Adaptive Protocols for Lake Okeechobee Operations

Interim Solutions for Improving Performance of the Central & Southern Florida System

Presented to the
Water Resources Advisory Commission
June 7, 2012

Calvin Neidrauer, P.E.
Susan Gray, Ph.D.

Presentation Topics

- **Part 1. Background**
  (2008 LORS, 2010 Adaptive Protocols)
- **Part 2. Recent Lake O Operations Analysis**
  - Purpose
  - Ideas analyzed
  - Results of analysis
- **Part 3. Additional Analysis**
  - Lake O water quality
  - Everglades hydrology

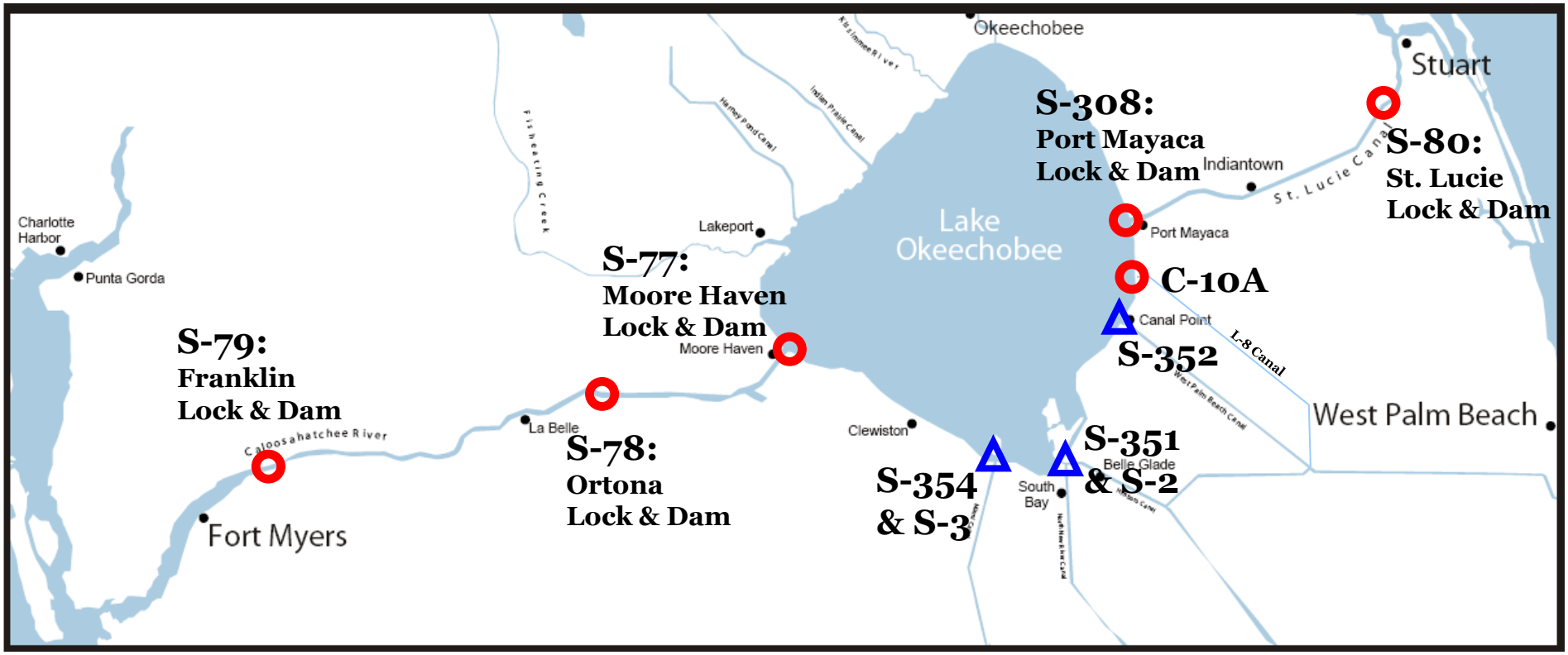
PART 1. BACKGROUND

- 2008 LAKE OKEECHOBEE REGULATION SCHEDULE (LORS)
- 2010 ADAPTIVE PROTOCOLS

Calvin Neidrauer, P.E.

Chief Engineer, Water Control Operations

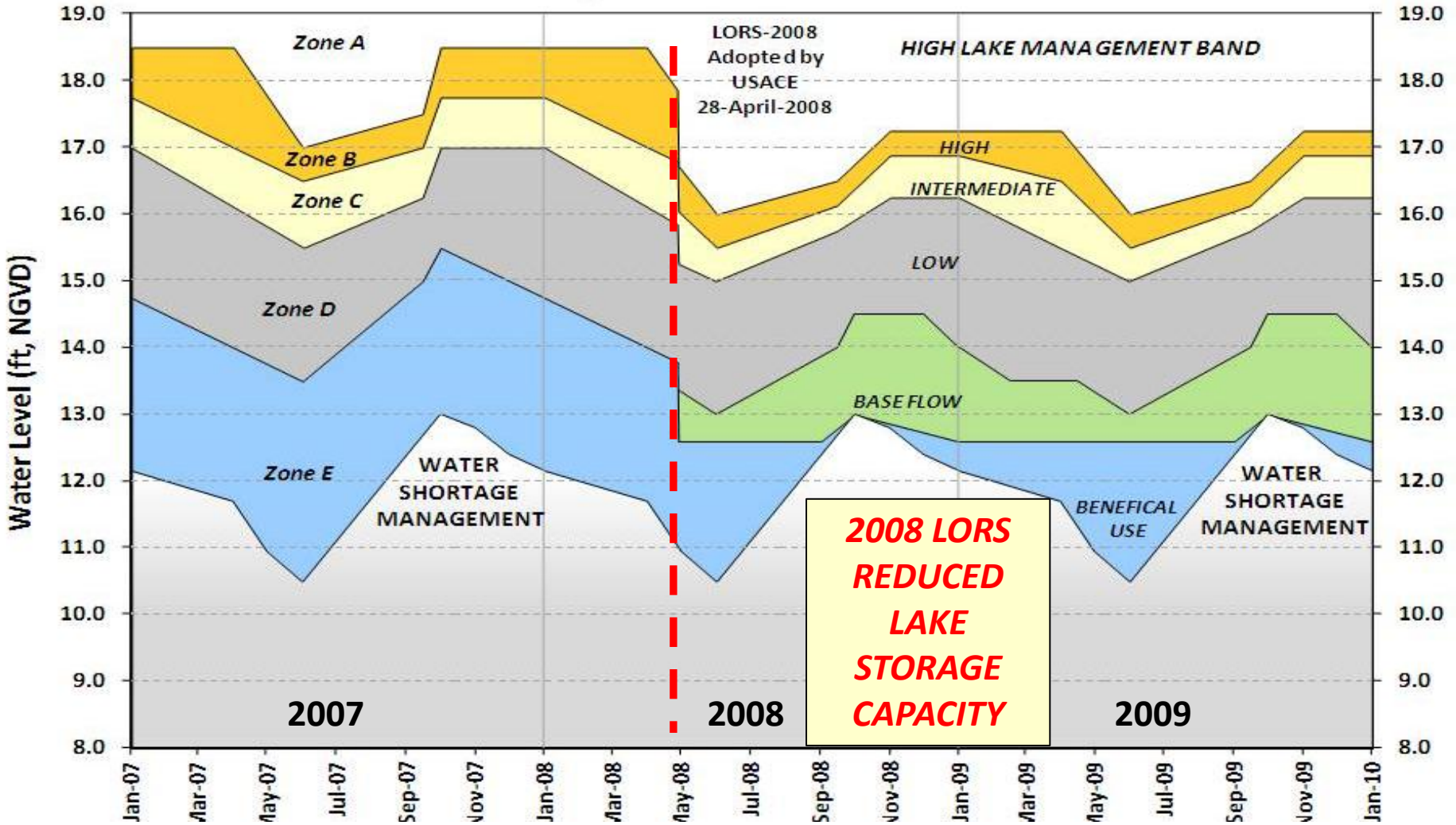
Lake Okeechobee Outlet Structures Managed by the USACE (red o) and the SFWMD (blue Δ)



Lake Okeechobee Operations Federal Regulation Schedule

- Lake Okeechobee water levels are managed according to a federal regulation schedule
- U.S. Army Corps of Engineers lowered the Lake Okeechobee Regulation Schedule in 2008 (LORS 2008)
- Driving factors: public health, safety & welfare concerns related to the integrity of the Herbert Hoover Dike
- Dike repairs expected to take 15-20 years
- More than 1 foot of water storage lost as a result of schedule change
- Adverse impacts to water supply
- Adverse impacts to Lake Okeechobee Minimum Flow & Level

Lake Okeechobee Regulation Schedule
Transition from 2000 LORS (WSE) to 2008 LORS



Lake Okeechobee Operations

Multiple and Competing Water Needs:

- Lake Okeechobee Service Area
  ~ 700,000 irrigated acres
- Caloosahatchee River & Estuary
- Everglades National Park
- Lake Okeechobee ecological resources
- Lower East Coast (public water supply for 5.5 million people, maintain canal levels to help prevent salt water intrusion)
- Stormwater Treatment Areas (57,000 acres)
- Water Conservation Areas
  - currently used for LEC pass-thru flows
  - WCA specific water needs to be met with CERP components

What are the Adaptive Protocols for Lake Okeechobee Operations?

- Operating Guidance used by SFWMD to make release recommendations to the USACE
- Clarifies release amounts that are within the "flexibility" provided in the USACE's Lake Okeechobee Regulation Schedule (2008 LORS)
- SFWMD public process began in August 2009
  - final document accepted by SFWMD Governing Board in September 2010

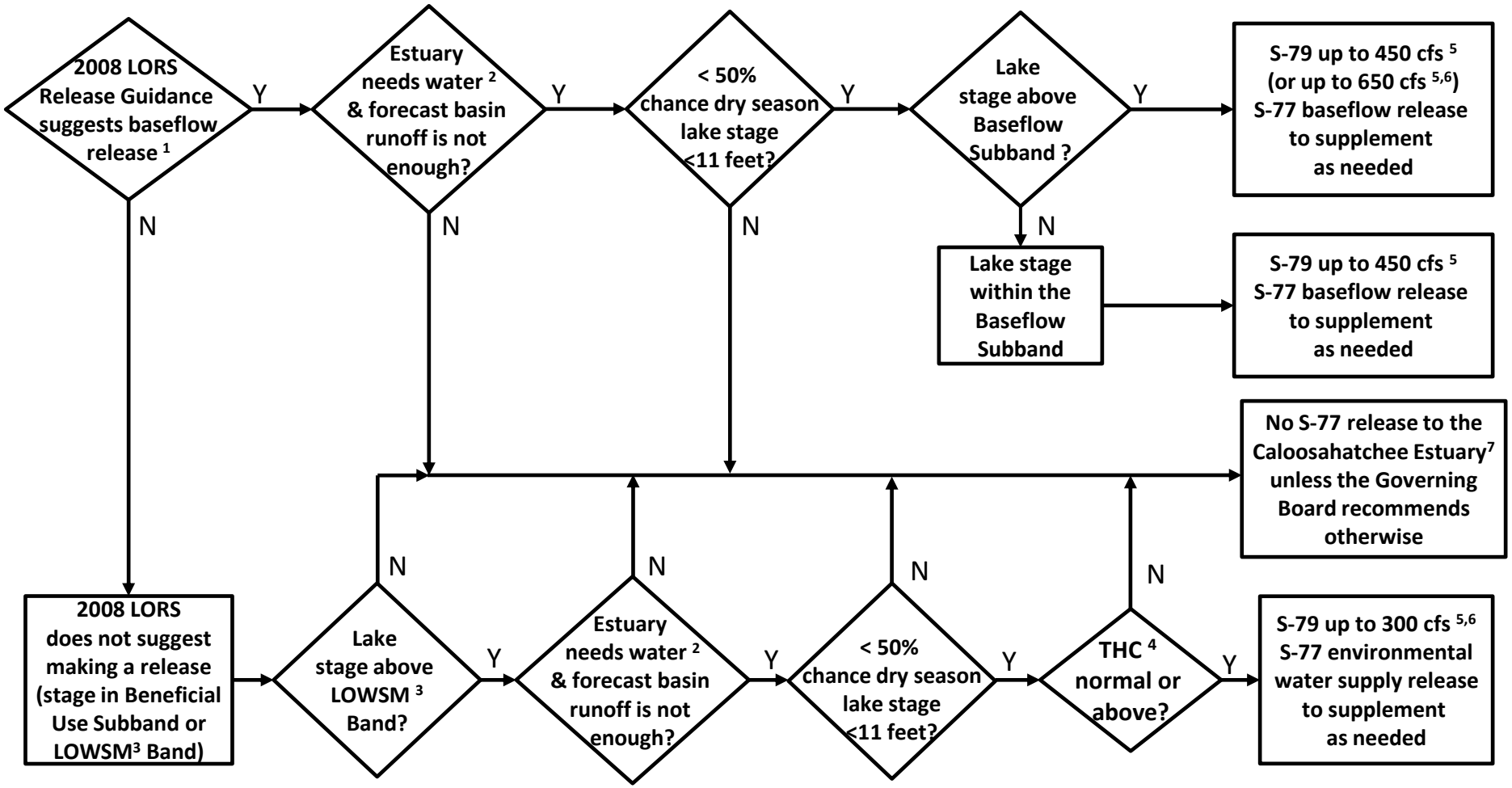
"Boundaries" of the 2010 Adaptive Protocol Revisions

- Revisions within the existing USACE Lake Okeechobee Regulation Schedule (2008 LORS)
- Focus where the schedule allows releases "up to" an amount but does not set specific flow targets or where no release volume described
- Did not revise the USACE Lake regulation schedule
- Did not revise the SFWMD water shortage rule
- Semi-annual public review of performance and 6-month look ahead

Lake O Adaptive Protocols
Key Components

- Provide guidance where releases are expressed as a range of volumes, e.g. “up to 2000 cfs”
- Identified opportunities for “win-win” or “win-neutral” improvements for resources such as
  - environmental deliveries to the estuaries
  - water supply for the STAs
  - Lake Okeechobee MFL
  - water supply deliveries to permitted users
- Provide guidance on releases to the estuaries in the Low, Base Flow and Beneficial Use subbands of LORS-2008

Flowchart to Guide Recommendations for Lake Okeechobee Releases to the Caloosahatchee Estuary for 2008 LORS Baseflow & for Environmental Water Supply



[1]The 2008 LORS Release Guidance (Part D) can suggest baseflow releases in the Intermediate, Low, or Baseflow Subbands.

[2]Estuary "needs" water when the 30-day moving average salinity at I-75 bridge is projected to exceed 5 practical salinity units (psu) within 2 weeks.

