An Overview of the REservoir Sizing and OPerations Screening (RESOPS) Model

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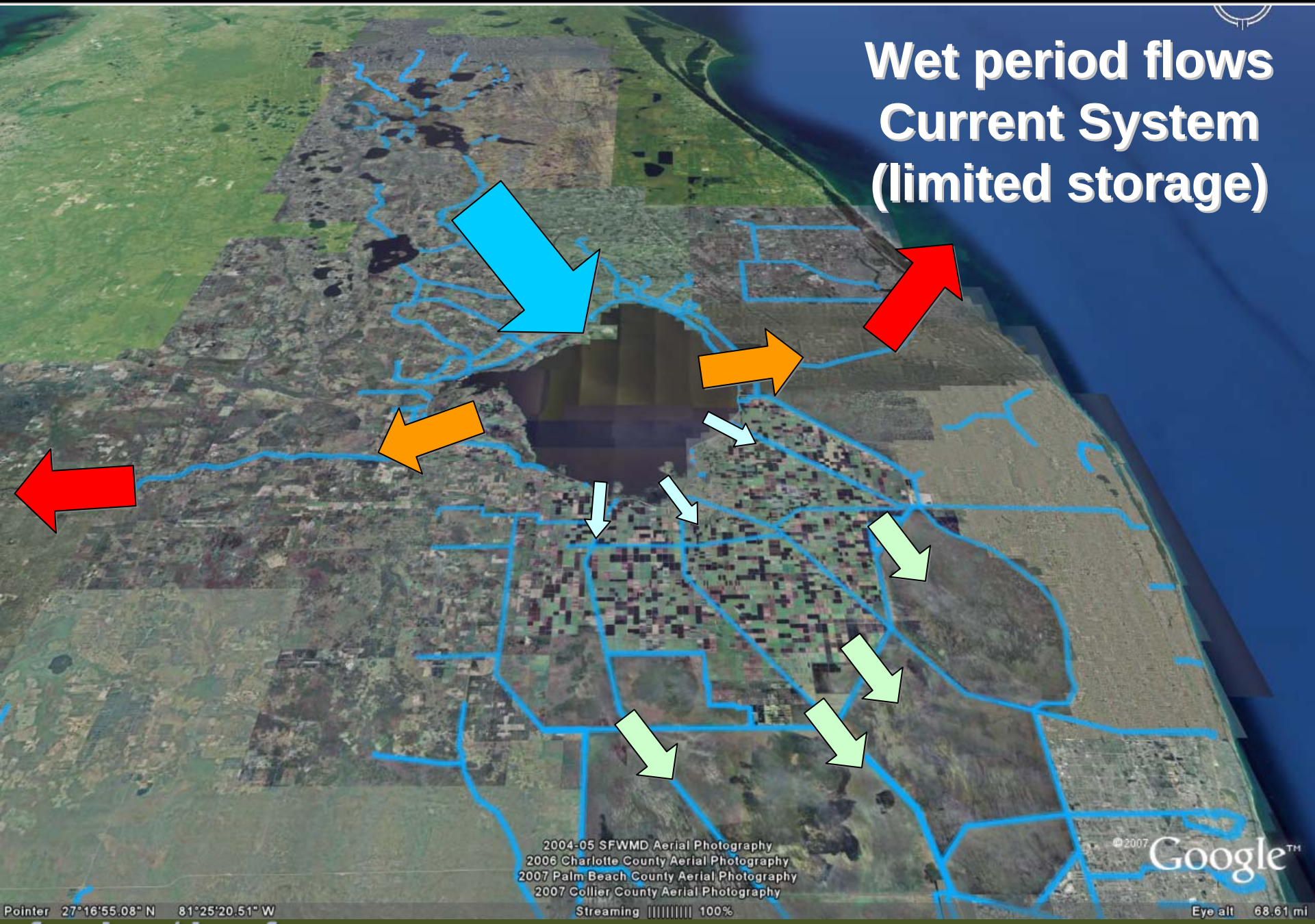
Topics

1. The South Florida System
2. RESOPS Model Background & Basic Features
3. Outputs & Performance Measures - Demo
4. Model Validation
5. Operating Rule Optimization
6. Performance Summary Maps
7. RESOPS Applications - Demo
8. Findings from the 2008 Due Diligence Application
9. RESOPS Strengths & Weaknesses
10. Next Steps

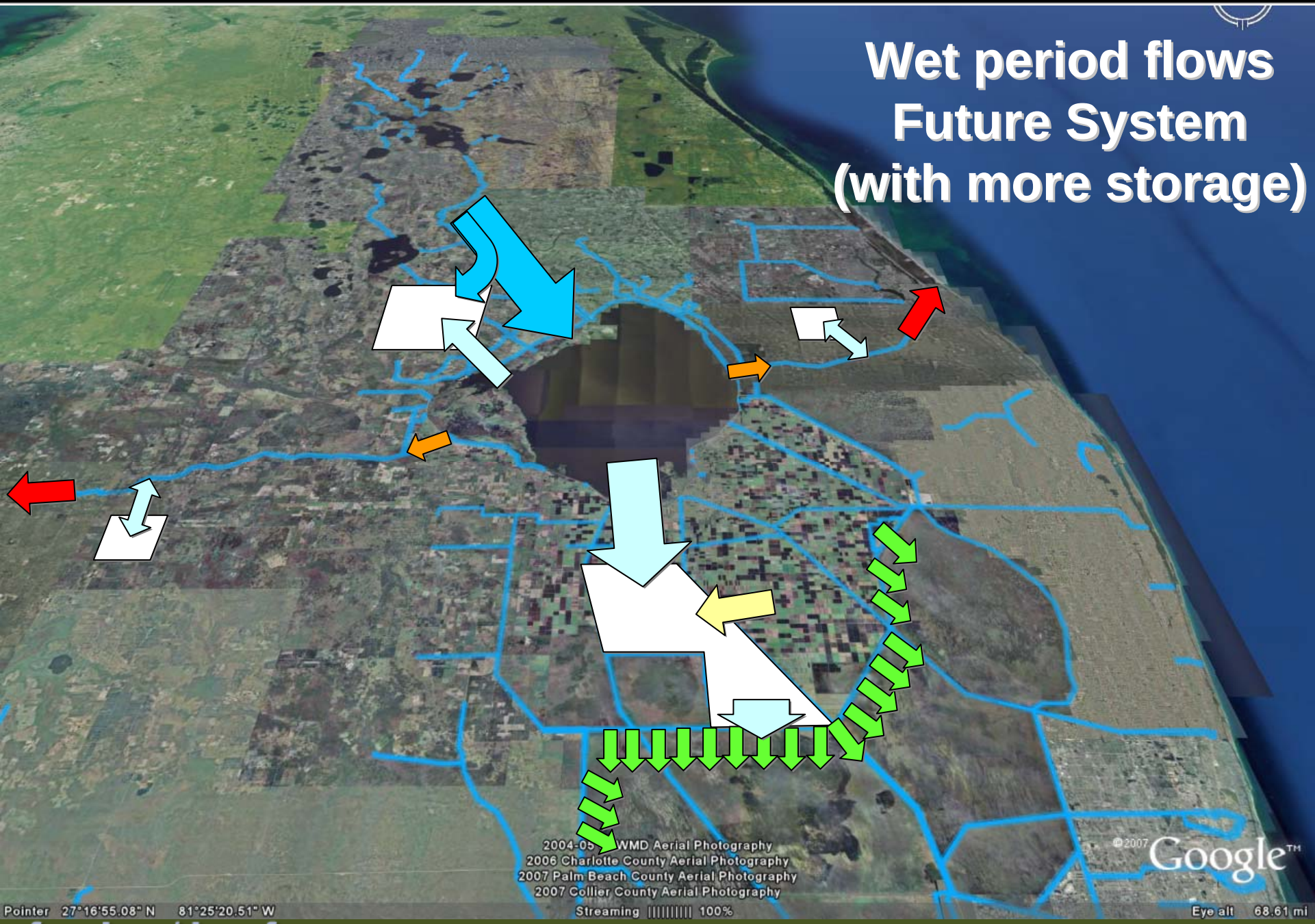
The South Florida System

- The south Florida system is highly integrated, with observably complex infrastructure and operational protocols.
- Changing structural and operational features in one geographic area can create benefits and/or impacts throughout the regional system
- RESOPS can help to evaluate the changes associated with different assumed configurations of storage in the Lake Okeechobee vicinity

