Appendix D: Hydrodynamic and Water Quality Modeling Report for Nutrient Criteria for Florida Estuary Systems

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Contents

1.0 INTRODUCTION AND MODELING APPROACH **D-1**

2.0 MODEL SELECTION **D-2**

2.1 EFDC Hydrodynamic Model D-2
2.2 EFDC Model History D-2
2.3 WASP7 Model Selection D-3
2.4 WASP7 Model History D-3
2.5 Model Linkage D-4

3.0 MODEL CALIBRATION AND VALIDATION **D-5**

3.2 Light Attenuation Modeling Approach D-7

4.0 PERDIDO BAY MODEL **D-8**

4.1 Physical Characteristics of the Model Study Area D-8
4.2 Model Segmentation D-10
4.3 Perdido Bay Monitoring Stations D-13
4.4 Hydrodynamic Model Forcing Conditions D-13
Meteorological Factors and Offshore Boundary Conditions D-13
Freshwater Flows and Temperature D-13
4.5 Hydrodynamic Model Calibration and Validation Analysis D-13
Water Surface Elevation D-14
Salinity D-14
Water Temperature D-14
4.6 Water Quality Model Forcing Conditions D-14
Point and Nonpoint Sources Loads D-15
Solar Radiation and Air Temperature D-15
Benthic Nutrient Fluxes and Sediment Oxygen Demand D-15
Reaeration D-15
Boundary Conditions D-15
4.7 Water Quality Validation Analysis D-15
4.8 Perdido Bay Model Summary and Conclusions D-16

5.0 PENSACOLA BAY MODEL **D-18**

5.1 Physical Characteristics of the Model Study Area D-18
5.2 Model Segmentation D-21
5.3 Pensacola Bay Monitoring Stations D-22
5.4 Hydrodynamic Model Forcing Conditions D-22
Meteorological Factors D-22
Freshwater Flows and Temperature D-22
Point Sources D-23
Offshore Boundary WSE and Water Temperature D-25
Offshore Boundary Salinity D-25
5.5 Hydrodynamic Model Calibration and Validation Analysis D-25
Water Surface Elevation D-25

Salinity D-26
Temperature..... D-26
5.6 Water Quality Model Forcing Conditions..... D-26
Point and Nonpoint Sources Loads D-26
Solar Radiation and Air Temperature..... D-26
Benthic Nutrient Fluxes and Sediment Oxygen Demand..... D-27
Reaeration..... D-27
Boundary Conditions..... D-27
5.7 Water Quality Calibration and Validation Analysis D-29
5.8 Pensacola Bay Model Summary and Conclusions..... D-30

6.0 CHOCTAWHATCHEE BAY MODEL..... D-32
6.1 Physical Characteristics of the Model Study Area..... D-32
6.2 Model Segmentation D-34
6.3 Choctawhatchee Bay Monitoring Stations..... D-38
6.4 Hydrodynamic Model Forcing Conditions D-38
Meteorological Factors..... D-38
Freshwater Flows and Temperature D-38
Point Sources..... D-38
Offshore Boundary WSE and Water Temperature..... D-39
Offshore Boundary Salinity..... D-39
6.5 Hydrodynamic Model Calibration and Validation Analysis..... D-39
Water Surface Elevation..... D-39
Salinity D-40
Temperature..... D-40
6.6 Water Quality Model Forcing Conditions..... D-40
Point and Nonpoint Sources Loads D-40
Solar Radiation and Air Temperature..... D-40
Benthic Nutrient Fluxes and Sediment Oxygen Demand..... D-41
Reaeration..... D-41
Boundary Conditions..... D-41
6.7 Water Quality Calibration and Validation Analysis D-43
6.8 Choctawhatchee Bay Model Summary and Conclusions D-44

7.0 ST. ANDREWS BAY MODEL..... D-45
7.1 Physical Characteristics of the Model Study Area..... D-45
7.2 Model Segmentation D-47
7.3 St. Andrews Bay Monitoring Stations D-51
7.4 Hydrodynamic Model Forcing Conditions D-51
Meteorological Factors..... D-51
Freshwater Flows and Temperature D-51
Point Sources..... D-51
Offshore Boundary WSE and Water Temperature..... D-52
Offshore Boundary Salinity..... D-52
7.5 Hydrodynamic Model Calibration and Validation Analysis..... D-53

Water Surface Elevation D-53
Salinity D-53
Temperature D-53
7.6 Water Quality Model Forcing Conditions D-53
Point and Nonpoint Sources Loads D-53
Solar Radiation and Air Temperature D-54
Benthic Nutrient Fluxes and Sediment Oxygen Demand D-54
Reaeration D-54
Boundary Conditions D-54
7.7 Water Quality Calibration and Validation Analysis D-56
7.8 St. Andrews Bay Model Summary and Conclusions D-57

8.0 FLORIDA BIG BEND MODEL D-58
8.1 Physical Characteristics of the Model Study Area D-58
Apalachicola Bay D-58
Alligator Harbor D-59
Ochlockonee Bay D-60
Apalachee Bay D-61
The Suwannee, Waccasassa, and Withlacoochee Estuaries D-62
Springs Coast Estuarine Area D-63
8.2 Model Segmentation D-64
8.3 Florida Big Bend Monitoring Stations D-69
8.4 Hydrodynamic Model Forcing Conditions D-70
Meteorological Factors D-70
Freshwater Flows and Temperature D-70
Point Sources D-70
Offshore Boundary WSE and Water Temperature D-71
Offshore Boundary Salinity D-71
8.5 Hydrodynamic Model Calibration and Validation Analysis D-71
Water Surface Elevation D-71
Salinity D-72
Temperature D-72
8.6 Water Quality Model Forcing Conditions D-73
Nonpoint Sources Loads D-73
Solar Radiation and Air Temperature D-73
Benthic Nutrient Fluxes and Sediment Oxygen Demand D-73
Reaeration D-73
Boundary Conditions D-73
8.7 Water Quality Calibration and Validation Analysis D-75
8.8 Florida Big Bend Model Summary and Conclusions D-76

9.0 TAMPA-SARASOTA BAY MODEL D-78

10.0 CHARLOTTE HARBOR, CALOOSAHATCHEE ESTUARY, AND ESTERO BAY MODEL D-79

11.0 LAKE WORTH LAGOON MODEL D-80
11.1 Physical Characteristics of Lake Worth Lagoon D-80
11.2 Model Segmentation D-82
11.3 Lake Worth Lagoon Monitoring Stations D-86
11.4 Hydrodynamic Model Forcing Conditions D-86
Meteorological Factors D-86
Freshwater Flows and Temperature D-86
Offshore and Inland WSE Boundary D-86
Offshore Boundary Salinity and Temperature D-87
11.5 Hydrodynamic Model Calibration and Validation Analysis D-87
Water Surface Elevation D-87
Salinity D-87
Temperature D-88
11.6 Water Quality Model Forcing Conditions D-88
Boundary Conditions D-88
11.7 Water Quality Calibration and Validation Analysis D-90
11.8 Lake Worth Lagoon Model Summary and Conclusions D-91

12.0 LOXAHATCHEE RIVER AND ESTUARY MODEL D-92
12.1 Physical Characteristics of Loxahatchee Estuary D-92
12.2 Model Segmentation D-94
12.3 Loxahatchee Estuary Monitoring Stations D-98
12.4 Hydrodynamic Model Forcing Conditions D-98
Meteorological Factors D-98
Freshwater Flows and Temperature D-98
Offshore and Inland WSE Boundary D-99
Offshore Boundary Salinity and Temperature D-99
12.5 Hydrodynamic Model Calibration and Validation Analysis D-99
Water Surface Elevation D-99
Salinity D-99
Temperature D-100
12.6 Water Quality Model Forcing Conditions D-100
Point and Nonpoint Sources Loads D-100
Solar Radiation and Air Temperature D-100
Benthic Nutrient Fluxes and Sediment Oxygen Demand D-100
Boundary Conditions D-100
12.7 Water Quality Calibration and Validation Analysis D-102
12.8 Loxahatchee Estuary Model Summary and Conclusions D-104

13.0 ST. LUCIE ESTUARY MODEL D-105
13.1 Physical Characteristics of the Model Study Area D-105
13.2 Model Segmentation D-107
13.3 St. Lucie Estuary Monitoring Stations D-110
13.4 Hydrodynamic Model Forcing Conditions D-110
Meteorological Factors D-110

Freshwater Flows and Temperature D-110
Offshore Boundary WSE, Salinity, and Water Temperature D-110
13.5 Hydrodynamic Model Calibration and Validation Analysis D-111
Water Surface Elevation D-111
Salinity D-111
Temperature D-111
13.6 Water Quality Model Forcing Conditions D-112
Point and Nonpoint Sources Loads D-112
Solar Radiation and Air Temperature D-112
Benthic Nutrient Fluxes and Sediment Oxygen Demand D-112
Reaeration D-112
Boundary Conditions D-112
13.7 Water Quality Calibration and Validation Analysis D-114
13.8 St. Lucie Estuary Model Summary and Conclusions D-115

14.0 ST. JOHNS RIVER D-117

15.0 ST. MARYS-NASSAU ESTUARY MODEL D-118
15.1 Physical Characteristics of the Model Study Area D-118
15.2 Model Segmentation D-120
15.3 St. Marys-Nassau Estuary Monitoring Stations D-124
15.4 Hydrodynamic Model Forcing Conditions D-124
Meteorological Factors D-124
Freshwater Flows and Temperature D-124
Point Sources D-124
Offshore Boundary WSE and Water Temperature D-125
Offshore Boundary Salinity D-125
15.5 Hydrodynamic Model Calibration and Validation Analysis D-125
Water Surface Elevation D-126
Salinity D-126
Temperature D-126
15.6 Water Quality Model Forcing Conditions D-126
Point and Nonpoint Sources Loads D-126
Solar Radiation and Air Temperature D-126
Benthic Nutrient Fluxes and Sediment Oxygen Demand D-126
Marsh Nutrient Loads D-127
Reaeration D-127
Boundary Conditions D-127
15.7 Water Quality Calibration and Validation Analysis D-129
15.8 St. Marys-Nassau Estuary Model Summary and Conclusions D-130

REFERENCES D-132

ATTACHMENTS D-136

Figures

Figure D-1. Linkage between LSPC, EFDC, and WASP7 .... D-4
Figure D-2. Perdido Bay model and watershed location D-9
Figure D-3. Orthogonal curvilinear system of Perdido Bay D-10
Figure D-4. Perdido Bay bathymetry D-12
Figure D-5. Pensacola Bay model and watershed location D-19
Figure D-6. Pensacola Bay bathymetry D-20
Figure D-7. Orthogonal curvilinear system of Pensacola Bay D-21
Figure D-8. Point source locations for the Pensacola Bay model D-24
Figure D-9. Choctawhatchee Bay model and watershed location D-33
Figure D-10. Orthogonal curvilinear system of Choctawhatchee Bay D-35
Figure D-11. Point source locations for the Choctawhatchee Bay model D-36
Figure D-12. Choctawhatchee Bay bathymetry D-37
Figure D-13. St. Andrews Bay model and watershed location D-46
Figure D-14. Orthogonal curvilinear system of St. Andrews Bay D-48
Figure D-15. Point sources in the St. Andrews Bay model D-49
Figure D-16. St. Andrews Bay bathymetry D-50
Figure D-17. Apalachicola Bay D-59
Figure D-18. Alligator Harbor (FDEP 2010b) D-60
Figure D-19. Ochlockonee Bay (FDEP 2010c) D-61
Figure D-20. Apalachee Bay (FDEP 2010d) D-62
Figure D-21. Suwannee, Waccasassa, and Withlacoochee estuaries (FDEP 2010e) D-63
Figure D-22. Springs Coast estuarine area (FDEP 2010f) D-64
Figure D-23. Florida Big Bend model and watershed location D-65
Figure D-24. LSPC watershed input locations for the Florida Big Bend model from the Apalachicola watershed to the Econfina watershed D-66
Figure D-25. LSPC watershed input locations for the Florida Big Bend model from the Econfina watershed to the Crystal watershed D-67
Figure D-26. Point source locations for the Florida Big Bend model D-68
Figure D-27. Florida Big Bend bathymetry D-69
Figure D-28. Lake Worth Lagoon model and watershed location D-81
Figure D-29. Orthogonal curvilinear system of Lake Worth Lagoon D-83
Figure D-30. Lake Worth Lagoon bathymetry D-84
Figure D-31. Point source locations for the Lake Worth Lagoon model D-85
Figure D-32. Loxahatchee Estuary model and watershed location D-93
Figure D-33. Orthogonal curvilinear system of Loxahatchee Estuary D-95
Figure D-34. Loxahatchee Estuary bathymetry D-96
Figure D-35. Point source locations for the Loxahatchee Estuary model D-97

Figure D-36. St. Lucie Estuary model and watershed location....D-106
Figure D-37. Orthogonal curvilinear system of St. Lucie Estuary D-107
Figure D-38. St. Lucie Estuary bathymetry D-109
Figure D-39. St. Marys-Nassau Estuary model and watershed location....D-119
Figure D-40. Orthogonal curvilinear system of St. Marys-Nassau Estuary....D-121
Figure D-41. Point source locations for the St. Marys-Nassau Estuary model....D-122
Figure D-42. St. Marys-Nassau Estuary bathymetry D-123

Tables

Table D-1. General calibration/validation rating system for EFDC/WASP7 applications for Florida estuaries D-6
Table D-2. Perdido Bay hydrodynamic and water quality model data sources D-17
Table D-3. Point sources in the Pensacola Bay model D-23
Table D-4. Calibration rates and coefficients for Pensacola Bay water quality modeling D-28
Table D-5. Pensacola Bay hydrodynamic and water quality model data sources D-30
Table D-6. Point source for the Choctawhatchee Bay model D-39
Table D-7. Offshore concentration boundary conditions D-41
Table D-8. Calibration rates and coefficients for Choctawhatchee Bay water quality modeling D-42
Table D-9. Choctawhatchee Bay hydrodynamic and water quality model data sources D-44
Table D-10. Point sources for St. Andrews Bay model D-52
Table D-11. Offshore concentration boundary conditions D-54
Table D-12. Calibration Rates and Coefficients for the St. Andrews Bay WASP7 Water Quality Model D-55
Table D-13. St. Andrews Estuary hydrodynamic and water quality model data sources D-57
Table D-14. NOAA tidal stations for 1997–2008 .... D-70
Table D-15. Florida Big Bend point sources D-71
Table D-16. Offshore concentration boundary conditions D-74
Table D-17. Water quality model input parameters D-74
Table D-18. Florida Big Bend hydrodynamic and water quality model data sources D-77
Table D-19. Offshore concentration boundary conditions D-88
Table D-20. Calibration rates and coefficients for Lake Worth Lagoon water quality modeling D-89
Table D-21. Lake Worth Lagoon hydrodynamic and water quality model data sources D-91
Table D-22. Offshore concentration boundary conditions D-101
Table D-23. Calibration rates and coefficients for Loxahatchee Estuary water quality modeling D-101
Table D-24. Loxahatchee River hydrodynamic and water quality model data sources D-104
Table D-25. Offshore concentration boundary conditions D-112
Table D-26. Calibration rates and coefficients for St. Lucie Estuary water quality modeling D-113
Table D-27. St. Lucie Estuary hydrodynamic and water quality model data summaries D-115
Table D-28. Point sources for St. Marys-Nassau Estuary model D-125
Table D-29. Offshore concentration boundary conditions D-127
Table D-30. Calibration rates and coefficients for the St. Marys-Nassau Estuary WASP7 water quality model D-128
Table D-31. St. Marys-Nassau Estuary hydrodynamic and water quality model data sources D-130

Abbreviations and Acronyms

ADEM	Alabama Department of Environmental Management
CBOD	carbonaceous biochemical oxygen demand
Chl-a	Chlorophyll *a*
cm	centimeter
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DON	Dissolved Organic Nitrogen
DOP	Dissolved Organic Phosphorus
EFDC	Environmental Fluid Dynamics Code
EPA	United States Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
g	grams
HUC8	8-digit hydrologic units
IWR	Impaired Waters Rule
K_d	Light Attenuation Coefficient
km	kilometer
L	liters
LSPC	Loading Simulation Program C++
m	meter
mg	milligrams
mg Phyt C/L	milligrams of phytoplankton carbon per liter
mgd	million gallons per day
mi	mile
NH_3-N	Ammonia Nitrogen
NO_3+NO_2	Nitrate-Nitrite Nitrogen
NOAA	National Oceanic and Atmospheric Administration
PO_4-P	Phosphate Phosphorus
ppt	parts per thousand
PSU	practical salinity units
Q	Flow
S	Salinity
SFWMD	South Florida Water Management District
SOD	Sediment Oxygen Demand
T	Temperature
TMDL	total maximum daily load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USGS	United States Geological Survey
WASP	Water Quality Analysis Simulation Program
WASP7	Water Quality Analysis Simulation Program Version 7.4.1w
WSE	Water Surface Elevation
WWTP	Waste Water Treatment Plant
%	percent
˚C	degrees Celsius
µg	microgram
µg/L	micrograms per liter

1.0 INTRODUCTION AND MODELING APPROACH

U.S. Environmental Protection Agency (EPA) developed 9 three-dimensional hydrodynamic and water quality models of major estuary systems in Florida using the Environmental Fluid Dynamics Code (EFDC) for the hydrodynamic and the Water Quality Analysis Simulation Program (WASP) for the water quality modeling. A crosswalk of the EFDC and WASP models with the 19 Florida estuary systems delineated by EPA is shown in Table 1-6 in Volume 1 (Estuaries) of this TSD.

This appendix includes the hydrodynamic and water quality calibration and validation results for those estuary systems. The calibration and validation of the models were performed with data spanning from 2002 to 2009. For each estuary, the most comprehensive data set that was within the 2002 to 2009 period was selected for calibration and validation.

The hydrodynamic model includes the heat exchange with the atmosphere and the soil to simulate the estuary water temperature and salinity. Temperature and salinity effects on the hydrodynamics are included by simulating their effect on the water density through the equation of state. The water quality model incorporates normal oxygen dynamics, including reaeration, sediment oxygen demand (SOD), carbonaceous biochemical oxygen demand (CBOD), algal activity, phosphorous and nitrogen kinetics, and total suspended solids (TSS). The modeling approach was a five-step process:

1. Determining upstream boundary conditions from the watershed models.
2. Determining ocean boundary conditions.
3. Developing point sources loadings.
4. Determining the in-stream modeling parameters and kinetic rates by calibrating to measured data.
5. Validating the model results with an independent measured data set.

2.0 MODEL SELECTION

2.1 EFDC Hydrodynamic Model

EFDC was selected to perform the hydrodynamic simulations because it is able to fulfill all the study's requirements. EFDC has been used for many water bodies for total maximum daily load (TMDL) and permitting modeling projects including complex systems similar to those in this study in EPA Region 4 areas such as Mobile Bay, Alabama; Neuse River and Estuary, North Carolina; Brunswick Harbor, Georgia; Indian River Lagoon system, Florida; Florida Bay, Lake Okeechobee, Florida; and Cape Fear River, North Carolina. EFDC has proven to capture the complex hydrodynamics in all those similar systems.

The EFDC model is a part of EPA's TMDL Modeling Toolbox because of its application in many TMDL-type projects. As such, the code has been peer reviewed and tested. The EFDC model is nonproprietary and publicly available through EPA Office of Research and Development and Region 4 from the Watershed and Water Quality Modeling Technical Support Center (http://www.epa.gov/athens/wwqtsc/index.html). The models, tools, and databases in the TMDL Modeling Toolbox are continually updated and upgraded through TMDL development in Region 4.

2.2 EFDC Model History

The EFDC model is an advanced three-dimensional surface water modeling system for hydrodynamic and reactive transport simulations of rivers, lakes, reservoirs, wetland systems, estuaries, and the coastal ocean. The modeling system was originally developed at the Virginia Institute of Marine Science as part of a long-term research program to develop operational models for resource management applications in Virginia's estuarine and coastal waters (Hamrick 1992). The EFDC model is public domain software, with current users including universities, government agencies, and engineering consultants. The model's capabilities and previous applications and its theoretical and computational formulations are described below.

The EFDC model's hydrodynamic model component is based on the three-dimensional, shallow water equations and includes dynamically coupled salinity and temperature transport. The basic physical process simulation capabilities of EFDC's hydrodynamic component are similar to those of the Blumberg-Mellor or POM model (Blumberg and Mellor 1987), the U.S. Army Corps of Engineers' CH3D-WES model (Wang and Johnson 2000), and the TRIM model. Notable extensions to the EFDC hydrodynamic model include representation of hydraulic structures for controlled flow systems, vegetation resistance for wetland systems, and high frequency surface wave radiation stress forcing for nearshore coastal simulations.

EFDC is a multifunctional, surface-water modeling system that includes hydrodynamic, sediment-contaminant, and eutrophication components. The EFDC system is capable of 1-, 2-, and 3-dimensional spatial resolution. The model employs a curvilinear-orthogonal horizontal grid and a sigma or terrain following vertical grid. The model's hydrodynamic component employs a semi-implicit, conservative, finite volume-finite difference, solution scheme for the hydrostatic primitive equations with either two or three-level time stepping (Hamrick 1992). The semi-implicit scheme is based on external mode splitting with the external mode being implicit with respect to the water surface elevation (WSE) and the internal mode being implicit with respect to vertical turbulent momentum diffusion. Advective and Coriolis-curvature accelerations in both the external and internal modes are represented by explicit conservative formulations. Salinity and temperature transport are simultaneously solved with the hydrodynamics and dynamically coupled through an equation of state. The hydrodynamic component includes two additional scalar transported variables, a reactive variable that can be used to represent dye or pathogenic organisms, and a shellfish larvae variable that includes a number vertical swimming behavior options. Scalar transport options include several high-accuracy advection schemes including flux-corrected MPDATA and flux-limited COSMIC. Additional hydrodynamic component features include the Mellor-Yamada turbulence closure formulation (Mellor and Yamada 1982), simulation of drying and wetting, representation of hydraulic control structures, vegetation resistance, wave-current boundary layers and wave induced currents, and dynamic time stepping. An embedded single- and multi-port buoyant jet module is included for coupled near- and far-field mixing analysis.

The EFDC hydrodynamic model can run independently of a water quality model. The EFDC model simulates the hydrodynamic and constituent transport and then writes a hydrodynamic linkage file for a water quality model such as the Water Quality Analysis Simulation Program Version 7.4.1 (WASP7) model. This model linkage, from EFDC hydrodynamics to WASP water quality, has been applied in many EPA Region 4 projects in support of TMDLs and is well tested (Wool et al. 2003). EFDC is also directly linked to Waterways Experiment Station three-dimensional eutrophication model, CE-QUAL-ICM (Cerco and Cole 1993).

2.3 WASP7 Model Selection

The WASP 7 model was used for the water quality model because of its comparative advantages explained below. WASP7 is an enhanced Windows version of EPA's WASP (Ambrose et al. 1988; Connolly and Winfield 1984; Di Toro et al. 1983), with many upgrades to the user interface and the model's capabilities. The major upgrades to WASP are additions of multiple carbonaceous biochemical oxygen demand (CBOD) components, sediment diagenesis routines, and periphyton routines. WASP7 has features including a pre-processor, a rapid data processor, and a graphical post-processor that enable the modeler to run WASP more quickly and easily and evaluate model results both numerically and graphically. With WASP7, model execution can be performed up to 10 times faster than the previous EPA DOS version of WASP. Nonetheless, WASP7 uses the same algorithms to solve water quality problems as those used in the earlier version. The hydrodynamic file generated by EFDC is compatible with WASP7, and it transfers segment volumes, velocities, temperature and salinity, and flows between segments. The time step is also set in WASP7 on the basis of the hydrodynamic simulation.

WASP7 helps users interpret and predict water quality responses to natural phenomena and man-made pollution for various pollution management decisions. WASP7 is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. The time-varying processes of advection, dispersion, point and diffuse mass loading and boundary exchange are represented in the basic program. Water quality processes are represented in special kinetic subroutines that are either chosen from a library or written by the user. WASP is structured to permit easy substitution of kinetic subroutines into the overall package to form problem-specific models. WASP7 comes with two such models, TOXI for toxicants and EUTRO for conventional water quality.

2.4 WASP7 Model History

WASP7 is an enhancement of the original WASP (Di Toro et al. 1983; Connolly and Winfield 1984; Ambrose et al. 1988). WASP has a long history of application to various problems. Some applications have been validated with field data, or verified by model experiments and reviewed by independent experts. Earlier versions of WASP have been used to examine eutrophication of Tampa Bay, phosphorus loading to Lake Okeechobee, eutrophication of the Neuse River and Estuary (Wool et al. 2003), eutrophication and polychlorinated biphenyl pollution of the Great Lakes (Di Toro and Connolly 1980; Thomann 1975; Thomann et al. 1976;), eutrophication of the Potomac Estuary (Ambrose et al. 1998), Kepone pollution of the James River Estuary (O'Connor et al. 1983), volatile organic pollution of the

Delaware Estuary (Ambrose 1987) and heavy metal pollution of the Deep River, North Carolina (Ambrose et al. 1988). In addition to those, numerous applications are listed in Di Toro et al. (1983).

2.5 Model Linkage

Three models were used to simulate the hydrology and water quality of the watersheds and the in-stream hydrodynamics and water quality of the estuaries. The Loading Simulation Program C++ (LSPC) was used to represent the hydrological and water quality conditions in the watersheds. LSPC provided tributary flows and temperature to the EFDC estuary models and tributary water quality concentrations to WASP7 estuary models. EFDC and WASP7 are linked through the hydrodynamic linkage file. The hydrodynamic linkage file provides the inter-cell flow and velocities, as well as the cells' volume, temperature and salinity at each simulation time step. Figure D-1 shows how the three models interact with one another.

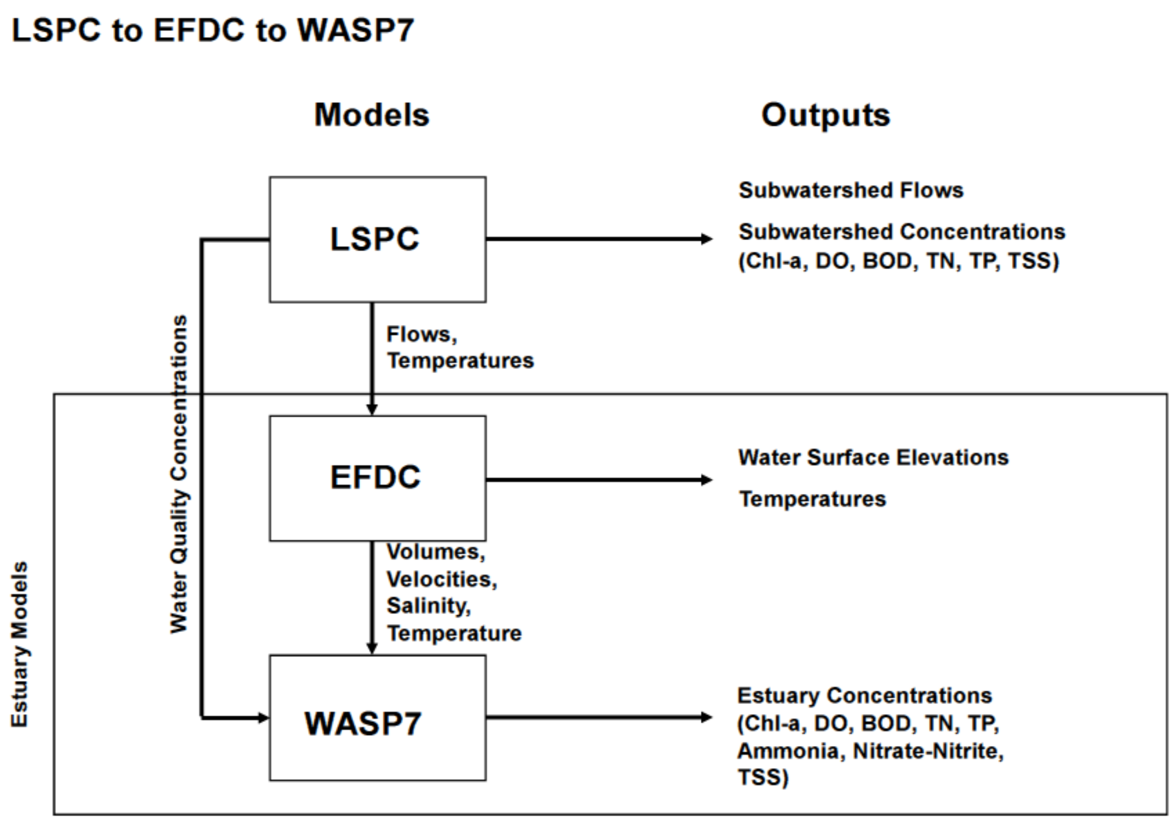


Figure D-1. Linkage between LSPC, EFDC, and WASP7

3.0 MODEL CALIBRATION AND VALIDATION

Calibration and validation have been defined as follows (Donigian 2000):

- Calibration. A test of the model with known input and output information that is used to adjust or estimate factors for which data are not available.
- Validation. Comparison of model results with numerical data independently derived from experiments or observations of the environment.

Ideally, a model should be constructed on the basis of the knowledge available on the system. In reality, there are usually too few field observations, the time series are too short, or the model has too many parameters to be identified. If a model's inputs cannot be fully identified, calibration becomes essential.

Calibration focuses on the comparison between model results and field observations. An important principle is that the smaller the deviation between the calculated model results and the field observations, the better the model is considered to fit the system. Calibration is an iterative procedure of parameter evaluation and refinement, as a result of comparing simulated and observed model constituencies and processes.

The deviation between the model results and the field observations are determined by many factors:

- Conceptual errors. These are inaccuracies in the model definition, such as simplified complex structure, neglecting certain processes and incomplete mathematical description of each process.
- Parameter values. Hydrodynamic and water quality models entail many parameters whose values are not exactly known.
- Errors in driving forces. This is expressed, for instance, in errors in the boundary or meteorological conditions of the model.
- Measuring errors in the field observations used for calibration or estimating parameters.

The calibrated model must be validated, which shows the model is able to reproduce field observations from an independent data set (i.e., a data set not used in calibration) with a certain pre-set degree of fit (e.g., not worse than for the period of calibration). Confidence in the model can be increased only by experimenting with that model, i.e., by carrying out multiple validation tests. If validation has taken place, particularly for situations that closely resemble the situation for which the model is to make predictions, the prediction might be reasonably reliable, but it is by no means certain. It is then important that the remaining uncertainty be statistically estimated, to avoid the model being afforded too much confidence.

It is important that the calibration and validation data cover the range of conditions over which predictions are desired (McCutcheon et al. 1990).

Although no universal consensus on model calibration and validation criteria can be found in model-related literature, several basic concepts are accepted by most modelers (Donigian 2000):

- Models are an approximation of reality; they cannot precisely represent natural systems.
- No single, accepted statistic or test determines whether or not a model is validated.
- Both graphical comparisons and statistical tests are required in model calibration and validation.

- The model cannot be expected to be more accurate than the errors (confidence intervals) in the input and observed data.

Model calibration and validation are necessary and critical steps in any Florida estuary application. Model performance (i.e., the ability to reproduce field observations) is evaluated through qualitative and quantitative analyses involving both graphical comparisons and statistical tests. For hydrodynamic state variables (WSE, salinity, and temperature) where long-term, continuous data records are available, visual and statistical techniques can be employed and the same types of comparisons should be performed during the calibration and validation phases. For water quality constituents, model performance is based primarily on visual and graphical presentations because the low frequency of observed water quality data allows for a very limited use of statistical measures.

An estuary model's calibration is a hierarchical process beginning with WSE calibration, which is based on appropriate tidal station's hourly measurements. WSE is the major forcing factor of water dynamics in Florida estuaries. The coefficient of determination, R^2, was used to check how well the simulated WSE data correlated with the observed data. An R^2 value of 1 indicates a perfect correlation between the simulated and observed values, whereas a value of 0 indicates no correlation. Note, the value of R^2 only indicates linear correlation between the simulated and observed values and not the model accuracy. The range of R^2 values reported for previous estuary modeling studies is large, however a value above 0.8 is generally considered to indicate good correlation between simulated and observed values (DRBC 2003; LDNR 2006). The next step involved calibration of EFDC salinity and water temperature dynamics. Both visual and statistical measures were used in this and subsequent estuary model calibration steps. Validation of the EFDC model was conducted using comparisons of simulated data with independent data (different monitoring stations' locations or periods of observation). It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration.

The calibrated EFDC model produces dynamical fields of velocities, water temperatures, salinity and volumes of cells for using in the water quality model (WASP7) calibration and validation. WASP7 calibration includes selection of values of numerous biological and chemical parameters that populate mathematical equations that describe chemical and biological transformation of the model constituents.

Table D-1 presents the rating system for determining the overall success of calibration-validation for the hydrodynamics and water quality models for Florida estuaries. The rating system is based on EPA's technical guidance for model applications (Donigian 2000; McCutcheon et al. 1990). The rating categories provide a general guidance in terms of the percent mean differences between simulated and observed values for the different state variables.

Table D-1. General calibration/validation rating system for EFDC/WASP7 applications for Florida estuaries

State Variable	Percent Difference between Simulated and Observed Values		
	Very Good	Good	Fair
Salinity	< 15	15–25	25–40
Water temperature	< 7	7–12	12–18
Water quality/DO	< 15	15–25	25–35
Nutrients/chl-a	< 30	30–45	45–60

3.2 Light Attenuation Modeling Approach

The water quality models of Florida estuaries were created with WASP7 using the Beer-Lambert function of light attenuation with depth ($I_z / I_0 = e^{-K_d z}$), where I_0 is the light just beneath surface (langleys/day), K_d is the light attenuation coefficient, and z is depth (m).

The total light attenuation coefficient is calculated as

$$K_d = k_{shd} + k_{solid} + k_{doc1} + k_{doc2} + k_{doc3}$$

where k_{shd} is the algae self shading; k_{solid} is the total inorganic solids and detritus light attenuation; k_{doc1}, k_{doc2} and k_{doc3} are three WASP available dissolved organic carbon (DOC) groups of light attenuation.

For each of the Florida estuary water quality models, EPA assumes that DOC1 is the watershed's CBOD load (output of LSPC model), DOC2 is the CBOD load from the point sources discharging directly into the estuary, and DOC3 receives all CBOD loads from algal life activity. DOC1 is the major factor of color influenced light attenuation. k_{solid}, k_{doc1}, and k_{shd} are major factors of light attenuation. The role of k_{doc2} and k_{doc3} is much less important, except for situations where internal point sources load highly colored waters into an estuary.

The majority of light attenuation measurements in Florida estuaries are connected with the depth of Secchi disk measurements. The Secchi disk is one of the most widely used limnological and oceanographic instruments, because of its low cost and convenience. The measurements of Secchi disk depth are correlated with beam transmittance in turbid coastal water. Tyler (1968) and Holmes (1970) show that both K_d (the light attenuation coefficient) and α (the beam attenuance coefficient) can be estimated from the Secchi depth either on an empirical basis or by using the Duntley-Preisendorfer equation of contrast reduction

$$C_R = C_0 e^{-(\alpha + K_d)R}$$

where C_R is the apparent contrast of an object against its background, R is the length of the path of sight in water; and C_0 is the inherent contrast of the object against its background.

Holmes suggests that since biologists might not require the high degree of precision and accuracy required by optical oceanographers, it is possible that estimates of α and K_d useful to biologists can be obtained from Secchi depth. Such indirect estimates would naturally have relatively large standard errors, but they might be acceptable in certain types of study. Further Holmes uses the turbid Coleta Bay (close to Santa Barbara campus) Secchi depth observations to connect with K_d. Holmes had shown that the well-known Poole and Atkins (1929) formula for estimating K_d from Secchi depth (K_d = 1.7 / Secchi depth) yields K_d values that are too high, at least for turbid waters of the Coleta Bay, and the empirical formula K_d = 1.44 / Secchi depth works much better. The same conclusions were obtained by applying the Poole and Atkins, and Holmes formula for connection of Secchi depths and values of light attenuation coefficients observed by EPA in Pensacola Bay (2002–2004). The Holmes formula generates better corresponding values of Secchi depth and was the formula selected for calculating the light attenuation coefficient on the basis of Secchi depth measurements for all the estuary models.

4.0 PERDIDO BAY MODEL

4.1 Physical Characteristics of the Model Study Area

The detailed description of morphological, physical and hydro-biological features of the Perdido Bay system is in Livingston (2001).

Perdido Bay drains the Perdido River in Baldwin County, Alabama, and Escambia County, Florida (Figure D-2). It is a shallow to moderate depth inshore body of water that is oriented mainly northeast to southwest, approximately perpendicular to the Gulf of Mexico. Perdido Bay is 53.4 km long, averages 4.2 km wide, and averages 2.2 m deep. The primary source of freshwater input to the estuary is the Perdido River that flows southward about 96.5 km, draining an area of about 3,000 km^2. Freshwater inflow peaks during March and April and is lower in October and November. The tidal range is diurnal and averages 0.2 to 0.3 m.

On the basis of morphology, the entire study area can be divided into six major systems: the lower Perdido River, the upper Perdido Bay, the lower Perdido Bay, the Gulf Intracoastal Waterway, the Perdido Pass complex, and the Wolf Bay complex. The Perdido Bay system is dynamically connected to the Gulf of Mexico through the Perdido Pass. The U.S. Army Corps of Engineers maintains the Perdido Pass Channel at about 4 m as part of the Gulf Intracoastal Waterway. The upper Perdido Bay is relatively shallow, and its depth tends to increase southward. The deepest parts of the estuary are at the mouth of the Perdido River and in the lower bay.

Perdido Key provides a physical barrier between Perdido Bay and the Gulf of Mexico.

The basin includes 19 terminal watersheds, which drain water and nutrients into the bay system (Appendix C).

Figure D-2. Perdido Bay model and watershed location

4.2 Model Segmentation

An orthogonal, curvilinear grid system was used for the hydrodynamic and water quality model (Figure D-3). The watershed inflows incoming grid cells are also shown in Figure D-3. Perdido Bay bathymetry is shown in Figure D-4.

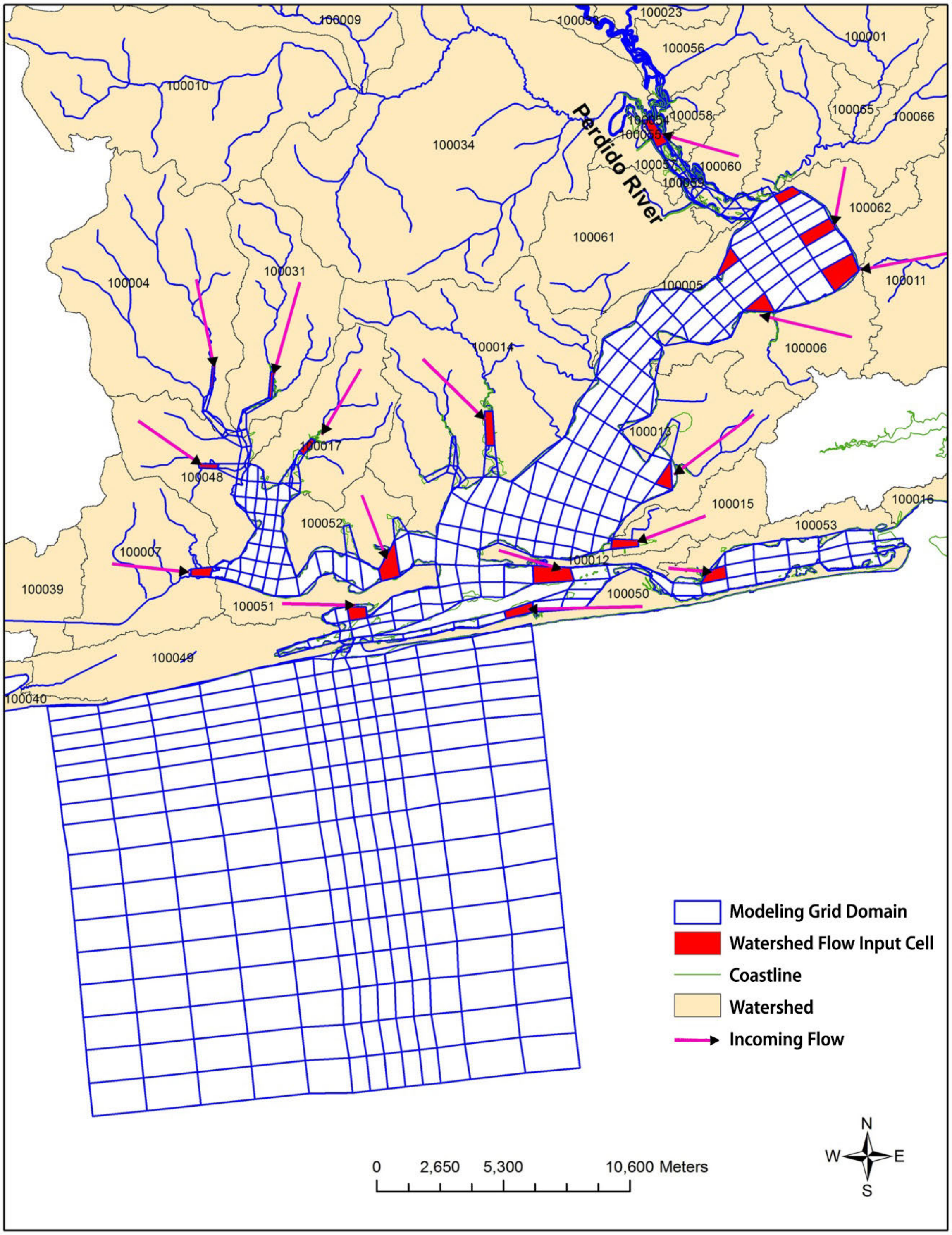


Figure D-3. Orthogonal curvilinear system of Perdido Bay

The grid consists of 453 horizontal cells and 5 equally spaced vertical σ layers.

The grid has 13 offshore boundary cells and 19 inland boundary cells. The 15 watershed discharges are described in Appendix C. According to that report, freshwater flows from watersheds are calculated on the basis of geographical, hydrological, and meteorological factors (land use/cover, landscape parameters, soils, air temperature, rainfall, and such). In Figure D-3 the flow inputs from terminal watersheds are marked by arrows.

The major watershed discharges are associated with Perdido River. The inland boundaries include freshwater flows and water temperature. The offshore boundary conditions include WSE, salinity, and water temperature.

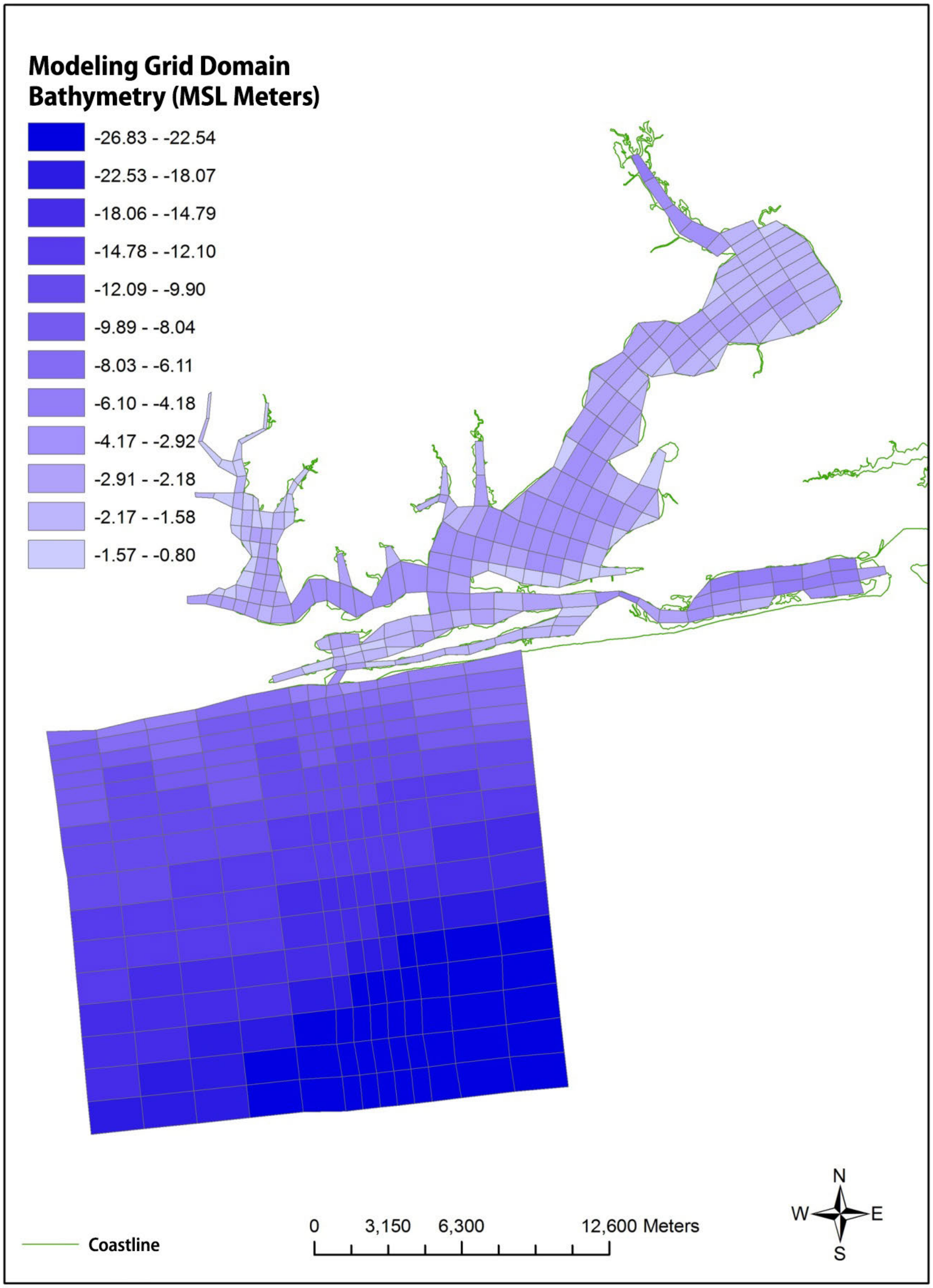


Figure D-4. Perdido Bay bathymetry

4.3 Perdido Bay Monitoring Stations

The calibration-validation process for the Perdido Bay model used data that were collected by Florida Department of Environmental Protection (FDEP), Alabama Department of Environmental Management (ADEM), and the National Oceanic and Atmospheric Administration (NOAA). The locations of the FDEP, NOAA and ADEM monitoring stations are shown in Attachment 1, Figure D1-1.

The data used for calibration-validation of the EFDC based model are:

- NOAA 8729941 Perdido tidal station: 2009 WSE
- 2002–2004 records of salinity and temperature at stations 21FLBFA 33020M31, 21FLPNS 33010H24, 21FLPNS 33010C14, 21FLPNS 33010G10
- 2002–2004 records of DO at stations 21FLBFA 33020M31, 21FLPNS 33010H24, 21FLPNS 33010C14, 21FLPNS 33010G10, AP-1, PDBB-0

The data used for calibration-validation of the WASP water quality model are 2002–2009 records of chl-a, nitrate-nitrite, ammonia, TN, TP, and the light attenuation coefficient collected at several of the following stations:

- FDEP stations: 21FLBFA 33020M31, 21FLPNS 33010H24, 21FLPNS 33010C14, 21FLPNS 33010G10
- ADEM stations: AP-1, PDBB-0, WLFB-1, WLFB-2, WLFB-4, WLFB-10 WLFB-11.

4.4 Hydrodynamic Model Forcing Conditions

Meteorological Factors and Offshore Boundary Conditions

Meteorological forcing functions and offshore boundary conditions for WSE, water temperature, salinity, and appropriate physical parameters used for the Perdido Bay model were the same as those used in the Pensacola Bay model. The bays are close to each other, and the thoroughly calibrated and validated Pensacola Bay model allows the use of the same forcing functions for meteorological and offshore boundary conditions. The functions and conditions are in the EFDC model input files: ASER.INP, WSER.INP, PSER.INP, TSER.INP, and SSER.INP.

Freshwater Flows and Temperature

The watershed freshwater discharges and temperatures were calculated using an LSPC watershed model (Appendix C). The discharges contain all point and nonpoint sources flows. The correspondent flow and temperature data are in the files QSER.INP and TSER.INP.

All offshore and inland boundaries and physical parameters of the hydrodynamic model are referred or presented in the input file EFDC.INP.

4.5 Hydrodynamic Model Calibration and Validation Analysis

Results (Tables D1-1 to D1-3) of the Perdido Bay hydrodynamic model calibration and validation are presented in Attachment 1 and graphical analyses are provided in the data files for the Perdido Bay model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Water Surface Elevation

Hourly measurements of WSE at NOAA tidal station 8729941 Perdido were selected as the validation data set. The period of validation is 2009 (only available WSE measured data at the station). Table D1-1 represents statistics of WSE validation. The errors of simulation-observation differences in the table are presented in meters. Percent errors were not used because the mean WSE values are so close to zero making the percent numbers unreasonable. The table presents the 5^{th} and 95^{th} WSE percentiles that allow one to estimate the WSE dynamic range.

The mean and percentiles difference between observed and simulated hourly WSE sets are in the range of 0 to -6 cm. The correlation coefficient (R^2) value of 0.89 shows good correlation between the simulated and measured data. Graphical analyses demonstrate close correspondence of the model WSE output to NOAA observations.

Salinity

Four FDEP monitoring stations were used for validation. The period of validation was 2002–2004. The percent error results in Table D1-2 range from -24 to -13. Graphical analyses demonstrate reasonable visual correspondence of the model salinity outputs with measured data for all four monitoring stations.

Water Temperature

Table D1-3 presents surface water temperature validation for four FDEP monitoring stations in 2002–2004. Mean errors in Table D1-3 range from 0 to 3 percent. Graphical analyses demonstrate good visual correspondence of the simulated water temperature with measured data for all four monitoring stations.

4.6 Water Quality Model Forcing Conditions

WASP7 water quality modeling was conducted to reproduce the three-dimensional transport and chemical and biological interactions of major components of water quality in Perdido Bay. Fourteen components were selected:

- Chlorophyll *a* (chl-a)
- Nitrate-nitrite nitrogen (NO_3+NO_2)
- Ammonia nitrogen (NH_3-N)
- Dissolved organic nitrogen (DON)
- Detrital nitrogen
- Phosphate phosphorus (PO_4-P)
- Dissolved organic phosphorus (DOP)
- Detrital phosphorus
- Carbonaceous biochemical oxygen demand 1 (CBOD1)
- Carbonaceous biochemical oxygen demand 2 (CBOD2)
- Carbonaceous biochemical oxygen demand 3 (CBOD3)
- Detrital carbon
- Dissolved oxygen (DO)
- Total suspended solids (TSS)

CBOD1 receives inputs from watershed simulation model—LSPC. CBOD1 was assumed as a major factor of DOC (color) attenuation of light in waters of an estuary. CBOD2 receives inputs from the point sources in the estuary's domain. CBOD3 receives inputs from chlorophyll dynamics in the estuary.

The model predicts these parameters in response to a set of hydrological, meteorological, atmospheric, and chemical and biological factors: loads from point and nonpoint sources, benthic ammonia and phosphate phosphorus (PO_4-P) fluxes, SOD, solar radiation, air temperature, reaeration, offshore and inland boundary conditions.

Point and Nonpoint Sources Loads

Time series of watershed concentrations were obtained from LSPC simulations (Appendix C) for dissolved mineral and organic nutrients, TSS, CBOD and DO. All point sources are included in the watershed model.

Solar Radiation and Air Temperature

The meteorological data for WASP7 was the same used for the heat exchange simulation for the hydrodynamic EFDC model using data from measured at station WBAN 13899, Pensacola.

Benthic Nutrient Fluxes and Sediment Oxygen Demand

Ammonia nitrogen and phosphate nutrient fluxes and SOD values were selected on the basis of observations and analysis presented in Murrell et al. (2009).

Reaeration

The reaeration process in WASP7 was calculated using the O'Connor-Dobbins option.

Boundary Conditions

Chl-a concentrations in all watershed discharges were assumed as 2 μg/L.

Time series of chl-a concentrations at offshore boundary, and chemical and biological constants of the water quality model were the same as for the Pensacola Bay model.

Inland and offshore boundary conditions for detrital components of the model were assumed as 0 mg/L.

All forcing functions, boundary conditions, calibration rates, and constants are in the WASP7 input file.

4.7 Water Quality Validation Analysis

Results (Tables D1-4 to D1-7) of validation for water quality components of the Perdido Bay model are presented in Attachment 1 and graphical analyses are provided in the data files for the Perdido Bay model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Due to their proximity to each other, Perdido Bay was initially modeled together with Pensacola Bay. The calibration was done using extensive data sets collected by Florida DEP and EPA in Pensacola Bay. The bays were separated for validation; Perdido Bay was validated using data collected by Florida DEP and Alabama ADEM.

All available measurements of chl-a, ammonia, nitrate-nitrite, TN, TP, DO, and light attenuation coefficient at FDEP monitoring stations (Figure D1-1, Attachment 1) in 2002–2009 were used as validation data sets. Graphical analyses provided in the data files for the Perdido Bay model demonstrate seasonal dynamics of chl-a, ammonia, nitrate-nitrite, TN, TP, DO, and light attenuation coefficient.

Table D1-4 shows comparison of mean simulated and measured chl-a in the surface layer of the water quality monitoring stations. The simulated and measured chl-a mean percent error values range from -50 to 36 percent.

Table D1-5 presents comparisons of mean values of simulated and measured nutrient levels (nitrate-nitrite, ammonia, TN, and TP) in the surface layer of the monitoring stations. The simulated and measured mean percent error values range from -41 to 514 for nitrate-nitrite, -31 to 236 for ammonia, -51 to -24 for TN, and -76 to 11 for TP.

Table D1-6 presents comparisons of mean values of simulated and measured DO concentrations in the surface layer of the monitoring stations. The simulated and measured mean percent error values for DO range from 1 to 30.

Table D1-7 presents comparisons of mean values of simulated and measured light attenuation coefficients for two available monitoring stations. The simulated and measured light attenuation coefficient mean values range from -36 to -37 percent error.

4.8 Perdido Bay Model Summary and Conclusions

The Perdido Bay modeling study area is divided into six subareas: the lower Perdido River, the upper Perdido Bay, the lower Perdido Bay, the Gulf Intracoastal Waterway, the Perdido Pass complex, and the Wolf Bay complex. The Perdido Bay system is dynamically connected to the Gulf of Mexico through the Perdido Pass 4-m deep channel.

The time variable, three-dimensional system of hydrodynamic and water quality models of Perdido Bay uses the same calibrated parameters and boundary conditions used for the Pensacola Bay model.

The hydrodynamic model was validated with 2009 NOAA WSE data that were collected hourly, and 2002–2004 FDEP-collected salinity and temperature data. The water quality model was validated with 2002–2009 FDEP collected chl-a, nutrient (nitrate-nitrite, ammonia, and TP) and DO data from six monitoring stations.

The validated EFDC-based hydrodynamic model represents the overall circulation and mixing characteristics of the Perdido Bay system on the basis of reasonable agreement between observed and calculated temporal and spatial distributions of WSE, salinity, and temperature. The validated WASP7-based water quality model reasonably represents the overall phytoplankton, nutrient and DO interactions in the Perdido Bay system.

Perdido Bay hydrodynamic and water quality model data sources are provided in Table D-2.

Table D-2. Perdido Bay hydrodynamic and water quality model data sources

Data	Source	Location Used
Atmospheric and Wind Data at Surface Airways Stations	National Climatic Data Center (EarthInfo 2009)	Perdido Estuary Model
Bathymetric Data	National Oceanic and Atmospheric Administration, National Geophysical Data Center (NOAA GEODAS No Date)	Perdido Estuary Model
Digitized Shoreline Data	National Oceanic and Atmospheric Administration (NOAA No Date a)	Perdido Estuary Model
IWR Run 40 Salinity and Temperature Data	Florida Department of Environmental Protection (FDEP 2010a)	Perdido Estuary Model
Measured and Predicted Water Surface Elevation Data	National Oceanic and Atmospheric Administration (NOAA No Date b)	Perdido Estuary Model
Wastewater Facility Regulation Municipal and Industrial Point Sources Discharging Directly into Estuary	Florida Department of Environmental Protection (FDEP No Date)	Perdido Estuary Model

5.0 PENSACOLA BAY MODEL

5.1 Physical Characteristics of the Model Study Area

The general morphological features of the Pensacola Bay system, as well as major physical processes in the system are well documented (Gallagher et al. 1999). Pensacola Bay is in northwest Florida in Escambia and Santa Rosa counties (Figure D-5).

On the basis of morphology, the entire study area can be divided into three major systems: the Pensacola-Escambia Bay, Blackwater-East Bay, and Santa Rosa Sound systems. Using the response of the salinity distributions to the variety of forcing mechanisms (geomorphology, freshwater discharges, tides, atmospheric and meteorological conditions), the system can be subdivided into four hydrodynamically connected subsystems: Escambia Bay, Pensacola Bay, East Bay, and Blackwater Bay. The system is dynamically connected to the Gulf of Mexico through the inlet on the eastern most end of Santa Rosa Island. The Gulf Breeze Peninsula provides a physical barrier between these two systems. The Pensacola Bay's bathymetry is shown in Figure D-6.

The combined system is medium-sized (370 km^2), shallow (mean depth = 3.0 m), and has been characterized as a partially stratified, drowned river valley estuary (Hagy and Murrell 2007; Schroeder and Wiseman 1999). Tides are diurnal and have low amplitude, ranging from 15 to 65 cm. The basin has three major watersheds that drain via the Escambia, Blackwater, and Yellow rivers. The Escambia River discharges into Escambia Bay, whereas the Blackwater and Yellow rivers discharge into Blackwater Bay. Both bays join Pensacola Bay, which connects to the Gulf of Mexico through the narrow (approximately 800 m wide) Pensacola Pass. Small openings also permit exchanges with Big Lagoon through a shallow (approximately 3 m), narrow (100 m) channel to the west and Santa Rosa Sound to the east through a 1 km opening. Santa Rosa Sound extends approximately 52 km to the east from Pensacola Bay and ultimately narrows to approximately approximately75 m before opening into Choctawhatchee Bay. Because of the small size of these channels, flow through them is expected to be minimal compared to Pensacola Pass.

Figure D-5. Pensacola Bay model and watershed location

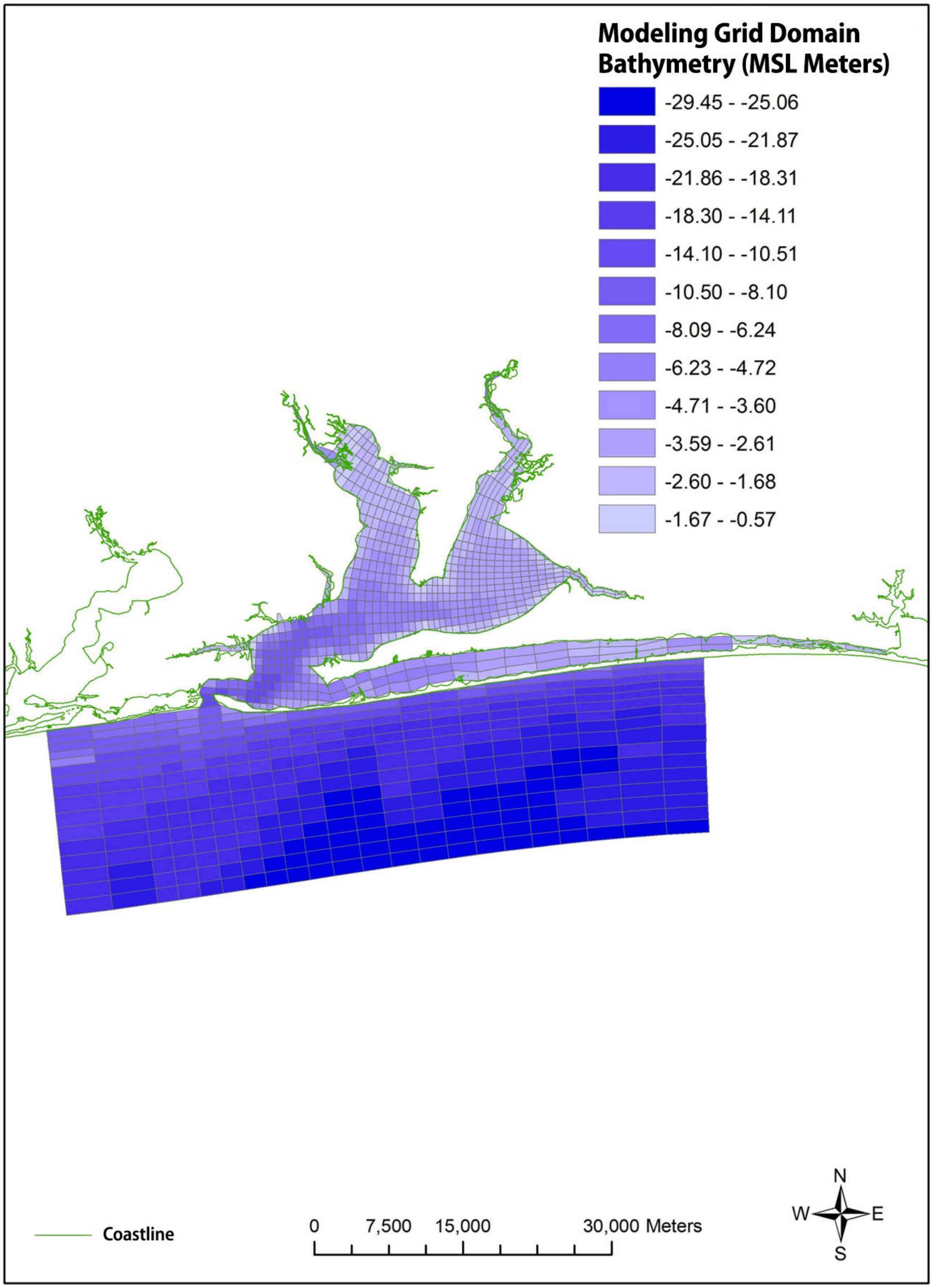


Figure D-6. Pensacola Bay bathymetry

5.2 Model Segmentation

An orthogonal, curvilinear grid system used in the hydrodynamic model is shown in Figure D-7.

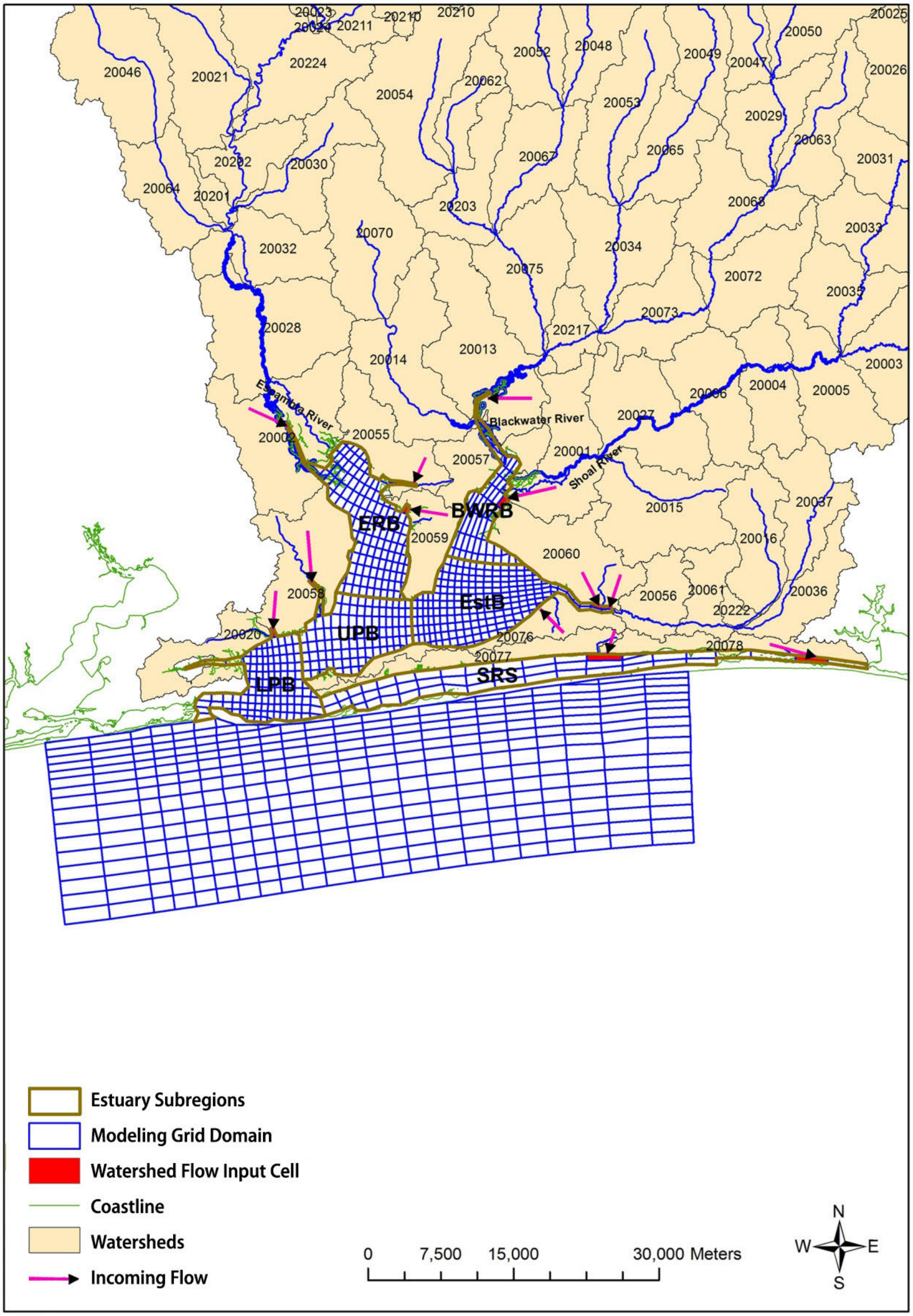


Figure D-7. Orthogonal curvilinear system of Pensacola Bay

The grid consists of 998 horizontal cells and 5 equally spaced vertical layers. The grid has 22 offshore boundary cells and 12 inland boundary cells, corresponding to 8 watershed discharges and 5 major point source discharges. The watershed flows were obtained from LSPC model outputs (Appendix C) calculated on the basis of geographical, hydrological and meteorological factors (land use/cover, landscape parameters, soils, air temperature, rainfall, and the like). The watershed flows are marked by arrows in Figure D-7.