[3]LOWSM = Lake Okeechobee Water Shortage Management.

[4]Tributary Hydrologic Condition (THC) is based on classification of Lake Okeechobee Net Inflow and Palmer Index.

[5]Can release less than the "up to" limit if lower release is sufficient to reach or sustain desired estuary salinity; cfs = cubic feet per second.

[6]After reviewing conditions in Water Conservation Areas (WCAs), Stormwater Treatment Areas (STAs), ENP, St. Lucie Estuary and Lake Okeechobee.

[7]Should this condition be reached, the Governing Board will be briefed at their next regularly scheduled meeting as part of the State of the Water Resources agenda item.

PART 2. RECENT ANALYSES OF LAKE OKEECHOBEE OPERATIONS

Calvin Neidrauer, P.E.

Chief Engineer, Water Control Operations

Purpose of 2011-12 Lake Okeechobee Operations Analysis

- **To try to find additional performance improvements from exploring the effects of hypothetical changes to Lake O operating criteria**
  - 2008 Lake Okeechobee Regulation Schedule
  - 2009 Lake Okeechobee Water Supply Management
  - 2010 Adaptive Protocols
  - Others (e.g., Water Supply Augmentation)
- **To identify performance trade-offs and potential compromise solutions toward improved system performance and a better balance among competing performance objectives**

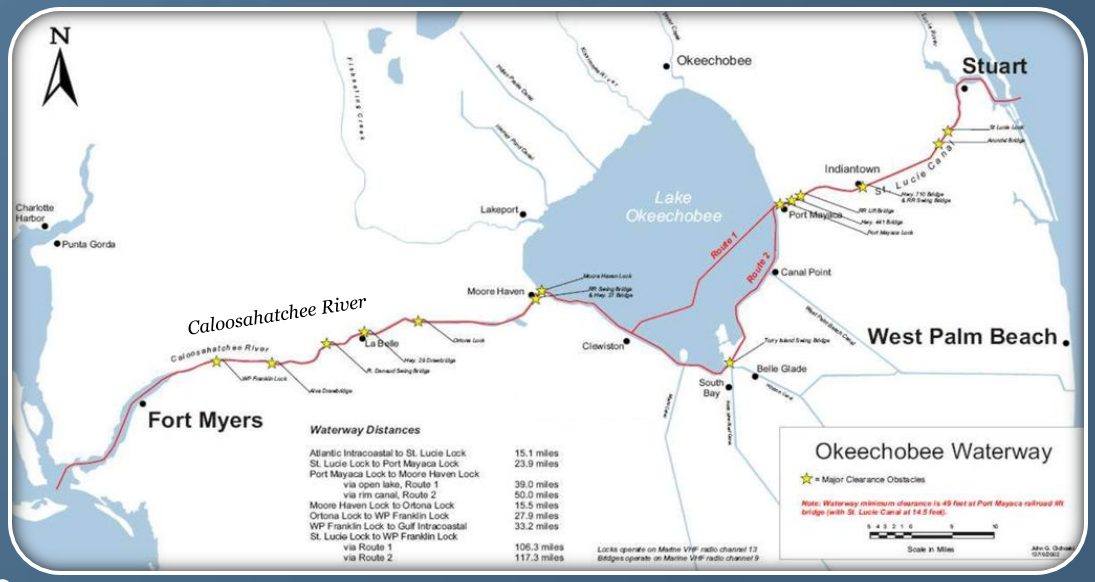
Tools

- **Lake Okeechobee Operations Screening (LOOPS) Model (Neidrauer, et al, 2006)**
  - Regional hydrologic and water management simulation model for the system including Lake O, LOSA, the C-43 and C-44 basins and estuaries (uses SFWMM algorithms)
  - Daily time-step, continuous simulation driven by 41-years (1965-2005) of historical rainfall
  - Can quickly test a broad variety of operating strategies
  - Gives instant feedback using standard measures of performance
- **Multi-objective Trade-off Methodology:**
  - Generates thousands of simulations using combinations of operating parameters
  - Identifies subset of noninferior (i.e., best) solutions
  - Displays performance tradeoffs

Strategies Analyzed Since Summer 2011

1. **LORS-2008 flexibility (to improve storage capability)**
   - Reduced discharge during stage recessions
   - Relax peak stage constraint
   - etc
2. **Adaptive Protocol mods (to improve CE salinity)**
   - Relax Tributary Hydrologic Condition
   - Allow releases in Water Shortage Management Band
   - etc
3. **LOSA water shortage management (increase cutbacks and cutback sooner)**
4. **Water Supply Augmentation**

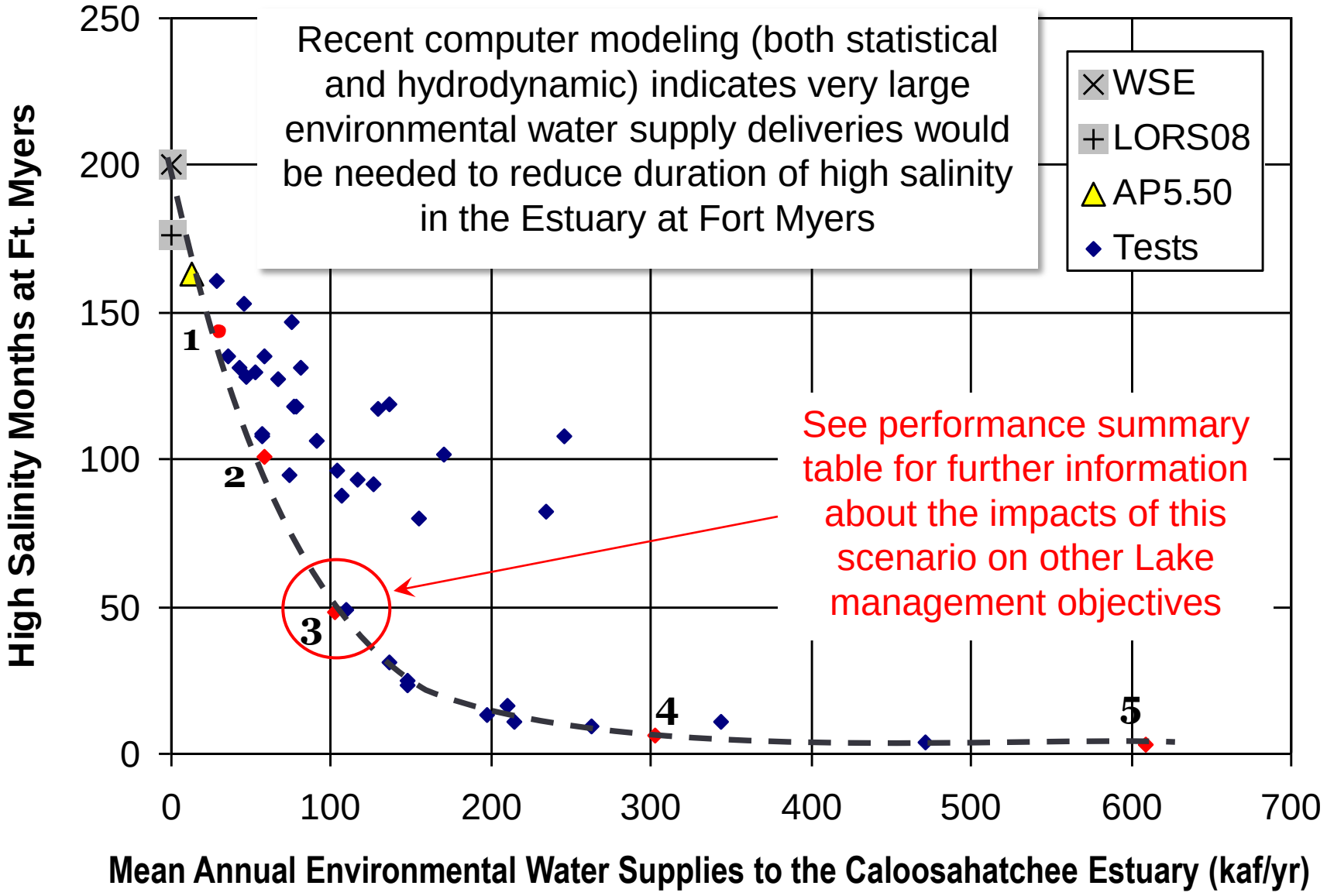
How much water would it take to reduce the Caloosahatchee Estuary high salinity months at Ft. Myers?



Short Answer:

Substantial volumes in excess of current water availability would be needed, and would require more water storage capacity.

Simulated CE high salinity vs CE EWS



Common assumptions for Tests: AP550 with no THC, lowchance=100%, Baseflow=450cfs.
41 years = 492 months = 14,975 day simulation period

Baseline Simulations

WSE = previous Lake O Regulation Schedule (2000-LORS) and current Lake O Water Shortage Management Plan (LOWSM)

LORS08 = current LORS and current LOWSM

AP5.50 = LORS08 with 2010 Adaptive Protocol Release Guidance Flowchart

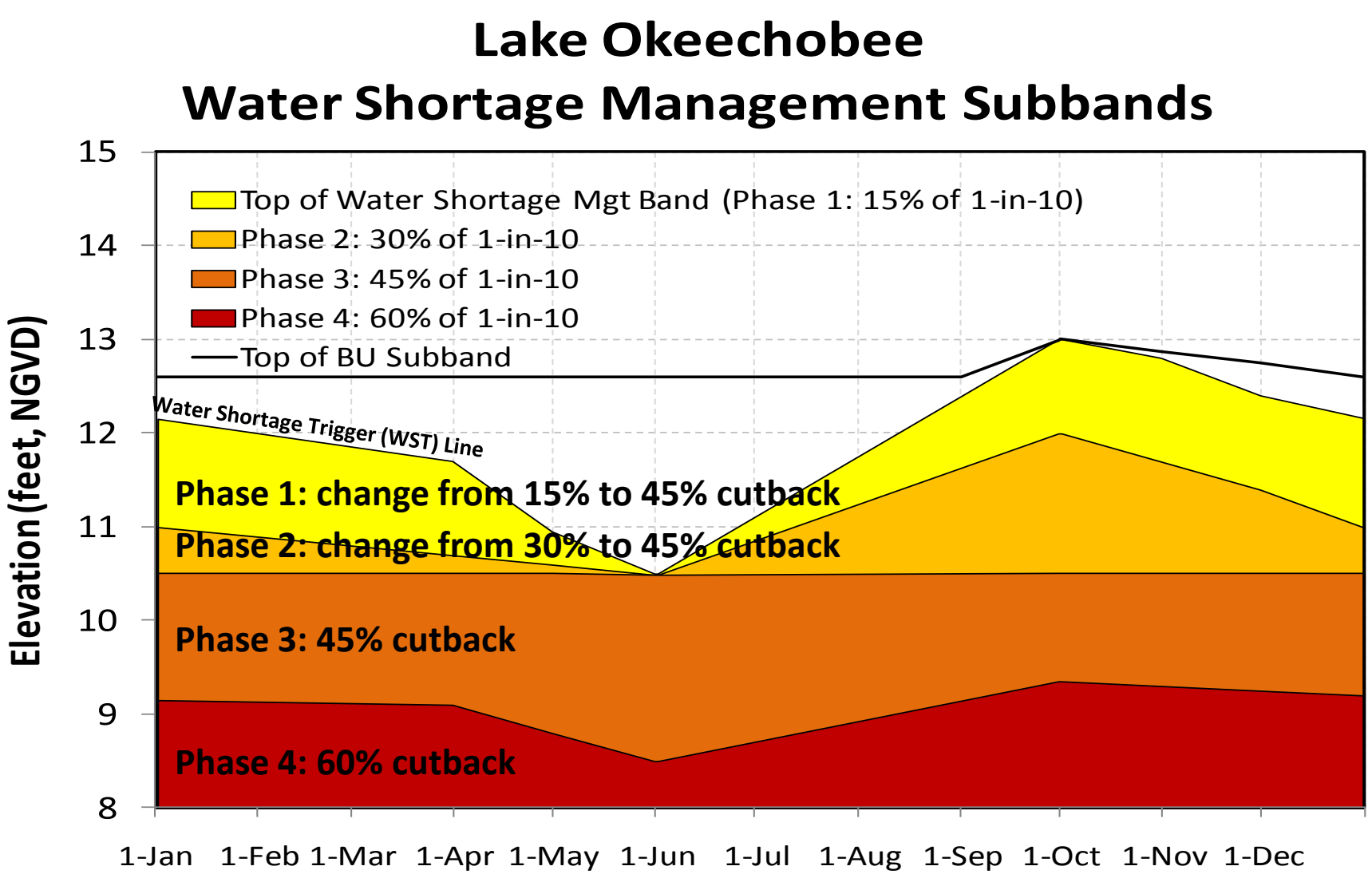
What-if Scenario #1: TA465 2008 LORS and 2010 AP Modifications

- Reduced discharge when stages are falling in Intermediate subband (90%) & Low Subband (70%)
- Limit releases in lower 1/3 of the Low Subband to Baseflow
- Retain the Tributary Hydrologic Condition check
- No CE Environmental Water Supply in the Water Shortage Band
- Can be implemented within existing operational flexibility of LORS-08