Wet period flows Current System (limited storage)



Wet period flows Future System (with more storage)



Purpose of the RESOPS Model

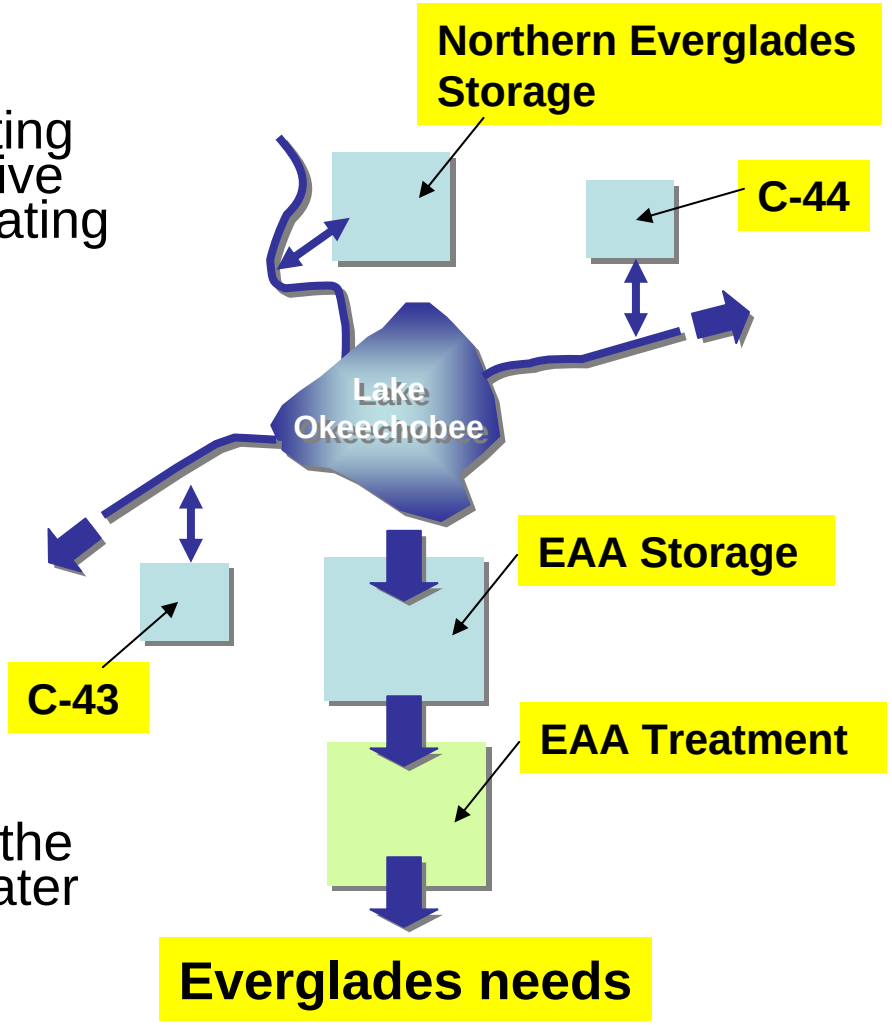
The RESOPS Model was developed to assist with the preliminary analyses and testing of alternative storage configurations that consider the interconnectivity of Lake Okeechobee, the Lake Okeechobee Service Area, the northern estuary watershed systems, and the Everglades.

Hydrologic Analysis Tool Selection

- Initial River of Grass planning efforts in 2008-09 required a relatively simple tool for screening a large number of conceptual facilities and operations in a short period of time
- Available planning-level simulation tools provide a wealth of information, but can require extensive time to set-up, run, and evaluate
  - Regional Simulation Model (RSM) used for Northern Everglades
  - South Florida Water Management Model (SFWMM, aka 2x2) used for 1999 C&SF Restudy and CERP
- The REservoir Sizing and OPerations Screening (RESOPS) Model was initially built and used as a screening tool for the Northern Everglades Planning Effort in 2007-08
  - Simple, flexible and fast water budget analysis tool developed as an EXCEL spreadsheet application

What is RESOPS?

- Coarse-scale Water Management Simulation Model
- Provides rapid screening-level testing of the integrated effects of alternative reservoir sizes and proposed operating rules for…
  - Lake Okeechobee,
  - Northern Everglades Storage
  - EAA Storage
  - C-43 Storage
  - C-44 Storage
  - Flows to the Everglades Water Conservation Areas.
- Performs 41-year continuous simulations (monthly time-step) of the hydrology and operations of the water management system



What is RESOPS? (continued)

- The strength of the RESOPS Model is its ability to quickly test the performance of alternative configurations and scenarios to screen ideas for further in-depth analysis.
  - Not a replacement for the detailed regional models
  - Can reduce the burden on the SFWMM and SFRSM
- It also includes an optimization routine that can automatically evaluate thousands of operating rules and select the best performer.

What is RESOPS? (continued)

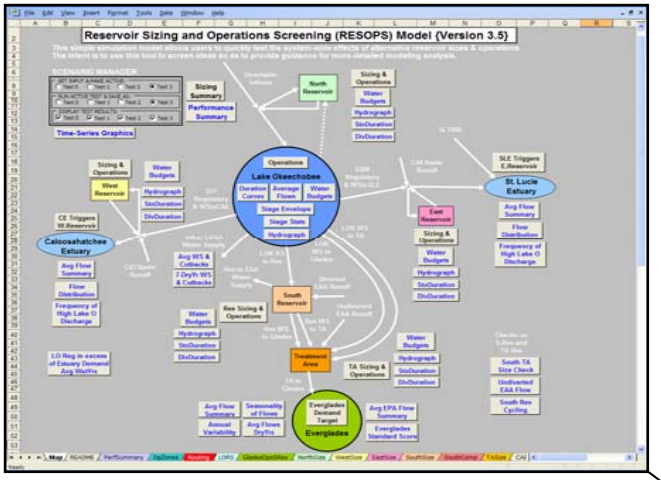
- Input requirements include:
  - Reservoir and treatment area capacities & operations, and Lake Okeechobee operations;
  - Monthly time-series (1965-2005) of rainfall, evaporation, tributary basin runoff, service area demands, estuary water needs.
    - Source of inputs is primarily the SFWMM
  - Everglades water needs
    - Monthly flow target time-series
    - Uncertainty in water needs of the Everglades
    - Multiple flow targets can be tested with RESOPS

What is RESOPS? (continued)

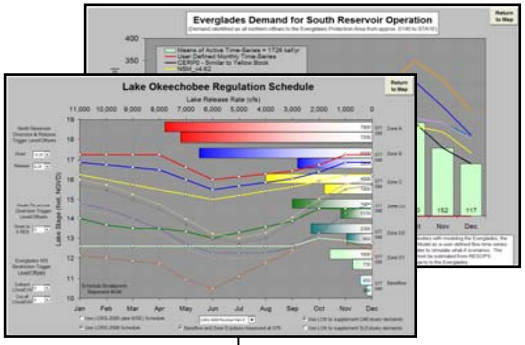
- Simulates flows to the Everglades by attempting to meet a flow target time-series at the northern boundary of the Everglades Protection Area (EPA)
  - Users can experiment with alternative time-series, or use a multiplier to simulate what-if scenarios
- Specific benefits or impacts to the Everglades hydropatterns from additional flows cannot be estimated from RESOPS
  - Requires more detailed models such as the SFWMM or RSM to evaluate

