The Lake Okeechobee Watershed Project (LOWP) performed extensive screening-level modeling using RESOPS in late 2016 to identify feasible features (reservoirs, aquifer storage & recovery and deep injection wells) and sizes that could meet project objectives of improving Lake Okeechobee, L.O. watershed (e.g. wetland restoration) and Northern Estuary conditions.

Detailed hydrologic modeling using RSMBN is currently underway in support of LOWP. Detailed RSMBN model baseline scenarios representing the Existing Condition (ECB) and Future Without LOWP (FWO) were released on February 2, 2017.

A first round of three alternatives with potential LOWP project features was released on March 8, 2017 and a summary presentation made to the Project Delivery Team (PDT) on March 15, 2017 (similar to today’s presentation).

It is anticipated that subsequent modeling will be performed incorporating Project Delivery Team /workshop feedback and refinements after the first round of results is fully evaluated.
Background: Example Screening Modeling (RESOPS)

St Lucie Estuary High Discharge Months from Lake Okeechobee vs. Reservoir Size

- Number of Months of High Discharge Exceedences from LOK during 41 Year (492 month) Simulation
- Reservoir Size

- 0 Well ASR Configuration
- 40 Well ASR Configuration
- 60 Well ASR Configuration
- 80 Well ASR configuration
Background: Regional Modeling Approach

Scenario

Model Output
- Daily time series of water levels, flows
- Demands not met

Evaluation
(Environmental, Water Supply, etc...)

Period of record: 1965-2005

Climatic Input
- Rainfall
- ET

Boundary Conditions

Project Features
- Operating Criteria

- Climatic Input
  - Rainfall
  - ET

- Project Features

- Operating Criteria
Model Assumptions & Setup
1st round of modeling and benefits calculation to optimize water storage and recovery for improvement in high and low lake stages and estuary releases.

2nd round of modeling and benefits calculation to optimize water management measures for improvement in undesirable regulatory discharges to northern estuaries along with wetland restoration measures.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Reservoir Component</th>
<th>ASR Component</th>
<th>DIW Component</th>
<th>Compatible Wetland Components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reservoir (s)</td>
<td>Storage Capacity (acre-feet)</td>
<td># of ASR wells (assuming 5 mgd capacity)</td>
<td># of DIWs (assuming 15 mgd capacity)</td>
</tr>
<tr>
<td>No Action (FWO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative 1</td>
<td>K05 (North and South)</td>
<td>258K</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>Alternative 2</td>
<td>K-05 (North and South) and K-42</td>
<td>408K</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>Alternative 2b</td>
<td>K-05 North and K-42</td>
<td>264K</td>
<td>110</td>
<td></td>
</tr>
<tr>
<td>Alternative 3</td>
<td>K-42 and I-01</td>
<td>254K</td>
<td>112</td>
<td></td>
</tr>
</tbody>
</table>

Note: Estimated reservoir storage capacity will be updated as additional engineering detail becomes available.
ALT1 Assumes:
258 kac-ft storage at K05 Reservoir locations +
110 ASR as shown
(60 ASR co-located at K05)

K05 North 7,605 ac
K05 South 9,625 ac

Reservoirs assumed 15 ft maximum depth

Note: Each ASR is assumed to be 5 MGD capacity
Alternative 2 Assumes:
408 kac-ft storage at K05 and K42
Reservoir locations + 110 ASR as shown
(60 ASR co-located at K05)

K42 9,984 ac
K05 North 7,605 ac
K05 South 9,625 ac

Reservoirs assumed 15 ft maximum depth

Paradise Run
10 ASR

TC West
6 ASR

L-63N
6 ASR

S-191
10 ASR

Lakeside Ranch
4 ASR

C-41
4 ASR

C-40
10 ASR

Note: Each ASR is assumed to be 5 MGD capacity
ALT3 Assumes: 254 kac-ft storage at K42 and I01 Reservoir locations + 112 ASR as shown (40 ASR co-located at I01)

K42 9,984 ac
I01 6,965 ac

Reservoirs assumed 15 ft maximum depth

Note: Each ASR is assumed to be 5 MGD capacity
Example Modeling Detail
Showing Assumed Lower Kissimmee Basin & Lake Okeechobee Inflow Routing for ALT1 Scenario
• In addition to infrastructure assumptions, there is a need to define rules for diverting water to and recovering water from reservoir and ASR storage.