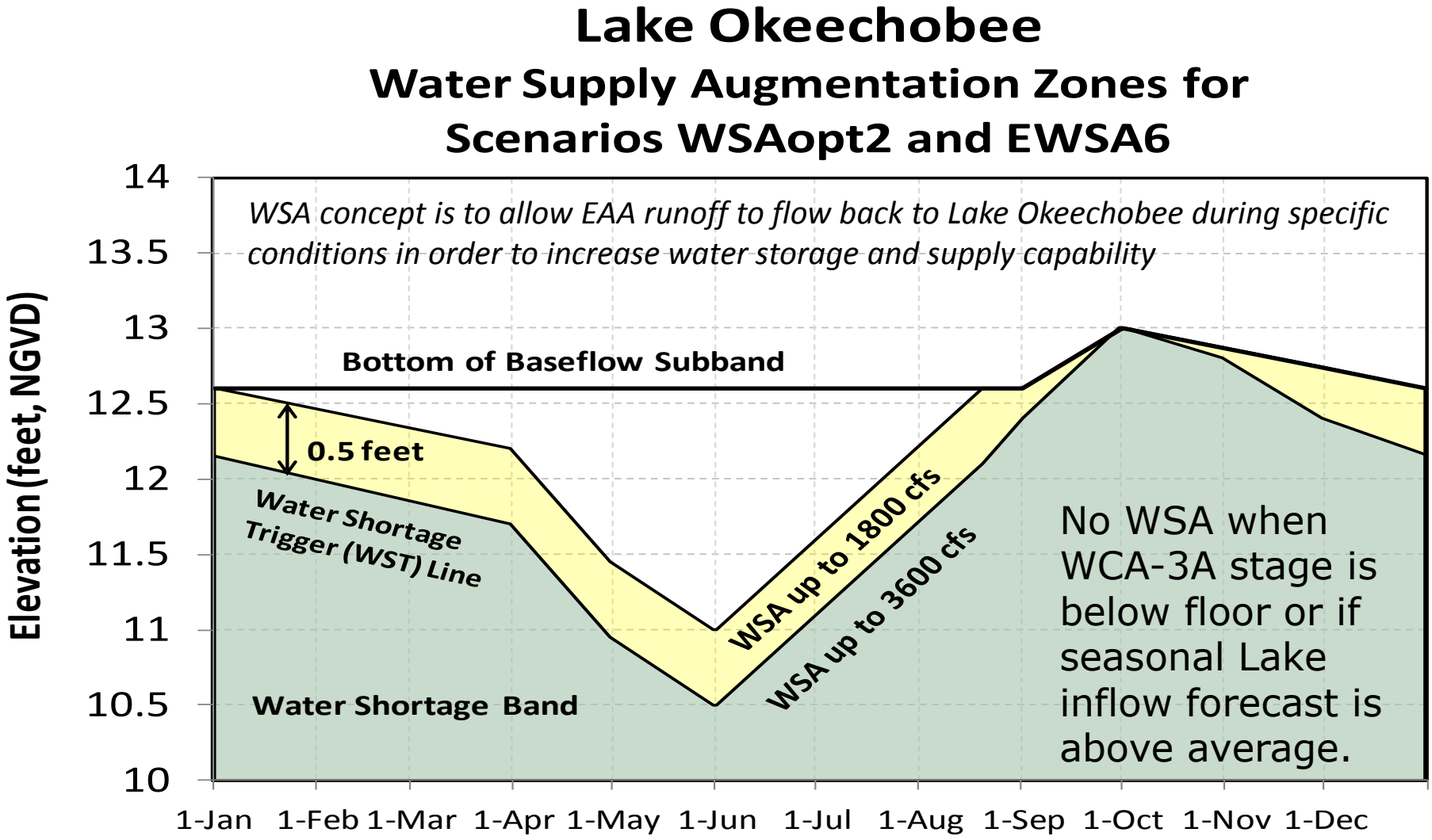
What-if Scenario #2: EWS3 Increased Environmental Water Supply to CE

- **Modified Environmental Water Supply Branch of the Adaptive Protocol Release Guidance**
  - **Tributary Hydrologic Condition bypassed**
  - **Forecast Lake stage bypassed**
- **Estuary "needs" water redefined to when the forecast of Val-I75 30-day moving average salinity exceeds 4 psu within 2 weeks**
- **Increased environmental water supply to CE from 300 cfs to 1100 cfs (EWS = 100 kaf/yr)**

What-if Scenario #3: LP3334 Increased LOSA Water Shortage Cutbacks



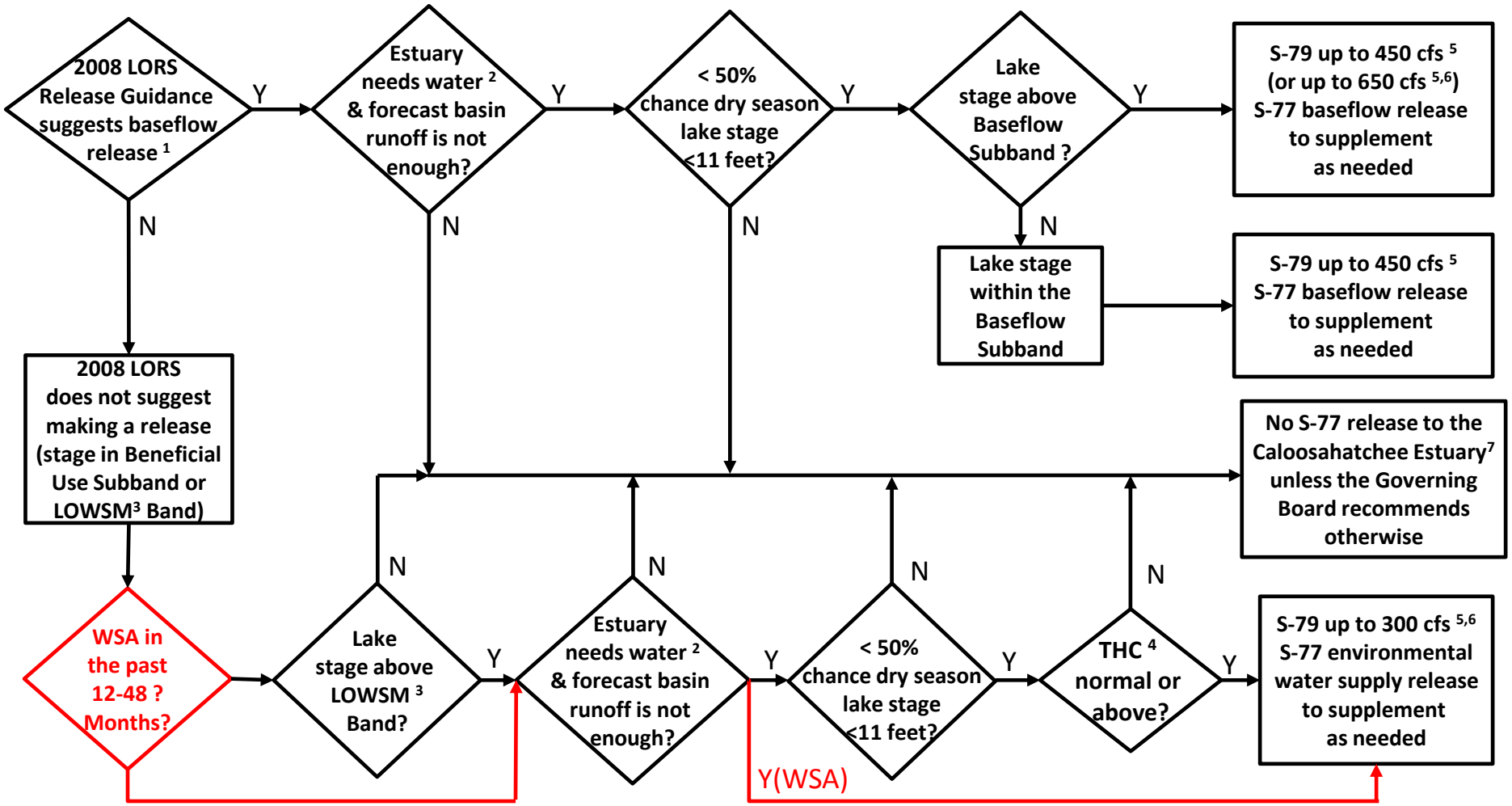
What-if Scenario #4: WSAopt2
Water Supply Augmentation (WSA)



What-if Scenario #5: EWSA6
WSA with Adaptive Protocol Modifications

- **aka Water Supply Augmentation & Supplemental Environmental Flows (WSA-SEF)**
- **Combined WSA with SEF to the Caloosahatchee Estuary**
  - Augmented inflow enables supplemental outflow
- **Same operating criteria as WSA2**
- **Modified Environmental Water Supply Branch of the Adaptive Protocol Release Guidance**
  - Tributary Hydrologic Condition bypassed
  - Forecast Lake stage bypassed
  - etc

ONE POSSIBLE MODIFICATION TO THE Flowchart to Guide Recommendations for Lake Okeechobee Releases to the Caloosahatchee Estuary for 2008 LORS Baseflow & for Environmental Water Supply



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[6]After reviewing conditions in Water Conservation Areas (WCAs), Stormwater Treatment Areas (STAs), ENP, St. Lucie Estuary and Lake Okeechobee.
[7]Should this condition be reached, the Governing Board will be briefed at their next regularly scheduled meeting.

Short Descriptions of What-if Scenarios

TA465: Optimized LORS-08 and AP parameters

EWS3: Relaxed AP constraints and increased environmental water supply to CE (EWS = 100 kaf/yr)

LP3334: LOWSM phase 1-4 water restriction cutbacks increased from (15%,30%,45%,60%) to (45%,45%,45%,60%)

WSA2: AP550 with WSA up to 1800 cfs when LOK stage falls within 0.5' above WST, 3600 cfs when stage falls below WST;
- no WSA when WCA-3A stage is below floor or if seasonal Lake inflow forecast is above average.

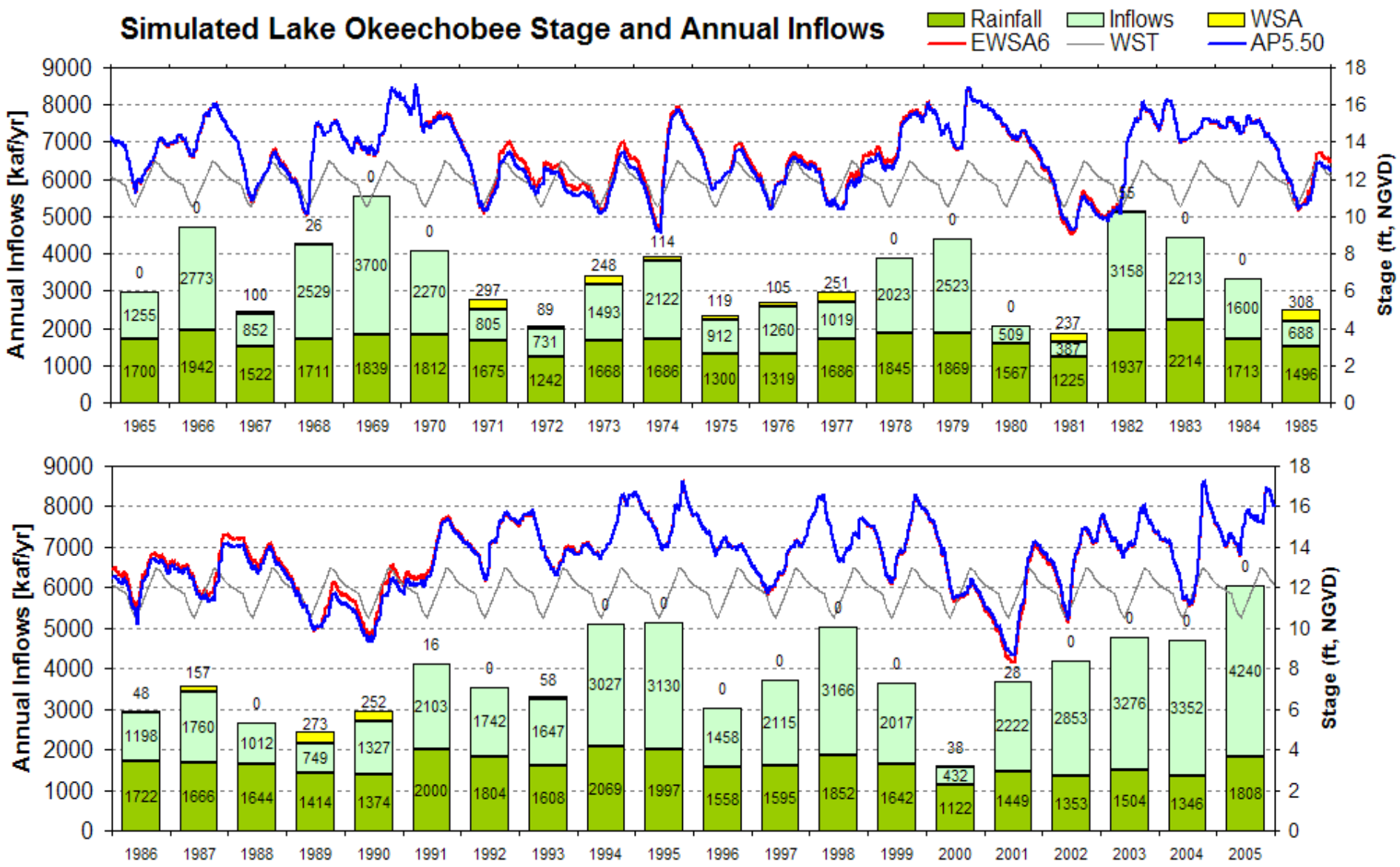
EWSA6: Combined/optimized features of EWS and WSA
- same assumptions for WSA2,
- CE_EWS = 300 cfs in Beneficial Use and Water Shortage bands w/no cutbacks, no THC constraint, and no Lake stage low-chance constraints, LORS-08 baseflow=450cfs.

Note: EWSA6 was tuned to provide most benefits to the CE. Other solutions can be developed which have a different balance of the benefits of WSA.

