RWPP Research and Water Quality Monitoring Plan Outline
02/05/08

1. Introduction
   1.1. Description of Enabling Legislation
   1.2. Document Structure

2. Goals and Objectives of Monitoring and Research

3. The River and Its Watershed: Status, Trends and Targets in Hydrology, Water Quality and Aquatic Habitat
   3.1. Delineation of Study Area
      3.1.1. The River and Estuary
      3.1.2. The Watershed and Lake Okeechobee Connection
   3.2. Watershed Hydrology and Loading
      3.2.1. Hydrology
      3.2.2. Water Quality Status and Trend: Nutrient and DO
      3.2.3. Nutrient Loading
   3.3. River/Estuary Salinity, Water Quality and the Related Aquatic Habitats
      3.3.1. Salinity: Range and Stratification, Flow Correlation
      3.3.2. Water Quality Status and Trend: DO, Nutrients, and Chlorophyll-a, Nutrient Susceptibility Index
      3.3.3. Aquatic Habitats
         3.3.3.1. Submersed Aquatic Vegetation
         3.3.3.2. Oysters
   3.4. Salinity Envelopes and Freshwater Inflow Targets
      3.4.1. Technical Basis
      3.4.2. Envelopes and Targets
   3.5. Influence of Lake Okeechobee and Watershed Discharge on Freshwater Inflow to Estuaries

4. Watershed and Estuarine Monitoring Program
   4.1. Introduction
   4.2. Watershed Monitoring Program
      4.2.1. Flow
      4.2.2. Water Quality (land use, tributaries, structure)
   4.3. Estuarine Monitoring Program
      4.3.1. Estuarine Salinity
      4.3.2. Estuarine Water Quality
      4.3.3. Aquatic habitat – Oysters and SAV
   4.4. Power Analysis
      4.4.1. Water Quality Example
      4.4.2. Submersed Aquatic Vegetation Example

5. Research for Adaptive Management
   5.1. Introduction (Purpose of Research)
   5.2. Status of Current Researches

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Northern Everglades River Watershed Research & Water Quality Monitoring Program

St. Lucie River Watershed

February 2008

sfwmd.gov

UPDATE

- **Research and Monitoring Plan**
  - **Content:**
    - **Plans for Monitoring at the Project Level will be included in the River Watershed Construction Plan**
    - **Chapter 5 has been eliminated**
    - **Chapter 4 is now entitled “Watershed and Estuarine Monitoring Programs”**

Chapter 4: Watershed and Estuarine Monitoring Programs

- **What is Monitoring?**
  - **Monitoring is (1) the systematic collection of data that (2) measures change or progress towards (3) a goal, be it a level of project performance or a target and can be used to (4) determine when modifications to the project are required.**

Chapter 4: Watershed and Estuarine Monitoring Programs

- **Developing a Monitoring Plan**
  - **Important first step is to identify the goals of the project and identify the type of information that is required to measure progress towards those goals.**

Chapter 4: Watershed and Estuarine Monitoring Programs

- **Goals of the River Watershed Protection Plans (Senate Bill 253)**
  1) **Pollutant load reductions based on the TMDL**
  2) **Salinity envelopes and freshwater inflow targets based on existing information**
  3) **Reduce frequency and duration of undesirable salinity ranges**
  4) **Annual conditions report: hydrology, water quality, and aquatic habitat**

Chapter 4: Watershed and Estuarine Monitoring Programs

- **Monitoring Program**
  - **Loads for pollutants requiring TMDL (concentration x flow)**
  - **TMDL pollutant concentrations in estuarine receiving waters**
  - **Parameters upon which TMDL is based (e.g. nutrient TMDL based on Chl *a*)**
  - **Salinity**
  - **Aquatic Habitat: Oysters, SAV**

Chapter 4: Watershed and Estuarine Monitoring Programs

- **Plan Formulation**

1) **Inventory Existing Monitoring (Ch 4)**
2) **Assessment (Is it adequate to meet goals?) (Ch 4)**
3) **Recommendations (CH 6)**

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

St. Lucie Estuary "Salinity Envelope": Establishing Freshwater Inflow Targets to Evaluate Alternative Management Scenarios

Northern Everglades River Watershed Research & Water Quality Monitoring Program St. Lucie River Watershed

February 2008

sfwmd.gov

Valued Ecosystem Components (VECs) Concept:

The application of a resource-based management strategy developed by the U.S. Environmental Protection Agency as part of its National Estuary Program. Through this strategy, a suitable salinity and water quality environment for VECs attains management objectives.

VECs sustain an important ecological or water resource function by providing food, living space, refuge, and foraging sites for other desirable species in the estuary.

Valued Ecosystem Components (Cont.)

The approach assumes environmental conditions suitable for VECs are suitable for other desirable species and that enhancement of VECs will lead to enhancement of other species.

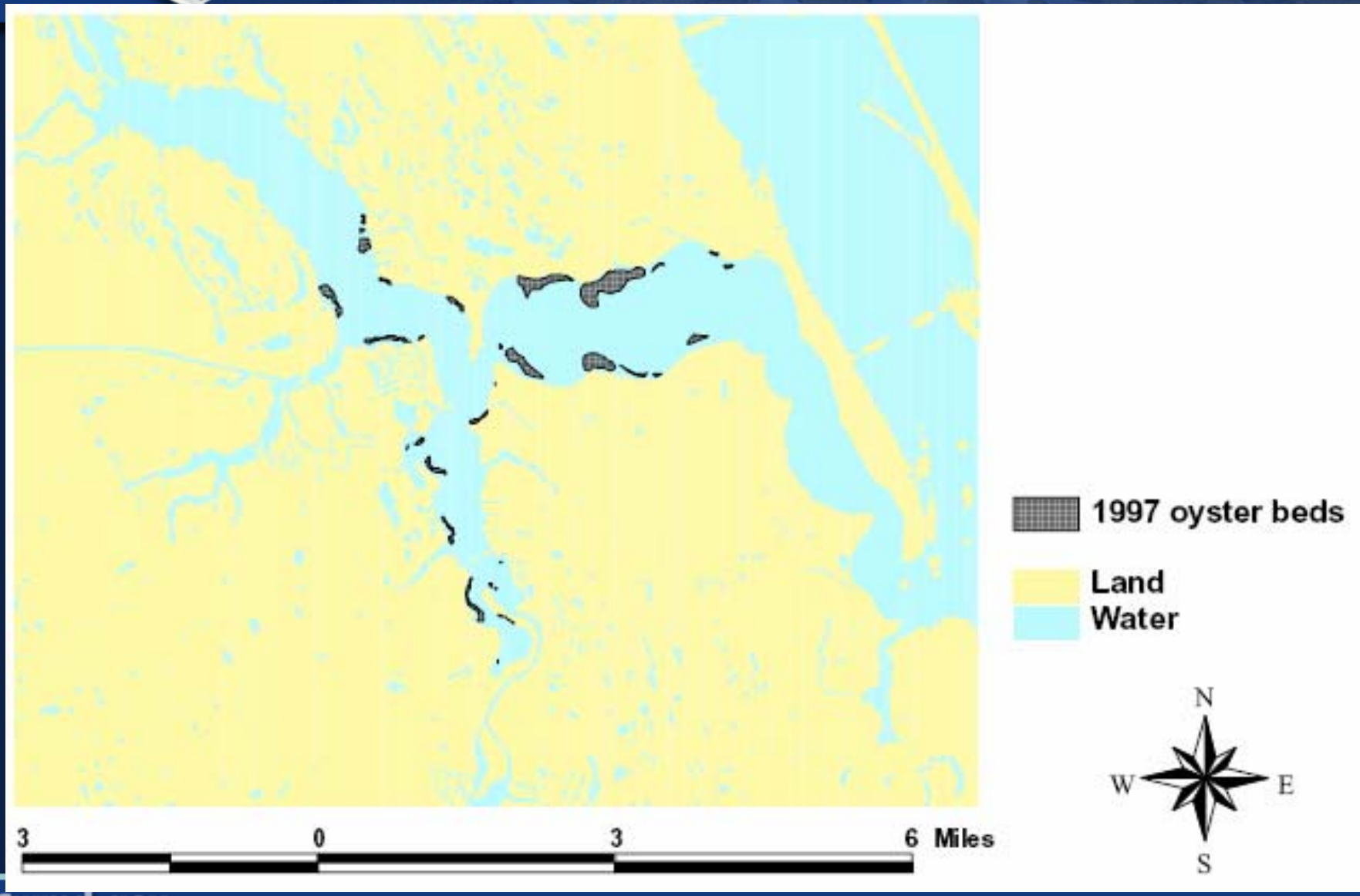
VECs identified for the St. Lucie estuary are (1) oyster populations; and (2) submerged aquatic vegetation; and (3) proposed low salinity zone/fish nursery

Oyster Bar

1. Oyster spat, 2. Skilletfish, 3. Hooked mussel, 4. Whip mud worms, 5. Sea squirts, 6. Sea anemone, 7. Barnacles, 8. Fan worms, 9. Mud crab

Oyster reef community. Illustration credit: Alice Jane Lippson, from Life in the Chesapeake Bay, by Alice Jane Lippson and Robert L. Lippson.

Oyster Distribution in the St. Lucie Estuary



Salinity tolerances for life stages of the Eastern Oyster (*Crassostrea virginica*) to address low salinity / high flow target for middle estuary

Life Stage	Salinity (ppt)	Duration (days)	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Eggs			X	X	X	X									Wilson et al. 2004
Harm	7.5 - 10.0	1													Burrel 1986
Mortality	0.0 - 7.5	1													Burrel 1986
Larvae					X	X	X								Wilson et al. 2004
Stress	10.0 - 12.0	1													Loosanoff 1965; Davis 1958
Harm	0.0 - 10.0	1													Davis 1958
Mortality	0.0 - 10.0	14													Davis 1958
Spat & Juveniles						X	X	X	X						Wilson et al. 2004
Stress	5.0 – 10.0	1													Ray and Benefield 1997
Harm	0.0 -5.0	1													Loosanoff 1953
Mortality	0.0 – 5.0	7													Volety et al. 2003
Adults			X	X	X	X	X	X	X	X	X	X	X	X	
Stress	7.5 - 10.0														Woodward-Clyde 1998
Harm	5.0 – 7.5	1													Loosanoff 1953, 1965
Mortality	2.0 – 5.0	28													Loosanoff 1953; Volety et al 2003
Mortality	0.0 – 2.0	14													Roesijadi 2004

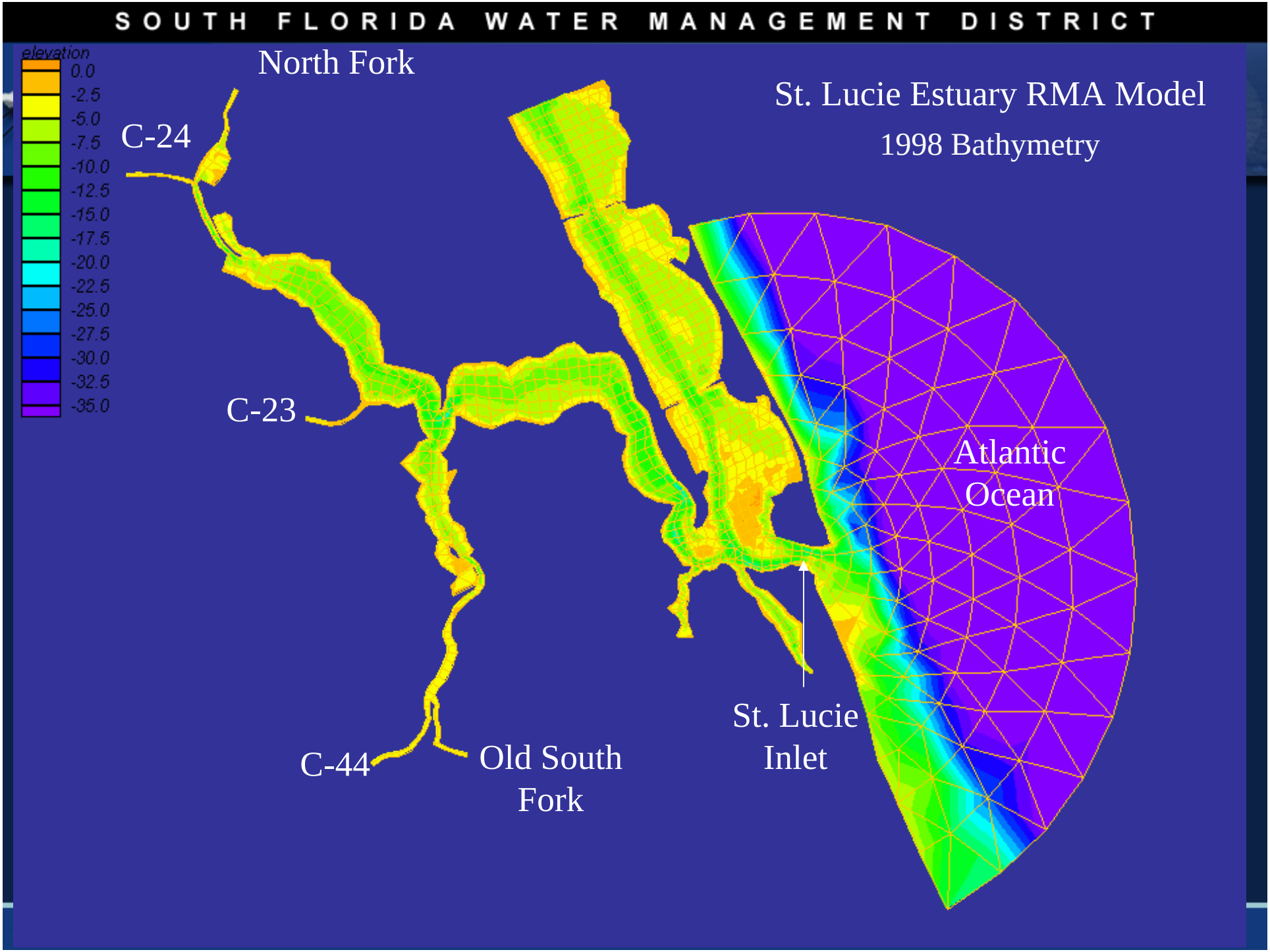
Effects of high salinity on oysters to address a low flow target

When salinity is greater than about 25 ppt:

- **The prevalence of disease that causes stress (reduced egg production, reduced fat reserves) and potential mortality of oysters increases, especially when water temperatures are above approximately 20 degrees C.**
- **Marine oyster predators are no longer restricted to the outer estuary salinity habitats and therefore can inhabit the mid-estuary oyster reefs**

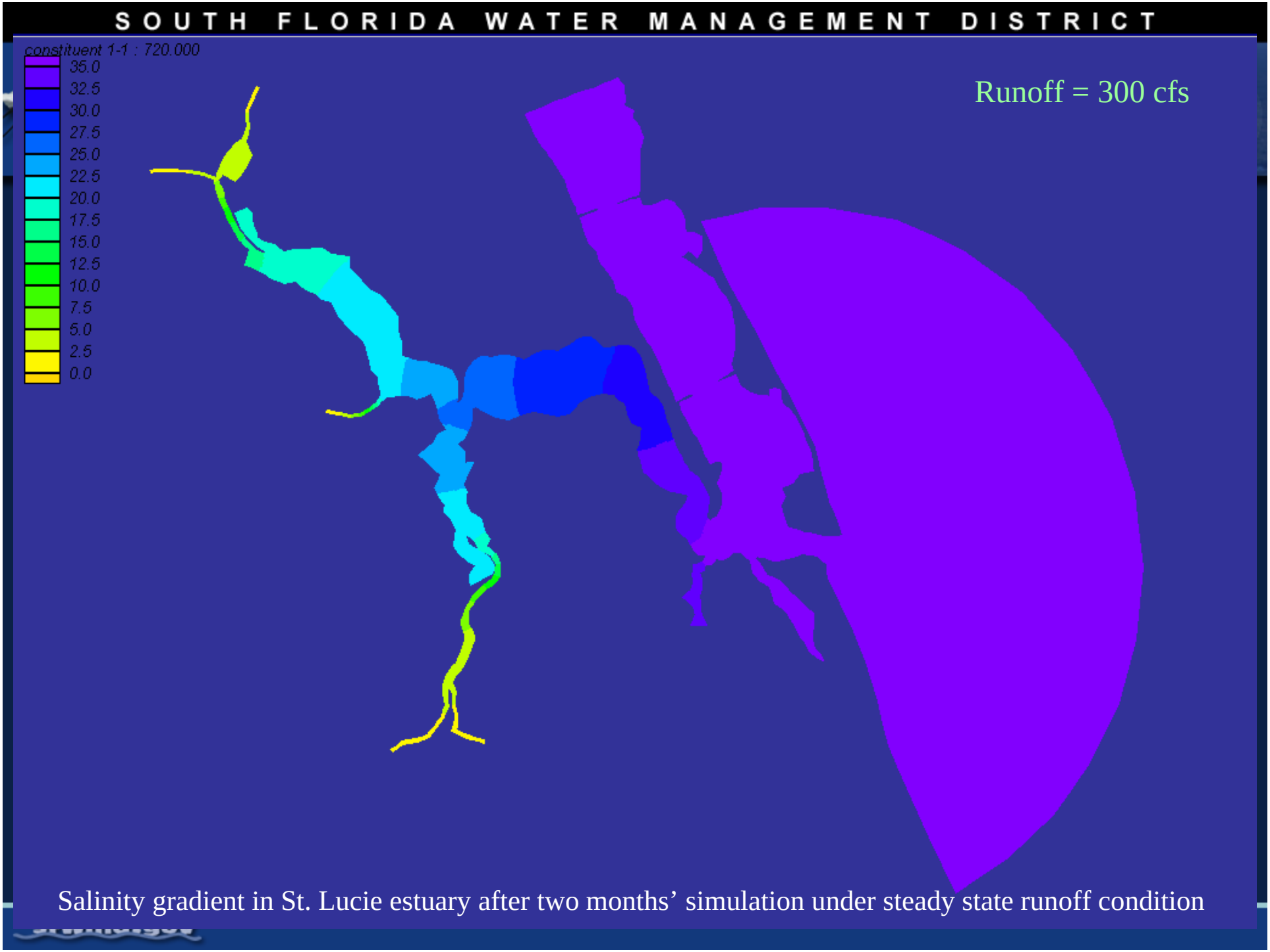
Determining the Relationships of Freshwater Inflows to Salinity for the St. Lucie Estuary:

A two dimensional depth-averaged finite element model


SOUTH FLORIDA WATER MANAGEMENT DISTRICT
elevation
0.0
-2.5
-5.0
-7.5
-10.0
-12.5
-15.0
-17.5
-20.0
-22.5
-25.0
-27.5
-30.0
-32.5
-35.0
North Fork
C-24
C-23
C-44
Old South Fork
St. Lucie Inlet
Atlantic Ocean
St. Lucie Estuary RMA Model
1998 Bathymetry

Salinity Contour Maps and Family of Salinity Gradient Curves

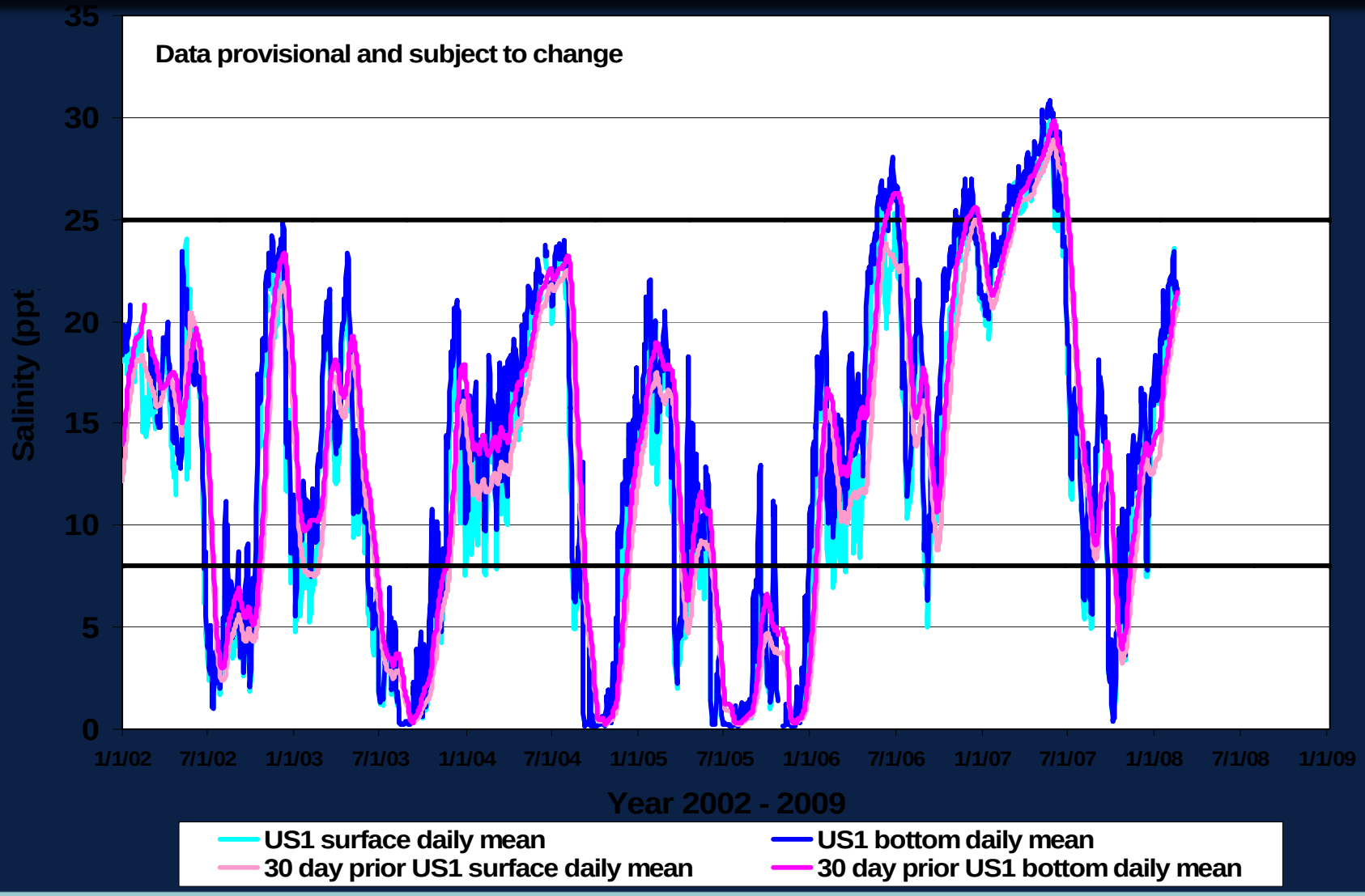
Net freshwater inflows of 300 to 10,000 cfs were simulated until a salinity gradient equilibrium in the estuary was obtained for each inflow.

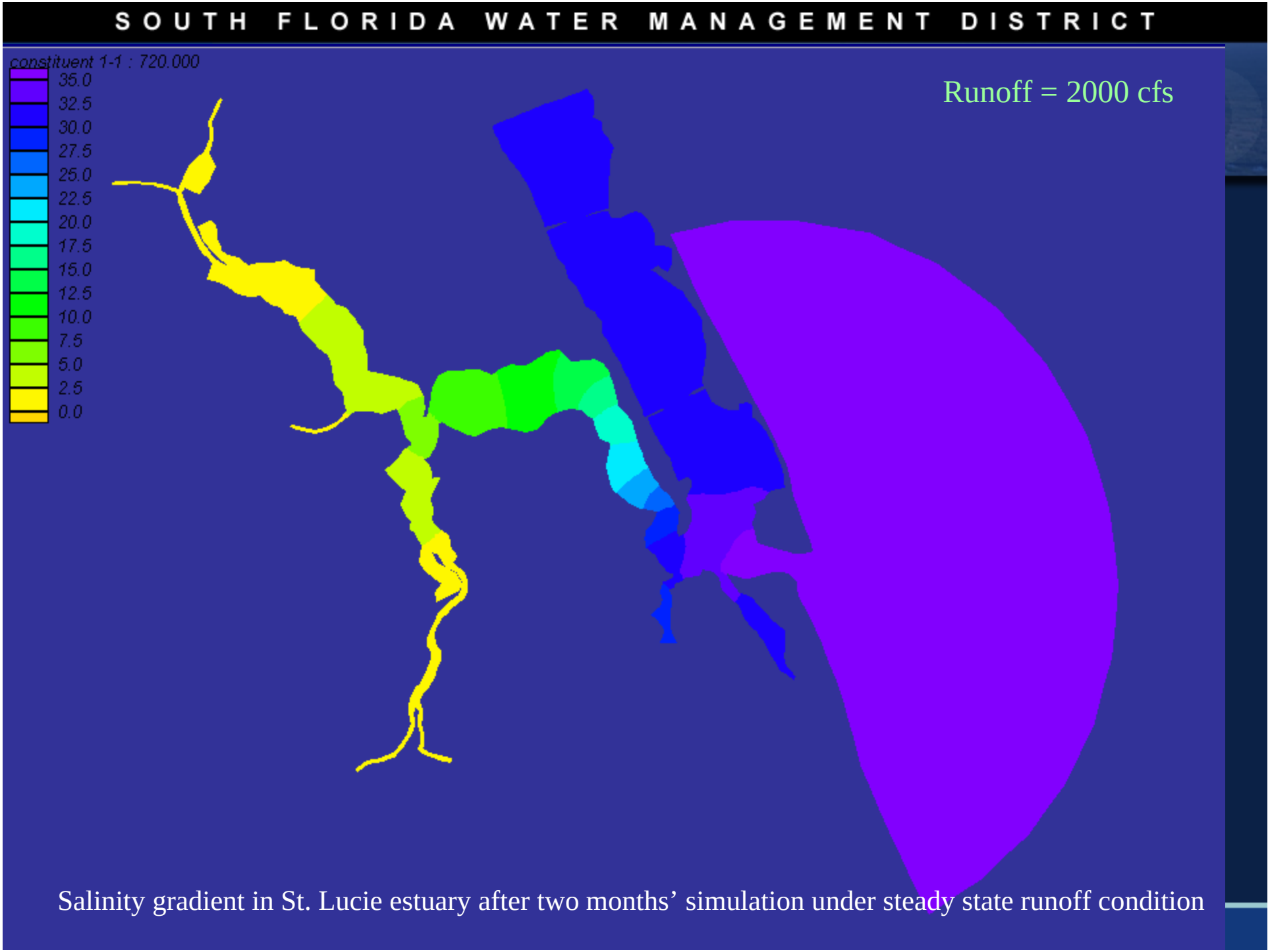


Salinity gradient in St. Lucie estuary after two months' simulation under steady state runoff condition

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Salinity Envelope
Surface and Bottom Mean Daily Salinity in the St. Lucie Estuary at US1

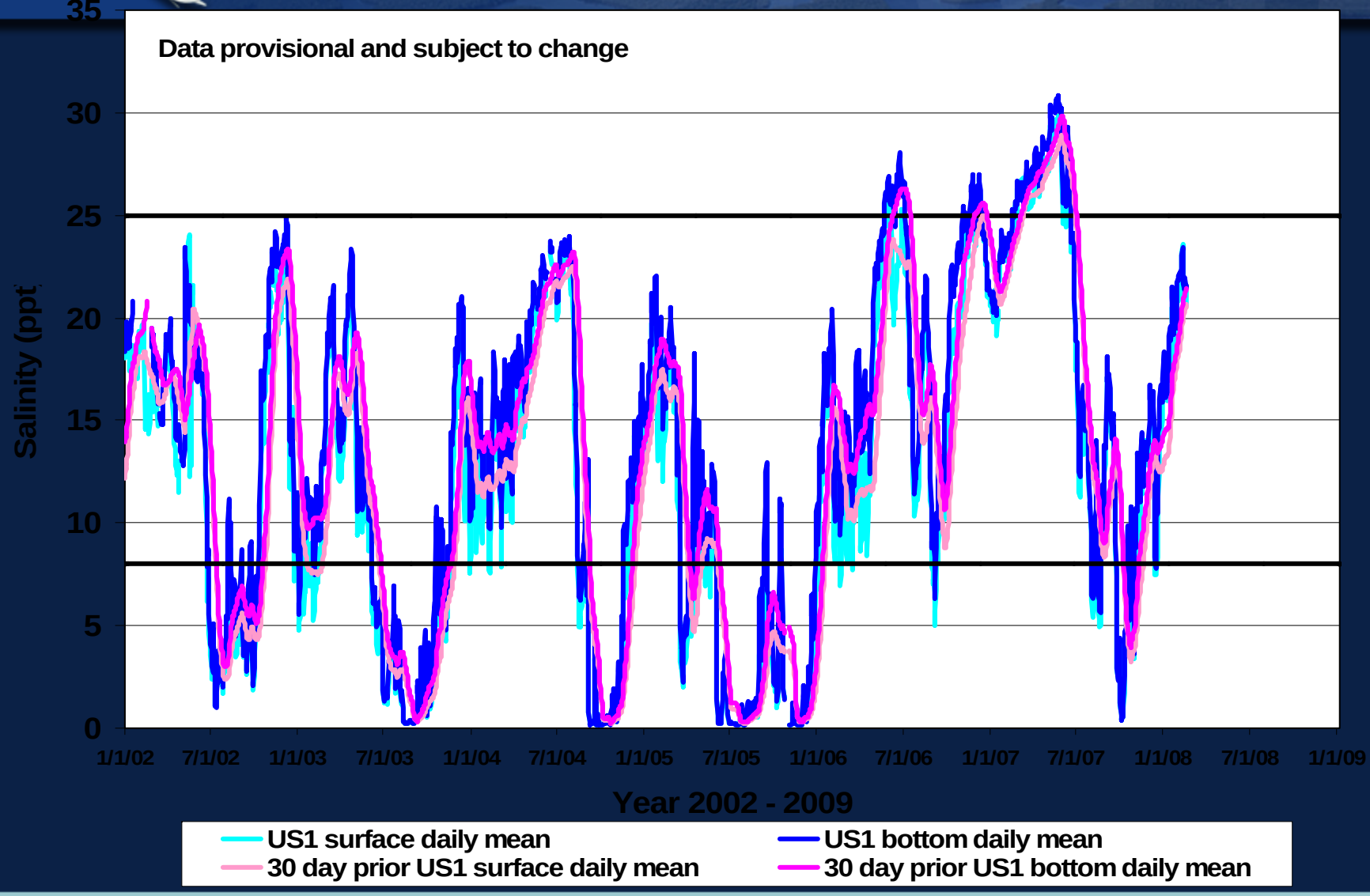


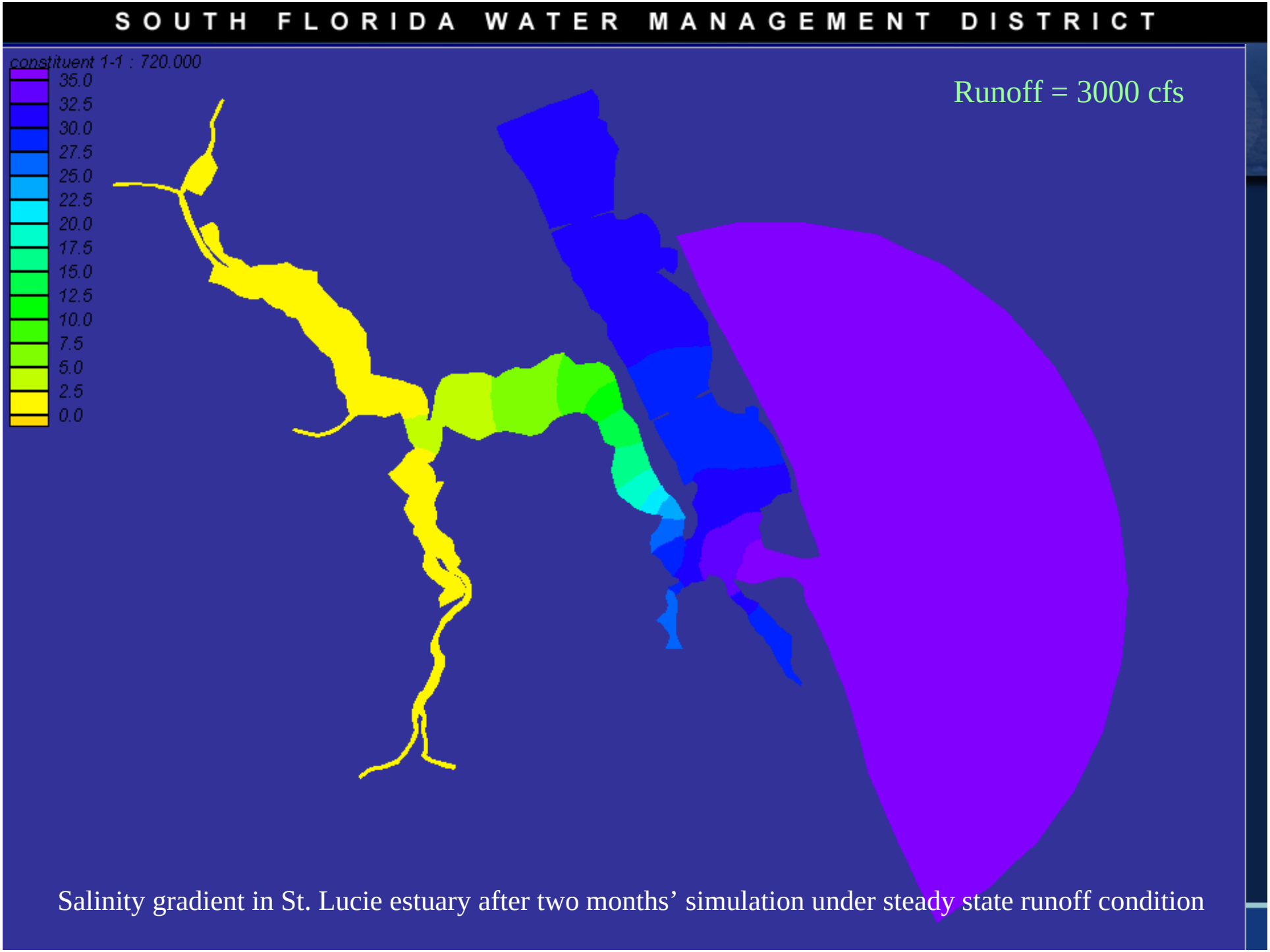


Salinity gradient in St. Lucie estuary after two months' simulation under steady state runoff condition