RESOPS Model Basic Structure

MAP GUI



OTHER GUIs



OPERATIONS & PRIMARY SWITCHES

BASIC DATA
- RF, ET, Runoff, Inflow, Demand
- Sto(h), Area(h)

OUTPUT FOR PERFORMANCE MEASURE GRAPHICS

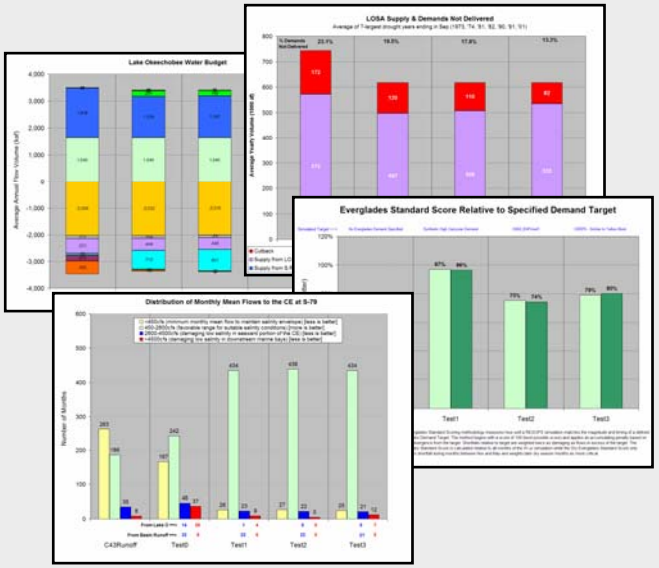
INFO SHEETS FOR SCENARIOS/TESTS

Test0
Test1
Test2
Test3

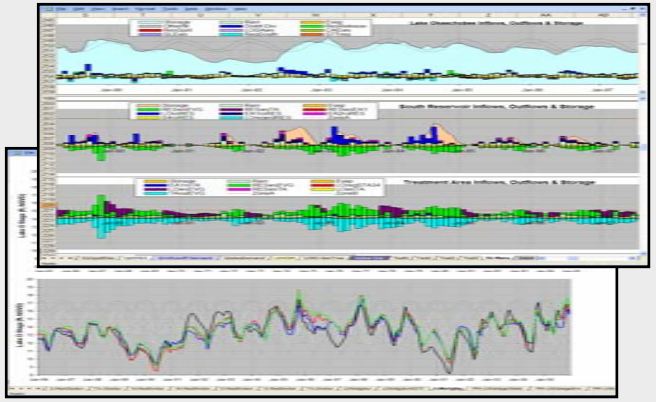
ACTIVE TEST

ROUTING & RELEASE CALCULATIONS

PERFORMANCE MEASURE GRAPHICS



TIME-SERIES PLOTS



Data Management handled with simple macros

RESOPS Model Outputs

Model Demonstration

RESOPS Performance Measures and Performance Indicators

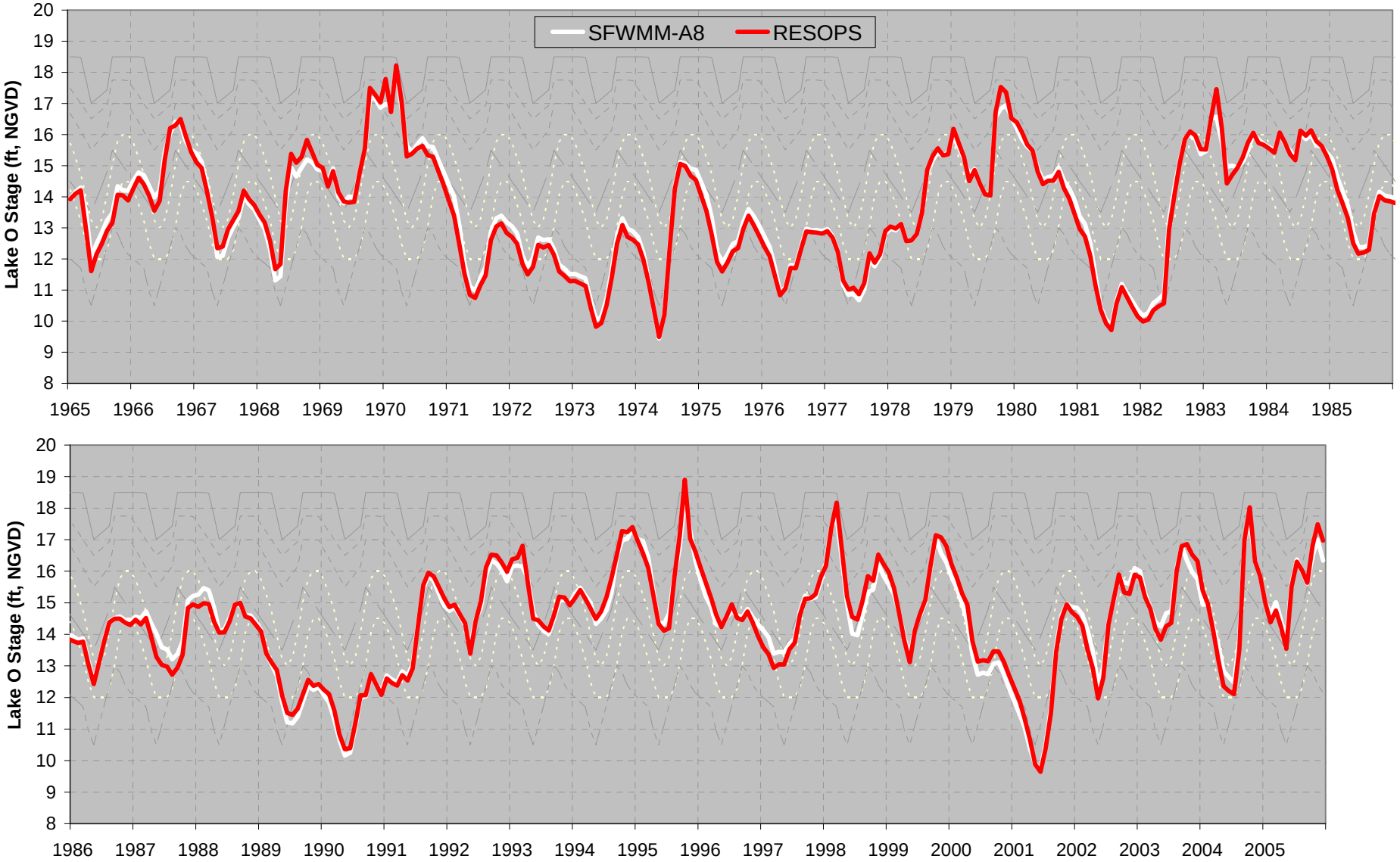
Performance Measures include:
Lake O stage envelope, estuary flow distribution, Everglades flow stats, water shortage stats, etc