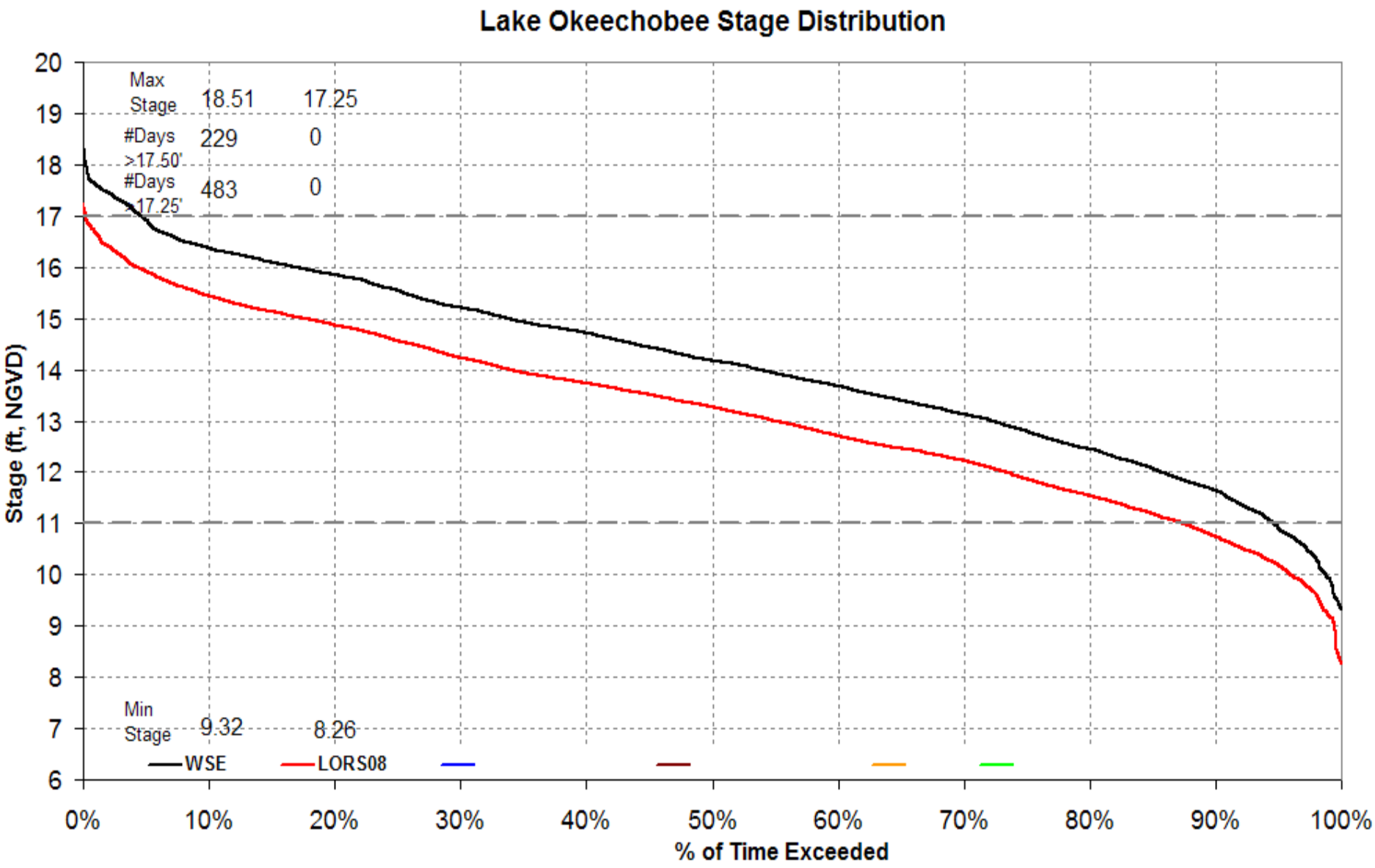
Simulation Results

- Massive amounts of model outputs were generated for each 41-yr simulation
  - Daily Lake stage and flow hydrographs
  - Daily and monthly estuary flows
  - Supply & Demand summaries
  - Standard Performance Measures
- Next 2 slides are sample results shown to illustrate relative effects on Lake O inflows and stages

Simulated Lake O Stage and Annual Inflows



Simulated Lake O Stage Distribution Curves



Performance Measures used for Analysis

A Performance Measure (PM) is a key summary statistic that represents an important characteristic of a system. PMs are used in modeling analyses to make relative comparisons among alternative plans or what-if scenarios.

1. LOK: Maximum Stage
2. LOK: # of days above elevation 17.25 ft, NGVD*
3. LOK: # of MFL Rule Exceedances*
4. LOSA: # of months of significant water shortage cutbacks*
5. CE: # of months of high salinity (> 10 psu) at Val-I75*
6. CE: # of months of high salinity (> 10 psu) at Ft. Myers
7. SLE: # of months of damaging high discharge > 2000 cfs*
8. CE: # of months of damaging high discharge > 2800 cfs*

* Same PMs used for development of 2010 Adaptive Protocols

Performance Summary Table

	WSE	LORS08	AP5.50
LOK: Peak stage (ft)	18.51	17.25	17.31
LOK: Days>17.25'	483	0	11
LOK: MFL Exc	4	10	7
LOSA: Cutback Mos	26	42	37
CE-I75: Mos>10psu	118	79	58
CE-FM: Mos>10psu	200	176	163
SLE: Mos>2000cfs	72	78	79
CE: Mos>2800cfs	95	88	97

Performance Summary Table

PERFORMANCE SUMMARY

	WSE	LORS08	AP5.50	TA465	EWS3	LP3334	WSAopt2	EWSA6
LOK: Peak stage (ft)	18.51	17.25	17.31	17.30	17.28	17.32	17.45	17.28
LOK: Days>17.25'	483	0	11	10	3	11	16	3
LOK: MFL Exc	4	10	7	6	12	7	3	5
LOSA: Cutback Mos	26	42	37	36	55	47	25	33
CE-I75: Mos>10psu	118	79	58	53	0	56	43	0
CE-FM: Mos>10psu	200	176	163	168	48	160	156	118
SLE: Mos>2000cfs	72	78	79	77	77	79	79	78
CE: Mos>2800cfs	95	88	97	89	89	97	101	97

PERFORMANCE CHANGES RELATIVE TO AP5.50

	AP5.50	TA465	EWS3	LP3334	WSAopt2	EWSA6
LOK: Peak stage (ft)	**17.31**	**-0.01**	**-0.03**	**0.01**	**0.14**	**-0.03**
LOK: Days>17.25'	**11**	**-1**	**-8**	**0**	**5**	**-8**
LOK: MFL Exc	**7**	**-1**	**5**	**0**	**-4**	**-2**
LOSA: Cutback Mos	**37**	**-1**	**18**	**10**	**-12**	**-4**
CE-I75: Mos>10psu	**58**	**-5**	**-58**	**-2**	**-15**	**-58**
CE-FM: Mos>10psu	**163**	**5**	**-115**	**-3**	**-7**	**-45**
SLE: Mos>2000cfs	**79**	**-2**	**-2**	**0**	**0**	**-1**
CE: Mos>2800cfs	**97**	**-8**	**-8**	**0**	**4**	**0**

Short Summary of Tests

- Combinations of LORS and AP refinements show small improvements for most of the key measures of performance
- Further marginal improvement if Lake stages are allowed to peak slightly higher
- Increasing cutbacks per the Lake O water shortage management plan (LOWSM) worsens LOSA performance and does not significantly improve performance for the Lake O MFL or CE high salinity
- Relatively larger improvements from Water Supply Augmentation & Supplemental Environmental Flows to the Caloosahatchee Estuary (WSA-SEF)

PART 3. ADDITIONAL ANALYSES

- LAKE O WATER QUALITY
- EVERGLADES HYDROLOGY

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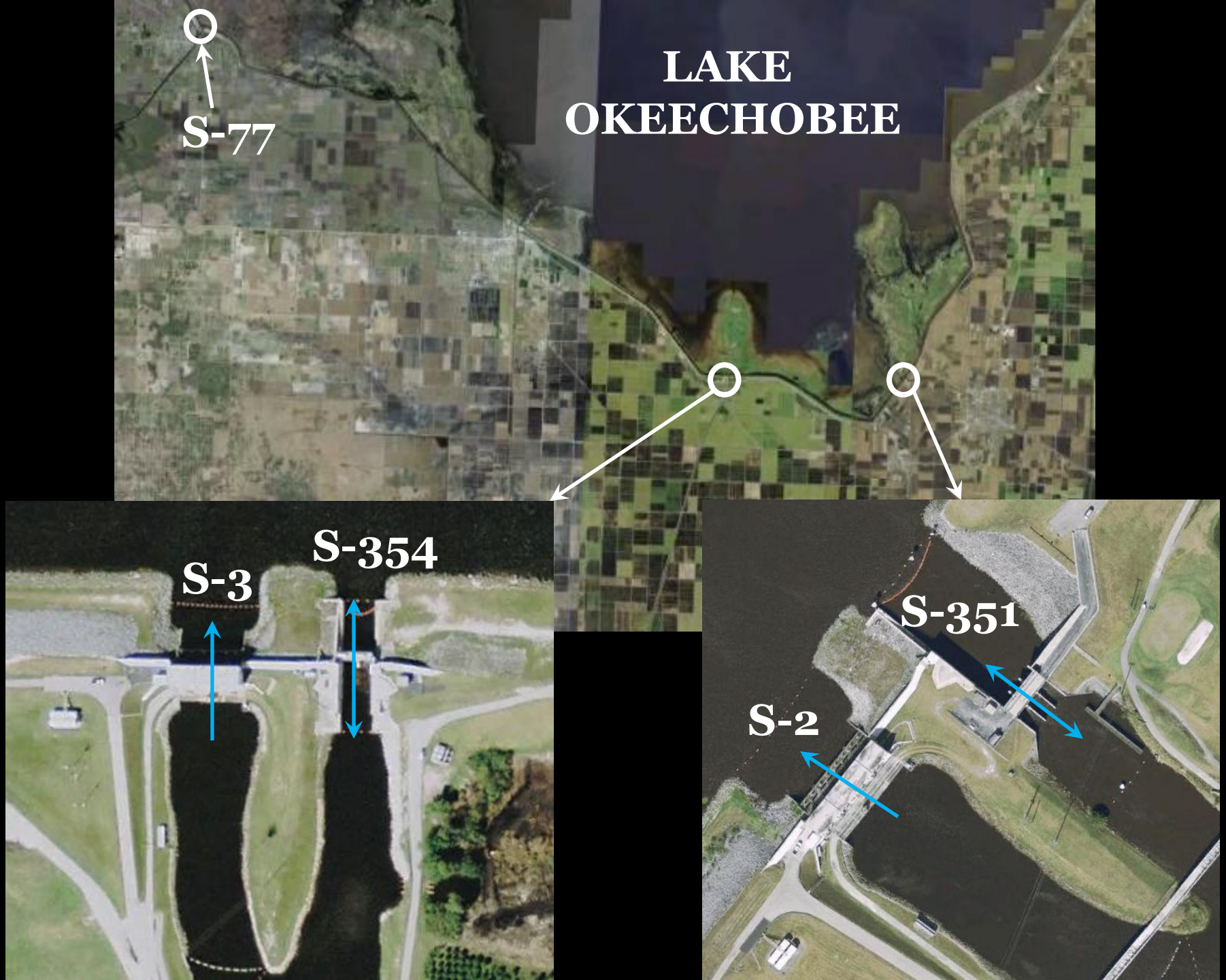
Chief Environmental Scientist, Applied Sciences

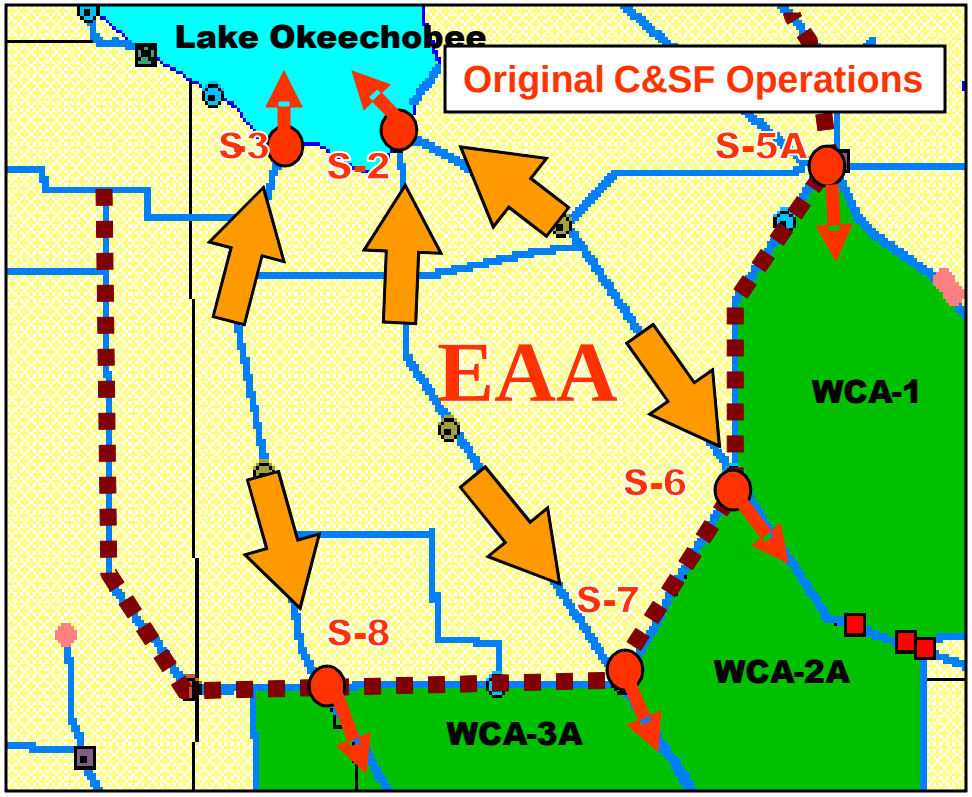
Water Supply Augmentation-Supplemental Environmental Flows (WSA-SEF)

- Potential interim solution until CERP storage areas are constructed and operable
- WSA concept is to allow EAA runoff to flow back to Lake Okeechobee during specific conditions in order to increase water storage and supply capability
- Not the same as historical flood control "backpumping"
  - WSA has much lower frequency, volumes and loads
  - EAA BMPs have considerably improved water quality
- Not the same as historical water supply "backpumping"
  - WSA can benefit multiple uses, primarily environmental water supply


LAKE
OKEECHOBEE
S-77
S-3
S-354
S-351
S-2

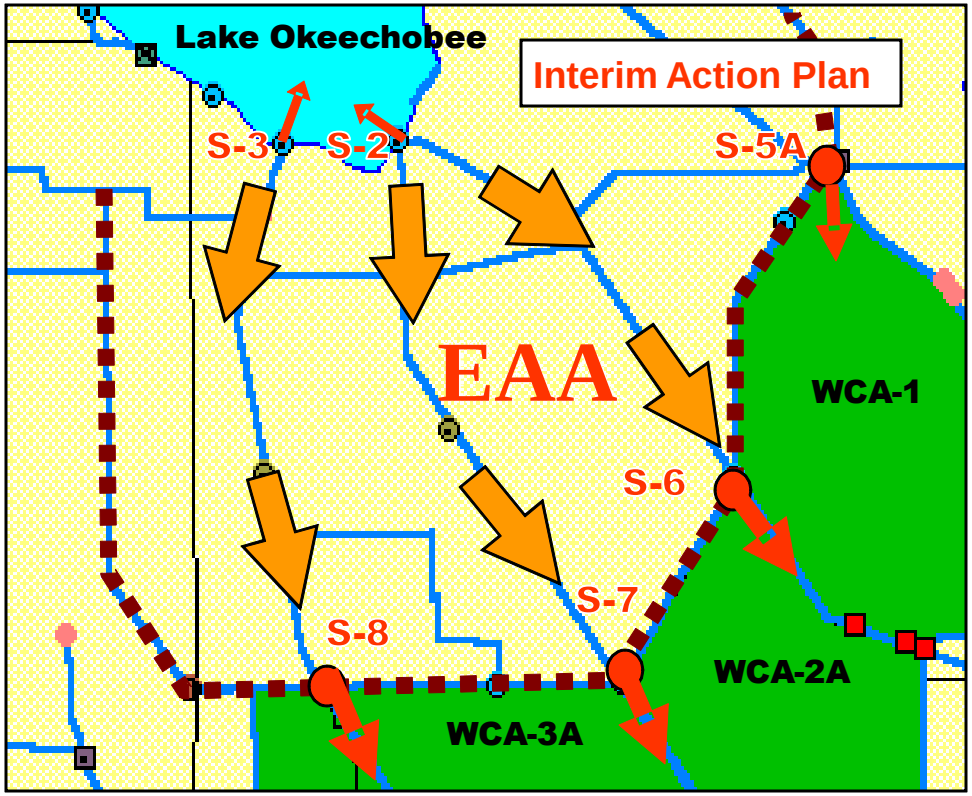
C&SF Project Design
EAA Flood Control Operation prior to 1979