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Salinity Envelope
Surface and Bottom Mean Daily Salinity in the St. Lucie Estuary at US1

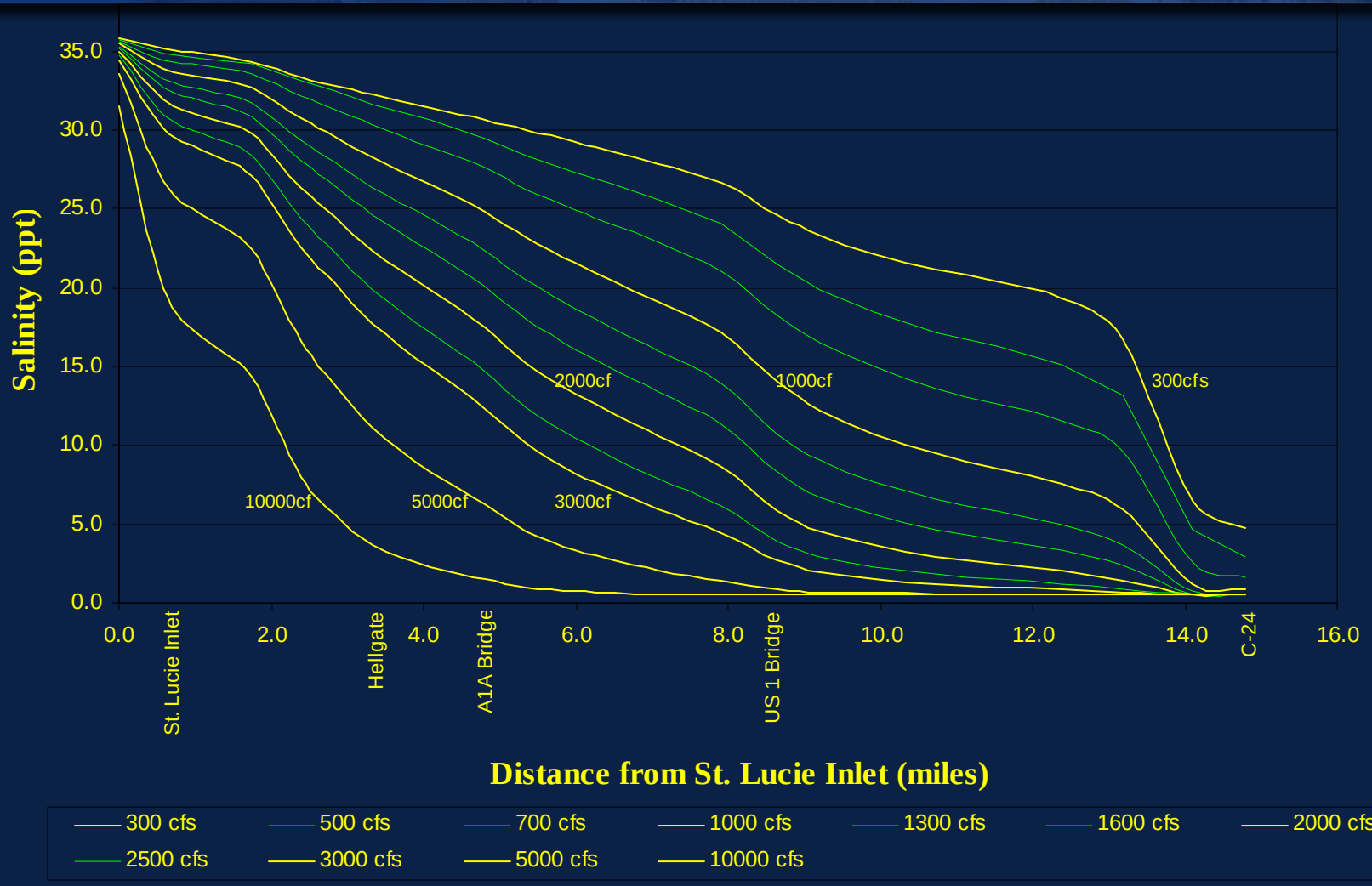




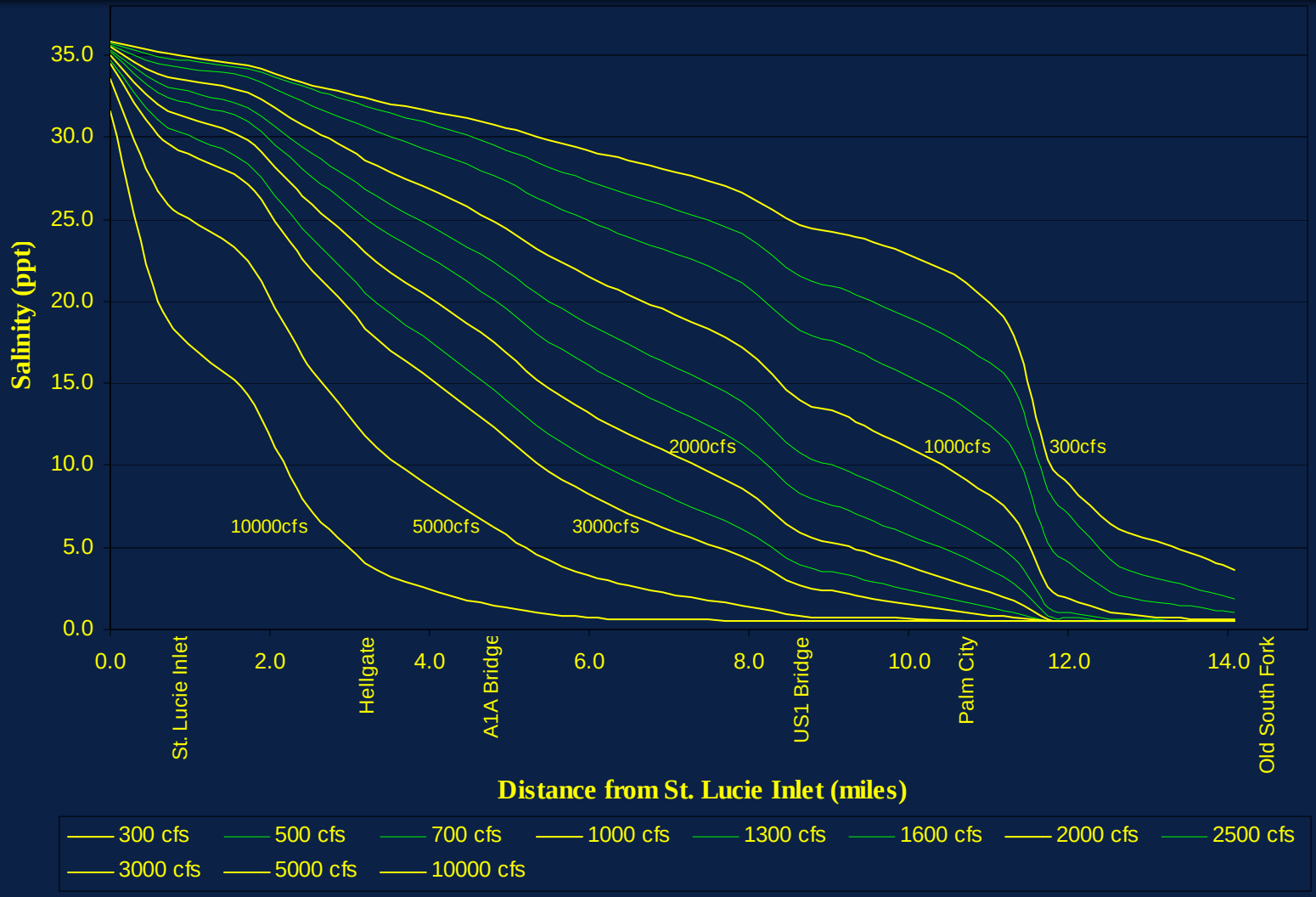
Salinity gradient in St. Lucie estuary after two months' simulation under steady state runoff condition

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Salinity gradient in St. Lucie Estuary at various magnitude of freshwater inflow



Salinity gradient in St. Lucie Estuary at various magnitude of freshwater inflow



What is "Net Freshwater Inflow"?

- The net freshwater inflow includes all surface water **(surface water runoff from all basins in the watershed, Structure S-80 lockage and leakage from S-80, S-49, Gordy Road)** and all groundwater; minus evaporation **from the surface of the estuary.**

- This relates to a net inflow that may range from about 125 to 200 cfs (best estimate at this time) from all sources except surface water runoff in the dry and wet season, respectively. (The salinity at the U.S. 1 Bridge indicates the quantity of net freshwater inflow to the inner estuary using the figures shown)

Summary of Inflow Threshold Targets for Culling Alternative Management Scenarios

- **High, Net Freshwater Inflow Target: 2000 cfs (about 200 cfs is not surface water runoff, therefore, about 1800 cfs from surface water).**

- **Low, Net Freshwater Inflow Target: 350 cfs (about 125 cfs is not surface water runoff, therefore, about 225 cfs from surface water to reduce oyster stress and enhance the Low Salinity Zone Habitat/fish nursery function in the North Fork with special emphasis on winter and spring fish spawning seasons).**

Refining Freshwater Inflow Targets by adding frequency of occurrence

List of natural flow-frequency distributions compared to existing condition (1995) distributions based with 1965-1995 climatic conditions (Haunert and Konyha 2004)

flow range		probability in each range (%)			
		NSM (target)	HSPF	Peace River	1995 Base
<350 cfs	<21,130 af/m	54.8%	47.6%	51.9%	31.2%
350 to 680 cfs	21,130 to 41,053 af/m	17.7%	19.9%	20.4%	24.2%
680 to 1010 cfs	41,053 to 60,976 af/m	6.5%	9.7%	12.6%	12.1%
1010 to 1340 cfs	60,976 to 80,898 af/m	6.5%	5.9%	4.3%	8.9%
1340 to 1670 cfs	80,898 to 100,821 af/m	4.3%	4.0%	4.6%	7.8%
1670 to 2000 cfs	100,821 to 120,744 af/m	3.0%	4.8%	2.2%	4.3%
2000 to 3000 cfs	120,744 to 181,116 af/m	4.6%	5.9%	2.4%	7.5%
>3000 cfs	>181116 af/m	2.7%	2.2%	1.6%	4.0%
average annual runoff (in/y)		11.3	14.6	10	16.1

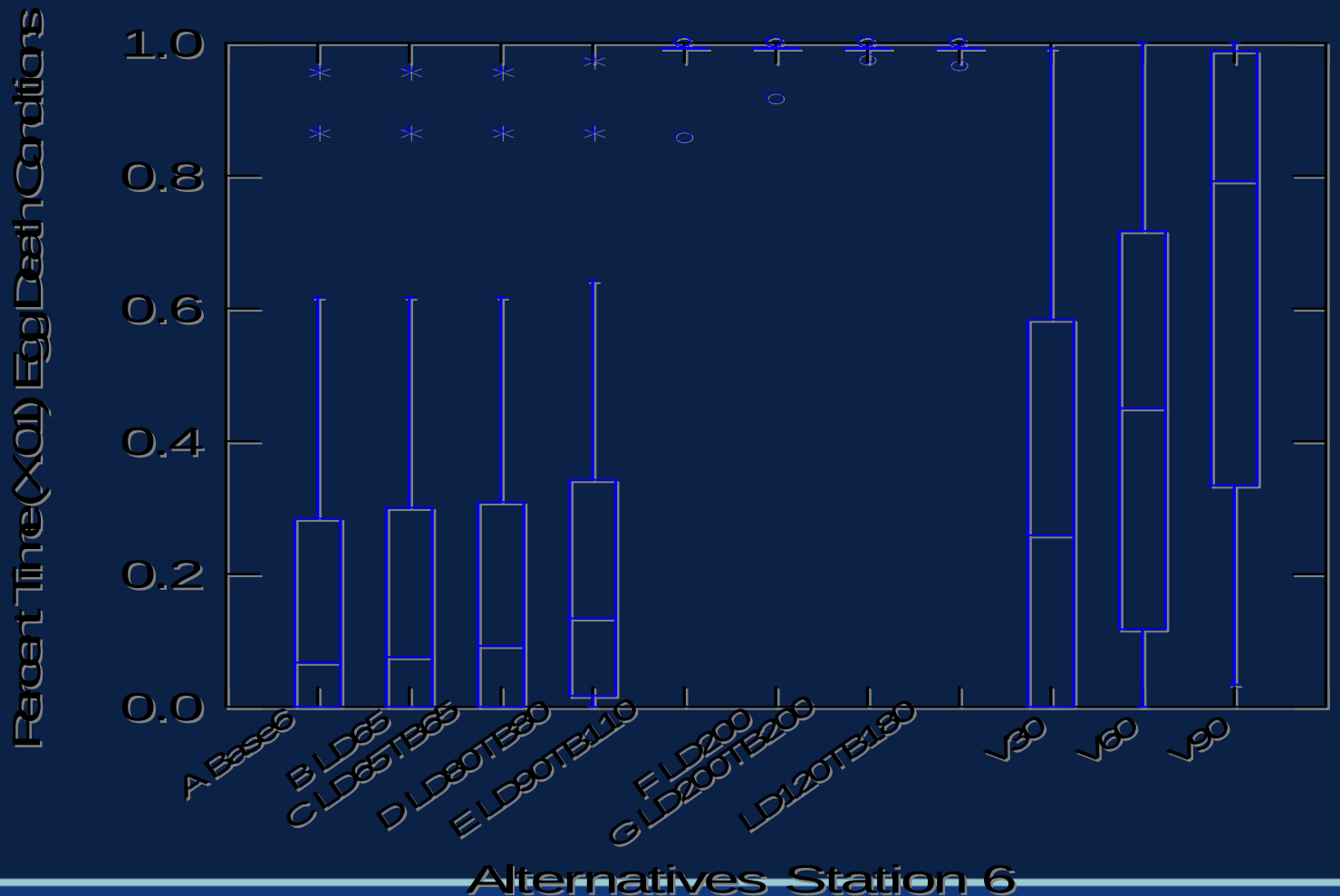
Estimated average monthly flows obtained from the NSM-SLE model (31 year or 372 month POR) to address the frequency of occurrence

- Flows less than 350 cfs for 178 months or less (or 47.8% of the time) Further refinement needed and planned for using LSZ concept
- Flows between 350 and 2,000 cfs for 171 months or more (or 46.0%)
- Flows between 2,000 and 3,000 cfs for 18 months or less (or 4.8%)
- Flows greater than 3,000 cfs for 5 months or less (1.3%)