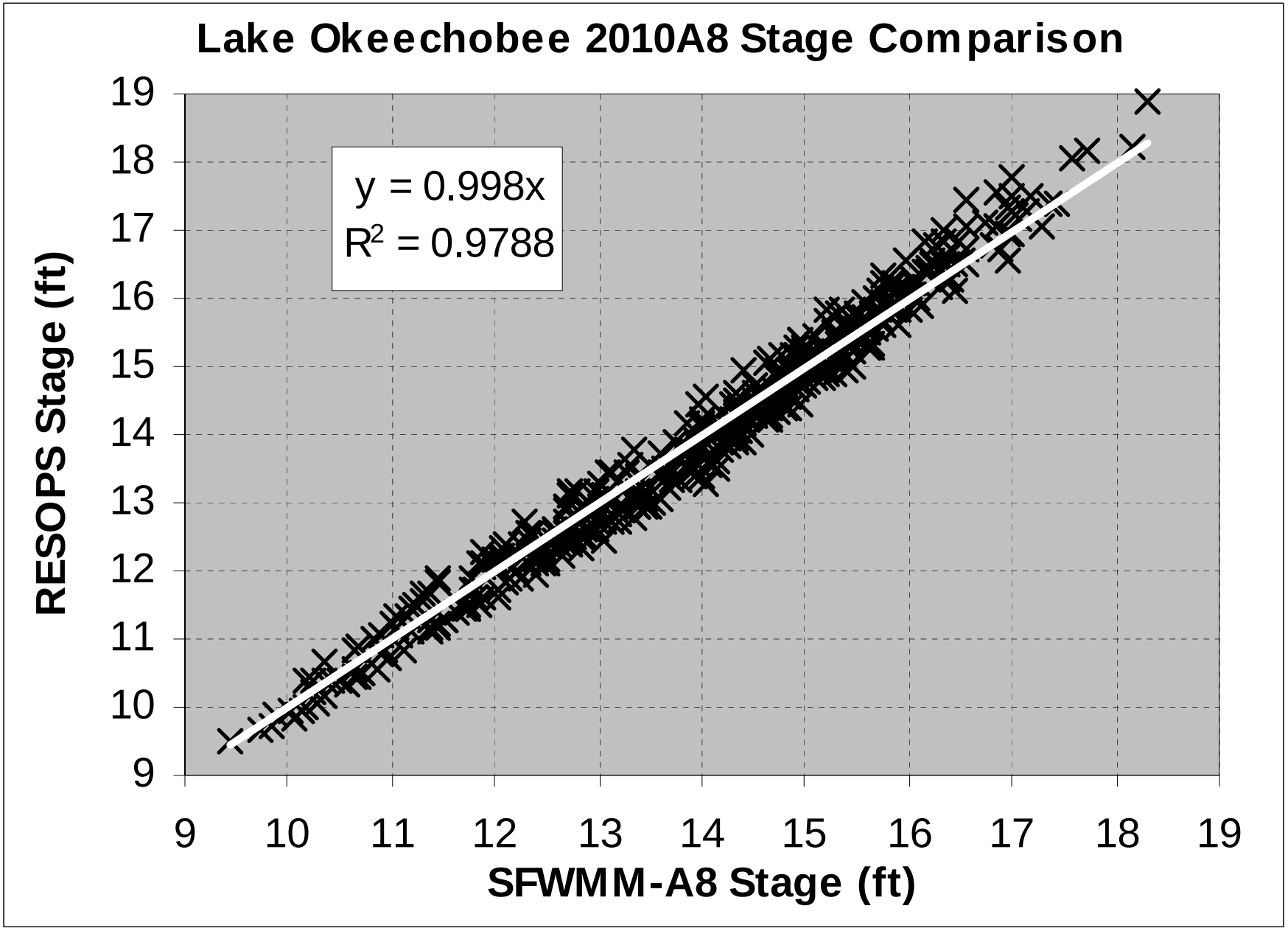
Performance Indicators include:
water budgets, hydrographs, duration curves, stats, etc

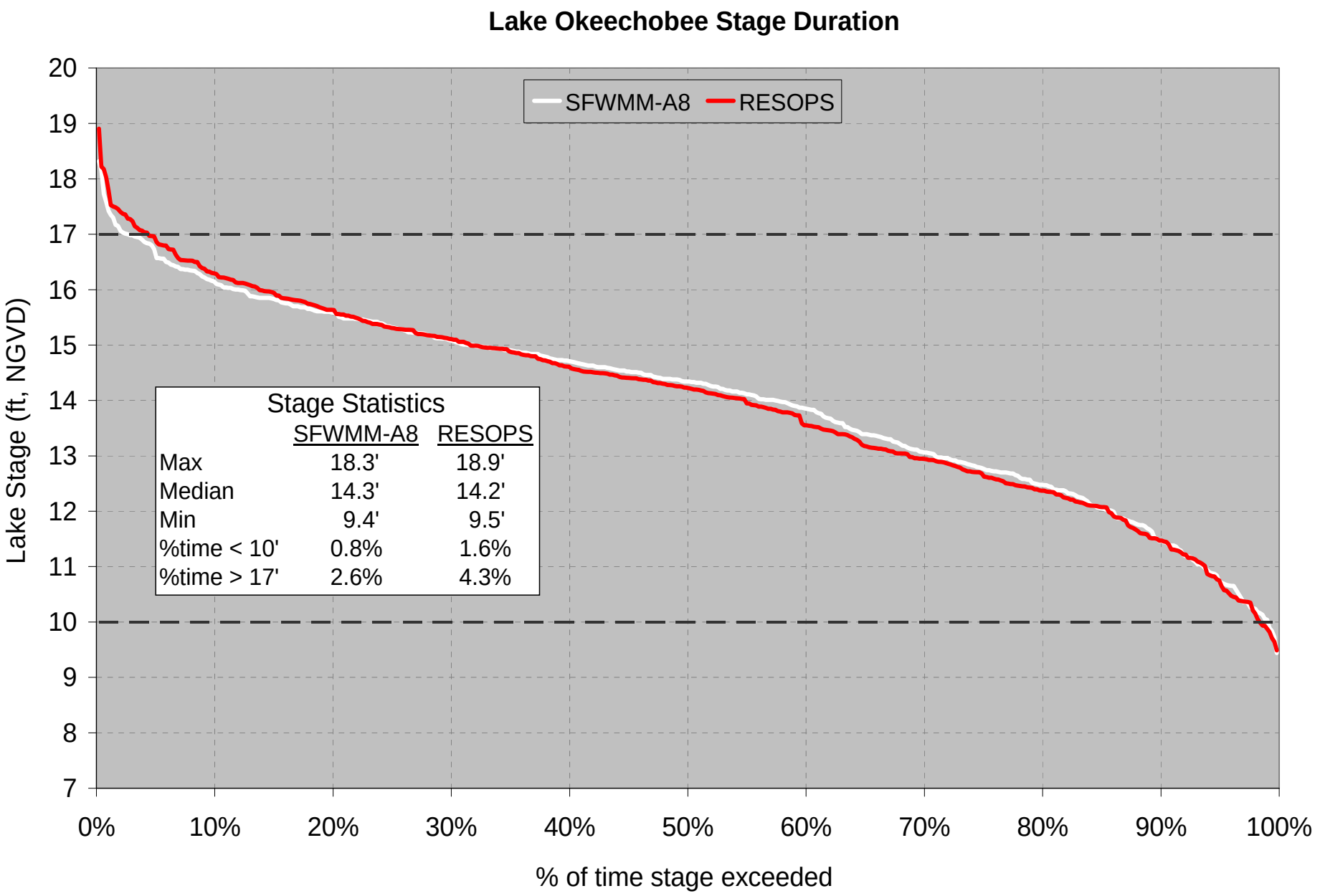
RESOPS Model Validation

- Extensive testing was performed to ensure that the RESOPS Model could reasonably reproduce key results from the SFWMM-A8 simulation.
- Switches in Routing sheet allow selective use of the SFWMM data to enable incremental testing and separate verification of the various operating rules. (eg, force SFWMM Lake O stages to be used to validate regulation schedule logic).
- After the operating rules were verified, they were used simultaneously to produce a RESOPS simulation and compared with the SFWMM-A8 simulation as a validation comparison.
- Validation Comparisons include:
  - Lake stage hydrograph, distribution, and goodness of fit stats
  - Water Budgets (RESOPS conserves mass)
  - Estuary Flow distributions