- C&SF Project design discharged runoff from the northern EAA to Lake Okeechobee
  - Only the southern EAA discharged runoff to the WCAs
- Average annual runoff from the EAA is roughly 1 million acre feet



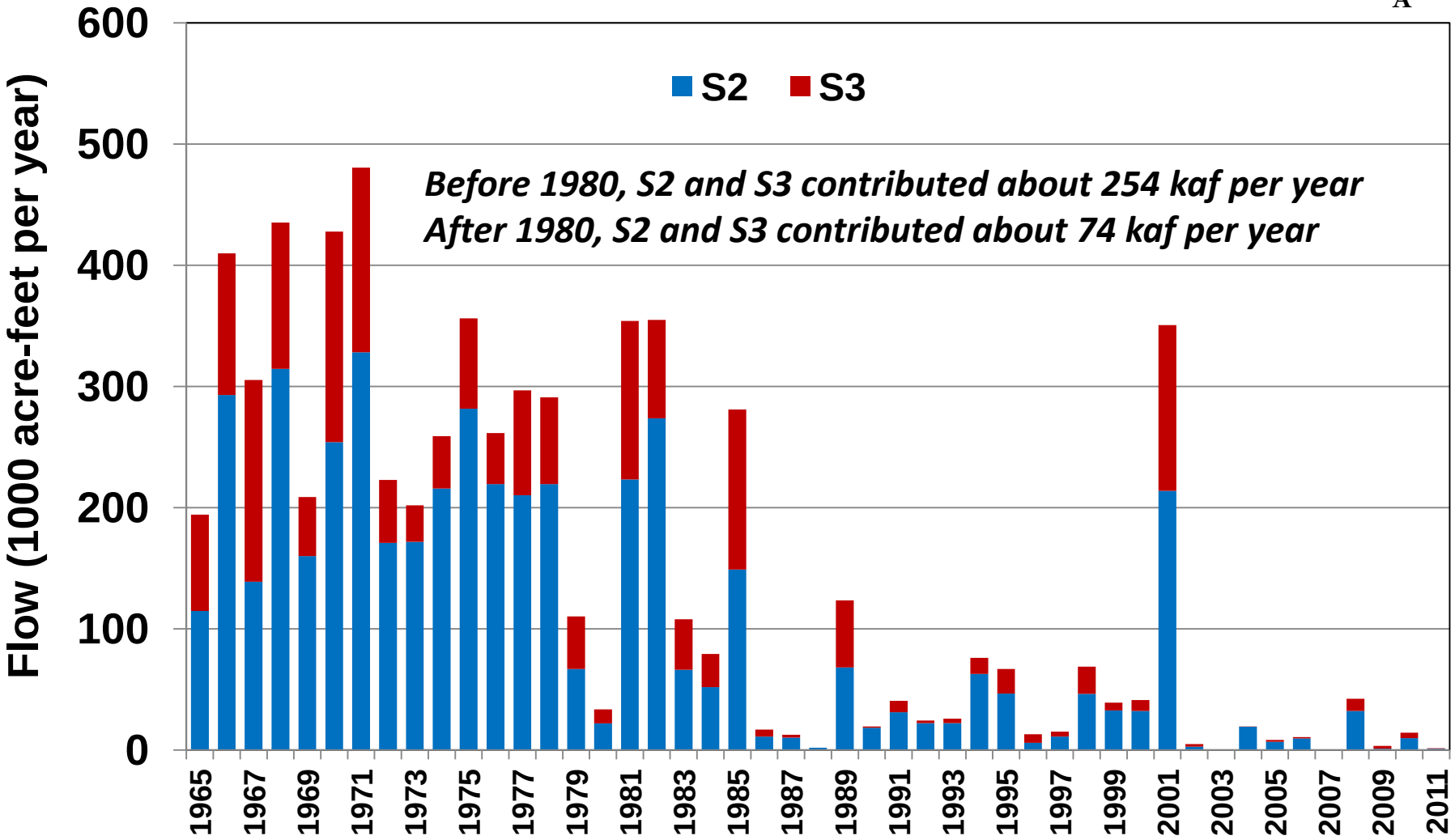
C&SF Project Design
EAA Flood Control Operation post 1979

- In early 1980's, the SFWMD implemented the "Interim Action Plan" (IAP)
- Additional EAA runoff discharged to the WCAs under the IAP is between 200,000 and 300,000 ac-ft per year
- S2 and S-3 are now primarily used as a last resort to reduce the risk of flooding
  - IAP focused most EAA runoff to the WCAs in an effort to reduce nutrient impacts to Lake O

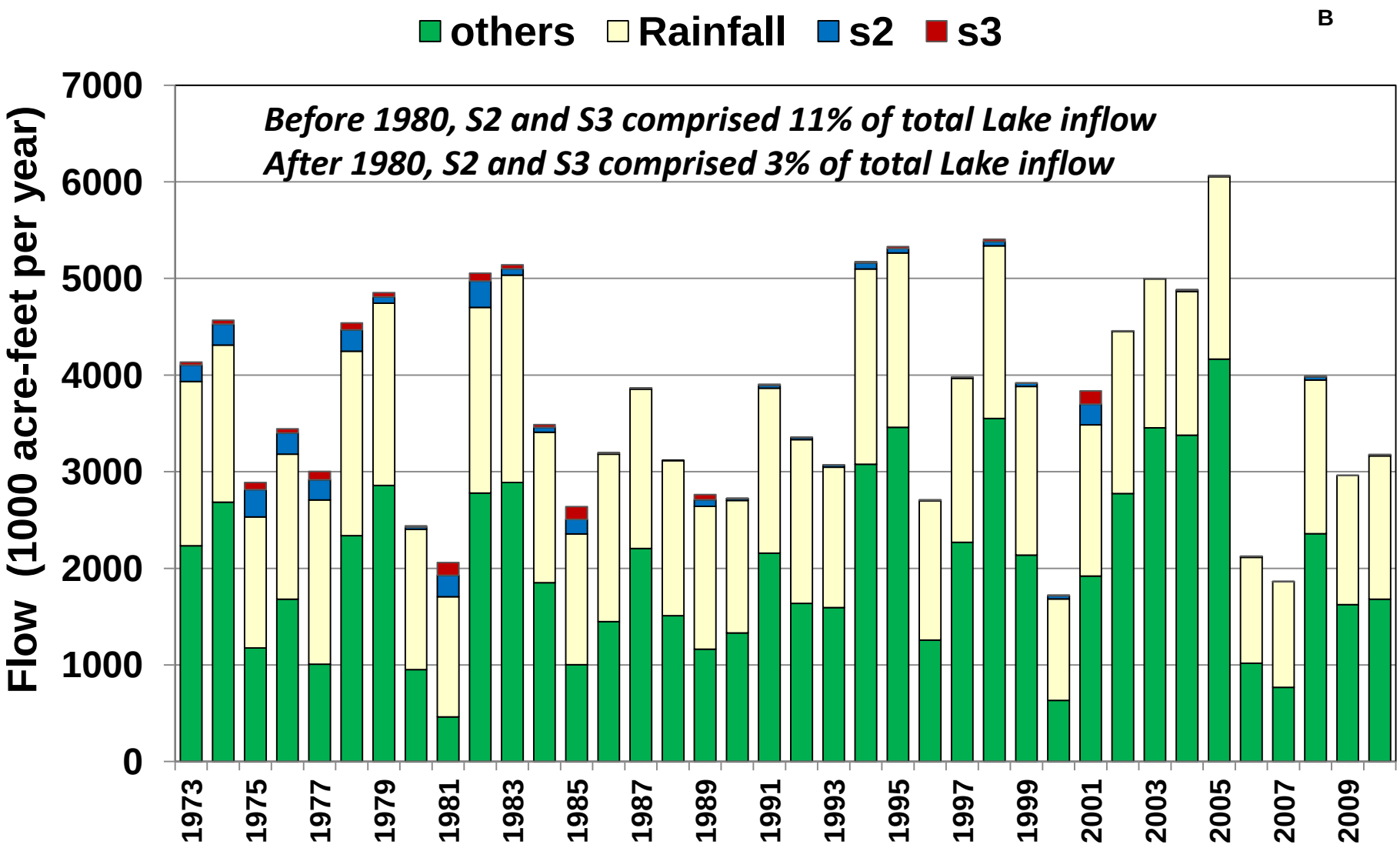


Historical S2 & S3 Operation (kaf/yr)

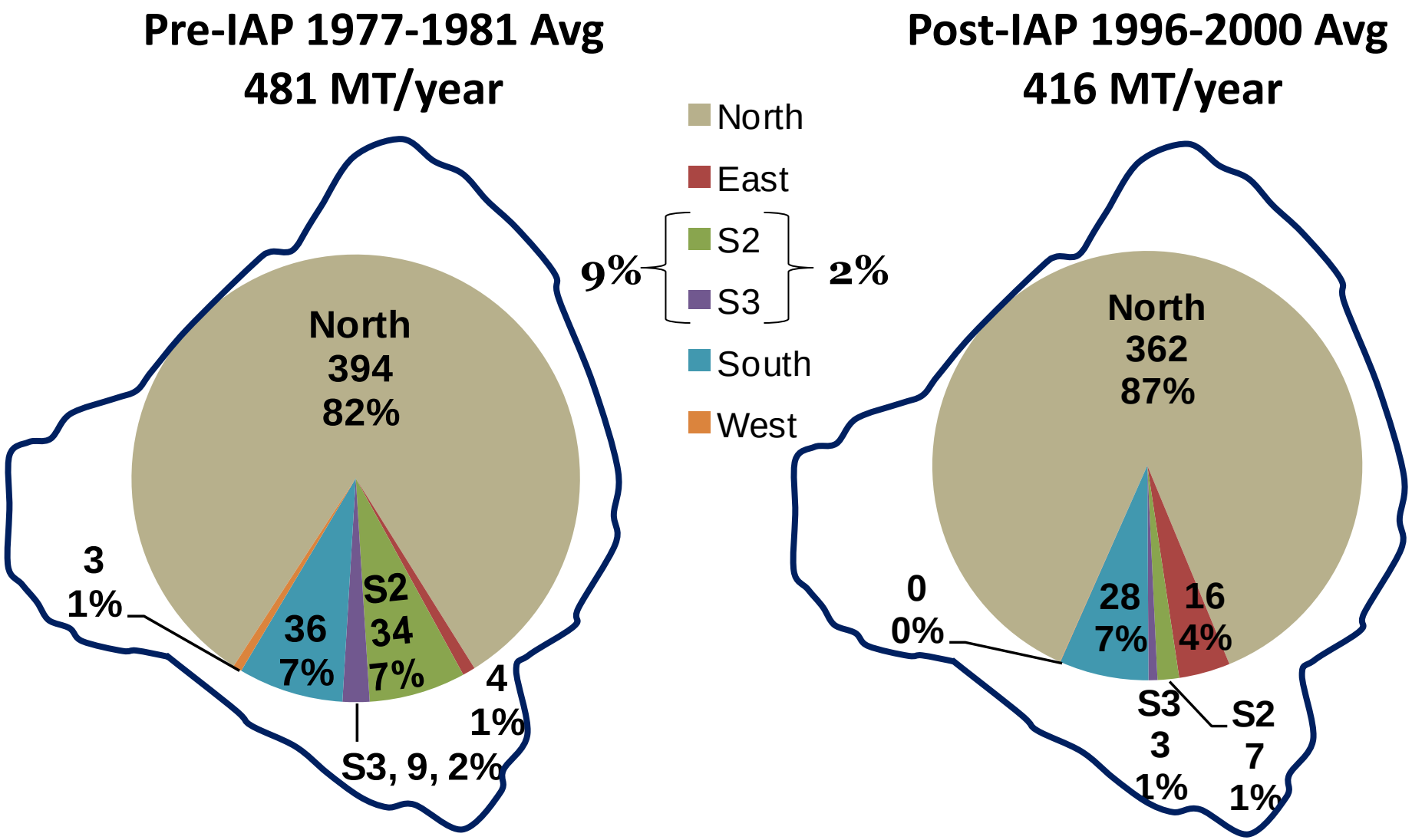
A



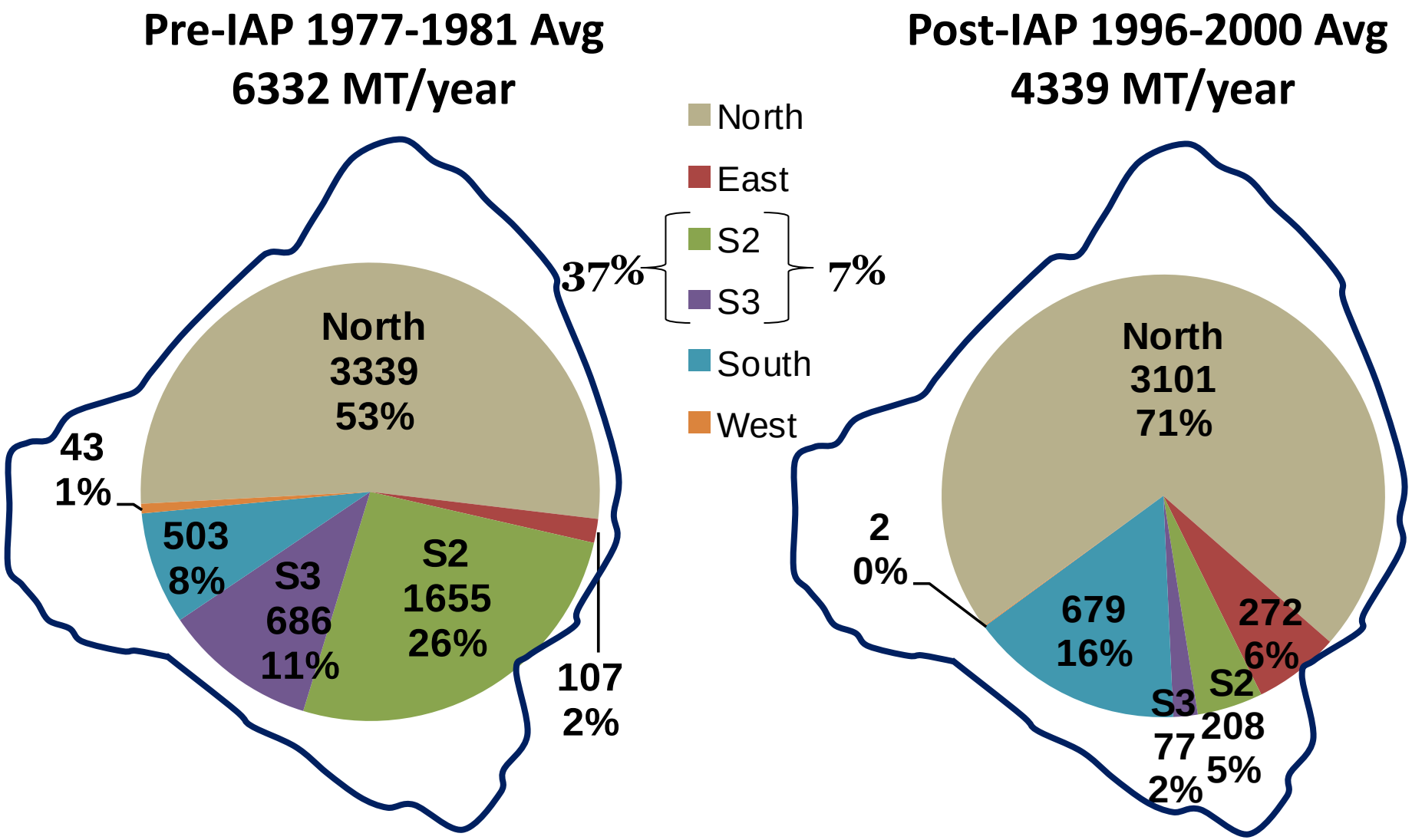
Historical Lake O Inflows (kaf/yr)



Historical Average Phosphorus Inflow Load Pre & Post IAP Comparison



Historical Average Nitrogen Inflow Load Pre & Post IAP Comparison



How could WSA affect Lake Okeechobee & Caloosahatchee Estuary Water Quality?

