## 5.3 EFDC Model

### 5.3.1 EFDC MODEL DEVELOPMENT

This Section summarizes the development of the site-specific hydrodynamic and water quality model using the Environmental Fluid Dynamics Code (EFDC) (Hamrick, 1995) for the Caloosahatchee River tidal estuary. The EFDC water quality model being developed for the TMDL process for the Caloosahatchee River tidal estuary (hereafter simply called the Caloosahatchee) was initially based on the EFDC model of the Caloosahatchee for the U.S. Army Corps of Engineers (USACE) (DSLLC, 2007). The USACE Caloosahatchee model was developed to evaluate release scenarios from Lake Okeechobee and as a water management tool. The model was calibrated for salinity for the Year 2000. Where appropriate, the model parameterization and lessons learned from that study were used to setup the FDEP TMDL model of the Caloosahatchee.

The Caloosahatchee water quality model needed to be configured allow for multiple year simulations to allow management scenarios to be analyzed. This issue impacted the selected of the model domain and grid due to computational issues and simulation productivity. As a result, the model domain and grid needed to reflect

#### 5.3.1.1 Topographic, Shoreline and Bathymetry Data

Topographic elevation data and map coordinates for the shoreline of the physical domain of the Model were obtained from the USGS Digital Line Graph (DLG). Shoreline data were obtained from NOAA's National Geophysical Data Center (NGDC) Coastline Extractor. Map coordinates (xy) are defined for the project as North Atlantic Datum 1983 (NAD83) Universal Transverse Mercator (UTM) northing's and easting's (meters) for UTM Zone 17. All elevations in the Model have been adjusted so that their reference point (or zero datum) is mean sea level (MSL) at Ft. Myers for the current Epoch as defined by NOAA. Table 1 is provided by NOAA and shows the relationship between mean sea level and various other datum elevations at Ft. Myers.

**Table 1. Datum Elevations in MSL Feet at Ft. Myers (NOAA#8725520)**

| | |
|---|---|
| Highest Observed Water Level (11/23/1988) | 4.088 |
| Mean Higher High Water (MHHW) | 0.682 |
| Mean High Water (MHW) | 0.466 |
| North American Vertical Datum-1988 (NAVD) | 0.410 ✓ |
| Mean Sea Level (MSL) | 0.000 |
| Mean Tide Level (MTL) | -0.007 |
| Mean Low Water (MLW) | -0.479 |
| Mean Lower Low Water (MLLW) | -0.633 |
| National Geodetic Vertical Datum-1929 (NGVD) | -0.764 |
| Lowest Observed Water Level (09/08/1965) | -3.494 |