The major watershed discharges are related to Escambia, Blackwater and Yellow rivers. The inland boundaries conditions for the hydrodynamic model include freshwater flows and water temperature. The offshore boundary conditions include WSE, salinity, and water temperature.

5.3 Pensacola Bay Monitoring Stations

The calibration-validation process for Pensacola Bay model uses data collected by EPA Gulf Breeze Division and NOAA. Locations of the EPA and NOAA monitoring stations are shown in Attachment 2, Figures D2-1 and D2-2.

The data used for calibration-validation of the EFDC hydrodynamic model are:

- NOAA Pensacola tidal station: 2002-2009 WSE and temperature
- EPA 2009 continuous records of WSE, salinity and temperature
- EPA 2007-2009 continuous records of salinity and temperature at Pensacola Pass
- EPA 2002-2004 monthly measurements of water quality parameters and salinity at 16 monitoring stations in Pensacola-Escambia Bay, Blackwater-East Bay, and Santa Rosa Sound.

5.4 Hydrodynamic Model Forcing Conditions

EFDC hydrodynamic modeling was conducted to reproduce the three-dimensional circulation dynamics and salinity and temperature structure in the bay system. The model predicts these parameters in response to multiple factors: wind speed and direction, freshwater discharge, tidal water level fluctuation, rainfall, surface heat flux, and temperature and salinity associated with boundary fluxes.

Meteorological Factors

Hourly measurements of atmospheric pressure, dry and wet bulb atmospheric temperatures, rainfall rate, wind speed and direction, and fractional cloud cover were obtained from data collected at station WBAN 13899 Pensacola for 1997–2009. Solar shortwave radiation was calculated using the CE-QUAL-W2 method. WSER file includes hourly measurements of wind speed and directions. The meteorological factors for the EFDC hydrodynamic model are included in the file ASER.INP.

Freshwater Flows and Temperature

Freshwater flows and water temperatures from watersheds are included in files QSER.INP and TSER.INP, respectively. The watershed freshwater discharges and temperatures were obtained from the LSPC watershed model (Appendix C).

Point Sources

Five major point sources are included in the model setup: Ascend Performance Materials LLC (FL0002488), Main Street Waste Water Treatment Plant (WWTP) (FL0021440), Milton WWTP (FL0021903), Navarre Beach WWTP (FL0023981), and Pensacola Beach WWTP (FL0024007) (Figure D-8). The correspondent flow and temperature data are in the files QSER.INP and TSER.INP. Table D-3 presents the list of the point sources included in the model.

Table D-3. Point sources in the Pensacola Bay model

Permit No	Name	Permit Flow (mgd)
FL0021440	Main Street WWTP	20.00
FL0021903	Milton WWTP	2.50
FL0023981	Navarre Beach WWTP	0.90
FL0024007	Pensacola Beach WWTP	2.40
FL0002488	Ascend Performance Materials LLC	27.00

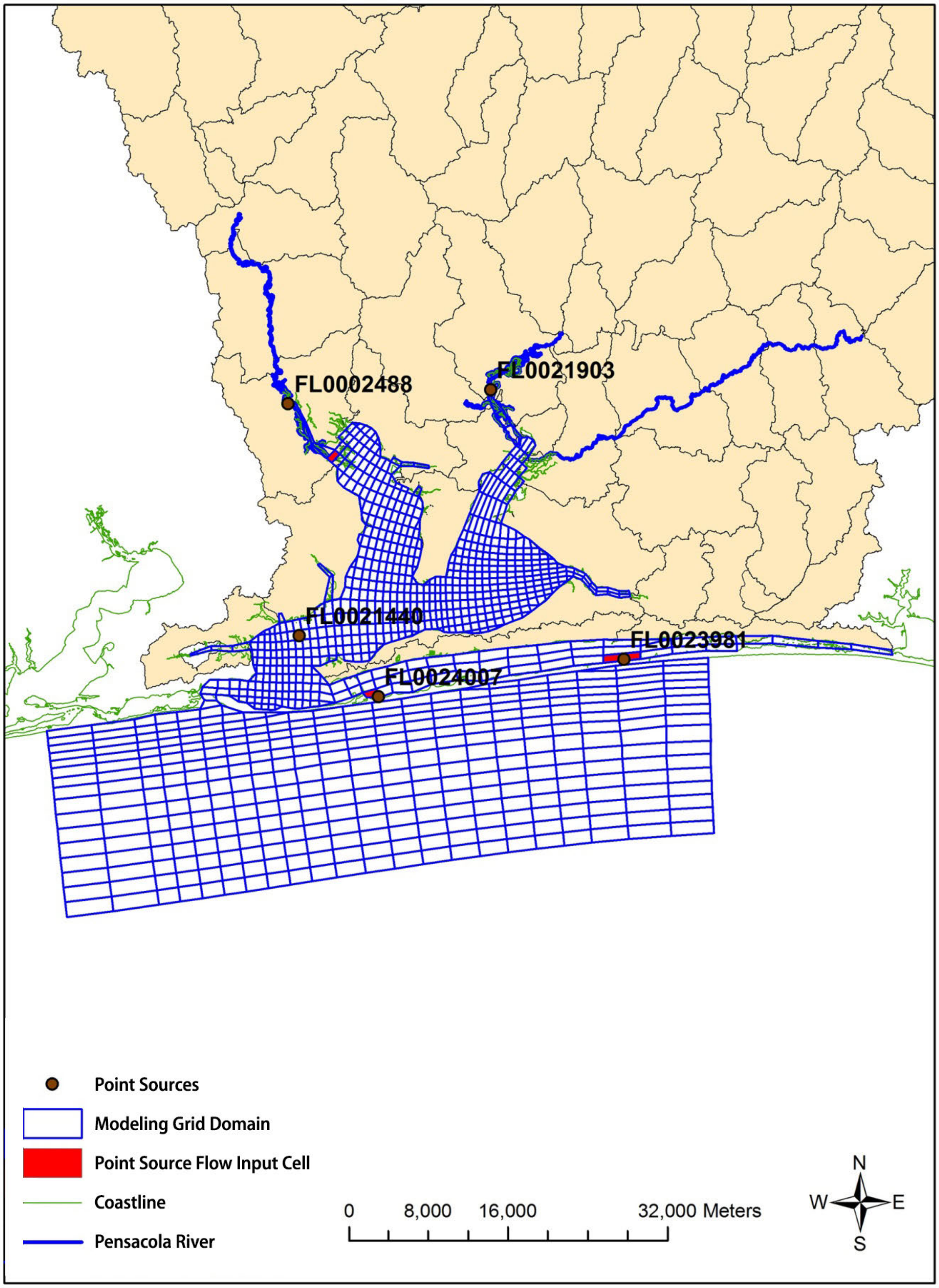


Figure D-8. Point source locations for the Pensacola Bay model

Offshore Boundary WSE and Water Temperature

Hourly WSE data measured at NOAA tidal station 8729840 Pensacola were initially used as boundary conditions at the offshore open boundary. These boundary conditions were adjusted during the WSE calibration by comparison of observed data with WSE simulations at the tidal station location. WSE open boundary conditions for the EFDC model are included in the file PSER.INP.

Daily temperature data observed at NOAA tidal station 8729840 Pensacola were initially used as boundary conditions at the offshore boundary. The boundary conditions were adjusted during the temperature calibration by comparing observed data with the simulations at location of the tidal station. The calibrated open boundary conditions for temperature are in the file TSER.INP.

Offshore Boundary Salinity

Salinity field measurements are not available close to the open boundary. Therefore, constant values of salinity (35 ppt at the surface layer linearly increasing up to 37 ppt at the bottom layer) were selected as the open boundary condition. The salinity values are in general correspondence to average salinity in northern part of the Gulf of Mexico. Salinity at the open boundary for the EFDC model is in the file SSER.INP.

5.5 Hydrodynamic Model Calibration and Validation Analysis

Statistical results (Tables D2-1 to D2-6) of calibration and validation of the hydrodynamic components of the Pensacola Bay model are in Attachment 2 and graphical results are in the data files for the Pensacola Bay model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Water Surface Elevation

Hourly measurements of WSE at NOAA tidal station 8729840 Pensacola were selected as calibration data set. The period of calibration is 2002–2009. Table D2-1 represents statistics of WSE calibration for each year and entire calibration period. The errors or simulation-observation differences in the table are presented in meters (m). Percent errors were not used because the mean WSE values are so close to zero making the percent numbers unreasonable. The summary table (D2-1) presents 5th and 95th WSE percentiles that allow one to estimate the dynamic range of WSE.

The mean difference between observed and simulated hourly WSE sets is in the range of -1 to 1 cm for the majority of WSE measurements; only the 2004 WSE measurement shows a 95th percentile difference of 2 cm. Note that 2004 was the year of Hurricane Ivan, which disabled NOAA tidal equipment, and WSE data were reconstructed by using circumstantial data. Most correlation coefficient (R^2) values show good correlation between simulations and observations. Graphical analyses demonstrate close correspondence of the calibrated model WSE output to NOAA observations.

Table D2-2 shows the WSE validation results. The validation process uses observations of relative depth changes in locations of EPA 2009 monitoring stations at Pensacola Pass, Escambia River mouth, and Navarre. The mean difference between observed and simulated hourly WSE sets is in the range of -11 to 16 cm. The simulated and observed statistics show good agreement for WSE validation, with high R^2 coefficients. Graphical analyses demonstrate acceptable correspondence of the calibrated model WSE output to EPA observations.

Salinity

Continuous thirty-minute measurements of salinity at EPA monitoring stations at Pensacola Pass in 2007-2009 and Buoy during 2009 were selected as calibration data sets. Data from 16 EPA monthly monitoring stations in 2002, 2003, and 2004 were used as salinity validation data sets.

Table D2-3 presents statistical results for comparisons of simulations with continuously measured salinity data at EPA monitoring stations. Statistics of calibration were based on continuous measurements at Pensacola Pass station during 2007, 2008 and 2009 separately, and integral measurements for 2007–2009 (Table D2-3). Percent error values for simulated and measured mean range from -25 to 12. Graphical analyses demonstrate visual correspondence of sets of model outputs with measured data used for calibration purposes.

Table D2-4 demonstrates mean salinity validation statistics for surface and bottom layers at 16 EPA monthly monitoring stations in 2002–2004. Percent error values for salinity in Table D2-4 range from -18 to 196 percent for the surface layer and -44 to 29 for the bottom layer. Graphical analyses also demonstrate acceptable visual correspondence of the model salinity outputs with monthly measured data for all 16 monitoring stations.

Temperature

Daily measurements of water temperature at NOAA tidal station 8729840 Pensacola in 2002–2009 and 30-minute measurements at EPA stations (Pensacola Pass in 2007–2009, Buoy and Navarre in 2009) were selected as a calibration data set.

Table D2-5 represents statistics of mean water temperature calibration for the entire calibration period at NOAA tidal station 8729840 Pensacola, EPA station Pensacola Pass for 2007-2009 and for each year, and for 2009 for EPA stations Buoy and Navarre. The percent error values for temperature in Table D2-5 for the surface layer ranges from -27 to -2. Graphical analyses show visual correspondence of sets of model outputs with those used to calibrate measured water temperature data.

Table D2-6 presents the results of surface and bottom water temperature validation for 16 EPA monthly monitoring stations in 2002–2004. Mean percent error values for temperature in Table D2-6 range from -17 to -4 for the surface layer and -22 to -2 for the bottom layer. Graphical analyses demonstrate good visual correspondence of the model water temperature outputs with monthly measured data for all 16 monitoring stations.

5.6 Water Quality Model Forcing Conditions

The selection of the WASP7-based water quality model's state variables is described in Section 4.6.

Point and Nonpoint Sources Loads

Time series of watershed loads' concentrations were obtained from LSPC simulations (Appendix C) for dissolved mineral and organic nutrients, TSS, CBOD, and DO. Time series of point sources loads were obtained from discharge monitoring reports (DMRs) in the Permit Compliance System (PCS) database.

Solar Radiation and Air Temperature

The meteorological data for WASP7 was the same used for the heat exchange simulation for the hydrodynamic EFDC model using data measured at station WBAN 13899 Pensacola.

Benthic Nutrient Fluxes and Sediment Oxygen Demand

Ammonia nitrogen (NH_3-N), phosphate nutrient fluxes, and SOD values were initially selected on the basis of observations and analysis presented in Murrell et al. (2009). Ammonia nitrogen and phosphate fluxes were used as is. The SOD values were adjusted during the DO calibration process.

Reaeration

The reaeration process in WASP7 was calculated using the O'Connor-Dobbins option.

Boundary Conditions

Chl-a concentrations in point sources discharges were assumed as 0 µg/L.

Chl-a concentrations for all watershed discharges were assumed as 2 µg/L.

Chl-a concentrations in the offshore boundary was initially selected as 2 µg/L and corrected later in accordance with remote-sensing chlorophyll concentrations series, collected through EPA's remote-sensing program.

Inland and offshore boundary conditions for detrital components of the model were assumed as 0 mg/L.

Final calibration values for chemical and biological constants of the water quality model are presented in Table D-4.

All forcing functions, boundary conditions, calibration rates and constants are in the WASP7 input file.

Table D-4. Calibration rates and coefficients for Pensacola Bay water quality modeling

Water Quality Variable	Definition	Value	Minimum	Maximum
Phytoplankton	Phytoplankton Maximum Growth Rate Constant @20 °C (per day)	2.0	0	3
	Phytoplankton Growth Temperature Coefficient	1.07	0	1.07
	Phytoplankton Self Shading Extinction (Dick Smith Formulation)	0.017	0	0.02
	Phytoplankton Carbon to Chlorophyll Ratio	35.0	0	200
	Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	0.025	0	0.05
	Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	0.001	0	0.05
	Phytoplankton Endogenous Respiration Rate Constant @20 °C (per day)	0.10	0	0.5
	Phytoplankton Respiration Temperature Coefficient	1.05	0	1.08
	Phytoplankton Death Rate Constant (Non-Zooplankton Predation) (per day)	0.03	0	0.25
	Phytoplankton Zooplankton Grazing Rate Constant (per day)	0.02	0	5.0
	Phytoplankton Phosphorus to Carbon Ratio	0.019	0	0.24
	Phytoplankton Nitrogen to Carbon Ratio	0.40	0	0.43
	Phytoplankton Half-Sat. for Recycle of Nitrogen and Phosphorus (mg Phyt C/L)	0.005	0	1
Ammonia	Nitrification Rate Constant @20 °C (per day)	0.01	0	10
	Nitrification Temperature Coefficient	1.08	0	1.07
	Half Saturation Constant for Nitrification Oxygen Limit (mg O/L)	0.50	0	2
Nitrate-Nitrite	Denitrification Rate Constant @20 °C (per day)	0.09	0	0.09
	Denitrification Temperature Coefficient	1.045	0	1.04
	Half Saturation Constant for Denitrification Oxygen Limit (mg O/L)	0.01	0	0.1
Organic Nitrogen	DON Mineralization Rate Constant @20 °C (per day)	0.05	0	1.08
	DON Mineralization Temperature Coefficient	1.047	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Nitrogen	1.00	0	1
Organic Phosphorus	Mineralization Rate Constant for Dissolved Organic P @20 °C (per day)	0.05	0	0.22
	DOP Mineralization Temperature Coefficient	1.040	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Phosphorus	1.00	0	1

Water Quality Variable	Definition	Value	Minimum	Maximum
Light	Light Option (1 uses input light; 2 uses calculated diel light)	2	1	2
	Phytoplankton Maximum Quantum Yield Constant	720.0	0	720
	Phytoplankton Optimal Light Saturation	350.0	0	350
	Detritus and Solids Light Extinction Multiplier	0.02	0	10
	DOC1 Light Extinction Multiplier	4.00	0	10
DO	Water body Type Used for Wind Driven Reaeration Rate	2	0	3
	Calc Reaeration Option - O'Connor	1	0	4
	Reaeration Option -Sums Wind and Hydraulic Ka	1	0	1
	Theta -- Reaeration Temperature Correction	1.022	0	1.03
	Oxygen to Carbon Stoichiometric Ratio	2.66	0	2.67
CBOD	CBOD Decay Rate Constant @20 °C (per day)	0.10	0	5.6
	CBOD Decay Rate Temperature Correction Coefficient	1.04	0	1.07
	CBOD Half Saturation Oxygen Limit (mg O/L)	0.20	0	0.5
Detritus	Detritus Dissolution Rate (1/day)	0.10	0	0
	Temperature Correction for Detritus Dissolution	1.080	0	0

5.7 Water Quality Calibration and Validation Analysis

Results (Tables D2-7 to D2-10) of calibration and validation of water quality components of the Pensacola bay model are presented in Attachment 2 and graphical results are in the data files for the Pensacola Bay model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Monthly measurements of chl-a, ammonia, nitrate-nitrite, phosphate, DO, and light attenuation coefficient at 16 EPA monitoring stations in 2002–2004 were used as calibration and validation data sets. The comparisons of the calibrated model run with observed data for all 16 monitoring stations in 2002–2004 are presented in Section D2.5 of Attachment 2.

Graphical analyses provided in the data files for the Pensacola Bay model demonstrate seasonal dynamics of chl-a, nitrate-nitrite, ammonia, phosphate, DO, and light attenuation coefficient. Table D2-7 shows comparisons of mean simulated and measured chl-a in the surface layer of the water quality monitoring stations. The mean percent error values for simulated and measured mean chl-a measurements range from -42 to 4.

Table D2-8 presents comparisons of mean simulated and measured nutrient values (nitrate-nitrite, ammonia, and phosphate) in the surface layer of the monitoring stations. As shown in Table D2-8, the percent error values range from -14 to 275 for nitrate-nitrite, -48 to 132 for ammonia, and 31 to 150 for phosphate.

Table D2-9 presents comparisons of mean values of simulated and measured DO concentrations in surface and bottom layers of the monitoring stations. As shown in Table D2-9, the percent error values range from 2 to 33 for the surface layer mean values and from -2 to 59 for the bottom layer mean values.

Table D2-10 presents comparisons of mean values of water column average light attenuation coefficient. The comparison of mean values of simulated and measured light attenuation coefficient values range from -37 to 33 percent error.

5.8 Pensacola Bay Model Summary and Conclusions

The Pensacola Bay modeling study area has three major systems: the Pensacola-Escambia Bay, Blackwater-East Bay, and Santa Rosa Sound systems. The basin includes three major watersheds, which drain via the Escambia, Blackwater, and Yellow rivers. The bay connects to the Gulf of Mexico through the narrow (approximately 800 m wide) Pensacola Pass. Small opening also permit exchanges with Big Lagoon through Santa Rosa Sound.

The time-variable, three-dimensional system of hydrodynamic and water quality models of the Pensacola Bay were calibrated with data collected by EPA and NOAA from 2002 to 2009.

The hydrodynamic model was calibrated with 2004–2005 NOAA hourly collected WSE and temperature data. The model was calibrated with 2007–2009 EPA continuously measured data for salinity and temperature. The model was validated with 2009 EPA collected WSE data and 2002–2004 EPA monthly data for salinity and temperature.

The water quality model was calibrated and validated with 2002–2004 EPA monthly collected chl-a, nutrient, and DO data.

The calibrated EFDC-based hydrodynamic model represents the overall circulation and mixing characteristics of the Pensacola Bay system using reasonable agreement between observed and calculated temporal, spatial, and vertical distributions of WSE, salinity, and temperature.

The calibrated WASP-based water quality model reasonably represents the overall phytoplankton, nutrient and DO interactions in the Pensacola Bay system. The water quality simulations show reasonable agreement with monthly observed data.

Pensacola Bay hydrodynamic and water quality model data sources are provided in Table D-5.

Table D-5. Pensacola Bay hydrodynamic and water quality model data sources

Data	Source	Location Used
Atmospheric and Wind Data at Surface Airways Stations	National Climatic Data Center (EarthInfo 2009)	Pensacola Estuary Model
Bathymetric Data	National Oceanic and Atmospheric Administration, National Geophysical Data Center (NOAA GEODAS No Date)	Pensacola Estuary Model
Digitized Shoreline Data	National Oceanic and Atmospheric Administration (NOAA No Date a)	Pensacola Estuary Model
IWR Run 40 Salinity and Temperature Data	Florida Department of Environmental Protection (FDEP 2010a)	Pensacola Estuary Model

Data	Source	Location Used
Measured and Predicted Water Surface Elevation Data	National Oceanic and Atmospheric Administration (NOAA No Date b)	Pensacola Estuary Model
Wastewater Facility Regulation Municipal and Industrial Point Sources Discharging Directly into Estuary	Florida Department of Environmental Protection (FDEP No Date)	Pensacola Estuary Model
Continuous Record of Salinity and Water Temperature in Pensacola Bay	EPA Gulf Ecology Division (Hagy and Murrell 2007)	Pensacola Estuary Model
Monthly Water Quality Data in Pensacola Bay 1998-2004	EPA Gulf Ecology Division (Hagy and Murrell 2007)	Pensacola Estuary Model

6.0 CHOCTAWHATCHEE BAY MODEL

6.1 Physical Characteristics of the Model Study Area

Choctawhatchee Bay runs along the upper Gulf Coast from east to west for about 43 km (27 mi) ranging in width from 2 to 10 km (1 to 6 mi) (Figure D-9). The bay covers an estimated surface area of 348 km^2 in the Florida counties of Okaloosa and Walton. The depths range from 3 to 13 m, with a mean depth of 3.8 m (Schaeffer 2010). The bay is connected to the Gulf of Mexico through a narrow, shallow opening at East Pass, immediately west of Destin (Ruth and Handley 2007). The bay is characterized by shallow shelf areas and relatively steep slopes that eventually level out to average depths of 3 m in eastern sections and 8 m in western sections (Livingston 2001).

The major source of freshwater input is the Choctawhatchee River and its tributaries, including Pea River, Wrights Creek, Sandy Creek, Pine Log Creek, Seven Runs, Holmes Creek, and Bruce Creek. These have significant groundwater contribution from springs and the Floridan aquifer (Ruth and Handley 2007). Several small creeks empty into the bay directly, most notably Turkey, Rocky, Swift, and Alaqua creeks.

Choctawhatchee Bay opens to the Gulf Intracoastal Waterway in the east connecting it to the West Bay. In the west the bay is connected to the Pensacola Bay system through the Gulf Intracoastal Waterway and Santa Rosa Sound (Blaylock 1983).

Choctawhatchee Bay has minimum tidal exchanges through the narrow and shallow East Pass (about 0.15 m) (Blaylock 1983). As a result, the bay exhibits a strong halocline nature (noticeable difference in surface and bottom salinities). It has four basic natural habitats: shallow slope areas (vegetated, unvegetated, and oyster beds), deep central basin regions (unvegetated), bayous, and a river delta area.

Figure D-9. Choctawhatchee Bay model and watershed location

6.2 Model Segmentation

An orthogonal, curvilinear grid system used in the hydrodynamic model is shown in Figure D-10. The grid consists of 897 horizontal cells and 5 equally spaced vertical σ layers. It has 23 offshore boundary cells and 16 inland boundary cells.

The inland boundary cells receive LSPC-simulated watershed discharges and point source discharge (FL0102482). The watershed boundary cells are marked in Figure D-10, and the point source location is shown in Figure D-11. The watershed discharges are described in Appendix C. According to the report, freshwater flows from watersheds are calculated on the basis of geographical, hydrological, and meteorological factors (land use/cover, landscape parameters, soils, air temperature, rainfall, and such). The major watershed is related to the Choctawhatchee River and its tributaries.

Bathymetry data for the Gulf of Mexico adjacent area and Choctawhatchee Bay were obtained from the National Geophysical Data Center. The bathymetry data were interpolated into the grid resulting in the grid bathymetry shown in Figure D-12.

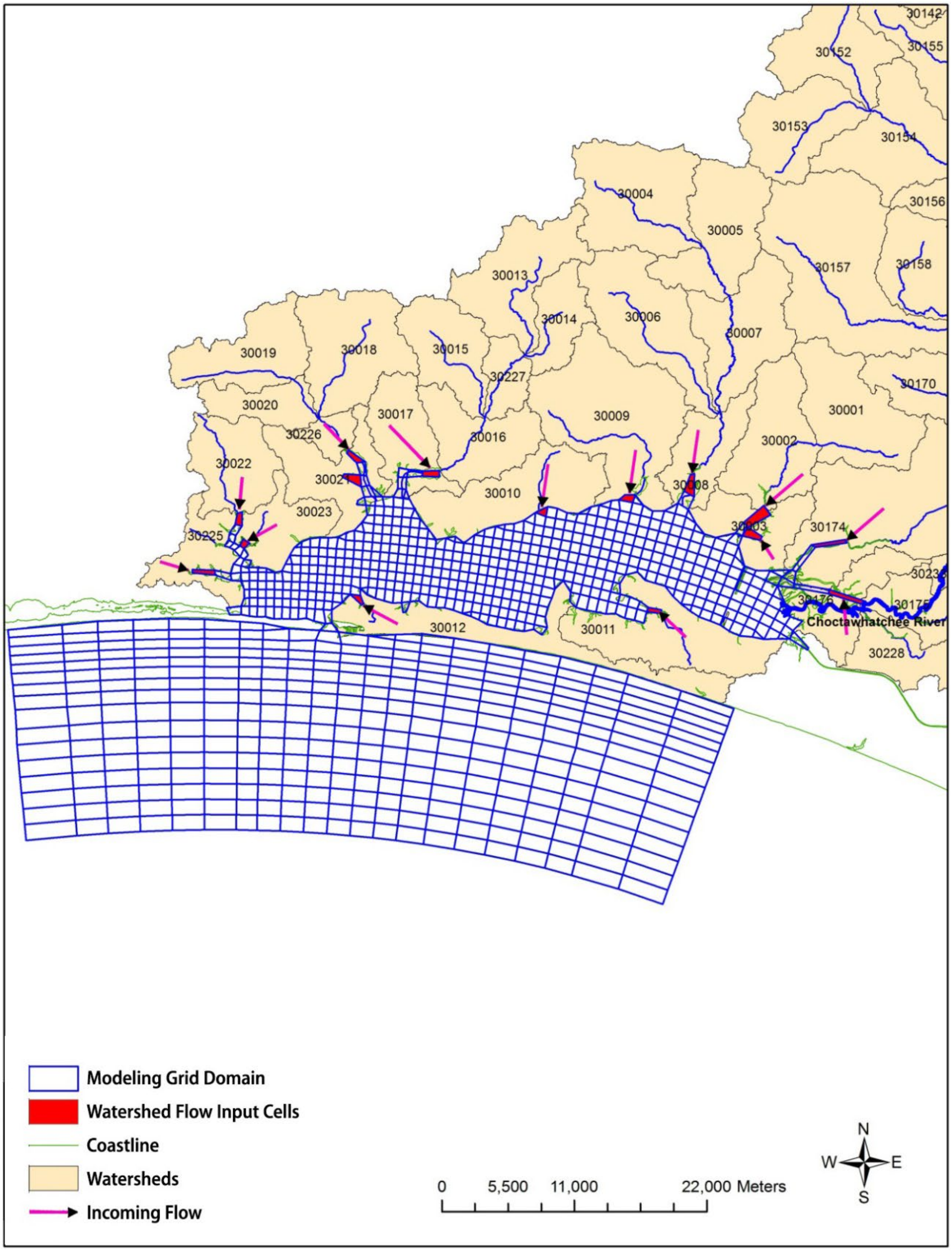


Figure D-10. Orthogonal curvilinear system of Choctawhatchee Bay

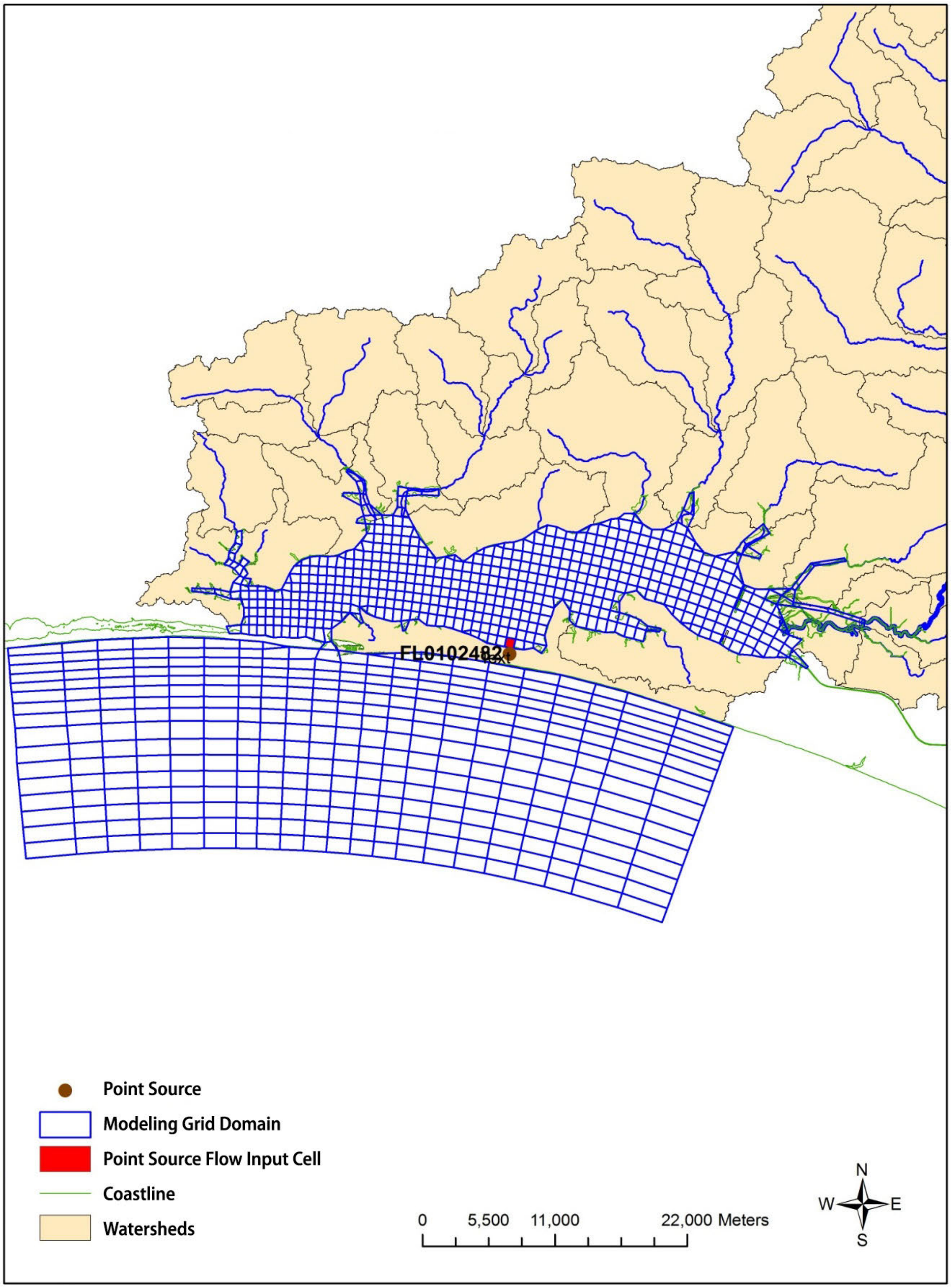


Figure D-11. Point source locations for the Choctawhatchee Bay model

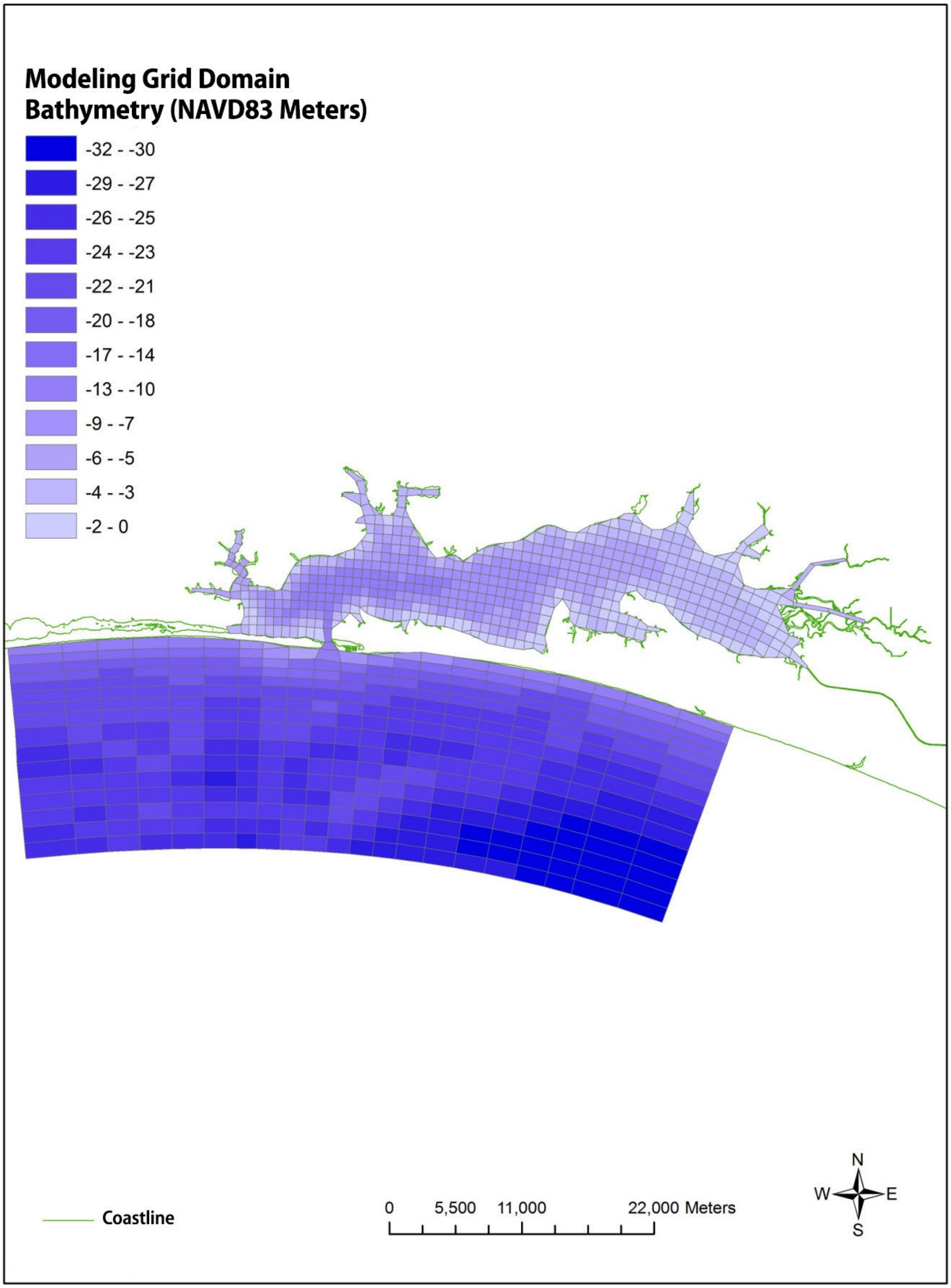


Figure D-12. Choctawhatchee Bay bathymetry

6.3 Choctawhatchee Bay Monitoring Stations

The calibration-validation process for the Choctawhatchee Bay model uses data collected by FDEP and NOAA at the stations shown in Figure D3-1, Attachment 3. The WASP7 model was calibrated for DO, nutrients and TSS using data for 2002–2004 at the stations shown in Figure D3-2.

The data used for calibration and validation of EFDC and WASP7 based model are:

- NOAA tidal station 8729501 Valparaiso (station T01 in Figure D3-1, Attachment 3): 2002-2003 WSE for calibration and 2004 WSE for validation.
- FDEP 2002-2004 measurements of salinity and temperature (stations S01-S05 for calibration and stations S06-S10 for validation in Figure D3-1).
- FDEP 2002-2004 measurements of water quality parameters at monitoring stations in Choctawhatchee Bay (Figure D3-2).

The EFDC model was calibrated for salinity and temperature using data for 2002–2004 at five stations (S01-S05). The entire period was used for calibration to include the full range of hydrodynamic conditions covered by the 3-year period. For validation, data for the same period (2002–2004) at a set of five different stations (S06-S10) was used.

6.4 Hydrodynamic Model Forcing Conditions

EFDC-based hydrodynamic modeling was conducted to reproduce the three-dimensional circulation dynamics and salinity and temperature structure in the bay system. The model predicts these parameters in response to multiple factors: wind speed and direction, freshwater discharge, water level fluctuation, rainfall, surface heat flux, and temperature and salinity associated with boundary fluxes.

Meteorological Factors

Hourly measurements of atmospheric pressure, dry and wet bulb atmospheric temperatures, rainfall rate, wind speed and direction, and fractional cloud cover were obtained from data collected at station WBAN 13899 Pensacola for 1997–2009. Solar shortwave radiation was calculated using the CE-QUAL-W2 method. The meteorological factors for the EFDC hydrodynamic model are included in the ASER.INP file. The WSER.INP file includes hourly measurements of wind speed and directions.

Freshwater Flows and Temperature

The watershed flows discharge into the bay and temperatures were calculated using the LSPC watershed model (Appendix C). The watershed input boundary cells are shown in Figure D-10. Freshwater flows and water temperatures from watersheds are included in files QSER.INP and TSER.INP, respectively.

Point Sources

One major point source is included in the hydrodynamic and water quality model setup: South Walton Utility Company WWTP (permit FL0102482). The point source location is shown in Figure D-11, and its characteristic discharge is shown in Table D-6. The correspondent flow and temperature data are in the files QSER.INP and TSER.INP.

Table D-6. Point source for the Choctawhatchee Bay model

Permit No	Name	Permit Flow (MGD)
FL0102482	South Walton Utility Company WWTP	2.50

Offshore Boundary WSE and Water Temperature

Hourly time series of WSE data from NOAA tidal station 8729501 Valparaiso were initially used as boundary conditions. These boundary conditions were adjusted during the WSE calibration by comparing observed data with WSE simulations at the tidal station. The datum used for WSE is mean sea level.

Observed temperature data at FDEP monitoring stations 21FLA 06622SEAS, 21FLCBA FRE10, and 21FLDOHOKALOOSA198 were used as boundary conditions at the open, east, and west boundaries, respectively.

WSE and temperature at open boundary for the EFDC model are included in files PSER.INP and TSER.INP, respectively.

Offshore Boundary Salinity

Salinity field measurements close to the open boundary do not exist. As a result, a constant value of salinity (35 ppt) was selected as the open boundary condition. That salinity value generally corresponds to average salinity in northern part of the Gulf of Mexico. Salinity at open boundary for the EFDC model is included in the file SSER.INP.

All offshore and inland boundaries and physical parameters of the hydrodynamic model are in the input file EFDC.INP.

6.5 Hydrodynamic Model Calibration and Validation Analysis

Statistical results (Tables D3-1 to D3-6) of calibration and validation of the hydrodynamic components of the Choctawhatchee Bay model are presented in Attachment 3 and graphical results are in the data files for the Choctawhatchee Bay model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Water Surface Elevation

Hourly WSE data at NOAA tidal station 8729501 Valparaiso (marked as station T01 in Figure D3-1, Attachment 3) were selected as the calibration data set. The period of calibration is 2002–2003. Table D3-1 represents statistics of WSE calibration for the two years. The errors or simulation-observation differences in the table are in meters. Percent errors were not used because the mean WSE values are so close to zero making the percent numbers unreasonable. The table also presents 5th and 95th WSE percentiles that allow one to estimate the WSE dynamic range.

The mean and percentiles difference between observed and simulated hourly WSE sets are in the range of -3 to 0 cm. Correlation coefficient (R^2) values of 0.88 and 0.86 show good correlation between simulations and observations. Graphical analyses demonstrate close WSE correspondence.

Table D3-2 shows the WSE validation results. The validation process uses observations at the same station for 2004. To calculate the statistics, the period of Hurricane Ivan in September 2004 was excluded, because only predicted data were available for that period. The mean and percentiles difference between observed and simulated hourly WSE sets are in the range of -3 to -1 cm for the validation data set. The correlation coefficient (R^2) value of 0.90 shows good correlation between simulations and observations. Graphical analysis demonstrates acceptable correspondence of the calibrated model WSE output to NOAA data during the validation period.

Salinity

Salinity measurements at five FDEP monitoring stations S01-S05 (Figure D3-1) for 2002–2004 were used as calibration data sets. Table D3-3 presents the calibration statistics of surface and bottom salinity. The percent error results range from 2.2 to 22.6 for the surface layer and 4.7 to 23.3 for the bottom layer. Graphical analyses show good visual correspondence between the measured and simulated values of salinity. Data measured at another five stations (S06-S10), for the same period (2002–2004) were used for validation. The statistics for the validation data set are presented in Table D3-4; the mean percent error results ranged from -24.1 to 37.2 for the surface layer and 1.0 to 14.9 for the bottom layer.

Temperature

Measurements of water temperature at FDEP stations S01-S05 were selected as the calibration data set. The calibration period is 2002–2004.

Table D3-5 presents the statistics of surface and bottom temperature calibration for the calibration period. The mean percent error results range from -8.3 to 21.6 for the surface layer and from -16.9 to 22.0 for the bottom layer. Graphical analyses show visual correspondence of model outputs with measured water temperature data used for calibration purposes.

The validation statistics that are based on temperature measurements at stations S06 through S10 in 2002–2004 are shown in Table D3-6. The mean percent error results ranged from -5.7 to 16.6 for the surface layer and from -25.6 to -0.3 for the bottom layer. Graphical analyses demonstrate good visual correspondence of model outputs with measured data.

6.6 Water Quality Model Forcing Conditions

The selection of the WASP7-based water quality model's state variables is described in Section 4.6.

Point and Nonpoint Sources Loads

Time series of watershed loads were obtained from LSPC simulations (Appendix C) for organic nutrients, TSS, CBOD, and DO. The load from point source FL0102482 is directly discharged to the estuary boundary grid cell (Figure D-11). The point source discharge values were obtained from DMR data in PCS.

Solar Radiation and Air Temperature

The meteorological data for WASP7 was the same used for the heat exchange simulation for the hydrodynamic EFDC model using data measured at station WBAN 13899 Pensacola.

Benthic Nutrient Fluxes and Sediment Oxygen Demand

Ammonia nitrogen and phosphate nutrient fluxes and SOD values were selected on the basis of observations and analysis presented in Murrell et al. (2009) for Pensacola Bay. The fluxes were adjusted for Choctawhatchee Bay during the calibration process.

Reaeration

The reaeration process in WASP7 was calculated using the O'Connor-Dobbins option.

Boundary Conditions

The offshore boundary conditions for the WASP7 model are presented in Table D-7.

Table D-7. Offshore concentration boundary conditions

Parameter	Concentration
Ammonia (mg/L)	0.02
Nitrate (mg/L)	0.01
Organic Nitrogen (mg/L)	0.1
Orthophosphate (mg/L)	0.005
Organic Phosphorus (mg/L)	0.005
Chl-a (ug/L)	2
Dissolved Oxygen (mg/L)	7
CBODu (mg/L)	2
Total Suspended Solids (mg/L)	0.5

Inland and offshore boundary conditions for detritus components of the model were assumed as 0 mg/L.

Table D-8 presents the water quality model's final chemical and biological calibration constant values.

All forcing functions, boundary conditions, calibration rates, and constants are in the WASP7 input file.

Table D-8. Calibration rates and coefficients for Choctawhatchee Bay water quality modeling

Water Quality Variable	Definition	Value	Minimum	Maximum
Phytoplankton	Phytoplankton Maximum Growth Rate Constant @20 °C (per day)	3.0	0	3
	Phytoplankton Growth Temperature Coefficient	1.07	0	1.07
	Phytoplankton Self Shading Extinction (Dick Smith Formulation)	0.017	0	0.02
	Phytoplankton Carbon to Chlorophyll Ratio	60	0	200
	Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	0.025	0	0.05
	Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	0.001	0	0.05
	Phytoplankton Endogenous Respiration Rate Constant @20 °C (per day)	0.100	0	0.5
	Phytoplankton Respiration Temperature Coefficient	1.05	0	1.08
	Phytoplankton Death Rate Constant (Non-Zooplankton Predation) (per day)	0.04	0	0.25
	Phytoplankton Zooplankton Grazing Rate Constant (per day)	0.00	0	5.0
	Phytoplankton Phosphorus to Carbon Ratio	0.01	0	0.24
	Phytoplankton Nitrogen to Carbon Ratio	0.43	0	0.43
	Phytoplankton Half-Sat. for Recycle of Nitrogen and Phosphorus (mg Phyt C/L)	0.00	0	1
Ammonia	Nitrification Rate Constant @20 °C (per day)	0.01	0	10
	Nitrification Temperature Coefficient	1.07	0	1.07
	Half Saturation Constant for Nitrification Oxygen Limit (mg O/L)	0.50	0	2
Nitrate-Nitrite	Denitrification Rate Constant @20 °C (per day)	0.10	0	0.09
	Denitrification Temperature Coefficient	1.02	0	1.04
	Half Saturation Constant for Denitrification Oxygen Limit (mg O/L)	0.01	0	0.1
Organic Nitrogen	DON Mineralization Rate Constant @20 °C (per day)	0.05	0	1.08
	DON Mineralization Temperature Coefficient	1.047	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Nitrogen	1.0	0	1
Organic Phosphorus	Mineralization Rate Constant for Dissolved Organic P @20 °C (per day)	0.05	0	0.22
	DOP Mineralization Temperature Coefficient	1.04	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Phosphorus	1.00	0	1

Water Quality Variable	Definition	Value	Minimum	Maximum
Light	Light Option (1 uses input light; 2 uses calculated diel light)	2	1	2
	Phytoplankton Maximum Quantum Yield Constant	720.0	0	720
	Phytoplankton Optimal Light Saturation	350.0	0	350
	Detritus and Solids Light Extinction Multiplier	0.17	0	10
	DOC1 Light Extinction Multiplier	0.12	0	10
DO	Water body Type Used for Wind Driven Reaeration Rate	2	0	3
	Calc Reaeration Option - O'Connor	1	0	4
	Reaeration Option -Sums Wind and Hydraulic Ka	1	0	1
	Theta -- Reaeration Temperature Correction	1.022	0	1.03
	Oxygen to Carbon Stoichiometric Ratio	2.66	0	2.67
CBOD	CBOD Decay Rate Constant @20 °C (per day)	0.10	0	5.6
	CBOD Decay Rate Temperature Correction Coefficient	1.04	0	1.07
	CBOD Half Saturation Oxygen Limit (mg O/L)	0.20	0	0.5
Detritus	Detritus Dissolution Rate (1/day)	0.100	0	0
	Temperature Correction for Detritus Dissolution	1.040	0	0

6.7 Water Quality Calibration and Validation Analysis

The results (Tables D3-7 to D3-14) of calibration and validation of water quality components of the Choctawhatchee Bay model are presented in Attachment 3 and graphical results are in the data files for the Choctawhatchee Bay model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Monthly measurements of chl-a, ammonia, and nitrate-nitrite, TN, TP, TSS, light attenuation coefficient, and DO at sixteen FDEP stations (Figure D3-2, Attachment 3) for 2002–2004 were used as calibration and validation data sets. Graphical analyses show the visual correspondence of the simulated values and measured data.

Table D3-7 shows comparisons of mean simulated and measured chl-a at five water quality monitoring stations for model calibration and validation. As shown in Table D3-7, the percent error values range from -40.2 to 42.2.

Table D3-8 shows comparisons of mean simulated and measured DO in surface and bottom layers, respectively, at four water quality monitoring stations. The percent error values range from -3.6 to 1.2 for surface layer and from -0.2 to 33.3 for bottom layer.

Tables D3-9 through D3-12 show comparisons of mean simulated to measured data at the water quality stations for TN, ammonia, nitrate-nitrite, and TP, respectively. The percent error values range from -26.3 to 120.8 for TN, -16.0 to 70.8 for ammonia, -78.3 to 46.2 for nitrate-nitrite, and -26.1 to 27.3 for TP.

Table D3-13 shows comparisons of mean simulated TSS in the surface layer and measured data at six water quality monitoring stations. The percent error values for TSS range from -52.6 to -7.2.

Table D3-14 shows the comparisons of mean simulated and measured light attenuation coefficients. The percent error values range from -18.1 to 41.3 percent.

6.8 Choctawhatchee Bay Model Summary and Conclusions

The hydrodynamic and water quality model for Choctawhatchee Bay was calibrated and validated for data collected in 2002–2004.

The EFDC hydrodynamic model represents the overall circulation and mixing characteristics of the Choctawhatchee Bay system on the basis of reasonable agreement between observed and calculated temporal and spatial distributions of WSE, salinity and temperature.

The WASP7 water quality model reasonably represents the overall phytoplankton, nutrient, and DO interactions in the Choctawhatchee Bay system. The water quality simulations show reasonable agreement with observed data.

Choctawhatchee Bay hydrodynamic and water quality model data sources are provided in Table D-9.

Table D-9. Choctawhatchee Bay hydrodynamic and water quality model data sources

Data	Source	Location Used
Atmospheric and Wind Data at Surface Airways Stations	National Climatic Data Center (EarthInfo 2009)	Choctawhatchee Bay Estuary Model
Bathymetric Data	National Oceanic and Atmospheric Administration, National Geophysical Data Center (NOAA GEODAS No Date)	Choctawhatchee Bay Estuary Model
Digitized Shoreline Data	National Oceanic and Atmospheric Administration (NOAA No Date a)	Choctawhatchee Bay Estuary Model
IWR Run 40 Salinity and Temperature Data	Florida Department of Environmental Protection (FDEP 2010a)	Choctawhatchee Bay Estuary Model
Measured and Predicted Water Surface Elevation Data	National Oceanic and Atmospheric Administration (NOAA No Date b)	Choctawhatchee Bay Estuary Model
Wastewater Facility Regulation Municipal and Industrial Point Sources Discharging Directly into Estuary	Florida Department of Environmental Protection (FDEP No Date)	Choctawhatchee Bay Estuary Model

7.0 ST. ANDREWS BAY MODEL

7.1 Physical Characteristics of the Model Study Area

St. Andrews Bay runs along the upper Gulf Coast from east to west for about 43 km (27 mi) with width ranging from 2 to 10 km (1 to 6 mi) (Figure D-13). The bay covers an estimated surface area of 348 km^2 in the Florida counties of Bay and Gulf. Water depths range from 3 to 13 m, with a mean depth of 3.8 m. The bay is connected to the Gulf of Mexico through a narrow passage located between Shell Island and Panama City Beach.

The major source of freshwater input is Deer Point Lake, which receives flows from several tributaries, with Econfina Creek as the largest contributor. Deer Point Lake and the other bay tributaries have significant groundwater contribution from springs and the Floridan aquifer (Ruth and Handley 2007). Several small creeks empty into the bay directly, most notable among them being Burnt Mill, Crooked, Cedar and Sandy creeks.

St. Andrews Bay is connected to the Gulf Intracoastal Waterway at the western end of West Bay. The Gulf Intracoastal Waterway is tidally influenced and connects to Choctawhatchee Bay to the west. At the eastern end of St. Andrews Bay, East Bay is connected to the Apalachicola Bay system and the Apalachicola River through the Gulf Intracoastal Waterway and Lake Wimico. During testing of the hydrodynamic model it was found that the physical connection of the Gulf Intracoastal Waterway to the eastern end of East Bay does not result in significant water mass transfer into and out of the St. Andrews Bay system. On the basis of this finding, it was concluded that this physical connection constitutes a nodal point. Accordingly, it was not included as an open tidal boundary in the hydrodynamic model. However, a tributary watershed input does enter East Bay at this point. Approximately 8 percent of the Apalachicola River flow enters the northeastern side of St. Joseph Bay, via the tidally influenced Gulf County Canal.

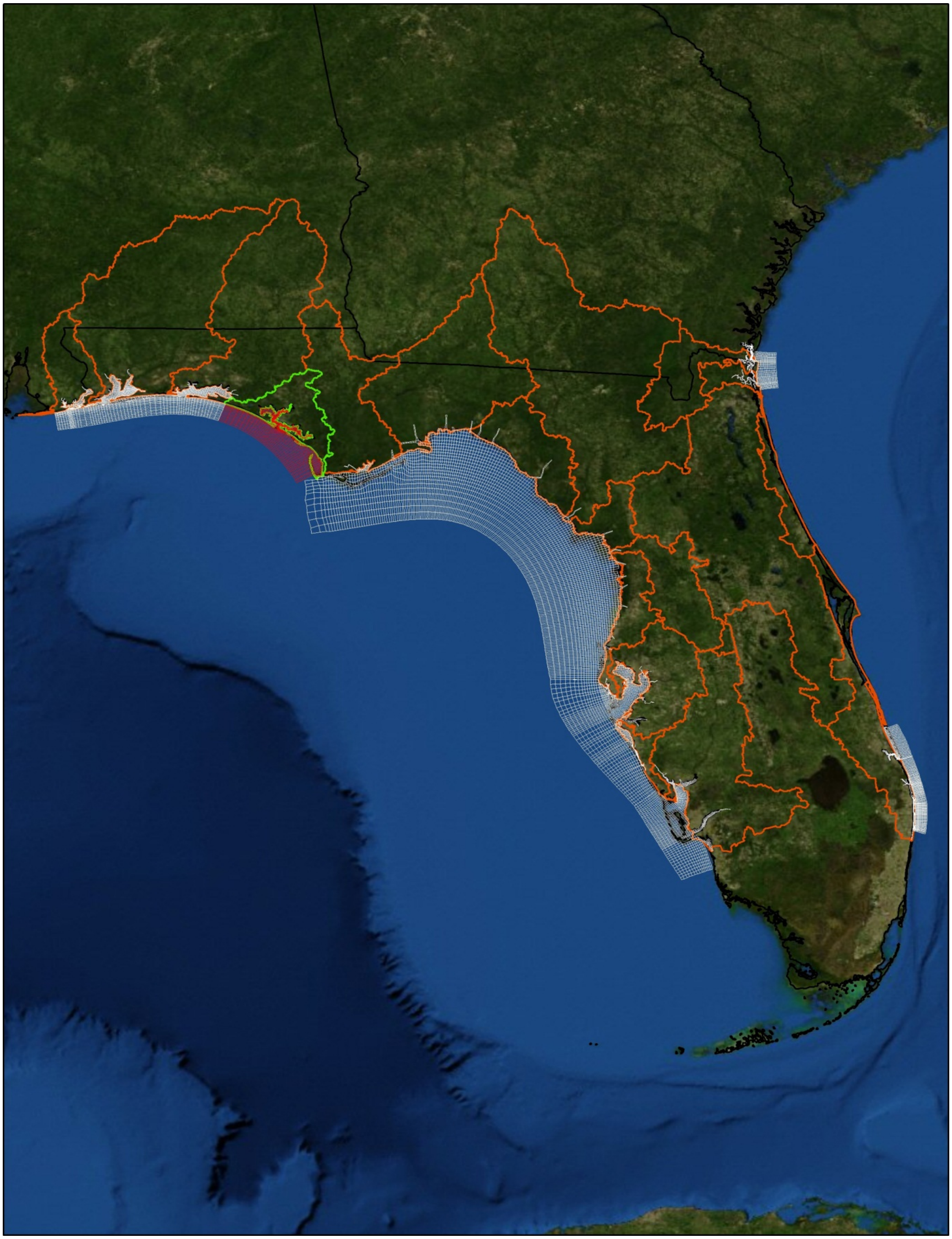


Figure D-13. St. Andrews Bay model and watershed location

7.2 Model Segmentation

The orthogonal, curvilinear grid system used in the hydrodynamic model is shown in Figure D-14. The grid consists of 1,439 horizontal cells and 4 equally spaced vertical layers. There are 41 offshore ocean boundary cells, 1 boundary cell at the Gulf Intracoastal Waterway connection to the western end of West Bay and 37 inland boundary cells receiving LSPC inputs.

The inland boundary cells receive LSPC simulated watershed discharges and point source discharges. The watershed boundary cells are marked in Figure D-14 and the point source locations are shown in Figure D-15. The watershed discharges were described in Appendix C. According to that report, freshwater flows from watersheds are calculated on the basis of geographical, hydrological and meteorological factors (land use/cover, landscape parameters, soils, air temperature, rainfall, and such). The major watersheds enter Deer Point Lake and are subsequently discharged from the lake outlet to the North Bay segment of St. Andrews Bay.

Bathymetry data for the Gulf of Mexico adjacent area and St. Andrews Bay were obtained from the National Geophysical Data Center. The bathymetry data were interpolated into the grid resulting in the grid bathymetry shown in Figure D-16.

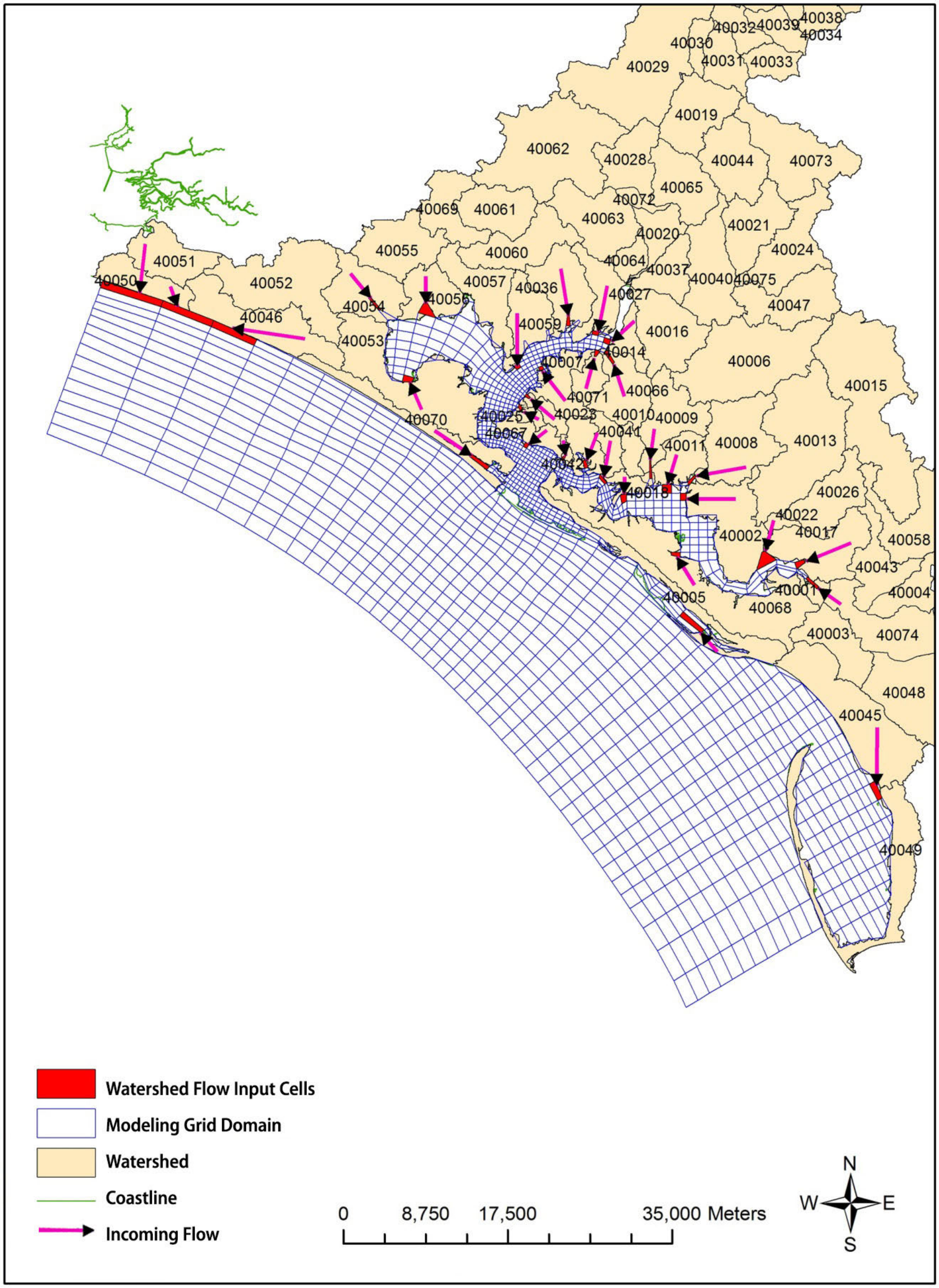


Figure D-14. Orthogonal curvilinear system of St. Andrews Bay

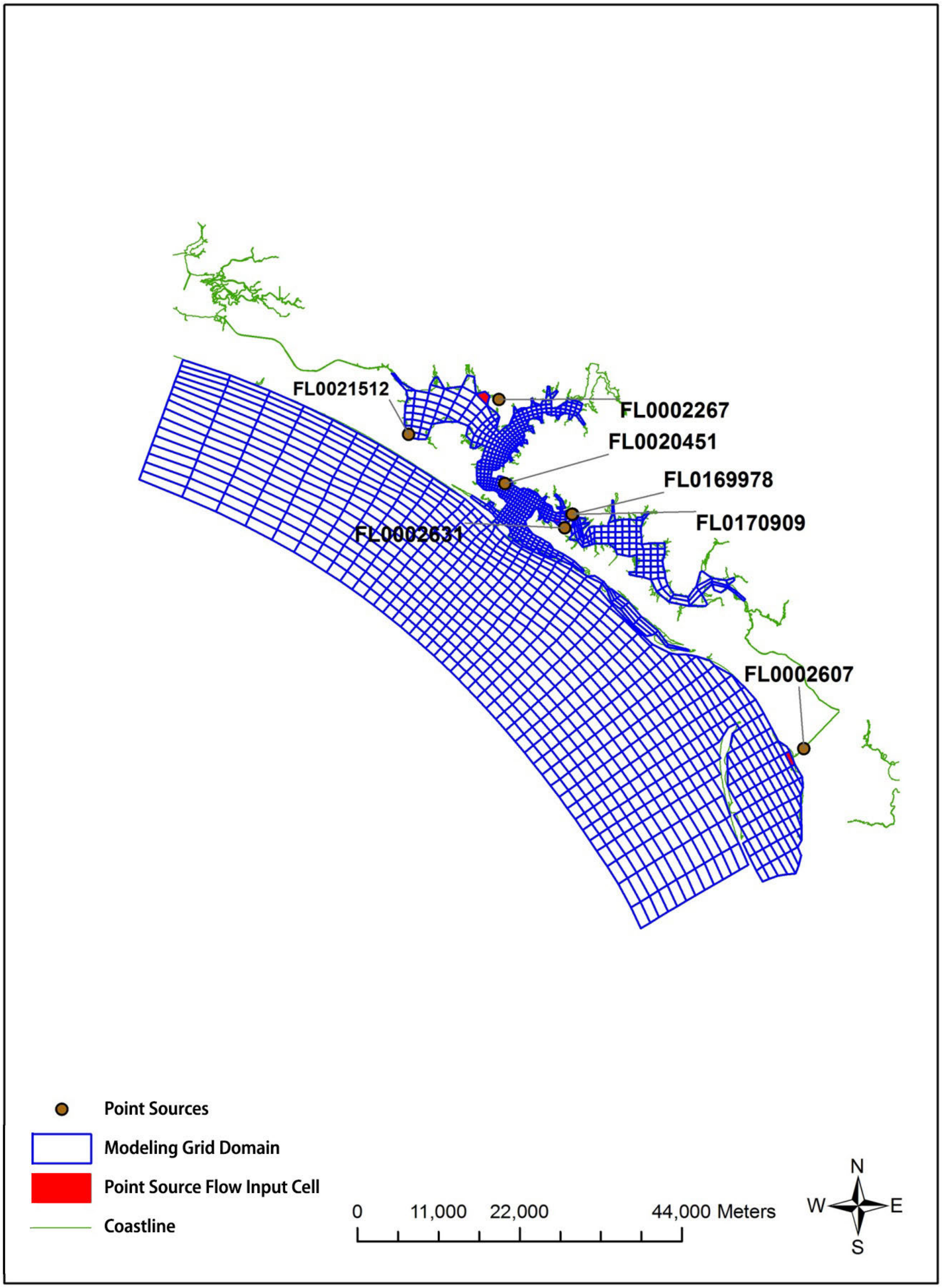


Figure D-15. Point sources in the St. Andrews Bay model

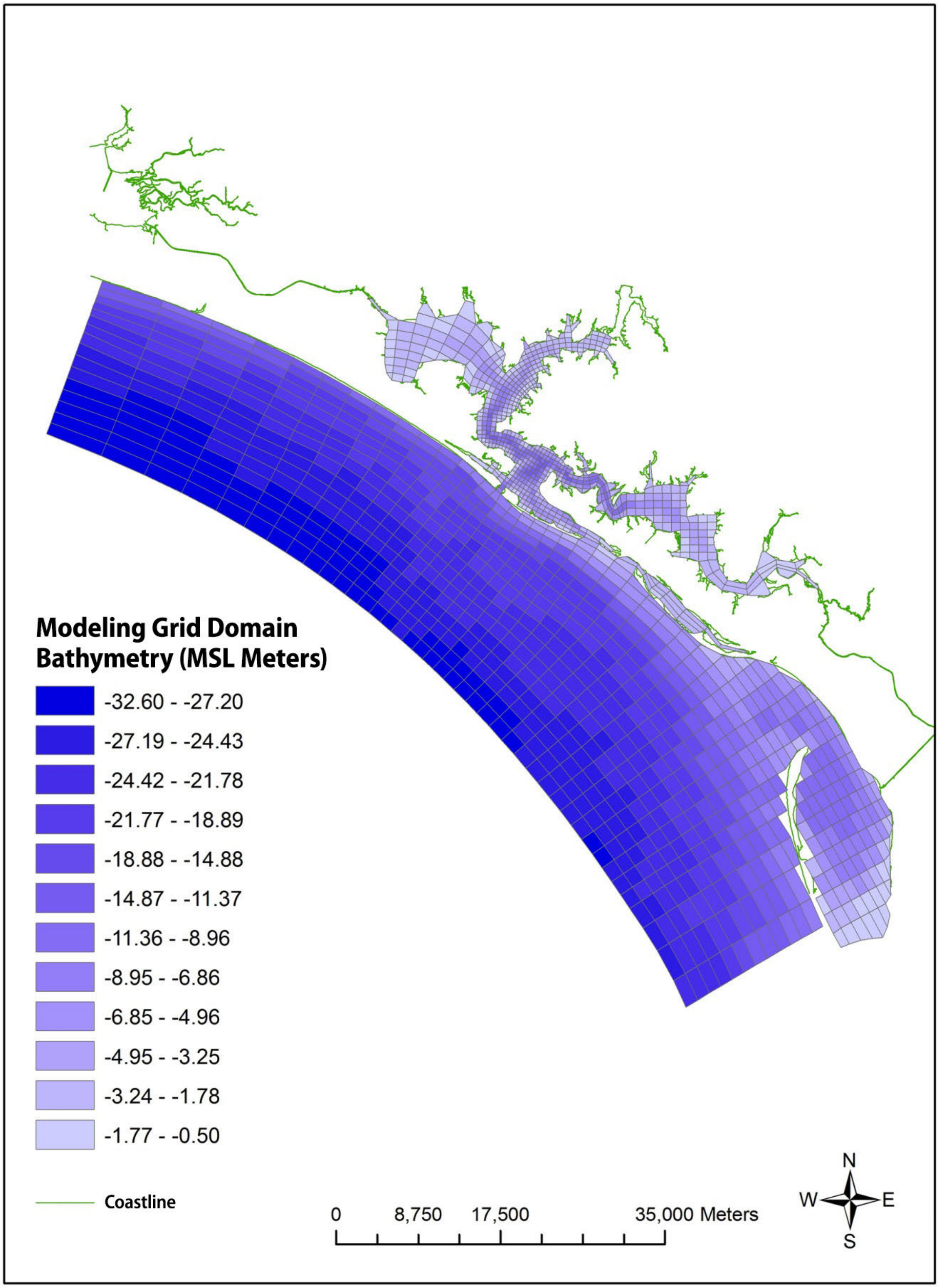


Figure D-16. St. Andrews Bay bathymetry

7.3 St. Andrews Bay Monitoring Stations

The calibration-validation process for the St. Andrews Bay model uses mostly data collected by FDEP and NOAA. Locations of the monitoring stations are shown in Attachment 4, Figures D4-1 and D4-2.

