velocity vectors: towards the saltwater interface
- 2040: Conditions are almost the same

<table>
<thead>
<tr>
<th>Permit No</th>
<th>Permittee</th>
<th>Aquifer</th>
<th>2014 (MGD)</th>
<th>2040 (MGD)</th>
<th>Increase</th>
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<tbody>
<tr>
<td>11-00017-W</td>
<td>City of Naples</td>
<td>Lower Tamiami Aquifer</td>
<td>3.75</td>
<td>3.78</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Saltwater Interface (LTA)

- Upward
- Downward

Velocity vectors in every model cell
Vector size proportional to velocity
Maximum vector length = 2,000 ft
Lee County Utilities – Sandstone Aquifer (Clastic)

<table>
<thead>
<tr>
<th>Permittee</th>
<th>Aquifer</th>
<th>2014 (MGD)</th>
<th>2040 (MGD)</th>
<th>Increase</th>
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</thead>
<tbody>
<tr>
<td>Lee Co Utilities</td>
<td>Sandstone Aquifer</td>
<td>8.45</td>
<td>9.24</td>
<td>0.79</td>
</tr>
</tbody>
</table>

- 2014: No significant movement near saltwater interface
- 2040: Conditions are almost the same

Saltwater Interface (SSA)

- 2009
- 2014
- 2019

Velocity vectors in every model cell
Vector size proportional to velocity

2014 RC

- No significant movement near saltwater interface

2040

- Conditions are almost the same
Lee County Utilities – Sandstone Aquifer (Carbonate)

- Permittee: Lee Co Utilities
- Aquifer: Sandstone Aquifer
- 2014 (MGD): 8.45
- 2040 (MGD): 9.24
- Increase: 0.79

- 2014: Direction of velocity vectors towards the wellfield from the saltwater interface
- 2040: Slight increase in size of vectors

Saltwater Interface (SSA)
- 2009
- 2014
- 2019

Velocity vectors in every model cell
Vector size proportional to velocity
Modeling Conclusions

- LWCSIM – regional, calibrated, peer-reviewed model for the SAS/IAS in the Lower West Coast planning area

- Model indicates that 2040 demands can be met without undue impacts to existing groundwater resources and the natural system
  - Water levels rebounded in Cape Coral area of Mid-Hawthorn aquifer and southeastern Hendry County of Water Table, Lower Tamiami, and Sandstone aquifers due to decline in projected pumping

- Wetland analysis (pumps off scenarios)
  - Model calibrated to boundary conditions with pumping occurring, not to extreme condition of no pumps
  - Drainage and developments were not considered in this analysis
  - Some increases in wetland acreage associated with increase of 1 ft or more drawdown with 2040 demands
  - Water level rebounds in southeastern Hendry County, reduced current impacts in the future
MDL analysis

- Limitation: Aquifer top elevations are interpolated values and may have a ±5 ft error
- Limitation: Agriculture pumping rates were estimated using AFSIRS due to a lack of metered data
- Lower Tamiami aquifer: Potentially vulnerable area has no confinement between Lower Tamiami and Water Table aquifers, makes interpretation and MDL analysis difficult (i.e., difficult to define the aquifer)
  - Monitor wells indicated MDL was not violated in 1-in-10 drought condition in May 2007
- Sandstone aquifer: Potentially vulnerable area has no tight confinement between Sandstone and Lower Tamiami aquifers, makes interpretation and MDL analysis difficult (i.e., difficult to define the aquifer)
  - Decline in future demands and no potential growth in vulnerable area indicate the MDL violation is unlikely in the future
- Mid Hawthorn aquifer: Model did not show any violation
- Close attention needs to be paid to potentially vulnerable areas in LTA and SSA in the future
Saltwater intrusion analysis

- LWCSIM is not a density-dependent model but potentially vulnerable areas for lateral intrusion can be identified using freshwater velocity vectors.
- Velocity vectors indicate no major lateral intrusion issues under current or proposed future conditions.
Modeling Team

- Robert Earle, CGWP
- David Butler, P.G.
- Yirgalem Assegid, Ph.D.
- Michael Parrish, Ph.D., P.E.
- Anushi Obeysekera, E.I.T.
- Kevin Rodberg
- Uditha Bandara, Ph.D., P.E.
Thank You