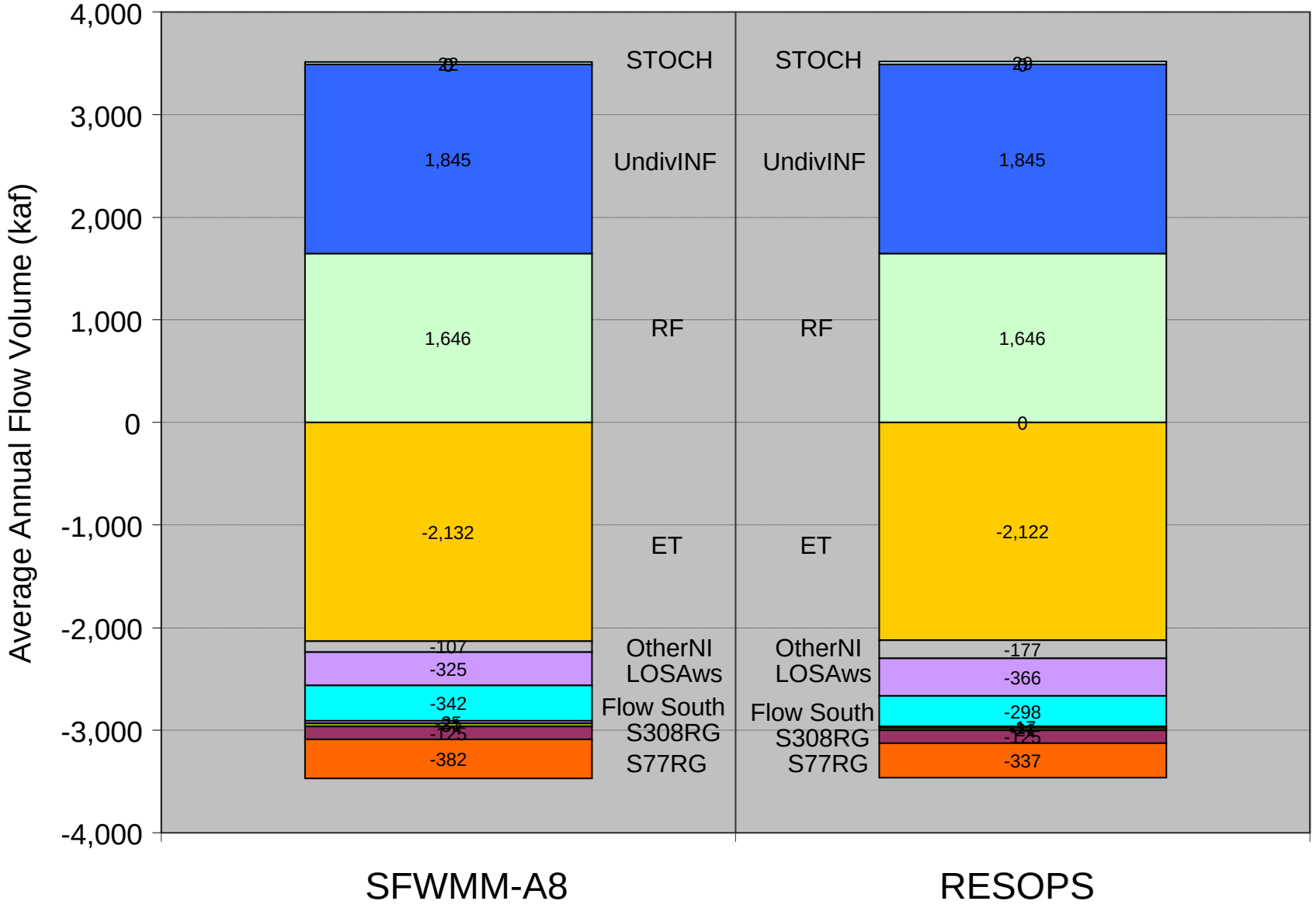
Lake Okeechobee Stage Hydrographs

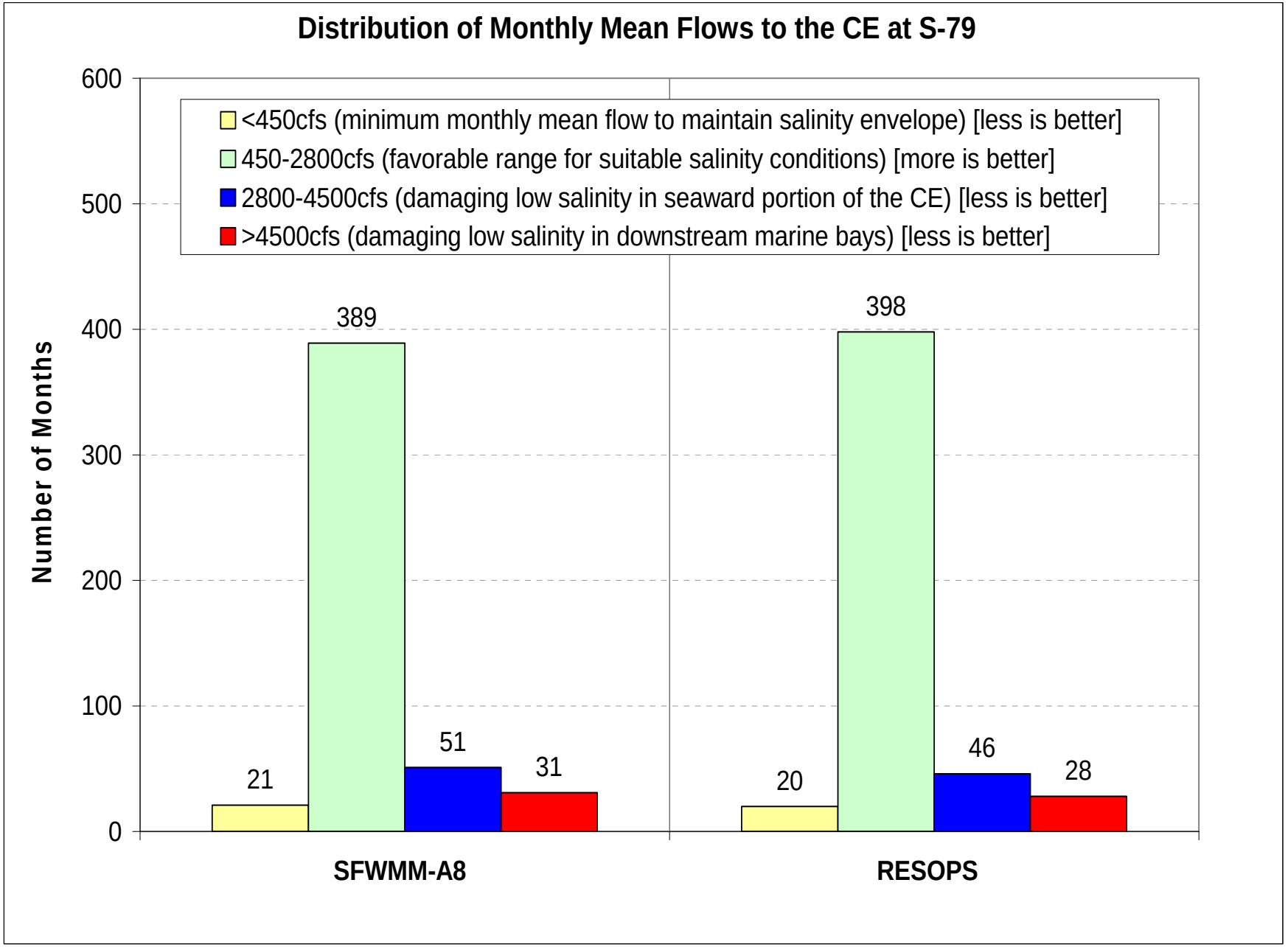


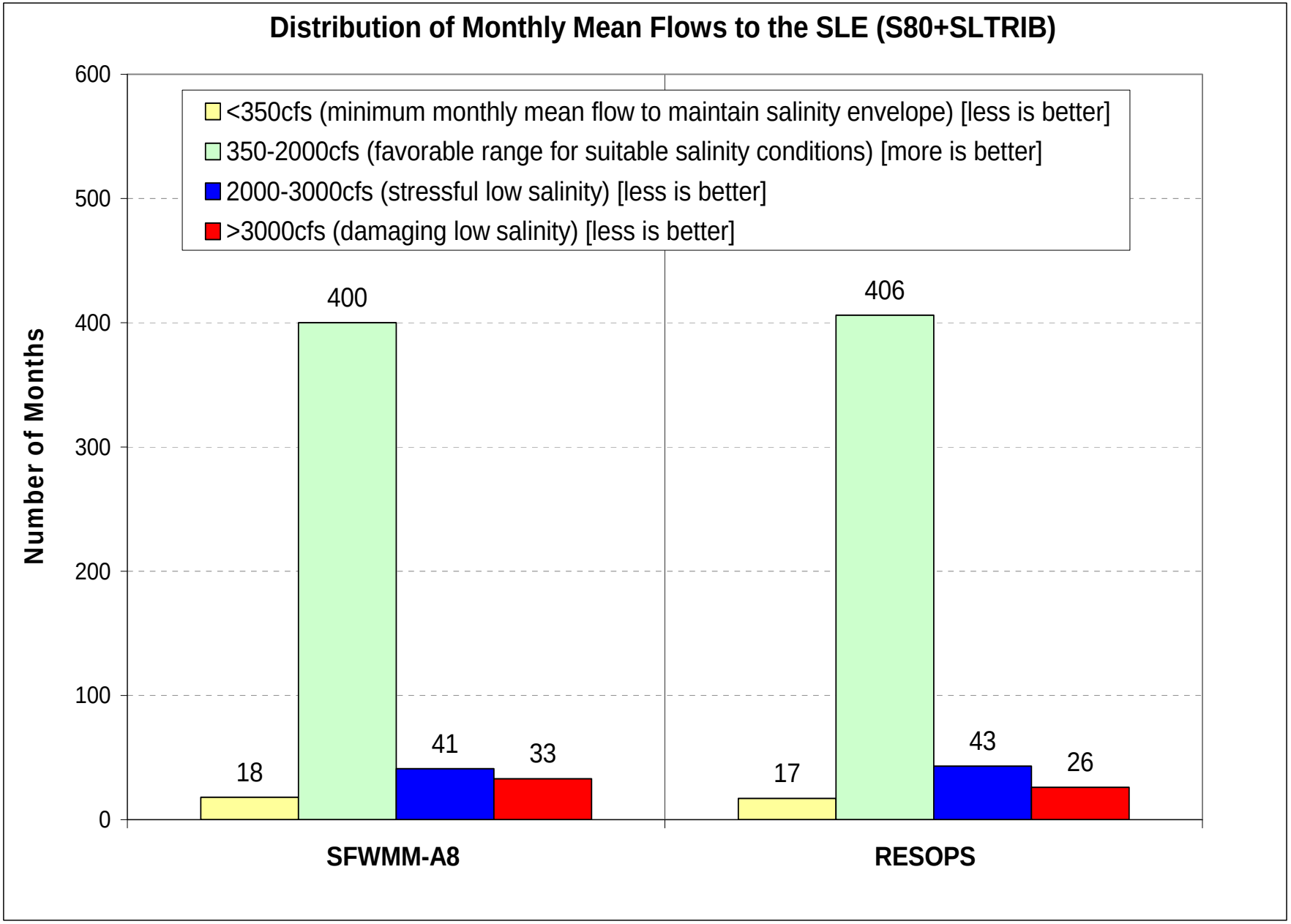

Lake Okeechobee 2010A8 Stage Comparison
y = 0.998x
R2 = 0.9788
RESOPS Stage (ft)
SFWMM-A8 Stage (ft)
9
10
11
12
13
14
15
16
17
18
19


Lake Okeechobee Stage Duration
SFWMM-A8
RESOPS
Lake Stage (ft, NGVD)
% of time stage exceeded
20
19
18
17
16
15
14
13
12
11
10
9
8
7
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Stage Statistics
SFWMM-A8 RESOPS
Max 18.3' 18.9'
Median 14.3' 14.2'
Min 9.4' 9.5'
%time < 10' 0.8% 1.6%
%time > 17' 2.6% 4.3%

Lake Okeechobee Water Budget




Distribution of Monthly Mean Flows to the CE at S-79
<450cfs (minimum monthly mean flow to maintain salinity envelope) [less is better]
450-2800cfs (favorable range for suitable salinity conditions) [more is better]
2800-4500cfs (damaging low salinity in seaward portion of the CE) [less is better]
>4500cfs (damaging low salinity in downstream marine bays) [less is better]
Number of Months
600
500
400
300
200
100
0
21
389
51
31
20
398
46
28
SFWMM-A8
RESOPS


Distribution of Monthly Mean Flows to the SLE (S80+SLTRIB)
<350cfs (minimum monthly mean flow to maintain salinity envelope) [less is better]
350-2000cfs (favorable range for suitable salinity conditions) [more is better]
2000-3000cfs (stressful low salinity) [less is better]
>3000cfs (damaging low salinity) [less is better]
Number of Months
600
500