The data used for calibration-validation of the EFDC and WASP7-based models are:

- NOAA Panama City tidal station (station ID 8729108): 2004-2005 for calibration and 2006-2007 for validation WSE.
- FDEP 2004-2005 and 2006-2007 measurements of temperature and salinity at 10 and 13 monitoring stations, respectively, in St. Andrews and St. Joseph Bays.
- FDEP 2003-2005 measurements of water quality parameters at monitoring stations in St. Andrews and St. Joseph Bays.

The EFDC model was calibrated for salinity and temperature using data for the period 2004-2005 at 10 monitoring stations. The EFDC model was validated for salinity and temperature using data for the period of 2006-2007 at 13 monitoring stations.

The WASP7 model was calibrated for chl-a, DO, nutrients (ammonia, nitrate-nitrite, TN, and TP), TSS and light attenuation coefficient, using data for the period of 2003-2005.

7.4 Hydrodynamic Model Forcing Conditions

EFDC-based hydrodynamic modeling was conducted to reproduce the three-dimensional circulation dynamics and salinity and temperature structure in the bay system. The model predicts these parameters in response to multiple factors: wind speed and direction, freshwater discharge, water level fluctuation, rainfall, surface heat flux, and temperature and salinity associated with boundary fluxes.

Meteorological Factors

Hourly measurements of atmospheric pressure, dry and wet bulb atmospheric temperatures, rainfall rate, wind speed and direction, and fractional cloud cover were obtained from data collected at station WBAN 13899 Pensacola for 1997–2009. Solar shortwave radiation was calculated using the CE-QUAL-W2 method. The meteorological factors for the EFDC hydrodynamic model are in the ASER.INP file. The WSER.INP file includes hourly measurements of wind speed and direction.

Freshwater Flows and Temperature

The watershed flows and water temperatures discharged into St. Andrews and St. Joseph Bays and were calculated using the LSPC watershed model (Appendix C). The watershed input boundary cells are shown in Figure D-14. Freshwater flows and water temperatures from watersheds are included in files QSER.INP and TSER.INP, respectively.

Point Sources

Eight major point sources were included in the hydrodynamic and water quality model setup. These discharges are listed in Table D-10, along with their current average discharge rates. The locations of these point sources are shown in Figure D-15. The correspondent flow and temperature data are included in the files QSER.INP and TSER.INP. The Gulf Power Company non-contact cooling water canal intake from North Bay and canal discharge into West Bay was included in the hydrodynamic model as a withdrawal-return pair, with a constant 11 degree centigrade temperature rise above predicted ambient water temperatures within North Bay, at the location of the intake canal. This withdrawal-return pair was also included in the WASP7 model as a transfer of water mass and water quality constituent mass between the intake within North Bay and the discharge within West Bay.

Table D-10. Point sources for St. Andrews Bay model

Permit No	Name	Permit Flow (MGD)
FL0002267	Gulf Power Non-Contact Cooling Water	230.0
FL0002631	Bay County Regional WWTP	25.0
FL0167959	Military Point Regional AWT	0.3
FL0002607	Premier Chemicals Process Water	10.0
FL0020451	St. Andrews WWTP	2.5
FL0021512	Panama City Beach WWTP	3.5
FL0169978	Lynn Haven WWTP	1.5
FL0170909	Millville WWTP	2.7

Offshore Boundary WSE and Water Temperature

Hourly time series data of WSE from NOAA tidal station 8729108 (Panama City) were initially used as offshore boundary conditions in the hydrodynamic model. The timing and amplitude of these boundary conditions, which included the effects of the hydrodynamics of tidal flows into and within the bay, were adjusted during the WSE calibration. Adjustments in the timing and amplitude at the offshore ocean boundary were made by comparing observed data with WSE predictions at the location of the tidal station within the bay to get close agreement between predicted and measured WSE variations at Panama City. The datum used for WSE is mean sea level.

Observed water temperature data at the St. Andrews Bay monitoring stations, during the full monitoring period, were used in a spreadsheet to determine the phase (timing) and amplitude of a temperature sine curve. This calibrated sine curve was subsequently used to generate daily water temperature boundary conditions specified for all 4-layers in the hydrodynamic model, at the offshore and western Gulf Intracoastal Waterway open boundaries.

WSE and water temperatures specified at open boundaries of the EFDC model are included in files PSER.INP and TSER.INP, respectively.

Offshore Boundary Salinity

Because there is a lack of salinity field measurements close to the open boundary, a constant value of salinity (36 ppt) was selected as the open boundary condition, for all 4-layers. These salinity values are in general correspondence to average salinity in the northern part of the Gulf of Mexico. Salinity specified at the open tidal boundary at the Gulf Intracoastal Waterway connection to the western end of West Bay was set at a constant value of 30 ppt, for all 4-layers. Salinities specified at open boundaries in the EFDC hydrodynamic model are included in the file SSER.INP.

All offshore, Gulf Intracoastal Waterway and inland watershed input boundaries and point source inputs, as well as physical parameters input to the EFDC hydrodynamic model, are given in the EFDC master input file EFDC.INP.

7.5 Hydrodynamic Model Calibration and Validation Analysis

Results (Tables D4-1 to D4-6) of calibration and validation of the hydrodynamic components of the St. Andrews Bay model are presented in Attachment 4 and graphical results are in the data files for the St. Andrews Bay model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Water Surface Elevation

Hourly data of WSE at NOAA tidal station 8729108, Panama City were selected as the calibration and validation data set. The period of calibration is 2004–2005 and the validation period is 2006–2007. Graphical analyses demonstrate the close correspondence of the calibrated and validated model WSE output to NOAA observations at Panama City. Tables D4-1 and D4-2 present the calibration and validation statistics for predicted versus measured WSE, respectively. The mean difference between observed and simulated hourly WSE, sets is in the range of -3 to 0 cm for calibration and -3 to 2 for validation. The calibration and validation correlation coefficient (R^2) values of 0.91 and 0.94, respectively, show good correlation between simulations and observations.

Salinity

Salinity measurements at 10 FDEP monitoring stations for the period 2004-2005 were used as the calibration data set. Salinity measurements at 13 FDEP monitoring stations for the period 2006-2007 were used as the validation data set. Tables D4-3 and D4-4 present the calibration and validation error statistics, respectively, for predicted versus measured salinity. The percent error values range from -14 to 17 for calibration and from -32 to 7 for validation. Graphical analyses demonstrate good visual correspondence between the measured and simulated values of salinity, during the calibration and validation periods.

Temperature

Temperature measurements at 10 FDEP monitoring stations for the period 2004-2005 were used as the calibration data set. Temperature measurements at 13 FDEP monitoring stations for the period 2006-2007 were used as the validation data set. Tables D4-5 and D4-6 present the calibration and validation error statistics, respectively, for predicted versus measured temperature. The percent error values range from -3 to 36 for calibration and -6 to 27 for validation. Graphical analyses demonstrate good visual correspondence between the measured and simulated values of temperature, during the calibration and validation periods.

7.6 Water Quality Model Forcing Conditions

The selection of the WASP7 based water quality model's state variables is described in section 4.6.

Point and Nonpoint Sources Loads

Time series of watershed loads were obtained from LSPC simulations (Appendix C) for organic nutrients, TSS, CBOD and DO. Water quality constituent mass loads from point sources given in Table D-10 are discharged directly into the estuary input boundary grid cells (Figure D-15). The point source discharge values were obtained from DMR data in EPA's PCS.

Solar Radiation and Air Temperature

The meteorological data for WASP7 was the same used for the heat exchange simulation for the hydrodynamic EFDC model using data measured at station WBAN 13899, Pensacola.

Benthic Nutrient Fluxes and Sediment Oxygen Demand

Benthic ammonia nitrogen and phosphate nutrient fluxes were set to zero. A global bottom layer SOD value of 0.8 g/m^2/day was determined for St. Andrews and St. Joseph Bays, during the calibration process.

Reaeration

Reaeration processes for all water surface cells were calculated using the O'Connor-Dobbins option in WASP7.

Boundary Conditions

The offshore boundary conditions for the WASP7 model are presented in Table D-11.

Table D-11. Offshore concentration boundary conditions

Parameter	Concentration
Ammonia (mg/L)	0.02
Nitrate (mg/L)	0.02
Organic Nitrogen (mg/L)	0.1
Orthophosphate (mg/L)	0.004
Organic Phosphorus (mg/L)	0.004
Chl-a (ug/L)	2
Dissolved Oxygen (mg/L)	6.5
CBODu (mg/L)	2
Total Suspended Solids (mg/L)	5

Inland and offshore boundary conditions for detrital carbon, nitrogen and phosphorus components of the model were assumed as 0 mg/L.

Final calibration values for chemical and biological constants of the water quality model are presented in Table D-12.

All forcing functions, boundary conditions, calibration rates and constants are in the WASP7 input file.

Table D-12. Calibration Rates and Coefficients for the St. Andrews Bay WASP7 Water Quality Model

Water Quality Variable	Definition	Value	Minimum	Maximum
Phytoplankton	Phytoplankton Maximum Growth Rate Constant @20 °C (per day)	3.0	0	3
	Phytoplankton Growth Temperature Coefficient	1.070	0	1.07
	Phytoplankton Self Shading Extinction (Dick Smith Formulation)	0.017	0	0.02
	Phytoplankton Carbon to Chlorophyll Ratio	60.0	0	200
	Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	0.025	0	0.05
	Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	0.001	0	0.05
	Phytoplankton Endogenous Respiration Rate Constant @20 °C (per day)	0.10	0	0.5
	Phytoplankton Respiration Temperature Coefficient	1.050	0	1.08
	Phytoplankton Death Rate Constant (Non-Zooplankton Predation) (per day)	0.04	0	0.25
	Phytoplankton Zooplankton Grazing Rate Constant (per day)	0.00	0	5.0
	Phytoplankton Phosphorus to Carbon Ratio	0.010	0	0.24
	Phytoplankton Nitrogen to Carbon Ratio	0.43	0	0.43
	Phytoplankton Half-Sat. for Recycle of Nitrogen and Phosphorus (mg Phyt C/L)	0.005	0	1
Ammonia	Nitrification Rate Constant @20 °C (per day)	0.10	0	10
	Nitrification Temperature Coefficient	1.07	0	1.07
	Half Saturation Constant for Nitrification Oxygen Limit (mg O/L)	0.50	0	2
Nitrate-Nitrite	Denitrification Rate Constant @20 °C (per day)	0.10	0	0.09
	Denitrification Temperature Coefficient	1.020	0	1.04
	Half Saturation Constant for Denitrification Oxygen Limit (mg O/L)	0.01	0	0.1
Organic Nitrogen	DON Mineralization Rate Constant @20 °C (per day)	0.025	0	1.08
	DON Mineralization Temperature Coefficient	1.047	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Nitrogen	1.00	0	1
Organic Phosphorus	Mineralization Rate Constant for Dissolved Organic P @20 °C (per day)	0.03	0	0.22
	DOP Mineralization Temperature Coefficient	1.024	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Phosphorus	1.00	0	1

Water Quality Variable	Definition	Value	Minimum	Maximum
Light	Light Option (1 uses input light; 2 uses calculated diel light)	2	1	2
	Phytoplankton Maximum Quantum Yield Constant	720.0	0	720
	Phytoplankton Optimal Light Saturation	350.0	0	350
	Detritus and Solids Light Extinction Multiplier	0.17	0	10
	DOC1 Light Extinction Multiplier	1.80	0	10
DO	Water body Type Used for Wind Driven Reaeration Rate	2	0	3
	Calc Reaeration Option - O'Connor	1	0	4
	Reaeration Option -Sums Wind and Hydraulic Ka	1	0	1
	Theta -- Reaeration Temperature Correction	1.022	0	1.03
	Oxygen to Carbon Stoichiometric Ratio	2.66	0	2.67
CBOD	CBOD Decay Rate Constant @20 °C (per day)	0.10	0	5.6
	CBOD Decay Rate Temperature Correction Coefficient	1.040	0	1.07
	CBOD Half Saturation Oxygen Limit (mg O/L)	0.20	0	0.5
Detritus	Detritus Dissolution Rate (1/day)	0.10	0	0
	Temperature Correction for Detritus Dissolution	1.040	0	0

7.7 Water Quality Calibration and Validation Analysis

Results (Tables D4-7 to D4-14) of calibration and validation of water quality components of the St. Andrews Bay model are presented in Attachment 4. Graphical analyses in the data files for the St. Andrews Bay model demonstrate the visual comparisons of the calibrated and validated model run with observed data.

It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Monthly measurements of chl-a, ammonia, nitrate-nitrite, TN, TP, DO, TSS and light attenuation coefficient, during the years 2003-2005 were used as calibration-validation data sets.

Table D4-7 shows statistical comparisons of mean simulated and measured chl-a in the surface layer, for thirteen water quality monitoring stations. The percent error values ranged from -66 to 31.

Table D4-8 shows statistical comparisons of mean simulated and measured DO in the surface layer, for three water quality monitoring stations. The percent error values in Table D4-8 range from 6 to 9.

Table D4-9 shows statistical comparisons of mean simulated and measured light attenuation coefficient in the surface layer, for four water quality monitoring stations. The percent error values in Table D4-9 range from -52 to 31.

Table D4-10 shows statistical comparisons of mean simulated and measured ammonia in the surface layer, for two water quality monitoring stations. The percent error values in Table D4-10 range from -91 to -85.

Table D4-11 shows statistical comparisons of mean simulated and measured nitrate-nitrite in the surface layer, for two water quality monitoring stations. The percent error values in Table D4-11 are both -90.

Table D4-12 shows statistical comparisons of mean simulated and measured TN in the surface layer, for thirteen water quality monitoring stations. The percent error values in Table D4-12 range from -72 to 42.

Table D4-13 shows statistical comparisons of mean simulated and measured TP in the surface layer for thirteen water quality monitoring stations. The percent error values in Table D4-13 range from -48 to 15.

Table D4-14 shows statistical comparisons of mean simulated and measured TSS in the surface layer, for three water quality monitoring stations. The percent error values in Table D4-14 range from -66 to -40.

7.8 St. Andrews Bay Model Summary and Conclusions

The hydrodynamic and water quality model for St. Andrews Bay was calibrated and validated for data collected in 2003–2007.

The EFDC hydrodynamic model represents the overall circulation and mixing characteristics of the St. Andrews Bay system based on reasonable agreement between observed and calculated temporal and spatial distributions of WSE, salinity and temperature.

The WASP7 water quality model reasonably represents the overall phytoplankton, nutrient and DO interactions in the St. Andrews Bay system. In general, the water quality simulations show good agreement with the observed data.

St. Andrews Estuary hydrodynamic and water quality model data sources are provided in Table D-13.

Table D-13. St. Andrews Estuary hydrodynamic and water quality model data sources

Data	Source	Location Used
Atmospheric and Wind Data at Surface Airways Stations	National Climatic Data Center (EarthInfo 2009)	St. Andrews Estuary Model
Bathymetric Data	National Oceanic and Atmospheric Administration, National Geophysical Data Center (NOAA GEODAS No Date)	St. Andrews Estuary Model
Digitized Shoreline Data	National Oceanic and Atmospheric Administration (NOAA No Date a)	St. Andrews Estuary Model
IWR Run 40 Salinity and Temperature Data	Florida Department of Environmental Protection (FDEP 2010a)	St. Andrews Estuary Model
Measured and Predicted Water Surface Elevation Data	National Oceanic and Atmospheric Administration (NOAA No Date b)	St. Andrews Estuary Model
Wastewater Facility Regulation Municipal and Industrial Point Sources Discharging Directly into Estuary	Florida Department of Environmental Protection (FDEP No Date)	St. Andrews Estuary Model

8.0 FLORIDA BIG BEND MODEL

8.1 Physical Characteristics of the Model Study Area

The Florida Big Bend model runs along the Gulf Coast from Apalachicola Bay in the west to Clearwater Harbor in the east. The model covers six major estuarine systems and six 8-digit hydrologic units (HUC8) basins or watersheds. The model extends into the Gulf for more than 20 mi with depths ranging from 30 m at the ocean boundary to 1.5 m in the embayments.

The six major estuarine systems are

- Apalachicola Bay
- Alligator Harbor
- Ochlockonee Bay
- Apalachee Bay
- Suwannee, Waccasassa, and Withlacoochee estuaries
- Springs Coast estuarine area

Apalachicola Bay

Apalachicola Bay is a dynamic, highly productive estuary in the Florida Panhandle (see Figure D-17). The bay is a bar-built, subtropical estuary characterized by large quantities of freshwater inflows from the Apalachicola River. The bay is divided into four major parts: St. George Sound, Apalachicola Bay, East Bay, and St. Vincent Sound. The bay has an estuarine surface area of 539 km^2, a mean depth of 2.3 m, and mean residence time of 6 days. The major freshwater inflow is the Apalachicola River (FDEP 2010a).

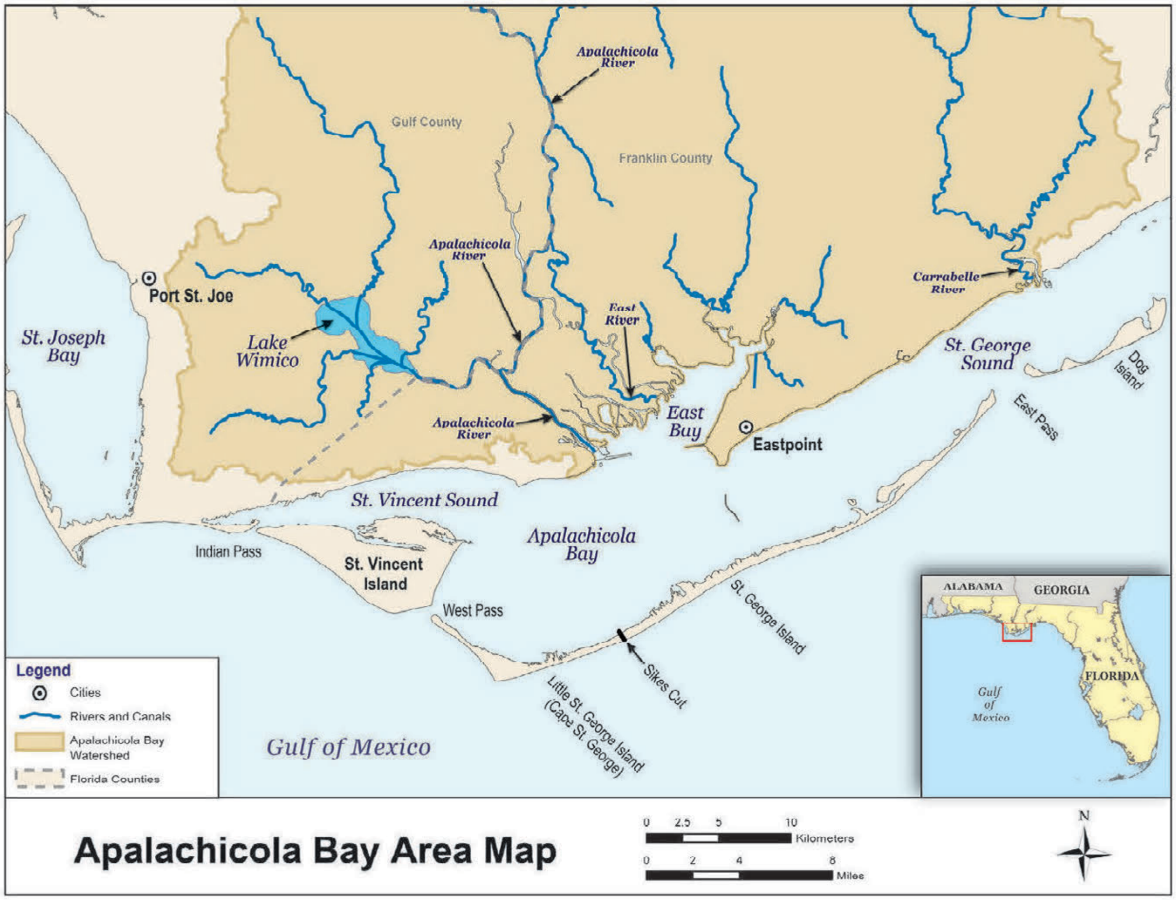


Figure D-17. Apalachicola Bay

Alligator Harbor

Alligator Harbor is a shallow, high-salinity lagoon partially separated from the nearshore Gulf of Mexico by barrier sand spit (see Figure D-18). Alligator Harbor is entirely within an FDEP aquatic preserve and is bordered by several prominent offshore shoal systems, including Dog Island Reef to the southwest, South Shoal to the southeast, and the Ochlockonee Shoal to the east. The bay has an estuarine surface area of 4,045 acres, a mean depth of 1.5 m, and minimal freshwater inflow (FDEP 2010a).

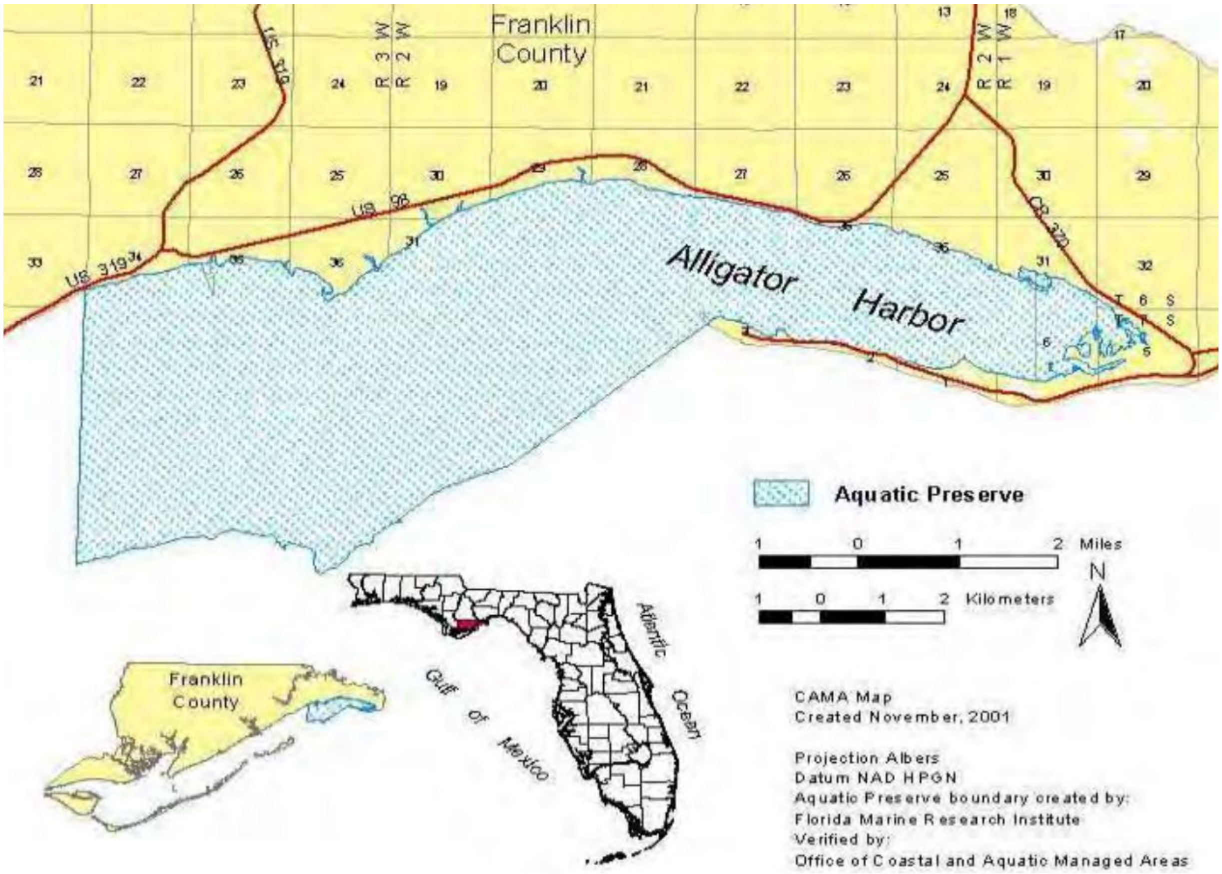


Figure D-18. Alligator Harbor (FDEP 2010b)

Ochlockonee Bay

Ochlockonee Bay is a coastal plain estuary east of Alligator Bay (see Figure D-19). The bay is small (8.5 km long by 2 km wide), rapidly flushed, well-mixed, and relatively shallow (1 to 2 m average depth). Extensive shoals (sand and mud flats) are throughout the bay, many becoming exposed at low tide. Ochlockonee Bay receives tannin-rich waters from the Ochlockonee–Sopchoppy River system. The bay has an estuarine surface area of 17 to 30 km^2, a mean depth of 1 to 2 m, and mean residence time of 10 days. The major freshwater inflow is the Ochlockonee River (FDEP 2010a).

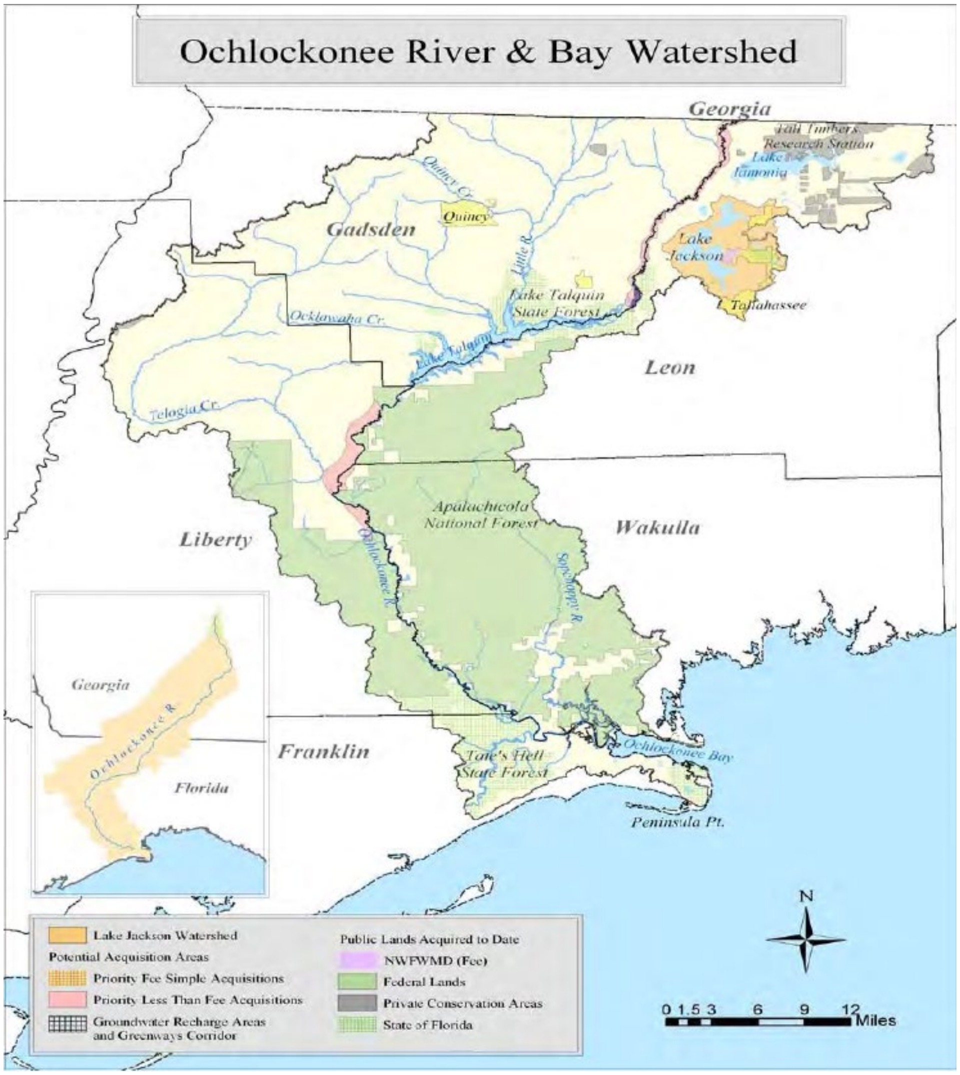


Figure D-19. Ochlockonee Bay (FDEP 2010c)

Apalachee Bay

Greater Apalachee Bay is a high-salinity, relatively shallow, wind-driven estuary in the Big Bend of Florida; adjacent to and contiguous with the Gulf of Mexico (see Figure D-20). The greater Apalachee Bay system extends from the area just east of Ochlockonee Bay to the Steinhatchee River and includes the Aucilla, Econfina, Fenholloway, and St. Marks rivers. Apalachee Bay comprises 85,112 acres, much of which is included in the Big Bend Seagrass Aquatic Preserve, which is also designated as an Outstanding Florida Water. That seagrass aquatic preserve includes most of the Wakulla and St. Marks rivers southward to the mouth of the Steinhatchee River. The net movement of water is from east to west, with the river inputs mixing with the more saline Gulf water (Site-Specific Information in Support of Establishing Numeric Nutrient Criteria in Greater Apalachee Bay, FDEP 2010a). The Steinhatchee River Estuary area is also included in the greater Apalachee Bay area.

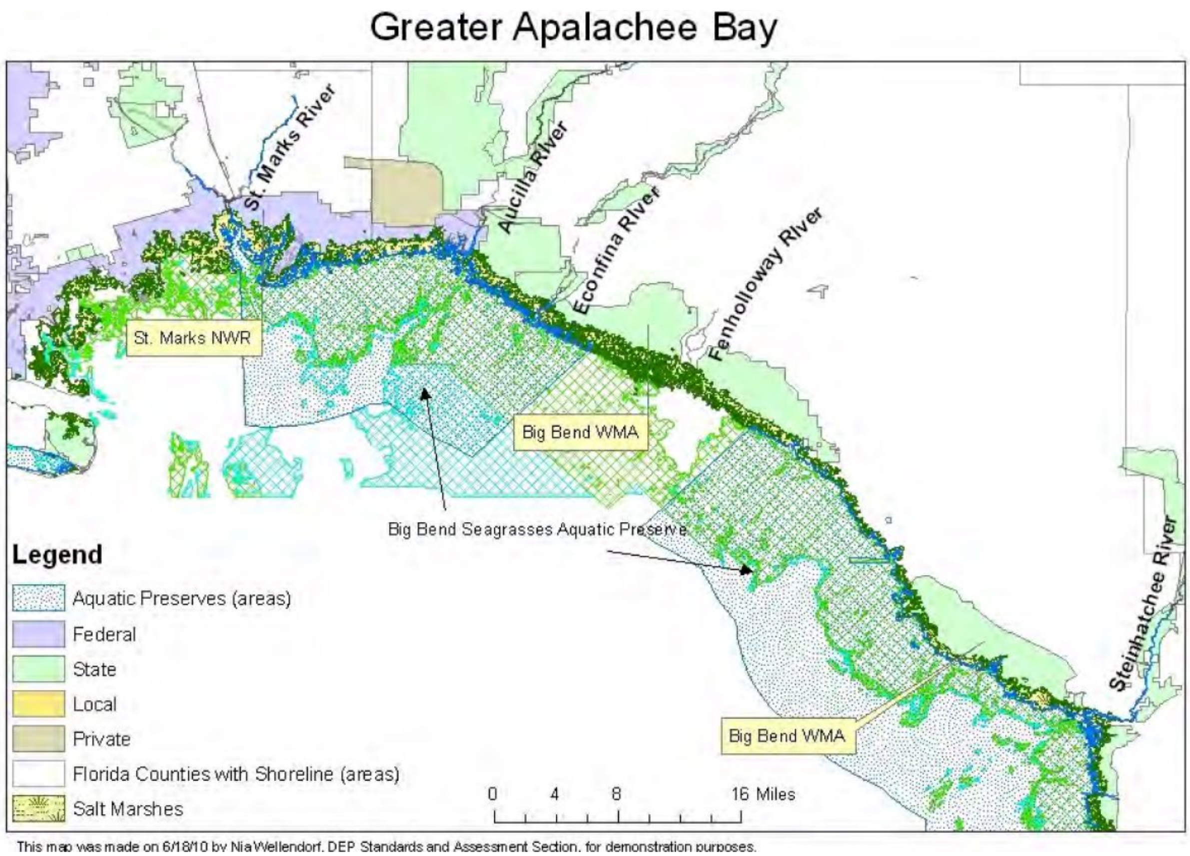


Figure D-20. Apalachee Bay (FDEP 2010d)

The Suwannee, Waccasassa, and Withlacoochee Estuaries

The Suwannee, Waccasassa, and Withlacoochee estuaries are open, shallow estuaries in Florida's Big Bend (see Figure D-21). The estuaries are fed by rivers with a high percentage of wetlands in their watersheds, so color and organic matter concentrations are high, which suppresses algal productivity in the rivers but naturally fuels it in the estuary. This portion of Florida's coast contains many conservation lands; therefore, wide expanses of swamps and coastal marshes remain intact to support the ecosystem and provide a filter between uplands and the coastal areas. The Suwannee, Waccasassa, and Withlacoochee estuaries have an estuarine surface area of 70, 40, 45 km^2, respectively and an average mean depth of approximately 2 m. The major freshwater inflows are the Suwannee, Waccasassa, and Withlacoochee rivers.

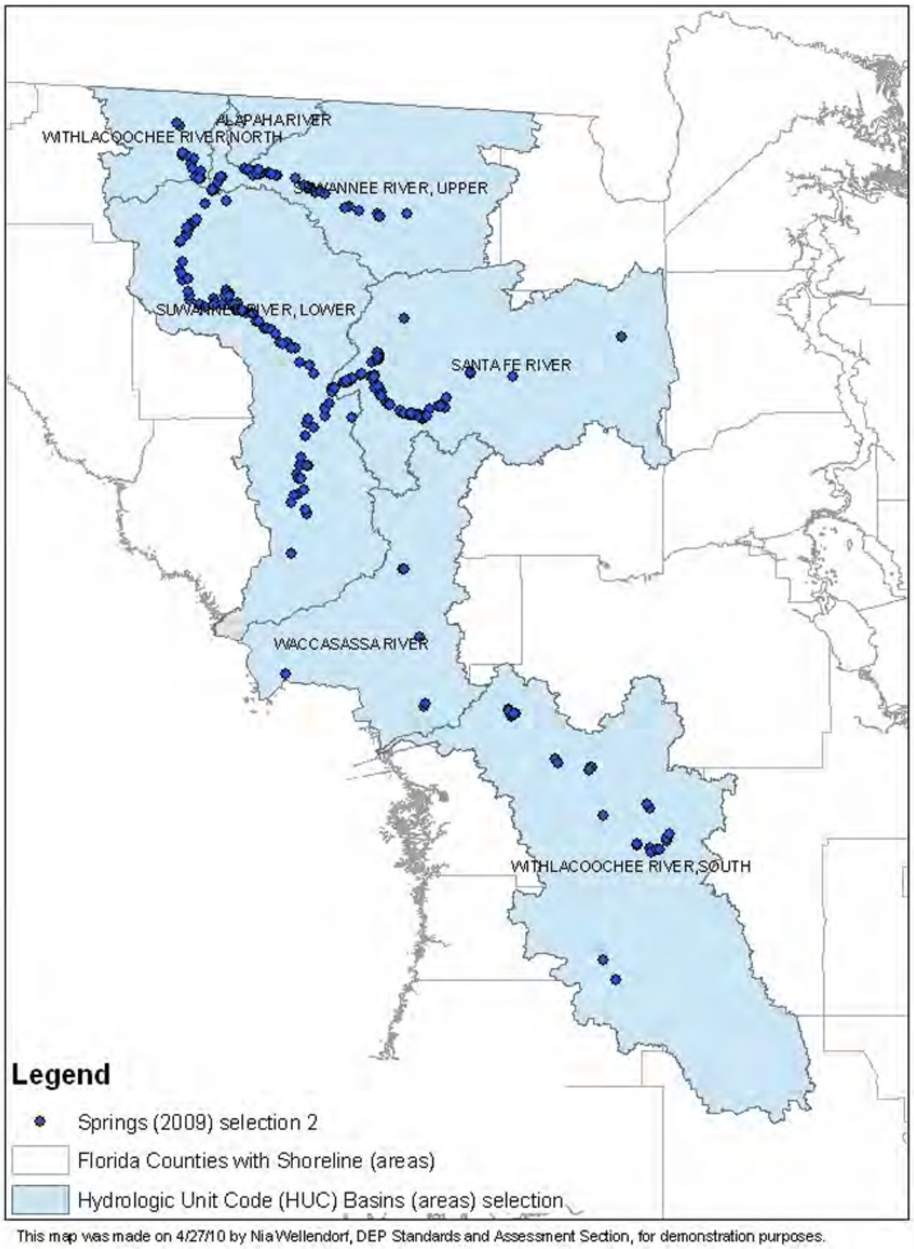
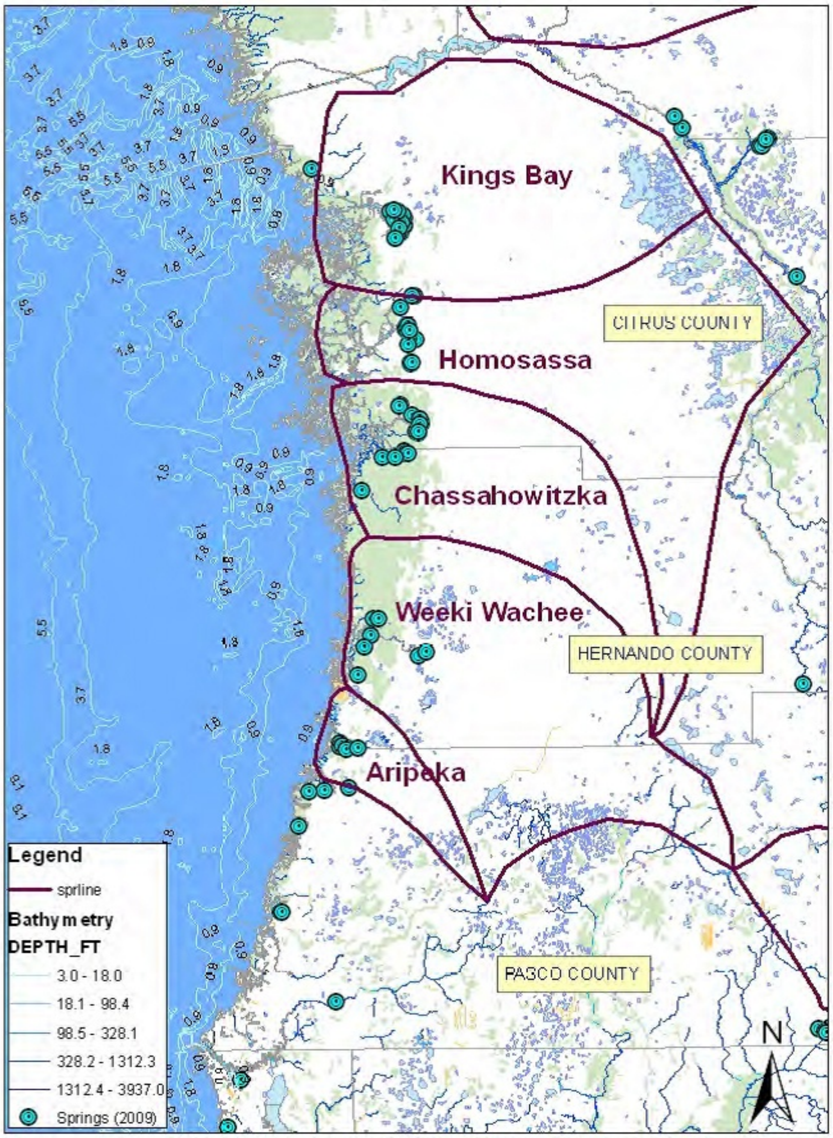


Figure D-21. Suwannee, Waccasassa, and Withlacoochee estuaries (FDEP 2010e)

Springs Coast Estuarine Area

The Springs Coast of Florida is a low-energy coastline that functions like an estuary, despite the lack of physical barriers and enclosures (see Figure D-22). The region is characterized by extensive tidal marshes and swamps, with much of the coastline in conservation land, and a wide continuous seagrass bed that extends 15–30 mi offshore in some areas because of the very shallow and clear water of the coastline. The Springs Coast watershed includes coastal areas off Citrus, Hernando, and Pasco counties, from Crystal River south to the Anclote River. The six major rivers in the watershed—Crystal, Homosassa, Chassahowitzka, Weeki Wachee, Anclote, and Pithlachascotee—their springs, and their associated coastal aquatic resources are dominant features. The coastline has very low relief, so the nearshore areas are very shallow with low wave energy. The coast contains numerous tidal creeks and salt marshes and isolated islands fringed with mangroves. The area has very few natural sandy beaches. Most of the region functions like an estuary, with its shallow waters, abundant freshwater flows, and low-energy shoreline. Seagrass beds cover almost the entire nearshore area where depths are sufficient, and extensive oyster reefs are also present. Vast salt marshes up to 10 mi wide provide a buffer between the upland land uses and the estuaries.



This map was made on 4/5/10 by Nia Wellendorf, DEP Standards and Assessment Section, for informational purposes.
Springshed coverage courtesy of SWFWMD, March 2010.

Figure D-22. Springs Coast estuarine area (FDEP 2010f)

8.2 Model Segmentation

An orthogonal, curvilinear grid system used in the hydrodynamic model is shown in Figure D-23. The grid consists of 3,995 horizontal cells and 4 equally spaced vertical σ layers. The system has 198 offshore boundary cells and 69 inland boundary cells.

The inland boundary cells receive LSPC simulated watershed discharges and point source discharges. The watershed input locations are marked in Figure D-24 and Figure D-25 and the point source locations are shown in Figure D-26. The watershed discharges are described in Appendix C. According to that report, freshwater flows from watersheds are calculated using geographical, hydrological, and meteorological factors (land use/cover, landscape parameters, soils, air temperature, rainfall, and such). The physical characteristics of the major watersheds and their rivers are discussed in Appendix C.

Bathymetry data for the Gulf of Mexico adjacent area and Apalachicola Bay were obtained from the National Geophysical Data Center. The bathymetry data were interpolated into the grid resulting in the grid bathymetry shown in Figure D-27.

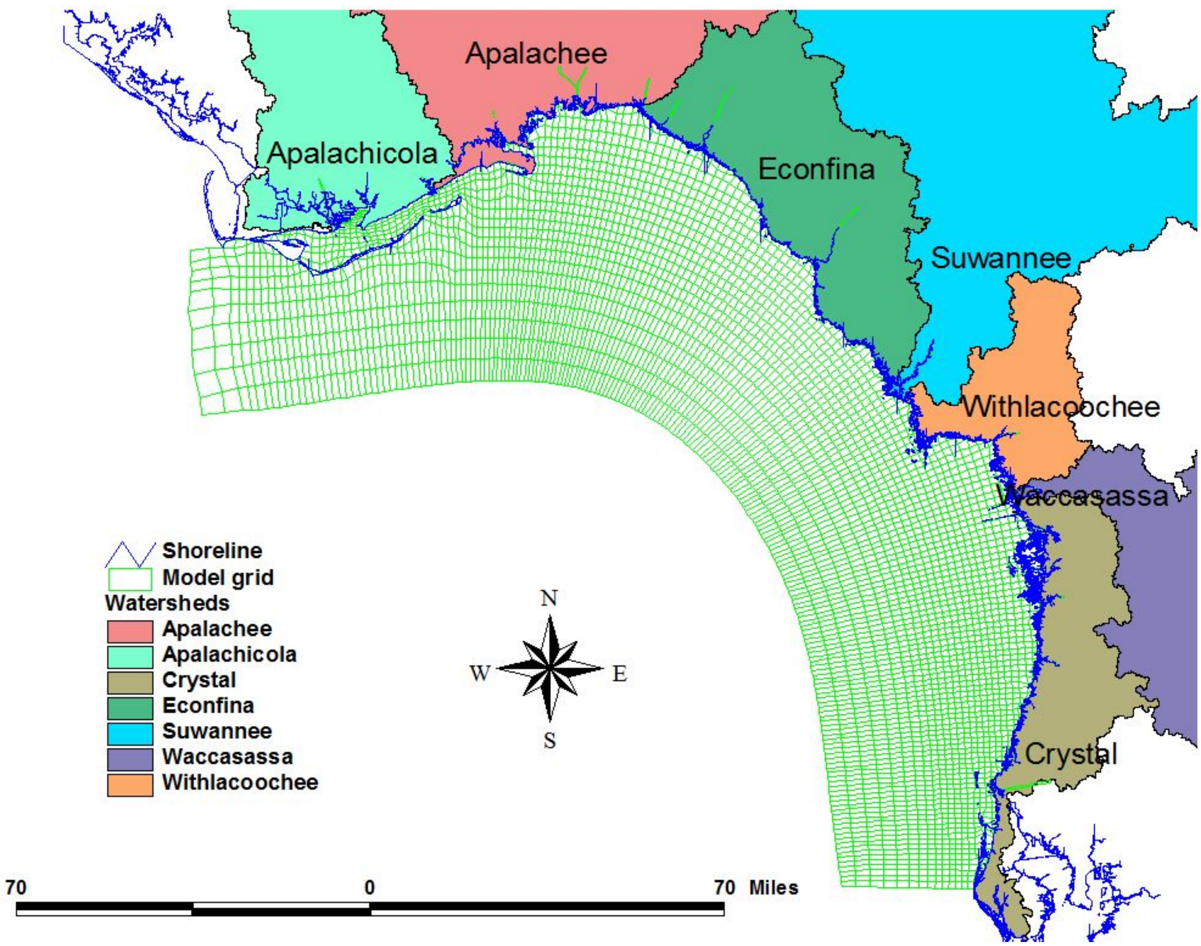


Figure D-23. Florida Big Bend model and watershed location

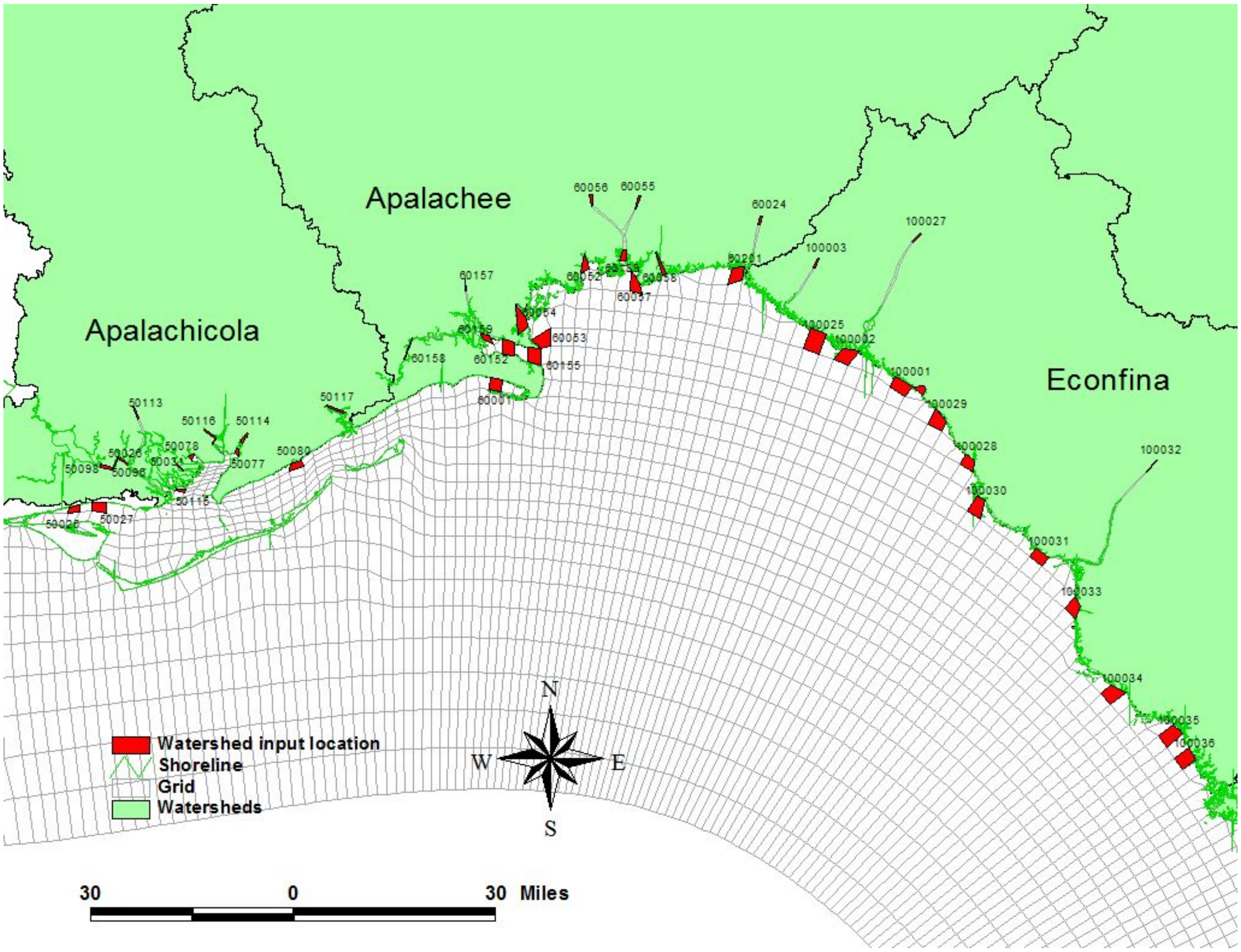


Figure D-24. LSPC watershed input locations for the Florida Big Bend model from the Apalachicola watershed to the Econfina watershed

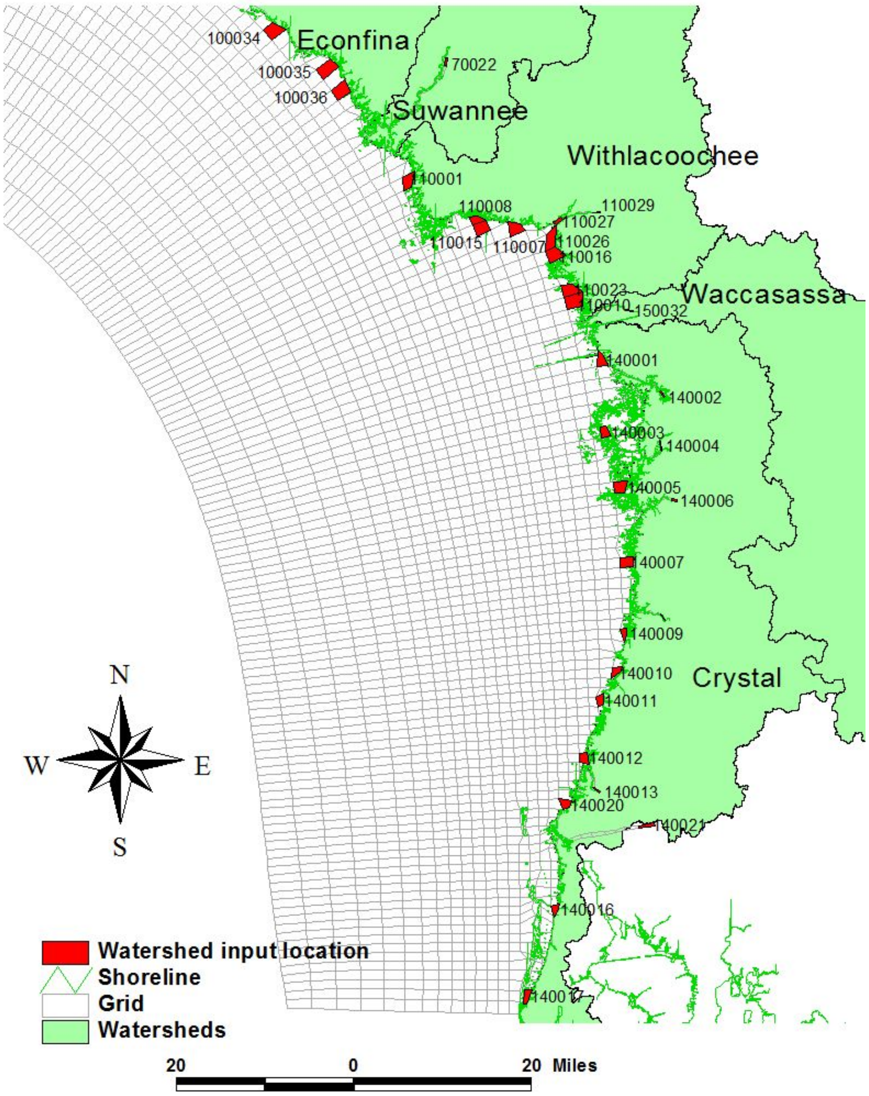


Figure D-25. LSPC watershed input locations for the Florida Big Bend model from the Econfina watershed to the Crystal watershed

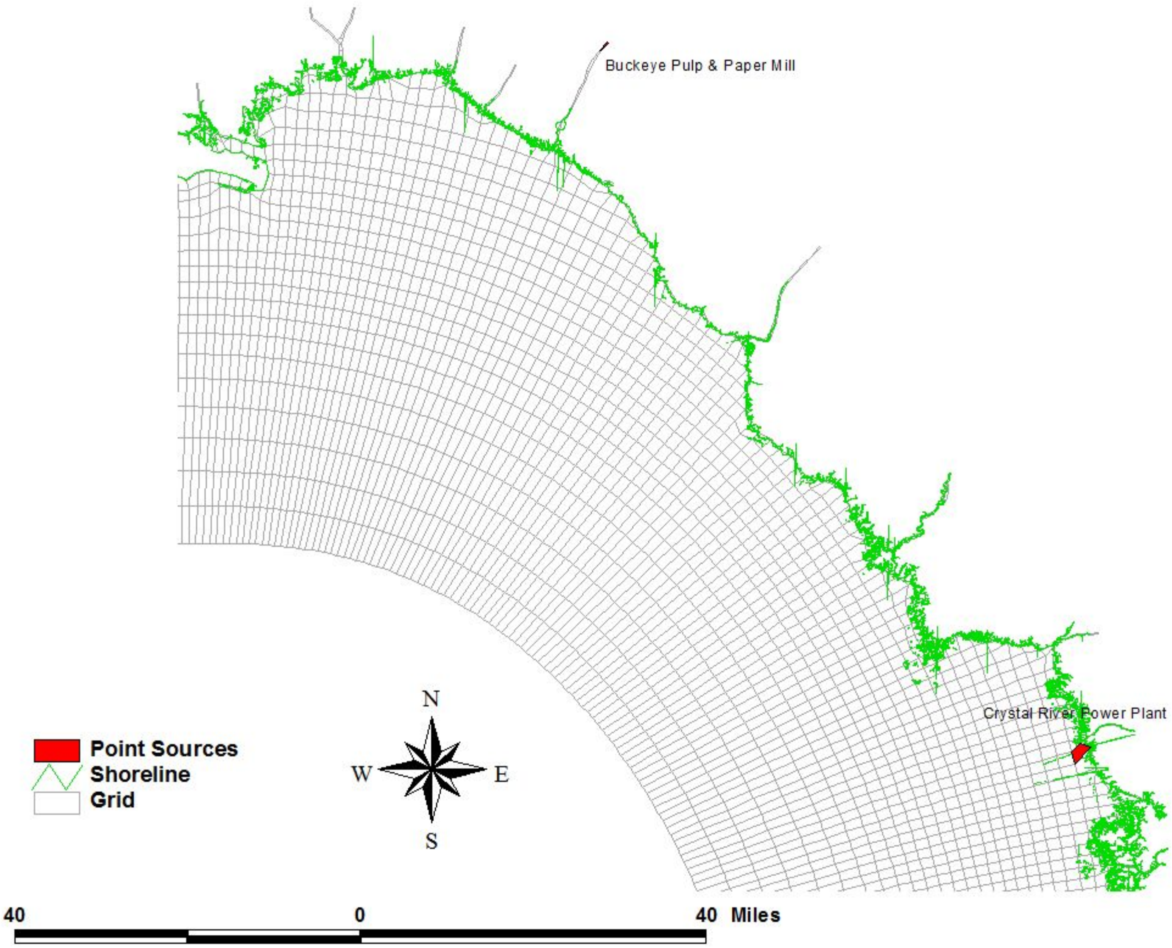


Figure D-26. Point source locations for the Florida Big Bend model

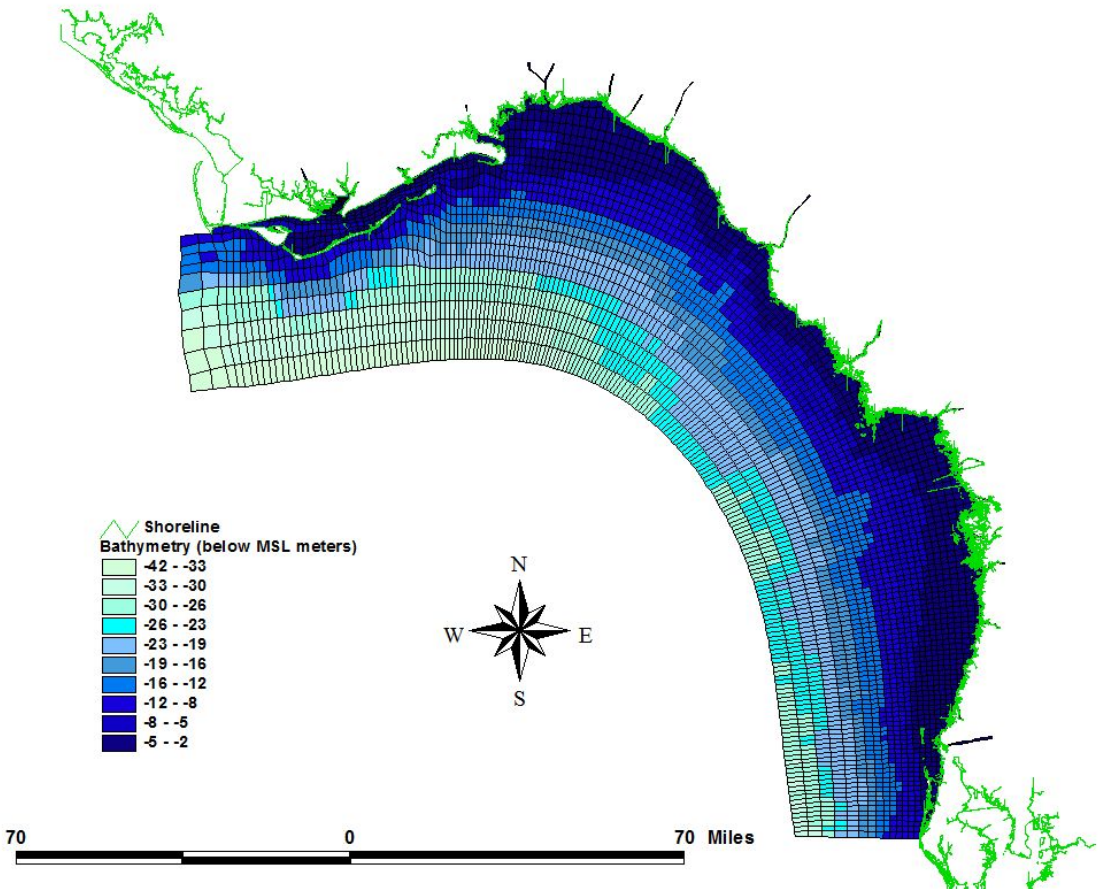


Figure D-27. Florida Big Bend bathymetry

8.3 Florida Big Bend Monitoring Stations

The calibration-validation process for the Florida Big Bend model uses mostly data that were assembled by FDEP in its Impaired Waters Rule (IWR) database and collected by NOAA at its Apalachicola, Cedar Key and Clearwater Beach tidal stations (Table D-14). The data used for calibration-validation of EFDC hydrodynamic and water quality based model are:

- NOAA tidal stations (Apalachicola, Cedar Key, and Clearwater Beach stations): 2003-2009 WSE for calibration and 1997-2002 WSE for validation.
- FDEP IWR database containing measurements of temperature and salinity at various monitoring stations in the Florida Big Bend area for 1997–2009. The samples were collected by various collection agencies that collected various types of data at various periods and locations in the same general area. Data that were collected at various monitoring stations near a model grid cell were grouped as one model cell station for model calibration. Because the data were combined from multiple stations and multiple locations and from all depths, the range of data for a given location and time is greater than would be expected from data collected at a single station. However this method of combining data provided a long-term period of record and the ability to assess the model performance over the period 1997–2009. That period has a wide range of flow, tidal, and meteorological conditions—from dry years to hurricane conditions and therefore provides a good predictive model for evaluating potential scenarios.