Questions?
## Model Layer Structure

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Kx Range - ft/day</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topo NGVD29</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>L1</strong></td>
<td>Surficial Aquifer System</td>
<td>0.01 – 22,000</td>
<td>825</td>
</tr>
<tr>
<td><strong>L2</strong></td>
<td>Tamiami Confining Unit (TCU)</td>
<td>0.061 - 16</td>
<td>6.4</td>
</tr>
<tr>
<td><strong>L3</strong></td>
<td>Lower Tamiami Aquifer (LTA)</td>
<td>29.7 - 12000</td>
<td>605</td>
</tr>
<tr>
<td><strong>L4</strong></td>
<td>Upper Hawthorn Confining Unit (H1)</td>
<td>6.18 - 151</td>
<td>47.2</td>
</tr>
<tr>
<td><strong>L5</strong></td>
<td>Sandstone Aquifer – Clastic Zone (S2)</td>
<td>3.6 - 678</td>
<td>37.2</td>
</tr>
<tr>
<td><strong>L6</strong></td>
<td>Sandstone Aquifer – Confining Unit (SC)</td>
<td>0.4 - 1151</td>
<td>111.7</td>
</tr>
<tr>
<td><strong>L7</strong></td>
<td>Sandstone Aquifer – Carbonate Zone (S1)</td>
<td>2 - 1459</td>
<td>115</td>
</tr>
<tr>
<td><strong>L8</strong></td>
<td>Mid-Hawthorn Confining Unit (H2)</td>
<td>5.48 - 1046</td>
<td>135</td>
</tr>
<tr>
<td><strong>L9</strong></td>
<td>Mid-Hawthorn Aquifer (MH)</td>
<td>3.18 - 141</td>
<td>135</td>
</tr>
</tbody>
</table>

### Water Table Aquifer (WTA)

- **Layer Surface elevation range**: ft ngvd29
  - Topo: (127.149 to -7.881 ft ngvd29)
  - L1: (51.4663 to -208.972 ft ngvd29)
  - L2: (50.7077 to -212.318 ft ngvd29)
  - L3: (50.7077 to -214.814 ft ngvd29)
  - L4: (50.17 to -261.87 ft ngvd29)
  - L5: (50.17 to -261.87 ft ngvd29)
  - L6: (50.17 to -261.87 ft ngvd29)
  - L7: (50.17 to -261.87 ft ngvd29)
  - L8: (50.17 to -261.87 ft ngvd29)
  - L9: (50.17 to -261.87 ft ngvd29)

### Tamiami Group

- **Sy**: 0.3
- **Por**: 0.25
- **Ss range**: 3.3e-6 – 0.257
- **Avg**: 0.007

### Upper Hawthorn Group

- **Sy**: 0.3
- **Por**: 0.25
- **Ss range**: 1e-5 – 0.091
- **Avg**: 0.0016

### Mid-Hawthorn Group

- **Sy**: 0.3
- **Por**: 0.25
- **Ss range**: 2.5e-6 – 0.019
- **Avg**: 1.1e-3

### Other

- **Sy**: 0.3
- **Por**: 0.05
- **Ss range**: 2.1e-6 – 0.002
- **Avg**: 3.6e-4
Simulated Average Annual Water Levels – Water Table Aquifer

2014

2040

Black dots are head calibration targets
Simulated Average Annual Water Levels – Lower Tamiami Aquifer

Black dots are head calibration targets
Simulated Average Annual Water Levels – Sandstone Aquifer (Clastic)

2014

2040

Black dots are head calibration targets
Simulated Average Annual Water Levels – Sandstone Aquifer (Carbonate)

2014

2040

Black dots are head calibration targets
Simulated Average Annual Water Levels – Mid-Hawthorn Aquifer

Black dots are head calibration targets
1-in-10 Year Drought

- 1-in-10 drought year was calculated based on rainfall data from 1965 to 2013
- 1-in-10 drought year rainfall ~45 inches
- 2007 had the closest rainfall (43 inches) to the 1-in-10 drought year within the model simulation period
Recreation/Landscape Wells