400
300
200
100
0
18
400
41
33
17
406
43
26
SFWMM-A8
RESOPS

RESOPS Model Operating Rule Optimization

- Determines the best combination of several Lake Okeechobee operating parameters from a user-defined set
- Uses a simple simulation-based constrained optimization within a discrete search space
- Optimization maximizes the value of a weighted objective function
  - User can change the objective function weights
  - User can specify the ranges and the discretization level of the operating parameters

RESOPS Model Operating Rule Optimization

- **Maximize Performance =** $\sum_{i=1}^{n} \omega_i \bullet X_i$
- **Subject to:**

X_1 > 30 (corresponds to performance of existing condition simulation)

X_2 > 80 (corresponds to performance of existing condition simulation)

where:

n = number of performance measures used in the weighted objective function (currently, n=6, but any number of measures can be used)

X_1 = Lake Okeechobee Stage Envelope, Standard Score Below

X_2 = Lake Okeechobee Stage Envelope, Standard Score Above

X_3 = Caloosahatchee Estuary, % decrease in months of Lake-triggered damaging high discharges (relative to the current condition simulation)

X_4 = St. Lucie Estuary, % decrease in months of Lake-triggered damaging high discharges (relative to the current condition simulation)

X_5 = Everglades Standard Score, measures how well the simulation matches the magnitude and timing of a defined Everglades Demand Target