• Also, as storage is added and system infrastructure capability is increased, it makes sense to develop optimized Lake Okeechobee schedule rules that work with storage and focus on the events beyond what storage or conveyance south can handle.

Note: The Yellow Book contemplated schedule changes for the same reasons
Lake Okeechobee Regulation Schedule in the RESTUDY (Yellow Book or D13R)

Component F3

Geographic Region: Lake Okeechobee

Component Title: Lake Okeechobee Regulation Schedule (same as Alternatives 3, 4 and 5)

Purpose: Operating criteria for Lake Okeechobee that includes flood control, water supply (including releases to the Water Conservation Areas to meet estimated natural system needs), and Lake littoral zone and estuary protection.

Operation: Use current regulation schedule with the design modifications made in components A and GG and with the exception of eliminating all St. Lucie and Caloosahatchee regulatory discharges (except emergency releases - zone A, from Run 25).

Design: Operational changes only. Modify the regulation schedule by eliminating all but emergency discharges to both the St. Lucie and Caloosahatchee Estuaries.

Location: Within existing boundary of Lake Okeechobee
Counts: Glades, Hendry, Martin, Okeechobee and Palm Beach

Assumptions and related considerations:
1) It is assumed that the implementation of other project components will reduce the frequency of high Lake stage events therefore reducing the need for regulatory releases to the St. Lucie and Caloosahatchee Estuaries.

Note: RESTUDY planning done with Run25 Lake Schedule which had a higher Zone A / High Lake Band than LORS08
Operations Optimization for LOWP ALTs

- Operational criteria for Storage (Reservoir and ASR) and Lake Okeechobee Regulatory releases were optimized to work with improved infrastructure contemplated by LOWP.

- Approximately 30 parameters affecting the Lake Okeechobee decision outcomes (e.g. “up-to” limits, classification of tributary conditions, etc...) along with a variety of storage diversion and recovery lines were analyzed.

- Constrained and unconstrained Latin Hypercube sampling techniques were used to explore up to 10,000 unique operational strategies per ALT.

- Selected operations were identified using acceptable performance criteria (e.g. Lake O and Estuary PMs) and Pareto analysis.
For Example (~30 parameters):

Consider releasing different "up-to" steady or pulse releases.

Consider redefining what is considered "dry" or "wet" for the THC (or forecasts).
Optimization Methodology
Procedure for Finding the Best-performing Operations

Select key model input parameters & ranges
Generate 1000's of parameter sets (PARsets) via Latin Hypercube Sampling (LHS)
Without LHS, there would be ~ 2.4 x 10^57 sets to analyze

RSMBN Model
Simulated Performance Measure Sets (PMsets)
One PMset for each PARset
Non-Dominated Sorting
Pareto-Optimal Solutions
Satisficing to meet MAPLs

RSMBN: Regional Simulation Model - Basins
PARset: one combination of input parameters for a single RSM-BN simulation
PMset: Performance Measure output set corresponding to a single PARset
MAPL: Minimum Acceptable Performance Level

Final Subset of Pareto-Optimal Solutions meeting MAPLs
Priority to Estuary PMs

“Best” Solution
Example Outcome: Operational Triggers for LOWP Storage Components

- **Water Shortage Trigger Line**: Above this line, divert to available storage. Below this line, recover from storage.

- **Desired Lake Stage Envelope**

---

**Lake Okeechobee Stage (ft, NGVD)**

- 17.0
- 16.0
- 15.0
- 14.0
- 13.0
- 12.0
- 11.0
- 10.0

**Months**

- Jan
- Feb
- Mar
- Apr
- May
- Jun
- Jul
- Aug
- Sep
- Oct
- Nov
- Dec
### Parameter Sensitivity Matrix