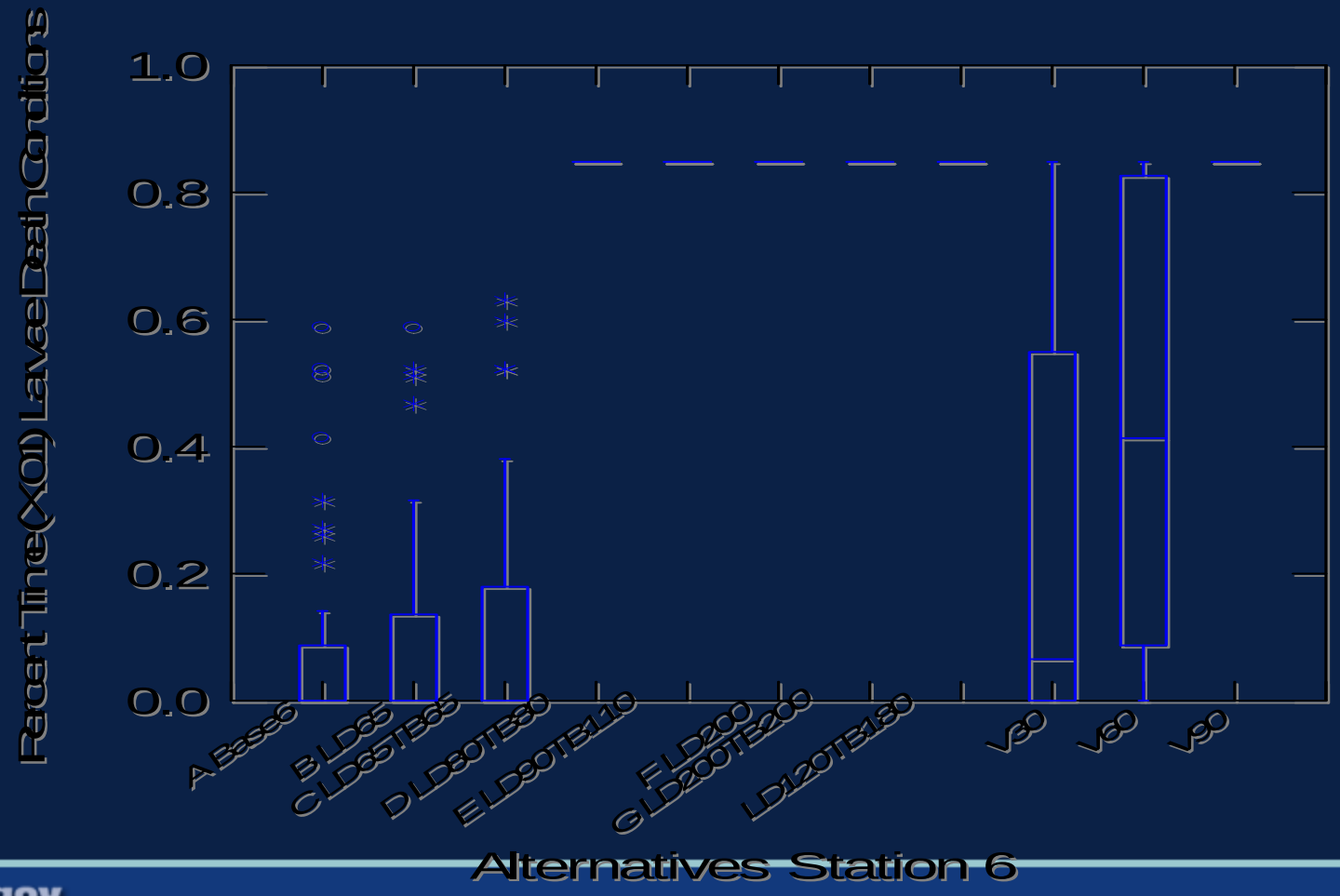
Salinity tolerances for Oyster life stages to address high flow target (seasonality and daily salinity for greater resolution)

Life Stage	Salinity (ppt)	Duration (days)	J	F	M	A	M	J	J	A	S	O	N	D	Reference
Eggs			X	X	X	X									Wilson et al. 2004
Harm	7.5 - 10.0	1													Burrel 1986
Mortality	0.0 - 7.5	1													Burrel 1986
Larvae					X	X	X								Wilson et al. 2004
Stress	10.0 - 12.0	1													Loosanoff 1965; Davis 1958
Harm	0.0 - 10.0	1													Davis 1958
Mortality	0.0 - 10.0	14													Davis 1958
Spat & Juveniles						X	X	X	X						Wilson et al. 2004
Stress	5.0 – 10.0	1													Ray and Benefield 1997
Harm	0.0 -5.0	1													Loosanoff 1953
Mortality	0.0 – 5.0	7													Volety et al. 2003
Adults			X	X	X	X	X	X	X	X	X	X	X	X	
Stress	7.5 - 10.0														Woodward-Clyde 1998
Harm	5.0 – 7.5	1													Loosanoff 1953, 1965
Mortality	2.0 – 5.0	28													Loosanoff 1953; Volety et al 2003
Mortality	0.0 – 2.0	14													Roesijadi 2004

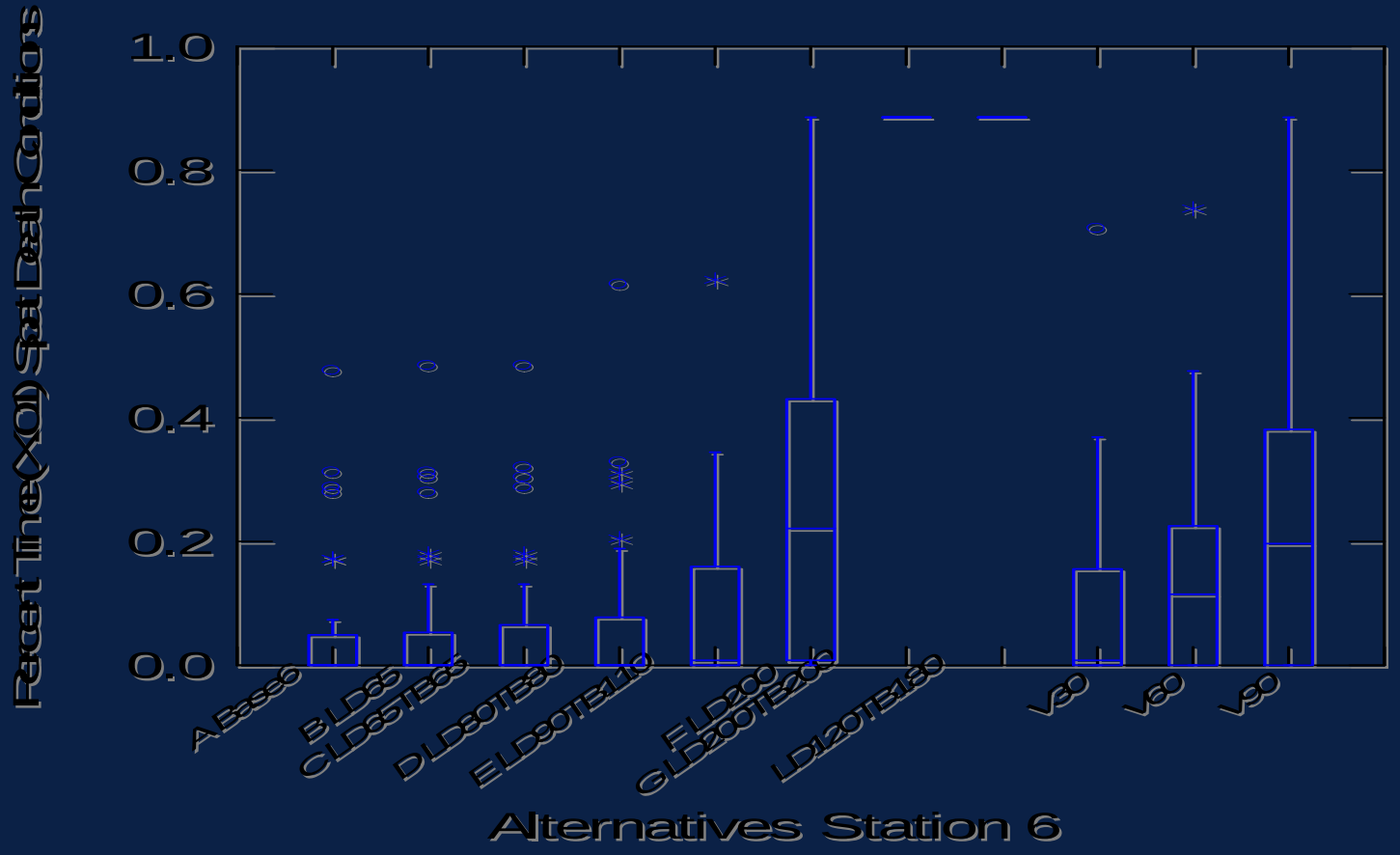
Example: Oyster Model Results (Eggs) for Alternative Water Management Scenarios for Loxahatchee Management Plan



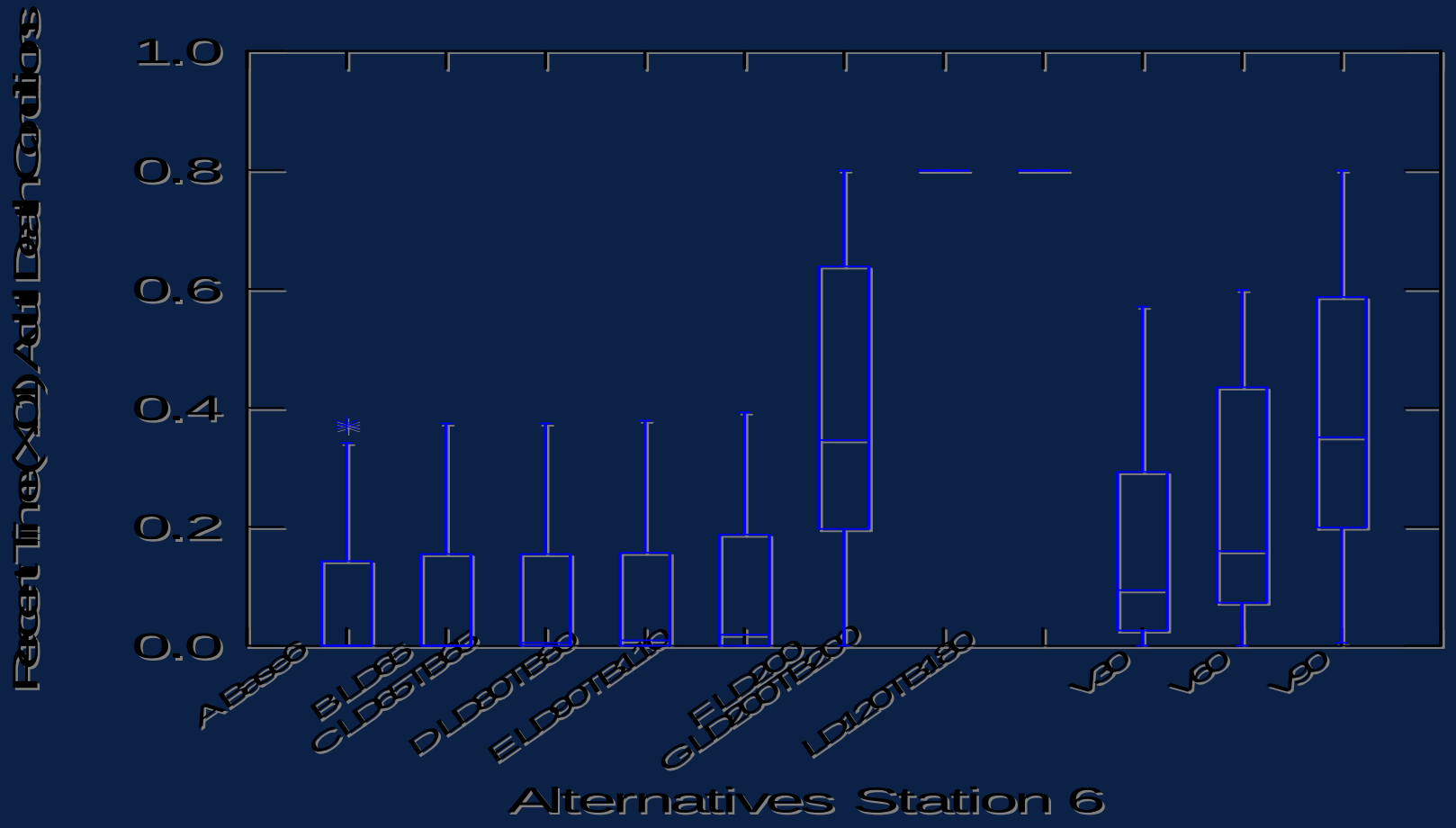
Example: Oyster Model Results (Larvae) for Alternative Water Management Scenarios for Loxahatchee Management Plan



Example: Oyster Model Results (Spat) for Alternative Water Management Scenarios for Loxahatchee Management Plan



Example: Oyster Model Results (Adults) for Alternative Water Management Scenarios for Loxahatchee Management Plan



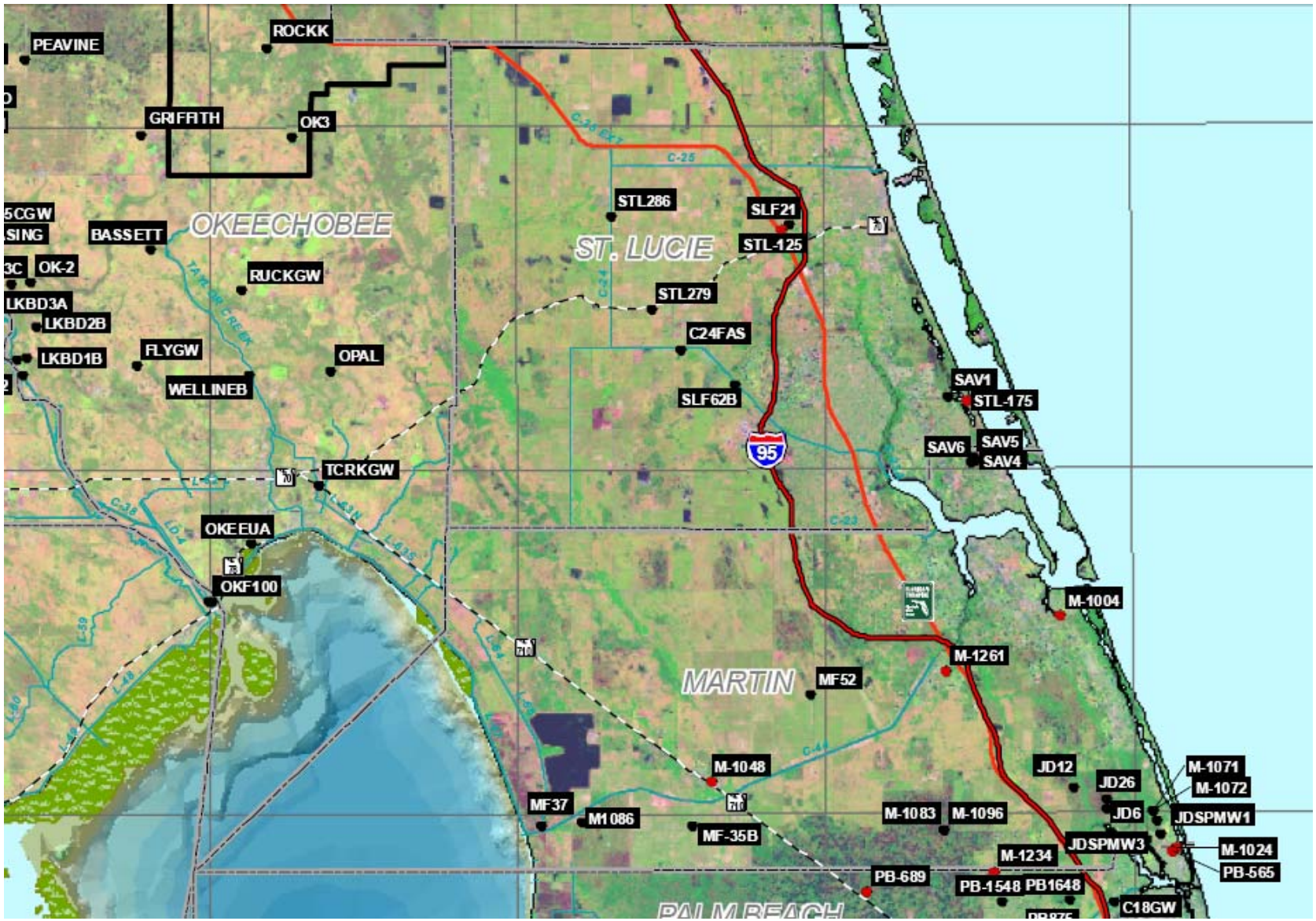
Future Enhancement of Low Flow Target Using Low Salinity Zone/Fish Nursery Function as a VEC

- Effects of dredging the North and South Forks of the SLE on salinity gradients and available fish nursery habitat
- CH3D SLE Model simulations to develop a family of curves and salinity time series for “historical” conditions.
- Studies are being conducted to determine the relationship of flow/salinity on the LSZ/ fish nursery function