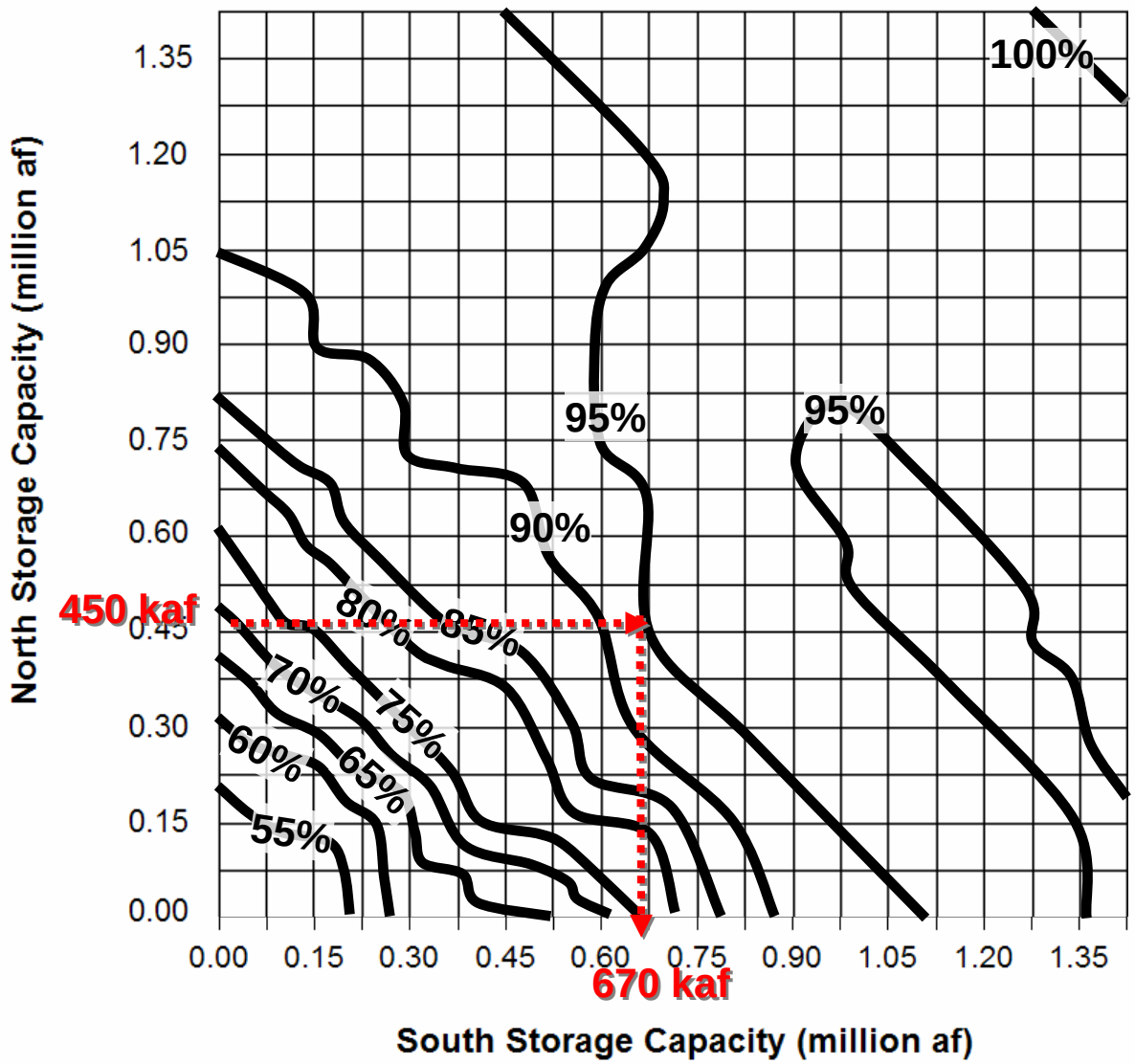
X_6 = Dry Season Everglades Standard Score

ω_i = user-assigned objective function weights

Performance Summary Maps

- Performance Maps summarize thousands of RESOPS simulations and provide a handy tool for:
  - selecting reservoir size needed to meet desired performance
  - illustrating performance trade-offs
- Example maps were developed from 140,000 RESOPS simulations
- Shape of performance surface changes with different assumptions for Everglades needs, reservoir maximum depths, etc.
- Maps were used to guide conceptual designs during Phase 1 Planning effort for Governor's River of Grass initiative.

% Reduction in Lake-Triggered High Discharges to the Northern Estuaries

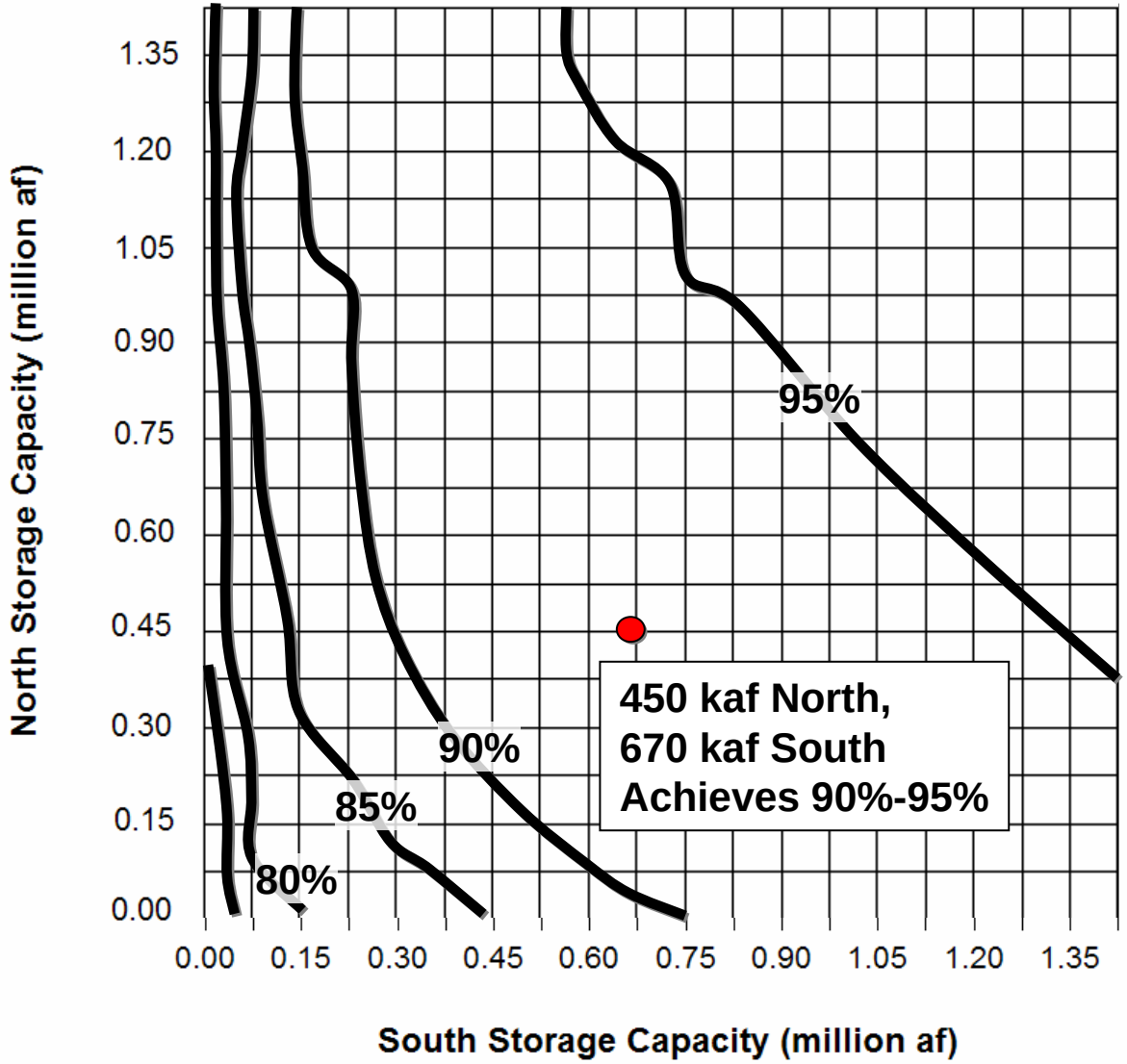


Performance Maps provide guidance for selecting storage size combinations to achieve desired levels of performance.

Results from RESOPS Model simulations of specific configurations will consider more detailed specifications and performance may vary from the general guidance provided here.

Note:
Each of the 400 points used to create this map represents an optimized operation of the corresponding storage configurations. Approx. 350 RESOPS model simulations were performed for each storage configuration.