- Staff analyzed WSA2 scenario using the Lake Okeechobee Water Quality Model (LOWQM)
  - Close look at TP and TN
- Results show little, if any adverse impacts from WSA
- Increases Lake inflow load for TP (2%) and TN (6%)
- However, little to no change in in-lake TN or TP concentrations due to internal processes
- 8-9% increase in loads discharged at S-77 due solely to increased Lake O release volumes, not from changes in Lake O water quality

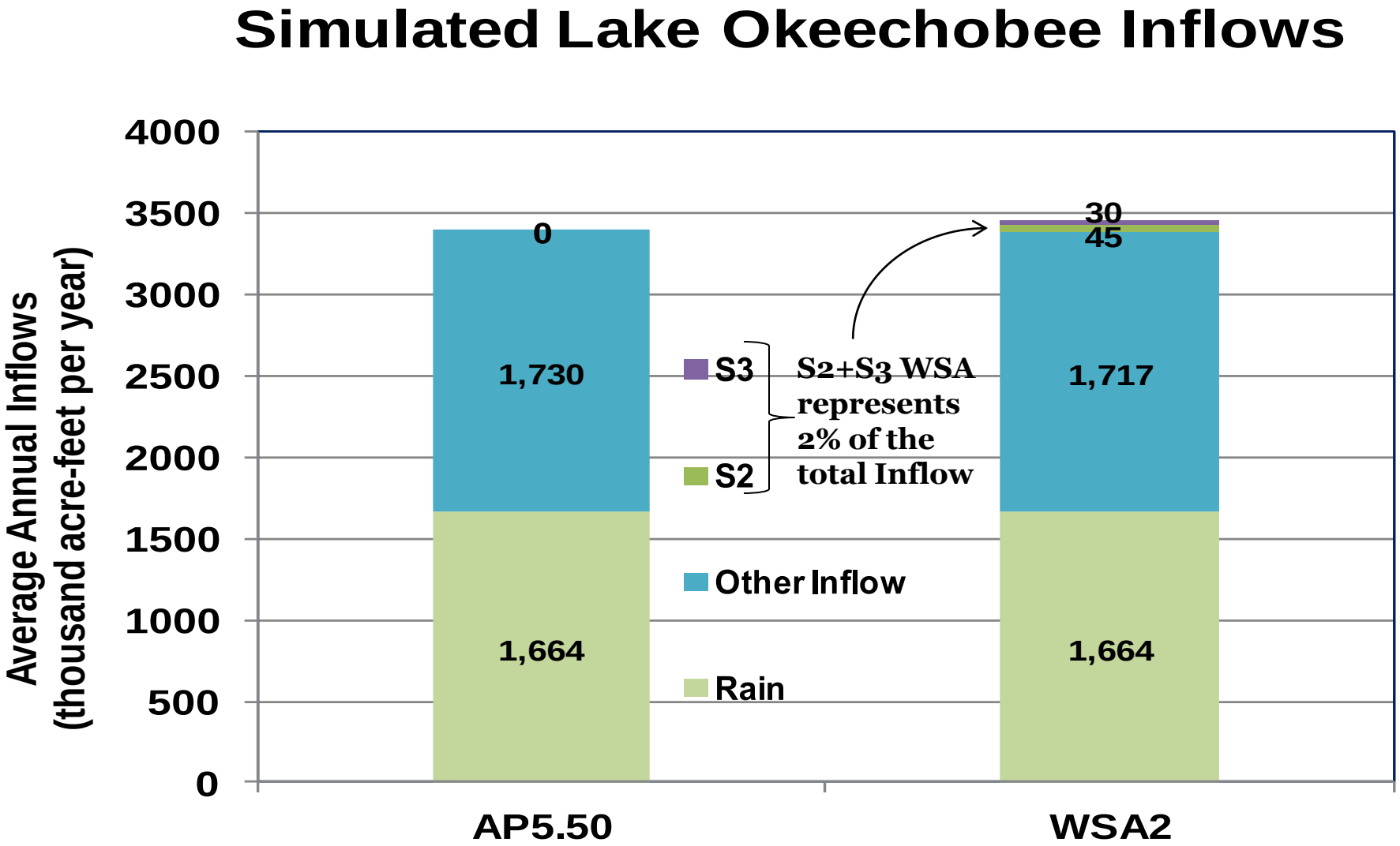
Table 1. TN and TP inflow concentrations to determine load simulations.

Lake Okeechobee Water Quality
Nitrogen and Phosphorus Concentrations used for modeling analyses

	TN (mg/L)	TP (mg/L)
Lake O Average Inflow	**1.640**	**0.185**
Miami Basin (S3)	**4.330**	**0.116**
NNRH Basin (S2)	**3.620**	**0.116**

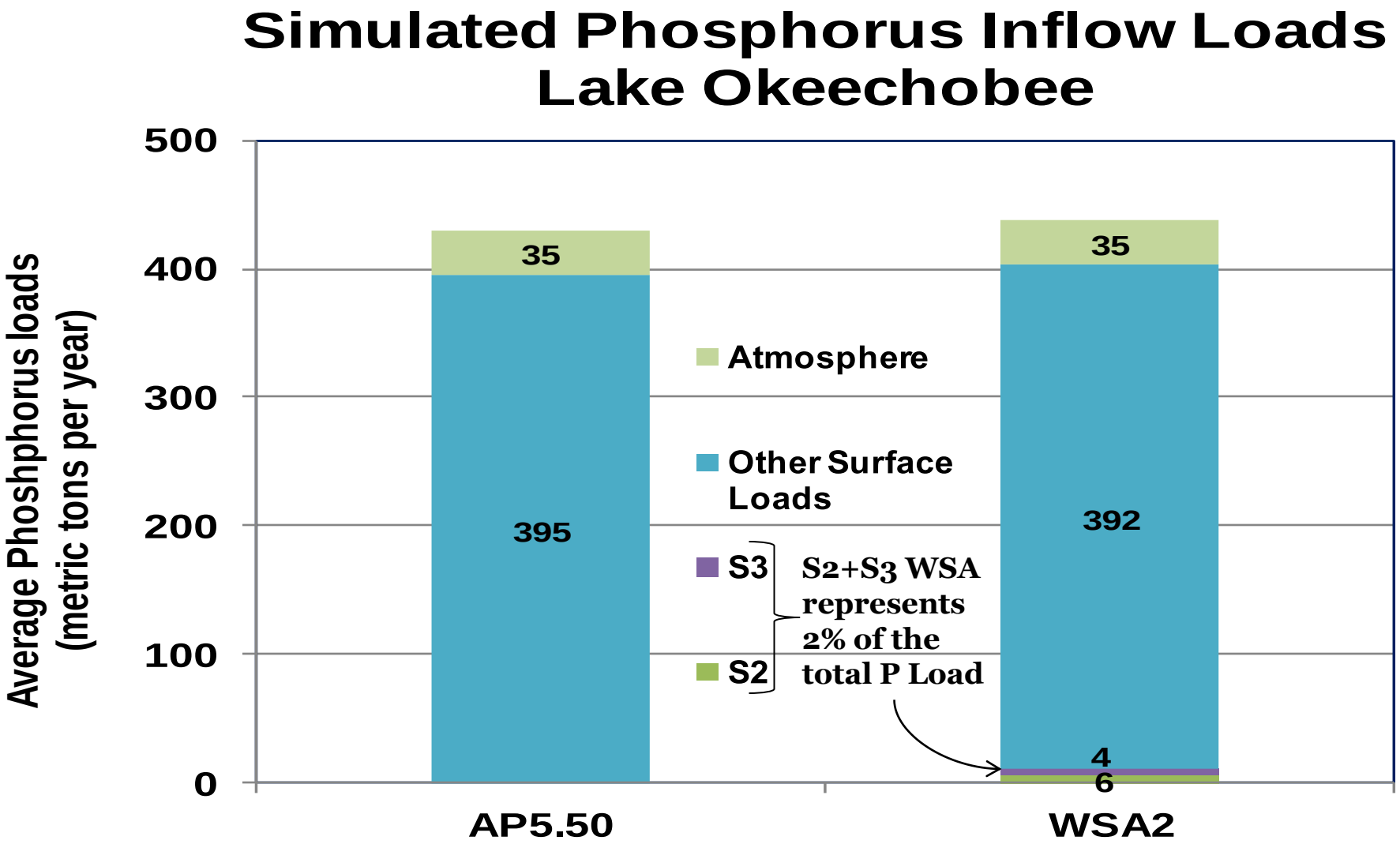
Flow-weighted mean concentration values from South Florida Environmental Report