#### Performance Measures

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SLE1_Score</th>
<th>SLE2_Score</th>
<th>AvgAnnCEAE1</th>
<th>ScanAE2_Score</th>
<th>AvgAnnCE_An3B</th>
<th>Ctcbb_BucT</th>
<th>Hs_ScRib_Sc</th>
<th>Lo_ScRiSc</th>
<th>ExtremesAV_Sc</th>
<th>Scanscrap_ScBact_Ophyte_Scipelion_ScanSfSh_SfsECO_ScumECO_Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>p&lt;0.01</td>
<td>0.101601</td>
<td>0.375409</td>
<td>0.210729</td>
<td>0.008082</td>
<td>0.402914</td>
<td>0.151861</td>
<td>0.251823</td>
<td>-0.66373</td>
<td>-0.00209</td>
<td>0.22397</td>
</tr>
<tr>
<td>p&lt;0.01</td>
<td>0.101601</td>
<td>0.375409</td>
<td>0.210729</td>
<td>0.008082</td>
<td>0.402914</td>
<td>0.151861</td>
<td>0.251823</td>
<td>-0.66373</td>
<td>-0.00209</td>
<td>0.22397</td>
</tr>
</tbody>
</table>

#### Lake schedule “up-to” release recovery lines.

Demonstrates that ALL performance is most dependent on identification of appropriate storage diversion and recovery lines.
Model Results
Summary
Examples of Available Water Budget Maps
Meaningful reduction in Events Caused by Lake Okeechobee

Events that Do Occur are Shorter in Duration
Improvements observed in both "High" and "Extremely High" discharge events.

Note: In the FWO, a combined 37 Events are a Result of Basin Runoff.
Meaningful reduction in Events Caused by Lake Okeechobee

Events from Lake Okeechobee
Events from Caloos Basin Runoff

Note: In the FWO, a combined 47 Events are a Result of Basin Runoff

Events that Do Occur are Shorter in Duration

RECOVER Performance Measure
Improvements observed in both “High” and “Extremely High” discharge events.
Improvements observed in both "High" and "Extremely High" discharge events.

Flow Duration Curve for S79(cfs)

- CAL_EST05
- FWO Runoff Only
- ALT1
- ALT2
- ALT3
- ECB (Current)

Reduced Lake O Discharges (When Estuary Does Not Want Them)
Improved Lake ecology and generally improved high and low lake stages; brief excursions during extreme high stages allowable with expected HHD improvements and additional LOWP infrastructure capacity.
Higher Scores = Improved Lake O. Ecology

Lake Okeechobee Stage Envelope
Score Above Envelope - Weekly Calculation (1965-2005)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Standard Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECBLOW</td>
<td>*75.63</td>
</tr>
<tr>
<td>FWOLOW</td>
<td>*71.73</td>
</tr>
<tr>
<td>ALT1</td>
<td>*76.04</td>
</tr>
<tr>
<td>ALT2</td>
<td>*76.92</td>
</tr>
<tr>
<td>ALT3</td>
<td>*76.46</td>
</tr>
</tbody>
</table>

Note: A score of 0% is the worst score. The stage exceeds the envelope by 1 ft or more on average. A score of 100% is the best score. The stage never exceeds the envelope.
Higher Scores = Improved Lake O. Ecology
Higher Scores = Improved Lake O. Ecology
Higher Scores = Improved Lake O. Ecology

Lake Okeechobee Extreme Low Lake Stage

Stage Below 10 Feet NGVD (1965-2005)

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Standard Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECBLOW</td>
<td>86.67</td>
</tr>
<tr>
<td>FWOLOW</td>
<td>88.62</td>
</tr>
<tr>
<td>ALT1</td>
<td>97.93</td>
</tr>
<tr>
<td>ALT2</td>
<td>99.13</td>
</tr>
<tr>
<td>ALT3</td>
<td>98.86</td>
</tr>
</tbody>
</table>

Note: A score of 0% is the worst score. The stage falls below 10 feet for an average of 15 weeks per year or more. A score of 100% is the best score. The stage never falls below 10 feet.
Higher Scores = Improved Lake O. Ecology

Lake Okeechobee Extreme Low Lake Stage
Stage Below 10 Feet NGVD (1965-2005)

Standard Score (%)

ECBLOW FWOLOW ALT1 ALT2 ALT3

Note: A score of 0% is the worst score. The stage falls below 10 feet for an average of 15 weeks per year or more. A score of 100% is the best score. The stage never falls below 10 feet.