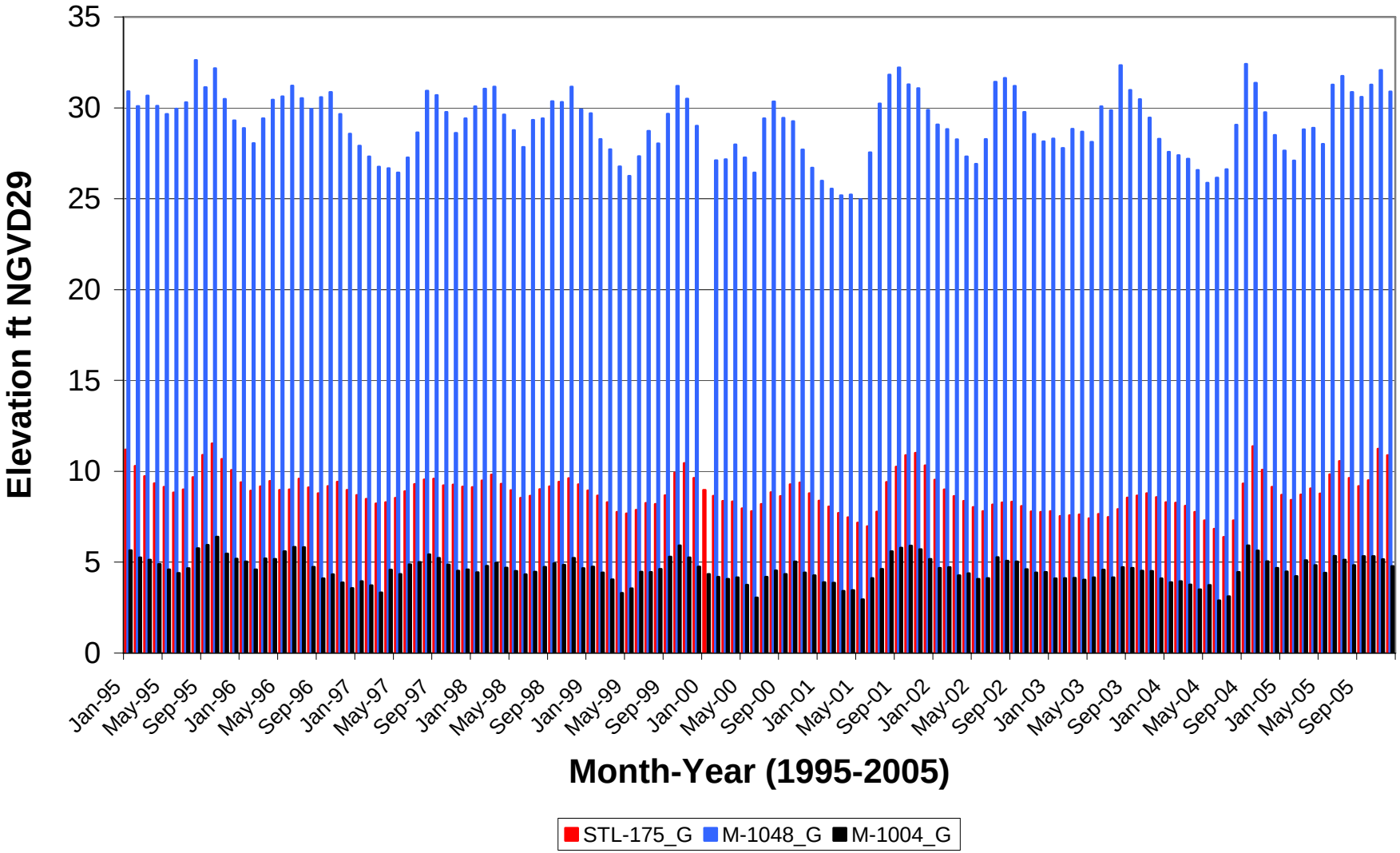
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Measurements of the Direct Groundwater Seepage into the St. Lucie Estuary

sfwmd.gov


PEAVINE
ROCKK
GRIFFITH
OK3
OKEECHOBEE
BASSETT
OK-2
RUCKGW
LKBD3A
LKBD2B
LKBD1B
FLYGW
OPAL
WELLINEB
TCRKGW
OKEEUA
OKF100
ST. LUCIE
STL286
SLF21
STL-125
STL279
C24FAS
SLF62B
SAV1
STL-175
SAV6
SAV5
SAV4
95
M-1004
M-1261
MARTIN
MF52
M-1048
MF37
M1086
MF-35B
M-1083
M-1096
JD12
JD26
JD6
M-1071
M-1072
JDSPMW1
JDSPMW3
M-1024
PB-565
M-1234
PB-689
PB-1548
PB1648
C18GW
PALM BEACH

Three Groundwater Monitoring Wells in Surrounding Area of SLE



SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Overview of the St. Lucie Estuary/Indian River Lagoon Groundwater/Surface Water Interaction Study

Northern Everglades River Watershed Research & Water Quality Monitoring Program St. Lucie River Watershed

February 2008

sfwmd.gov

Purpose of Project

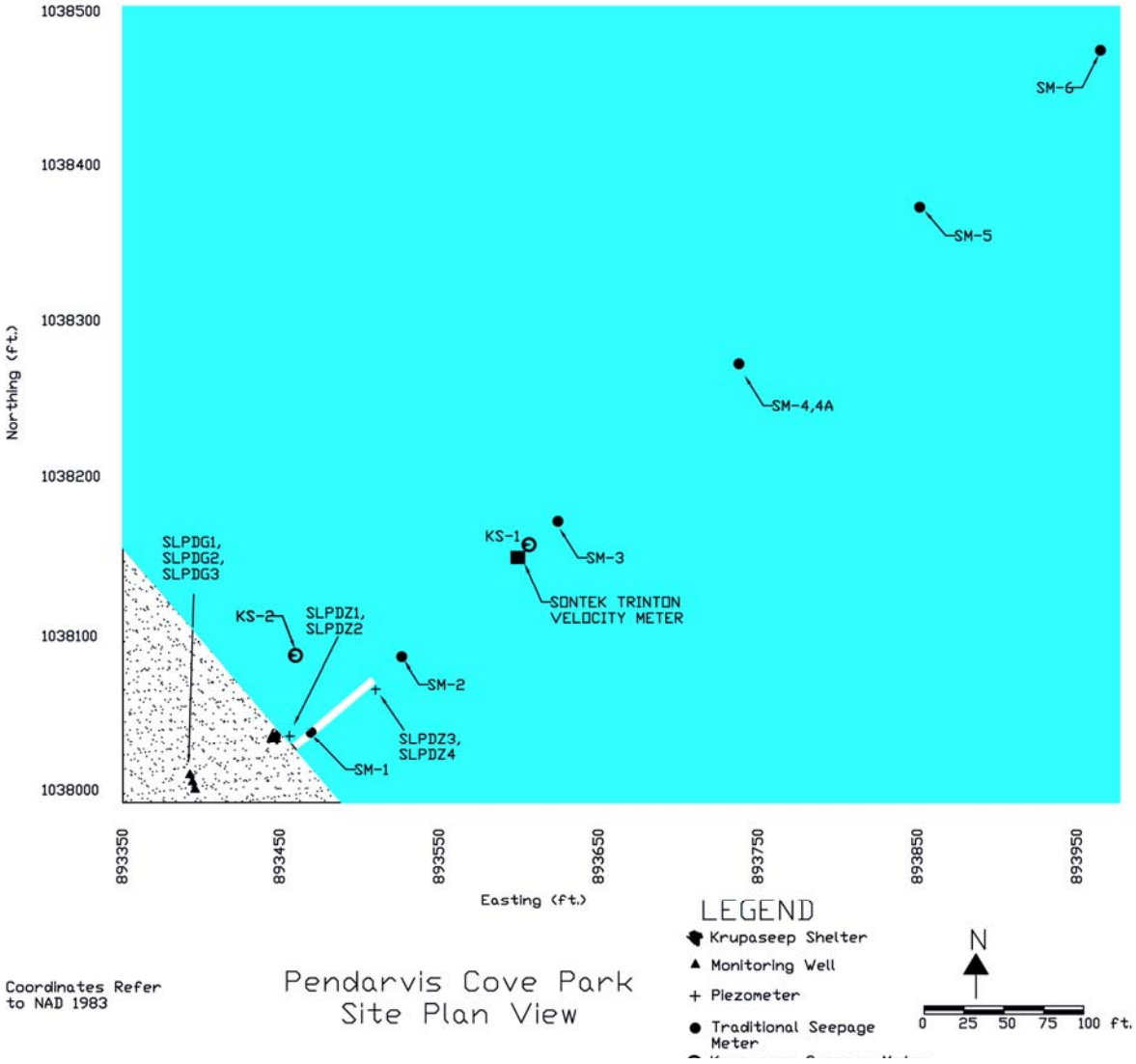
To provide information to develop Pollutant Load Reduction Goals:

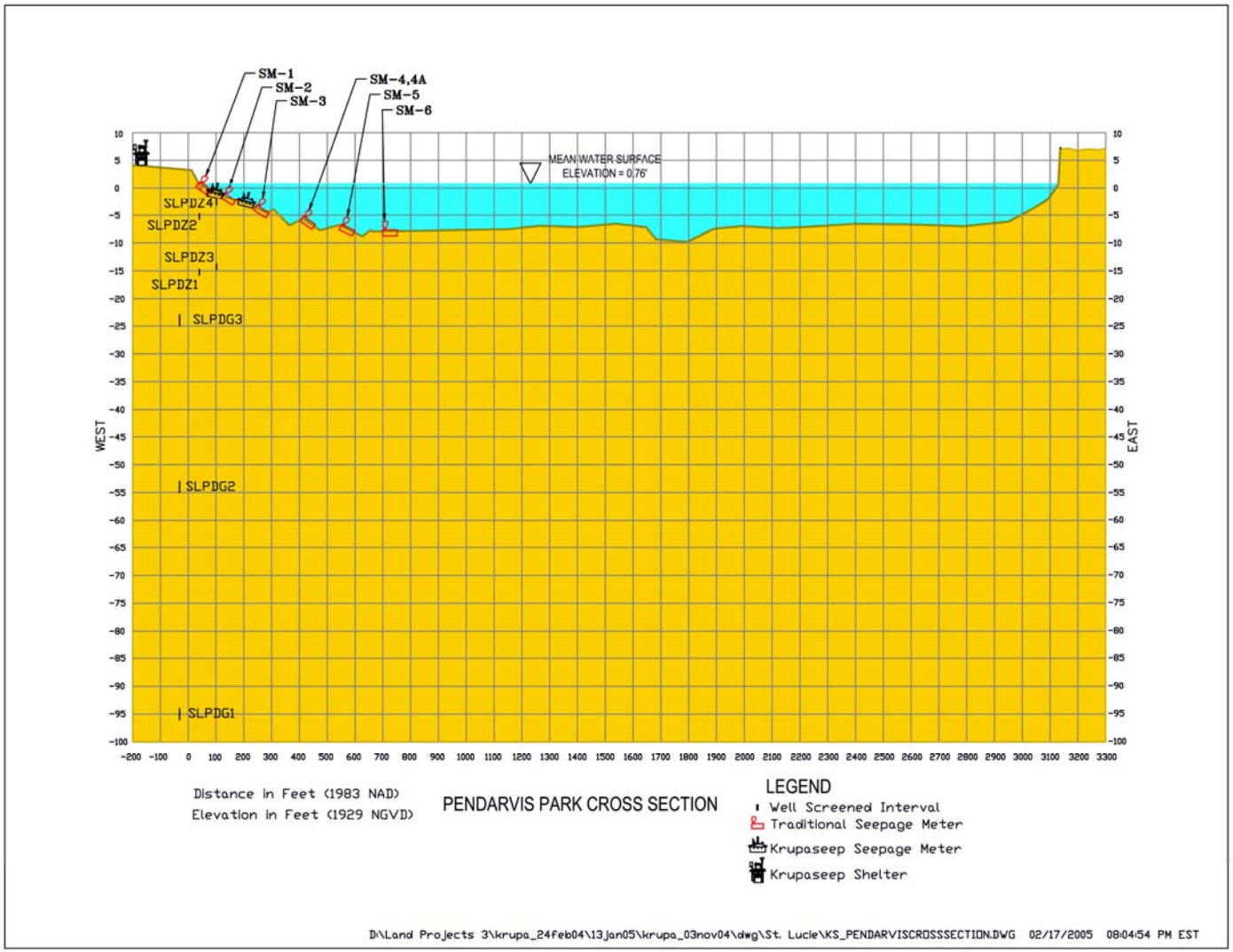
- **Monitor the levels of groundwater and surface water and surface water field parameters**
- **Determine hydraulic properties of the underlying sediments**
- **Understand seepage gains/losses into the surface water**
- **Evaluate water chemistry to determine ground water flow patterns**
- **Calculate nutrient loads**

Project Overview

- Site selection – six sites
- Continuous geological sampling, geophysically logged boreholes and installed wells in 2001
- Surveyed in the wells, piezometers and seepage meters. Surveyed cross sections at each location.
- Installed dataloggers and YSI sensors at each site.
- Conducted traditional “Lee” style seepage meter study –six measurement periods.
- Deployed the Krupaseep seepage meter system at three locations


St. Lucie Estuary/Indian River Lagoon
Groundwater, Surface Water
Interaction Studies
Monitoring Sites
IRMN
Indian River Lagoon
Atlantic Ocean
North Fork
C-24
IRLM
SLCM
SLHR
St. Lucie
Estuary
C-23
SLLT
SLPD
South Fork
N
0 1 2 3 4 5 Miles


1038500
1038400
1038300
1038200
1038100
1038000
Northing (ft.)
893350
893450
893550
893650
893750
893850
893950
Easting (ft.)
SM-6
SM-5
SM-4,4A
SM-3
KS-1
SONTEK TRINTON
VELOCITY METER
SLPDG1,
SLPDG2,
SLPDG3
KS-2
SLPDZ1,
SLPDZ2
SM-2
SLPDZ3,
SLPDZ4
SM-1
LEGEND
Krupaseep Shelter
Monitoring Well
Piezometer
Traditional Seepage
Meter
N
0 25 50 75 100 ft.
Coordinates Refer
to NAD 1983
Pendarvis Cove Park
Site Plan View


SM-1
SM-2
SM-3
SM-4,4A
SM-5
SM-6
MEAN WATER SURFACE ELEVATION = 0.76'
SLPDZ4
SLPDZ2
SLPDZ3
SLPDZ1
SLPDG3
SLPDG2
SLPDG1
WEST
EAST
Distance in Feet (1983 NAD)
Elevation in Feet (1929 NGVD)
PENDARVIS PARK CROSS SECTION
LEGEND
Well Screened Interval
Traditional Seepage Meter
Krupaseep Seepage Meter
Krupaseep Shelter
D:\Land Projects 3\krupa_24feb04\13jan05\krupa_03nov04\dwg\St. Lucie\KS_PENDARVISCROSSSECTION.DWG 02/17/2005 08:04:54 PM EST

Parameters Collected by Krupaseep

Flowmeters: Flux as recharge or discharge

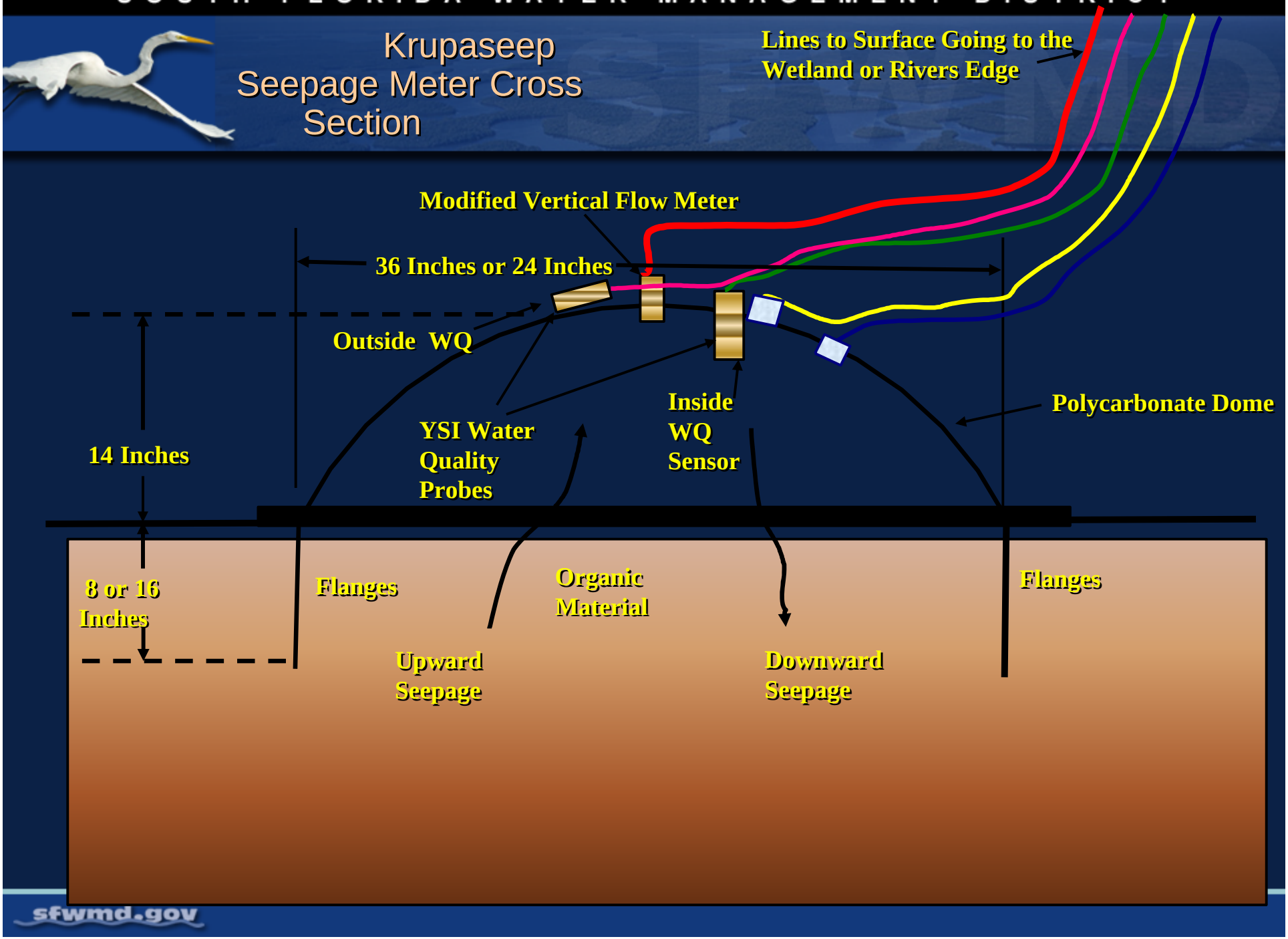
Water Quality: Water temperature, salinity, DO, specific conductivity, pH, and ORP

Weather: Air temperature, wind speed, wind direction, barometric pressure, surface PAR, and rainfall.