Everglades Demand Target Delivered – Standard Score



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Note:
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RESOPS Applications

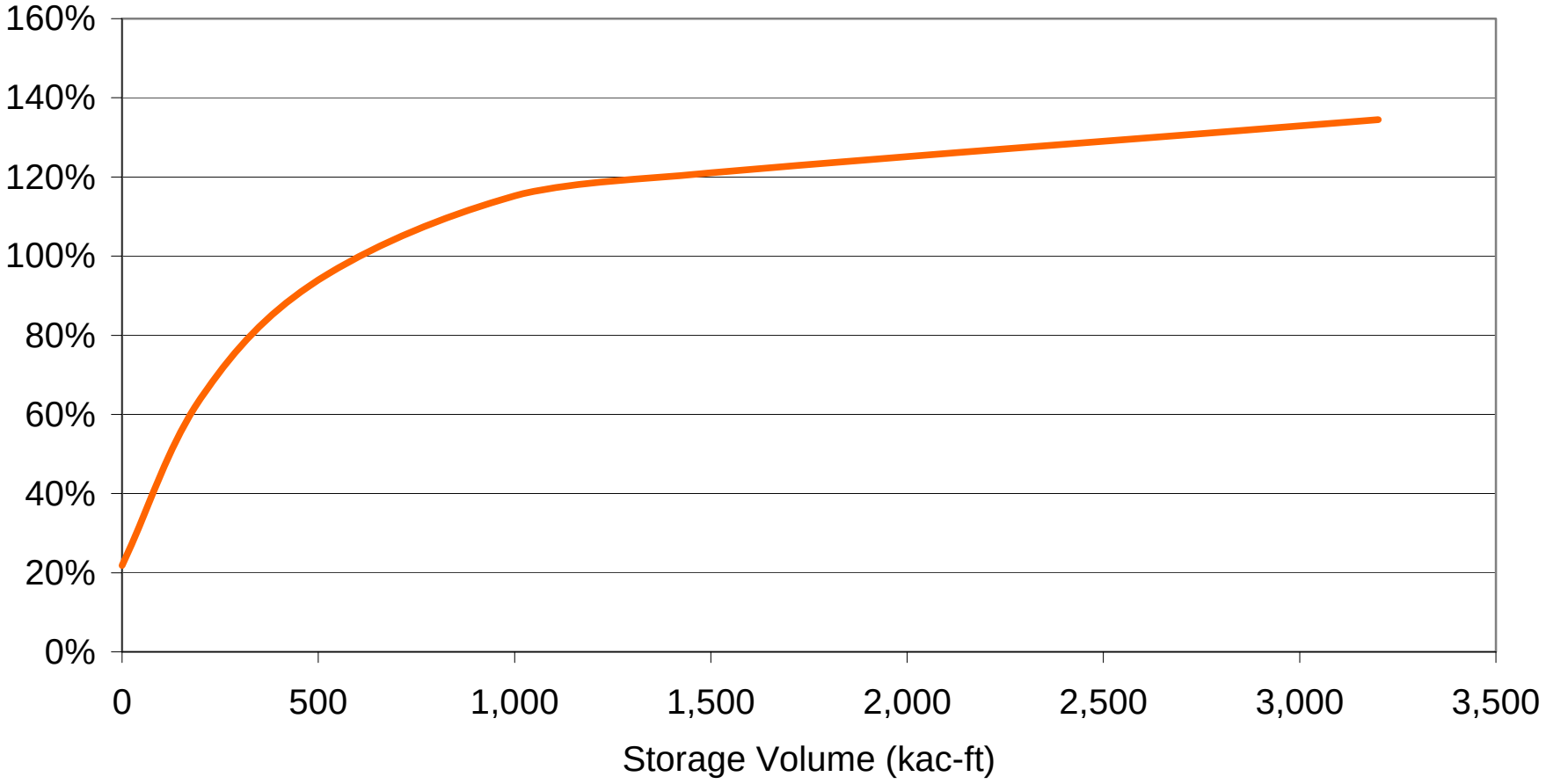
Model Demonstrations

1. Change Lake O regulation schedule
2. Change Storage Reservoir Sizes
   - examples based on ROG Phase 1 Planning effort
3. Optimize Operating Rules
   - Examples showing how to change objective weights

Preliminary Findings from the 2008 Due Diligence Effort

- Increasing the storage size in the EAA generally improves system performance for most of the key performance measures
- There is generally a range of diminishing returns where additional increases in EAA storage capacity does not result in large performance improvements

Percentage Increase in Dry Season Flows to the Everglades with the Addition of Storage South of Lake Okeechobee



Based on RESOPS Screening Analysis of November to May Deliveries During the 1965 to 2005 Period.

Preliminary Findings - Everglades

- Everglades water needs are uncertain and can heavily influence storage capacity
- Flows to the Everglades can be substantially increased with the addition of EAA storage and treatment.
- Timing of flows to the Everglades improves with additional storage
- Year-to-Year (Inter-annual) variability of flows to the Everglades is likely to increase with additional storage
- Meeting dry period needs of the Everglades increases the need for storage

Preliminary Findings – Lake Okeechobee

- Increasing regional water flow to the south from Lake Okeechobee tends to increase the frequency and duration of low Lake stages
- Northern Everglades storage is effective in improving Lake Okeechobee lower stage envelope performance
  - Allows water to be released to Lake Okeechobee to offset low stages in dry periods
- Lake Okeechobee Regulation Schedule modifications need to take into consideration storage added to the system

Preliminary Findings - Estuaries

- Significant reduction in Lake-triggered high discharge events are observed with additional storage/treatment
- Estuary performance is highly sensitive to Everglades needs
  - Larger Everglades demand = better estuary performance
  - Why?
    - Larger Everglades demand leads to more storage facility releases from the south reservoir to the Everglades
    - This frees up storage capacity in the south reservoir to receive Lake releases
    - Fewer Lake Okeechobee regulatory releases to estuaries are needed
- Both North and South storage can be used to effectively meet estuary objectives

Preliminary Findings – Water Quality

- Additional treatment area beyond currently planned STA capacities is required when providing increased flows to the Everglades
  - Based on a range of 100 to 200 ppb inflow concentrations and assuming a flow volume of approximately 1 million acre-feet per year, additional treatment area between 12,000 and 45,000 acres may be required.
- Evapotranspiration losses in a wetted treatment area can significantly impact the ability to achieve system objectives
  - New treatment area design and operational concepts may be needed to optimize water usage for facilities at this scale.

Summary of 2008 Due Diligence Findings

- Based on the analysis to-date, the proposed acquisition can facilitate additional storage and treatment capacities to provide significant benefits to Lake Okeechobee, the Caloosahatchee and St. Lucie estuaries and the Everglades
- Careful future consideration must be given to potential issues of treatment area management and water depths in the Water Conservation Areas
- The optimal size, capacity, configuration and costs of facilities and the associated operations will be developed through subsequent open, public planning processes

Additional Information

- For more information on the modeling support of the River of Grass initiative:

  Go to www.sfwmd.gov and navigate through the following links:

  Everglades – Reviving the River of Grass – Restoration Project Planning

- Summary paper of Due Diligence effort available at:

  http://my.sfwmd.gov/pls/portal/docs/PAGE/COMMON/NEWSR/ROG_DUE_DILIGENCE_HYDROLOGY.PDF

RESOPS Strengths and Weaknesses

- Strengths:
  - Can quickly test the integrated effects of alternative reservoir sizes and system operating rules for the region surrounding and including Lake Okeechobee
  - Operating rule optimization capability automates development of performance tradeoff curves & maps
  - Appropriate for conceptual planning & screening
  - Can reduce the burden on the detailed planning models
- Weaknesses
  - Use of RESOPS requires significant understanding of south Florida system hydrology and operations as well as familiarity with Excel
  - Impact of additional flows on Everglades hydropatterns cannot be estimated with RESOPS

Next Steps for RESOPS

- Incorporate improved data sets and time-series for Everglades water needs (based on outcomes from January 2009 Everglades Flow Targets Workshop)
- Additional Model Documentation
- Provide screening-level hydrologic analysis for the 2009 River of Grass - Phase 1 Planning Effort
- **Peer Review**
- **Implement Peer Review Recommendations**
- **Finalize Model Documentation Report**

Questions?