- FDEP IWR database containing measurements of water quality parameters at various monitoring stations in Florida Big Bend area for 1997–2009. These data were combined in the same manner as the salinity and temperature data.

Figures D5-1, D5-2, D5-3, and D5-4 (Attachment 5) show the locations of the various monitoring stations in the Florida Big Bend area. Table D5-1 (Attachment 5) provides a list of the monitoring stations.

Table D-14. NOAA tidal stations for 1997–2008

Station ID	Name
8728690	Apalachicola, FL
8727520	Cedar Key, FL
8726724	Clearwater Beach, FL

The EFDC hydrodynamic model was calibrated for 2003–2009 for salinity at 37 stations and for temperature at 35 stations. The entire period was used for calibration to include the full range of hydrodynamic conditions covered by the time period. The EFDC hydrodynamic model was validated for 1997–2002 for salinity at 36 stations and for temperature at 35 stations.

The EFDC water quality model was calibrated for DO, nutrients, chl-a, color, and light attenuation coefficient using data for 2003–2009. The entire period was used for calibration to include the full range of hydrodynamic conditions covered by the time period. For validation, data from 1997–2002 were used.

8.4 Hydrodynamic Model Forcing Conditions

EFDC-based hydrodynamic modeling was conducted to reproduce the three-dimensional circulation dynamics and salinity and temperature structure in the Florida Big Bend system. The model predicts these parameters in response to multiple factors: wind speed and direction, freshwater discharge, water level fluctuation, rainfall, surface heat flux, and temperature and salinity associated with boundary fluxes.

Meteorological Factors

Hourly measurements of atmospheric pressure, dry and wet bulb atmospheric temperatures, rainfall rate, wind speed and direction, and fractional cloud cover were obtained from data collected at two WBAN Stations, Apalachicola and Clearwater for 1997–2009. Solar shortwave radiation was calculated using the CE-QUAL-W2 method. The meteorological factors for the EFDC hydrodynamic model are in the ASER.INP file. The WSER.INP file has hourly measurements of wind speed and directions.

Freshwater Flows and Temperature

The watershed flows discharging into the Florida Big Bend and corresponding temperatures were calculated using the LSPC watershed model (Appendix C). The watershed input locations are shown in Figure D-24 and Figure D-25. Freshwater flows and water temperatures from watersheds are included in files QSER.INP and TSER.INP, respectively.

Point Sources

Two major point sources are included in the hydrodynamic and water quality model setup. These are the Buckeye (color only – flow, TSS and water quality parameters were input in the watershed model) and Crystal River Power Station (temperature). Buckeye discharge is on the Fenholloway River in the

Econfina watershed and the Power Plant is in Crystal River watershed. Locations are shown in Figure D-26, and their characteristic discharges are shown in Table D-15. The corresponding color and temperature data are in the files DSER.INP and EFDC.INP.

Table D-15. Florida Big Bend point sources

Permit No	Name	Discharger Average Flow (MGD)	
FL000861	Buckeye	42	Color added at 1200 – 1700 ntu
FL0036366	Progress Energy Florida - Crystal River Units 4 & 5	1800	Temperature added at 5 degrees C

Offshore Boundary WSE and Water Temperature

Hourly time series of WSE data from NOAA tidal stations previously mentioned were initially used as boundary conditions. The boundary conditions were adjusted in the WSE calibration by comparing observed data with WSE simulations at the location of the tidal station. The datum used for WSE is mean sea level.

Observed temperature data at monitoring stations near Apalachicola Bay were used as boundary conditions at the open boundaries. WSE and temperature at the open boundary for the EFDC model are included in files PSER.INP and TSER.INP, respectively.

Offshore Boundary Salinity

A lack of salinity field measurements exists close to the open boundary. As a result, a constant value of salinity (37 ppt) was selected as the open boundary condition. These salinity values are in general correspondence to average salinity in this part of the Gulf of Mexico and similar to the maximum salinities measured in the Florida Big Bend area. Salinity at open boundary for the EFDC model is included in the file SSER.INP.

All offshore and inland boundaries, as well as physical parameters of the hydrodynamic model are presented in the input file EFDC.INP.

8.5 Hydrodynamic Model Calibration and Validation Analysis

Results (Table D5-2 to D5-7) of calibration and validation of the hydrodynamic components of the Florida Big Bend area model are presented in Attachment 5 and graphical results are in the data files for the Big Bend model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Water Surface Elevation

Hourly data of WSE at NOAA tidal stations were selected as the calibration data set. The period of calibration is 2003–2009. Table D5-2 (Attachment 5) presents statistics of WSE. The errors or simulation-observation differences in the table are presented in meters. Percent errors were not used because the mean WSE values are so close to zero making the percent numbers unreasonable. The table also presents 5th and 95th WSE percentiles that allow one to estimate the WSE dynamic range.

The calibration results show the high accuracy of the modeling. The mean difference between observed and simulated hourly WSE sets are in the range of -1 to 4 cm for the calibration data set. Correlation coefficient (R^2) values of 0.88, 0.94, and 0.90 show good correlation between simulations and observations.

Table D5-3 shows the WSE validation results. The validation process uses observations at the same stations for 1997–2002. The mean difference between observed and simulated hourly WSE sets are in the range of -2 to 3 cm for the validation data set. Correlation coefficient (R^2) values of 0.88, 0.94, and 0.89 show good correlation between simulations and observations. Graphical analyses demonstrate close correspondence of the calibrated model WSE output to NOAA observations for the calibration and validation periods.

Salinity

Salinity measurements at 37 Florida Big Bend monitoring stations for 2003–2009 were used as the calibration data set and at 36 Florida Big Bend monitoring stations for 1997–2002 for the validation data set. Tables D5-4 and D5-5 present the calibration and validation statistics for salinity, respectively.

The Florida Big Bend model cell salinity results were compared to all the measured data that were combined near the respective model cell sampling location. These samples were collected by several agencies that collected data at various periods and locations in the same general area. Data that were collected at various monitoring stations near a model grid cell were combined as one model cell station for model calibration as shown in Table D5-1. Because the data were combined from multiple stations and multiple locations and from all depths, the range of data for a given location and time is greater than would be expected from data collected at a single station.

That method of combining data provided a long-term period of record and the ability to assess the model performance over the period 1997–2009. That period of record has a wide range of flow, tidal, and meteorological conditions—from dry years to hurricane conditions and, therefore, provides a good predictive model for evaluating potential scenarios. On the basis of the range of data at the model cell stations, the mean percent error ranges from -89 to 449 for the calibration period and -91 to 251 for the validation period. Because the model covers a very large area with almost 200 mi of open boundary, the calibration was targeted at the near shore area in the Econfina Basin region resulting in higher localized errors in a few stations near the Steinhatchee, Fenholloway and Econfina Rivers. Although these relative percent errors are large, the predictions are still informative in that area to illustrate the trend of decreasing salinity from top of river to the river mouth. Calibration and validation graphical analyses demonstrate good visual correspondence between the measured and simulated values of salinity. A visual examination illustrates that the model is predicting the seasonal salinity trends for the wide range of flow, tidal, and meteorological conditions.

Temperature

Temperature measurements at 35 Florida Big Bend monitoring stations for 2003–2009 were used as the calibration data set and 1997–2002 for the validation data set. Tables D5-6 and D5-7 present the calibration and validation statistics for temperature, respectively.

The Florida Big Bend model cell temperature results were compared to all the measured data combined near the respective model cell sampling location. The samples were collected by various agencies that collected various types of data at various periods and locations in the same general area. Data that were collected at various monitoring stations near a model grid cell were combined as one model cell station for model calibration. Because the data were combined from multiple stations and multiple locations and from all depths, the range of data for a given location and time is greater than would be expected from data collected at a single station. However this method of combining data provided a long-term period of record and the ability to assess the model performance over 1997–2009. That period of record has a wide range of flow, tidal, and meteorological conditions—from dry years to hurricane conditions and, therefore, provides a good predictive model for evaluating potential scenarios. On the basis of the range of data at the model cell stations, the mean percent error values range from -9.6 to 13.2 for the calibration period and -17.3 to 18 for the validation period (Tables D5-6 and D5-7). Graphical analyses demonstrate good visual correspondence between the measured and simulated values of temperature. A visual examination shows that the model is predicting the seasonal temperature trends for the wide range of flow, tidal, and meteorological conditions.

8.6 Water Quality Model Forcing Conditions

The selection of the EFDC ICM-based water quality model was necessary because of the large size of the grid, which WASP7 model could not handle. The EFDC water quality input parameters were set to match the WASP7 parameters, and the state variables are described in the Pensacola Bay model description.

Nonpoint Sources Loads

Time series of watershed loads were received by LSPC simulations (Appendix C) for dissolved mineral and organic nutrients, TSS, CBOD, and DO.

Solar Radiation and Air Temperature

The meteorological data for WASP7 was the same used for the heat exchange simulation for the hydrodynamic EFDC model using data measured at the Apalachicola and Clearwater WBAN stations.

Benthic Nutrient Fluxes and Sediment Oxygen Demand

Ammonia nitrogen and phosphate nutrient fluxes and SOD values were selected on the basis of observations and analysis in the Florida Big Bend area. These fluxes were adjusted in the calibration process.

Reaeration

The reaeration process in EFDC water quality model was calculated using the O'Connor-Dobbins option.

Boundary Conditions

The offshore boundary conditions for the WASP7 model are presented in Table D-16.

Table D-16. Offshore concentration boundary conditions

Parameter	Concentration
Ammonia (mg/L)	0.02
Nitrate (mg/L)	0.025
Organic Nitrogen (mg/L)	0.1
Orthophosphate (mg/L)	0.01
Organic Phosphorus (mg/L)	0.02
Chl-a (ug/L)	2
Dissolved Oxygen (mg/L)	Time series calculated at 85% of Temperature saturation
CBODu (mg/L)	2.7
Total Suspended Solids (mg/L)	2

Final calibration values for chemical and biological parameters and constants of the water quality model are presented in Table D-17. All forcing functions, boundary conditions, calibration rates, and constants are in the EFDC water quality input files EFDC.inp and WQ3DWC.inp.

Table D-17. Water quality model input parameters

Water Quality Variable	Definition	Value
Phytoplankton	Phytoplankton Maximum Growth Rate (per day)	2.5
	Lower Optimal Temperature for Phytoplankton Growth (°C)	15.0
	Upper Optimal Temperature for Phytoplankton Growth (°C)	25.0
	Suboptimal Temperature Effect Coefficient for Phytoplankton Growth	0.004
	Superoptimal Temperature Effect Coefficient for Phytoplankton Growth	0.007
	Phytoplankton Basal Metabolism Rate @20 °C (per day)	0.05
	Temperature Effect Coefficient for Phytoplankton Metabolism	0.032
	Predation Rate on Phytoplankton (per day)	0.10
	Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	0.005
	Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	0.005
	Phytoplankton Carbon to Chlorophyll Ratio (mg C/ µg Chl-a)	0.060
	Phytoplankton Nitrogen to Carbon	0.167

Water Quality Variable	Definition	Value
Organic Carbon	Dissolution Rate of Organic Carbon @20 °C (per day)	0.01
	Temperature Effect Constant for Hydrolysis	0.069
	Temperature Effect Constant for Mineralization	0.069
	Oxic Respiration Half Saturation Constant for DO (mg O2/L)	0.50
	Ratio of Denitrification Rate to Oxic Respiration Rate	0.50
	Half Saturation Constant for Denitrification (mg N/L)	0.10
Ammonia	Maximum Nitrification Rate (mg/L N/day)	0.3
	Reference Temperature for Nitrification (°C)	30
	Suboptimal Temperature Effect Constant for Nitrification	0.0045
	Superoptimal Temperature Effect Constant for Nitrification	0.0045
	Nitrification Half Saturation Constant for DO (mg O/L)	1
	Nitrification Half Saturation Constant for Ammonium (mg N/L)	0.1
Organic Nitrogen	Hydrolysis Rate of Organic Nitrogen (per day)	0.03
Organic Phosphorus	Hydrolysis Rate of Organic Phosphorus (per day)	0.05
Light	Detritus and Solids Light Extinction Multiplier	0.17
	DOC1 Light Extinction Multiplier	0.12
DO	Reaeration Option	O'Connor
	Temperature Rate Constant for Reaeration	1.024
	Oxygen to Carbon Stoichiometric Ratio	2.66

8.7 Water Quality Calibration and Validation Analysis

Results (Tables D5-8 to D5-23) of calibration and validation of water quality components of the Florida Big Bend model are presented in Attachment 5 and graphical results are in the data files for the Big Bend model. Monthly measurements of chl-a, ammonia, nitrate-nitrite, TN, TP, DO, color and light attenuation were used as calibration and validation data sets. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Samples were collected by several agencies that collected data at various periods and locations in the same general area. Data that were collected at various monitoring stations near a model grid cell were combined as one model cell station for model calibration. Because the data were combined from multiple stations and multiple locations and from all depths, the range of data for a given location and time is greater than would be expected from data collected at a single station. However this method of combining data provided a long-term period of record and the ability to assess the model performance over 1997–2009. That period of record has a wide range of flow, tidal, and meteorological conditions—from dry years to hurricane conditions and, therefore, provides a good predictive model for evaluating potential scenarios.

Table D5-8 shows comparisons of mean simulated and measured chl-a at twelve water quality monitoring stations for 2003–2009. Table D5-9 shows comparisons of mean simulated and measured chl-a at nine water quality monitoring stations for 1997–2002. Graphical analyses illustrate the chl-a trends for the corresponding time periods and monitoring stations. The mean percent error values range from -90 to -27 for calibration and -78 to 136 for validation.

Table D5-10 shows comparisons of mean simulated and measured DO at forty-five water quality monitoring stations for 2003–2009. Table D5-11 shows comparisons of mean simulated and measured DO at thirty-eight water quality monitoring stations for 1997–2002. Graphical analyses illustrate the DO trends for the corresponding time periods and monitoring stations. The mean percent error values range from -22 to 21 for calibration and -28 to 13 for validation.

Table D5-12 shows comparisons of mean simulated and measured TN at twelve water quality monitoring stations for 2003–2009. Table D5-13 shows comparisons of mean simulated and measured TN at fourteen water quality monitoring stations for 1997–2002. Graphical analyses illustrate the TN trends for the corresponding time periods and monitoring stations. The mean percent error values range from -39.1 to 11.0 for calibration and -45.8 to 84.8 for validation.

Table D5-14 shows comparisons of mean simulated and measured ammonia at seventeen water quality monitoring stations for 2003–2009. Table D5-15 shows comparisons of mean simulated and measured ammonia at eleven water quality monitoring stations for 1997–2002. Graphical analyses illustrate the ammonia trends for the corresponding time periods and monitoring stations. The mean percent error values range from -78 to 154 for calibration and -75 to 198 for validation.

Table D5-16 shows comparisons of mean simulated and measured nitrate-nitrite at seventeen water quality monitoring stations for 2003–2009. Table D5-17 shows comparisons of mean simulated and measured nitrate-nitrite at fifteen water quality monitoring stations for 1997–2002. Graphical analyses illustrate the nitrate-nitrite trends for the corresponding time periods and monitoring stations. The mean percent error values range from -76 to 912 for calibration and -74 to 969 for validation.

Table D5-18 shows comparisons of mean simulated and measured TP at twenty-seven water quality monitoring stations for 2003–2009. Table D5-19 shows comparisons of mean simulated and measured TP at thirty-five water quality monitoring stations for 1997–2002. Graphical analyses illustrate the TP trends for the corresponding time periods and monitoring stations. The mean percent error values range from -92 to 33 for calibration and -81 to 51 for validation.

Table D5-20 shows comparisons of mean simulated and measured color at twenty-five water quality monitoring stations for 2003–2009. Table D5-21 shows comparisons of mean simulated and measured color at twenty-two water quality monitoring stations for 1997–2002. Graphical analyses illustrate the color trends for the corresponding time periods and monitoring stations. The mean percent error values range from -44 to 268 for calibration and 47 to 614 for validation.

Table D5-22 shows comparisons of mean simulated and measured light attenuation coefficient at eleven water quality monitoring stations for 2003–2009. Table D5-23 shows comparisons of mean simulated and measured light attenuation coefficient at twelve water quality monitoring stations for 1997–2002. Graphical analyses illustrate the light attenuation coefficient trends for the corresponding time periods and monitoring stations. The mean percent error values range from 18 to 311 for calibration and 18 to 441 for validation.

8.8 Florida Big Bend Model Summary and Conclusions

The hydrodynamic and water quality model for Florida Big Bend was calibrated and validated for data collected for 1997–2009.

The EFDC hydrodynamic model represents the overall circulation and mixing characteristics of the Florida Big Bend system based on reasonable agreement between observed and calculated temporal and spatial distributions of WSE, salinity, and temperature.

The EFDC water quality model reasonably represents the overall phytoplankton, nutrient and DO interactions in the Florida Big Bend system. The water quality simulations show fair agreement with observed data.

The EFDC water quality model reasonably represents the overall water color and resulting light attenuation of the Florida Big Bend system.

Florida Big Bend hydrodynamic and water quality model data sources are provided in Table D-18.

Table D-18. Florida Big Bend hydrodynamic and water quality model data sources

Data	Source	Location Used
Atmospheric and Wind Data at Surface Airways Stations	National Climatic Data Center (EarthInfo 2009)	Florida Big Bend Estuary Model
Bathymetric Data	National Oceanic and Atmospheric Administration, National Geophysical Data Center (NOAA GEODAS No Date)	Florida Big Bend Estuary Model
Digitized Shoreline Data	National Oceanic and Atmospheric Administration (NOAA No Date a)	Florida Big Bend Estuary Model
IWR Run 40 Salinity and Temperature Data	Florida Department of Environmental Protection (FDEP 2010a)	Florida Big Bend Estuary Model
Measured and Predicted Water Surface Elevation Data	National Oceanic and Atmospheric Administration (NOAA No Date b)	Florida Big Bend Estuary Model
Wastewater Facility Regulation Municipal and Industrial Point Sources Discharging Directly into Estuary	Florida Department of Environmental Protection (FDEP No Date)	Florida Big Bend Estuary Model

9.0 TAMPA-SARASOTA BAY MODEL

EPA is not presenting a hydrodynamic/water quality model for this estuarine system.

10.0 CHARLOTTE HARBOR, CALOOSAHATCHEE ESTUARY, AND ESTERO BAY MODEL

EPA is not presenting a hydrodynamic/water quality model for this estuarine system.

11.0 LAKE WORTH LAGOON MODEL

11.1 Physical Characteristics of Lake Worth Lagoon

Lake Worth Lagoon is on Florida's east coast in northern Palm Beach and southern Martin counties (see Figure D-28). It is approximately 34 km long and up to 600 m wide. Lake Worth Lagoon is connected to the Atlantic Ocean via two inlets. The largest inlet is the Lake Worth Inlet at the north and is approximately 240 m wide; the second and smallest inlet is the South Lake Worth Inlet (also known as the Boynton Inlet) and is approximately 40 m wide. The Atlantic Intracoastal Waterway runs the entire length of the lagoon and plays a role in driving astronomic tides in and out of the lagoon. Circulation in the Lake Worth Lagoon is primarily due to tides from the Atlantic Ocean, and the tidal range varies between 1 and 2 m with a strong semidiurnal character. Also episodic freshwater from West Palm Beach (Canal C-51), Earman River (Canal C-17) and Boynton Canal (C-16) flow into the lagoon.

The Earman River Canal (C-17) discharges to the north or upper portion of the lagoon; the West Palm Beach Canal (C-51) and the Boynton Beach Canal (C-16) discharge to the central and the southern portions of the lagoon, respectively. The canals discharge significant volumes of freshwater containing nutrients, suspended and dissolved organic matter, and other contaminants that can affect the lagoon's flora and fauna (Crigger et al. 2005).

Figure D-28. Lake Worth Lagoon model and watershed location

11.2 Model Segmentation

Figure D-29 shows the grid used to solve the three-dimension transport and water quality model equations in Lake Worth Lagoon. Lake Worth Lagoon was divided into 877 grid cells with a horizontal grid spacing that varies between 150 to 250 m at the central bay and 100 to 250 m at the Atlantic Intracoastal Waterway canals. Bathymetry for the Lake Worth Lagoon and the nearby continental shelf was obtained from NOAA. Figure D-30 shows contour of bed elevation of the lagoon that was used.

The model domain includes the entire lagoon and a portion of the Atlantic Intracoastal Waterway. The domain was extended to Ronald Ross and Delray bridges along the Atlantic Intracoastal Waterway in the north and south of the lagoon, respectively. On the ocean side, the model domain was extended 10 km offshore into the Atlantic Ocean to obtain a relatively stable salinity boundary condition and to minimize the influence of return constituents that left the estuary during ebb tide in the subsequent flood tide. The grid has 45 offshore boundary cells and 8 inland boundaries. Five equally spaced vertical layers were used.

The inland boundary cells receive LSPC simulated watershed discharges, point source discharges (Figure D-31), and measured discharges from the three controlled canals (C17, C51, and C16). The inland boundaries, watershed, and point source discharge locations are marked in Figure D-29. The watershed discharges and nutrient loadings are described in Appendix C. The freshwater flows from the watershed are calculated on the basis of geographical, hydrological, and meteorological factors (land use/cover, landscape parameters, soils, air temperature, rainfall, and such).

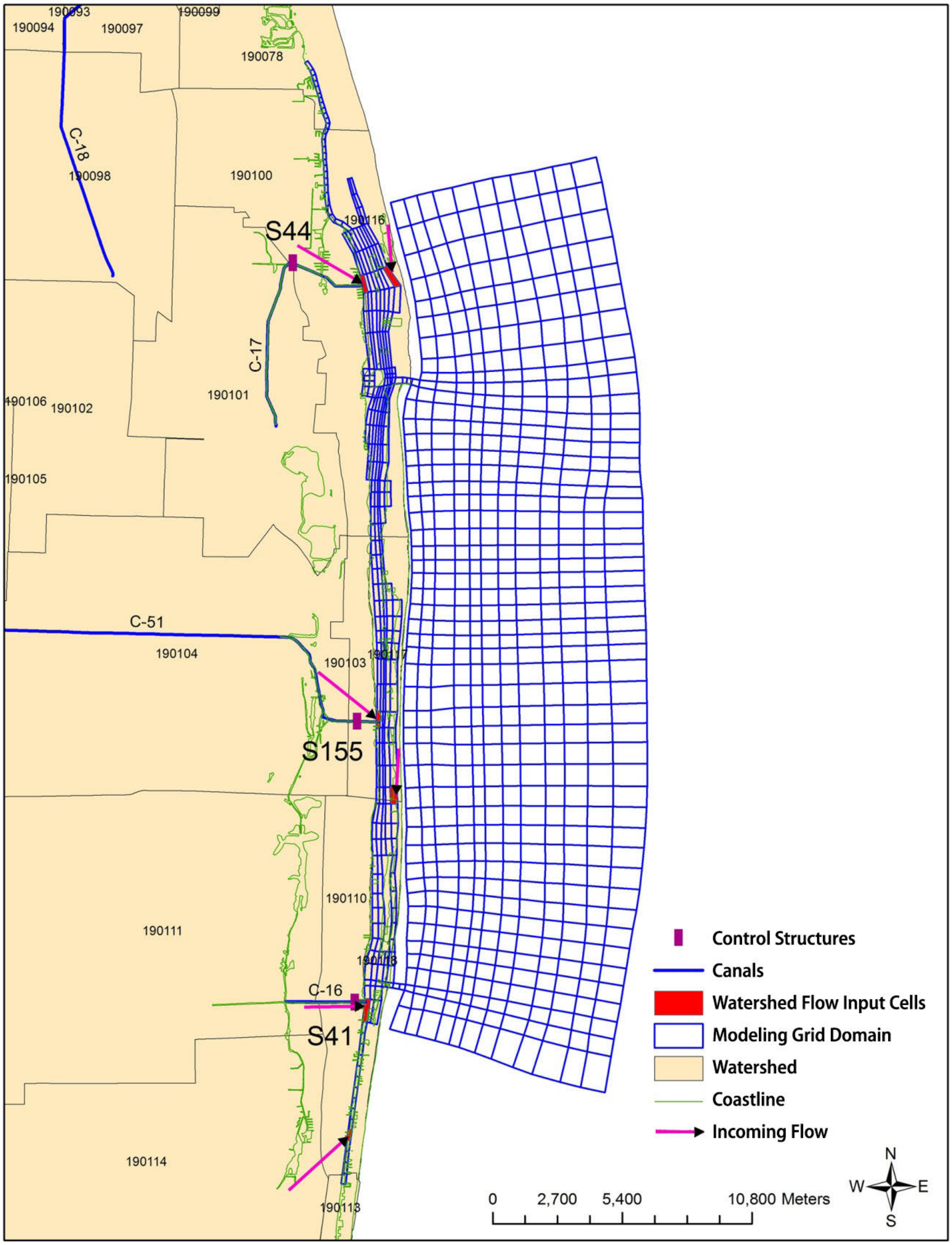


Figure D-29. Orthogonal curvilinear system of Lake Worth Lagoon

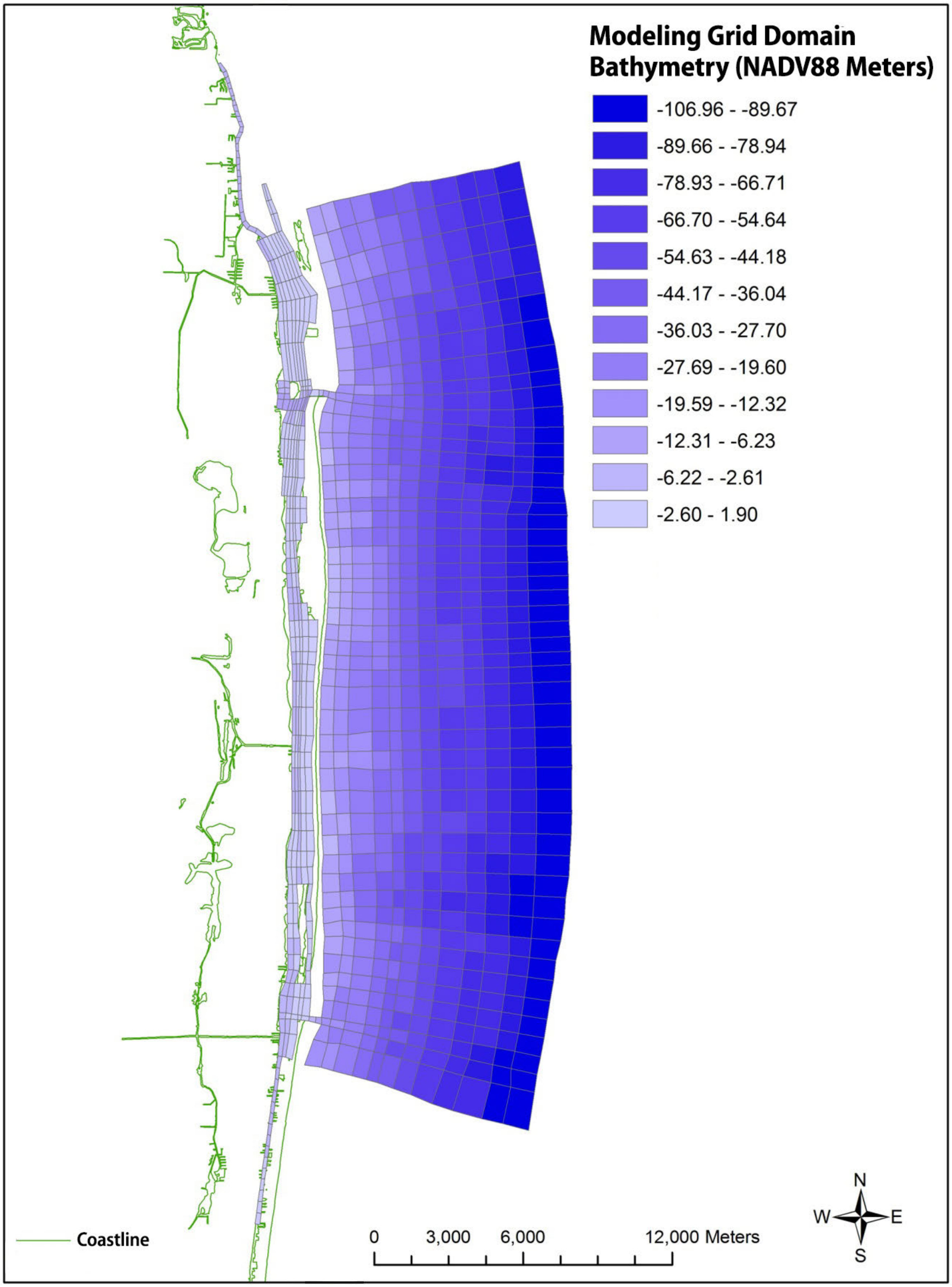


Figure D-30. Lake Worth Lagoon bathymetry

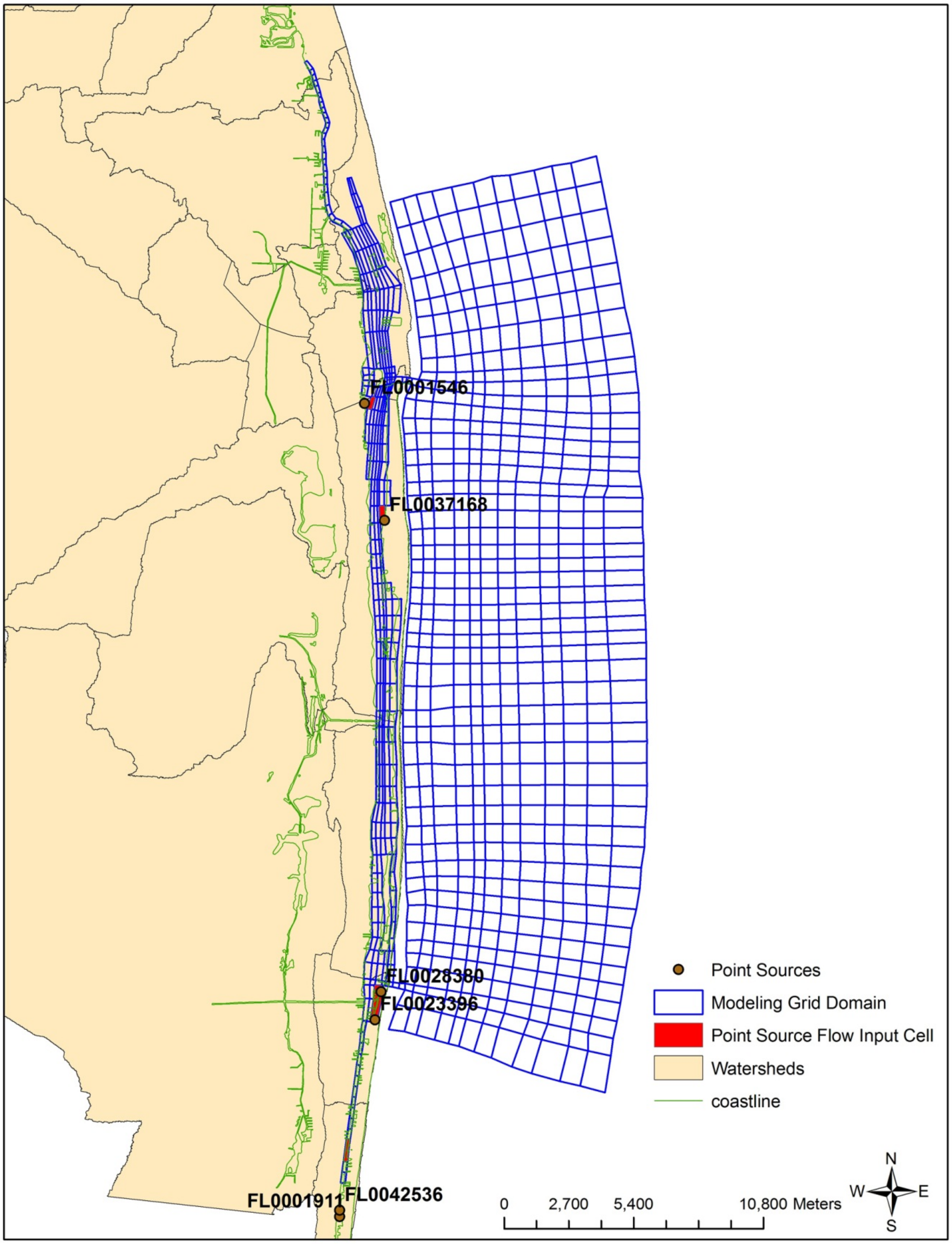


Figure D-31. Point source locations for the Lake Worth Lagoon model

11.3 Lake Worth Lagoon Monitoring Stations

The calibration-validation process for Lake Worth Lagoon model uses data collected by FDEP and NOAA. Because of the long-term and historic analysis nature of the modeling effort, monitoring stations with reasonable continuous record and spatial representation were selected for water quality model calibration and validation. Figure D8-1 (Attachment 8) shows the monitoring station locations. It also shows locations of WSE monitoring stations used for hydrodynamic calibration and validation.

Hydrodynamic model calibration involved adjusting open boundary forcing, bottom roughness, and bottom elevations to obtain a general best agreement between model predictions and observations of water surface propagation, salinity and water temperature distributions. Similarly, the calibration process for water quality involves varying parameters and kinetics values within reasonable and observed ranges to reproduce observed spatial and time varying water quality distributions within the Lagoon. During the model validation process, no adjustments were made to the parameters adopted during the calibration process. Quantitative evaluation of the calibration is based on comparing observed and model-predicted data (WSE, salinities, and temperatures). Statistical measures were used to quantify and verify the calibration and validation processes. The following subsections summarize the steps followed in the calibration and validation processes.

The hydrodynamic (EFDC) model was calibrated and validated for WSE, salinity and temperature for 2002–2009 at selected stations.

Similarly the WASP7 (water quality) model was calibrated and validated for DO, nutrients, chl-a, light attenuation coefficient, and TSS for 2002–2009.

11.4 Hydrodynamic Model Forcing Conditions

Hydrodynamic modeling was conducted to reproduce the three-dimensional circulation and transport dynamics of the lagoon. The model predicts time and space varying WSE, temperatures, and salinities and water currents in response to multiple factors: wind speed and direction, freshwater discharge, water level fluctuation, rainfall, surface heat flux, and temperature and salinity associated with boundary fluxes.

Meteorological Factors

Hourly measurements of atmospheric pressure, dry and wet bulb atmospheric temperatures, rainfall rate, wind speed and direction, and fractional cloud cover were obtained from NOAA National Climatic Data Center for Miami Airport. Solar shortwave radiation was calculated using the CE-QUAL-W2 method. The meteorological factors for the EFDC hydrodynamic model are in the files ASER.INP and WSER.INP.

Freshwater Flows and Temperature

Freshwater inflows to and associated water temperatures in the Lake Worth Lagoon were based on daily model output from the LSPC watershed model, the six point sources and the three controlled structures. The relative locations of point sources and model grid cells that receive the freshwater inflows are shown in Figure D-29 and Figure D-31. Freshwater flows and water temperatures from watersheds are in files QSER.INP and TSER.INP, respectively.

Offshore and Inland WSE Boundary

In the east (open to the Atlantic), 15-minute time series of WSE data from NOAA tidal station 8722670 at Lake Worth Pier were initially used as boundary conditions. For the two inland open boundaries, WSE at

Delray Bridge was used in the north open boundary and WSE from Donald Ross Bridge at the south. The boundary conditions were adjusted in the WSE calibration until the best fit prediction of WSE propagation was obtained. The forced radiation hydrodynamic boundary condition, which specifies incoming waves while allowing no reflection of outgoing waves, is used at the open boundaries.

Offshore Boundary Salinity and Temperature

Observed time varying salinity and temperature data at Coast Guard monitoring stations of Loxahatchee Estuary were used at the south and north open boundaries. Because there is no significant variation in offshore salinity in the Atlantic Ocean, a constant salinity of 35.5 PSU was used in the east open boundary. Salinity at open boundary for the EFDC model is in the file SSER.INP.

All offshore and inland boundaries and physical parameters of the hydrodynamic model are in the file EFDC.INP.

11.5 Hydrodynamic Model Calibration and Validation Analysis

Results (Tables D8-1 to D8-6) of calibration and validation of the hydrodynamic components of the Lake Worth Lagoon model are presented in Attachment 8 and graphical results are in the data files for the Lake Worth Lagoon model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Water Surface Elevation

The model is calibrated for WSE by analyzing observed and model-predicted WSE time series at two locations: North Palm Beach and Port of Palm Beach. Graphical analyses demonstrate the comparison of simulated and measured WSE at the North Palm Beach and Port of Palm Beach stations, respectively, for the calibration period 2003-2004. Table D8-1 (Attachment 8) shows the statistical error measures for WSE calibration for the two stations. The errors or simulation-observation differences in the table are presented in meters. The table also presents 5th and 95th WSE percentiles, which allow one to estimate the WSE dynamic range. The calibration results show the high accuracy of the modeling. The difference between observed and simulated mean WSE sets are in the range of -1 to11 cm for the calibration data set. Correlation coefficient (R^2) values of 0.90 and 0.95 show strong correlation between model simulations and observations.

Graphical analyses demonstrate the comparison of simulated and measured WSE variations at Lake Worth Pier for the validation period of 2003-2004. Table D8-2 shows the statistical error measures of WSE validation results. The difference between observed and simulated WSE sets is -6 to 13 cm for the validation dataset. The R^2 value of 0.94 shows strong correlation between simulations and observations.

Salinity

Graphical analyses demonstrate the comparison of simulated and observed salinity variations at those stations with available measured salinity. Table D8-3 presents the calibration statistics on salinity. The table also shows the percent error values between model predicted and measured salinities. The percent error values for the calibration process range from -37.9 to -2.6.

Graphical analyses demonstrate the comparison of model prediction and measured salinities variation for the validation period. Table D8-4 summarizes the statistics of salinity for the validation period. The percent error salinity values for the validation process range from -59.9 to -8.6.

Temperature

Graphical analyses demonstrate the comparison of simulated and measured surface water temperature variations at 21FLWPB 28010775, 21FLPBCH14 and 21FLWPB 28010783 stations, for the calibration period. Additional graphical analyses demonstrate corresponding comparisons of simulated and measured water temperature at stations 21FLWPB 28010366, 21FLWPB 28010769, and 21FLWPB 28010724 for the validation period. As shown in the graphical analyses, there is reasonable agreement between model predicted and measured data.

Table D8-5 presents the statistical analysis of mean water temperature predictions for 2002–2009 for calibration. The percent error values range from -8.6 to -6.5. Table D8-6 shows the statistical analysis of water temperature predictions for the validation period of 2002–2009. The percent error values range from -7.0 to -4.6.

11.6 Water Quality Model Forcing Conditions

The WASP7 model was used to simulate the water quality process in Lake Worth Lagoon. The state variables chosen in this study are discussed in section 4.6.

Boundary Conditions

The offshore boundary conditions for the WASP7 model are presented in Table D-19.

Inland and offshore boundary conditions for detritus components of the model were assumed as 0 mg/L.

Table D-20 shows summary of kinetic parameters used in the Lake Worth Lagoon WASP model.

All forcing functions, boundary conditions, calibration rates, and constants are in the WASP7 input file.

Table D-19. Offshore concentration boundary conditions

Parameter	Concentration
Ammonia (mg/L)	0.05
Nitrate (mg/L)	0.05
Organic Nitrogen (mg/L)	0.35
Orthophosphate (mg/L)	0.005
Organic Phosphorus (mg/L)	0.005
Chl-a (ug/L)	2
Dissolved Oxygen (mg/L)	6.5
CBODu (mg/L)	3.5
Total Suspended Solids (mg/L)	3

Table D-20. Calibration rates and coefficients for Lake Worth Lagoon water quality modeling

Water Quality Variable	Definition	Value	Minimum	Maximum
Phytoplankton	Phytoplankton Maximum Growth Rate Constant @20 °C (per day)	2.2	0	3
	Phytoplankton Growth Temperature Coefficient	1.070	0	1.07
	Phytoplankton Self Shading Extinction (Dick Smith Formulation)	0.017	0	0.02
	Phytoplankton Carbon to Chlorophyll Ratio	35.0	0	200
	Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	0.025	0	0.05
	Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	0.001	0	0.05
	Phytoplankton Endogenous Respiration Rate Constant @20 °C (per day)	0.05	0	0.5
	Phytoplankton Respiration Temperature Coefficient	1.050	0	1.08
	Phytoplankton Death Rate Constant (Non-Zooplankton Predation) (per day)	0.20	0	0.25
	Phytoplankton Zooplankton Grazing Rate Constant (per day)	0.00	0	5.0
	Phytoplankton Phosphorus to Carbon Ratio	0.010	0	0.24
	Phytoplankton Nitrogen to Carbon Ratio	0.35	0	0.43
	Phytoplankton Half-Sat. for Recycle of Nitrogen and Phosphorus (mg Phyt C/L)	0.005	0	1
Ammonia	Nitrification Rate Constant @20 °C (per day)	0.01	0	10
	Nitrification Temperature Coefficient	1.08	0	1.07
	Half Saturation Constant for Nitrification Oxygen Limit (mg O/L)	0.50	0	2
Nitrate-Nitrite	Denitrification Rate Constant @20 °C (per day)	0.09	0	0.09
	Denitrification Temperature Coefficient	1.045	0	1.04
	Half Saturation Constant for Denitrification Oxygen Limit (mg O/L)	0.00	0	0.1
Organic Nitrogen	DON Mineralization Rate Constant @20 °C (per day)	0.05	0	1.08
	DON Mineralization Temperature Coefficient	1.047	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Nitrogen	0.30	0	1
Organic Phosphorus	Mineralization Rate Constant for Dissolved Organic P @20 °C (per day)	0.05	0	0.22
	DOP Mineralization Temperature Coefficient	1.040	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Phosphorus	1.00	0	1

Water Quality Variable	Definition	Value	Minimum	Maximum
Light	Light Option (1 uses input light; 2 uses calculated diel light)	2	1	2
	Phytoplankton Maximum Quantum Yield Constant	720.0	0	720
	Phytoplankton Optimal Light Saturation	350.0	0	350
	Detritus and Solids Light Extinction Multiplier	0.12	0	10
	DOC1 Light Extinction Multiplier	0.80	0	10
DO	Water body Type Used for Wind Driven Reaeration Rate	2	0	3
	Calc Reaeration Option - O'Connor	1	0	4
	Reaeration Option -Sums Wind and Hydraulic Ka	1	0	1
	Theta -- Reaeration Temperature Correction	1.022	0	1.03
	Oxygen to Carbon Stoichiometric Ratio	2.66	0	2.67
CBOD	CBOD Decay Rate Constant @20 °C (per day)	0.10	0	5.6
	CBOD Decay Rate Temperature Correction Coefficient	1.040	0	1.07
	CBOD Half Saturation Oxygen Limit (mg O/L)	0.20	0	0.5
Detritus	Detritus Dissolution Rate (1/day)	0.10	0	0
	Temperature Correction for Detritus Dissolution	1.040	0	0

11.7 Water Quality Calibration and Validation Analysis

Results (Table D8-7 to D8-14) of calibration and validation of water quality components of the Lake Worth Lagoon model are presented in Attachment 8 and graphical results are in the data files for the Lake Worth Lagoon model. Generally, the percent difference in means (computed – measured) along with visual inspection (plot of data versus simulation) were used to determine the optimum fit between predicted and observed values for the water quality calibration. Physically, the first criteria measure the total mass comparison (model versus data) where zero difference implies the average mass of the model equals the average observed mass. The intent was to get both a reasonable fit between measured and simulated water quality variables and to capture expected seasonal and spatial dynamics of water quality of interest. The field data set, which in most cases were collected monthly or less frequently, does not capture every aspect and detail of the processes and conditions that could occur. However, the important driving forces and internal dynamics of these processes are defined in the model.

It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Measurements of chl-a, ammonia, nitrate-nitrite, TN, TP, TSS, light attenuation coefficient, and DO at FDEP stations (Figure D8-1, Attachment 8) during 2002-2009 years were used as calibration and validation data sets. Percent error values for chl-a in Table D8-7 range from -42.9 to 9.4. Table D8-8 presents the statistical analysis for DO modeling for the calibration-validation period. Percent error values in Table D8-8 range from -18.6 to 8.6. Table D8-9 shows the statistical analysis for modeled versus measured data for TN for the calibration and validation period. Percent error values in Table D8-9 range from 31 to 92. The statistical analyses for modeled versus measured data for ammonia for the calibration and validation period are presented in Table D8-10. Percent error values in Table D8-10 range from 34 to 762. The statistical analyses of modeled versus measured data for nitrate-nitrite for the calibration and validation periods are presented in Table D8-11. Percent error values in Table D8-11 range from -55 to 600. The statistical analyses of modeled versus measured data for TP is presented in Table D8-12. The percent error values in Table D8-12 range from -29 to 33. The statistical analysis of modeled versus measured data for TSS is presented in Table D8-13. The percent error values in Table D8-13 range from -78 to -58. The statistical analysis of modeled versus measured data for light attenuation coefficient is presented in Table D8-14. Percent error values in Table D8-14 range from -48.5 to 23.6.

11.8 Lake Worth Lagoon Model Summary and Conclusions

A three-dimensional hydrodynamic model was developed for Lake Worth Lagoon. EFDC was used as a computational framework. The model was calibrated and validated for data collected in 2002–2009. The model performance in simulating WSE, salinity and temperature distributions in Lake Worth Lagoon is judged to be acceptable.

The WASP7 water quality model was used to simulate chl-a, nutrients, DO, TSS and light attenuation coefficient in the Lake Worth Lagoon system. The model was calibrated and validated for data collected in 2002–2009. The water quality simulations show reasonable agreement with observed data.

Lake Worth Lagoon hydrodynamic and water quality model data sources are provided in Table D-21.

Table D-21. Lake Worth Lagoon hydrodynamic and water quality model data sources

Data	Source	Location Used
Atmospheric and Wind Data at Surface Airways Stations	National Climatic Data Center (EarthInfo 2009)	Lake Worth Lagoon Estuary Model
Bathymetric Data	National Oceanic and Atmospheric Administration, National Geophysical Data Center (NOAA GEODAS No Date)	Lake Worth Lagoon Estuary Model
Digitized Shoreline Data	National Oceanic and Atmospheric Administration (NOAA No Date a)	Lake Worth Lagoon Estuary Model
IWR Run 40 Salinity and Temperature Data	Florida Department of Environmental Protection (FDEP 2010a)	Lake Worth Lagoon Estuary Model
Measured and Predicted Water Surface Elevation Data	National Oceanic and Atmospheric Administration (NOAA No Date b)	Lake Worth Lagoon Estuary Model
Wastewater Facility Regulation Municipal and Industrial Point Sources Discharging Directly into Estuary	Florida Department of Environmental Protection (FDEP No Date)	Lake Worth Lagoon Estuary Model
Measured Water Surface Elevation Data	South Florida Water Management District (SFWMD 2005)	Lake Worth Lagoon Estuary Model

12.0 LOXAHATCHEE RIVER AND ESTUARY MODEL

12.1 Physical Characteristics of Loxahatchee Estuary

The Loxahatchee River and Estuary is on Florida's east coast in northern Palm Beach and southern Martin counties (see Figure D-32). The Loxahatchee River connects to the Atlantic Ocean via the Jupiter Inlet near Jupiter. Jupiter Inlet is along the Atlantic Intracoastal Waterway, which acts as an additional hydraulic mechanism driving astronomic tides in and out of the Loxahatchee Estuary. The Loxahatchee Estuary central embayment is at the confluence of three major tributaries—the Northwest Fork, the North Fork, and the Southwest Fork. The Northwest Fork of the river also represents one of the largest vestiges of native cypress river-swamp in southeast Florida. The natural hydrologic regime of this area has been altered dramatically because of agricultural and residential developments in the past. Circulation is primarily from the Atlantic Ocean tides. The tidal range is between 1 and 2 m and has a strong semidiurnal character. Periodic saltwater intrusion has threatened the freshwater cypress trees and many other species in the area.

Figure D-32. Loxahatchee Estuary model and watershed location

12.2 Model Segmentation

Figure D-33 shows the grid used to solve the three-dimensional transport and water quality model in the Loxahatchee Estuary. The Loxahatchee Estuary was divided into 462 horizontal grid cells with a horizontal grid spacing that varies between 100 to 150 m at the central bay and 200 to 300 m at the riverine portion. Bathymetry for the Loxahatchee Estuary and the nearby the continental shelf was obtained from NOAA. Figure D-34 shows bed elevation contours of the estuary used in this application.

The model domain includes the entire Loxahatchee Estuary, the riverine portion of the Loxahatchee up to Leinhart Dam and portion of the Atlantic Intracoastal Waterway. The domain was extended up to Ronald Ross and Hope Sound bridges along the Atlantic Intracoastal Waterway in the south and north, respectively. On the ocean side, the model domain was extended 10 km offshore in the Atlantic Ocean to obtain a relatively stable salinity boundary condition and to minimize the influence of return constituents that left the estuary during ebb tide in the subsequent flood tide. The grid has 13 offshore boundary cells and 15 inland boundaries. Five equally spaced vertical σ layers were used.

The inland boundary cells receive LSPC-simulated watershed discharges and point source discharges. One inland boundary receives freshwater from controlled structure C-48. The locations of the inland boundaries and watershed are marked in Figure D-33. The watershed discharges are described in Appendix C. The freshwater flows from the watershed are calculated using geographical, hydrological, and meteorological factors (land use/cover, landscape parameters, soils, air temperature, rainfall, and the like). Point source discharge locations are marked in Figure D-35.

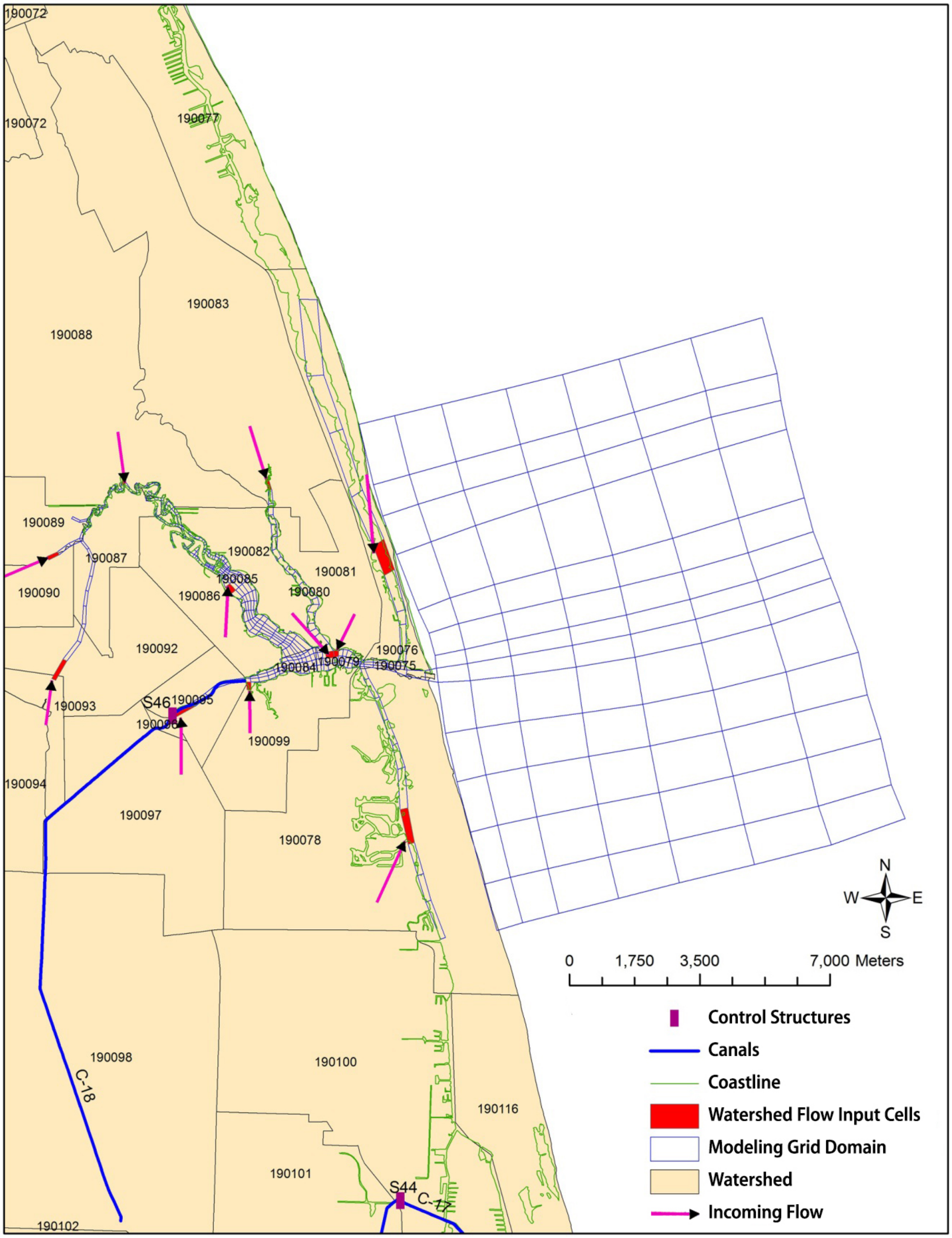


Figure D-33. Orthogonal curvilinear system of Loxahatchee Estuary

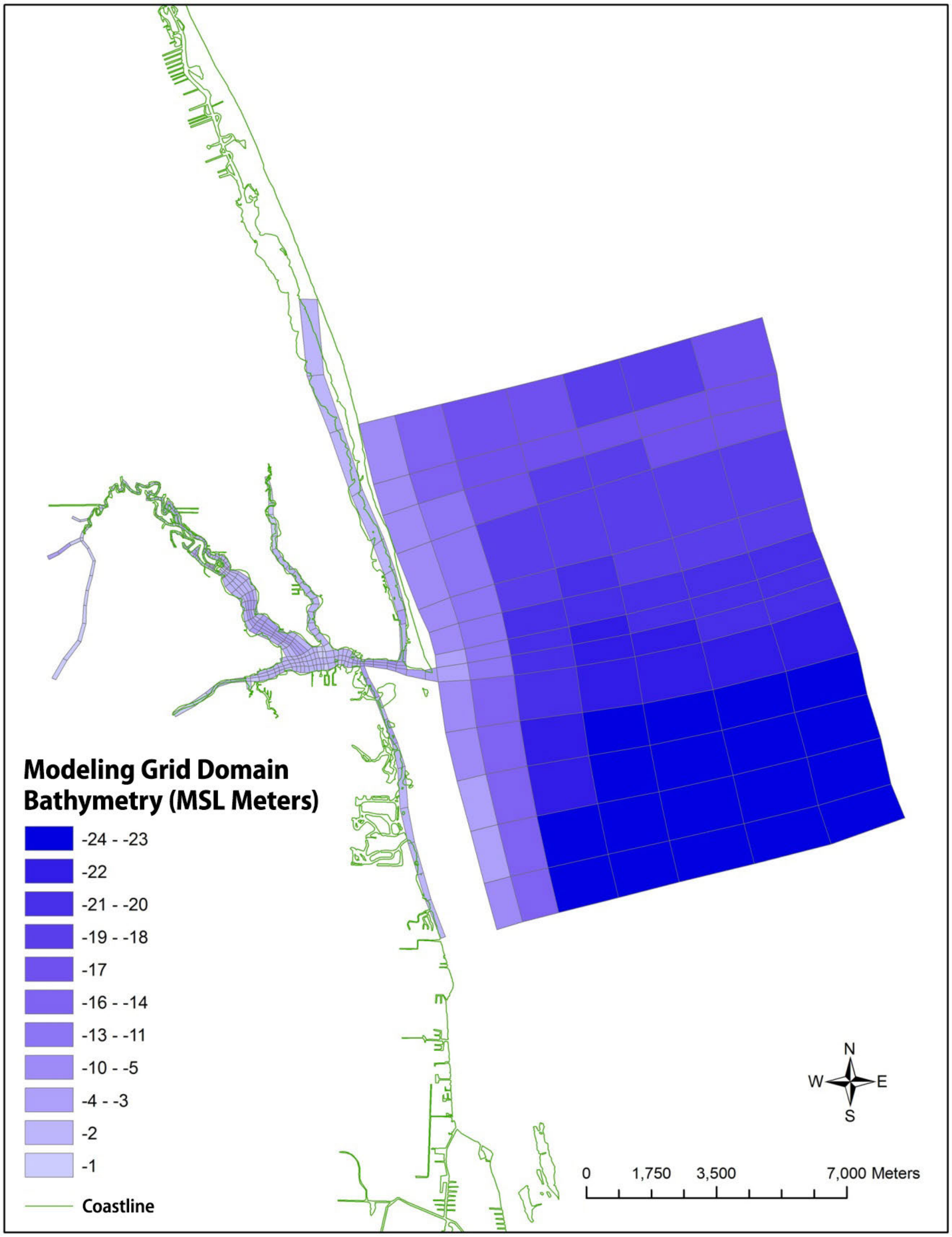


Figure D-34. Loxahatchee Estuary bathymetry

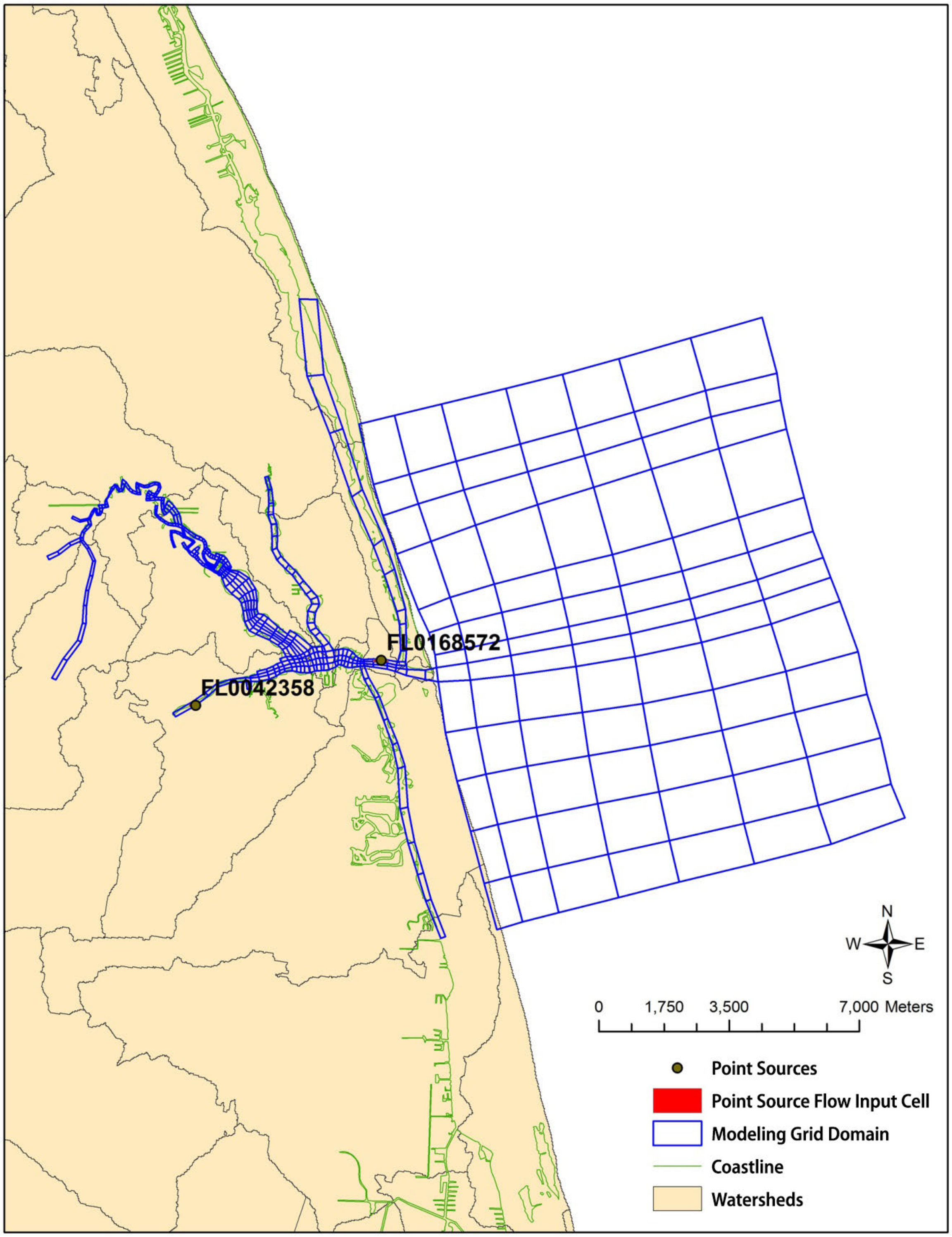


Figure D-35. Point source locations for the Loxahatchee Estuary model

12.3 Loxahatchee Estuary Monitoring Stations

The hydrodynamic and transport calibration-validation process for Loxahatchee Estuary used data collected by USGS and FDEP. Records of water-level, salinity, and temperature (sampled at 15-minute intervals) at four gaging stations in the Loxahatchee Estuary were obtained from USGS. Additional records of salinity and temperature were obtained from FDEP-collected data. Figure D9-1, Attachment 9 shows the monitoring stations.

The water quality calibration-validation process used data collected by FDEP. Because of the long-term and historic analysis nature of this modeling effort, monitoring stations with reasonable continuous record and spatial representation were selected for the water quality model calibration and validation process. Figure D9-1 shows the locations of the monitoring stations.

Hydrodynamic model calibration involved adjusting open boundary forcing, bottom roughness, and bottom elevations to obtain a general best agreement between model predictions and observations of water surface propagation, salinity, and water temperature distributions. Similarly, the calibration process for water quality involves varying parameters and kinetics values within reasonable and yet observed ranges to reproduce observed spatial and time varying water quality distributions in the estuary. During the model validation process, no adjustments were made to the parameters adopted during the calibration process. Quantitative evaluation of the calibration is based on comparison of observed and model predicted data (WSE, salinities and temperatures). Statistical measures were used to quantify and verify the calibration and validation process. The following subsections summarize the steps followed in the calibration and validation processes.

The hydrodynamic (EFDC) model was calibrated and validated for WSE, salinity, and temperature for 2002–2009 at the selected stations. The entire period was used for calibration to include the full range of hydrodynamic conditions covered during that period.

Similarly the WASP7 (water quality) model was calibrated and validated for DO, nutrients, chl-a, TSS, and light attenuation coefficient for 2002–2009.

12.4 Hydrodynamic Model Forcing Conditions

Hydrodynamic modeling was conducted to reproduce the three-dimensional circulation and transport dynamics in the Loxahatchee Estuary. The model predicts time and space varying WSE, temperature, and salinity and water currents in response to multiple factors: wind speed and direction, freshwater discharge, water level fluctuation, rainfall, surface heat flux, and temperature and salinity associated with boundary fluxes.

Meteorological Factors

Hourly measurements of atmospheric pressure, dry and wet bulb atmospheric temperatures, rainfall rate, wind speed and direction, and fractional cloud cover were obtained NOAA National Climatic Data Center for Miami Airport. Solar shortwave radiation was calculated using the CE-QUAL-W2 method. The meteorological factors for the EFDC hydrodynamic model are in the file ASER.INP. The WSER.INP file includes hourly measurements of wind speed and direction.

Freshwater Flows and Temperature

Freshwater inflows and associated water temperatures to the LRE were based on daily model output from the LSPC watershed model and the three point sources. The cells that receive the freshwater inflows are shown in Figure D-33. Freshwater flows and water temperatures from watersheds are included in files QSER.INP and TSER.INP, respectively.

Offshore and Inland WSE Boundary

In the east (open to the Atlantic), 15-minute time series of WSE data from USGS tidal station at CGD were initially used as boundary conditions. For the two inland open boundaries, WSE at Hope Sound Bridge was used in the south boundary and WSE at Donald Ross Bridge at the north boundary. These boundary conditions were adjusted during the WSE calibration until best fit prediction of WSE propagation was obtained. The forced radiation hydrodynamic boundary condition, which specifies incoming waves while allowing no reflection of outgoing waves, is used at the east open boundaries.