Other: Submerged PAR and water particle velocity

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Krupaseep Seepage Meter Cross Section

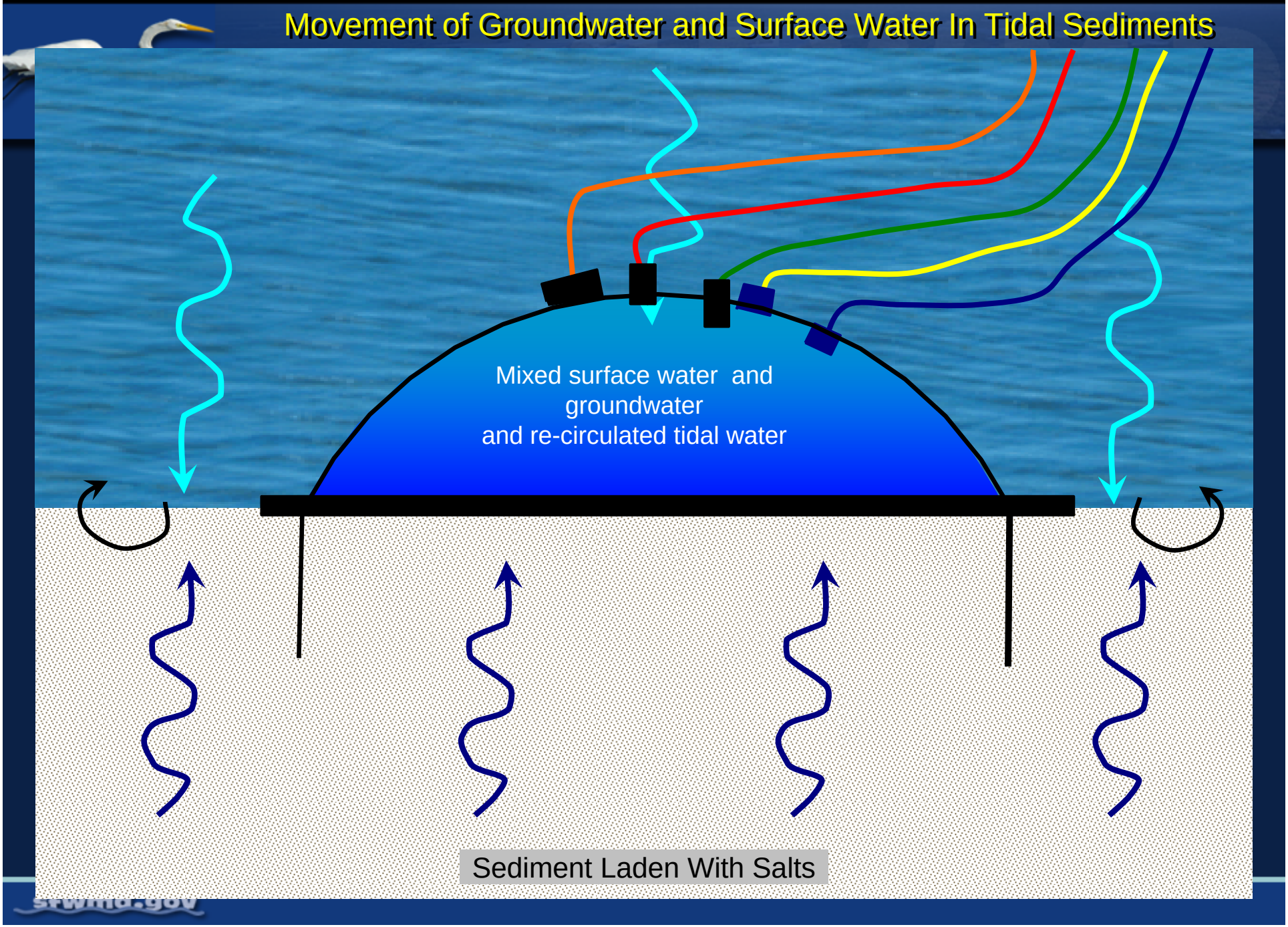


sfwmd.gov

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

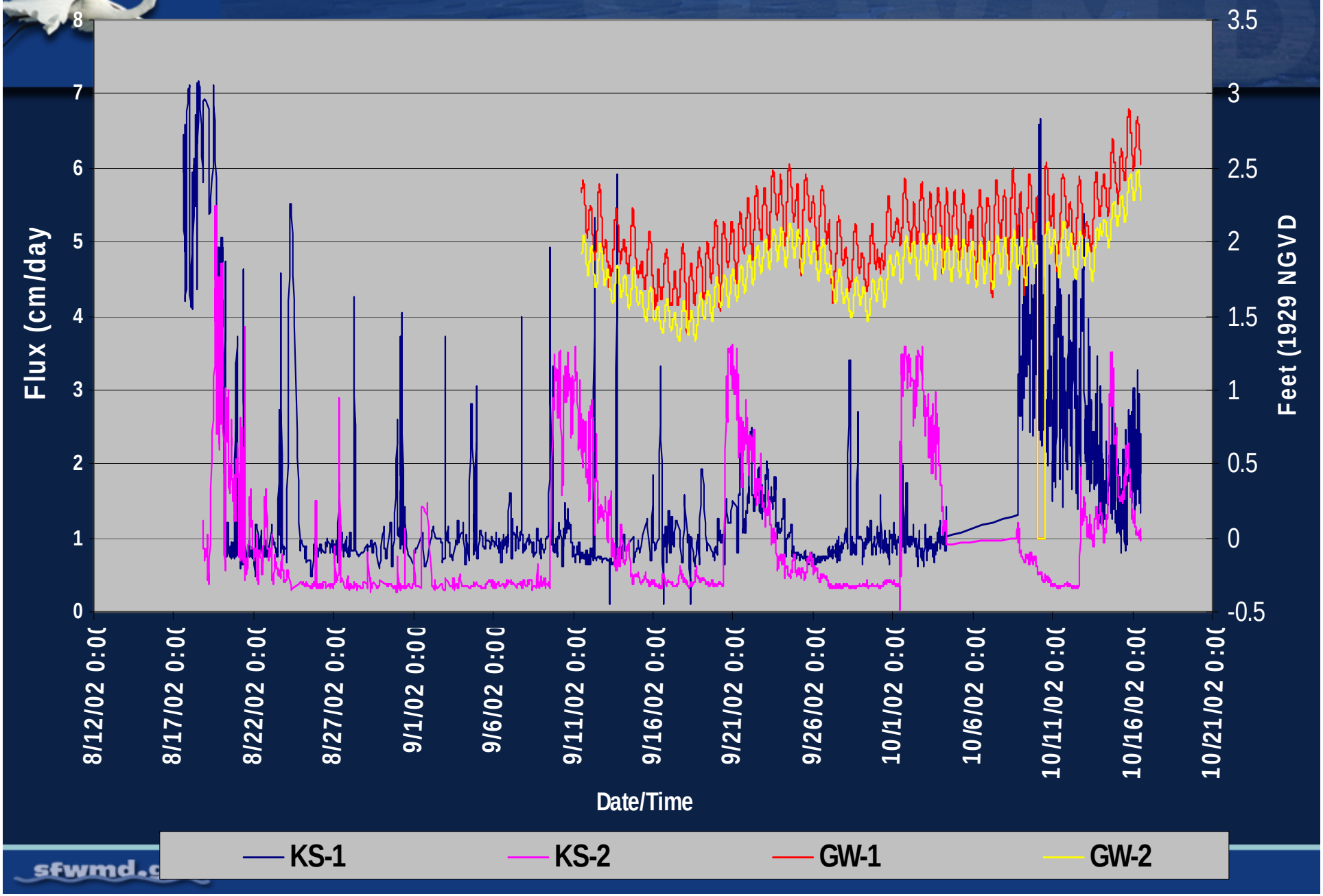
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Movement of Groundwater and Surface Water In Tidal Sediments



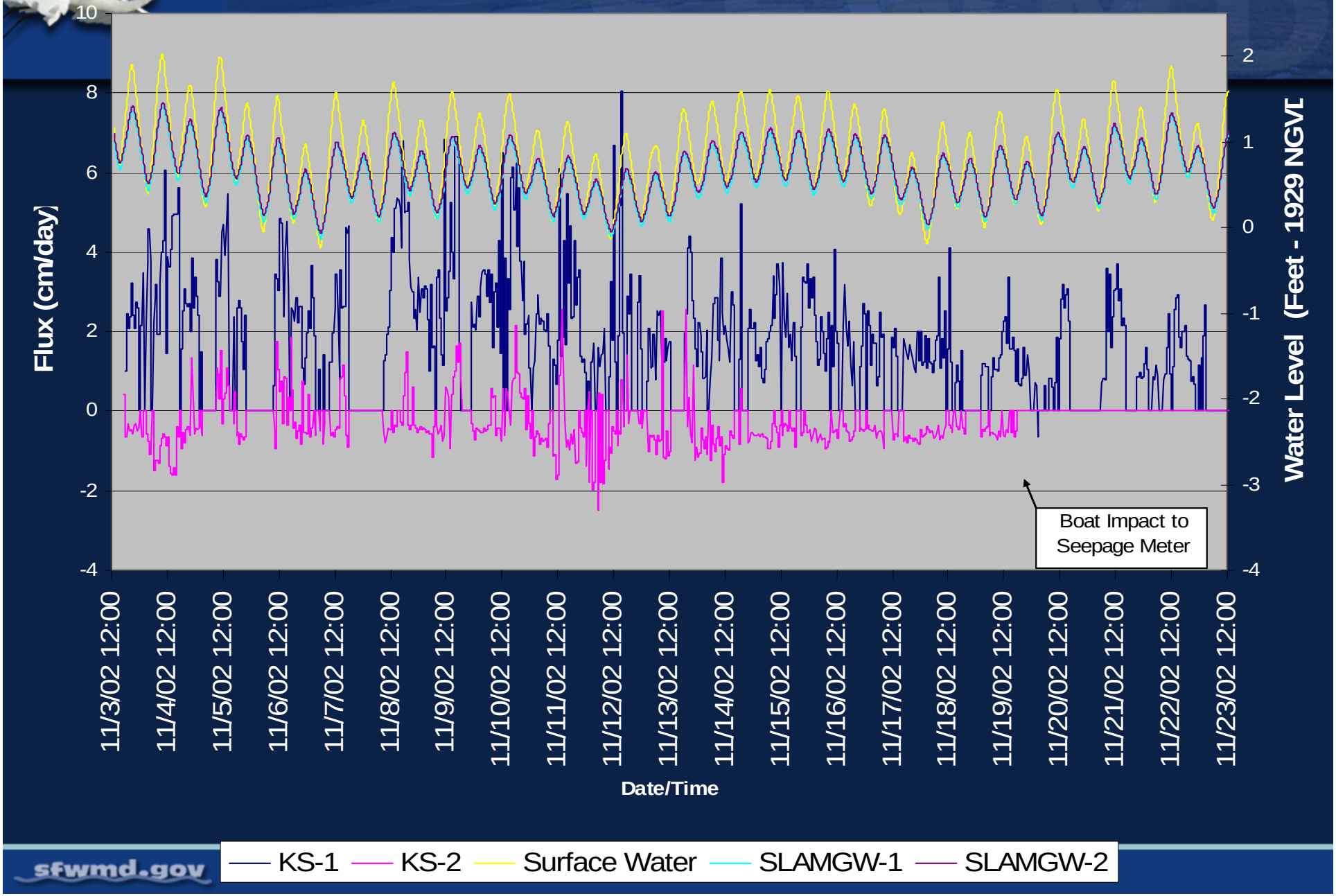
SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Seepage at the Minton Site

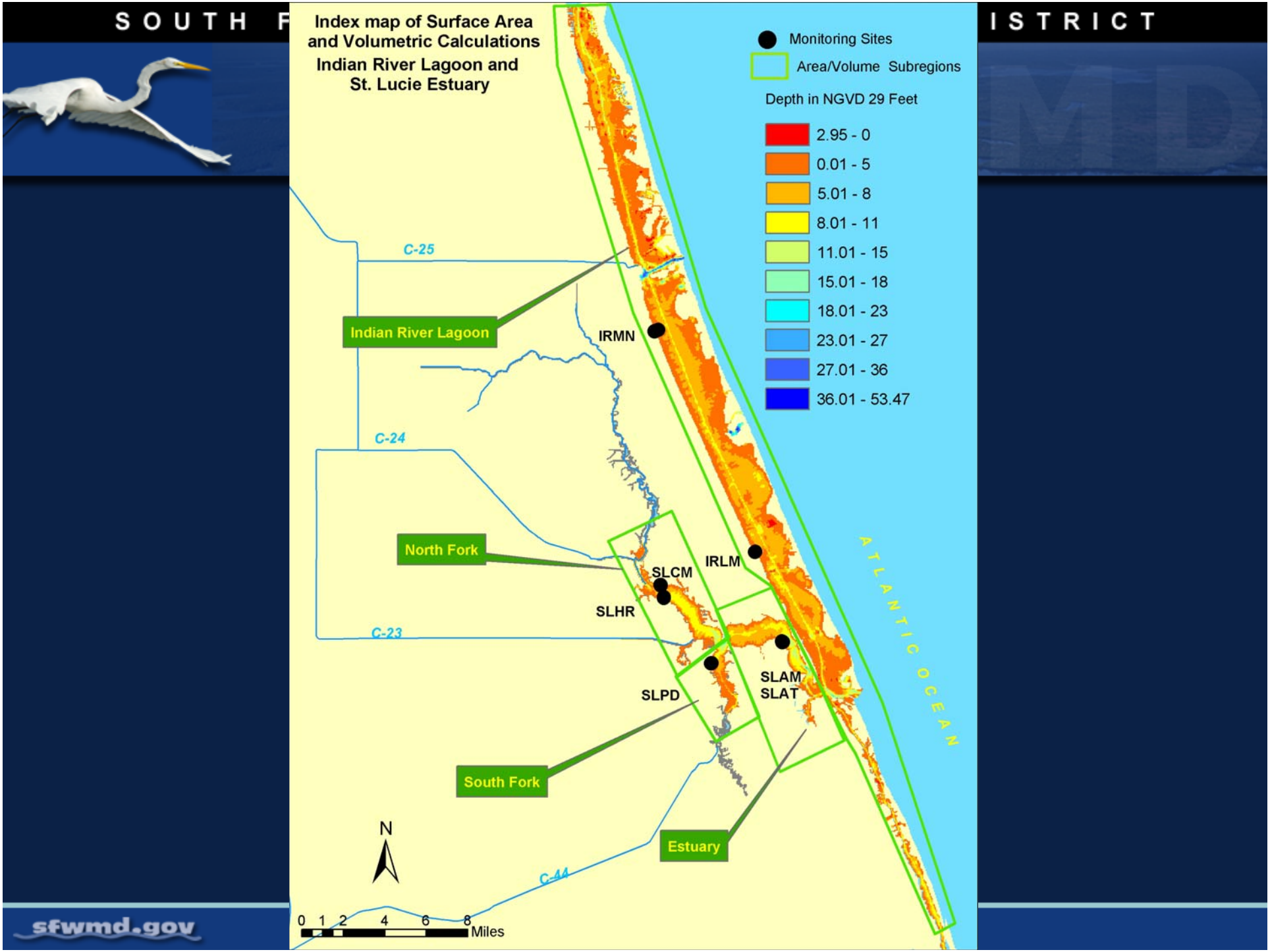


SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Seepage Rates at the Lutz Site



sfwmd.gov


SOUTH F
ISTRICT
Index map of Surface Area and Volumetric Calculations
Indian River Lagoon and St. Lucie Estuary
Monitoring Sites
Area/Volume Subregions
Depth in NGVD 29 Feet
2.95 - 0
0.01 - 5
5.01 - 8
8.01 - 11
11.01 - 15
15.01 - 18
18.01 - 23
23.01 - 27
27.01 - 36
36.01 - 53.47
C-25
C-24
C-23
C-44
Indian River Lagoon
North Fork
South Fork
Estuary
IRMN
IRLM
SLCM
SLHR
SLPD
SLAM
SLAT
ATLANTIC OCEAN
N
0 1 2 4 6 8
Miles
sfwmd.gov

Area and Volume Statistics

Calculates area and volume statistics for a surface above or below a reference plane at a specified height.