Comparison of Average Annual Simulated Lake Inflows



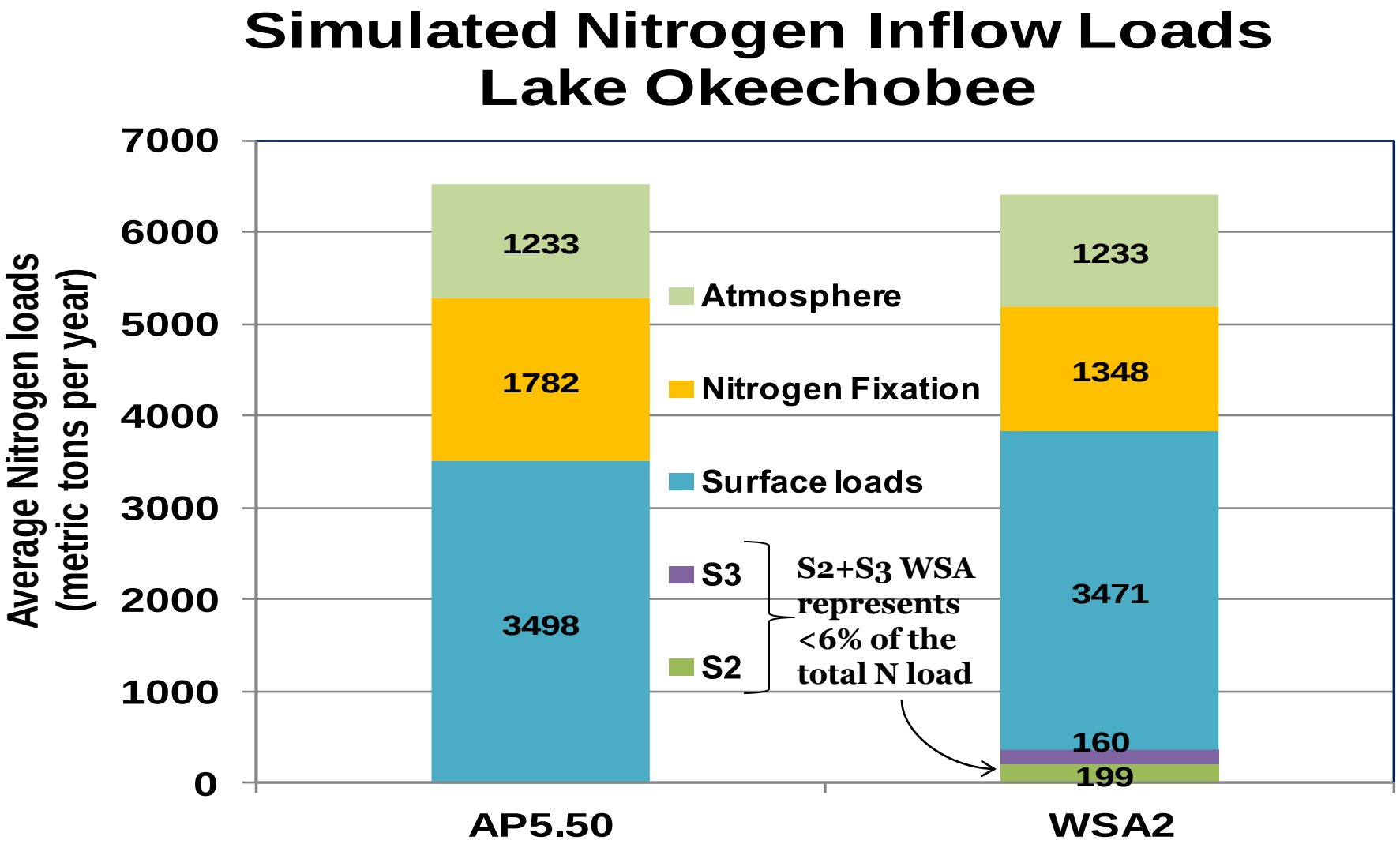
LOWQM simulation period: 1973-2000

Comparison of Average Annual Simulated Phosphorus Loads



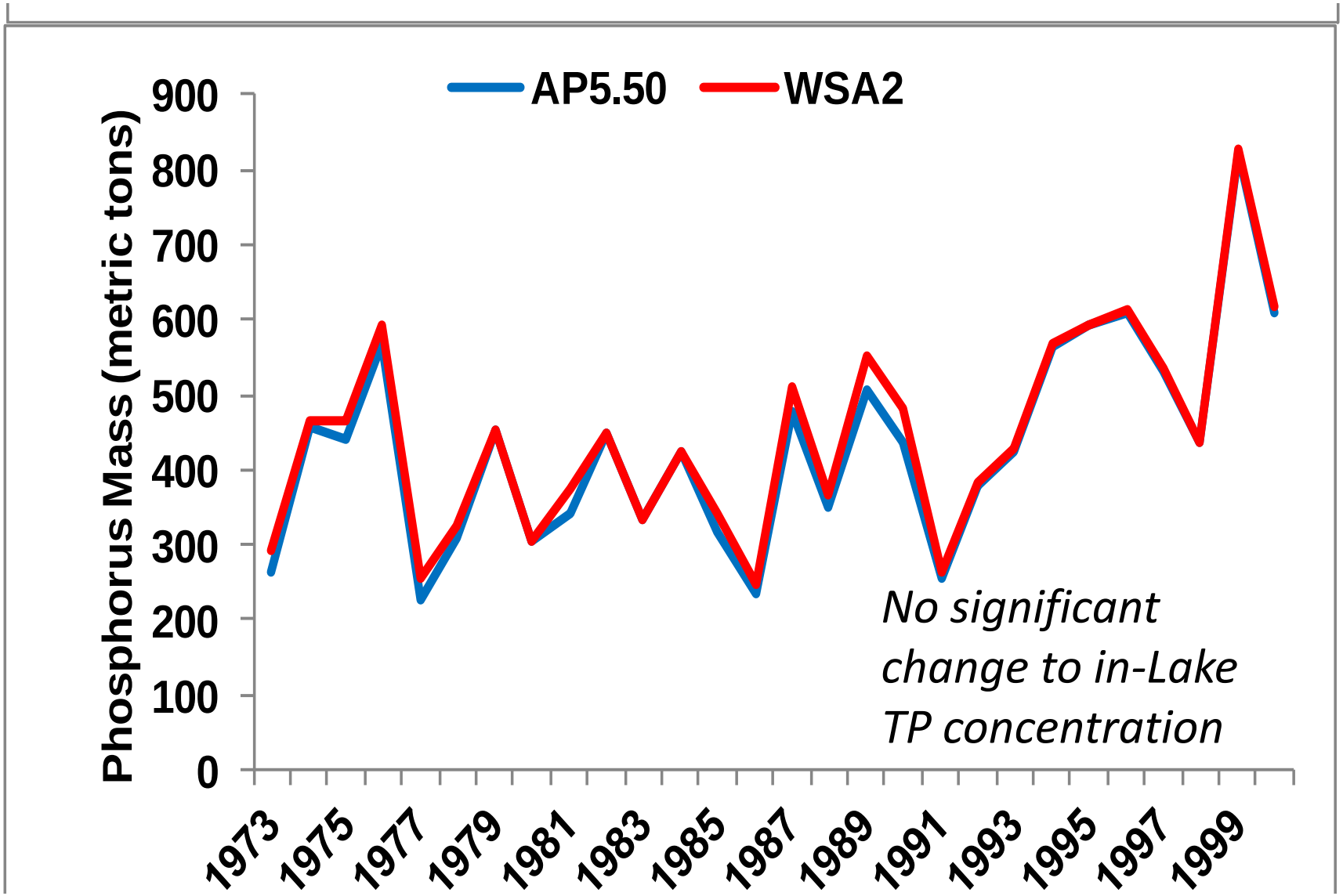
LOWQM simulation period: 1973-2000

Comparison of Average Annual Simulated Nitrogen Loads

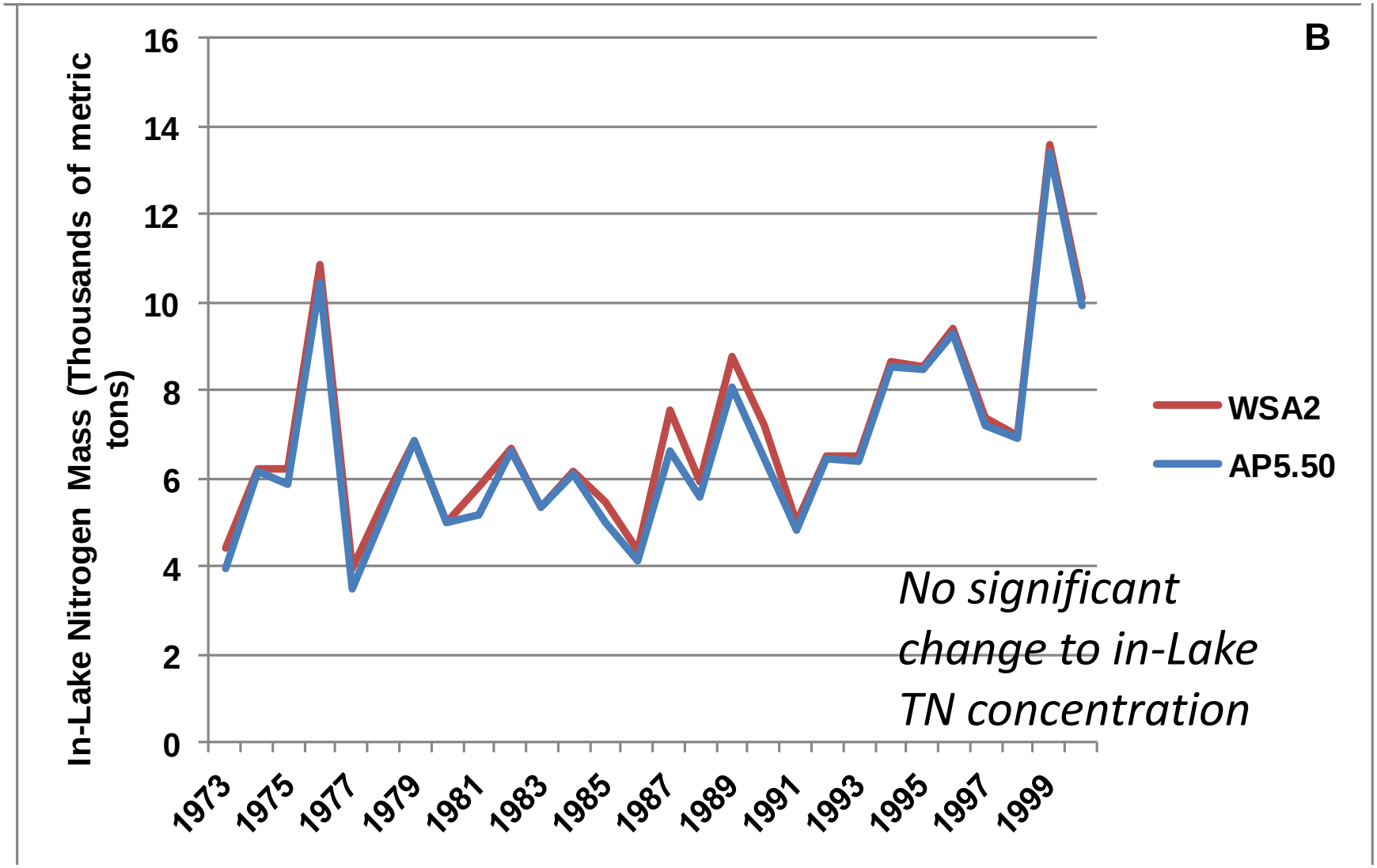


LOWQM simulation period: 1973-2000

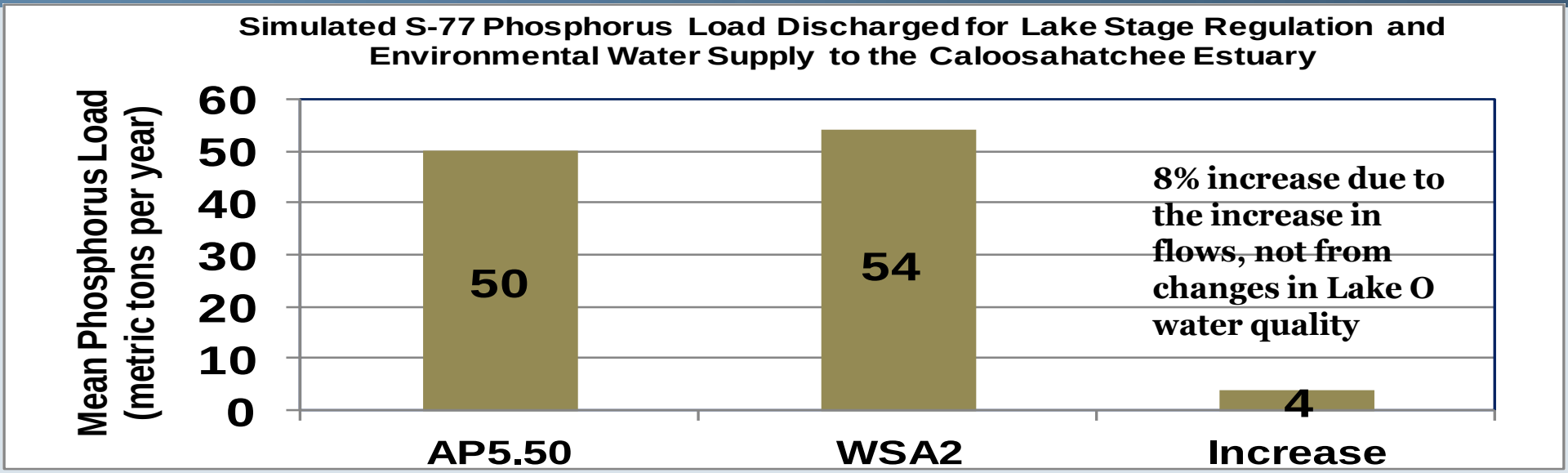
Simulated In-Lake TP Mass

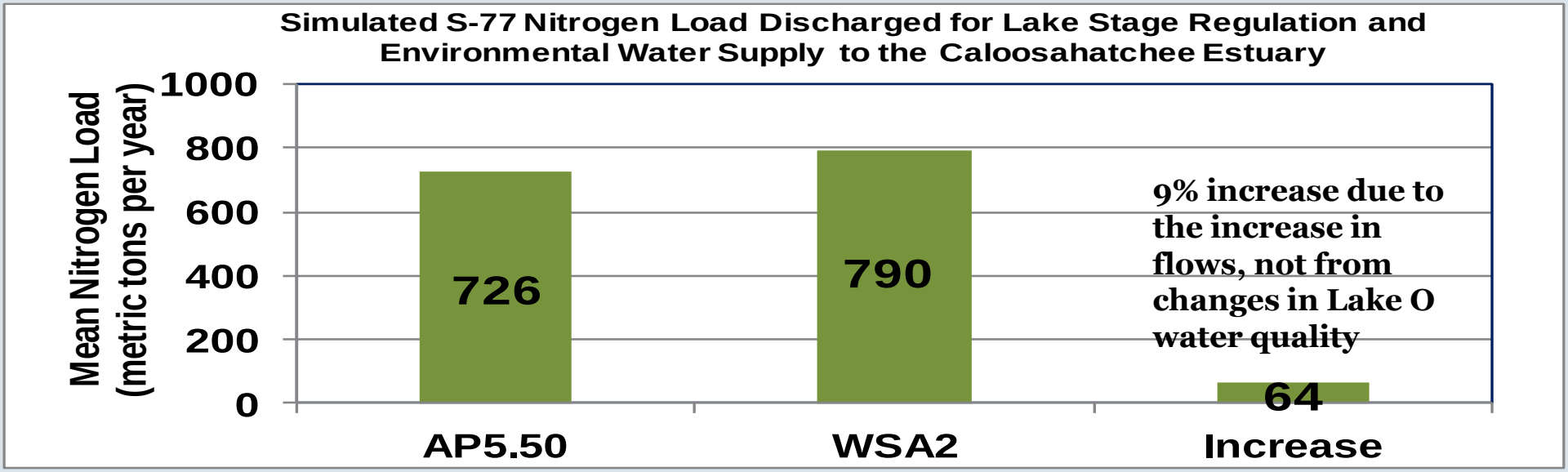


Simulated In-Lake TN Mass



Nitrogen and Phosphorus Loads Discharged from Lake O via S-77 to the Caloosahatchee Estuary





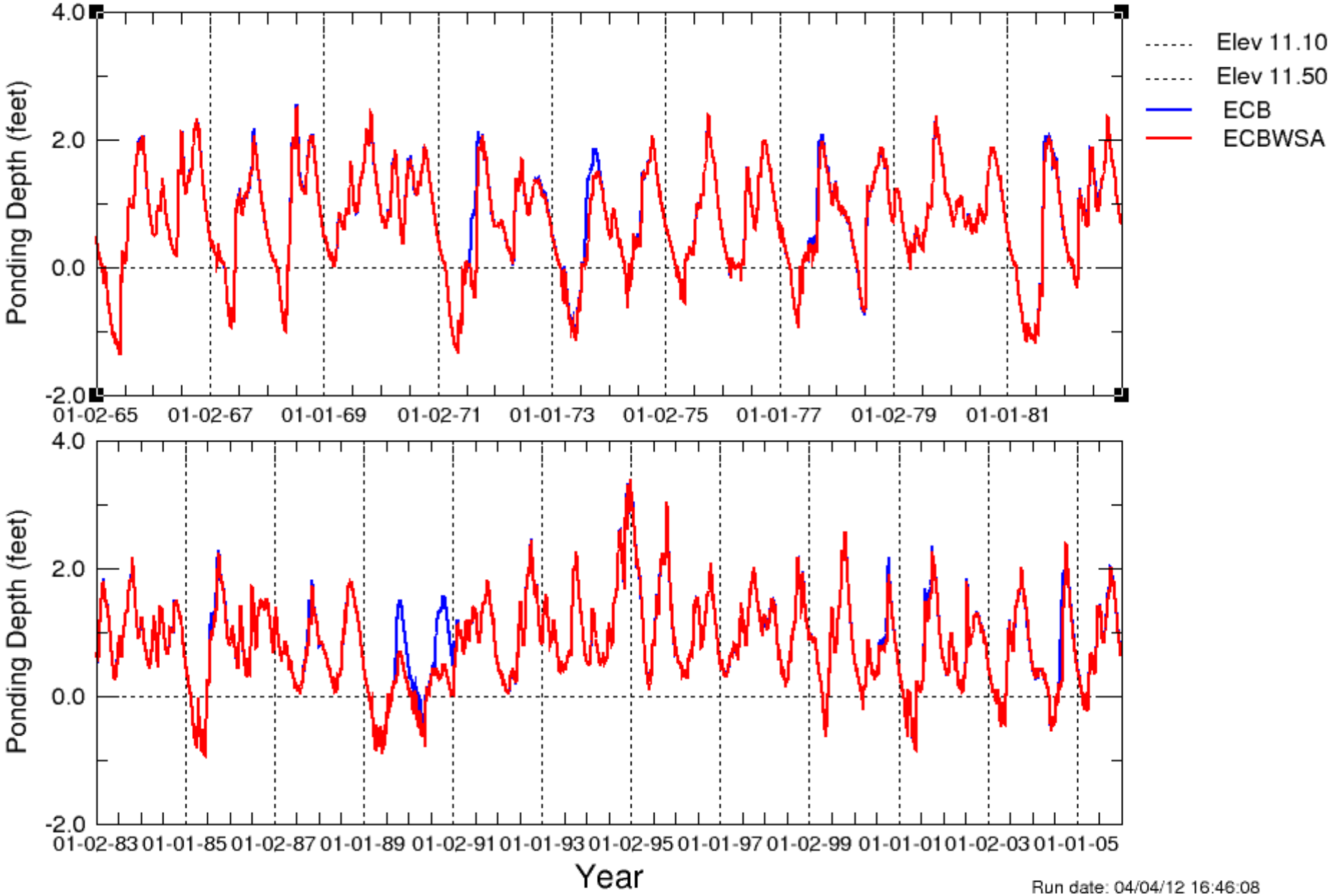
LOWQM simulation period: 1973-2000

How could WSA affect the Water Conservation Areas & Everglades National Park?