Offshore Boundary Salinity and Temperature

Observed time varying salinity and temperature data at Coast Guard monitoring stations were used at the south and north open boundaries. Because the Atlantic Ocean salinity has no significant variation, a constant salinity of 35.5 PSU was used in the east open boundary. Salinity at the open boundary for the EFDC model is in the file SSER.INP.

All offshore and inland boundaries and physical parameters of the hydrodynamic model are presented in the file EFDC.INP.

12.5 Hydrodynamic Model Calibration and Validation Analysis

Results (Tables D9-1 to D9-6) of calibration and validation of the hydrodynamic components of the Loxahatchee Estuary model are presented in Attachment 9 and graphical results are in the data files for the Loxahatchee Estuary model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Water Surface Elevation

The model is calibrated and verified for WSE by analyzing observed and model-predicted WSE time series at four locations: Coast Guard Dock, Pompano Drive, Boy Scout Dock, and Kitching Creek. WSE at Kitching Creek and Pompano Drive were used for model calibration; measurements at Coast Guard Dock and Boy Scout Dock were used for model validation. Graphical analyses demonstrate that generally there is a good agreement between measured and simulated WSE. Table D9-1 represents statistics of WSE calibration for the two stations. The errors or simulation-observation differences in the table are presented in meters. The mean difference between observed and simulated WSE sets is in the range of -13 to 28 cm for the calibration data set. Correlation coefficient (R^2) values of 0.92 and 0.89 show good correlation between simulations and observations.

Table D9-2 shows statistics of WSE's model validation results. The mean difference between observed and simulated WSE sets is in the range of -15 to 31 cm for the validation data set. Correlation coefficient (R^2) values of 0.93 and 0.98 show strong correlation between simulations and observations.

Salinity

The calibration and validation processes were done using the four USGS and five FDEP monitoring stations, respectively. Graphical analyses demonstrate that the model was able to simulate the transport and mixing of salt reasonably. Table D9-3 presents the mean calibration statistics for salinity. The percent error values range from -15.6 to 7.8. Table D9-4 summarizes the mean statistics of salinity for the validation set. The percent error values range from -24.9 to -4.5.

Temperature

Graphical analyses show reasonable agreement between modeled and measured data. Table D9-5 presents the statistical analysis for temperatures for the calibration period. The table presents water temperature simulated and measured mean values. The percent error values range from -4.8 to 2.4.

Table D9-6 shows the validation statistical analysis of water temperature predictions. The table presents water temperature simulated and measured mean values. The percent error values range from -5.0 to 1.9.

12.6 Water Quality Model Forcing Conditions

WASP7 was used to simulate the water quality in this study. Time and space varying flows, depths, velocities, temperatures, and salinities created by EFDC were linked with WASP7 to simulate water quality variation in Loxahatchee Estuary. This section presents model input variables (forcing functions), parameters, and results.

Point and Nonpoint Sources Loads

Time series of watershed loads were received by LSPC simulations (Appendix C) for dissolved mineral and organic nutrients, TSS, CBOD, and DO. In addition to the nonpoint source load from the watershed, two point sources discharge directly into the estuary (Figure D-35): the water treatment plant at Tequesta Village (FL0168572) and Jupiter Town water treatment plant (FL0042358). The point source discharge values were obtained from DMR data in PCS.

Solar Radiation and Air Temperature

The meteorological data for WASP7 was the same used for the heat exchange simulation for the hydrodynamic EFDC model using data measured at Miami Airport.

Benthic Nutrient Fluxes and Sediment Oxygen Demand

Values of benthic fluxes of nutrients and DO were determined through trial and error during the calibration period.

Boundary Conditions

The offshore boundary conditions for the WASP7 model are presented in Table D-22.

Inland and offshore boundary conditions for detritus components of the model were assumed as 0 mg/L.

Table D-23 shows summary of kinetic parameters used the Loxahatchee Estuary WASP model.

All forcing functions, boundary conditions, calibration rates and constants are in the WASP7 input file.

Table D-22. Offshore concentration boundary conditions

Parameter	Concentration
Ammonia (mg/L)	0.05
Nitrate (mg/L)	0.05
Organic Nitrogen (mg/L)	0.35
Orthophosphate (mg/L)	0.005
Organic Phosphorus (mg/L)	0.005
Chl-a (ug/L)	2
Dissolved Oxygen (mg/L)	6.5
CBODu (mg/L)	3.5
Total Suspended Solids (mg/L)	3

Table D-23. Calibration rates and coefficients for Loxahatchee Estuary water quality modeling

Water Quality Variable	Definition	Value	Minimum	Maximum
Phytoplankton	Phytoplankton Maximum Growth Rate Constant @20 °C (per day)	2.2	0	3
	Phytoplankton Growth Temperature Coefficient	1.070	0	1.07
	Phytoplankton Self Shading Extinction (Dick Smith Formulation)	0.017	0	0.02
	Phytoplankton Carbon to Chlorophyll Ratio	35.0	0	200
	Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	0.025	0	0.05
	Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	0.001	0	0.05
	Phytoplankton Endogenous Respiration Rate Constant @20 °C (per day)	0.05	0	0.5
	Phytoplankton Respiration Temperature Coefficient	1.050	0	1.08
	Phytoplankton Death Rate Constant (Non-Zooplankton Predation) (per day)	0.20	0	0.25
	Phytoplankton Zooplankton Grazing Rate Constant (per day)	0.00	0	5.0
	Phytoplankton Phosphorus to Carbon Ratio	0.010	0	0.24
	Phytoplankton Nitrogen to Carbon Ratio	0.35	0	0.43
	Phytoplankton Half-Sat. for Recycle of Nitrogen and Phosphorus (mg Phyt C/L)	0.005	0	1
Ammonia	Nitrification Rate Constant @20 °C (per day)	0.01	0	10
	Nitrification Temperature Coefficient	1.08	0	1.07
	Half Saturation Constant for Nitrification Oxygen Limit (mg O/L)	0.50	0	2

Water Quality Variable	Definition	Value	Minimum	Maximum
Nitrate-Nitrite	Denitrification Rate Constant @20 °C (per day)	0.09	0	0.09
	Denitrification Temperature Coefficient	1.045	0	1.04
	Half Saturation Constant for Denitrification Oxygen Limit (mg O/L)	0.00	0	0.1
Organic Nitrogen	DON Mineralization Rate Constant @20 °C (per day)	0.05	0	1.08
	DON Mineralization Temperature Coefficient	1.047	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Nitrogen	0.30	0	1
Organic Phosphorus	Mineralization Rate Constant for Dissolved Organic P @20 °C (per day)	0.05	0	0.22
	DOP Mineralization Temperature Coefficient	1.040	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Phosphorus	1.00	0	1
Light	Light Option (1 uses input light; 2 uses calculated diel light)	2	1	2
	Phytoplankton Maximum Quantum Yield Constant	720.0	0	720
	Phytoplankton Optimal Light Saturation	350.0	0	350
	Detritus and Solids Light Extinction Multiplier	0.12	0	10
	DOC1 Light Extinction Multiplier	0.80	0	10
DO	Water body Type Used for Wind Driven Reaeration Rate	2	0	3
	Calc Reaeration Option - O'Connor	1	0	4
	Reaeration Option -Sums Wind and Hydraulic Ka	1	0	1
	Theta -- Reaeration Temperature Correction	1.022	0	1.03
	Oxygen to Carbon Stoichiometric Ratio	2.66	0	2.67
CBOD	CBOD Decay Rate Constant @20 °C (per day)	0.10	0	5.6
	CBOD Decay Rate Temperature Correction Coefficient	1.040	0	1.07
	CBOD Half Saturation Oxygen Limit (mg O/L)	0.20	0	0.5
Detritus	Detritus Dissolution Rate (1/day)	0.10	0	0
	Temperature Correction for Detritus Dissolution	1.040	0	0

12.7 Water Quality Calibration and Validation Analysis

Results (Tables D9-7 to D9-22) of calibration and validation of water quality components of the Loxahatchee Estuary model are presented in Attachment 9 and graphical results are in the data files for the Loxahatchee Estuary model. Generally, the percent difference in means (computed – measured) along with visual inspection (plot of data versus simulation) were used to determine the optimum fit between predicted and observed values for the water quality calibration. Physically, the first criteria measure the total mass comparison (model versus data) where zero difference implies the average mass of the model equals the average observed mass. The intent was to get both a reasonable fit between measured and simulated water quality variables, and to capture expected seasonal and spatial dynamics of water quality of interest. The field data set, which in most cases was collected monthly, does not capture every aspect and detail of the processes and conditions that could occur. However, the important driving forces and internal dynamics of these processes are defined in the model and have been accepted by the water quality modeling community.

It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Measurements of chl-a, ammonia, nitrate-nitrite, TN, TP, DO and light attenuation coefficient at FDEP stations (Figure D9-1) in 2002–2009 were used for calibration and validation.

Chl-a is the total sum of all types of phytoplankton present in the system and the model assumes a fixed ratio between chl-a and phytoplankton biomass, whereas the actual ratio can be variable with time; with different phytoplankton species having different chl-a to phytoplankton biomass ratios. Table D9-7 shows comparisons of mean simulated and measured chl-a at six water quality monitoring stations for the calibration period. Percent error values in Table D9-7 range from -70.7 to -3.7. Table D9-8 shows comparisons of mean simulated and measured chl-a at six water quality monitoring stations for the validation period. Percent error values in Table D9-8 range from -61.7 to -43.7.

Table D9-9 shows the comparisons of mean simulated and measured DO at six water quality monitoring stations for the calibration period. Percent error values in Table D9-9 range from -12.6 to 9.6. Table D9-10 shows the comparisons of mean simulated and measured DO at six water quality monitoring stations for the validation period. Percent error values in Table D9-10 range from -14.5 to 2.1.

Table D9-11 shows the comparisons of mean simulated and measured TN at five water quality monitoring stations for the calibration period. Percent error values in Table D9-11 range from -16.3 to 15.2. Table D9-12 shows the comparisons of mean simulated and measured TN at six water quality monitoring stations for the validation period. Percent error values in Table D9-12 range from -31.9 to -7.6.

The statistical analysis of mean modeled versus measured data for ammonia is presented in Tables D9-13 and D9-14. The percent error values range from 263.3 to 678.0 for the calibration period and from 180.2 to 740.0 for the validation period. The statistical analysis of mean modeled versus measured data for nitrate-nitrite is presented in Tables D9-15 and D9-16. The percent error values range from -82.5 to 241.7 for the calibration period and from 30.4 to 408.3 for the validation period. The statistical analysis of mean modeled versus measured data for TP is presented in Tables D9-17 and D9-18. The percent error values range from -24.5 to 67.2 for the calibration period and from -37.8 to 37.0 for the validation period.

Table D9-19 shows the comparisons of mean simulated and measured TSS at six water quality monitoring stations for the calibration period. Percent error values in Table D9-19 range from 23.2 to 149.6. Table D9-20 shows the comparisons of mean simulated and measured TSS at six water quality monitoring stations for the validation period. Percent error values in Table D9-20 range from -58.3 to 97.2.

The statistical analyses of mean modeled versus measured data for light attenuation coefficient are presented in Tables D9-21 and D9-22. The percent error values range from -18.2 to 166.0 for calibration and from -45.9 to 80.0 for validation.

12.8 Loxahatchee Estuary Model Summary and Conclusions

A three-dimensional hydrodynamic model was developed for Loxahatchee Estuary. EFDC was used as a computational framework. The model was calibrated-validated for data collected for 2002–2009. The model performance in simulating WSE, salinity, and temperature distributions in the Loxahatchee Estuary are judged to be acceptable.

The WASP7 water quality model was used to simulate chl-a, nutrients, and DO in Loxahatchee Estuary system. The model was calibrated and validated using data collected in 2002–2009 and the results are judged to be acceptable.

Loxahatchee River hydrodynamic and water quality model data sources are provided in Table D-24.

Table D-24. Loxahatchee River hydrodynamic and water quality model data sources

Data	Source	Location Used
Atmospheric and Wind Data at Surface Airways Stations	National Climatic Data Center (EarthInfo 2009)	Loxahatchee Estuary Model
Bathymetric Data	National Oceanic and Atmospheric Administration, National Geophysical Data Center (NOAA GEODAS No Date)	Loxahatchee Estuary Model
Digitized Shoreline Data	National Oceanic and Atmospheric Administration (NOAA No Date a)	Loxahatchee Estuary Model
IWR Run 40 Salinity and Temperature Data	Florida Department of Environmental Protection (FDEP 2010a)	Loxahatchee Estuary Model
Measured and Predicted Water Surface Elevation Data	National Oceanic and Atmospheric Administration (NOAA No Date b)	Loxahatchee Estuary Model
Wastewater Facility Regulation Municipal and Industrial Point Sources Discharging Directly into Estuary	Florida Department of Environmental Protection (FDEP No Date)	Loxahatchee Estuary Model
Measured Water Surface Elevation Data	USGS (SFWMD 2005)	Loxahatchee Estuary Model

13.0 ST. LUCIE ESTUARY MODEL

13.1 Physical Characteristics of the Model Study Area

The St. Lucie Estuary is on the southeast coast of the Florida peninsula (Figure D-36). The estuary is one of the largest brackish water bodies on the east coast of Florida and intersects the southern Indian River Lagoon system near the St. Lucie Inlet, which is its outlet to the Atlantic Ocean. Drainage canal networks built for urban and agricultural development has expanded the estuary's original, mostly wetland, watershed and affected its water quality. The original watershed area estimated at 415 km^2 has almost tripled in size. The inner St. Lucie Estuary is composed of the South and North Forks of the St. Lucie River. Both forks converge to form the single middle estuary that connects with the Indian River Lagoon system. St. Lucie inlet is a man-made inlet that allows for ocean access and tidal exchange between the estuary and the Atlantic Ocean.

Figure D-36. St. Lucie Estuary model and watershed location

13.2 Model Segmentation

An orthogonal, curvilinear grid system used in the hydrodynamic model is shown in Figure D-37. The grid consists of 419 horizontal cells and 5 equally spaced vertical σ layers. The system has 17 offshore boundary cells and 13 inland boundary cells.

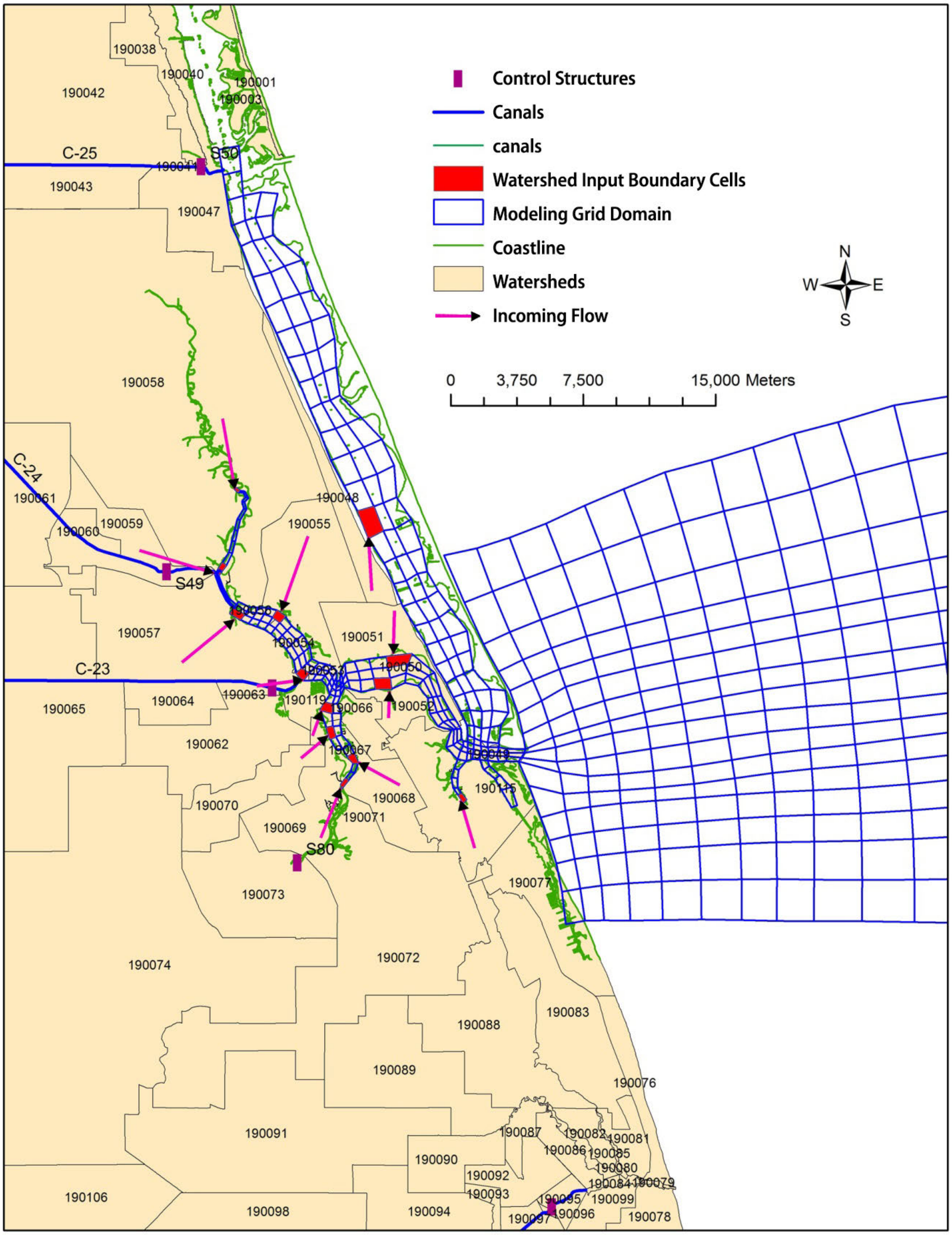


Figure D-37. Orthogonal curvilinear system of St. Lucie Estuary

The inland boundary cells receive measured flow from three major canals and LSPC-simulated watershed discharges (Figure D-37): C-44, which provides a connection to Lake Okeechobee, C-44 and C-23. The watershed discharges were described in Appendix C. The freshwater flows from watersheds are calculated on the basis of geographical, hydrological and meteorological factors (land use/cover, landscape parameters, soils, air temperature, rainfall, and such).

Bathymetry data for the Atlantic Ocean adjacent area and St. Lucie Estuary were obtained from the National Geophysical Data Center. The bathymetry data were interpolated into the grid resulting in the grid bathymetry shown in Figure D-38.

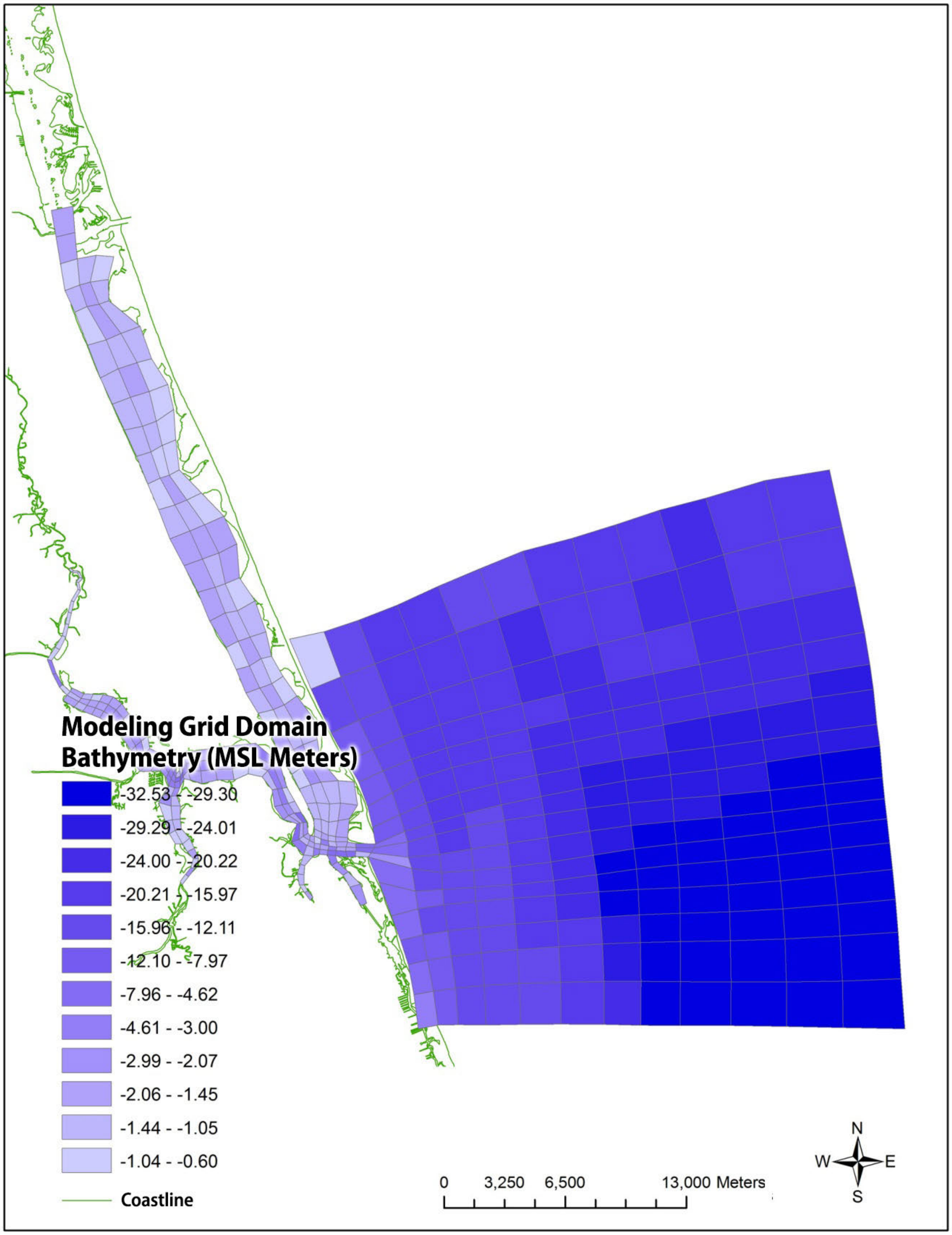


Figure D-38. St. Lucie Estuary bathymetry

13.3 St. Lucie Estuary Monitoring Stations

The calibration-validation process for St. Lucie Estuary model uses mostly data collected by FDEP. The stations used for calibration-validation of EFDC- and WASP7-based models for 2002–2009 are shown in Figure D10-1, Attachment 10. Also, WSE data collected by USGS at three monitoring stations (North Fork, Speedy Point and Steele Point) were used for model calibration and verification of tidal water surface propagation.

In this multiyear simulation, the calibration-validation process is done simultaneously in a way that the model skill in simulating observed hydrodynamics and water quality data at selected stations is used as model calibration, whereas the model performance in the remaining independent stations is considered as validation. The hydrodynamic model (EFDC) was calibrated and validated for WSE at the selected stations for 2003–2004 and 2003–2006, respectively; the model was calibration for salinity and temperature for 2002–2009 at the selected stations.

Similarly the WASP7 (water quality) model was calibrated and validated for DO, nutrients, and chl-a, light attenuation coefficient, and TSS for 2002–2009.

13.4 Hydrodynamic Model Forcing Conditions

EFDC-based hydrodynamic modeling was conducted to reproduce the three-dimensional circulation dynamics and salinity and temperature structure in the bay system. The model predicts these parameters in response to multiple factors: wind speed and direction, freshwater discharge, water level fluctuation, rainfall, surface heat flux, and temperature and salinity associated with boundary fluxes.

Meteorological Factors

Hourly measurements of atmospheric pressure, dry and wet bulb atmospheric temperatures, rainfall rate, wind speed and direction, and fractional cloud cover were obtained from data collected at station WBAN 12839 Miami Airport for 1997–2009. Solar shortwave radiation was calculated using the CE-QUAL-W2 method. The meteorological factors for the EFDC hydrodynamic model are in the ASER.INP file. The WSER.INP file includes hourly measurements of wind speed and direction.

Freshwater Flows and Temperature

The watershed flow discharges into the estuary and temperatures were calculated using the LSPC watershed model (Appendix C) and measured inflows from the three major canals (C-44, C-23 and C-24) were obtained from South Florida Water Management District (SFWMD) online database. The watershed and canals input boundary cells are shown in Figure D-37. The water discharges into the St. Lucie were determined by measurements taken by the U.S. Army Corps of Engineers and SFWMD at the following locations: S308 – flow data at S308 spillway on St. Lucie Canal at L. Okeechobee, S80 – flow data at S80, St. Lucie Locks and Spillway, S48 – flow data at S48 structure on C23 Canal, S97, S49 – flow data at S49 structure on C24 Canal freshwater flows and water temperatures from watersheds are in files QSER.INP and TSER.INP, respectively.

Offshore Boundary WSE, Salinity, and Water Temperature

Observed time varying salinity and temperature data at the Coast Guard monitoring station at the LRE were used at the east and north open boundaries. Since the Atlantic Ocean offshore salinity has no significant variation, a constant salinity of 36.5 ppt was used in the east open boundary. Salinity at open boundary for the EFDC model is in the file SSER.INP.

All offshore and inland boundaries and physical parameters of the hydrodynamic model are presented in the input file EFDC.INP.

13.5 Hydrodynamic Model Calibration and Validation Analysis

Results (Tables D10-1 to D10-6) of calibration and validation of the hydrodynamic components of the St. Lucie Estuary model are presented in Attachment 10 and graphical results are in the data files for the St. Lucie Estuary model.

It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Water Surface Elevation

Initially, the model was calibrated and validated for WSE by analyzing observed and model-predicted WSE time series at three locations: Speedy Point (C04-12), North Fork (C03-27), and Steele Point (C10-13). Water surface measurements at North Fork and Speedy Point are used as model calibration set. Graphical analyses compare simulated and measured WSE at North Fork and Speedy Point, respectively. WSE at Steele Point is used as model validation. Tables D10-1 and D10-2 show the statistical error measures for WSE calibration and validation, respectively. The errors or simulation-observation differences in the tables are presented in meters. The tables also present 5th and 95th WSE percentiles that allow one to estimate the WSE dynamic range. The calibration results show high accuracy of modeling. Correlation coefficient (R^2) values of 0.89, 0.91, and 0.92 show good correlation between simulations and observations.

Salinity

Salinity measurements at five locations (C04-12, C02-18, C03-08, C08-14, and C21-12) were used as the calibration data set. Table D10-3 presents the mean calibration statistics for salinity. Graphical analyses show the corresponding data against model simulation of salinity at these locations. The percent error values range from -6.9 to 57.7 for calibration. Salinity measurements at four other locations (C15-13, C20-31, C18-27, and C21-20) were used as the validation data set. Table D10-4 presents the mean validation statistics for salinity. Graphical analyses demonstrate good visual correspondence between the measured and simulated values of salinity. The percent error values range from 0.1 to 25.6 for validation.

Temperature

Measurements of water temperature at stations C02-18, C03-08, C04-12, and C21-12 were selected as the calibration data set. Similarly stations C18-27, C08-14, C15-13, C21-20, and C20-31 were used for temperature model validation. Graphical analyses plot model simulation against observed data of temperature for the calibration stations. Graphical analyses also plot model simulation against observed data of temperature for the validation stations.

Tables D10-5 and D10-6 present the statistics of surface mean temperature values for calibration and validation stations, respectively. The percent error values range from -15.1 to -3.7 for the calibration data set and from -8.8 to -3.6 for the validation data set.

13.6 Water Quality Model Forcing Conditions

The selection of the WASP7-based water quality model's state variables is described in Section 4.6.

Point and Nonpoint Sources Loads

Time series of watershed loads were obtained from LSPC simulations (Appendix C) for organic nutrients, TSS, CBOD, and DO. The point source discharge values were obtained from DMR data in PCS.

Solar Radiation and Air Temperature

The meteorological data for WASP7 was the same used for the heat exchange simulation for the hydrodynamic EFDC model using data measured at station WBAN 12839 Miami Airport.

Benthic Nutrient Fluxes and Sediment Oxygen Demand

Ammonia nitrogen and phosphate nutrient fluxes and SOD values were selected on the basis of observations and analysis presented in Murrell et al. (2009) for Pensacola Bay. These fluxes were adjusted for St. Lucie Estuary during the calibration process.

Reaeration

The reaeration process in WASP7 was calculated using the O'Connor-Dobbins option.

Boundary Conditions

The offshore boundary conditions for the WASP7 model are presented in Table D-25.

Table D-25. Offshore concentration boundary conditions

Parameter	Concentration
Ammonia (mg/L)	0.05
Nitrate (mg/L)	0.05
Organic Nitrogen (mg/L)	0.35
Orthophosphate (mg/L)	0.005
Organic Phosphorus (mg/L)	0.005
Chl-a (ug/L)	2
Dissolved Oxygen (mg/L)	6.5
CBODu (mg/L)	3.5
Total Suspended Solids (mg/L)	3

Inland and offshore boundary conditions for detritus components of the model were assumed as 0 mg/L.

Final calibration values for chemical and biological constants of the water quality model are presented in Table D-26.

All forcing functions, boundary conditions, calibration rates, and constants are in the WASP7 input file.

Table D-26. Calibration rates and coefficients for St. Lucie Estuary water quality modeling

Water Quality Variable	Definition	Value	Minimum	Maximum
Phytoplankton	Phytoplankton Maximum Growth Rate Constant @20 °C (per day)	2.2	0	3
	Phytoplankton Growth Temperature Coefficient	1.070	0	1.07
	Phytoplankton Self Shading Extinction (Dick Smith Formulation)	0.017	0	0.02
	Phytoplankton Carbon to Chlorophyll Ratio	35.0	0	200
	Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	0.025	0	0.05
	Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	0.001	0	0.05
	Phytoplankton Endogenous Respiration Rate Constant @20 °C (per day)	0.05	0	0.5
	Phytoplankton Respiration Temperature Coefficient	1.050	0	1.08
	Phytoplankton Death Rate Constant (Non-Zooplankton Predation) (per day)	0.20	0	0.25
	Phytoplankton Zooplankton Grazing Rate Constant (per day)	0.00	0	5.0
	Phytoplankton Phosphorus to Carbon Ratio	0.010	0	0.24
	Phytoplankton Nitrogen to Carbon Ratio	0.35	0	0.43
	Phytoplankton Half-Sat. for Recycle of Nitrogen and Phosphorus (mg Phyt C/L)	0.005	0	1
Ammonia	Nitrification Rate Constant @20 °C (per day)	0.01	0	10
	Nitrification Temperature Coefficient	1.08	0	1.07
	Half Saturation Constant for Nitrification Oxygen Limit (mg O/L)	0.50	0	2
Nitrate-Nitrite	Denitrification Rate Constant @20 °C (per day)	0.09	0	0.09
	Denitrification Temperature Coefficient	1.045	0	1.04
	Half Saturation Constant for Denitrification Oxygen Limit (mg O/L)	0.00	0	0.1
Organic Nitrogen	DON Mineralization Rate Constant @20 °C (per day)	0.050	0	1.08
	DON Mineralization Temperature Coefficient	1.047	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Nitrogen	0.30	0	1
Organic Phosphorus	Mineralization Rate Constant for Dissolved Organic P @20 °C (per day)	0.05	0	0.22
	DOP Mineralization Temperature Coefficient	1.040	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Phosphorus	1.00	0	1

Water Quality Variable	Definition	Value	Minimum	Maximum
Light	Light Option (1 uses input light; 2 uses calculated diel light)	2	1	2
	Phytoplankton Maximum Quantum Yield Constant	720.0	0	720
	Phytoplankton Optimal Light Saturation	350.0	0	350
	Detritus and Solids Light Extinction Multiplier	0.12	0	10
	DOC1 Light Extinction Multiplier	0.80	0	10
DO	Water body Type Used for Wind Driven Reaeration Rate	2	0	3
	Calc Reaeration Option - O'Connor	1	0	4
	Reaeration Option -Sums Wind and Hydraulic Ka	1	0	1
	Theta -- Reaeration Temperature Correction	1.022	0	1.03
	Oxygen to Carbon Stoichiometric Ratio	2.66	0	2.67
CBOD	CBOD Decay Rate Constant @20 °C (per day)	0.10	0	5.6
	CBOD Decay Rate Temperature Correction Coefficient	1.040	0	1.07
	CBOD Half Saturation Oxygen Limit (mg O/L)	0.20	0	0.5
Detritus	Detritus Dissolution Rate (1/day)	0.10	0	0
	Temperature Correction for Detritus Dissolution	1.040	0	0

13.7 Water Quality Calibration and Validation Analysis

Results (Tables D10-7 to D10-14) of calibration and validation of water quality components of the St. Lucie Estuary model are presented in Attachment 10. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Measurements of chl-a, ammonia, nitrate-nitrite, TN, TP, DO, TSS, and light attenuation coefficient were used as calibration and validation data sets. The visual comparisons of the calibrated model run with observed data are presented in graphical analyses for the St. Lucie Estuary model.

Chl-a model calibration and validation were done using measured data sets at stations C02-18, C02-08, C04-12, C08-14, C15-13, C18-27, C20-31 and C21-12. The statistics for mean model calibration and validation are presented in Table D10-7. It shows comparisons of mean percentiles of simulated and measured chl-a. The percent error values range from -64.3 to 23.8.

The model performance statistics for DO calibration and validation are presented in Table D10-8. The table shows comparisons of mean simulated and observed data. The percent error values range from -2.8 to 12.8.

The model performance statistics for TN calibration and verification are presented in Table D10-9. The table shows comparisons of mean simulated and observed data. The percent error values range from -29.6 to 1.8.

The model performance statistics for ammonia calibration and verification are presented in Table D10-10. The table shows comparisons of mean simulated and observed data. The mean percent error values in Table D10-10 range from -26.1 to 192.9.

The model performance statistics for nitrate-nitrite calibration and validation are presented in Table D10-11. The table shows comparisons of mean simulated and observed data. The percent error values in Table D10-11 range from -81.3 to -34.5.

The model performance statistics for TP calibration and verification are presented in Table D10-12. The tables show comparisons of mean simulated and observed data. The percent error values in Table D10-12 range from -40.4 to 137.9.

The model performance statistics for TSS mean calibration and validation are presented in Table D10-13. The percent error values in Table D10-13 range from -73.8 to -35.5.

The model performance statistics for light attenuation coefficient mean calibration and validation for light attenuation are present in Table D10-14. The percent error values in Table D10-14 range from -61.3 to -45.8.

13.8 St. Lucie Estuary Model Summary and Conclusions

The hydrodynamic and water quality model for St. Lucie Estuary was calibrated and validated for data collected for 2002–2009.

The EFDC hydrodynamic model represents the overall circulation and mixing characteristics of the St. Lucie Estuary system on the basis of reasonable agreement between observed and calculated temporal and spatial distributions of salinity and temperature.

The WASP7 water quality model reasonably represents the overall phytoplankton, nutrient and DO interactions in the St. Lucie Estuary system. The water quality simulations show fair agreement with observed data.

St. Lucie Estuary hydrodynamic and water quality model data sources are provided in Table D-27.

Table D-27. St. Lucie Estuary hydrodynamic and water quality model data summaries

Data	Source	Location Used
Atmospheric and Wind Data at Surface Airways Stations	National Climatic Data Center (EarthInfo 2009)	St. Lucie Estuary Model
Bathymetric Data	National Oceanic and Atmospheric Administration, National Geophysical Data Center (NOAA GEODAS No Date)	St. Lucie Estuary Model
Digitized Shoreline Data	National Oceanic and Atmospheric Administration (NOAA No Date a)	St. Lucie Estuary Model
IWR Run 40 Salinity and Temperature Data	Florida Department of Environmental Protection (FDEP 2010a)	St. Lucie Estuary Model
Measured and Predicted Water Surface Elevation Data	National Oceanic and Atmospheric Administration (NOAA No Date b)	St. Lucie Estuary Model

Data	Source	Location Used
Wastewater Facility Regulation Municipal and Industrial Point Sources Discharging Directly into Estuary	Florida Department of Environmental Protection (FDEP No Date)	St. Lucie Estuary Model

14.0 ST. JOHNS RIVER

EPA used modeling results from the Lower St. Johns River total maximum daily load analysis to determine candidate criteria for the St. Johns River. Descriptions of the models used, model setup, calibration, and results can be found in Volume 1 Appendix G: Supporting Materials for Alternate Analysis (the St. Johns TMDL Report; Chapter 5 and Appendices F and G (FDEP 2008)).

15.0 ST. MARYS-NASSAU ESTUARY MODEL

15.1 Physical Characteristics of the Model Study Area

The St. Marys-Nassau Estuary system consists of an extensive network of salt marshes and interconnected tidal creeks and tree islands bounded by the St. Marys River and Cumberland Sound on the north and the Nassau River and the St. Johns Estuary on the south (Figure D-39). This estuary system is in Baker, Nassau and Duval counties, just west of the coastal urban areas of Fernandina Beach and Amelia Island. The St. Marys Estuary is directly connected to the Atlantic Ocean at the St. Marys Inlet, and the Nassau Estuary is directly connected to the Atlantic Ocean at the Nassau Inlet. The St. Marys River, which is a blackwater river originating approximately 125 mi to the west, in the peat bogs of the Okefenokee Swamp, has an area of approximately 1,585 mi^2. The Nassau River, with a watershed area of only approximately 464 mi^2, forms the boundary between Nassau and Duval counties.

The Nassau Estuary waters are connected to the St. Johns Estuary and the Atlantic Ocean to the south through the Gunnison Cut, Sisters Creek, and the Fort George River. During initial testing of the hydrodynamic model, it was found that this physical connection does not likely result in significant water mass transfer into and out of this portion of the Nassau estuarine system. As a result, it was concluded that this physical connection constitutes a nodal point. Accordingly, it was not included as an open tidal boundary in the hydrodynamic model.

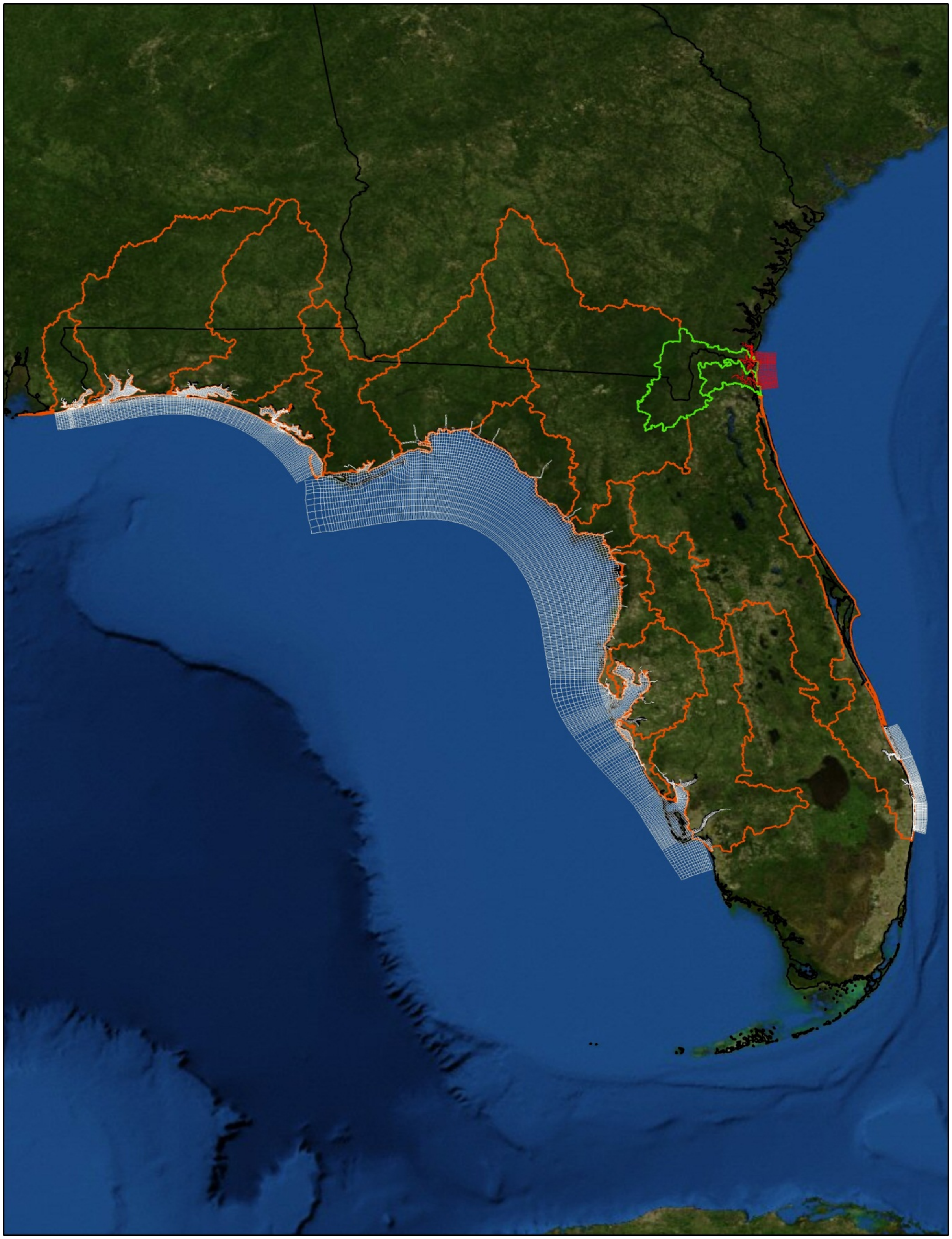


Figure D-39. St. Marys-Nassau Estuary model and watershed location

15.2 Model Segmentation

The orthogonal, curvilinear grid system used in the hydrodynamic model is shown in Figure D-40. The grid consists of 995 horizontal cells and 5 equally spaced vertical layers. The system has 29 offshore oceanic open boundary cells, one open boundary cell at the northern end of the Cumberland Island Sound and 19 inland boundary cells receiving LSPC inputs.

The inland boundary cells receive LSPC-simulated watershed discharges and point source discharges. The watershed boundary cells are marked in Figure D-40, and the point source locations are shown in Figure D-41. The watershed discharges were described in Appendix C. According to that report, freshwater flows from watersheds are calculated using geographical, hydrological and meteorological factors (land use/cover, landscape parameters, soils, air temperature, rainfall, and such).

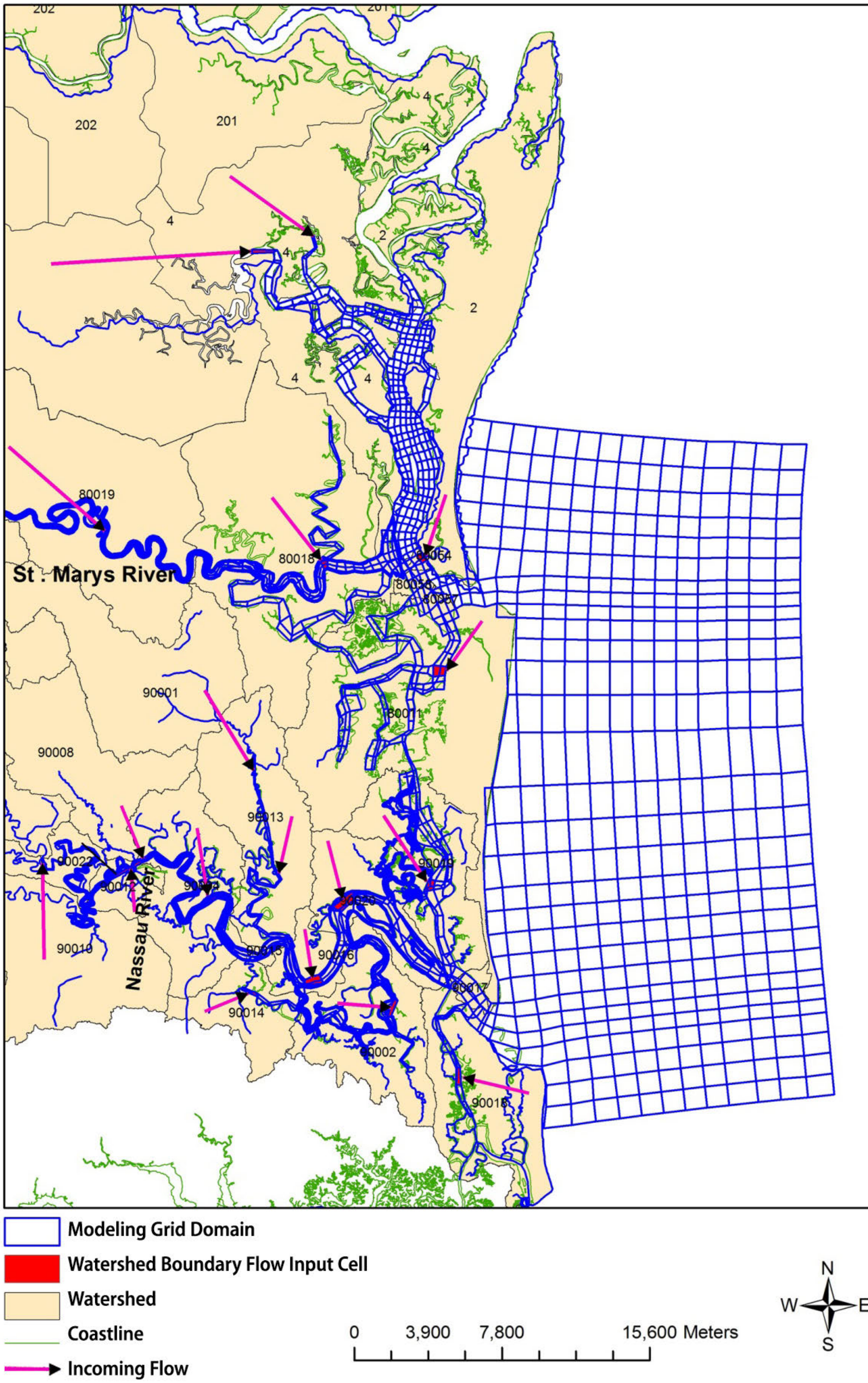


Figure D-40. Orthogonal curvilinear system of St. Marys-Nassau Estuary

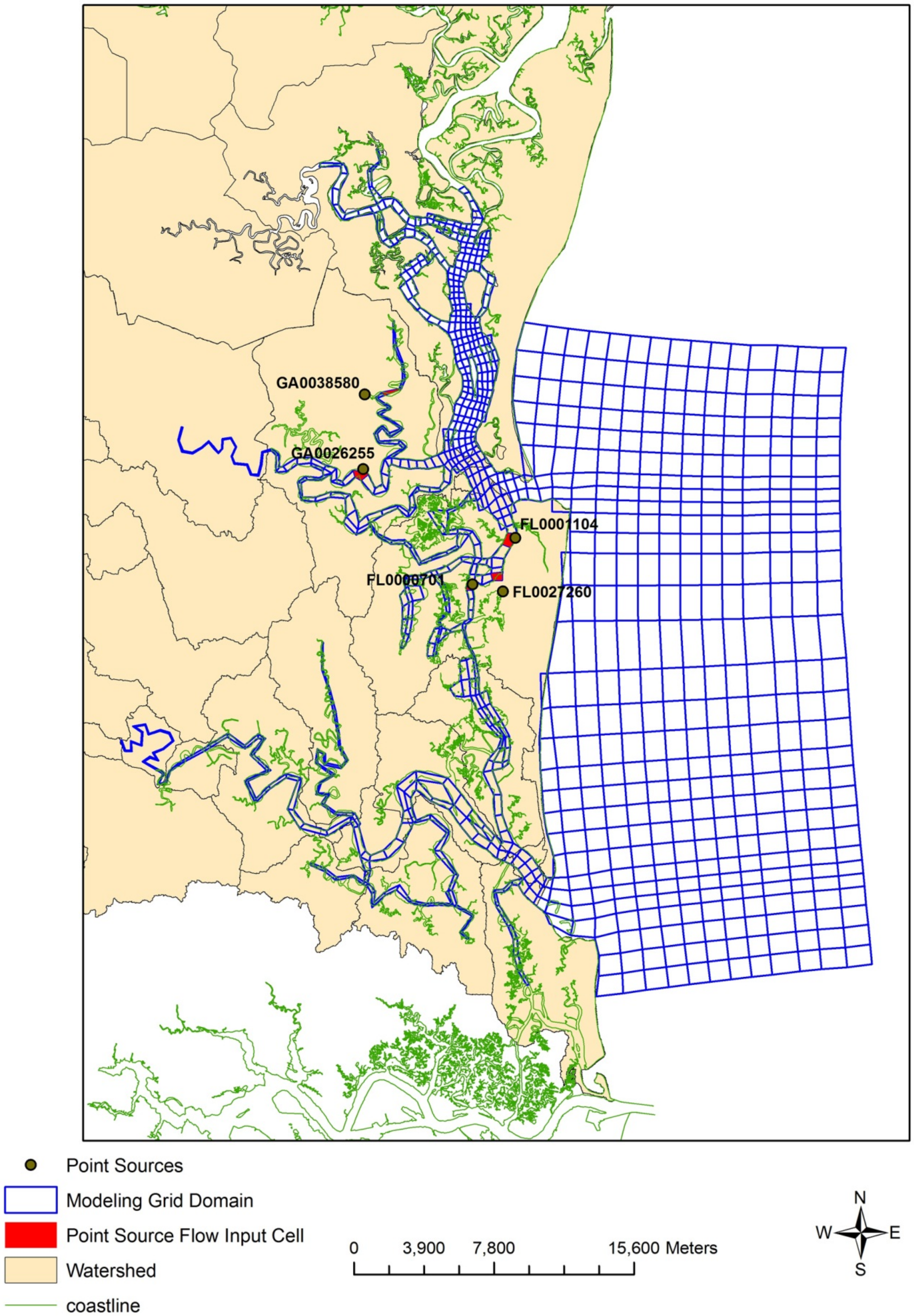


Figure D-41. Point source locations for the St. Marys-Nassau Estuary model

Bathymetry data for the Atlantic Ocean adjacent area and St. Marys-Nassau Estuary were obtained from the National Geophysical Data Center. The bathymetry data were interpolated into the grid resulting in the grid bathymetry shown in Figure D-42.

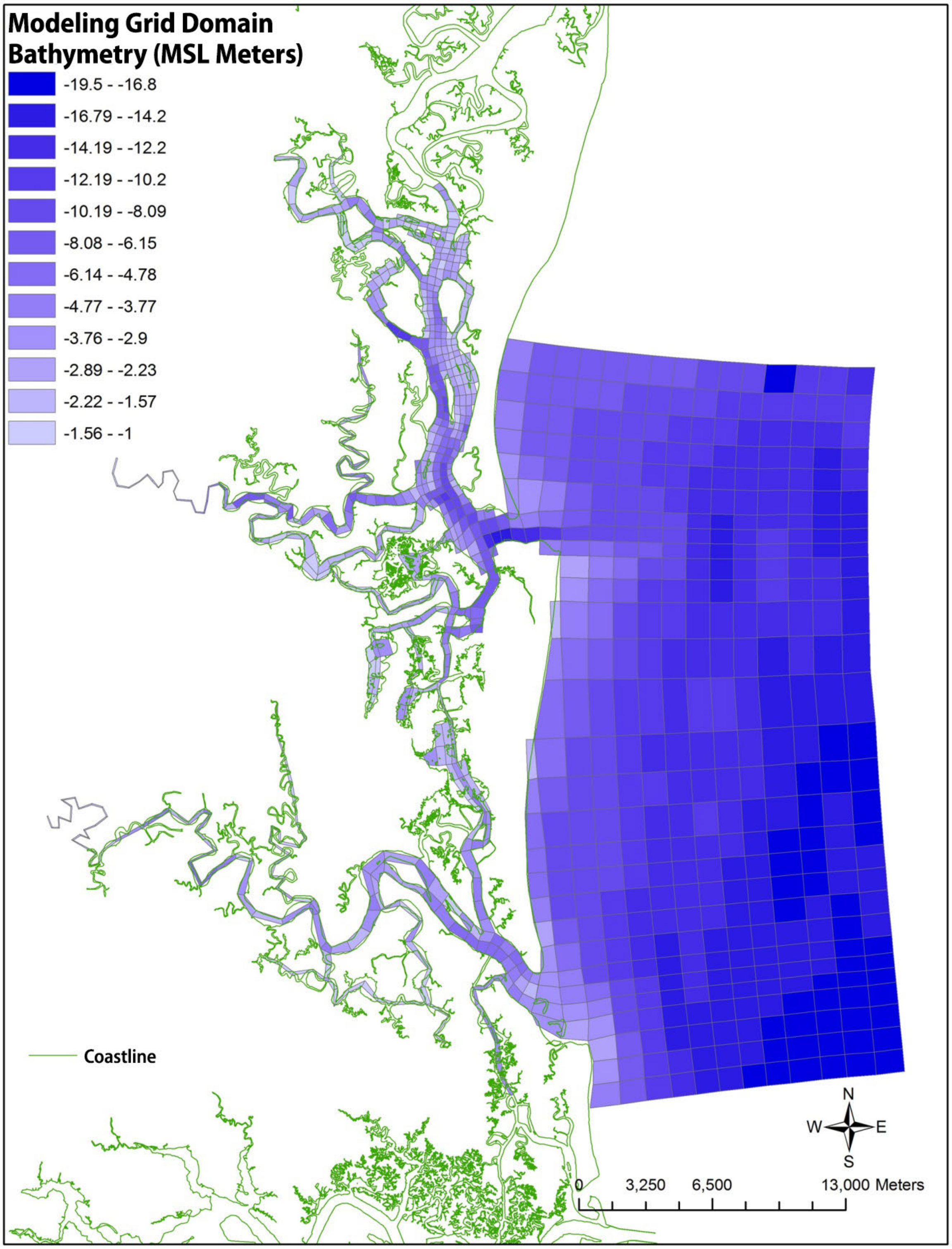


Figure D-42. St. Marys-Nassau Estuary bathymetry

15.3 St. Marys-Nassau Estuary Monitoring Stations

The calibration-validation process for the St. Marys-Nassau Estuary model mostly uses mostly data collected by FDEP and NOAA. See Figure D11-1, Attachment 11 for the monitoring stations.

The data used for calibration-validation of the EFDC and WASP7-based models are:

- NOAA Fernandina Beach tidal station (station ID 8729108): 2003–2004 WSE for calibration; 2006–2007 for validation.
- FDEP 2003–2004 measurements of temperature and salinity at monitoring stations in the St. Marys-Nassau Estuary for calibration.
- FDEP 2006–2007 measurements of temperature and salinity at monitoring stations in the St. Marys-Nassau Estuary for validation.
- FDEP 2002–2009 measurements of water quality parameters at monitoring stations in the St. Marys-Nassau Estuary for calibration and validation.

The EFDC model was calibrated for salinity and temperature using data for 2003–2004. The EFDC model was validated for salinity and temperature using data for 2006–2007.

The WASP7 model was calibrated for chl-a, DO, nutrients (ammonia, nitrate-nitrite, TN and TP), TSS and light attenuation coefficient using data for 2002–2009.

15.4 Hydrodynamic Model Forcing Conditions

EFDC-based hydrodynamic modeling was conducted to reproduce the three-dimensional circulation dynamics and salinity and temperature structure in the bay system. The model predicts these parameters in response to multiple factors: wind speed and direction, freshwater discharge, water level fluctuation, rainfall, surface heat flux, and temperature and salinity associated with boundary fluxes.

Meteorological Factors

Hourly measurements of atmospheric pressure, dry and wet bulb atmospheric temperatures, rainfall rate, wind speed and direction, and fractional cloud cover were obtained from data collected at station WBAN 13889 Jacksonville for 1997–2009. Solar shortwave radiation was calculated using the CE-QUAL-W2 method. The meteorological factors for the EFDC hydrodynamic model are in the ASER.INP file. The WSER.INP file includes hourly measurements of wind speed and direction.

Freshwater Flows and Temperature

The watershed flows and water temperatures discharged into the St. Marys-Nassau estuarine system were calculated using the LSPC watershed model (Appendix C). The watershed input boundary cells are shown in Figure D-40. Freshwater flows and water temperatures from watersheds are included in files QSER.INP and TSER.INP, respectively.

Point Sources

Five major point sources were included in the hydrodynamic and water quality model setup. Those discharges are listed in Table D-28 with their current average discharge rates. The locations of the point sources are shown in Figure D-41. The correspondent flow and temperature data are included in the files QSER.INP and TSER.INP.

Table D-28. Point sources for St. Marys-Nassau Estuary model

Permit Number	Facility Name	Avg. Flow (MGD)
GA0026255	St Marys WWCP	0.7
GA0038580	St Marys Point Peter WPCP	1.3
FL00027260	City of Fernandina Beach WWTP	2.0
FL0000701	Rayoner Fernandina Pulp Mill	9.8
FL0001104	Jefferson-Smurfit Paperboard Mill	19.8

Offshore Boundary WSE and Water Temperature

Hourly time series data of WSE from NOAA tidal station 8720030 (Fernandina Beach) were initially used as offshore boundary conditions in the hydrodynamic model. The timing and amplitude of the boundary conditions, which included the effects of the hydrodynamics of tidal flows into and within the bay, were adjusted in the WSE calibration. Adjustments in the timing and amplitude at the offshore ocean boundary were made by comparing observed data with WSE predictions at the location of the tidal station within the bay, to get close agreement between predicted and measured WSE variations at Fernandina Beach. The datum used for WSE is mean sea level.

Observed water temperature data at the St. Marys-Nassau Estuary monitoring stations, during the full monitoring period, were used in a spreadsheet to determine the phase (timing) and amplitude of a temperature sine curve. The calibrated sine curve was then used to generate daily water temperature boundary conditions specified for all five layers in the hydrodynamic model, at the offshore ocean and northern Cumberland Sound open boundaries.

WSE and water temperatures specified at open boundaries of the EFDC model are included in files PSER.INP and TSER.INP, respectively.

Offshore Boundary Salinity

A lack of salinity field measurements exists close to the open boundary. Because of that, a constant value of salinity (37 ppt) was selected as the open boundary condition, for all five layers. These salinity values are in general correspondence to average salinity in the northern part of the Atlantic Ocean. Salinity specified at the open tidal boundary at the Atlantic Intracoastal Waterway connection to the western end of West Bay was set at a constant value of 37 ppt for all five layers. Salinities specified at open boundaries in the EFDC hydrodynamic model are in the file SSER.INP.

All offshore and inland watershed input boundaries and point source inputs and physical parameters input to the EFDC hydrodynamic model are given in the EFDC master input file EFDC.INP.

15.5 Hydrodynamic Model Calibration and Validation Analysis

Results (Tables D11-1 to D11-6) of calibration and validation of the hydrodynamic components of the St. Marys-Nassau Estuary model are presented in Attachment 11 and graphical results are in the data files for the St. Marys-Nassau Estuary model. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Water Surface Elevation

Hourly data of WSE at NOAA tidal station 8720030 Fernandina Beach (Figure D11-1, Attachment 11) were selected as the calibration and validation data set. The period of calibration is 2003–2004, and the validation period is 2006–2007. Graphical analyses demonstrate the close correspondence of the calibrated and validated model WSE output to NOAA observations at Fernandina Beach. Tables D11-1 and D11-2 present the calibration and validation error statistics, respectively, for predicted versus measured WSE. The difference between mean observed and simulated hourly WSE ranges from -1 to 2 cm for calibration and -3 to -1 cm for validation. Correlation coefficient (R^2) values of 0.97 for calibration and 0.95 for validation show good correlation between simulations and observations.

Salinity

Salinity measurements at 11 FDEP monitoring stations (Figure D11-1) for 2003–2004 were used as the calibration data set. Salinity measurements at 5 FDEP monitoring stations (Figure D11-1) for 2006–2007 were used as the validation data set. Tables D11-3 and D11-4 present the calibration and validation error statistics, respectively, for mean predicted versus measured salinity. The percent error values range from -21 to 483 for calibration and from -56 to -23 for validation. Graphical analyses demonstrate good visual correspondence between the measured and simulated values of salinity, during the calibration and validation periods.

Temperature

Temperature measurements at 3 FDEP monitoring stations (Figure D11-1) for 2003–2004 were used as the calibration data set. Temperature measurements at 5 FDEP monitoring stations (Figure D11-1) for the period 2006–2007 were used as the validation data set. Tables D11-5 and D11-6 present the calibration and validation error statistics for mean predicted versus measured temperature. The percent error values range from -3 to 3 for calibration and -7.3 to 0.1 for validation. Graphical analyses demonstrate good visual correspondence between the measured and simulated values of temperature, during the calibration and validation periods.

15.6 Water Quality Model Forcing Conditions

The selection of the WASP7-based water quality model's state variables is described in Section 4.6.

Point and Nonpoint Sources Loads

Time series of watershed loads were obtained from LSPC simulations (Appendix C) for organic nutrients, TSS, CBOD, and DO. Water quality constituent mass loads from point sources given in Table D-28 are discharged directly into the estuary input boundary grid cells (Figure D-41). The point source discharge values were obtained from DMR data in EPA's PCS.

Solar Radiation and Air Temperature

The meteorological data for WASP7 was the same used for the heat exchange simulation for the hydrodynamic EFDC model using data measured at station WBAN 13889, Jacksonville.

Benthic Nutrient Fluxes and Sediment Oxygen Demand

Benthic ammonia nitrogen and phosphate nutrient fluxes were set to zero. The global bottom layer SOD values between 0.1 and 0.5 g/m^2/day were determined for the St. Marys-Nassau Estuary in the calibration process.

Marsh Nutrient Loads

During calibration of the WASP7 model, it was found that addition of loads of organic carbon, organic nitrogen, and organic phosphorus from the extensive marsh areas in the St. Marys-Nassau Estuary were required to simulate the levels of those nutrients measured throughout the estuary system. Accordingly, those loads were added for each LSPC watershed input to the system, on the basis of annual loads measured by Turner (1978) and others, in similar coastal Georgia salt marsh systems. Calculation of those constant loads was on the basis of actual wetland acreage in each of the LSPC input watersheds and annual carbon, nitrogen, and phosphorus loading rates from Turner's research. The loads were found to be of the same order of magnitude annually as those entering the system via watershed inputs.

Reaeration

The reaeration processes for all water surface cells were calculated using the Covar option in WASP7.

Boundary Conditions

The offshore boundary conditions for the WASP7 model are presented in Table D-29.

Table D-29. Offshore concentration boundary conditions

Parameter	Concentration
Ammonia (mg/L)	0.02
Nitrate (mg/L)	0.02
Organic Nitrogen (mg/L)	0.47
Orthophosphate (mg/L)	0.03
Organic Phosphorus (mg/L)	0.03
Chl-a (ug/L)	2
Dissolved Oxygen (mg/L)	6
CBODu (mg/L)	2
Total Suspended Solids (mg/L)	5

Inland and offshore boundary conditions for detrital components of the model were assumed as 0 mg/L.

Final calibration values for chemical and biological constants of the water quality model are presented in Table D-30.

All forcing functions, boundary conditions, calibration rates, and constants are in the WASP7 input file.

Table D-30. Calibration rates and coefficients for the St. Marys-Nassau Estuary WASP7 water quality model

Water Quality Variable	Definition	Value	Minimum	Maximum
Phytoplankton	Phytoplankton Maximum Growth Rate Constant @20 °C (per day)	3.0	0	3
	Phytoplankton Growth Temperature Coefficient	1.070	0	1.07
	Phytoplankton Self Shading Extinction (Dick Smith Formulation)	0.017	0	0.02
	Phytoplankton Carbon to Chlorophyll Ratio	60.0	0	200
	Phytoplankton Half-Saturation Constant for Nitrogen Uptake (mg N/L)	0.025	0	0.05
	Phytoplankton Half-Saturation Constant for Phosphorus Uptake (mg P/L)	0.001	0	0.05
	Phytoplankton Endogenous Respiration Rate Constant @20 °C (per day)	0.10	0	0.5
	Phytoplankton Respiration Temperature Coefficient	1.050	0	1.08
	Phytoplankton Death Rate Constant (Non-Zooplankton Predation) (per day)	0.04	0	0.25
	Phytoplankton Zooplankton Grazing Rate Constant (per day)	0.00	0	5.0
	Phytoplankton Phosphorus to Carbon Ratio	0.010	0	0.24
	Phytoplankton Nitrogen to Carbon Ratio	0.43	0	0.43
	Phytoplankton Half-Sat. for Recycle of Nitrogen and Phosphorus (mg Phyt C/L)	0.005	0	1
Ammonia	Nitrification Rate Constant @20 °C (per day)	0.10	0	10
	Nitrification Temperature Coefficient	1.07	0	1.07
	Half Saturation Constant for Nitrification Oxygen Limit (mg O/L)	0.50	0	2
Nitrate-Nitrite	Denitrification Rate Constant @20 °C (per day)	0.10	0	0.09
	Denitrification Temperature Coefficient	1.020	0	1.04
	Half Saturation Constant for Denitrification Oxygen Limit (mg O/L)	0.01	0	0.1
Organic Nitrogen	DON Mineralization Rate Constant @20 °C (per day)	0.025	0	1.08
	DON Mineralization Temperature Coefficient	1.047	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Nitrogen	1.00	0	1
Organic Phosphorus	Mineralization Rate Constant for Dissolved Organic P @20 °C (per day)	0.03	0	0.22
	DOP Mineralization Temperature Coefficient	1.024	0	1.08
	Fraction of Phytoplankton Death Recycled to Organic Phosphorus	1.00	0	1

Water Quality Variable	Definition	Value	Minimum	Maximum
Light	Light Option (1 uses input light; 2 uses calculated diel light)	2	1	2
	Phytoplankton Maximum Quantum Yield Constant	720.0	0	720
	Phytoplankton Optimal Light Saturation	350.0	0	350
	Detritus and Solids Light Extinction Multiplier	0.17	0	10
	DOC1 Light Extinction Multiplier	1.80	0	10
DO	Water body Type Used for Wind Driven Reaeration Rate	2	0	3
	Calc Reaeration Option - O'Connor	1	0	4
	Reaeration Option -Sums Wind and Hydraulic Ka	1	0	1
	Theta -- Reaeration Temperature Correction	1.022	0	1.03
	Oxygen to Carbon Stoichiometric Ratio	2.66	0	2.67
CBOD	CBOD Decay Rate Constant @20 °C (per day)	0.10	0	5.6
	CBOD Decay Rate Temperature Correction Coefficient	1.040	0	1.07
	CBOD Half Saturation Oxygen Limit (mg O/L)	0.20	0	0.5
Detritus	Detritus Dissolution Rate (1/day)	0.10	0	0
	Temperature Correction for Detritus Dissolution	1.040	0	0

15.7 Water Quality Calibration and Validation Analysis

Results (Tables D11-7 to D11-14) of calibration and validation of water quality components of the St. Marys-Nassau Estuary model are presented in Attachment 11. It should be noted that the model calibration is targeted at a global scale. There might be some localized effects that the model cannot capture without affecting the global calibration. Also, the percent error values were used as a general guidance in conjunction with the visual comparisons on the figures to capture seasonal trends and variations.