Run Date: Tue Mar 7 11:20:57 2017
Script Used: lo_generator.scr (ID380)
Filename: lo1_weekly_low_lake_annualized.agr
Higher Scores = Improved Lake O. Ecology
Higher Eco Scores = Improved Lake O. Ecology

Additional Detail: Examining a Generally Wetter Period

Lake Okeechobee Stage and Combined Ecological Score

- Eco score min = 3.0
- Eco score max = 10.5
- Eco score median = 8.0

Max Eco Score = 11


Model: RSMBN
Run Date: March 8, 2017
Water Shortage Cutbacks
Approximate or Improve
Upon “WSE-like”
Performance
Example Performance of K05N Above Ground Reservoir for ALT1

Frequent use of the above ground reservoir storage is evident across the RSMBN 1965-2005 simulation period.
Example Aquifer Storage & Recovery Performance for ALT1

asr1 - Lake Okeechobee
asr2 - K05 South
asr3 - K05 North

Peak ASR Storage = over 1.7 million ac-ft
## Northern Estuaries Benefits Summary

<table>
<thead>
<tr>
<th></th>
<th>Average Annual Lake O Regulatory Discharge (kac-ft)</th>
<th>% Estuary Regulatory Flow Reduction (relative to ECB)</th>
<th>Number of Years Lake O Causes a Damaging Event</th>
<th>% Estuary “Years with Impact” Reduction (relative to ECB)</th>
<th>Number of Months Lake O Causes a Damaging Event</th>
<th>% Estuary “Months with Impact” Reduction (relative to ECB)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>St Lucie Estuary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECB</td>
<td>165</td>
<td></td>
<td>15</td>
<td>27%</td>
<td>31</td>
<td>35%</td>
</tr>
<tr>
<td>FWO</td>
<td>126</td>
<td>24%</td>
<td>11</td>
<td>20</td>
<td>20</td>
<td>35%</td>
</tr>
<tr>
<td>ALT1</td>
<td>82</td>
<td>50%</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>71%</td>
</tr>
<tr>
<td>ALT2</td>
<td>80</td>
<td>52%</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>68%</td>
</tr>
<tr>
<td>ALT3</td>
<td>84</td>
<td>49%</td>
<td>7</td>
<td>53%</td>
<td>10</td>
<td>68%</td>
</tr>
<tr>
<td><strong>Caloosahatchee Estuary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECB</td>
<td>416</td>
<td></td>
<td>18</td>
<td>22%</td>
<td>38</td>
<td>39%</td>
</tr>
<tr>
<td>FWO</td>
<td>257</td>
<td>38%</td>
<td>14</td>
<td>23</td>
<td>23</td>
<td>39%</td>
</tr>
<tr>
<td>ALT1</td>
<td>140</td>
<td>66%</td>
<td>6</td>
<td>9</td>
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<td>76%</td>
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<tr>
<td>ALT2</td>
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<td>82%</td>
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<tr>
<td>ALT3</td>
<td>139</td>
<td>67%</td>
<td>9</td>
<td>50%</td>
<td>12</td>
<td>68%</td>
</tr>
</tbody>
</table>

Results based on RSMBN modeling using a 41 year, 1965-2005 Period of Simulation

Note: Outcomes equal or exceed expectations from RESOPS Screening Analysis
How to Access Model Data
March 8th Release of LOWP Initial Alternatives Array

- ECB vs FWO vs ALT1 vs ALT2 vs ALT3 Performance Measures for RSMBN (e.g. Lake O., Northern Estuaries, LOSA)
- Other Indicators (e.g. water budgets,) for RSMBN
- ALT1, ALT2, ALT3 model output for RSMBN
- Minor updates to ECB and FWO from Feb 2, 2017 release
- DMSTA validation that flows south to Everglades meet water quality planning targets
- Spreadsheets summarizing operations optimization
• LOWP Modeling data is permanently archived and available on the CERPZone Data Archival Storage and Recovery (DASR) system.
  • Step by step instructions previously provided to PDT or available upon request.
• For a short time, data is also available via ftp at:
Acknowledgements:
LOWP Hydrologic Modeling Team

- Alaa Ali
- Clay Brown
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