Input surface: C:\Share\bathy\maps\data\irlfeet

Reference parameters

Height of plane: 0

Input height range Z min: -2.95 Z max: 53.48

(•) Calculate statistics above plane

( ) Calculate statistics below plane

Z factor: 1.0000

Output statistics

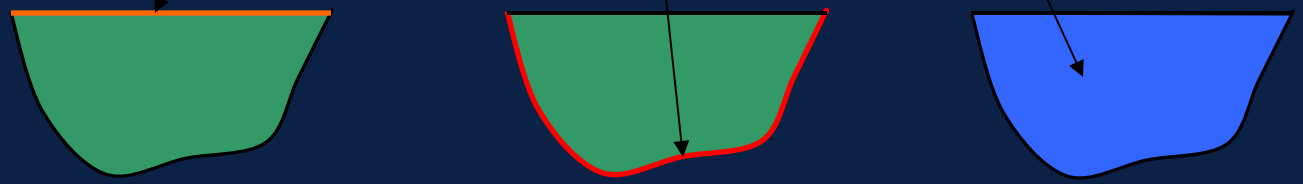
Calculate statistics

2D area:	Surface area:	Volume:
1606613960.59	1608282349.82	8583211828.57

[ ] Save/append statistics to text file

C:\Share\bathy\maps\data\areavol.txt

Done



GIS Area and Volume Analysis

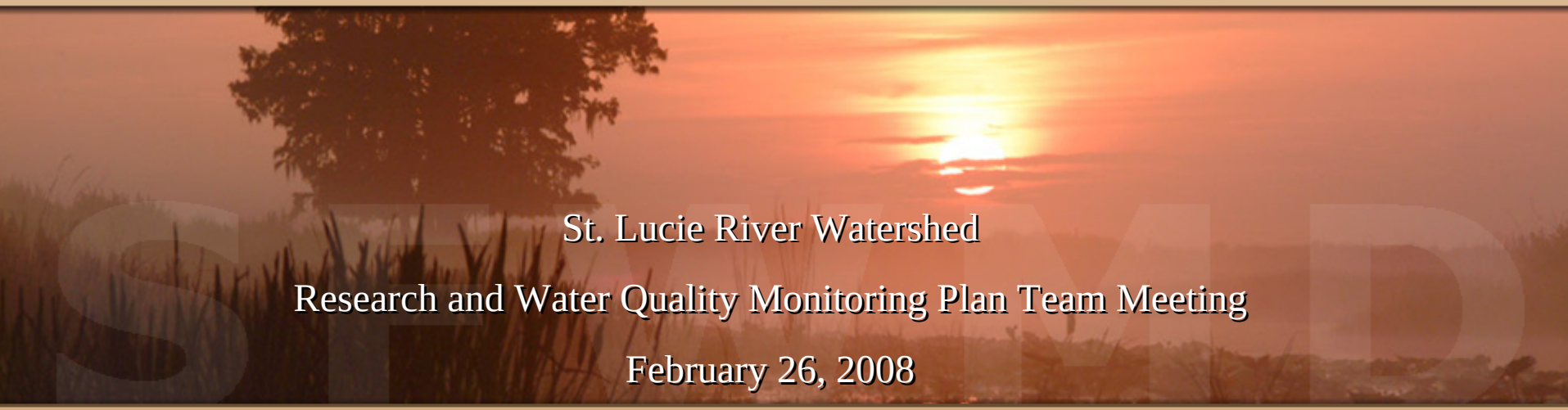
Area analysis	Submerged Surface Area ft^2	Submerged Surface Area Acres	Reach Volume ft^3
North Fork	118429490.1	2718.8	793575610.7
South Fork	48125969.8	1104.8	263040065
St. Lucie Estuary	147459190.6	3385.2	997555489.3
Indian River Lagoon	1608282350	36921.1	8583211829
Total	1903307315	43693.9	10571511006

Estimated Fresh Groundwater Contributions to St. Lucie Estuary/Indian River Lagoon

cm/day	cm3/day	Million Gals/Day	Ft3/day	Acre feet/Day	Percent GW	Time in Days	Time in Years
1	1.8E+12	467	6.2E+07	1434	1	169.3	0.5
2	3.5E+12	934	1.2E+08	2867	1	84.6	0.2
3	5.3E+12	1401	1.9E+08	4301	2	56.4	0.2
4	7.1E+12	1868	2.5E+08	5734	2	42.3	0.1
5	8.8E+12	2335	3.1E+08	7168	3	33.9	0.1

Estimated Fresh GW Contributions and Loads (metric tons/year)							
Flux cm/day	NOX	TPO4	NH4	TKN	Total N	OPO4	MBAS
1	75	153	419	610	683	115	45
2	151	305	838	1220	1365	230	90
3	226	458	1258	1831	2048	345	136


Questions?



St. Lucie River Watershed

Research and Water Quality Monitoring Plan Team Meeting

February 26, 2008

St. Lucie Estuary Water Quality Model Development Update

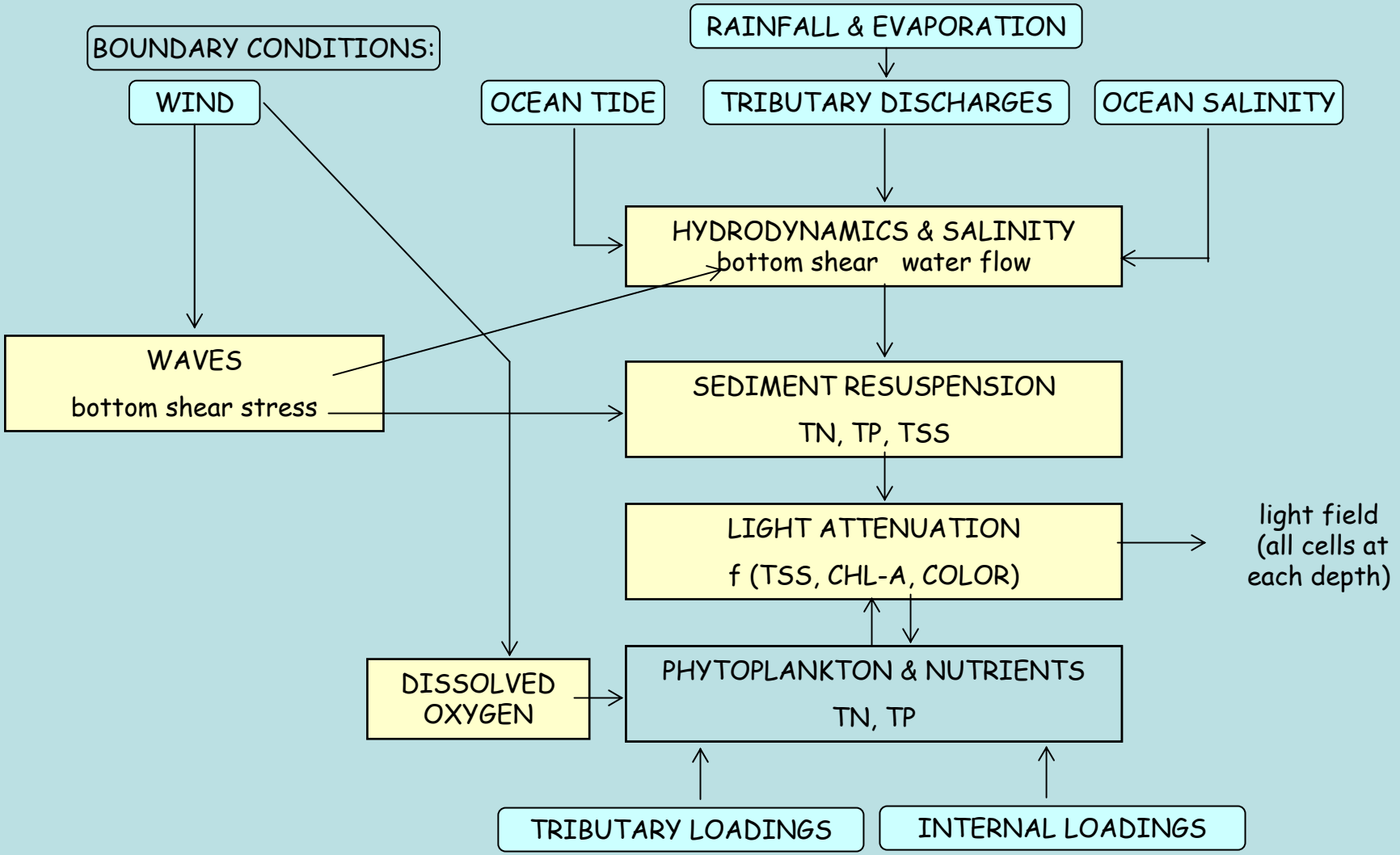
A Brief Review of History

- DYNTRAN, 1D hydrodynamic/salinity model
- RMA2/ RMA4 2D hydrodynamic/salinity model (IRL feasibility study) and upgraded to RMA10
- EFDC hydrodynamic, sediment transport and water quality model (simulation of 1999 and 2000)
- CH3D hydrodynamic/salinity model (simulation 1997 to 2005)
- Standalone water quality model based on EFDC and coupled with CH3D (simulation 1999 to 2003 and now extending to 2007)

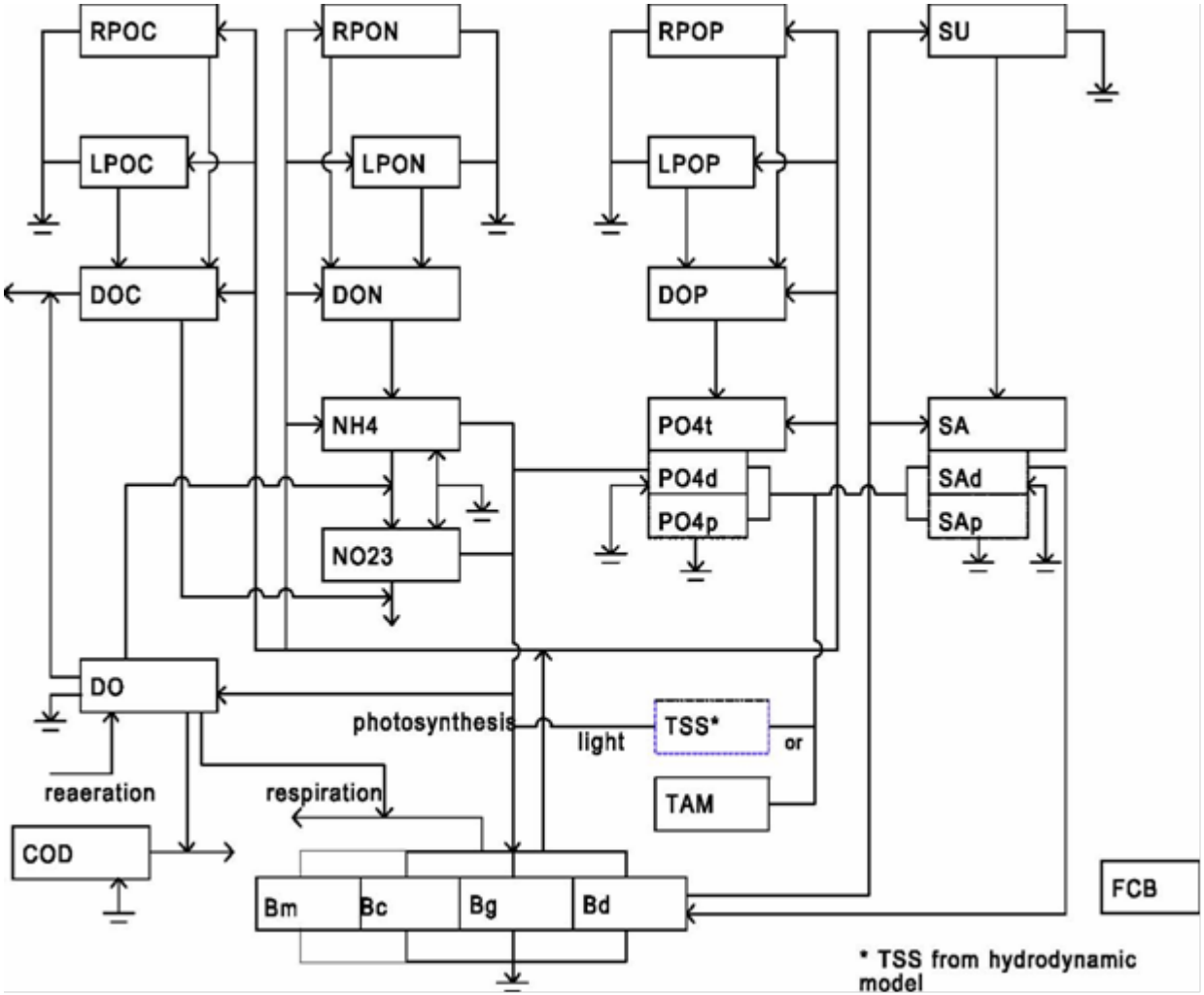
Model Components

- CH3D hydrodynamic
- CH3D-SED
- Standalone WQ model based on EFDC
- WASH (external)