Monthly measurements of chl-a, ammonia, nitrate-nitrite, TN, TP, DO, TSS and light attenuation coefficient at 2 FDEP stations for 2002–2009 were used as the calibration and validation data set. The visual comparisons of the calibrated model run with observed data for all the monitoring stations, for 2002–2009, are presented in the data files for the St. Marys-Nassau Estuary model.

Table D11-7 shows statistical comparisons of mean simulated and measured chl-a in the surface layer for two water quality monitoring stations. The percent error values presented in Table D11-7 range from -55 to 46.

Table D11-8 shows statistical comparisons of mean simulated and measured DO in the surface layer for fourteen water quality monitoring stations. The percent error values in Table D11-8 range from -37 to 30.

Table D11-9 shows statistical comparisons of mean simulated and measured light attenuation coefficient in the surface layer for thirteen water quality monitoring stations. The percent error values in Table D11-9 range from -86 to 26.

Table D11-10 shows statistical comparisons of mean simulated and measured ammonia in the surface layer for each of the water quality monitoring stations. The percent error values in Table D11-10 range from -53 to 92.

Table D11-11 shows statistical comparisons of mean simulated and measured nitrate-nitrite in the surface layer for thirteen water quality monitoring stations. The percent error values in Table D11-11 range from -85 to -27.

Table D11-12 shows statistical comparisons of mean simulated and measured TN in the surface layer for thirteen water quality monitoring stations. The percent error values in Table D11-12 range from -61 to 14.

Table D11-13 shows statistical comparisons of mean simulated and measured TP in the surface layer for thirteen water quality monitoring stations. The percent error values in Table D11-13 range from -46 to 117.

Table D11-14 shows statistical comparisons of mean simulated and measured TSS in the surface layer for eight water quality monitoring stations. The percent error values in Table D11-14 range from -55 to 142.

15.8 St. Marys-Nassau Estuary Model Summary and Conclusions

The hydrodynamic and water quality model for the St. Marys-Nassau Estuary was calibrated and validated for data collected for 2002–2009.

The EFDC hydrodynamic model represents the overall circulation and mixing characteristics of the St. Marys-Nassau Estuary system on the basis of reasonable agreement between observed and calculated temporal and spatial distributions of WSE, salinity and temperature.

The WASP7 water quality model reasonably represents the overall phytoplankton, nutrient, TSS, light attenuation coefficient, and DO interactions in the St. Marys-Nassau Estuary system.

St. Marys-Nassau Estuary hydrodynamic and water quality model data sources are provided in Table D-31.

Table D-31. St. Marys-Nassau Estuary hydrodynamic and water quality model data sources

Data	Source	Location Used
Atmospheric and Wind Data at Surface Airways Stations	National Climatic Data Center (EarthInfo 2009)	St. Marys-Nassau Estuary Model
Bathymetric Data	National Oceanic and Atmospheric Administration, National Geophysical Data Center (NOAA GEODAS No Date)	St. Marys-Nassau Estuary Model
Digitized Shoreline Data	National Oceanic and Atmospheric Administration (NOAA No Date a)	St. Marys-Nassau Estuary Model
IWR Run 40 Salinity and Temperature Data	Florida Department of Environmental Protection (FDEP 2010a)	St. Marys-Nassau Estuary Model
Measured and Predicted Water Surface Elevation Data	National Oceanic and Atmospheric Administration (NOAA No Date b)	St. Marys-Nassau Estuary Model

Data	Source	Location Used
Wastewater Facility Regulation Municipal and Industrial Point Sources Discharging Directly into Estuary	Florida Department of Environmental Protection (FDEP No Date)	St. Marys-Nassau Estuary Model
Salinity, Temperature and Water Quality Data	City of Jacksonville (FDEP 2007)	St. Marys-Nassau Estuary Model
Municipal and Industrial Point Sources	Georgia Environmental Protection Division (GAEPD 2008)	St. Marys-Nassau Estuary Model

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ATTACHMENTS

Attachment 1 Perdido Bay Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Attachment 2 Pensacola Bay Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Attachment 3 Choctawhatchee Bay Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Attachment 4 St. Andrews and St. Joseph Bays Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Attachment 5 Florida Big Bend Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Attachment 6 Tampa-Sarasota Bay Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Attachment 7 Charlotte Harbor, Caloosahatchee Estuary and Estero Bay Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Attachment 8 Lake Worth Lagoon Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Attachment 9 Loxahatchee Estuary Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Attachment 10 St. Lucie Estuary Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Attachment 11 St. Marys and Nassau Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Appendix D Attachments

Appendix D
Attachment 1: Perdido Bay Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Contents

D1.1 PERDIDO BAY LOCATION OF MONITORING STATIONS D1-1

D1.2 MODELING OF WATER SURFACE ELEVATION (WSE) D1-2

D1.3 MODELING OF SALINITY D1-3

D1.4 MODELING OF WATER TEMPERATURE D1-4

D1.5 MODELING OF WATER QUALITY D1-5

D1.5.1 Calibration and Validation for Chl-a D1-5
D1.5.2 Calibration and Validation for Nutrients D1-6
D1.5.3 Calibration and Validation for DO D1-7
D1.5.4 Calibration and Validation for Light Attenuation Coefficient (K_d) D1-7

Figures

Figure D1-1. NOAA tidal, FDEP and ADEM water quality monitoring stations D1-1

Tables

Table D1-1. Comparisons of simulated and measured WSE at NOAA tidal station 8729941, Perdido, FL D1-2

Table D1-2. Comparisons of simulated and measured salinity in surface layer at FDEP monitoring stations, Perdido, FL: 2002-2004 .... D1-3

Table D1-3. Comparisons of simulations and measurements of water temperature in surface layer at FDEP monitoring station, Perdido, FL: 2002-2004 .... D1-4

Table D1-4. Comparisons of simulated and measured chl-a at FDEP stations in surface layer D1-5

Table D1-5. Comparisons of simulated and measured nutrients at FDEP stations in surface layer D1-6

Table D1-6. Comparisons of simulated and measured DO at FDEP stations in surface layer D1-7

Table D1-7. Comparisons of simulations and measurements of K_d at FDEP stations: 2002-2009 .... D1-7

D1.1 Perdido Bay Location of Monitoring Stations

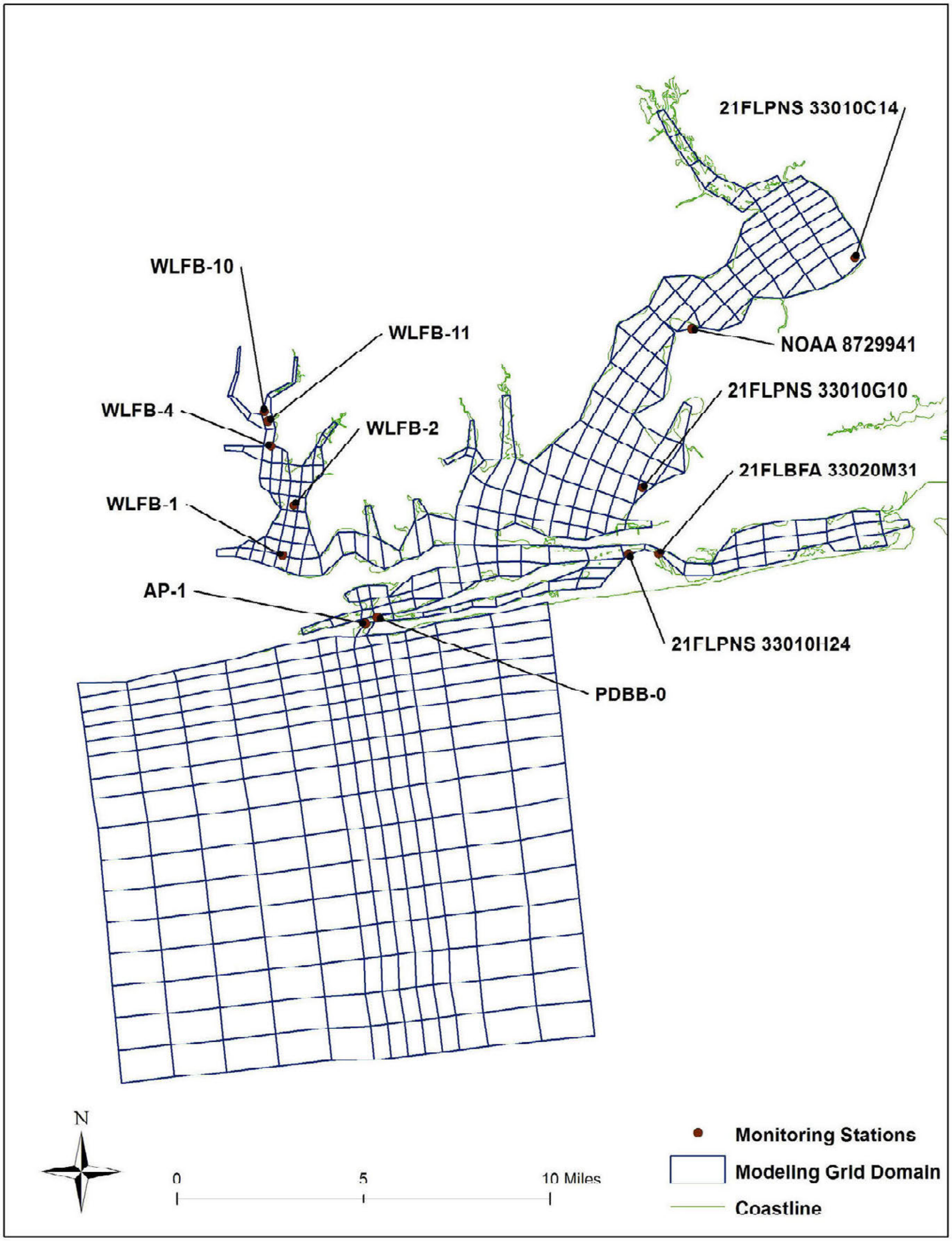

Figure D1-1. NOAA tidal, FDEP and ADEM water quality monitoring stations

D1.2 Modeling of Water Surface Elevation (WSE)

Table D1-1. Comparisons of simulated and measured WSE at NOAA tidal station 8729941, Perdido, FL

Year	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
2009	0.06	-0.22	0.33	0.09	-0.22	0.39	-0.03	0.00	-0.06	0.89

D1.3 Modeling of Salinity

Table D1-2. Comparisons of simulated and measured salinity in surface layer at FDEP monitoring stations, Perdido, FL: 2002-2004

Station	Salinity (PSU)			
	Simulated Surface Mean	Measurement Mean	Error	
			PSU	%
21FLBFA 33020M31	19.8	23.1	-3.3	-14
21FLPNS 33010H24	19.4	22.2	-2.8	-13
21FLPNS 33010C14	5.9	7.7	-1.8	-24
21FLPNS 33010G10	12.9	16.2	-3.3	-20

D1.4 Modeling of Water Temperature

Table D1-3. Comparisons of simulations and measurements of water temperature in surface layer at FDEP monitoring station, Perdido, FL: 2002-2004

Station	Temperature (Deg C)			
	Simulated Surface Mean	Measurement Mean	Error	
			Deg C	%
21FLBFA 33020M31	22.4	21.9	0.5	2
21FLPNS 33010H24	22.4	22.2	0.2	1
21FLPNS 33010C14	21.2	21.3	-0.1	0
21FLPNS 33010G10	22.2	21.5	0.7	3

D1.5 Modeling of Water Quality

D1.5.1 Calibration and Validation for Chl-a

Table D1-4. Comparisons of simulated and measured chl-a at FDEP stations in surface layer

Station	Period	Chl-a (µg/L)			
		Simulated Surface Mean	Measurement Mean	Error	
				µg/L	%
21FLBFA 33020M31	2002-2009	5.5	11.1	-5.6	-50
21FLPNS 33010H24	2002-2009	5.6	5.5	0.1	2
21FLPNS 33010C14	2002-2009	6.6	9.6	-2.9	-31
21FLPNS 33010G10	2002-2009	6.5	6.5	0.0	0
AP-1	2003-2005	5.2	4.5	0.7	15
PDBB-0	2005-2009	4.4	3.3	1.2	36

D1.5.2 Calibration and Validation for Nutrients

Table D1-5. Comparisons of simulated and measured nutrients at FDEP stations in surface layer

Station	Period	Nitrate-Nitrite				Ammonia				TN				TP			
		Mean Simulated Surface	Mean Measured	Error		Mean Simulated Surface	Mean Measured	Error		Mean Simulated Surface	Mean Measured	Error		Mean Simulated Surface	Mean Measured	Error	
		mg/L	mg/L	mg/L	%	mg/L	mg/L	mg/L	%	mg/L	mg/L	mg/L	%	mg/L	mg/L	mg/L	%
21FLBFA 33020M31	2002-2009	0.038	0.064	-0.026	-41	0.035	0.051	-0.016	-31	0.304	0.626	-0.3220	-51	0.021	0.039	-0.02	-46
21FLPNS 33010H24	2002-2009	0.040	0.010	0.030	300	0.037	0.011	0.026	236	0.311	0.439	-0.1280	-29	0.021	0.019	0.00	11
21FLPNS 33010C14	2002-2009	0.172	0.028	0.144	514	0.088	0.057	0.031	54	0.583	0.765	-0.1820	-24	0.032	0.034	0.00	-6
21FLPNS 33010G10	2002-2009	0.078	0.013	0.065	500	0.060	0.018	0.042	233	0.421	0.552	-0.1310	-24	0.026	0.029	0.00	-10
AP-1	2003-2005	0.027	0.033	-0.006	-18	0.029	0.024	0.005	21					0.018	0.075	-0.06	-76
PDBB-0	2005-2009	0.027	0.028	-0.001	-4	0.029	0.024	0.005	21					0.019	0.023	0.00	-17

D1.5.3 Calibration and Validation for DO

Table D1-6. Comparisons of simulated and measured DO at FDEP stations in surface layer

Station	Period	DO (mg/L)			
		Simulated Surface Mean	Measurement Mean	Error	
				mg/L	%
21FLBFA 33020M31	2002-2004	7.7	6.6	1.1	16
21FLPNS 33010H24	2002-2004	7.7	7.6	0.1	2
21FLPNS 33010C14	2002-2004	8.2	6.3	1.9	30
21FLPNS 33010G10	2002-2004	8.0	7.0	1.0	14
AP-1	2003-2005	7.4	7.3	0.1	1
PDBB-0	2005-2009	7.4	6.4	1.0	15

D1.5.4 Calibration and Validation for Light Attenuation Coefficient (K_d)

Table D1-7. Comparisons of simulations and measurements of K_d at FDEP stations: 2002-2009

Station	Light Attenuation Coefficient (K_d) (1/m)			
	Simulated Surface Mean	Measurement Mean	Error	
			1/m	%
21FLBFA 33020M31	0.93	1.46	-0.5	-36
21FLPNS 33010H24	0.88	1.40	-0.5	-37

Appendix D
Attachment 2: Pensacola Bay Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Contents

D2.1 LOCATION OF MONITORING STATIONS D2-1

D2.2 MODELING OF WATER SURFACE ELEVATION (WSE) D2-3

D2.3 MODELING OF SALINITY D2-4

D2.3.1 Calibration Comparisons with 2007-2009 Continuously Measured Data D2-4

D2.3.2 Validation Comparisons with 2002-2004 Monthly Measured Data D2-4

D2.4 MODELING OF WATER TEMPERATURE D2-5

D2.4.1 Calibration Comparisons with 2007-2009 Continuously Measured Data D2-5

D2.4.2 Validation Comparisons with 2002-2004 Monthly Measured Data D2-6

D2.5 MODELING OF WATER QUALITY D2-7

D2.5.1 Statistics of Calibration and Validation D2-7

Figures

Figure D2-1. NOAA and EPA hydraulic monitoring stations D2-1
Figure D2-2. EPA water quality monitoring stations (monthly measurements) D2-2

Tables

Table D2-1. Calibration comparisons of simulated and measured WSE NOAA tidal station 8729840, Pensacola, FL: 2002-2009 .... D2-3
Table D2-2. Validation comparisons of simulated and measured WSE at EPA monitoring stations: 2009 .... D2-3
Table D2-3. Calibration comparisons of simulated and measured salinity at EPA Pensacola Bay monitoring stations: 2007-2009 .... D2-4
Table D2-4. Validation comparisons of simulated and measured surface and bottom salinity at EPA Pensacola Bay monitoring stations: 2002-2004 .... D2-4
Table D2-5. Calibration comparisons of simulated and measured water temperature at NOAA monitoring stations (2002-2009) and EPA monitoring stations (2007-2009) D2-5
Table D2-6. Validation comparisons of simulated and measured surface and bottom water temperature at EPA monitoring stations, Pensacola, FL: 2002-2004 .... D2-6
Table D2-7. Comparisons of simulated and measured chl-a in surface layer: 2002-2004 .... D2-7
Table D2-8. Comparisons of simulated and measured nutrients in surface layer: 2002-2004 .... D2-8
Table D2-9. Comparisons of simulated and measured DO in surface and bottom layers: 2002-2004 .... D2-9
Table D2-10. Comparisons of simulated and measured light attenuation coefficient: 2002-2004 .... D2-9

D2.1 Location of Monitoring Stations

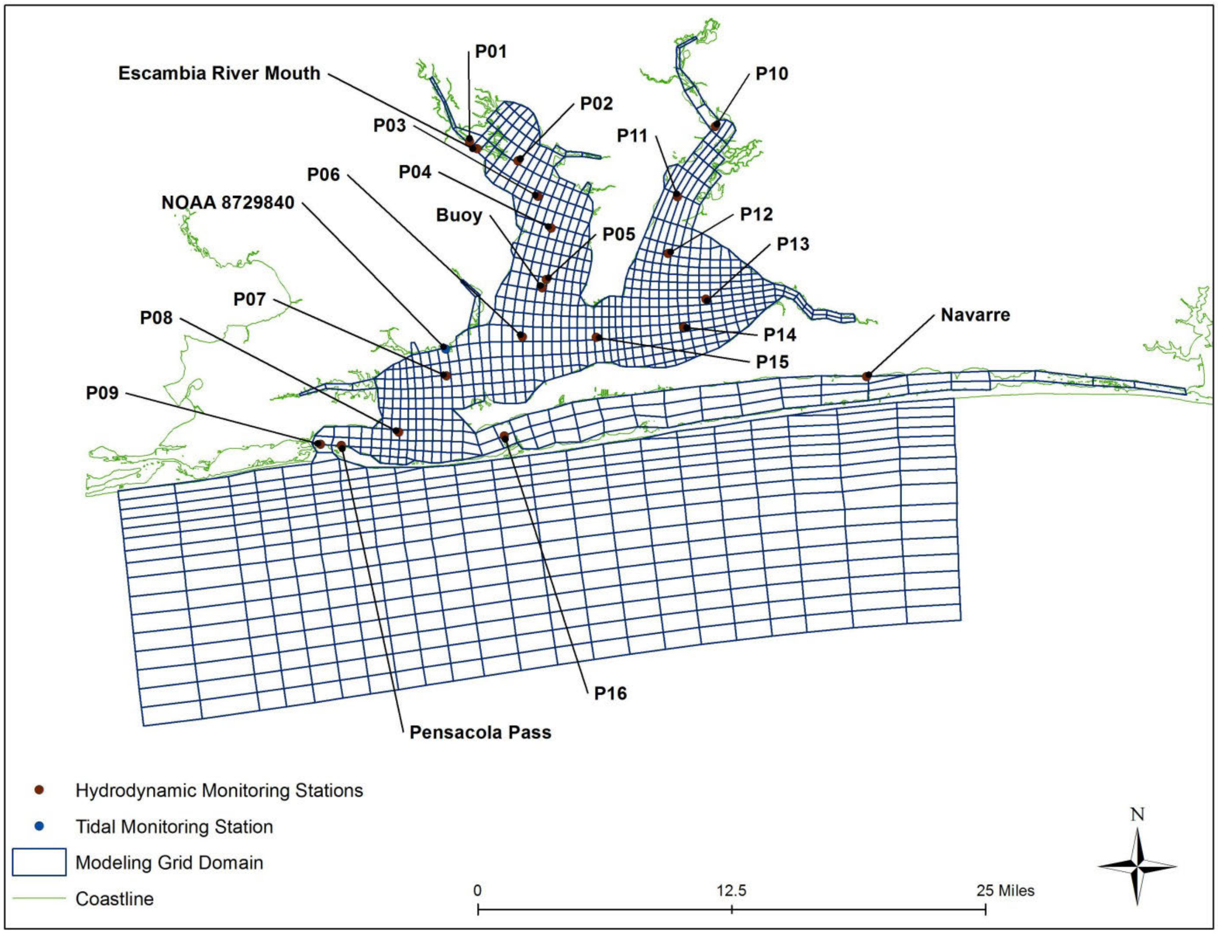

Figure D2-1. NOAA and EPA hydraulic monitoring stations

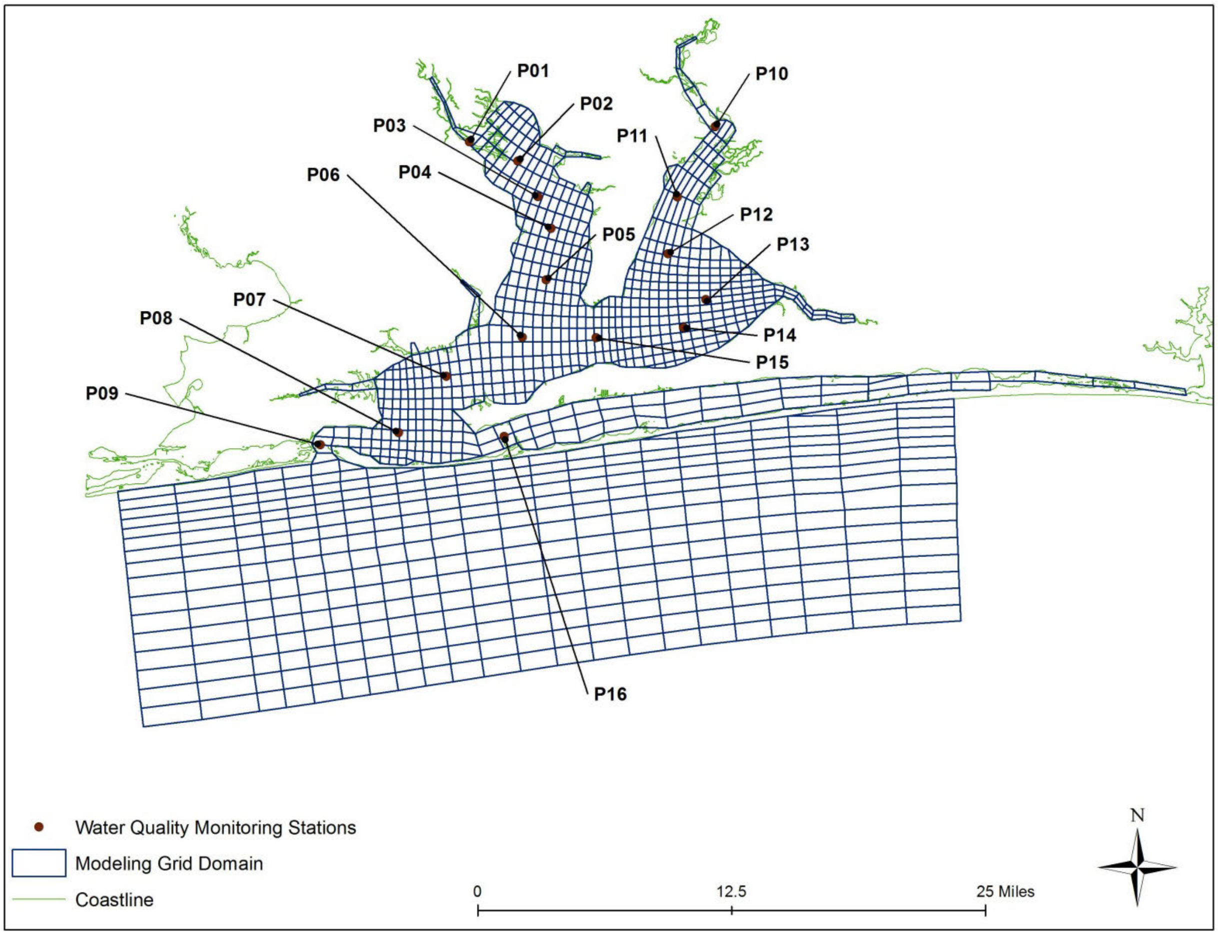

Figure D2-2. EPA water quality monitoring stations (monthly measurements)

D2.2 Modeling of Water Surface Elevation (WSE)

Table D2-1. Calibration comparisons of simulated and measured WSE NOAA tidal station 8729840, Pensacola, FL: 2002-2009

	Simulated (m)			Measured (m)			Error (m)			
Year	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	R^2
2002	0.02	-0.31	0.36	0.02	-0.32	0.35	0.00	0.01	0.01	0.98
2003	0.07	-0.28	0.38	0.07	-0.28	0.39	0.00	0.00	-0.01	0.98
2004	0.02	-0.31	0.33	0.01	-0.30	0.31	0.01	-0.01	0.02	0.71
2005	0.05	-0.31	0.39	0.06	-0.33	0.40	-0.01	0.02	-0.01	0.98
2006	0.00	-0.33	0.32	0.00	-0.32	0.31	0.00	-0.01	0.01	0.94
2007	0.02	-0.32	0.34	0.02	-0.32	0.34	0.00	0.00	0.00	0.94
2008	0.04	-0.30	0.36	0.04	-0.30	0.37	0.00	0.00	-0.01	0.84
2009	0.08	-0.26	0.40	0.08	-0.27	0.41	0.00	0.01	-0.01	0.72
2002-2009	0.03	-0.31	0.36	0.03	-0.31	0.36	0.00	0.00	0.00	0.89

Table D2-2. Validation comparisons of simulated and measured WSE at EPA monitoring stations: 2009

	Simulated (m)			Measured (m)			Error (m)			
Station	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	R^2
Pensacola Pass	0.07	-0.17	0.32	0.00	-0.26	0.27	0.07	0.09	0.05	0.95
Escambia River Mouth	0.16	-0.15	0.47	0.00	-0.04	0.43	0.16	-0.11	0.04	0.97
Navarre	0.14	-0.16	0.44	0.00	-0.30	0.36	0.14	0.14	0.08	0.96

D2.3 Modeling of Salinity

D2.3.1 Calibration Comparisons with 2007-2009 Continuously Measured Data

Table D2-3. Calibration comparisons of simulated and measured salinity at EPA Pensacola Bay monitoring stations: 2007-2009

Station	Year	Depth	Salinity (PSU)			
			Simulated Mean	Measurement Mean	Error	
					PSU	%
Pensacola Pass	2007-2009	Surface	27.8	27.5	0.3	1
	2007	Surface	30.3	31.0	-0.7	-2
	2008	Surface	27.5	26.2	1.3	5
	2009	Surface	25.5	25.2	0.3	1
Buoy	2009	Surface	10.7	14.3	-3.6	-25
	2009	Bottom	28.6	25.6	3.0	12

D2.3.2 Validation Comparisons with 2002-2004 Monthly Measured Data

Table D2-4. Validation comparisons of simulated and measured surface and bottom salinity at EPA Pensacola Bay monitoring stations: 2002-2004

Station	Salinity (PSU)				Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error		Simulated Bottom Mean	Measured Bottom Mean	Error	
			PSU	%			PSU	%
P01	3.5	1.2	2.3	196	11.6	8.9	2.6	29
P02	8.0	7.0	0.9	13	10.4	18.5	-8.1	-44
P03	10.0	9.1	0.9	10	21.5	20.0	1.5	7
P04	12.1	11.7	0.3	3	25.1	22.2	2.9	13
P05	15.1	14.6	0.6	4	29.5	26.8	2.7	10
P06	17.9	17.7	0.3	2	30.7	29.7	1.0	4
P07	21.9	19.2	2.6	14	33.7	31.9	1.7	5
P08	24.1	21.7	2.3	11	35.3	32.7	2.6	8
P09	27.4	26.4	0.9	4	35.2	33.2	1.9	6
P10	4.7	4.0	0.7	18	12.3	15.4	-3.0	-20
P11	8.6	8.7	-0.1	-1	16.6	17.6	-1.1	-6
P12	11.5	14.0	-2.5	-18	20.3	20.2	0.1	0
P13	16.2	17.5	-1.3	-7	19.8	21.1	-1.2	-6
P14	17.2	17.5	-0.3	-2	25.4	25.2	0.2	1
P15	17.1	17.3	-0.2	-1	28.2	28.2	0.1	0
P16	25.0	23.1	1.9	8	27.3	29.1	-1.8	-6

D2.4 Modeling of Water Temperature

D2.4.1 Calibration Comparisons with 2007-2009 Continuously Measured Data

Table D2-5. Calibration comparisons of simulated and measured water temperature at NOAA monitoring stations (2002-2009) and EPA monitoring stations (2007-2009)

Station	Year	Depth	Temperature (Deg C)			
			Simulated Surface Mean	Measurement Mean	Error	
					Deg C	%
NOAA 8729840	2002-2009	Surface	22.1	23.3	-1.2	-5
	2002	Surface	22.3	22.7	-0.5	-2
	2003	Surface	22.0	22.9	-0.9	-4
	2005	Surface	21.9	23.0	-1.1	-5
	2006	Surface	22.9	25.0	-2.2	-9
	2007	Surface	22.4	23.6	-1.2	-5
	2008	Surface	21.7	22.5	-0.8	-4
	2009	Surface	21.7	23.0	-1.3	-6
Pensacola Pass	2007-2009	Surface	22.3	24.2	-1.9	-8
	2007	Surface	22.9	25.4	-2.5	-10
	2008	Surface	22.0	24.1	-2.0	-8
	2009	Surface	22.0	23.2	-1.2	-5
Buoy	2009	Surface	21.5	28.2	-6.7	-24
Buoy	2009	Bottom	20.7	27.0	-6.3	-23
Navarre	2009	Surface	21.2	28.9	-7.8	-27

D2.4.2 Validation Comparisons with 2002-2004 Monthly Measured Data

Table D2-6. Validation comparisons of simulated and measured surface and bottom water temperature at EPA monitoring stations, Pensacola, FL: 2002-2004

Station	Temperature (Deg C)				Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error		Simulated Bottom Mean	Measured Bottom Mean	Error	
			Deg C	%			Deg C	%
P01	19.1	23.1	-4.0	-17	19.3	23.2	-3.8	-17
P02	20.6	23.1	-2.5	-11	19.3	24.2	-4.9	-20
P03	20.7	23.2	-2.5	-11	20.6	24.2	-3.6	-15
P04	21.4	23.5	-2.1	-9	21.2	24.3	-3.1	-13
P05	21.9	23.6	-1.8	-7	21.6	24.2	-2.5	-11
P06	22.0	23.8	-1.8	-8	22.1	24.2	-2.1	-9
P07	22.4	24.0	-1.6	-7	22.7	24.1	-1.4	-6
P08	22.6	24.1	-1.6	-6	22.9	24.0	-1.1	-4
P09	22.8	23.9	-1.1	-4	23.0	23.4	-0.5	-2
P10	20.5	23.4	-2.9	-12	19.0	24.3	-5.3	-22
P11	21.2	23.4	-2.2	-9	20.5	24.0	-3.5	-15
P12	21.2	24.4	-3.2	-13	21.0	24.9	-3.9	-16
P13	22.1	24.2	-2.0	-8	20.3	24.0	-3.6	-15
P14	22.1	23.8	-1.7	-7	21.4	24.0	-2.5	-11
P15	21.9	24.2	-2.2	-9	21.8	24.4	-2.6	-11
P16	22.5	24.6	-2.2	-9	21.8	24.2	-2.4	-10

D2.5 Modeling of Water Quality

D2.5.1 Statistics of Calibration and Validation

Table D2-7. Comparisons of simulated and measured chl-a in surface layer: 2002-2004

Station	Chl-a (µg/L)			
	Simulated Surface Mean	Measurement Mean	Error	
			µg/L	%
P01	2.5	3.7	-1.3	-34
P02	4.6	7.9	-3.3	-42
P03	4.8	8.0	-3.2	-40
P04	5.6	7.9	-2.3	-29
P05	5.8	7.3	-1.5	-20
P06	5.8	6.2	-0.4	-6
P07	5.0	5.4	-0.3	-6
P08	4.5	4.9	-0.4	-9
P09	3.9	3.2	0.7	23
P10	4.8	6.6	-1.8	-27
P11	6.2	6.6	-0.3	-5
P12	6.4	7.3	-0.9	-12
P13	6.8	9.5	-2.7	-28
P14	6.6	6.4	0.2	2
P15	6.2	6.0	0.2	4
P16	4.5	4.5	0.0	-1

Table D2-8. Comparisons of simulated and measured nutrients in surface layer: 2002-2004

Station	Nitrate-Nitrite (mg/L)				Ammonia (mg/L)				Phosphate (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error		Simulated Surface Mean	Measured Surface Mean	Error		Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%			mg/L	%			mg/L	%
P01	0.188	0.219	-0.031	-14	0.053	0.038	0.015	39	0.017	0.013	0.004	31
P02	0.130	0.116	0.014	12	0.056	0.055	0.001	2	0.015	0.009	0.006	67
P03	0.123	0.093	0.030	32	0.055	0.041	0.014	34	0.014	0.008	0.006	75
P04	0.100	0.077	0.023	30	0.054	0.034	0.020	59	0.013	0.007	0.006	86
P05	0.079	0.083	-0.004	-5	0.053	0.059	-0.006	-10	0.012	0.008	0.004	50
P06	0.066	0.054	0.012	22	0.056	0.027	0.029	107	0.01	0.004	0.006	150
P07	0.052	0.031	0.021	68	0.052	0.023	0.029	126	0.009	0.004	0.005	125
P08	0.040	0.043	-0.003	-7	0.045	0.086	-0.041	-48	0.008	0.004	0.004	100
P09	0.028	0.021	0.007	33	0.037	0.032	0.005	16	0.007	0.004	0.003	75
P10	0.224	0.217	0.007	3	0.085	0.038	0.047	124	0.013	0.008	0.005	63
P11	0.157	0.112	0.045	40	0.075	0.041	0.034	83	0.011	0.007	0.004	57
P12	0.129	0.051	0.078	153	0.071	0.035	0.036	103	0.011	0.005	0.006	120
P13	0.079	0.032	0.047	147	0.065	0.050	0.015	30	0.008	0.004	0.004	100
P14	0.072	0.031	0.041	132	0.063	0.041	0.022	54	0.009	0.004	0.005	125
P15	0.072	0.046	0.026	57	0.061	0.040	0.021	53	0.009	0.005	0.004	80
P16	0.030	0.008	0.022	275	0.044	0.019	0.025	132	0.008	0.005	0.003	60

Table D2-9. Comparisons of simulated and measured DO in surface and bottom layers: 2002-2004

Station	DO (mg/L)				DO (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error		Simulated Bottom Mean	Measured Bottom Mean	Error	
			mg/L	%			mg/L	%
P01	8.7	6.6	2.2	33	7.0	5.4	1.7	31
P02	8.5	6.7	1.8	27	6.7	4.2	2.5	59
P03	8.4	6.9	1.6	23	6.3	4.7	1.6	35
P04	8.3	7.2	1.1	15	6.3	4.6	1.7	36
P05	8.1	7.2	0.8	12	6.0	4.0	2.0	50
P06	7.8	7.2	0.5	7	5.8	4.2	1.6	38
P07	7.6	7.4	0.2	3	6.1	5.2	0.9	17
P08	7.4	7.3	0.1	2	6.3	5.8	0.4	7
P09	7.2	6.9	0.3	4	6.3	6.1	0.2	3
P10	8.5	7.2	1.4	19	6.3	5.3	0.9	17
P11	8.5	6.9	1.6	24	6.5	5.3	1.3	24
P12	8.3	6.9	1.4	20	6.1	5.0	1.1	23
P13	7.9	6.6	1.3	20	6.0	5.2	0.8	16
P14	7.9	7.1	0.7	10	5.7	4.6	1.1	25
P15	7.7	7.2	0.5	7	5.6	3.5	2.1	59
P16	7.4	7.0	0.4	6	5.6	5.7	-0.1	-2

Table D2-10. Comparisons of simulated and measured light attenuation coefficient: 2002-2004

Station	Light Attenuation Coefficient (Kd) (1/m)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			1/m	%
P01	1.1	1.8	-0.7	-37
P02	1.2	1.8	-0.6	-35
P03	1.0	1.4	-0.5	-32
P04	0.9	1.3	-0.4	-30
P05	0.8	1.0	-0.2	-22
P06	0.7	0.7	0.0	-3
P07	0.4	0.5	-0.1	-11
P08	0.3	0.4	-0.1	-22
P09	0.3	0.3	0.0	-13
P10	1.5	1.5	-0.1	-6
P11	1.2	1.4	-0.1	-10
P12	1.1	1.5	-0.4	-25
P13	1.1	1.2	-0.1	-5
P14	1.0	0.9	0.0	4
P15	0.8	0.8	0.0	-1
P16	0.6	0.5	0.1	33

Appendix D
Attachment 3: Choctawhatchee Bay Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Contents

D3.1 LOCATION OF MONITORING STATIONS D3-1

D3.2 MODELING OF WATER SURFACE ELEVATION (WSE) D3-3

D3.3 MODELING OF SALINITY D3-4

D3.3.1 Calibration D3-4
D3.3.2 Validation D3-4

D3.4 MODELING OF WATER TEMPERATURE D3-5

D3.4.1 Calibration D3-5
D3.4.2 Validation D3-5

D3.5 MODELING OF WATER QUALITY D3-6

D3.5.1 Calibration and Validation for Chl-a D3-6
D3.5.2 Calibration and Validation for DO D3-6
D3.5.3 Calibration and Validation for TN D3-7
D3.5.4 Calibration and Validation for Ammonia D3-7
D3.5.5 Calibration and Validation for Nitrate-Nitrite D3-8
D3.5.6 Calibration and Validation for TP D3-8
D3.5.7 Calibration and Validation for Total Suspended Solids (TSS) D3-9
D3.5.8 Calibration and Validation for Light Attenuation Coefficient (K_d) D3-9

Figures

Figure D3-1. Hydrodynamic monitoring stations....D3-1
Figure D3-2. Water quality monitoring stations....D3-2

Tables

Table D3-1. Calibration comparisons of simulated and measured WSE at NOAA tidal station T01: 2002-2003....D3-3
Table D3-2. Validation comparisons of simulated and measured WSE at NOAA tidal station T01: 2004....D3-3
Table D3-3. Calibration comparisons of simulated and measured surface and bottom salinity at Choctawhatchee Bay monitoring stations: 2002-2004....D3-4
Table D3-4. Validation comparisons of simulated and measured surface and bottom salinity at Choctawhatchee Bay: 2002-2004....D3-4
Table D3-5. Calibration comparisons of simulated and measured surface and bottom temperature at Choctawhatchee Bay monitoring stations: 2002-2004....D3-5
Table D3-6. Validation comparisons of simulated and measured surface and bottom temperature at Choctawhatchee Bay monitoring stations: 2002-2004....D3-5
Table D3-7. Comparisons of simulated and measured chl-a: 2002-2004....D3-6
Table D3-8. Comparisons of simulated and measured surface and bottom DO: 2002-2004....D3-6
Table D3-9. Comparisons of simulated and measured TN: 2002-2004....D3-7
Table D3-10. Comparisons of simulated and measured ammonia: 2002-2004....D3-7
Table D3-11. Comparisons of simulated and measured nitrate-nitrite: 2002-2004....D3-8
Table D3-12. Comparisons of simulated and measured TP: 2002-2004....D3-8
Table D3-13. Comparisons of simulated and measured TSS: 2002-2004....D3-9
Table D3-14. Comparisons of simulated and measured K_d: 2002-2004....D3-9

D3.1 Location of Monitoring Stations

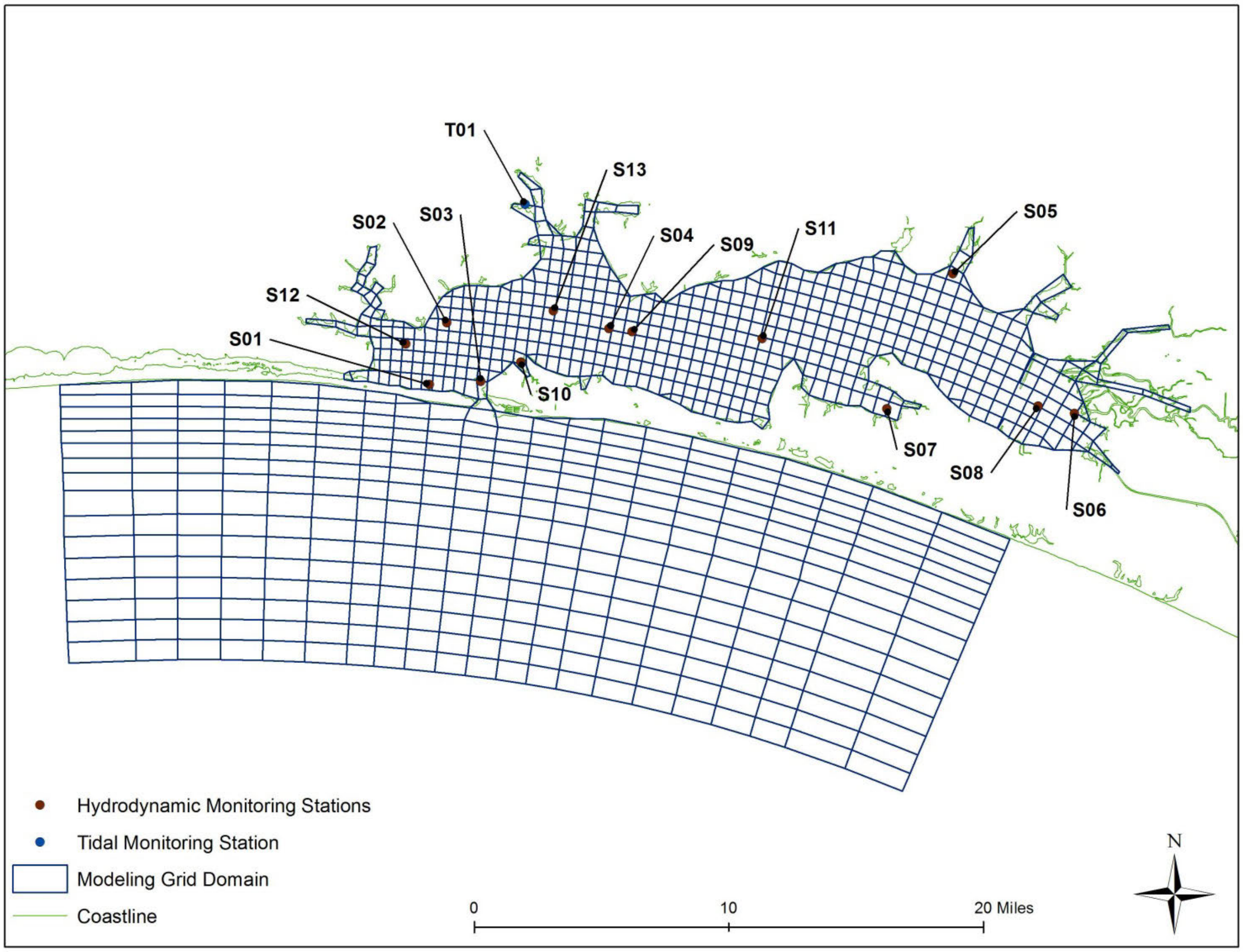

Figure D3-1. Hydrodynamic monitoring stations

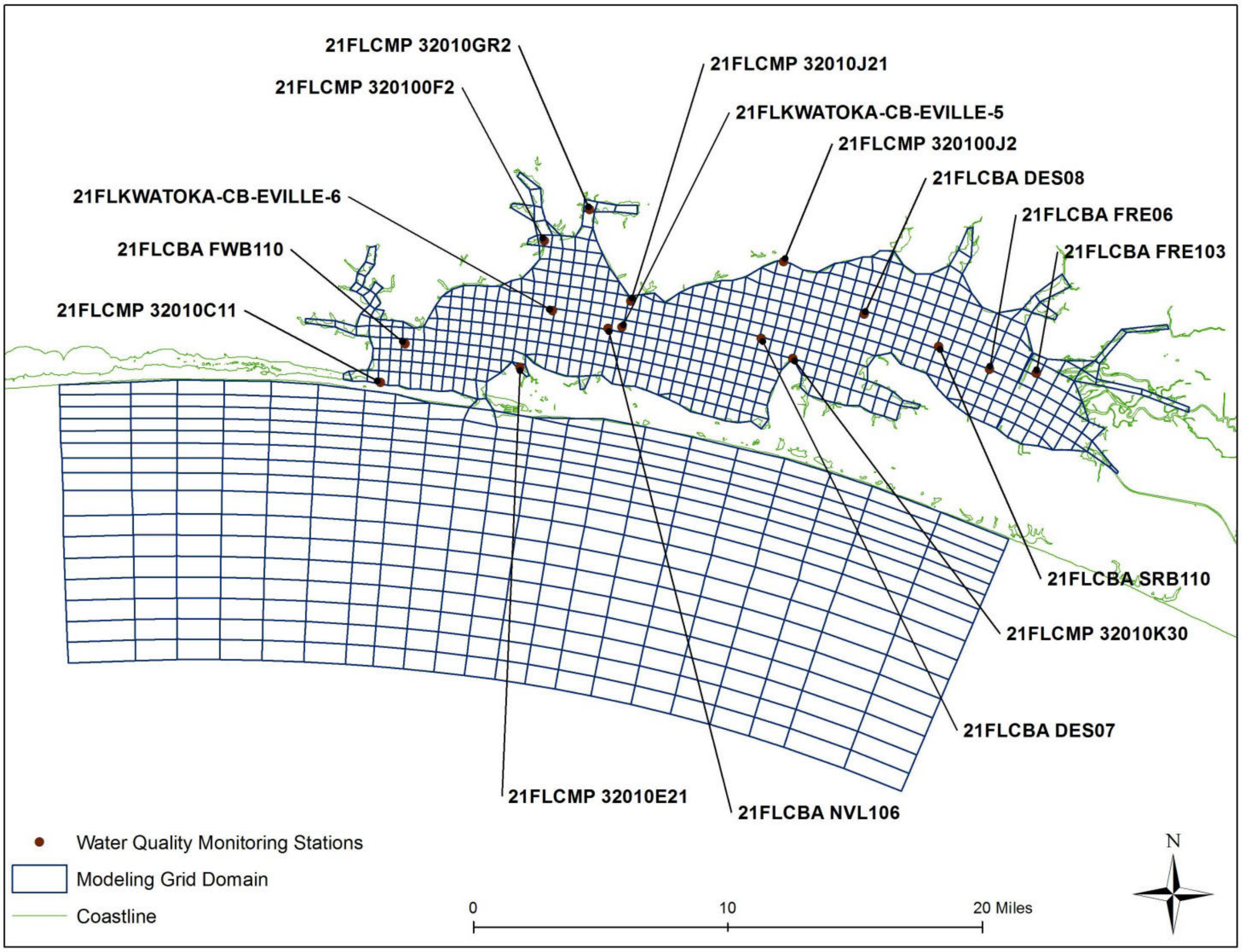

Figure D3-2. Water quality monitoring stations

D3.2 Modeling of Water Surface Elevation (WSE)

Table D3-1. Calibration comparisons of simulated and measured WSE at NOAA tidal station T01: 2002-2003

Year	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
2002	-0.03	-0.11	0.06	0.00	-0.07	0.08	-0.03	-0.03	-0.02	0.88
2003	-0.01	-0.10	0.08	0.00	-0.08	0.08	-0.01	-0.02	0.00	0.86

Table D3-2. Validation comparisons of simulated and measured WSE at NOAA tidal station T01: 2004

Year	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
2004	-0.02	-0.11	0.07	0.00	-0.08	0.08	-0.02	-0.03	-0.01	0.90

D3.3 Modeling of Salinity

D3.3.1 Calibration

Table D3-3. Calibration comparisons of simulated and measured surface and bottom salinity at Choctawhatchee Bay monitoring stations: 2002-2004

Station	Salinity (PSU)				Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error		Simulated Bottom Mean	Measured Bottom Mean	Error	
			PSU	%			PSU	%
S01	24.5	20.2	4.4	21.8	25.4	22.4	2.9	13.1
S02	24.0	19.6	4.4	22.6	33.3	31.7	1.6	5.0
S03	25.4	24.9	0.6	2.2	34.4	27.9	6.5	23.3
S04	23.2	22.6	0.6	2.6	34.2	32.7	1.6	4.7
S05	14.3	13.4	0.8	6.2	18.7	17.0	1.7	9.9

D3.3.2 Validation

Table D3-4. Validation comparisons of simulated and measured surface and bottom salinity at Choctawhatchee Bay: 2002-2004

Station	Salinity (PSU)				Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error		Simulated Bottom Mean	Measured Bottom Mean	Error	
			PSU	%			PSU	%
S06	8.0	9.2	-1.2	-13.4	17.4	15.2	2.2	14.3
S07	19.4	20.7	-1.3	-6.4	21.8	21.5	0.2	1.0
S08	7.2	9.5	-2.3	-24.1	21.4	18.6	2.8	14.9
S09	22.9	16.7	6.2	37.2	34.2	31.6	2.6	8.2
S10	22.7	20.7	2.0	9.8	25.2	22.4	2.9	12.8

D3.4 Modeling of Water Temperature

D3.4.1 Calibration

Table D3-5. Calibration comparisons of simulated and measured surface and bottom temperature at Choctawhatchee Bay monitoring stations: 2002-2004

	Temperature (Deg C)				Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error		Simulated Surface Mean	Measured Surface Mean	Error	
Station			Deg C	%			Deg C	%
S01	22.8	21.8	1.0	4.8	21.4	21.7	-0.3	-1.5
S02	23.0	22.1	0.9	4.0	22.1	22.0	0.2	0.7
S03	22.9	18.8	4.1	21.6	23.0	18.8	4.2	22.0
S04	22.8	22.8	0.0	0.0	21.4	23.0	-1.7	-7.2
S05	21.5	23.4	-1.9	-8.3	20.4	24.6	-4.2	-16.9

D3.4.2 Validation

Table D3-6. Validation comparisons of simulated and measured surface and bottom temperature at Choctawhatchee Bay monitoring stations: 2002-2004

	Temperature (Deg C)				Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error		Simulated Bottom Mean	Measured Bottom Mean	Error	
Station			Deg C	%			Deg C	%
S06	21.1	22.4	-1.3	-5.7	17.3	23.2	-5.9	-25.6
S07	21.3	18.5	2.8	15.3	16.3	18.5	-2.2	-11.7
S08	20.9	17.9	3.0	16.6	18.2	18.2	0.0	-0.3
S09	22.8	21.8	1.1	4.9	21.6	22.0	-0.4	-1.9
S10	22.0	21.7	0.3	1.6	20.9	21.6	-0.7	-3.3

D3.5 Modeling of Water Quality

D3.5.1 Calibration and Validation for Chl-a

Table D3-7. Comparisons of simulated and measured chl-a: 2002-2004

Station	Chl-a (µg/L)			
	Simulated Surface Mean	Measurement Mean	Error	
			µg/L	%
21FLCBA DES08	4.3	3.0	1.3	42.2
21FLCBA FRE103	3.9	6.5	-2.6	-40.2
21FLCBA SRB110	4.4	4.4	0.1	1.2
21FLKWATOKA-CB-EVILLE-5	3.7	3.0	0.7	23.4
21FLKWATOKA-CB-EVILLE-6	3.5	2.9	0.6	19.9

D3.5.2 Calibration and Validation for DO

Table D3-8. Comparisons of simulated and measured surface and bottom DO: 2002-2004

Station	DO (mg/L)				DO (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error		Simulated Bottom Mean	Measured Bottom Mean	Error	
			mg/L	%			mg/L	%
21FLCBA FRE06	8.0	7.9	0.1	1.2	5.6	4.8	0.8	16.6
21FLCBA DES07	7.5	7.7	-0.3	-3.6	4.8	3.6	1.2	33.3
21FLCBA NVL106	7.4	7.6	-0.2	-2.9	4.2	4.2	0.0	-0.2
21FLCBA DES08	7.7	7.8	-0.1	-1.1	4.4	3.8	0.6	15.2

D3.5.3 Calibration and Validation for TN

Table D3-9. Comparisons of simulated and measured TN: 2002-2004

Station	TN (mg/L)			
	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLCBA DES07	0.435	0.197	0.238	120.8
21FLCBA FRE06	0.549	0.423	0.126	29.8
21FLCBA FWB110	0.367	0.199	0.168	84.4
21FLKWATOKA-CB-EVILLE-6	0.381	0.227	0.154	67.8
21FLCMP 32010C11	0.353	0.419	-0.066	-15.8
21FLCMP 32010E21	0.522	0.401	0.121	30.2
21FLCMP 320100F2	0.423	0.375	0.048	12.8
21FLCMP 32010GR2	0.446	0.605	-0.159	-26.3
21FLCMP 320100J2	0.466	0.395	0.071	18.0
21FLCMP 32010J21	0.407	0.374	0.033	8.8
21FLCMP 32010K30	0.442	0.368	0.074	20.1

D3.5.4 Calibration and Validation for Ammonia

Table D3-10. Comparisons of simulated and measured ammonia: 2002-2004

Station	Ammonia (mg/L)			
	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLCMP 32010C11	0.021	0.025	-0.004	-16.0
21FLCMP 32010E21	0.039	0.034	0.005	14.7
21FLCMP 32010GR2	0.041	0.024	0.017	70.8
21FLCMP 32010J21	0.028	0.021	0.007	33.3
21FLCMP 32010K30	0.032	0.03	0.002	6.7
21FLCMP 320100F2	0.033	0.029	0.004	13.8
21FLCMP 320100J2	0.033	0.025	0.008	32.0

D3.5.5 Calibration and Validation for Nitrate-Nitrite

Table D3-11. Comparisons of simulated and measured nitrate-nitrite: 2002-2004

Station	Nitrate-Nitrite (mg/L)			
	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLCMP 32010C11	0.004	0.015	-0.011	-73.3
21FLCMP 32010E21	0.019	0.013	0.006	46.2
21FLCMP 32010GR2	0.013	0.060	-0.047	-78.3
21FLCMP 32010J21	0.007	0.021	-0.014	-66.7
21FLCMP 32010K30	0.009	0.024	-0.015	-62.5
21FLCMP 320100F2	0.009	0.024	-0.015	-62.5
21FLCMP 320100J2	0.009	0.027	-0.018	-66.7

D3.5.6 Calibration and Validation for TP

Table D3-12. Comparisons of simulated and measured TP: 2002-2004

Station	TP (mg/L)			
	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLCBA DES07	0.017	0.014	0.003	21.4
21FLCBA FRE06	0.026	0.024	0.002	8.3
21FLCBA FWB110	0.013	0.011	0.002	18.2
21FLKWATOKA-CB-EVILLE-6	0.014	0.011	0.003	27.3
21FLCMP 32010C11	0.013	0.016	-0.003	-18.8
21FLCMP 32010E21	0.016	0.021	-0.005	-23.8
21FLCMP 320100F2	0.013	0.017	-0.004	-23.5
21FLCMP 32010GR2	0.012	0.014	-0.002	-14.3
21FLCMP 320100J2	0.017	0.023	-0.006	-26.1
21FLCMP 32010J21	0.015	0.014	0.001	7.1
21FLCMP 32010K30	0.017	0.020	-0.003	-15.0

D3.5.7 Calibration and Validation for Total Suspended Solids (TSS)

Table D3-13. Comparisons of simulated and measured TSS: 2002-2004

Station	TSS (mg/L)			
	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLCMP 32010C11	5.3	9.4	-4.1	-43.6
21FLCMP 32010E21	7.4	7.9	-0.6	-7.2
21FLCMP 32010GR2	5.2	6.1	-0.9	-14.1
21FLCMP 32010J21	6.7	8.3	-1.6	-19.6
21FLCMP 32010K30	7.4	11.3	-3.9	-34.7
21FLCMP 320100J2	8.1	17.0	-8.9	-52.6

D3.5.8 Calibration and Validation for Light Attenuation Coefficient (K_d)

Table D3-14. Comparisons of simulated and measured K_d: 2002-2004

Station	K_d (1/m)			
	Simulated Surface Mean	Measurement Mean	Error	
			1/m	%
21FLCBA DES07	0.65	0.46	0.19	41.3
21FLKWATOKA-CB-EVILLE-5	0.47	0.57	-0.10	-16.8
21FLKWATOKA-CB-EVILLE-6	0.43	0.52	-0.10	-18.1

Appendix D
Attachment 4: St. Andrews and St. Joseph Bays Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Contents

D4.1 LOCATION OF MONITORING STATIONS D4-1
D4.2 MODELING OF WATER SURFACE ELEVATION (WSE) D4-3
D4.3 MODELING OF SALINITY D4-4
D4.3.1 Calibration D4-4
D4.3.2 Validation D4-4
D4.4 MODELING OF WATER TEMPERATURE D4-5
D4.4.1 Calibration D4-5
D4.4.2 Validation D4-5
D4.5 MODELING OF WATER QUALITY D4-6
D4.5.1 Calibration and Validation for Chl-a D4-6
D4.5.2 Calibration and Validation for DO D4-6
D4.5.3 Calibration and Validation for Light Attenuation Coefficient (K_d) D4-6
D4.5.4 Calibration and Validation for Ammonia D4-7
D4.5.5 Calibration and Validation for Nitrate-Nitrite D4-7
D4.5.6 Calibration and Validation for TN D4-7
D4.5.7 Calibration and Validation for TP D4-8
D4.5.8 Calibration and Validation for Total Suspended Solids (TSS) D4-8

Figures

Figure D4-1. Hydrodynamic monitoring stations....D4-1
Figure D4-2. Water quality monitoring stations....D4-2

Tables

Table D4-1. Calibration comparisons of simulated and measured WSE: 2004-2005....D4-3
Table D4-2. Validation comparisons of simulated and measured WSE: 2006-2007....D4-3
Table D4-3. Calibration comparisons of simulated and measured salinity: 2004-2005....D4-4
Table D4-4. Validation comparisons of simulated and measured salinity: 2006-2007....D4-4
Table D4-5. Calibration comparisons of simulated and measured water temperature: 2004-2005....D4-5
Table D4-6. Validation comparisons of simulated and measured water temperature: 2006-2007....D4-5
Table D4-7. Comparisons of simulated and measured chl-a: 2003-2005....D4-6
Table D4-8. Comparisons of simulated and measured DO: 2003-2005....D4-6
Table D4-9. Comparisons of simulated and measured K_d: 2003-2005....D4-6
Table D4-10. Comparisons of simulated and measured ammonia: 2003-2005....D4-7
Table D4-11. Comparisons of simulated and measured nitrate-nitrite: 2003-2005....D4-7
Table D4-12. Comparisons of simulated and measured TN: 2003-2005....D4-7
Table D4-13. Comparisons of simulated and measured TP: 2003-2005....D4-8
Table D4-14. Comparisons of simulated and measured TSS: 2003-2005....D4-8

D4.1 Location of Monitoring Stations

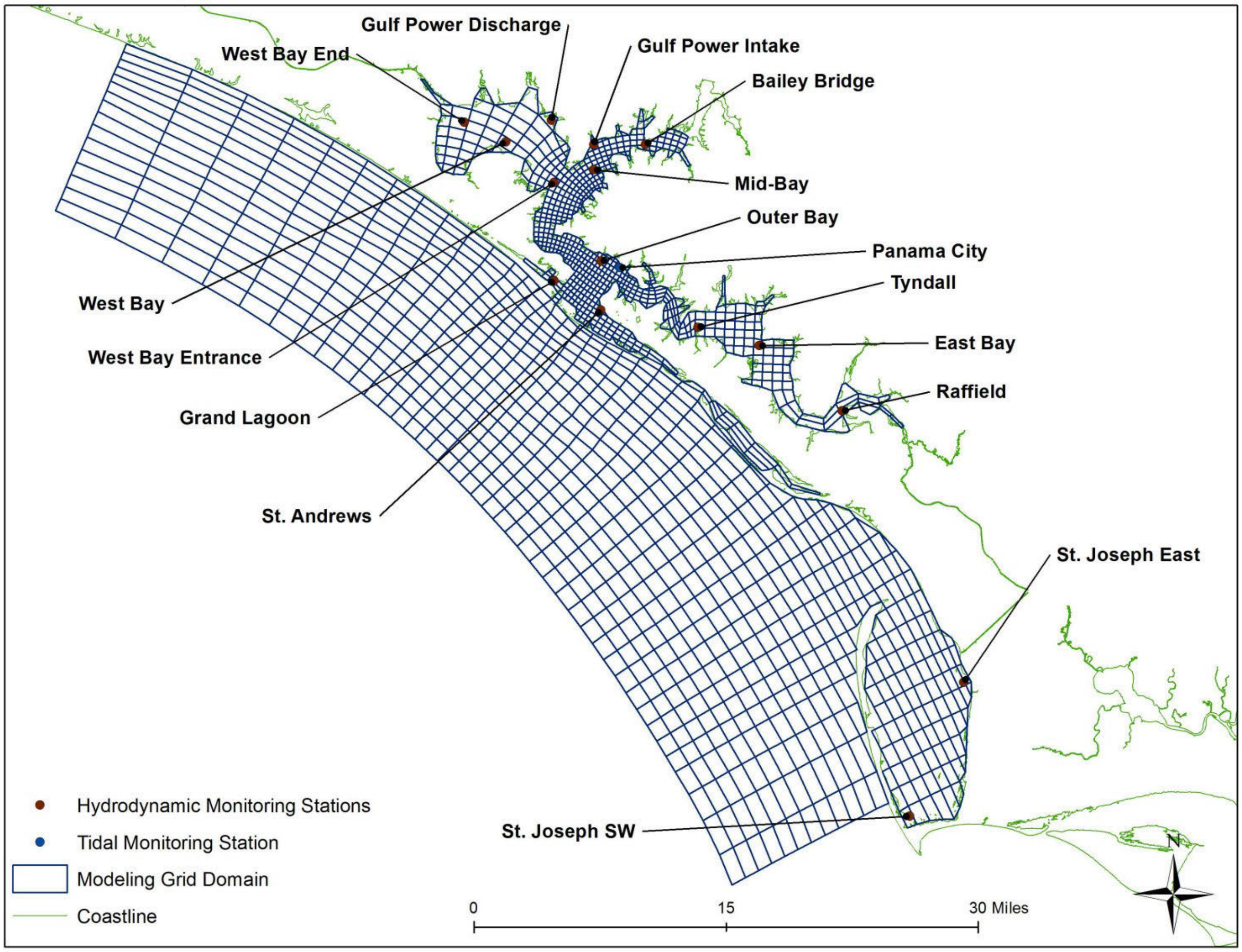

Figure D4-1. Hydrodynamic monitoring stations

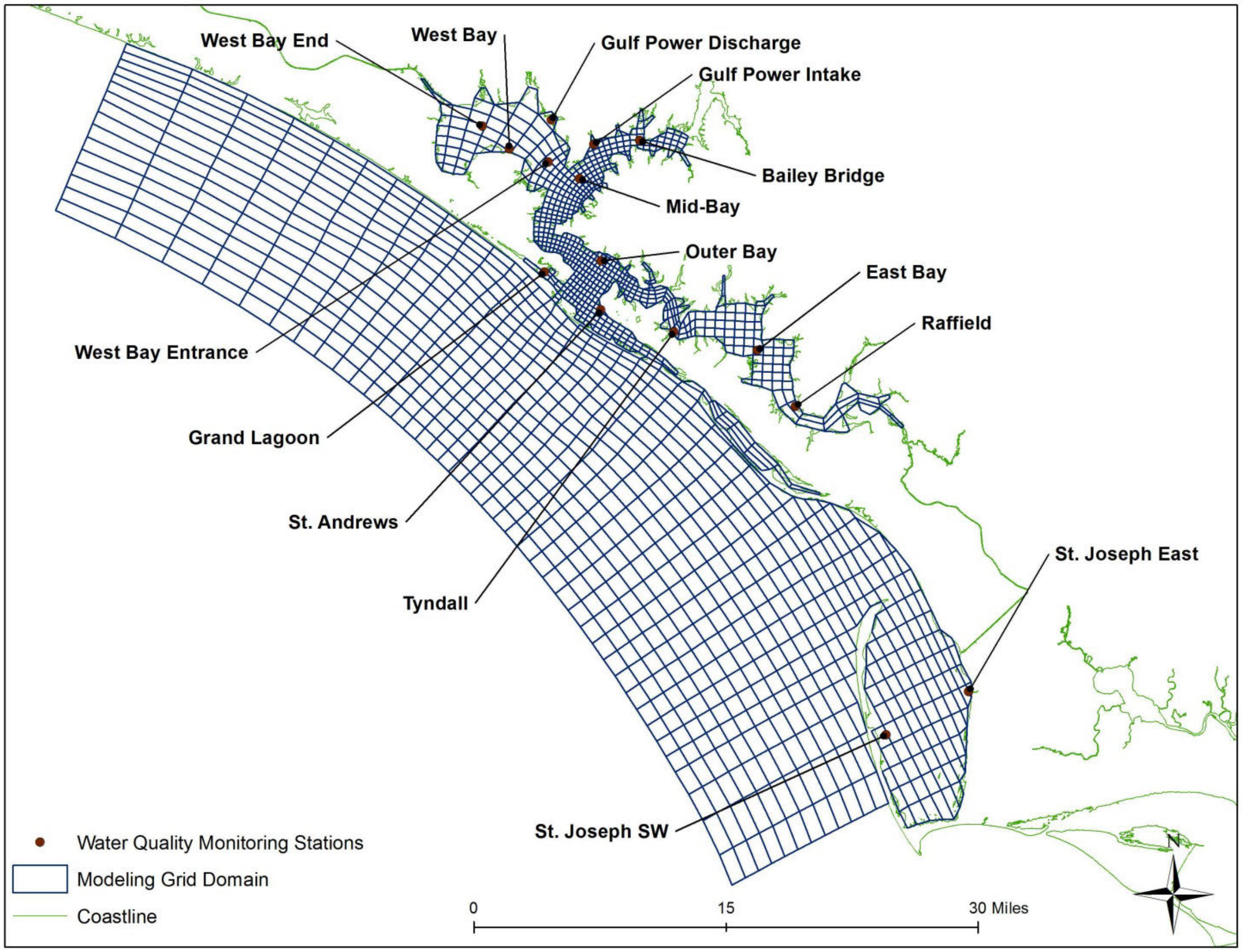

Figure D4-2. Water quality monitoring stations

D4.2 Modeling of Water Surface Elevation (WSE)