- Staff analyzed WSA scenarios using the South Florida Water Management Model (SFWMM)
  - Focused on WCA-2A, WCA-3A and ENP
- Preliminary SFWMM results show
  - Slightly lower stages in WCAs during some of the WSA periods, but similar hydropatterns
  - Reduced flood control discharges (2%) to ENP's Shark Slough
  - No change in flows to meet ENP rain-driven flow component
- A closer review by Everglades staff highlighted a few accelerated dryout events in northern WCA-3A and WCA-2A
  - Further restrictions on WSA operation can be designed to minimize these events

Normalized Hydrographs for Central Portion of WCA-2A

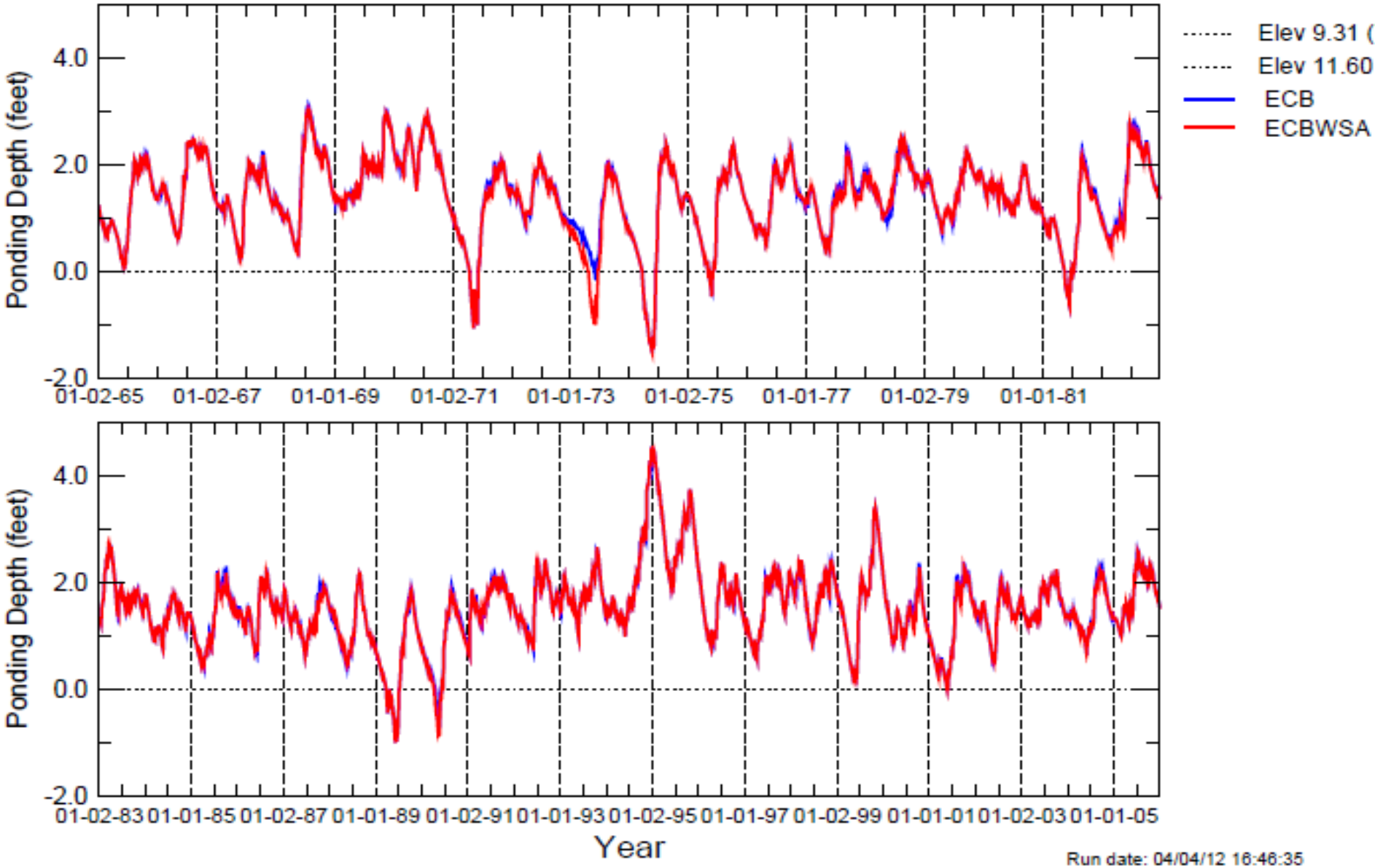
(Gage 2A-17, Cell Row 40 Col 29)



Run date: 04/04/12 16:46:08
SFWMM V6.6.0r1

Normalized Hydrographs for North End of WCA3A

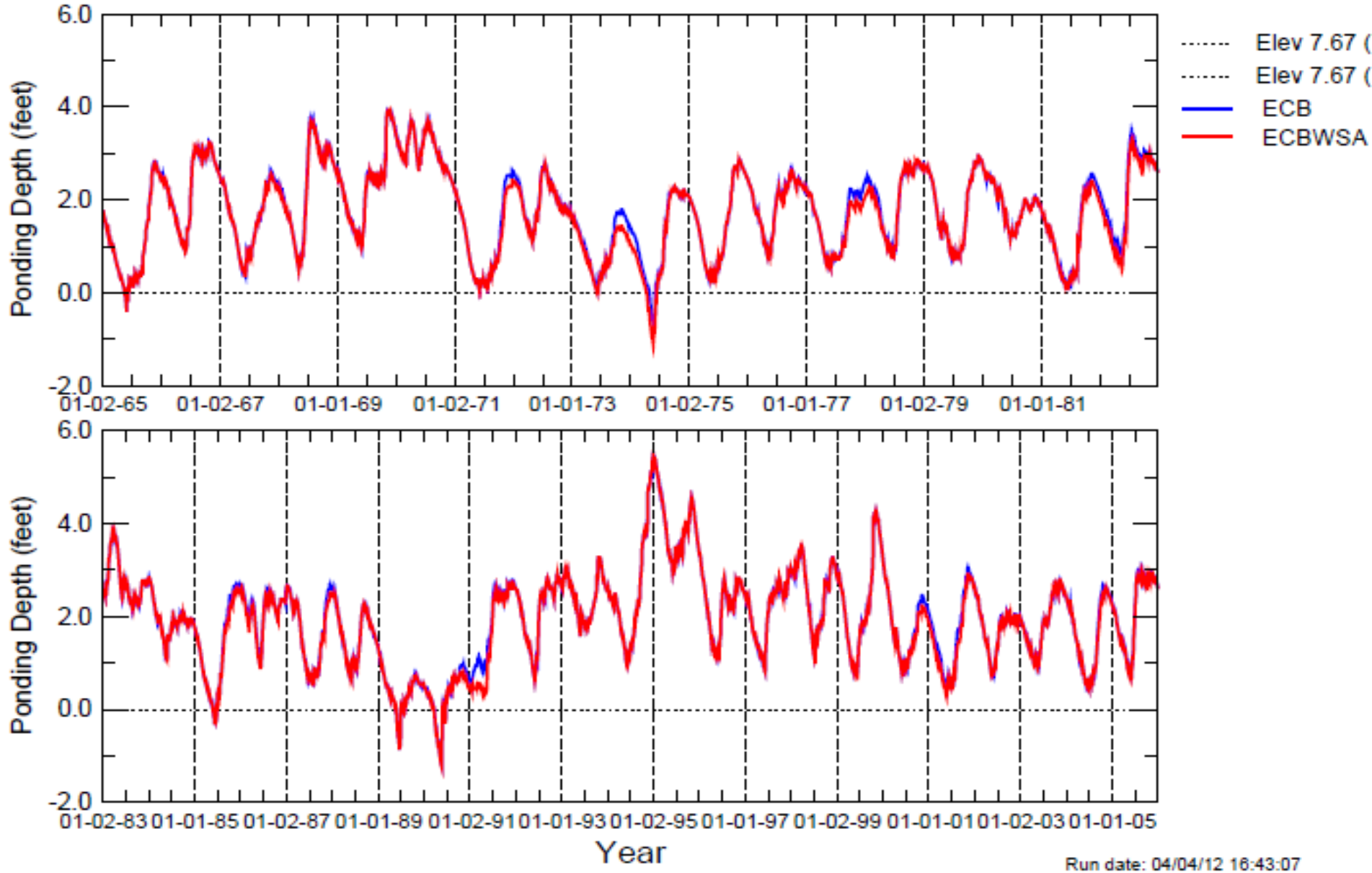
(Gage 3A-2, Cell Row 36 Col 18)



Run date: 04/04/12 16:46:35
SFWMM V6.6.0r1

Normalized Hydrographs for South End of WCA-3A

(Gage 3A-28, Cell Row 24 Col 19)



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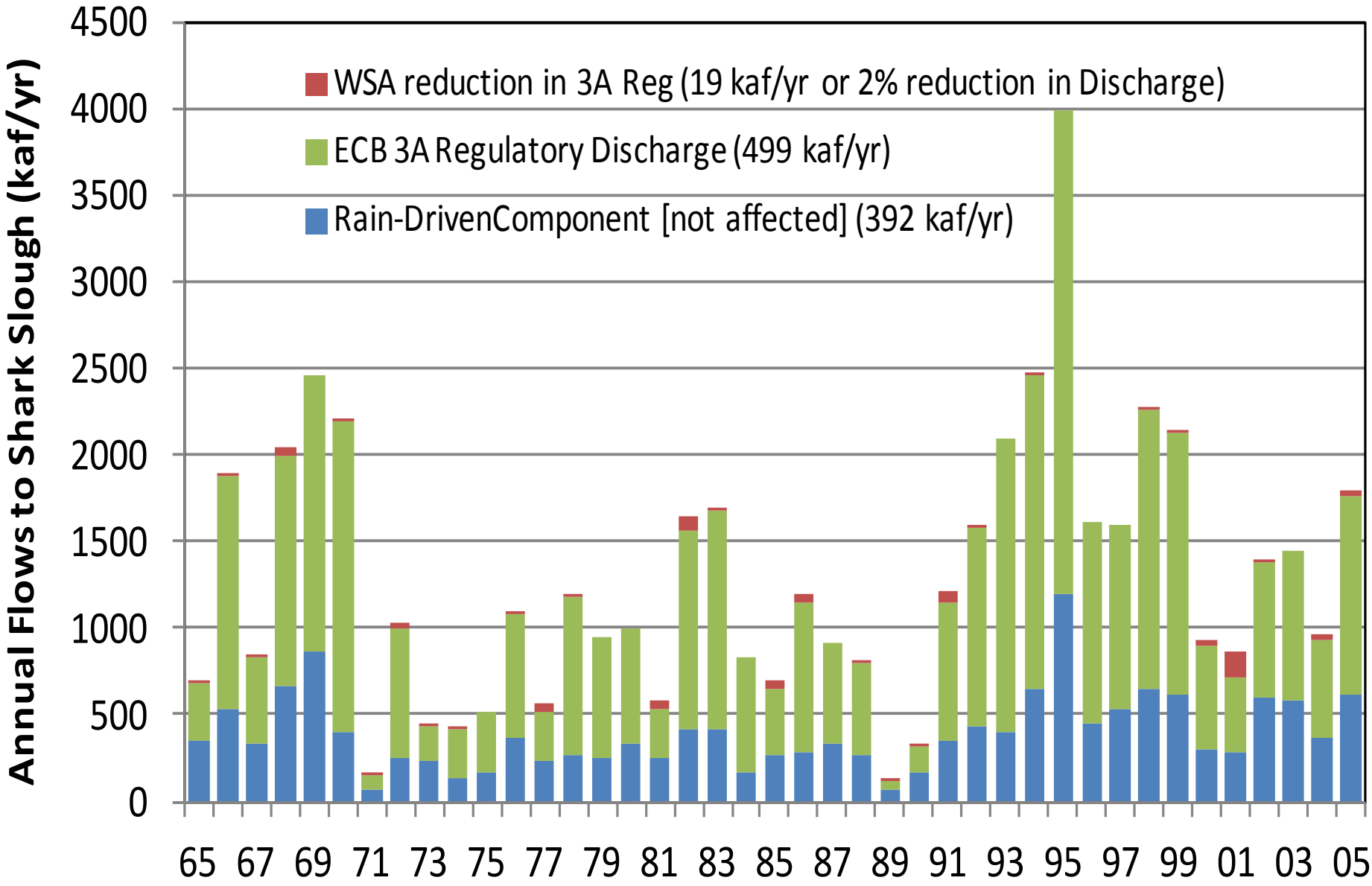
SFWMM V6.6.0r1

Simulated Flow to Shark Slough (S12+S333)



Summary of Simulation Modeling Results

Preliminary simulation model analysis of Water Supply Augmentation & Supplemental Environmental Flows to the Caloosahatchee Estuary shows:

- **Improved Performance For:**
  - Caloosahatchee Estuary (significantly reduces high salinity months at Val-I75 and Ft. Myers)
  - Lake O MFL Rule exceedances (fewer exceedances)
  - Lake O Service Area water supply (slightly fewer water shortage cutbacks)
- **A Closer Look At Possible Adverse Impacts Shows:**
  - TP & TN Load increases to Lake O, but is relatively small and has minor, if any, affect on Lake O water chemistry
  - Minor affect on WCA water levels & flows to ENP




Adaptive Protocols For Lake Okeechobee Operations

Interim Solutions for Improving Performance of the Central & Southern Florida System

Questions & Discussion

Thank You