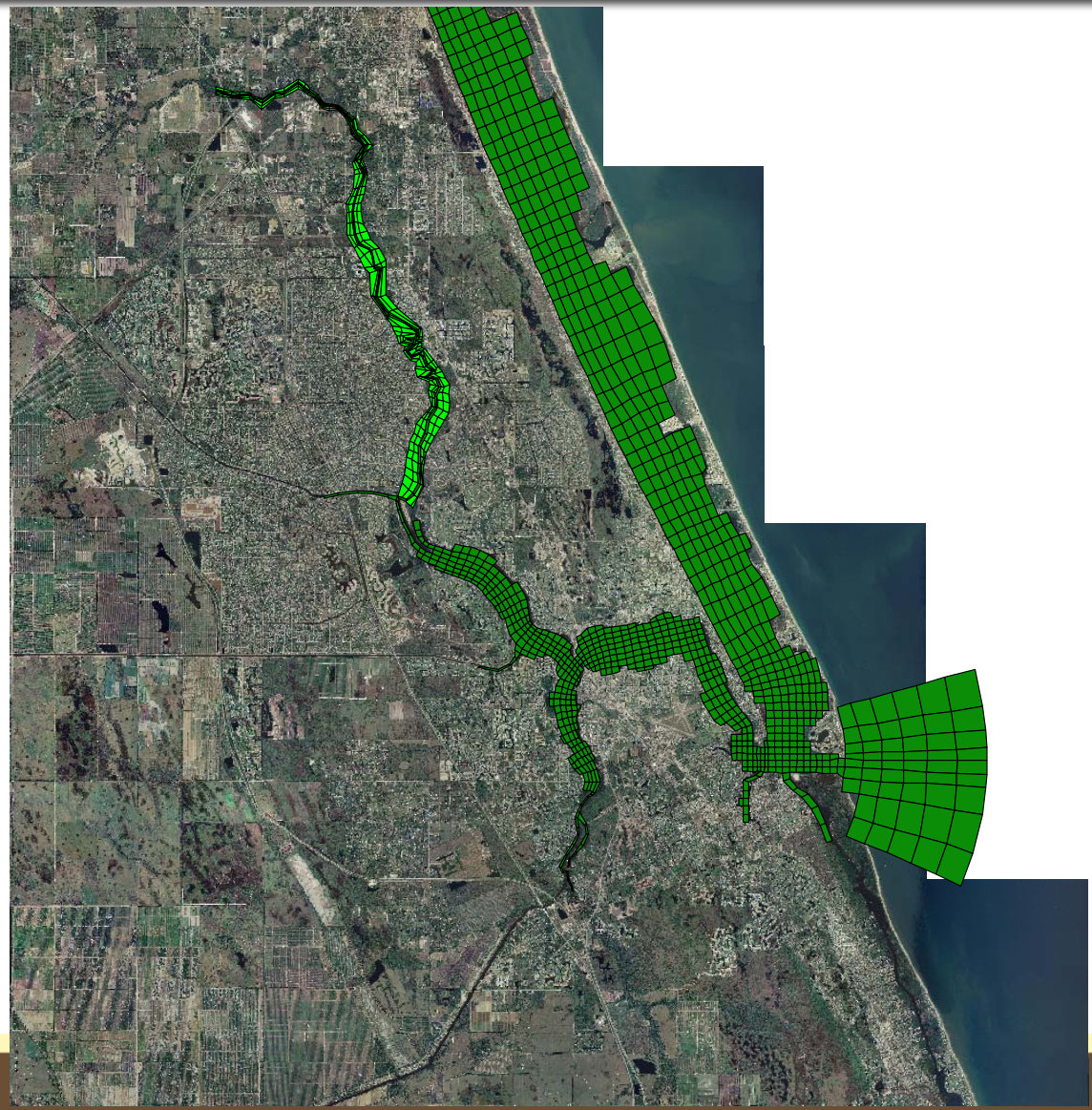
An Integrated Modeling System



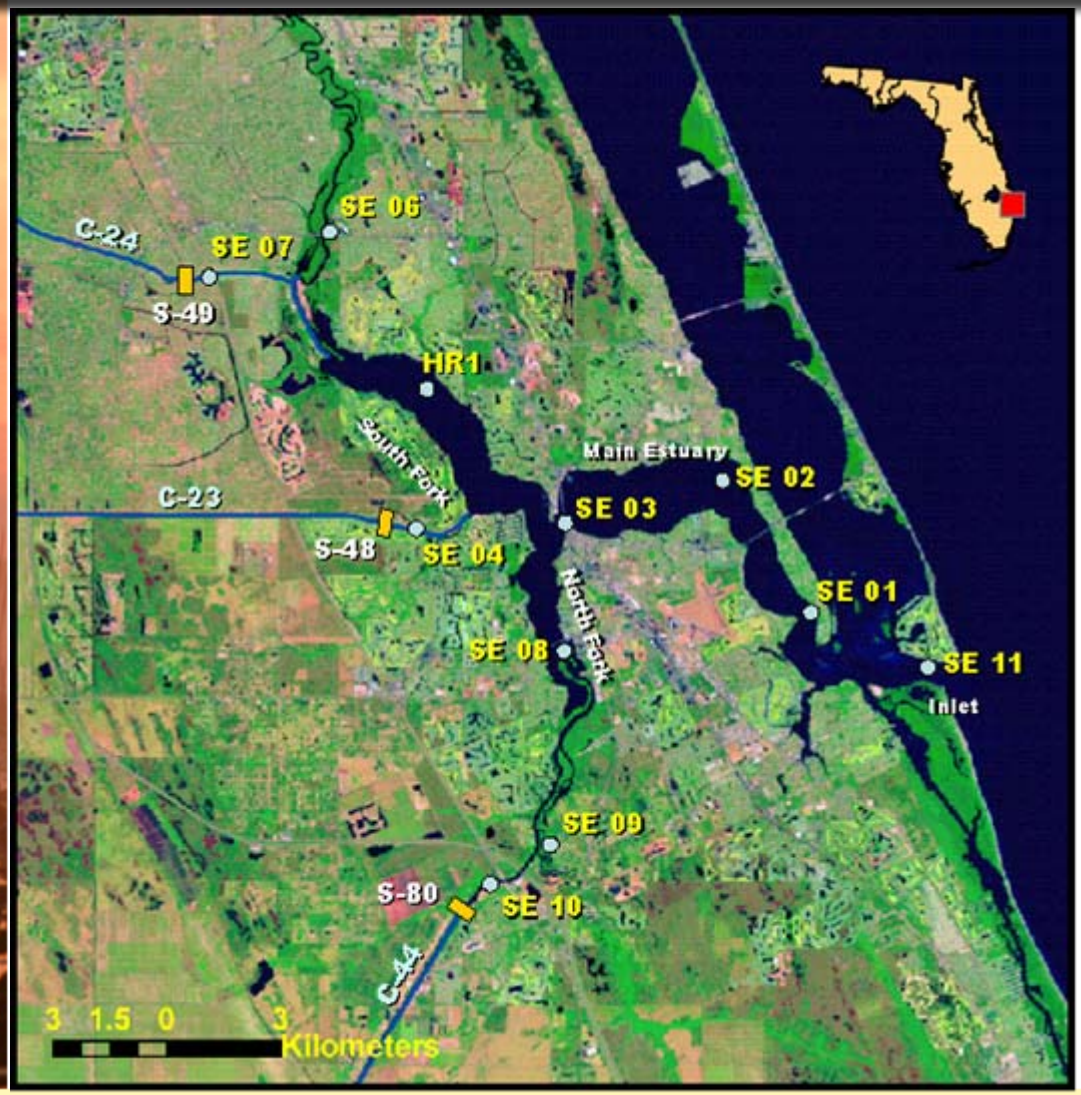
The Standalone Water Quality Model



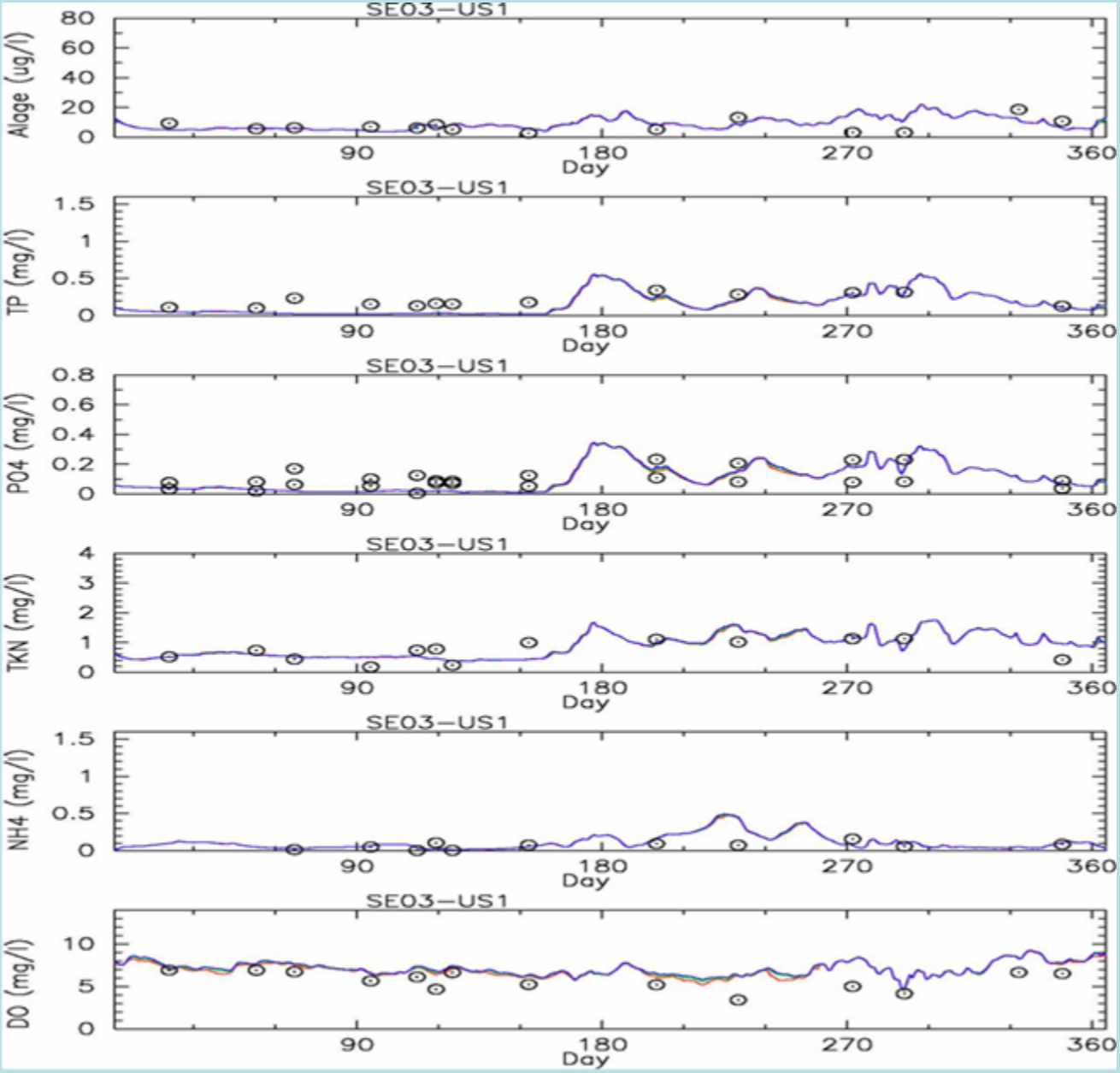
SLE Model Grid



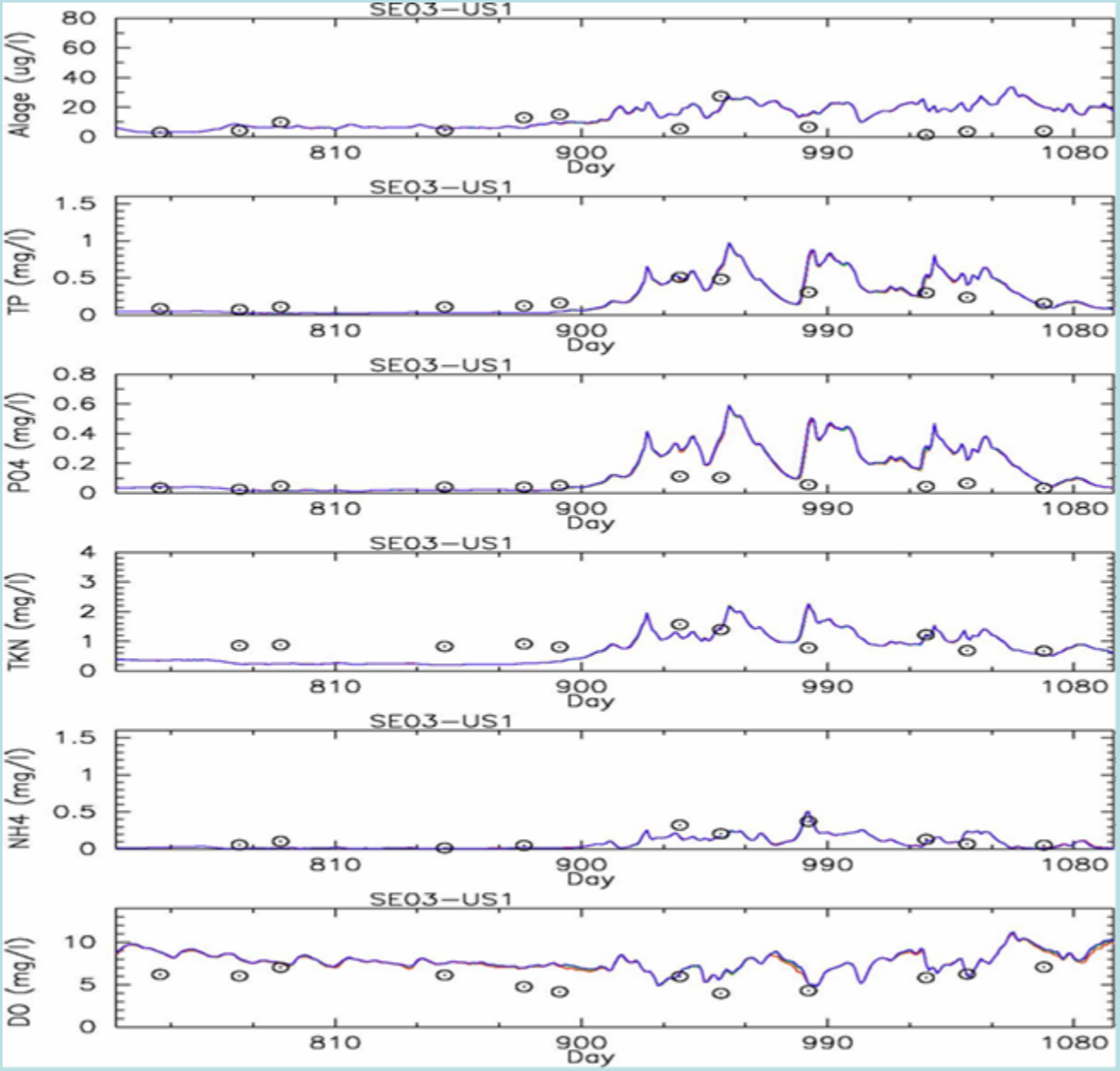
SLE Water Quality Monitoring Stations



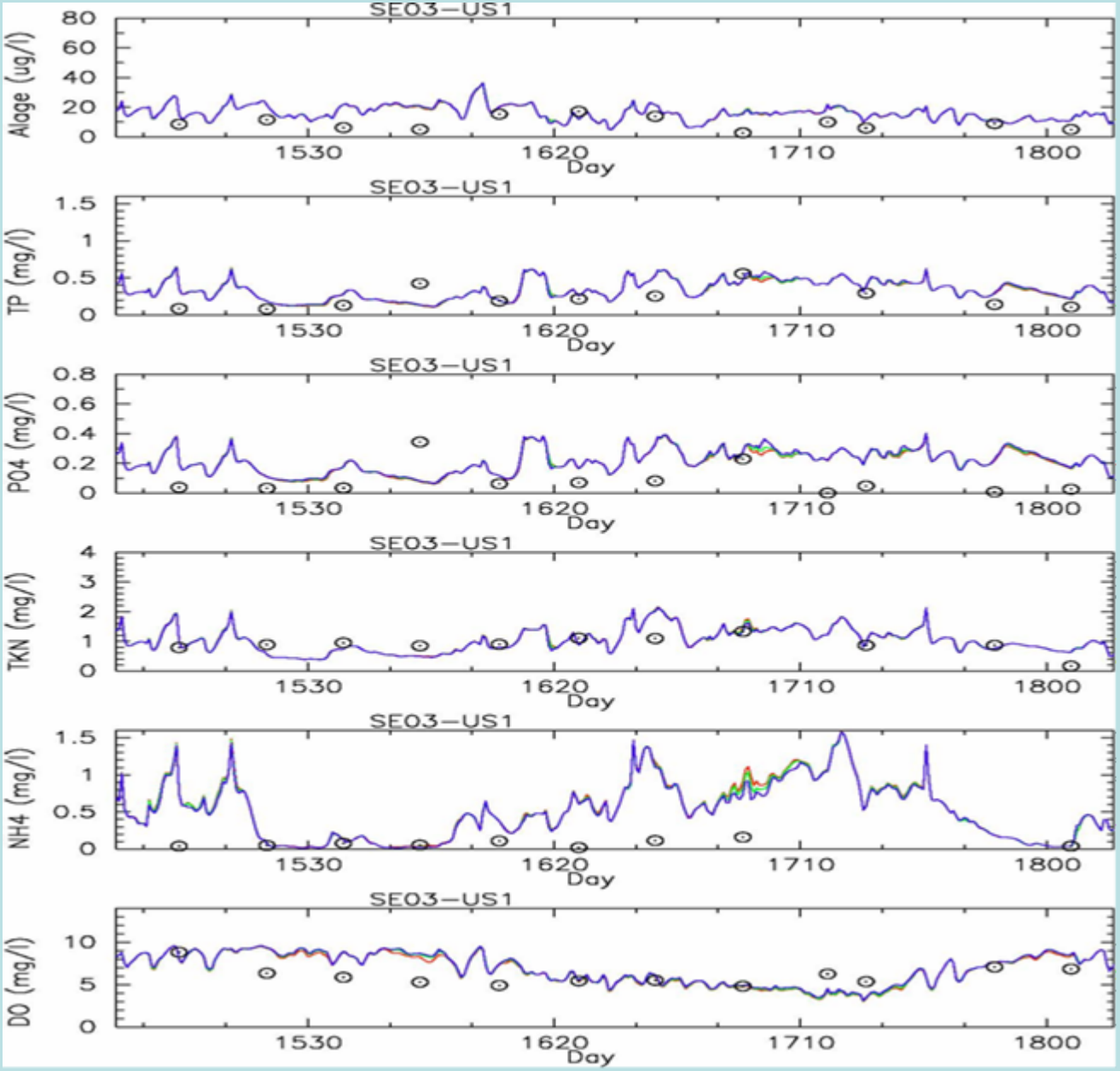
Water Quality Model Results (1999)



Water Quality Model Results (2001)



Water Quality Model Results (2003)



Ongoing Work

- Further calibration of the WQ model
- Extending simulation (1999 to 2007)
- Sediment transport model calibration/verification including wave-induced sediment resuspension
- Estimated WQ model development completion 1~ 1.5 year

Applications and Potential Applications

- MFL
- Salinity envelop
- Water quality targets
- TMDL
- Ten Mile Creek
- Lake Release