Table D4-1. Calibration comparisons of simulated and measured WSE: 2004-2005

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
Panama City	0.015	-0.321	0.339	0.031	-0.321	0.371	-0.02	0.00	-0.03	0.91

Table D4-2. Validation comparisons of simulated and measured WSE: 2006-2007

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
Panama City	-0.001	-0.322	0.31	0.009	-0.342	0.339	-0.01	0.02	-0.03	0.94

D4.3 Modeling of Salinity

D4.3.1 Calibration

Table D4-3. Calibration comparisons of simulated and measured salinity: 2004-2005

Station	Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			PSU	%
East Bay	25.9	22.2	3.7	17
Grand Lagoon	32.9	29.1	3.8	13
Gulf Power Intake	20.3	23.6	-3.2	-14
Mid-Bay	23.0	26.3	-3.3	-13
St. Andrews	32.5	30.0	2.5	8
St. Joseph SW	29.4	31.8	-2.4	-7
Tyndall	28.0	27.7	0.3	1
West Bay	25.5	23.4	2.1	9
West Bay End	24.6	23.6	1.1	5
West Bay Entrance	26.0	25.9	0.2	1

D4.3.2 Validation

Table D4-4. Validation comparisons of simulated and measured salinity: 2006-2007

Station	Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			PSU	%
Bailey Bridge	17.2	25.5	-8.3	-32
East Bay	30.5	28.4	2.1	7
Grand Lagoon	34.5	33.1	1.4	4
Gulf Power Discharge	28.6	27.8	0.7	3
Gulf Power Intake	24.4	28.8	-4.4	-15
Mid-Bay	26.7	28.4	-1.8	-6
Raffield	19.5	20.7	-1.2	-6
St. Andrews	34.4	33.2	1.3	4
St. Joseph SW	31.8	33.1	-1.3	-4
Tyndall	31.9	30.2	1.7	6
West Bay	29.1	28.3	0.8	3
West Bay End	28.5	27.0	1.5	5
West Bay Entrance	29.4	29.1	0.2	1

D4.4 Modeling of Water Temperature

D4.4.1 Calibration

Table D4-5. Calibration comparisons of simulated and measured water temperature: 2004-2005

Station	Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			Deg C	%
East Bay	23.1	20.4	2.7	13
Grand Lagoon	23.5	21.9	1.6	7
Gulf Power Intake	22.8	21.5	1.3	6
Mid-Bay	23.2	21.6	1.6	7
St. Andrews	23.6	21.6	2.0	9
St. Joseph SW	22.9	23.7	-0.8	-3
Tyndall	23.5	24.1	-0.6	-2
West Bay	22.8	18.3	4.5	25
West Bay End	22.5	16.6	5.9	36
West Bay Entrance	23.4	18.5	4.8	26

D4.4.2 Validation

Table D4-6. Validation comparisons of simulated and measured water temperature: 2006-2007

Station	Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			Deg C	%
Bailey Bridge	22.2	23.6	-1.5	-6
East Bay	23.3	20.8	2.5	12
Grand Lagoon	23.8	23.1	0.8	3
Gulf Power Intake	23.2	21.1	2.0	10
Gulf Power Discharge	26.3	20.8	5.5	27
Mid-Bay	23.7	20.6	3.0	15
Raffield	22.6	22.1	0.4	2
St. Andrews	23.9	22.3	1.6	7
St. Joseph SW	23.2	19.8	3.3	17
Tyndall	23.7	22.6	1.2	5
West Bay	23.1	18.5	4.5	25
West Bay End	22.8	18.8	4.0	21
West Bay Entrance	23.6	19.2	4.4	23

D4.5 Modeling of Water Quality

D4.5.1 Calibration and Validation for Chl-a

Table D4-7. Comparisons of simulated and measured chl-a: 2003-2005

Station	Chl-a (µg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			µg/L	%
Bailey Bridge	3.8	3.0	0.8	27
East Bay	4.6	3.7	0.9	26
Grand Lagoon	2.2	6.3	-4.1	-66
Mid-Bay	3.5	2.7	0.8	31
Outer Bay	3.1	3.1	0.0	-1
Raffield	4.6	3.6	1.1	30
St. Andrews	2.5	5.0	-2.5	-49
St. Joseph East	2.5	4.3	-1.8	-42
St. Joseph SW	2.9	4.4	-1.6	-35
Tyndall	4.2	3.4	0.8	25
West Bay End	3.7	4.1	-0.4	-9
West Bay Entrance	3.2	3.2	0.0	-1
West Bay	3.6	5.3	-1.7	-32

D4.5.2 Calibration and Validation for DO

Table D4-8. Comparisons of simulated and measured DO: 2003-2005

Station	DO (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
Grand Lagoon	6.8	6.2	0.5	9
St. Andrews	6.8	6.3	0.5	8
West Bay	7.2	6.8	0.4	6

D4.5.3 Calibration and Validation for Light Attenuation Coefficient (K_d)

Table D4-9. Comparisons of simulated and measured K_d: 2003-2005

Station	K_d (1/m)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			1/m	%
Grand Lagoon	0.30	0.34	-0.04	-11
St. Andrews	0.33	0.25	0.08	31
West Bay End	0.41	0.86	-0.45	-52
West Bay	0.41	0.56	-0.15	-26

D4.5.4 Calibration and Validation for Ammonia

Table D4-10. Comparisons of simulated and measured ammonia: 2003-2005

Station	Ammonia (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
Grand Lagoon	0.003	0.032	-0.029	-91
West Bay	0.003	0.020	-0.017	-85

D4.5.5 Calibration and Validation for Nitrate-Nitrite

Table D4-11. Comparisons of simulated and measured nitrate-nitrite: 2003-2005

Station	Nitrate-Nitrite (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
Grand Lagoon	0.001	0.010	-0.009	-90
West Bay	0.001	0.010	-0.009	-90

D4.5.6 Calibration and Validation for TN

Table D4-12. Comparisons of simulated and measured TN: 2003-2005

Station	TN (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
Bailey Bridge	0.214	0.257	-0.043	-17
East Bay	0.288	0.299	-0.011	-4
Grand Lagoon	0.128	0.459	-0.331	-72
Mid-Bay	0.205	0.235	-0.030	-13
Outer Bay	0.182	0.196	-0.014	-7
Raffield	0.301	0.373	-0.072	-19
St. Andrews	0.149	0.274	-0.125	-46
St. Joseph East	0.310	0.219	0.091	42
St. Joseph SW	0.192	0.177	0.015	8
Tyndall	0.255	0.259	-0.004	-2
West Bay End	0.212	0.253	-0.041	-16
West Bay Entrance	0.205	0.242	-0.037	-15
West Bay	0.212	0.436	-0.224	-51

D4.5.7 Calibration and Validation for TP

Table D4-13. Comparisons of simulated and measured TP: 2003-2005

Station	TP (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
Bailey Bridge	0.011	0.013	-0.002	-15
East Bay	0.013	0.014	-0.001	-7
Grand Lagoon	0.011	0.014	-0.003	-21
Mid-Bay	0.013	0.012	0.001	8
Outer Bay	0.015	0.013	0.002	15
Raffield	0.010	0.015	-0.005	-33
St. Andrews	0.012	0.023	-0.011	-48
St. Joseph East	0.009	0.016	-0.007	-44
St. Joseph SW	0.009	0.014	-0.005	-36
Tyndall	0.016	0.014	0.002	14
West Bay End	0.015	0.015	0.000	0
West Bay Entrance	0.014	0.013	0.001	8
West Bay	0.016	0.015	0.001	7

D4.5.8 Calibration and Validation for Total Suspended Solids (TSS)

Table D4-14. Comparisons of simulated and measured TSS: 2003-2005

Station	TSS (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
Grand Lagoon	5.16	13.13	-7.97	-61
St. Andrews	5.26	15.50	-10.25	-66
West Bay	6.60	10.97	-4.37	-40

Appendix D
Attachment 5: Florida Big Bend Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Contents

D5.1 LOCATION OF MONITORING STATIONS D5-1

D5.2 MODELING OF WATER SURFACE ELEVATION (WSE) D5-7

D5.3 MODELING OF SALINITY D5-8

D5.3.1 Calibration D5-8

D5.3.2 Validation D5-9

D5.4 MODELING OF WATER TEMPERATURE D5-10

D5.4.1 Calibration D5-10

D5.4.2 Validation D5-11

D5.5 MODELING OF WATER QUALITY D5-12

D5.5.1 Calibration and Validation for Chl-a D5-12

D5.5.2 Calibration and Validation for DO D5-13

D5.5.3 Calibration and Validation for TN D5-16

D5.5.4 Calibration and Validation for Ammonia D5-17

D5.5.5 Calibration and Validation for Nitrate-Nitrite D5-18

D5.5.6 Calibration and Validation for TP D5-19

D5.5.7 Calibration and Validation for Color D5-21

D5.5.8 Calibration and Validation for Light Attenuation Coefficient (K_d) D5-23

Figures

Figure D5-1. Florida Big Bend tidal monitoring stations D5-3
Figure D5-2. Florida Big Bend monitoring stations from Apalachicola to Florida Bend D5-4
Figure D5-3. Florida Big Bend monitoring stations from Florida Bend to Cedar Key D5-5
Figure D5-4. Florida Big Bend monitoring stations from Cedar Key to Clearwater D5-6

Tables

Table D5-1. Florida Big Bend monitoring stations D5-1
Table D5-2. Calibration comparisons of simulations and measurements of WSE at NOAA Tidal Stations, 8728690, 8727520, 8726724: 2003-2009 .... D5-7
Table D5-3. Validation comparisons of simulations and measurements of WSE at NOAA Tidal Stations, 8728690, 8727520, 8726724: 1997-2002 .... D5-7
Table D5-4. Calibration comparisons of simulations and measurements of salinity at Florida Big Bend monitoring stations: 2003-2009 .... D5-8
Table D5-5. Validation comparisons of simulations and measurements of salinity at Florida Big Bend monitoring stations: 1997-2002 .... D5-9
Table D5-6. Calibration comparisons of simulations and measurements of temperature for Florida Big Bend stations: 2003-2009 .... D5-10
Table D5-7. Validation comparisons of simulations and measurements of temperature for Florida Big Bend stations: 1997-2002 .... D5-11
Table D5-8. Comparisons of calibration simulations and measurements of chl-a: 2003-2009 .... D5-12
Table D5-9. Comparisons of validation simulations and measurements of chl-a: 1997-2002 .... D5-12
Table D5-10. Comparisons of calibration simulations and measurements of DO: 2003-2009 .... D5-13
Table D5-11. Comparisons of validation simulations and measurements of DO: 1997-2002 .... D5-14
Table D5-12. Comparisons of calibration simulations and measurements of TN: 2003-2009 .... D5-16
Table D5-13. Comparisons of validation simulations and measurements of TN: 1997-2002 .... D5-16
Table D5-14. Comparisons of calibration simulations and measurements of ammonia: 2003-2009 .... D5-17
Table D5-15. Comparisons of validation simulations and measurements of ammonia: 1997-2002 .... D5-17
Table D5-16. Comparisons of calibration simulations and measurements of nitrate-nitrite: 2003-2009 .... D5-18
Table D5-17. Comparisons of validation simulations and measurements of nitrate-nitrite: 1997-2002 .... D5-18
Table D5-18. Comparisons of calibration simulations and measurements of TP: 2003-2009 .... D5-19
Table D5-19. Comparisons of validation simulations and measurements of TP: 1997-2002 .... D5-20
Table D5-20. Comparisons of calibration simulations and measurements of color: 2003-2009 .... D5-21
Table D5-21. Comparisons of validation simulations and measurements of color: 1997-2002 .... D5-22
Table D5-22. Comparisons of calibration simulations and measurements of K_d: 2003-2009 .... D5-23
Table D5-23. Comparisons of validation simulations and measurements of K_d: 1997-2002 .... D5-23

D5.1 Location of Monitoring Stations

Table D5-1. Florida Big Bend monitoring stations

Station ID	Station Name	Watershed	Parameter
I=17 J=4	21FLPDEMW3-A-04-08	Clearwater	DO, Temperature, Nitrate-Nitrite, TP
I=18 J=10	21FLPDEMW2-A-03-05	Clearwater	DO, Salinity, TP
I=17 J=18	21FLPDEMW1-C-07-03	Clearwater	DO, Salinity, Temperature, TN, TP
I=20 J=31	21FLPCSWST1148000428400	Spring Coast	DO, Salinity, Temperature, TN, TP, Color
I=22 J=39	21FLPCSWST1150000430400	Spring Coast	DO, Salinity, Temperature, TN, TP, Color
I=25 J=44	21FLPCSWST1143000425400	Spring Coast	DO, Salinity, Temperature, TN, TP, Color
I=30 J=44	21FLGW 21836	Spring Coast	DO, Salinity, Chl-a, Nitrate-Nitrite, Ammonia, TP
I=24 J=47	21FLPCSWST1143000425900	Spring Coast	DO, Salinity, TN, TP, Color
I=27 J=53	112WRD 02310674	Spring Coast	DO, Salinity, Nitrate-Nitrite, Ammonia, TP, Color
I=24 J=59	21FLPCSWST1145000427300	Spring Coast	DO, Salinity, Temperature, TN, TP, Color
I=24 J=62	21FLA 37720SEAS	Spring Coast	DO, Salinity, TN, TP, Color
I=24 J=68	21FLA 34076SEAS	Withlacoochee to Suwannee	DO, Temperature, TN, Color
I=24 J=70	21FLA 34050SEAS	Withlacoochee to Suwannee	DO, Salinity, Temperature, TN, TP, Color
I=24 J=73	21FLA 34220SEAS	Withlacoochee to Suwannee	DO, TN, TP, Color
I=23 J=78	21FLA 32092SEAS	Withlacoochee to Suwannee	DO, Salinity
I=25 J=78	21FLA 32020SEAS	Withlacoochee to Suwannee	DO, Salinity, Temperature
I=28 J=78	21FLSUW WAC010C1	Withlacoochee to Suwannee	DO, TP
I=21 J=79	21FLA 32120SEAS	Withlacoochee to Suwannee	DO, Salinity, Temperature
I=17 J=84	21FLA 30112SEAS	Withlacoochee to Suwannee	Temperature
I=14 J=85	21FLA 30052SEAS	Withlacoochee to Suwannee	Salinity
I=13 J=89	21FLA 30448SEAS	Withlacoochee to Suwannee	DO, Salinity, Temperature
I=16 J=90	21FLA 28247SEAS	Withlacoochee to Suwannee	DO, Temperature
I=14 J=91	21FLA 28201SEAS	Withlacoochee to Suwannee	Chl-a, Nitrate-Nitrite, TP, Color
I=17 J=91	112WRD 291833083085100	Withlacoochee to Suwannee	Temperature, Chl-a, Nitrate-Nitrite, Ammonia, TP, Color,
I=28 J=91	21FLSUW SUW240C1	Withlacoochee to Suwannee	DO ,Temperature, Nitrate-Nitrite, Ammonia, TP, Color,
I=16 J=92	21FLA 28223SEAS	Withlacoochee to Suwannee	DO, Salinity, Temperature, Chl-a, Nitrate-Nitrite, Ammonia, Color, TP
I=16 J=98	21FLA 25165SEAS	Apalachee Bay	DO, Salinity, Temperature
I=16 J=102	Combined	Apalachee Bay	DO, Salinity
I=18 J=110	21FLSUW STN060C1	Apalachee Bay	DO, Salinity, Temperature, Chl-a, Nitrate-Nitrite, Ammonia, TP, Color
I=22 J=110	Combined	Apalachee Bay	Salinity, Nitrate-Nitrite, Ammonia, TP, Color
I=24 J=110	Combined	Apalachee Bay	DO, Nitrate-Nitrite, Ammonia, TP
I=21 J=127	Combined	Apalachee Bay	DO, Temperature, Ammonia, TN, TP, K_d
I=23 J=128	Combined	Apalachee Bay	Salinity, Temperature, Nitrate-Nitrite, TP, Color, K_d

Station ID	Station Name	Watershed	Parameter
I=25 J=128	Combined	Apalachee Bay	Chl-a, Nitrate-Nitrite, Ammonia, TP, Color, K_d
I=26 J=128	21FLA 22050030	Apalachee Bay	DO, Salinity, TP, K_d
I=31 J=128	21FLSUW FEN030C1	Apalachee Bay	Salinity, TP, K_d
I=21 J=129	Combined	Apalachee Bay	Salinity, TN, TP, Color, K_d
I=20 J=130	Combined	Apalachee Bay	Temperature, Chl-a, TP, Color, K_d
I=21 J=132	Combined	Apalachee Bay	Temperature, DO, TP, Color, K_d
I=23 J=133	Combined	Apalachee Bay	Salinity, Temperature, Chl-a, Ammonia, TN, TP, Color, K_d
I=26 J=133	Combined	Apalachee Bay	Salinity, Temperature, Nitrate-Nitrite, TP, K_d
I=31 J=133	Combined	Apalachee Bay	DO, Nitrate-Nitrite, Ammonia, TP, Color, K_d
I=21 J=134	Combined	Apalachee Bay	Salinity, Chl-a, Nitrate-Nitrite, Ammonia, TP, Color, K_d
I=26 J=145	21FLSEAS23SEAS030	Apalachee Bay	DO, Salinity, Nitrate-Nitrite, TN
I=27 J=145	Combined	Apalachee Bay	DO, Nitrate-Nitrite, Ammonia, TN, TP, Color
I=24 J=146	21FLSEAS23SEAS007	Apalachee Bay	Ammonia
I=24 J=150	21FLA 22101SEAS	Ochlockonee	DO, Salinity, Temperature, Chl-a, TP, Ammonia, Color
I=20 J=152	21FLA 20020SEAS	Ochlockonee	DO, Salinity
I=22 J=152	21FLA 20050SEAS	Ochlockonee	DO, Temperature, Chl-a
I=24 J=152	21FLA 20070SEAS	Ochlockonee	Chl-a
I=18 J=154	21FLA 18006SEAS	Alligator Harbor	DO, Salinity, Temperature
I=18 J=156	21FLA 18001SEAS	Alligator Harbor	DO, Salinity, Temperature
I=21 J=156	Combined	Alligator Harbor	DO, Salinity, Temperature
I=22 J=157	Combined	Apalachicola Bay	DO ,TP, Ammonia, Color
I=14 J=169	Combined	Apalachicola Bay	DO, Salinity, Temperature, Chl-a, TN, TP, Nitrate-Nitrite
I=14 J=175	Combined	Apalachicola Bay	DO, Temperature, Chl-a, Nitrate-Nitrite, Ammonia, TP
I=19 J=180	21FLA 16260SEAS	Apalachicola Bay	Salinity
I=20 J=180	21FLA 16255SEAS	Apalachicola Bay	Salinity
I=10 J=182	21FLA 16340SEAS	Apalachicola Bay	DO, Salinity
I=12 J=182	21FLA 16323SEAS	Apalachicola Bay	DO, Temperature, Chl-a
I=14 J=186	21FLA 16346SEAS	Apalachicola Bay	DO, Salinity, Temperature
I=14 J=188	21FLA 16341SEAS	Apalachicola Bay	Salinity, Temperature
I=14 J=189	21FLA 16347SEAS	Apalachicola Bay	DO, Salinity, Temperature

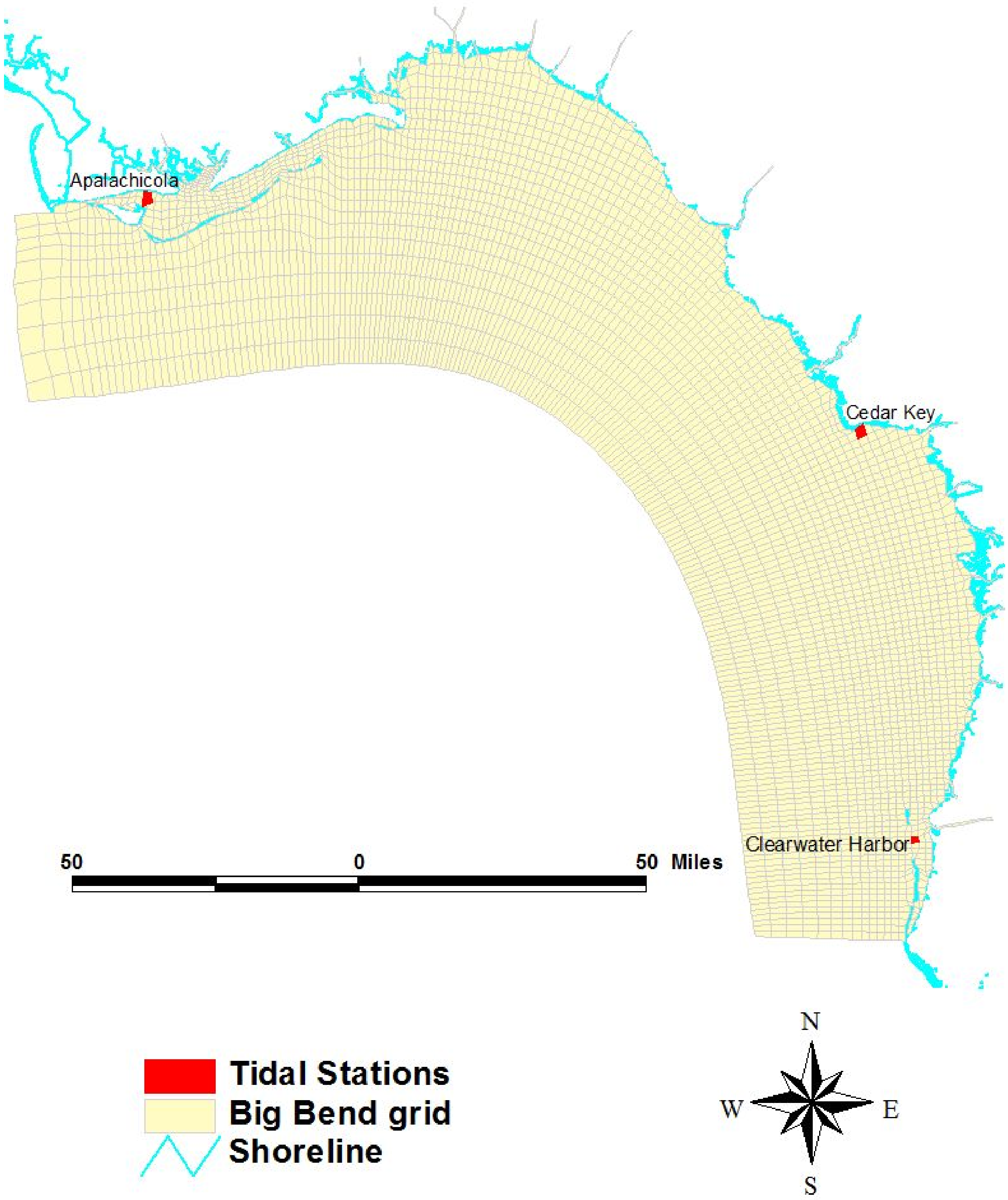

Figure D5-1. Florida Big Bend tidal monitoring stations

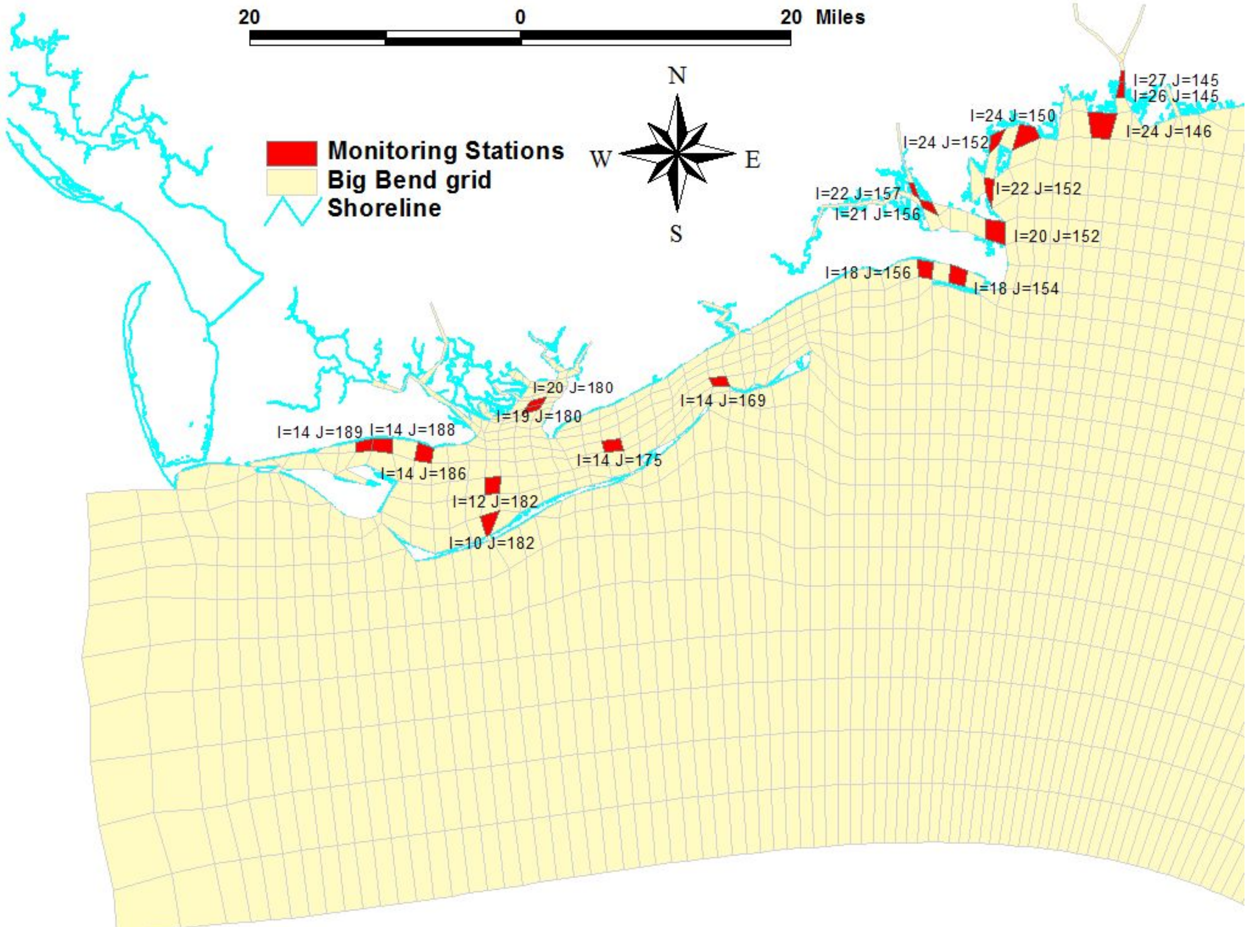

Figure D5-2. Florida Big Bend monitoring stations from Apalachicola to Florida Bend

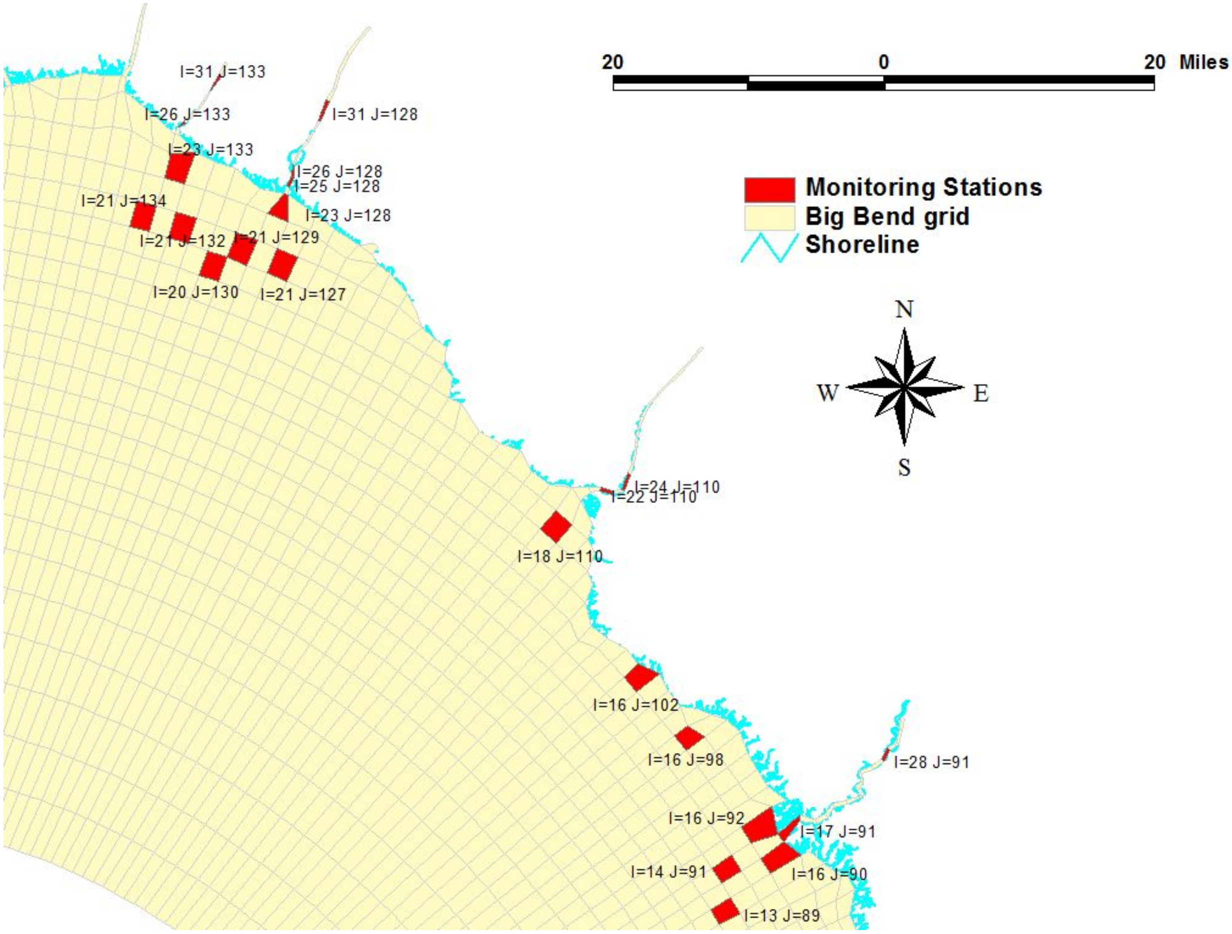

Figure D5-3. **Florida Big Bend monitoring stations from Florida Bend to Cedar Key**

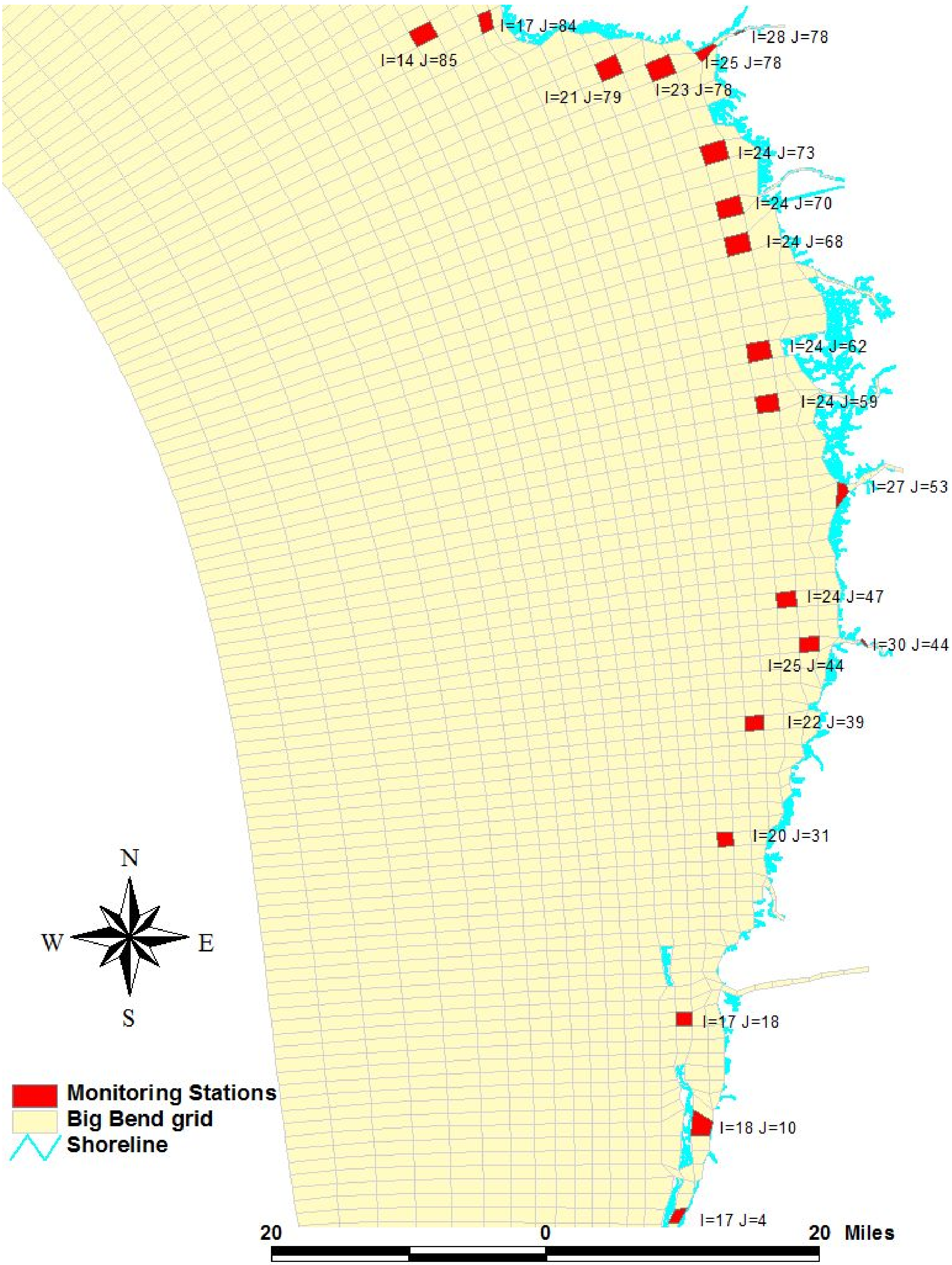

Figure D5-4. Florida Big Bend monitoring stations from Cedar Key to Clearwater

D5.2 Modeling of Water Surface Elevation (WSE)

Table D5-2. Calibration comparisons of simulations and measurements of WSE at NOAA Tidal Stations, 8728690, 8727520, 8726724: 2003-2009

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
Apalachicola	0.05	-0.34	0.40	0.03	-0.37	0.36	0.02	0.03	0.04	0.88
Cedar Key	0.01	-0.63	0.66	0.02	-0.65	0.62	-0.01	0.02	0.04	0.94
Clearwater Harbor	0.04	-0.46	0.52	0.04	-0.48	0.49	0.01	0.02	0.03	0.90

Table D5-3. Validation comparisons of simulations and measurements of WSE at NOAA Tidal Stations, 8728690, 8727520, 8726724: 1997-2002

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
Apalachicola	0.02	-0.34	0.35	0.00	-0.36	0.32	0.02	0.02	0.03	0.88
Cedar Key	-0.01	-0.61	0.61	0.01	-0.63	0.58	-0.02	0.02	0.02	0.94
Clearwater Harbor	0.02	-0.45	0.46	0.01	-0.47	0.44	0.01	0.02	0.02	0.89

D5.3 Modeling of Salinity

D5.3.1 Calibration

Table D5-4. Calibration comparisons of simulations and measurements of salinity at Florida Big Bend monitoring stations: 2003-2009

Station	Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			PSU	%
I=18 J=10	27.9	33.5	-5.6	-17
I=17 J=18	31.3	32.0	-0.7	-2
I=20 J=31	28.3	24.3	4.0	17
I=22 J=39	28.7	22.5	6.3	28
I=30 J=44	4.7	12.0	-7.3	-61
I=24 J=47	25.4	20.0	5.4	27
I=27 J=53	9.9	4.9	5.0	102
I=24 J=59	19.2	22.2	-3.0	-14
I=24 J=62	17.6	24.6	-7.0	-28
I=24 J=70	17.3	22.1	-4.8	-22
I=23 J=78	17.9	21.3	-3.4	-16
I=25 J=78	12.6	16.4	-3.8	-23
I=21 J=79	20.5	22.8	-2.4	-10
I=14 J=85	22.2	20.5	1.7	8
I=13 J=89	28.6	21.4	7.3	34
I=16 J=92	17.2	22.3	-5.1	-23
I=16 J=102	26.2	25.5	0.7	3
I=18 J=110	28.2	24.0	4.2	17
I=22 J=110	12.6	4.3	8.2	190
I=26 J=128	8.6	1.6	7.1	449
I=31 J=128	1.7	0.5	1.2	243
I=21 J=129	24.5	26.0	-1.4	-6
I=23 J=133	21.0	19.1	1.9	10
I=21 J=134	25.9	23.2	2.8	12
I=26 J=145	12.9	13.4	-0.5	-4
I=24 J=150	20.2	20.7	-0.5	-2
I=20 J=152	18.2	20.5	-2.3	-11
I=18 J=154	30.0	30.8	-0.9	-3
I=18 J=156	30.1	30.9	-0.8	-3
I=21 J=156	7.3	9.0	-1.7	-18
I=14 J=169	26.3	24.3	1.9	8
I=19 J=180	2.0	19.3	-17.3	-89
I=20 J=180	1.4	3.2	-1.8	-55
I=10 J=182	26.2	13.3	12.9	97
I=14 J=186	9.9	15.3	-5.4	-35
I=14 J=188	12.0	13.0	-1.1	-8
I=14 J=189	12.8	13.4	-0.6	-4

D5.3.2 Validation

Table D5-5. Validation comparisons of simulations and measurements of salinity at Florida Big Bend monitoring stations: 1997-2002

Station	Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			PSU	%
I=18 J=10	27.7	31.7	-4.0	-13
I=17 J=18	31.1	33.2	-2.0	-6
I=20 J=31	28.0	29.8	-1.7	-6
I=22 J=39	28.4	28.6	-0.3	-1
I=25 J=44	20.0	23.7	-3.7	-16
I=30 J=44	4.6	16.8	-12.2	-73
I=24 J=59	19.7	26.2	-6.5	-25
I=24 J=70	18.0	23.9	-5.9	-25
I=23 J=78	18.4	23.9	-5.5	-23
I=25 J=78	13.1	14.1	-1.0	-7
I=21 J=79	21.0	26.2	-5.2	-20
I=14 J=85	23.1	23.2	-0.1	0
I=13 J=89	29.6	23.9	5.6	24
I=16 J=92	18.1	23.0	-4.9	-21
I=16 J=98	25.3	27.6	-2.3	-8
I=16 J=102	26.9	29.1	-2.2	-8
I=18 J=110	28.6	29.4	-0.7	-3
I=22 J=110	13.3	3.8	9.5	251
I=23 J=128	21.6	22.8	-1.2	-5
I=31 J=128	1.7	0.6	1.1	182
I=21 J=129	25.2	29.2	-4.0	-14
I=23 J=133	21.8	24.8	-3.0	-12
I=26 J=133	13.3	15.1	-1.7	-11
I=21 J=134	26.6	27.7	-1.1	-4
I=24 J=150	20.6	21.3	-0.7	-3
I=20 J=152	19.3	23.7	-4.3	-18
I=18 J=154	30.2	31.5	-1.3	-4
I=18 J=156	30.3	31.5	-1.2	-4
I=21 J=156	9.2	11.3	-2.1	-18
I=14 J=169	25.9	27.3	-1.4	-5
I=19 J=180	1.9	21.1	-19.2	-91
I=20 J=180	1.2	7.8	-6.5	-84
I=10 J=182	26.3	15.1	11.2	74
I=14 J=186	10.3	17.6	-7.3	-41
I=14 J=188	12.5	14.5	-2.0	-14
I=14 J=189	13.3	14.2	-0.8	-6

D5.4 Modeling of Water Temperature

D5.4.1 Calibration

Table D5-6. Calibration comparisons of simulations and measurements of temperature for Florida Big Bend stations: 2003-2009

Station	Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			Deg C	%
I=17 J=4	23.1	23.4	-0.4	-1.5
I=17 J=18	24.1	23.5	0.6	2.5
I=20 J=31	24.5	23.3	1.2	5.3
I=22 J=39	24.6	23.7	0.9	3.9
I=25 J=44	24.5	23.2	1.3	5.8
I=24 J=59	24.2	23.3	0.9	3.8
I=24 J=68	23.3	23.4	-0.1	-0.3
I=24 J=70	23.2	23.2	0.1	0.3
I=25 J=78	22.6	25.0	-2.4	-9.6
I=21 J=79	23.1	25.2	-2.1	-8.3
I=17 J=84	21.8	21.9	-0.1	-0.2
I=13 J=89	21.8	22.0	-0.2	-0.8
I=16 J=90	21.4	20.7	0.7	3.4
I=17 J=91	20.7	22.2	-1.5	-6.7
I=28 J=91	20.3	21.6	-1.3	-6.2
I=16 J=92	21.3	21.3	-0.1	-0.3
I=16 J=98	21.4	22.4	-1.0	-4.3
I=18 J=110	21.6	21.7	-0.1	-0.4
I=21 J=127	21.9	21.7	0.2	1.0
I=23 J=128	21.9	21.6	0.3	1.2
I=20 J=130	21.9	21.0	0.9	4.2
I=21 J=132	21.9	22.0	-0.1	-0.3
I=23 J=133	22.0	21.5	0.5	2.1
I=26 J=133	21.8	20.4	1.5	7.3
I=24 J=150	21.5	20.6	0.8	4.1
I=22 J=152	21.5	21.3	0.3	1.2
I=18 J=154	21.1	21.7	-0.6	-2.7
I=18 J=156	21.4	21.7	-0.3	-1.3
I=21 J=156	21.4	22.1	-0.7	-3.0
I=14 J=169	21.5	19.5	2.0	10.1
I=14 J=175	21.8	20.0	1.7	8.7
I=12 J=182	21.3	21.3	0.0	0.1
I=14 J=186	21.5	22.0	-0.5	-2.5
I=14 J=188	21.6	21.3	0.3	1.6
I=14 J=189	21.6	19.1	2.5	13.2

D5.4.2 Validation

Table D5-7. Validation comparisons of simulations and measurements of temperature for Florida Big Bend stations: 1997-2002

Station	Temperature (Deg C)			
			Error	
	Simulated Surface Mean	Measured Surface Mean	Deg C	%
I=17 J=4	23.6	24.4	-0.7	-3.0
I=17 J=18	24.7	23.5	1.2	5.1
I=20 J=31	25.1	23.4	1.6	7.0
I=22 J=39	25.2	23.6	1.6	6.7
I=25 J=44	25.1	23.2	1.9	8.2
I=24 J=59	24.9	23.3	1.6	7.0
I=24 J=68	24.2	23.0	1.2	5.2
I=24 J=70	24.1	23.2	0.9	4.0
I=25 J=78	23.4	23.1	0.4	1.6
I=21 J=79	24.0	23.6	0.4	1.7
I=17 J=84	22.9	21.6	1.3	6.2
I=13 J=89	22.9	21.8	1.1	5.0
I=16 J=90	22.5	21.6	0.9	4.0
I=17 J=91	21.1	25.5	-4.4	-17.3
I=28 J=91	20.4	22.9	-2.6	-11.2
I=16 J=92	22.5	23.8	-1.3	-5.4
I=16 J=98	22.7	22.5	0.2	0.8
I=18 J=110	22.8	26.1	-3.3	-12.6
I=21 J=127	23.1	22.3	0.8	3.6
I=23 J=128	23.0	22.6	0.4	1.8
I=20 J=130	21.9	21.0	0.9	4.2
I=21 J=132	23.1	22.4	0.6	2.8
I=23 J=133	23.1	22.8	0.3	1.5
I=26 J=133	23.0	23.4	-0.4	-1.6
I=24 J=150	22.6	23.0	-0.4	-1.9
I=22 J=152	22.7	22.0	0.6	2.8
I=18 J=154	22.3	22.0	0.3	1.2
I=18 J=156	22.6	22.2	0.4	1.9
I=21 J=156	22.5	22.1	0.4	1.7
I=14 J=169	22.5	22.3	0.2	0.7
I=14 J=175	22.9	20.1	2.8	13.8
I=12 J=182	22.1	20.5	1.6	7.6
I=14 J=186	22.5	20.8	1.7	8.2
I=14 J=188	22.7	20.3	2.4	11.8
I=14 J=189	22.6	19.2	3.5	18.0

D5.5 Modeling of Water Quality

D5.5.1 Calibration and Validation for Chl-a

Table D5-8. Comparisons of calibration simulations and measurements of chl-a: 2003-2009

Station	Chl-a (µg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			µg/L	%
I=30 J=44	0.4	3.7	-3.3	-89
I=14 J=91	3.1	8.3	-5.2	-62
I=17 J=91	0.4	4.3	-3.9	-90
I=16 J=92	3.1	8.6	-5.5	-64
I=18 J=110	2.5	6.9	-4.4	-63
I=25 J=128	1.6	3.1	-1.4	-47
I=23 J=133	3.2	5.4	-2.2	-40
I=21 J=134	3.5	4.8	-1.3	-27
I=24 J=150	1.8	7.8	-6.0	-77
I=22 J=152	1.7	10.6	-8.9	-84
I=24 J=152	2.2	8.1	-5.9	-73
I=12 J=182	2.0	3.4	-1.4	-41

Table D5-9. Comparisons of validation simulations and measurements of chl-a: 1997-2002

Station	Chl-a (µg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			µg/L	%
I=14 J=91	3.9	5.1	-1.3	-25
I=17 J=91	0.7	2.9	-2.3	-78
I=16 J=92	4.0	4.5	-0.5	-11
I=18 J=110	2.6	2.1	0.5	24
I=25 J=128	1.7	4.0	-2.3	-58
I=20 J=130	3.5	1.5	2.0	136
I=23 J=133	3.6	2.3	1.3	54
I=14 J=169	3.0	3.5	-0.5	-15
I=14 J=175	3.7	5.5	-1.8	-32

D5.5.2 Calibration and Validation for DO

Table D5-10. Comparisons of calibration simulations and measurements of DO: 2003-2009

Station	DO (mg/L)			
			Error	
	Simulated Surface Mean	Measured Surface Mean	mg/L	%
I=17 J=4	7.0	6.4	0.6	8
I=18 J=10	7.1	6.3	0.8	12
I=17 J=18	6.8	6.7	0.1	2
I=20 J=31	6.5	7.1	-0.6	-8
I=22 J=39	6.5	7.3	-0.8	-11
I=25 J=44	6.8	7.6	-0.7	-9
I=30 J=44	5.4	6.3	-0.9	-14
I=24 J=47	6.6	7.4	-0.8	-11
I=27 J=53	5.4	6.4	-0.9	-15
I=24 J=59	6.9	7.9	-1.0	-13
I=24 J=62	6.9	7.5	-0.6	-8
I=24 J=68	7.0	7.0	-0.1	-1
I=24 J=70	6.8	7.1	-0.2	-3
I=24 J=73	6.9	7.3	-0.3	-5
I=23 J=78	6.9	6.3	0.6	10
I=25 J=78	6.5	5.7	0.8	14
I=28 J=78	5.6	6.4	-0.8	-12
I=21 J=79	6.9	6.5	0.3	5
I=13 J=89	7.7	7.2	0.5	7
I=16 J=90	7.0	7.5	-0.5	-6
I=28 J=91	5.9	6.8	-0.9	-13
I=16 J=92	7.4	7.0	0.4	6
I=16 J=98	7.4	7.2	0.2	3
I=16 J=102	7.1	7.0	0.1	1
I=18 J=110	6.6	7.4	-0.8	-11
I=24 J=110	5.2	6.6	-1.4	-22
I=21 J=127	7.2	7.7	-0.5	-6
I=26 J=128	4.7	4.0	0.7	18
I=21 J=132	7.2	7.6	-0.5	-6
I=31 J=133	5.1	5.3	-0.1	-2
I=26 J=145	6.9	6.1	0.8	13
I=27 J=145	6.8	5.8	1.0	17
I=24 J=150	7.6	7.3	0.3	5
I=20 J=152	7.6	6.8	0.9	13
I=22 J=152	7.6	6.8	0.9	13
I=18 J=154	7.2	6.9	0.3	4
I=18 J=156	7.2	6.9	0.3	4

Station	DO (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
I=21 J=156	8.1	6.8	1.4	20
I=22 J=157	8.4	7.0	1.4	21
I=14 J=169	7.6	6.9	0.7	10
I=14 J=175	8.1	7.3	0.8	11
I=10 J=182	7.3	7.0	0.4	5
I=12 J=182	8.0	7.0	1.0	14
I=14 J=186	8.0	7.4	0.6	8
I=14 J=189	7.9	7.4	0.4	6

Table D5-11. Comparisons of validation simulations and measurements of DO: 1997-2002

Station	DO (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
I=17 J=4	6.9	6.1	0.8	13
I=18 J=10	6.9	6.2	0.7	12
I=17 J=18	6.7	6.8	-0.1	-2
I=22 J=39	6.4	7.4	-1.0	-13
I=25 J=44	6.7	6.6	0.2	2
I=30 J=44	5.3	6.1	-0.8	-13
I=24 J=47	6.5	7.0	-0.5	-7
I=27 J=53	5.2	6.4	-1.2	-18
I=24 J=62	6.7	6.8	-0.2	-2
I=24 J=68	6.8	6.8	0.0	0
I=24 J=70	6.7	6.9	-0.2	-3
I=24 J=73	6.7	6.6	0.1	1
I=23 J=78	6.7	6.5	0.2	4
I=25 J=78	6.3	5.7	0.6	10
I=28 J=78	5.5	6.0	-0.5	-8
I=21 J=79	6.6	6.7	-0.1	-1
I=13 J=89	7.6	6.8	0.8	12
I=28 J=91	6.0	7.2	-1.2	-17
I=16 J=92	7.3	6.8	0.5	8
I=16 J=98	7.1	6.3	0.8	13
I=16 J=102	6.8	6.3	0.5	8
I=18 J=110	6.3	7.2	-0.9	-13
I=24 J=110	4.8	6.7	-1.9	-28
I=21 J=127	7.0	6.9	0.1	1
I=27 J=145	6.6	7.4	-0.8	-11
I=24 J=150	7.5	8.6	-1.1	-13

Station	DO (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
I=20 J=152	7.5	8.7	-1.3	-15
I=22 J=152	7.5	8.7	-1.3	-15
I=18 J=154	7.0	8.1	-1.1	-13
I=18 J=156	7.0	7.9	-0.9	-11
I=21 J=156	7.9	8.9	-1.0	-11
I=22 J=157	8.2	8.3	-0.1	-1
I=14 J=169	7.4	7.9	-0.5	-6
I=14 J=175	7.9	8.5	-0.6	-7
I=10 J=182	7.2	8.7	-1.5	-18
I=12 J=182	7.9	8.5	-0.6	-7
I=14 J=186	7.7	8.6	-0.8	-10
I=14 J=189	7.6	8.7	-1.1	-12

D5.5.3 Calibration and Validation for TN

Table D5-12. Comparisons of calibration simulations and measurements of TN: 2003-2009

Station	TN (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
I=17 J=18	0.29	0.35	-0.05	-15.7
I=20 J=31	0.26	0.35	-0.08	-24.2
I=22 J=39	0.26	0.38	-0.12	-30.7
I=25 J=44	0.26	0.39	-0.12	-32.2
I=24 J=47	0.24	0.38	-0.14	-37.0
I=24 J=59	0.23	0.38	-0.15	-39.1
I=24 J=62	0.24	0.35	-0.11	-31.7
I=24 J=68	0.35	0.32	0.04	11.0
I=24 J=70	0.42	0.45	-0.03	-6.3
I=24 J=73	0.39	0.50	-0.11	-21.9
I=26 J=145	0.49	0.51	-0.02	-3.0
I=27 J=145	0.50	0.51	-0.01	-1.4

Table D5-13. Comparisons of validation simulations and measurements of TN: 1997-2002

Station	TN (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
I=17 J=18	0.30	0.38	-0.08	-21.1
I=20 J=31	0.27	0.41	-0.14	-34.7
I=22 J=39	0.26	0.43	-0.16	-38.2
I=25 J=44	0.27	0.44	-0.18	-40.0
I=24 J=47	0.24	0.44	-0.20	-45.8
I=24 J=59	0.23	0.36	-0.13	-35.0
I=24 J=62	0.23	0.34	-0.11	-31.1
I=24 J=68	0.32	0.28	0.04	15.8
I=24 J=70	0.39	0.37	0.02	4.9
I=24 J=73	0.37	0.39	-0.03	-6.6
I=21 J=127	0.34	0.20	0.14	70.3
I=21 J=129	0.36	0.27	0.09	34.0
I=23 J=133	0.41	0.22	0.19	84.8
I=14 J=169	0.38	0.24	0.14	58.1

D5.5.4 Calibration and Validation for Ammonia

Table D5-14. Comparisons of calibration simulations and measurements of ammonia: 2003-2009

Station	Ammonia (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
I=30 J=44	0.02	0.09	-0.07	-78
I=27 J=53	0.01	0.03	-0.02	-63
I=17 J=91	0.15	0.06	0.09	154
I=28 J=91	0.17	0.08	0.09	115
I=16 J=92	0.05	0.07	-0.02	-29
I=18 J=110	0.02	0.06	-0.04	-61
I=22 J=110	0.09	0.06	0.03	51
I=24 J=110	0.12	0.06	0.07	114
I=21 J=127	0.02	0.04	-0.02	-42
I=25 J=128	0.35	0.25	0.10	40
I=23 J=133	0.02	0.04	-0.02	-40
I=31 J=133	0.06	0.07	-0.01	-11
I=21 J=134	0.02	0.04	-0.02	-53
I=27 J=145	0.05	0.06	-0.01	-10
I=24 J=146	0.03	0.06	-0.03	-56
I=24 J=150	0.02	0.09	-0.07	-77
I=22 J=157	0.09	0.04	0.05	124

Table D5-15. Comparisons of validation simulations and measurements of ammonia: 1997-2002

Station	Ammonia (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
I=30 J=44	0.02	0.04	-0.02	-49
I=17 J=91	0.13	0.05	0.09	198
I=22 J=110	0.09	0.04	0.05	111
I=24 J=110	0.12	0.05	0.08	173
I=21 J=127	0.02	0.07	-0.05	-73
I=25 J=128	0.34	0.50	-0.16	-31
I=23 J=133	0.02	0.06	-0.04	-62
I=31 J=133	0.05	0.06	-0.01	-9
I=21 J=134	0.02	0.06	-0.04	-72
I=24 J=150	0.02	0.06	-0.04	-75
I=14 J=175	0.04	0.04	0.00	-5

D5.5.5 Calibration and Validation for Nitrate-Nitrite

Table D5-16. Comparisons of calibration simulations and measurements of nitrate-nitrite: 2003-2009

Station	Nitrate-Nitrite (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
I=17 J=4	0.06	0.02	0.03	155
I=30 J=44	0.19	0.04	0.15	397
I=27 J=53	0.18	0.37	-0.19	-52
I=14 J=91	0.23	0.52	-0.28	-55
I=17 J=91	0.67	0.71	-0.04	-5
I=28 J=91	0.69	0.73	-0.04	-5
I=16 J=92	0.37	0.29	0.08	27
I=18 J=110	0.13	0.05	0.08	168
I=22 J=110	0.16	0.05	0.11	204
I=24 J=110	0.17	0.70	-0.53	-76
I=23 J=128	0.21	0.46	-0.25	-55
I=25 J=128	0.25	0.42	-0.18	-41
I=31 J=133	0.27	0.03	0.24	706
I=21 J=134	0.17	0.02	0.16	912
I=26 J=145	0.24	0.15	0.09	62
I=27 J=145	0.22	0.13	0.09	73
I=14 J=175	0.08	0.11	-0.03	-27

Table D5-17. Comparisons of validation simulations and measurements of nitrate-nitrite: 1997-2002

Station	Nitrate-Nitrite (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
I=17 J=4	0.07	0.04	0.04	111
I=30 J=44	0.19	0.05	0.15	313
I=27 J=53	0.19	0.47	-0.28	-60
I=14 J=91	0.18	0.27	-0.09	33
I=28 J=91	0.66	0.68	-0.02	-2
I=18 J=110	0.12	0.03	0.08	244
I=22 J=110	0.16	0.04	0.12	333
I=24 J=110	0.17	0.64	-0.47	-74
I=23 J=128	0.20	0.11	0.10	92
I=25 J=128	0.29	0.19	0.10	50
I=26 J=133	0.26	0.03	0.23	767
I=31 J=133	0.31	0.03	0.28	969
I=27 J=145	0.23	0.11	0.12	110
I=14 J=169	0.10	0.03	0.07	203
I=14 J=175	0.09	0.06	0.04	63

D5.5.6 Calibration and Validation for TP

Table D5-18. Comparisons of calibration simulations and measurements of TP: 2003-2009

Station	TP (mg/L)			
			Error	
	Simulated Surface Mean	Measured Surface Mean	mg/L	%
I=17 J=4	0.027	0.059	-0.032	-54
I=18 J=10	0.045	0.037	0.008	22
I=17 J=18	0.010	0.021	-0.011	-52
I=20 J=31	0.008	0.007	0.001	14
I=22 J=39	0.008	0.006	0.002	33
I=25 J=44	0.008	0.008	0.000	0
I=30 J=44	0.009	0.055	-0.046	-84
I=24 J=47	0.007	0.013	-0.006	-46
I=27 J=53	0.008	0.020	-0.012	-60
I=24 J=59	0.009	0.010	-0.001	-10
I=24 J=62	0.010	0.010	0.000	0
I=24 J=70	0.023	0.044	-0.021	-48
I=24 J=73	0.022	0.040	-0.018	-45
I=28 J=78	0.045	0.074	-0.029	-39
I=14 J=91	0.039	0.106	-0.067	-63
I=17 J=91	0.131	0.125	0.006	5
I=28 J=91	0.138	0.133	0.005	4
I=16 J=92	0.065	0.095	-0.030	-32
I=18 J=110	0.019	0.042	-0.023	-55
I=22 J=110	0.063	0.074	-0.011	-15
I=24 J=110	0.084	0.125	-0.041	-33
I=23 J=128	0.056	0.743	-0.687	-92
I=26 J=128	0.272	0.677	-0.405	-60
I=31 J=128	0.504	0.732	-0.228	-31
I=27 J=145	0.033	0.034	-0.001	-3
I=24 J=150	0.021	0.038	-0.017	-45
I=22 J=157	0.042	0.051	-0.009	-18

Table D5-19. Comparisons of validation simulations and measurements of TP: 1997-2002

Station	TP (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
I=17 J=4	0.028	0.045	-0.017	-38
I=18 J=10	0.047	0.041	0.006	15
I=17 J=18	0.010	0.016	-0.006	-38
I=20 J=31	0.008	0.010	-0.002	-20
I=22 J=39	0.008	0.009	-0.001	-11
I=25 J=44	0.008	0.013	-0.005	-38
I=30 J=44	0.009	0.047	-0.038	-81
I=24 J=47	0.007	0.009	-0.002	-22
I=27 J=53	0.009	0.023	-0.014	-61
I=24 J=59	0.009	0.012	-0.003	-25
I=24 J=62	0.010	0.011	-0.001	-9
I=24 J=70	0.024	0.037	-0.014	-35
I=24 J=73	0.023	0.033	-0.011	-30
I=28 J=78	0.044	0.069	-0.025	-36
I=14 J=91	0.042	0.118	-0.076	-64
I=17 J=91	0.160	0.112	0.048	43
I=28 J=91	0.174	0.115	0.059	51
I=16 J=92	0.074	0.070	0.004	6
I=18 J=110	0.019	0.034	-0.015	-44
I=22 J=110	0.060	0.062	-0.002	-3
I=24 J=110	0.082	0.114	-0.032	-28
I=21 J=127	0.028	0.025	0.002	12
I=23 J=128	0.062	0.184	-0.122	-66
I=25 J=128	0.212	0.344	-0.133	-38
I=31 J=128	0.613	0.949	-0.336	-35
I=21 J=129	0.029	0.032	-0.003	-9
I=20 J=130	0.020	0.025	-0.005	-20
I=21 J=132	0.020	0.023	-0.003	-13
I=23 J=133	0.027	0.029	-0.002	-7
I=26 J=133	0.036	0.048	-0.013	-25
I=31 J=133	0.048	0.086	-0.039	-44
I=21 J=134	0.017	0.024	-0.007	-29
I=24 J=150	0.022	0.043	-0.022	-49
I=14 J=169	0.012	0.030	-0.018	-60
I=14 J=175	0.019	0.044	-0.025	-57

D5.5.7 Calibration and Validation for Color

Table D5-20. Comparisons of calibration simulations and measurements of color: 2003-2009

Station	Color (NTU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			NTU	%
I=20 J=31	14.2	8.2	6.0	73
I=22 J=39	17.2	8.6	8.6	100
I=25 J=44	22.7	8.6	14.1	164
I=24 J=47	17.9	17.3	0.6	3
I=27 J=53	35.8	24.2	11.6	48
I=24 J=59	21.0	14.3	6.7	47
I=24 J=62	26.3	12.8	13.5	105
I=24 J=68	53.4	14.5	38.9	268
I=24 J=70	69.0	33.7	35.3	105
I=24 J=73	78.6	29.0	49.6	171
I=14 J=91	68.6	121.6	-53.0	-44
I=17 J=91	222.5	136.7	85.8	63
I=28 J=91	233.6	145.5	88.1	61
I=16 J=92	114.1	117.0	-2.9	-2
I=18 J=110	99.2	83.6	15.6	19
I=22 J=110	519.7	199.4	320.3	161
I=23 J=128	213.0	345.3	-132.3	-38
I=25 J=128	624.2	382.7	241.5	63
I=21 J=129	97.2	31.6	65.6	208
I=21 J=132	71.8	24.5	47.3	193
I=23 J=133	138.7	76.6	62.1	81
I=31 J=133	759.1	484.1	275.0	57
I=21 J=134	67.5	36.6	30.9	84
I=27 J=145	139.4	77.0	62.4	81
I=24 J=150	125.3	81.3	44.0	54

Table D5-21. Comparisons of validation simulations and measurements of color: 1997-2002

Station	Color (NTU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			NTU	%
I=20 J=31	16.1	6.4	9.7	152
I=22 J=39	18.9	6.4	12.5	195
I=25 J=44	24.0	6.4	17.6	275
I=24 J=47	19.5	13.3	6.2	47
I=27 J=53	35.8	21.9	13.9	63
I=24 J=59	21.7	11.2	10.5	94
I=24 J=62	25.9	10.4	15.5	149
I=24 J=68	50.7	7.1	43.6	614
I=24 J=70	65.9	14.2	51.7	364
I=24 J=73	76.3	12.8	63.5	496
I=14 J=91	66.0	40.8	25.2	62
I=17 J=91	224.2	63.4	160.8	254
I=28 J=91	239.7	65.0	174.7	269
I=16 J=92	113.0	19.2	93.8	489
I=18 J=110	90.7	34.1	56.6	166
I=22 J=110	479.4	124.4	355.0	285
I=23 J=128	192.3	117.7	74.6	63
I=25 J=128	594.1	316.7	277.4	88
I=21 J=129	89.7	28.3	61.4	217
I=21 J=132	66.8	15.3	51.5	337
I=23 J=133	124.1	40.0	84.1	210
I=24 J=150	120.1	45.0	75.1	167

D5.5.8 Calibration and Validation for Light Attenuation Coefficient (K_d)

Table D5-22. Comparisons of calibration simulations and measurements of K_d: 2003-2009

Station	K_d (1/m)			
	Simulated Mean	Measured Mean	Error	
			1/m	%
I=21 J=127	1.6	0.6	1.0	186
I=25 J=128	10.0	3.8	6.2	165
I=26 J=128	14.2	3.8	10.4	275
I=23 J=128	3.6	1.7	1.8	104
I=31 J=128	22.4	5.5	17.0	311
I=21 J=129	1.7	0.8	0.9	104
I=21 J=132	1.3	0.7	0.6	86
I=23 J=133	2.4	1.3	1.1	81
I=26 J=133	7.2	2.7	4.5	169
I=31 J=133	12.9	3.6	9.3	263
I=21 J=134	1.2	1.0	0.2	18

Table D5-23. Comparisons of validation simulations and measurements of K_d: 1997-2002

Station	K_d (1/m)			
	Simulated Mean	Measured Mean	Error	
			1/m	%
I=21 J=127	1.5	0.6	0.8	137
I=23 J=128	3.2	2.2	1.1	49
I=25 J=128	9.4	5.3	4.1	78
I=26 J=128	13.9	5.3	8.6	162
I=31 J=128	24.7	7.5	17.2	228
I=21 J=129	1.6	0.9	0.7	71
I=20 J=130	1.0	0.5	0.5	91
I=21 J=132	1.2	0.6	0.5	84
I=23 J=133	2.2	1.4	0.8	57
I=26 J=133	6.3	1.8	4.5	250
I=31 J=133	12.6	2.3	10.3	441
I=21 J=134	1.1	1.0	0.2	18

Attachment 6: Tampa-Sarasota Bay Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

EPA is not presenting a hydrodynamic/water quality model for this estuarine system.

Attachment 7: Charlotte Harbor, Caloosahatchee Estuary and Estero Bay Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

EPA is not presenting a hydrodynamic/water quality model for this estuarine system.

Appendix D
Attachment 8: Lake Worth Lagoon Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Contents

D8.1 LOCATION OF MONITORING STATIONS D8-1

D8.2 MODELING OF WATER SURFACE ELEVATION (WSE) D8-2

D8.2.1 Calibration of Water Surface Elevation D8-2

D8.2.2 Validation of Water Surface Elevation D8-2

D8.3 MODELING OF SALINITY D8-3

D8.3.1 Calibration D8-3

D8.3.2 Validation D8-3

D8.4 MODELING OF WATER TEMPERATURE D8-4

D8.4.1 Calibration D8-4

D8.4.2 Validation D8-4

D8.5 MODELING OF WATER QUALITY D8-5

D8.5.1 Calibration and Validation for Chl-a D8-5

D8.5.2 Calibration and Validation for DO D8-5

D8.5.3 Calibration and Validation for TN D8-5

D8.5.4 Calibration and Validation for Ammonia D8-6

D8.5.5 Calibration and Validation for Nitrate-Nitrite D8-6

D8.5.6 Calibration and Validation for TP D8-6

D8.5.7 Calibration and Validation for Total Suspended Solids (TSS) D8-7

D8.5.8 Calibration and Validation for Light Attenuation Coefficient (K_d) D8-7

Figures

Figure D8-1. Monitoring stations D8-1

Tables

Table D8-1. Calibration comparisons of simulated and measured WSE: 2003-2004 .... D8-2
Table D8-2. Validation comparisons of simulated and measured WSE: 2003-2004 .... D8-2
Table D8-3. Calibration comparisons of simulated and measured salinity: 2002-2009 .... D8-3
Table D8-4. Validation comparisons of simulated and measured salinity: 2002-2009 .... D8-3
Table D8-5. Calibration comparisons of simulated and measured temperature: 2002-2009 .... D8-4
Table D8-6. Validation comparisons of simulated and measured temperature: 2002-2009 .... D8-4
Table D8-7. Comparisons of simulated and measured chl-a: 2002-2009 .... D8-5
Table D8-8. Comparisons of simulated and measured DO: 2002-2009 .... D8-5
Table D8-9. Comparisons of simulated and measured TN: 2002-2009 .... D8-5
Table D8-10. Comparisons of simulated and measured ammonia: 2002-2009 .... D8-6
Table D8-11. Comparisons of simulated and measured nitrate-nitrite: 2002-2009 .... D8-6
Table D8-12. Comparisons of simulated and measured TP: 2002-2009 .... D8-6
Table D8-13. Comparisons of simulated and measured TSS: 2002-2009 .... D8-7
Table D8-14. Comparisons of simulated and measured K_d: 2002-2009 .... D8-7

D8.1 Location of Monitoring Stations

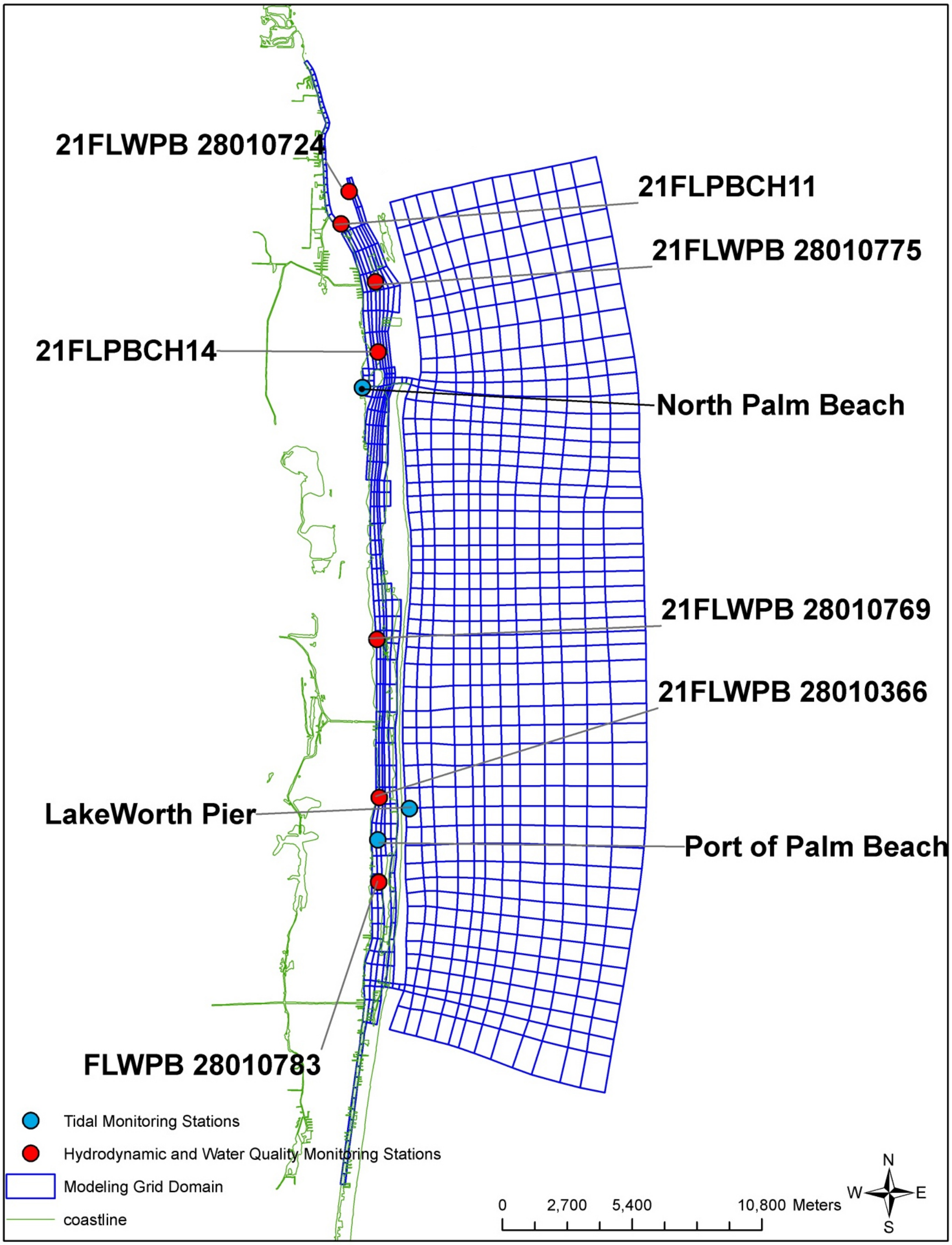

Figure D8-1. Monitoring stations

D8.2 Modeling of Water Surface Elevation (WSE)

D8.2.1 Calibration of Water Surface Elevation

Table D8-1. Calibration comparisons of simulated and measured WSE: 2003-2004

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
North Palm Beach	0.03	-0.34	0.46	0.02	-0.44	0.41	0.01	0.11	0.05	0.95
Port of Palm Beach	0.19	-0.23	0.67	0.17	-0.31	0.67	0.03	0.08	-0.01	0.90

D8.2.2 Validation of Water Surface Elevation

Table D8-2. Validation comparisons of simulated and measured WSE: 2003-2004

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
Lake Worth Pier	0.19	-0.44	0.83	0.16	-0.38	0.71	0.03	-0.06	0.13	0.94

D8.3 Modeling of Salinity

D8.3.1 Calibration

Table D8-3. Calibration comparisons of simulated and measured salinity: 2002-2009

Station	Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			PSU	%
21FLWPB 28010775	29.3	30.1	-0.8	-2.6
21FLPBCH11	29.3	30.9	-1.6	-5.2
21FLWPB 28010783	18.9	30.5	-11.6	-37.9

D8.3.2 Validation

Table D8-4. Validation comparisons of simulated and measured salinity: 2002-2009

Station	Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			PSU	%
21FLWPB 28010366	11.4	27.6	-16.2	-58.6
21FLWPB 28010769	11.3	28.2	-16.9	-59.9
21FLWPB 28010724	28.8	31.5	-2.7	-8.6

D8.4 Modeling of Water Temperature

D8.4.1 Calibration

Table D8-5. Calibration comparisons of simulated and measured temperature: 2002-2009

Station	Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			Deg C	%
21FLWPB 28010775	24.2	25.9	-1.7	-6.5
21FLPBCH14	24.2	26.5	-2.3	-8.6
21FLWPB 28010783	24.0	26.2	-2.2	-8.3

D8.4.2 Validation

Table D8-6. Validation comparisons of simulated and measured temperature: 2002-2009

Station	Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			Deg C	%
21FLWPB 28010366	24.0	25.8	-1.8	-7.0
21FLWPB 28010769	24.5	25.7	-1.2	-4.6
21FLWPB 28010724	24.5	26.0	-1.5	-5.7

D8.5 Modeling of Water Quality

D8.5.1 Calibration and Validation for Chl-a

Table D8-7. Comparisons of simulated and measured chl-a: 2002-2009

Station	Chl-a (µg/L)			
			Error	
	Simulated Surface Mean	Measured Surface Mean	µg/L	%
21FLWPB 28010775	4.5	4.3	0.2	4.4
21FLPBCH14	3.5	3.2	0.3	9.4
21FLWPB 28010783	6.4	10.4	-4.1	-39.0
21FLWPB 28010366	6.9	12.1	-5.2	-42.9
21FLWPB 28010769	8.9	10.2	-1.3	-12.6

D8.5.2 Calibration and Validation for DO

Table D8-8. Comparisons of simulated and measured DO: 2002-2009

Station	DO (mg/L)			
			Error	
	Simulated Surface Mean	Measured Surface Mean	mg/L	%
21FLWPB 28010775	6.74	6.77	-0.03	-0.5
21FLPBCH14	5.73	7.04	-1.31	-18.6
21FLWPB 28010366	7.43	6.94	0.48	7.0
21FLWPB 28010769	7.60	7.00	0.60	8.6

D8.5.3 Calibration and Validation for TN

Table D8-9. Comparisons of simulated and measured TN: 2002-2009

Station	TN (mg/L)			
			Error	
	Simulated Surface Mean	Measured Surface Mean	mg/L	%
21FLWPB 28010775	0.549	0.410	0.139	34
21FLPBCH14	0.552	0.288	0.264	92
21FLWPB 28010783	0.885	0.650	0.235	36
21FLWPB 28010366	1.085	0.768	0.317	41
21FLWPB 28010769	1.025	0.756	0.269	36
21FLWPB 28010724	0.608	0.465	0.143	31

D8.5.4 Calibration and Validation for Ammonia

Table D8-10. Comparisons of simulated and measured ammonia: 2002-2009

Station	Ammonia (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
21FLWPB 28010775	0.115	0.067	0.048	72
21FLPBCH14	0.181	0.021	0.160	762
21FLWPB 28010783	0.129	0.021	0.108	514
21FLWPB 28010366	0.162	0.070	0.092	131
21FLWPB 28010769	0.191	0.076	0.115	151
21FLWPB 28010724	0.083	0.062	0.021	34

D8.5.5 Calibration and Validation for Nitrate-Nitrite

Table D8-11. Comparisons of simulated and measured nitrate-nitrite: 2002-2009

Station	Nitrate-Nitrite (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
21FLWPB 28010775	0.023	0.013	0.010	77
21FLPBCH14	0.021	0.003	0.018	600
21FLWPB 28010783	0.026	0.058	-0.032	-55
21FLWPB 28010366	0.030	0.061	-0.031	-51
21FLWPB 28010769	0.041	0.068	-0.027	-40
21FLWPB 28010724	0.013	0.014	-0.001	-7

D8.5.6 Calibration and Validation for TP

Table D8-12. Comparisons of simulated and measured TP: 2002-2009

Station	TP (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
21FLWPB 28010775	0.036	0.051	-0.015	-29
21FLPBCH14	0.045	0.063	-0.018	-29
21FLWPB 28010783	0.063	0.061	0.002	3
21FLWPB 28010366	0.077	0.072	0.005	7
21FLWPB 28010769	0.096	0.072	0.024	33
21FLWPB 28010724	0.053	0.056	-0.003	-5

D8.5.7 Calibration and Validation for Total Suspended Solids (TSS)

Table D8-13. Comparisons of simulated and measured TSS: 2002-2009

Station	TSS (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
21FLWPB 28010783	4.1	19.0	-14.8	-78
21FLWPB 28010724	4.0	9.5	-5.5	-58
21FLWPB 28010775	3.6	12.2	-8.6	-71
21FLWPB 28010366	4.5	14.6	-10.1	-69
21FLWPB 28010769	4.6	13.9	-9.2	-67

D8.5.8 Calibration and Validation for Light Attenuation Coefficient (K_d)

Table D8-14. Comparisons of simulated and measured K_d: 2002-2009

Station	K_d (1/m)			
	Simulated Mean	Measured Mean	Error	
			1/m	%
21FLWPB 28010775	0.654	1.269	-0.615	-48.5
21FLWPB 28010783	0.977	0.980	-0.003	-0.3
21FLWPB 28010366	1.330	1.076	0.254	23.6
21FLWPB 28010769	1.323	1.137	0.186	16.4
21FLWPB 28010724	0.774	0.820	-0.046	-5.6

Appendix D
Attachment 9: Loxahatchee Estuary Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Contents

D9.1 LOCATION OF MONITORING STATIONS D9-1

D9.2 MODELING OF WATER SURFACE ELEVATION (WSE) D9-2

D9.2.1 Calibration and Validation for WSE D9-2

D9.3 MODELING OF SALINITY D9-3

D9.3.1 Calibration and Validation for Salinity D9-3

D9.4 MODELING OF WATER TEMPERATURE D9-4

D9.4.1 Calibration and Validation for Water Temperature D9-4

D9.5 MODELING OF WATER QUALITY D9-5

D9.5.1 Calibration and Validation for Chl-a D9-5

D9.5.2 Calibration and Validation for DO D9-6

D9.5.3 Calibration and Validation for TN D9-7

D9.5.4 Calibration and Validation for Ammonia D9-8

D9.5.5 Calibration and Validation for Nitrate-Nitrite D9-9

D9.5.6 Calibration and Validation for TP D9-10

D9.5.7 Calibration and Validation for Total Suspended Solids (TSS) D9-11

D9.5.8 Calibration and Validation for Light Attenuation Coefficient (K_d) D9-12

Figures

Figure D9-1. Monitoring stations ... D9-1

Tables

Table D9-1. Calibration comparisons of simulated and measured WSE: 2002-2009 ... D9-2
Table D9-2. Validation comparisons of simulated and measured WSE: 2002-2009 ... D9-2
Table D9-3. Calibration comparisons of simulated and measured salinity: 2002-2009 ... D9-3
Table D9-4. Validation comparisons of simulated and measured salinity: 2002-2009 ... D9-3
Table D9-5. Calibration comparisons of simulated and measured temperature: 2002-2009 ... D9-4
Table D9-6. Validation comparisons of simulated and measured temperature: 2002-2009 ... D9-4
Table D9-7. Calibration comparisons of simulated and measured chl-a: 2002-2009 ... D9-5
Table D9-8. Validation comparisons of simulated and measured chl-a: 2002-2009 ... D9-5
Table D9-9. Calibration comparisons of simulated and measured DO: 2002-2009 ... D9-6
Table D9-10. Validation comparisons of simulated and measured DO: 2002-2009 ... D9-6
Table D9-11. Calibration comparisons of simulated and measured TN: 2002-2009 ... D9-7
Table D9-12. Validation comparisons of simulated and measured TN: 2002-2009 ... D9-7
Table D9-13. Calibration comparisons of simulated and measured ammonia: 2002-2009 ... D9-8
Table D9-14. Validation comparisons of simulated and measured ammonia: 2002-2009 ... D9-8
Table D9-15. Calibration comparisons of simulated and measured nitrate-nitrite: 2002-2009 ... D9-9
Table D9-16. Validation comparisons of simulated and measured nitrate-nitrite: 2002-2009 ... D9-9
Table D9-17. Calibration comparisons of simulated and measured TP: 2002-2009 ... D9-10
Table D9-18. Validation comparisons of simulated and measured TP: 2002-2009 ... D9-10
Table D9-19. Calibration comparisons of simulated and measured TSS: 2002-2009 ... D9-11
Table D9-20. Validation comparisons of simulated and measured TSS: 2002-2009 ... D9-11
Table D9-21. Calibration comparisons of simulated and measured K_d: 2002-2009 ... D9-12
Table D9-22. Validation comparisons of simulated and measured K_d: 2002-2009 ... D9-12

D9.1 Location of Monitoring Stations

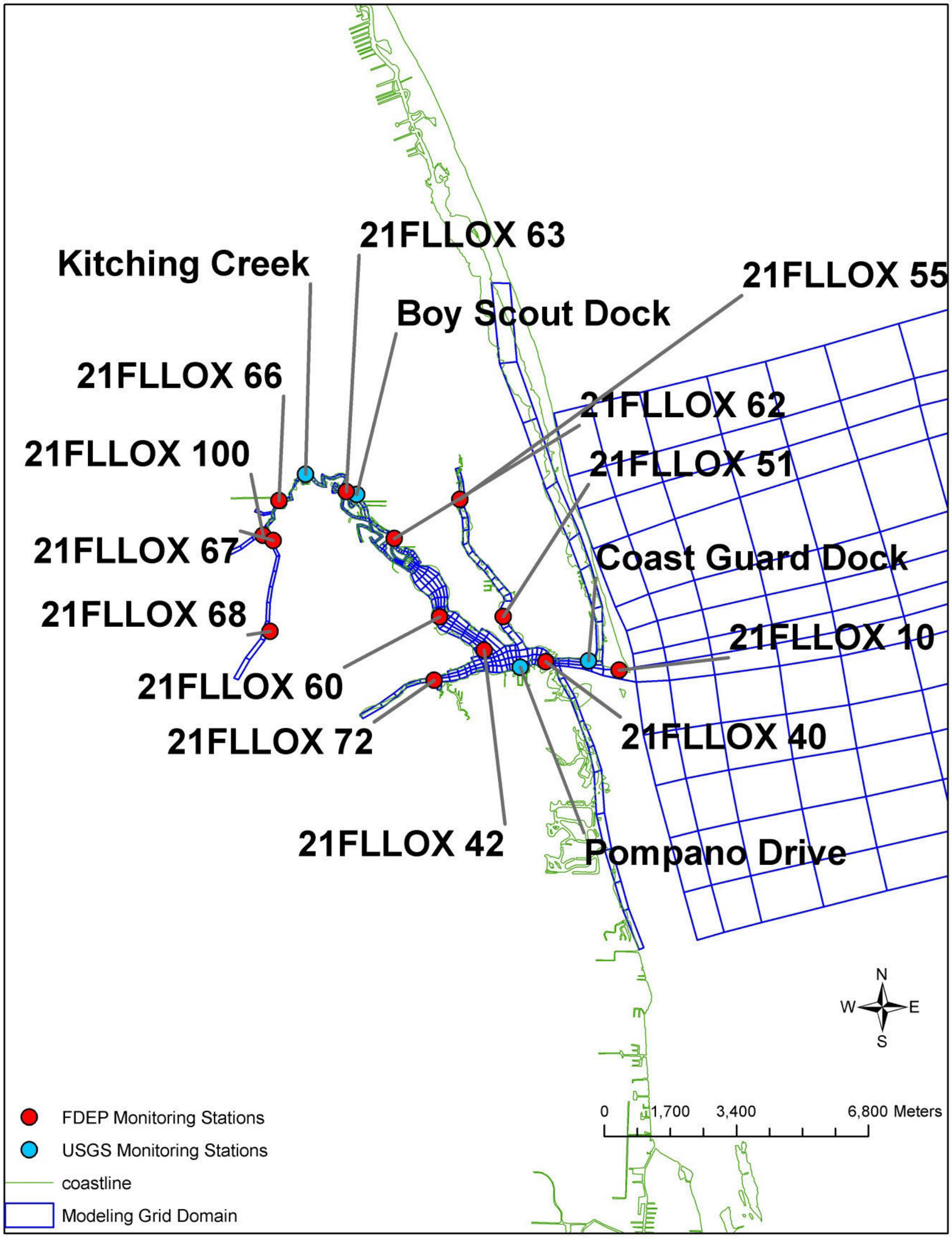

Figure D9-1. Monitoring stations

D9.2 Modeling of Water Surface Elevation (WSE)

D9.2.1 Calibration and Validation for WSE

Table D9-1. Calibration comparisons of simulated and measured WSE: 2002-2009

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
Kitching Creek	0.31	-0.21	0.90	0.20	-0.25	0.63	0.11	0.04	0.26	0.92
Pompano Drive	0.23	-0.38	0.88	0.16	-0.25	0.60	0.07	-0.13	0.28	0.89

Table D9-2. Validation comparisons of simulated and measured WSE: 2002-2009

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
Boy Scout Dock	0.33	-0.25	0.97	0.25	-0.19	0.67	0.08	-0.06	0.30	0.93
Coast Guard Dock	0.29	-0.39	0.96	0.20	-0.24	0.65	0.09	-0.15	0.31	0.98

D9.3 Modeling of Salinity

D9.3.1 Calibration and Validation for Salinity

Table D9-3. Calibration comparisons of simulated and measured salinity: 2002-2009

Salinity (PSU)				
Station	Simulated Surface Mean	Measurement Mean	Error	
			PSU	%
Kitching Creek	1.4	1.6	-0.3	-15.6
Pompano Drive	30.8	28.6	2.2	7.8
Coast Guard Dock	33.1	32.7	0.4	1.2
Boy Scout Dock	8.0	9.0	-1.0	-10.8

Table D9-4. Validation comparisons of simulated and measured salinity: 2002-2009

Salinity (PSU)				
Station	Simulated Surface Mean	Measurement Mean	Error	
			PSU	%
21FLLOX 72	23.7	27.2	-3.5	-13.0
21FLLOX 60	23.2	26.0	-2.8	-10.6
21FLLOX 62	13.2	17.6	-4.4	-24.9
21FLLOX 51	27.7	30.3	-2.6	-8.7
21FLLOX 55	17.7	18.6	-0.8	-4.5

D9.4 Modeling of Water Temperature

D9.4.1 Calibration and Validation for Water Temperature

Table D9-5. Calibration comparisons of simulated and measured temperature: 2002-2009

Temperature (Deg C)				
Station	Simulated Surface Mean	Measurement Mean	Error	
			Deg C	%
Coast Guard Dock	25.7	25.7	-0.1	-0.2
Pompano Drive	26.4	26.3	0.1	0.3
Kitching Creek	23.6	24.8	-1.2	-4.8
21FLLOX 63	24.1	24.5	-0.4	-1.6
21FLLOX 67	23.3	23.5	-0.2	-0.6
21FLLOX 100	23.8	23.3	0.6	2.4
21FLLOX 66	23.4	23.2	0.2	0.7

Table D9-6. Validation comparisons of simulated and measured temperature: 2002-2009

Temperature (Deg C)				
Station	Simulated Surface Mean	Measurement Mean	Error	
			Deg C	%
21FLLOX 72	24.6	25.1	-0.5	-1.9
21FLLOX 60	25.0	24.7	0.3	1.3
21FLLOX 62	24.6	24.7	-0.1	-0.4
21FLLOX 51	25.1	25.1	-0.1	-0.3
21FLLOX 55	23.6	24.9	-1.3	-5.0
21FLLOX 40	25.3	25.3	0.0	-0.1
21FLLOX 10	25.4	24.9	0.5	1.9

D9.5 Modeling of Water Quality

D9.5.1 Calibration and Validation for Chl-a

Table D9-7. Calibration comparisons of simulated and measured chl-a: 2002-2009

Chl-a (µg/L)				
			Error	
Station	Simulated Surface Mean	Measurement Mean	µg/L	%
21FLLOX 68	2.8	2.9	-0.1	-3.7
21FLLOX 63	3.4	9.0	-5.6	-62.2
21FLLOX 67	3.5	3.7	-0.3	-6.8
21FLLOX 100	3.1	4.8	-1.7	-36.3
21FLLOX 66	3.6	5.0	-1.5	-29.2
21FLLOX 72	5.4	18.4	-13.0	-70.7

Table D9-8. Validation comparisons of simulated and measured chl-a: 2002-2009

Chl-a (µg/L)				
			Error	
Station	Simulated Surface Mean	Measurement Mean	µg/L	%
21FLLOX 60	3.6	7.5	-3.9	-51.9
21FLLOX 62	3.7	9.7	-6.0	-61.7
21FLLOX 51	3.9	10.1	-6.2	-61.4
21FLLOX 55	5.2	9.3	-4.0	-43.7
21FLLOX 40	2.5	5.5	-3.0	-54.1
21FLLOX 10	2.2	3.9	-1.7	-44.3

D9.5.2 Calibration and Validation for DO

Table D9-9. Calibration comparisons of simulated and measured DO: 2002-2009

DO (mg/L)				
Station	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLLOX 68	5.3	6.0	-0.8	-12.6
21FLLOX 63	5.6	5.1	0.5	9.6
21FLLOX 67	5.8	5.6	0.3	5.1
21FLLOX 100	5.9	6.4	-0.5	-7.4
21FLLOX 66	6.0	5.6	0.5	8.3
21FLLOX 72	5.3	6.0	-0.7	-12.3

Table D9-10. Validation comparisons of simulated and measured DO: 2002-2009

DO (mg/L)				
Station	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLLOX 60	5.4	6.3	-0.9	-14.0
21FLLOX 62	5.7	5.6	0.1	2.1
21FLLOX 51	5.4	6.1	-0.7	-11.5
21FLLOX 55	4.7	4.7	0.0	0.6
21FLLOX 40	5.5	6.4	-0.9	-14.5
21FLLOX 10	5.6	6.3	-0.7	-11.8

D9.5.3 Calibration and Validation for TN

Table D9-11. Calibration comparisons of simulated and measured TN: 2002-2009

TN (mg/L)				
			Error	
Station	Simulated Surface Mean	Measurement Mean	mg/L	%
21FLLOX 68	0.922	1.054	-0.132	-12.5
21FLLOX 67	1.127	0.978	0.149	15.2
21FLLOX 100	1.265	1.110	0.155	14.0
21FLLOX 66	1.199	1.123	0.076	6.8
21FLLOX 72	1.149	1.372	-0.223	-16.3

Table D9-12. Validation comparisons of simulated and measured TN: 2002-2009

TN (mg/L)				
			Error	
Station	Simulated Surface Mean	Measurement Mean	mg/L	%
21FLLOX 60	1.026	1.395	-0.369	-26.5
21FLLOX 62	1.173	1.722	-0.549	-31.9
21FLLOX 51	0.907	1.055	-0.148	-14.0
21FLLOX 55	1.201	1.300	-0.099	-7.6
21FLLOX 40	0.683	0.872	-0.189	-21.7
21FLLOX 10	0.593	0.855	-0.262	-30.6

D9.5.4 Calibration and Validation for Ammonia

Table D9-13. Calibration comparisons of simulated and measured ammonia: 2002-2009

Ammonia (mg/L)				
Station	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLLOX 67	0.287	0.079	0.208	263.3
21FLLOX 66	0.319	0.041	0.278	678.0
21FLLOX 72	0.497	0.133	0.364	273.7

Table D9-14. Validation comparisons of simulated and measured ammonia: 2002-2009

Ammonia (mg/L)				
Station	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLLOX 62	0.456	0.110	0.346	314.5
21FLLOX 51	0.378	0.045	0.333	740.0
21FLLOX 55	0.537	0.096	0.441	459.4
21FLLOX 40	0.227	0.081	0.146	180.2

D9.5.5 Calibration and Validation for Nitrate-Nitrite

Table D9-15. Calibration comparisons of simulated and measured nitrate-nitrite: 2002-2009

Nitrate-Nitrite (mg/L)				
Station	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLLOX 67	0.020	0.114	-0.094	-82.5
21FLLOX 66	0.025	0.097	-0.072	-74.2
21FLLOX 72	0.082	0.024	0.058	241.7

Table D9-16. Validation comparisons of simulated and measured nitrate-nitrite: 2002-2009

Nitrate-Nitrite (mg/L)				
Station	Simulated Surface Mean	Measurement Mean	Error	
			mg/L	%
21FLLOX 60	0.068	0.026	0.042	161.5
21FLLOX 62	0.060	0.046	0.014	30.4
21FLLOX 51	0.063	0.015	0.048	320.0
21FLLOX 55	0.061	0.012	0.049	408.3
21FLLOX 40	0.052	0.016	0.036	225.0
21FLLOX 10	0.047	0.014	0.033	235.7

D9.5.6 Calibration and Validation for TP

Table D9-17. Calibration comparisons of simulated and measured TP: 2002-2009

TP (mg/L)				
			Error	
Station	Simulated Surface Mean	Measurement Mean	mg/L	%
21FLLOX 68	0.037	0.049	-0.012	-24.5
21FLLOX 63	0.070	0.065	0.005	7.7
21FLLOX 67	0.059	0.054	0.005	9.3
21FLLOX 100	0.107	0.064	0.043	67.2
21FLLOX 66	0.073	0.064	0.009	14.1
21FLLOX 72	0.048	0.041	0.007	17.1

Table D9-18. Validation comparisons of simulated and measured TP: 2002-2009

TP (mg/L)				
			Error	
Station	Simulated Surface Mean	Measurement Mean	mg/L	%
21FLLOX 60	0.051	0.039	0.012	30.8
21FLLOX 62	0.067	0.058	0.009	15.5
21FLLOX 51	0.037	0.027	0.010	37.0
21FLLOX 55	0.048	0.046	0.002	4.3
21FLLOX 40	0.029	0.026	0.003	11.5
21FLLOX 10	0.023	0.037	-0.014	-37.8

D9.5.7 Calibration and Validation for Total Suspended Solids (TSS)

Table D9-19. Calibration comparisons of simulated and measured TSS: 2002-2009

TSS (mg/L)				
			Error	
Station	Simulated Surface Mean	Measurement Mean	mg/L	%
21FLLOX 68	5.3	3.2	2.0	63.3
21FLLOX 63	8.9	4.5	4.5	99.9
21FLLOX 67	6.1	2.5	3.6	139.8
21FLLOX 100	7.3	2.9	4.4	149.6
21FLLOX 66	6.6	3.4	3.2	92.2
21FLLOX 72	9.1	7.4	1.7	23.2

Table D9-20. Validation comparisons of simulated and measured TSS: 2002-2009

TSS (mg/L)				
			Error	
Station	Simulated Surface Mean	Measurement Mean	mg/L	%
21FLLOX 60	7.6	5.2	2.4	46.4
21FLLOX 62	9.2	4.7	4.6	97.2
21FLLOX 51	7.2	9.8	-2.7	-27.2
21FLLOX 55	10.7	8.3	2.3	28.0
21FLLOX 40	5.0	11.9	-7.0	-58.3
21FLLOX 10	4.3	9.3	-5.1	-54.1

D9.5.8 Calibration and Validation for Light Attenuation Coefficient (K_d)

Table D9-21. Calibration comparisons of simulated and measured K_d: 2002-2009

Kd (1/m)				
			Error	
Station	Simulated Surface Mean	Measurement Mean	1/m	%
21FLLOX 100	3.1	1.2	2.0	166.0
21FLLOX 72	1.9	1.6	0.3	21.9
21FLLOX 42	1.1	1.3	-0.2	-18.2

Table D9-22. Validation comparisons of simulated and measured K_d: 2002-2009

Kd (1/m)				
			Error	
Station	Simulated Surface Mean	Measurement Mean	1/m	%
21FLLOX 60	1.4	1.3	0.1	7.6
21FLLOX 62	2.1	1.2	0.9	80.0
21FLLOX 40	0.9	1.4	-0.5	-36.9
21FLLOX 10	0.7	1.3	-0.6	-45.9

Appendix D
Attachment 10: St. Lucie Estuary Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Contents

D10.1 LOCATION OF MONITORING STATIONS D10-1

D10.2 MODELING OF WATER SURFACE ELEVATION (WSE) D10-2

D10.2.1 Calibration D10-2

D10.2.2 Validation D10-2

D10.3 MODELING OF SALINITY D10-3

D10.3.1 Calibration D10-3

D10.3.2 Validation D10-3

D10.4 MODELING OF WATER TEMPERATURE D10-4

D10.4.1 Calibration D10-4

D10.4.2 Validation D10-4

D10.5 MODELING OF WATER QUALITY D10-5

D10.5.1 Calibration and Validation for Chl-a D10-5

D10.5.2 Calibration and Validation for DO D10-5

D10.5.3 Calibration and Validation for TN D10-6

D10.5.4 Calibration and Validation for Ammonia D10-6

D10.5.5 Calibration and Validation for Nitrate-Nitrite D10-7

D10.5.6 Calibration and Validation for TP D10-7

D10.5.7 Calibration and Validation for Total Suspended Solids (TSS) D10-7

D10.5.8 Calibration and Validation for Light Attenuation Coefficient (K_d) D10-8

Figures

Figure D10-1. Hydrodynamic monitoring stations D10-1

Tables

Table D10-1. Calibration comparisons of simulated and measured WSE: 2003-2004 .... D10-2
Table D10-2. Validation comparisons of simulated and measured WSE: 2003-2006 .... D10-2
Table D10-3. Calibration comparisons of simulated and measured salinity: 2002-2009 .... D10-3
Table D10-4. Validation comparisons of simulated and measured salinity: 2002-2009 .... D10-3
Table D10-5. Calibration comparisons of simulated and measured water temperature: 2002-2009 .... D10-4
Table D10-6. Validation comparisons of simulated and measured water temperature: 2002-2009 .... D10-4
Table D10-7. Comparisons of simulated and measured chl-a: 2002-2009 .... D10-5
Table D10-8. Comparisons of simulated and measured DO: 2002-2009 .... D10-5
Table D10-9. Comparisons of simulated and measured TN: 2002-2009 .... D10-6
Table D10-10. Comparisons of simulated and measured ammonia: 2002-2009 .... D10-6
Table D10-11. Comparisons of simulated and measured nitrate-nitrite: 2002-2009 .... D10-7
Table D10-12. Calibration comparisons of simulated and measured TP: 2002-2009 .... D10-7
Table D10-13. Comparisons of simulated and measured TSS: 2002-2009 .... D10-7
Table D10-14. Comparisons of simulated and measured of K_d: 2002-2009 .... D10-8

D10.1 Location of Monitoring Stations

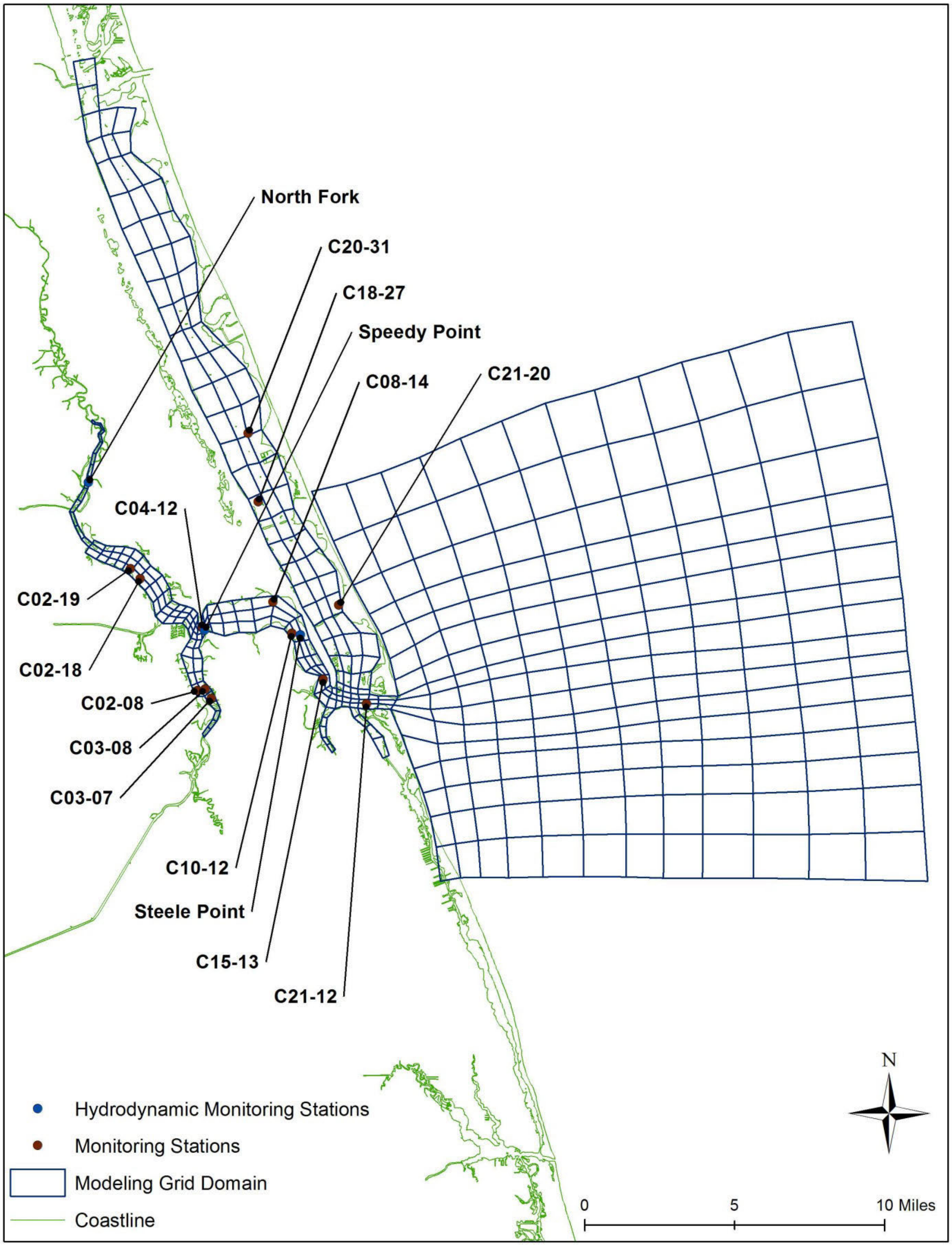

Figure D10-1. Hydrodynamic monitoring stations

D10.2 Modeling of Water Surface Elevation (WSE)

D10.2.1 Calibration

Table D10-1. Calibration comparisons of simulated and measured WSE: 2003-2004

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
North Fork	0.19	-0.09	0.52	0.23	-0.07	0.58	-0.04	-0.02	-0.07	0.89
Speedy Point	0.19	-0.09	0.50	0.21	-0.09	0.55	-0.02	0.01	-0.06	0.91

D10.2.2 Validation

Table D10-2. Validation comparisons of simulated and measured WSE: 2003-2006

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
Steele Point	0.19	-0.09	0.49	0.22	-0.08	0.57	-0.04	-0.01	-0.08	0.92

D10.3 Modeling of Salinity

D10.3.1 Calibration

Table D10-3. Calibration comparisons of simulated and measured salinity: 2002-2009

Station	Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			PSU	%
C04-12	16.4	10.4	6.0	57.7
C02-18	11.7	12.5	-0.9	-6.9
C03-08	12.6	8.4	4.2	50.5
C08-14	21.5	16.4	5.2	31.6
C21-12	31.8	24.5	7.3	30.0

D10.3.2 Validation

Table D10-4. Validation comparisons of simulated and measured salinity: 2002-2009

Station	Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			PSU	%
C15-13	27.4	21.8	5.6	25.6
C20-31	30.5	30.5	0.0	0.1
C18-27	32.0	29.6	2.3	7.9
C21-20	33.2	26.5	6.7	25.3

D10.4 Modeling of Water Temperature

D10.4.1 Calibration

Table D10-5. Calibration comparisons of simulated and measured water temperature: 2002-2009

Station	Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			Deg C	%
C02-18	24.1	25.0	-0.9	-3.7
C03-08	23.1	27.2	-4.1	-15.1
C04-12	24.0	24.9	-0.9	-3.7
C21-12	22.4	24.9	-2.4	-9.8

D10.4.2 Validation

Table D10-6. Validation comparisons of simulated and measured water temperature: 2002-2009

Station	Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			Deg C	%
C18-27	23.5	25.3	-1.8	-7.1
C08-14	23.7	25.0	-1.2	-4.9
C15-13	22.9	25.1	-2.2	-8.8
C21-20	23.4	24.7	-1.3	-5.3
C20-31	24.2	25.1	-0.9	-3.6

D10.5 Modeling of Water Quality

D10.5.1 Calibration and Validation for Chl-a

Table D10-7. Comparisons of simulated and measured chl-a: 2002-2009

Station	Chl-a (µg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			µg/L	%
C02-18	11.5	15.6	-4.0	-26.0
C02-08	8.6	24.0	-15.4	-64.3
C04-12	10.4	11.1	-0.7	-6.2
C08-14	10.7	9.5	1.1	11.8
C15-13	8.0	7.7	0.3	3.3
C18-27	6.4	7.2	-0.8	-11.1
C20-31	6.8	6.3	0.5	8.3
C21-12	6.1	4.9	1.2	23.8

D10.5.2 Calibration and Validation for DO

Table D10-8. Comparisons of simulated and measured DO: 2002-2009

Station	DO (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
C02-18	7.4	6.7	0.7	9.8
C03-08	7.5	6.7	0.8	11.2
C04-12	7.1	6.4	0.7	11.2
C08-14	7.1	6.3	0.8	12.8
C15-13	6.7	6.3	0.5	7.3
C18-27	6.9	7.1	-0.2	-2.8
C21-20	7.0	6.8	0.2	2.6
C20-31	6.8	6.7	0.1	1.6
C21-12	6.4	6.5	-0.1	-2.2

D10.5.3 Calibration and Validation for TN

Table D10-9. Comparisons of simulated and measured TN: 2002-2009

Station	TN (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
C02-18	0.803	0.988	-0.185	-18.7
C03-08	0.947	1.165	-0.218	-18.7
C04-12	0.810	1.051	-0.241	-22.9
C08-14	0.726	0.997	-0.271	-27.2
C15-13	0.621	0.882	-0.261	-29.6
C18-27	0.566	0.666	-0.100	-15.0
C21-20	0.485	0.595	-0.110	-18.5
C20-31	0.612	0.601	0.011	1.8
C21-12	0.539	0.737	-0.198	-26.9

D10.5.4 Calibration and Validation for Ammonia

Table D10-10. Comparisons of simulated and measured ammonia: 2002-2009

Station	Ammonia (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
C02-18	0.051	0.069	-0.018	-26.1
C02-08	0.044	0.047	-0.003	-6.4
C04-12	0.053	0.067	-0.014	-20.9
C08-14	0.055	0.064	-0.009	-14.1
C21-12	0.094	0.050	0.044	88.0
C15-13	0.082	0.063	0.019	30.2
C18-27	0.087	0.049	0.038	77.6
C21-20	0.093	0.038	0.055	144.7
C20-31	0.082	0.028	0.054	192.9

D10.5.5 Calibration and Validation for Nitrate-Nitrite

Table D10-11. Comparisons of simulated and measured nitrate-nitrite: 2002-2009

Station	Nitrate-Nitrite (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
C02-19	0.015	0.080	-0.065	-81.3
C02-08	0.085	0.207	-0.122	-58.9
C03-07	0.119	0.234	-0.115	-49.1
C10-12	0.036	0.055	-0.019	-34.5

D10.5.6 Calibration and Validation for TP

Table D10-12. Calibration comparisons of simulated and measured TP: 2002-2009

Station	TP (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
C02-18	0.190	0.238	-0.048	-20.2
C04-12	0.178	0.207	-0.029	-14.0
C08-14	0.141	0.175	-0.034	-19.4
C15-13	0.086	0.140	-0.054	-38.6
C18-27	0.103	0.070	0.033	47.1
C20-31	0.138	0.058	0.080	137.9
C21-12	0.053	0.089	-0.036	-40.4

D10.5.7 Calibration and Validation for Total Suspended Solids (TSS)

Table D10-13. Comparisons of simulated and measured TSS: 2002-2009

Station	TSS (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
C02-19	10.51	16.29	-5.79	-35.5
C02-08	11.44	41.75	-30.31	-72.6
C03-07	11.84	39.22	-27.37	-69.8
C10-12	8.87	33.80	-24.94	-73.8

D10.5.8 Calibration and Validation for Light Attenuation Coefficient (K_d)

Table D10-14. Comparisons of simulated and measured of K_d: 2002-2009

Station	TSS (1/m)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			1/m	%
C02-08	1.05	2.05	-1.00	-48.6
C15-13	0.71	1.82	-1.12	-61.3
C18-27	0.63	1.56	-0.93	-59.7
C20-31	0.65	1.19	-0.55	-45.8

Appendix D
Attachment 11: St. Marys and Nassau Hydrodynamic and Water Quality Model Calibration and Validation: Tables and Figures

Contents

D11.1 LOCATION OF MONITORING STATIONS D11-1

D11.2 MODELING OF WATER SURFACE ELEVATION (WSE) D11-2

D11.3 MODELING OF SALINITY D11-3

D11.3.1 Calibration D11-3

D11.3.2 Validation D11-3

D11.4 MODELING OF WATER TEMPERATURE D11-4

D11.4.1 Calibration D11-4

D11.4.2 Validation D11-4

D11.5 MODELING OF WATER QUALITY D11-5

D11.5.1 Calibration and Validation for Chl-a D11-5

D11.5.2 Calibration and Validation for DO D11-5

D11.5.3 Calibration and Validation for Light Attenuation Coefficient (K_d) D11-6

D11.5.4 Calibration and Validation for Ammonia D11-6

D11.5.5 Calibration and Validation for Nitrate-Nitrite D11-7

D11.5.6 Calibration and Validation for TN D11-7

D11.5.7 Calibration and Validation for TP D11-8

D11.5.8 Calibration and Validation for Total Suspended Solids (TSS) D11-8

Figures

Figure D11-1. Monitoring stations D11-1

Tables

Table D11-1. Calibration comparisons of simulated and measured WSE: 2003-2004 .... D11-2
Table D11-2. Validation comparisons of simulated and measured WSE: 2006-2007 .... D11-2
Table D11-3. Calibration comparisons of simulated and measured salinity: 2003-2004 .... D11-3
Table D11-4. Validation comparisons of simulated and measured salinity: 2006-2007 .... D11-3
Table D11-5. Calibration comparisons of simulated and measured temperature: 2003-2004 .... D11-4
Table D11-6. Validation comparisons of simulated and measured temperature: 2006-2007 .... D11-4
Table D11-7. Comparisons of simulated and measured chl-a: 2002-2009 .... D11-5
Table D11-8. Comparisons of simulated and measured DO: 2002-2009 .... D11-5
Table D11-9. Comparisons of simulated and measured K_d: 2002-2009 .... D11-6
Table D11-10. Comparisons of simulated and measured ammonia: 2002-2009 .... D11-6
Table D11-11. Comparisons of simulated and measured nitrate-nitrite: 2002-2009 .... D11-7
Table D11-12. Comparisons of simulated and measured TN: 2002-2009 .... D11-7
Table D11-13. Comparisons of simulated and measured TP: 2002-2009 .... D11-8
Table D11-14. Comparisons of simulated and measured TSS: 2002-2009 .... D11-8

D11.1 Location of Monitoring Stations

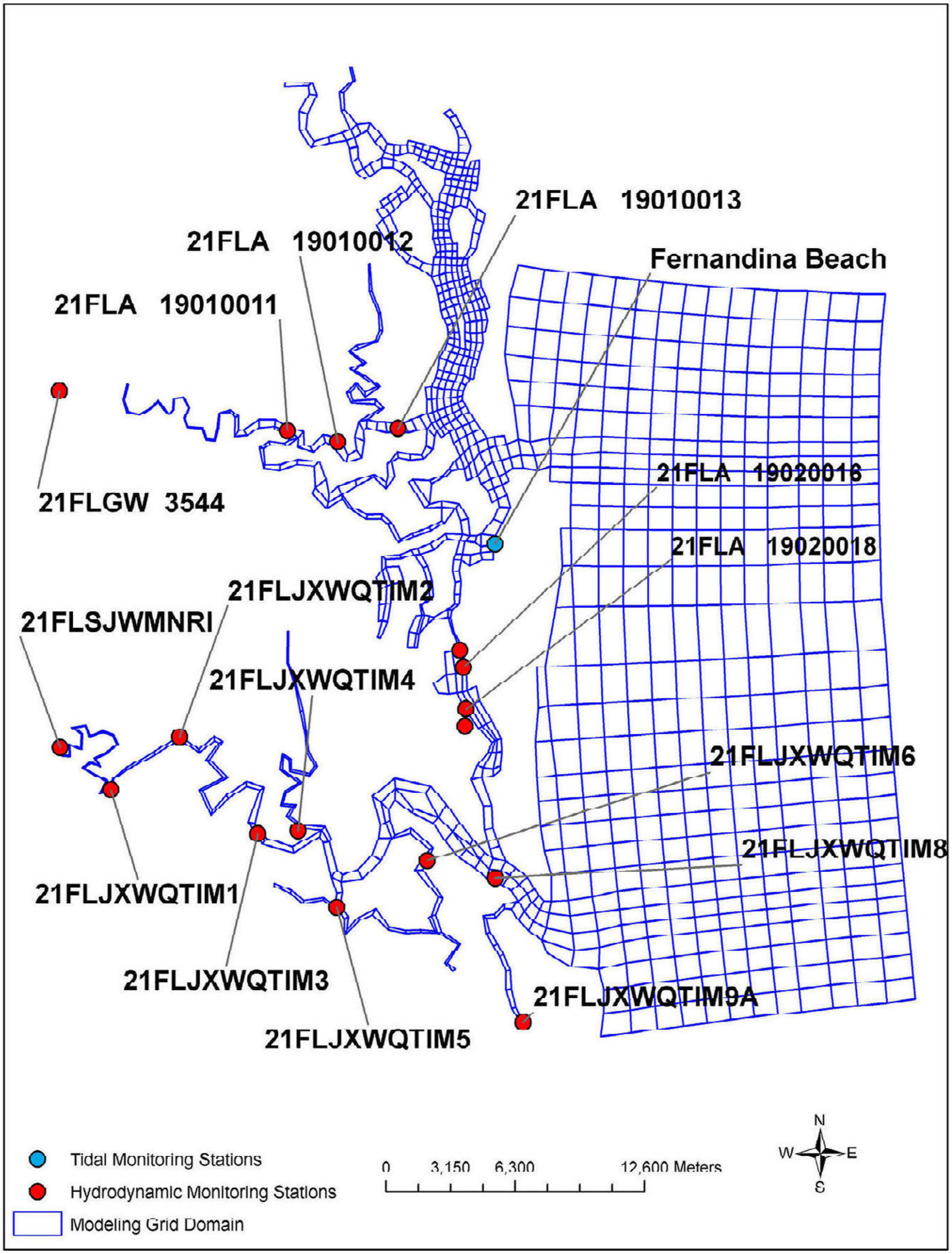

Figure D11-1. Monitoring stations

D11.2 Modeling of Water Surface Elevation (WSE)

Table D11-1. Calibration comparisons of simulated and measured WSE: 2003-2004

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
Fernandina Beach	0.03	-1.01	1.03	0.02	-1.04	1.05	0.01	0.02	-0.01	0.97

Table D11-2. Validation comparisons of simulated and measured WSE: 2006-2007

Station	Simulated (m)			Measured (m)			Error (m)			R^2
	Mean	5%ile	95%ile	Mean	5%ile	95%ile	Mean	5%ile	95%ile	
Fernandina Beach	0.03	-1.02	1.05	0.04	-0.99	1.06	-0.01	-0.03	-0.01	0.95

D11.3 Modeling of Salinity

D11.3.1 Calibration

Table D11-3. Calibration comparisons of simulated and measured salinity: 2003-2004

Station	Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			PSU	%
21FLGW 3544	3.535	2.184	1.351	62
21FLA 19010011	12.521	14.238	-1.717	-12
21FLSJWMNRI	2.477	0.425	2.052	483
21FLJXWQTIM1	4.997	2.458	2.539	103
21FLJXWQTIM2	6.029	4.532	1.497	33
21FLJXWQTIM3	14.491	15.978	-1.487	-9
21FLJXWQTIM4	15.080	17.860	-2.780	-16
21FLJXWQTIM5	18.071	22.791	-4.720	-21
21FLJXWQTIM6	20.555	23.951	-3.396	-14
21FLJXWQTIM8	31.423	31.826	-0.403	-1
21FLJXWQTIM9A	29.090	26.988	2.102	8

D11.3.2 Validation

Table D11-4. Validation comparisons of simulated and measured salinity: 2006-2007

Station	Salinity (PSU)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			PSU	%
21FLGW 3544	5.509	7.113	-1.604	-23
21FLSJWMNRI	2.639	4.015	-1.376	-34
21FLJXWQTIM1	6.248	14.234	-7.986	-56
21FLJXWQTIM2	7.667	15.704	-8.037	-51
21FLJXWQTIM3	17.752	27.180	-9.428	-35

D11.4 Modeling of Water Temperature

D11.4.1 Calibration

Table D11-5. Calibration comparisons of simulated and measured temperature: 2003-2004

Station	Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			Deg C	%
21FLGW 3544	21.607	21.182	0.425	2
21FLA 19010011	21.771	21.091	0.680	3
21FLSJWMNRI	20.560	21.210	-0.650	-3

D11.4.2 Validation

Table D11-6. Validation comparisons of simulated and measured temperature: 2006-2007

Station	Temperature (Deg C)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			Deg C	%
21FLGW 3544	21.863	21.920	-0.057	-0.3
21FLSJWMNRI	20.522	22.144	-1.622	-7.3
21FLJXWQTIM1	21.450	21.716	-0.266	-1.2
21FLJXWQTIM2	21.625	21.695	-0.070	-0.3
21FLJXWQTIM3	22.001	21.978	0.023	0.1

D11.5 Modeling of Water Quality

D11.5.1 Calibration and Validation for Chl-a

Table D11-7. Comparisons of simulated and measured chl-a: 2002-2009

Station	Chl-a (µg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			µg/L	%
21FLGW 3544	2.408	1.647	0.761	46
21FLSJWMNRI	3.704	8.217	-4.513	-55

D11.5.2 Calibration and Validation for DO

Table D11-8. Comparisons of simulated and measured DO: 2002-2009

Station	DO (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
21FLGW 3544	6.115	5.851	0.264	5
21FLA 19010011	6.059	5.909	0.150	3
21FLA 19010012	6.323	6.045	0.278	5
21FLA 19010013	6.372	6.375	-0.003	0
21FLA 19020016	5.661	5.920	-0.259	-4
21FLSJWMNRI	5.936	5.354	0.582	11
21FLJXWQTIM1	7.226	5.858	1.368	23
21FLJXWQTIM2	7.251	5.592	1.659	30
21FLJXWQTIM3	7.026	5.776	1.250	22
21FLJXWQTIM4	6.728	5.907	0.821	14
21FLJXWQTIM5	6.002	5.885	0.117	2
21FLJXWQTIM6	6.664	6.212	0.452	7
21FLJXWQTIM8	6.556	6.896	-0.340	-5
21FLJXWQTIM9A	4.326	6.898	-2.572	-37

D11.5.3 Calibration and Validation for Light Attenuation Coefficient (K_d)

Table D11-9. Comparisons of simulated and measured K_d: 2002-2009

Station	K_d (1/m)			
	Simulated Mean	Measured Mean	Error	
			1/m	%
21FLA 19010011	0.704	2.944	-2.240	-76
21FLA 19010012	0.790	1.969	-1.179	-60
21FLA 19010013	0.662	2.016	-1.354	-67
21FLA 19020016	0.320	1.400	-1.080	-77
21FLA 19020018	0.250	1.757	-1.507	-86
21FLSJWMNRI	1.215	3.453	-2.238	-65
21FLJXWQTIM1	1.411	3.555	-2.144	-60
21FLJXWQTIM2	1.478	3.017	-1.539	-51
21FLJXWQTIM4	1.631	2.676	-1.045	-39
21FLJXWQTIM5	1.009	2.112	-1.103	-52
21FLJXWQTIM6	0.697	1.967	-1.270	-65
21FLJXWQTIM8	0.936	1.175	-0.239	-20
21FLJXWQTIM9A	2.076	1.650	0.426	26

D11.5.4 Calibration and Validation for Ammonia

Table D11-10. Comparisons of simulated and measured ammonia: 2002-2009

Station	Ammonia (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
21FLGW 3544	0.028	0.035	-0.007	-20
21FLA 19010011	0.033	0.040	-0.007	-18
21FLA 19010012	0.028	0.035	-0.007	-20
21FLA 19010013	0.017	0.022	-0.005	-23
21FLSJWMNRI	0.028	0.039	-0.011	-28
21FLJXWQTIM1	0.042	0.051	-0.009	-18
21FLJXWQTIM2	0.040	0.058	-0.018	-31
21FLJXWQTIM3	0.038	0.043	-0.005	-12
21FLJXWQTIM4	0.028	0.038	-0.010	-26
21FLJXWQTIM5	0.023	0.032	-0.009	-28
21FLJXWQTIM6	0.014	0.030	-0.016	-53
21FLJXWQTIM8	0.023	0.012	0.011	92
21FLJXWQTIM9A	0.031	0.020	0.011	55

D11.5.5 Calibration and Validation for Nitrate-Nitrite

Table D11-11. Comparisons of simulated and measured nitrate-nitrite: 2002-2009

Station	Nitrate-Nitrite (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
21FLGW 3544	0.035	0.050	-0.015	-30
21FLA 19010011	0.020	0.137	-0.117	-85
21FLA 19010012	0.015	0.038	-0.023	-61
21FLA 19010013	0.009	0.033	-0.024	-73
21FLSJWMNRI	0.035	0.048	-0.013	-27
21FLJXWQTIM1	0.023	0.056	-0.033	-59
21FLJXWQTIM2	0.022	0.060	-0.038	-63
21FLJXWQTIM3	0.020	0.043	-0.023	-53
21FLJXWQTIM4	0.014	0.033	-0.019	-58
21FLJXWQTIM5	0.011	0.028	-0.017	-61
21FLJXWQTIM6	0.006	0.031	-0.025	-81
21FLJXWQTIM8	0.012	0.028	-0.016	-57
21FLJXWQTIM9A	0.010	0.038	-0.028	-74

D11.5.6 Calibration and Validation for TN

Table D11-12. Comparisons of simulated and measured TN: 2002-2009

Station	TN (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
21FLGW 3544	1.261	1.209	0.052	4
21FLA 19010011	1.098	1.307	-0.209	-16
21FLA 19010012	0.811	0.777	0.034	4
21FLA 19010013	0.447	0.764	-0.317	-41
21FLSJWMNRI	1.098	1.262	-0.164	-13
21FLJXWQTIM1	0.858	1.153	-0.295	-26
21FLJXWQTIM2	0.840	1.102	-0.262	-24
21FLJXWQTIM3	0.640	0.908	-0.268	-30
21FLJXWQTIM4	0.521	0.814	-0.293	-36
21FLJXWQTIM5	0.440	0.737	-0.297	-40
21FLJXWQTIM6	0.270	0.696	-0.426	-61
21FLJXWQTIM8	0.435	0.550	-0.115	-21
21FLJXWQTIM9A	0.699	0.611	0.088	14

D11.5.7 Calibration and Validation for TP

Table D11-13. Comparisons of simulated and measured TP: 2002-2009

Station	TP (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
21FLGW 3544	0.052	0.048	0.004	8
21FLA 19010011	0.055	0.081	-0.026	-32
21FLA 19010012	0.055	0.084	-0.029	-35
21FLA 19010013	0.058	0.089	-0.031	-35
21FLSJWMNRI	0.082	0.145	-0.063	-43
21FLJXWQTIM1	0.157	0.180	-0.023	-13
21FLJXWQTIM2	0.166	0.174	-0.008	-5
21FLJXWQTIM3	0.158	0.153	0.005	3
21FLJXWQTIM4	0.134	0.149	-0.015	-10
21FLJXWQTIM5	0.130	0.139	-0.009	-6
21FLJXWQTIM6	0.077	0.142	-0.065	-46
21FLJXWQTIM8	0.145	0.120	0.025	21
21FLJXWQTIM9A	0.287	0.132	0.155	117

D11.5.8 Calibration and Validation for Total Suspended Solids (TSS)

Table D11-14. Comparisons of simulated and measured TSS: 2002-2009

Station	TSS (mg/L)			
	Simulated Surface Mean	Measured Surface Mean	Error	
			mg/L	%
21FLSJWMNRI	9.323	11.634	-2.311	-20
21FLJXWQTIM1	19.400	27.000	-7.600	-28
21FLJXWQTIM2	20.406	25.622	-5.216	-20
21FLJXWQTIM4	15.673	25.354	-9.681	-38
21FLJXWQTIM5	14.929	22.555	-7.626	-34
21FLJXWQTIM6	9.032	19.955	-10.923	-55
21FLJXWQTIM8	15.188	17.465	-2.277	-13
21FLJXWQTIM9A	29.962	12.381	17.581	142