* ref to ft-NAVD

round to nearest 0.1 ft or 0.01 for this

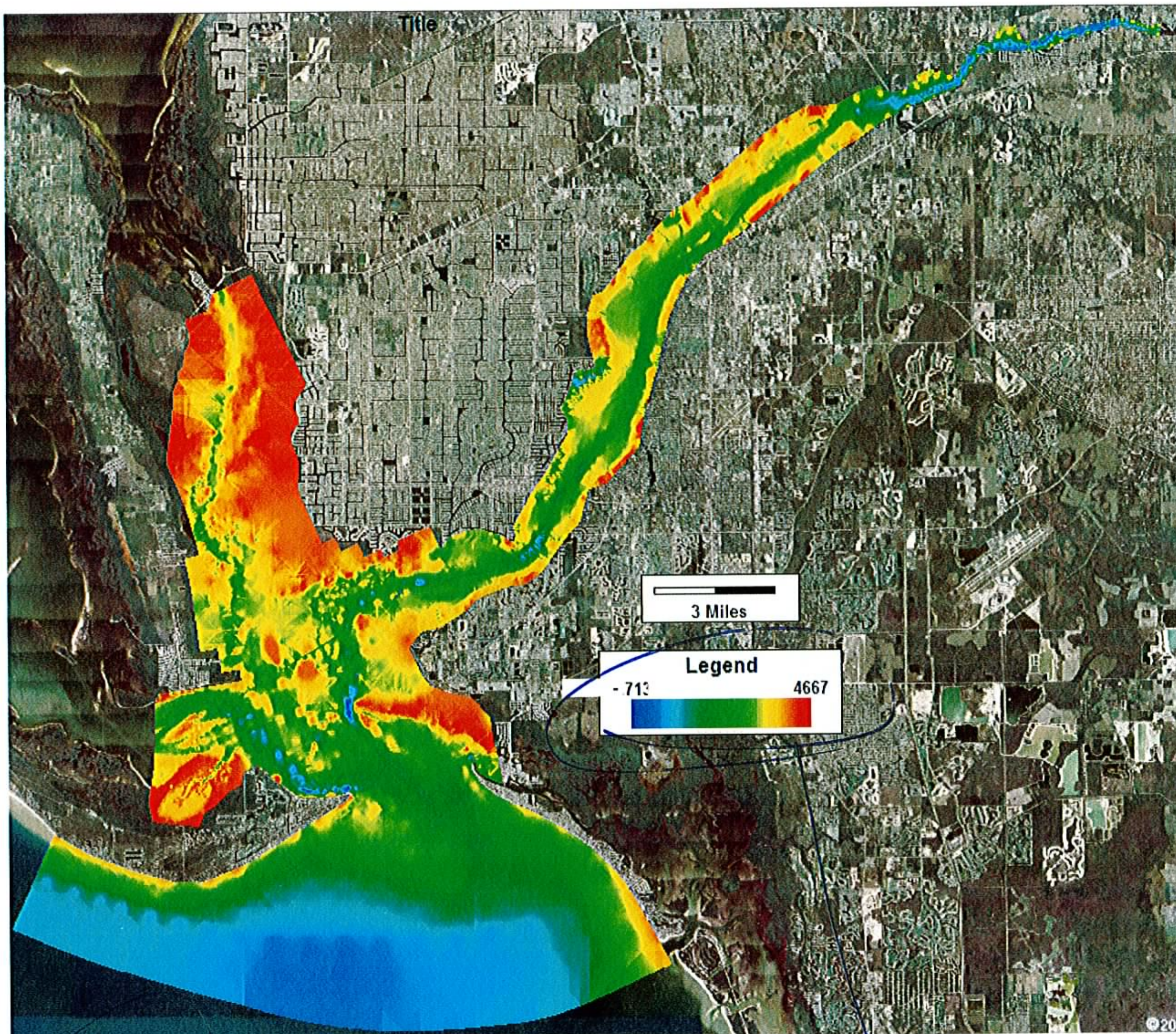


**Figure 7 Digital Terrain Model of the Caloosahatchee water quality model domain (elevations in feet relative to MSL).**

The bathymetric data used to process the DTM shown in Figure 1 is a composite from several data sources. The origins of these data were NOAA and the USGS (SFWMD, 2007). The data was supplied in four files/data sets. They were:

- NOAA NED 2004
- OWW 2003
- USGS 2003
- USGS SANDS 2003

These data represent the latest and most complete bathymetric data for the model domain.

The original vertical datum for these files was NAVD88. The elevations were adjusted to MSL by:

$$Elev_{MSL} = Elev_{NAVD88} + (Datum_{NAVD88} - Datum_{MSL})$$

Substituting the datums from Table 1 we obtain:

$$Elev_{MSL} = Elev_{NAVD88} + (0.41 - 0.0) = Elev_{NAVD88} + 0.41$$

The elevations are in feet so the offset is +0.41 feet (0.125 meters).

#### *5.3.1.2 Grid Development*

Grid development is a critical component of the hydrodynamic model. A model grid is the result of a balance of spatial resolution, site conceptual model and modeling objectives against the computational time and resources. High resolution grids can produce great horizontal and vertical detail, but if the run times are excessive, then the model will be limited due to the inability to produce enough runs to obtain good calibration, validation and target scenarios.
The final Caloosahatchee River tidal estuary grid is shown in **Figure 2.** The grid has 733 horizontal cells and four vertical layers. The grid was developed using the Delft RGFGrid program (Delft, 2006). The grid created by RGFGrid was then configured for EFDC by importing the GRD file into EFDC_Explorer (Craig, 2008). Final minor editing to the grid was performed using EFDC_Explorer. The average of the absolute orthogonality deviation for the final grid was 0.4 degrees. This is less than the target deviation of less than 2-3 degrees (Delft, 2006).

This grid addresses all of the critical components needed for the Caloosahatchee River water quality modeling. The upstream boundary of the model is located at the S79 Franklin Lock & Dam. This structure limits the tidal influence up the Caloosahatchee. All of the fresh water discharge points to Caloosahatchee River have been addressed in the HSPF modeling effort. Therefore, the EFDC model grid does not extend up these catchments. HSPF will provide the flow and water quality loadings at the boundaries of the Caloosahatchee EFDC model.

**Figure 2** shows the grid with some cells labeled with the EFDC's grid numbering scheme of I (generally the X/Easting component) and the J (generally the Y/Northing component). The Gulf of Mexico is located along the model boundary with the smallest J's and the eastern edge of model domain (near S79) has the largest I.

The EFDC model grid was configured with four layers to address the density dependent dynamics due to salinity and temperature profiles. For this case, each layer represents 25% of the water depth for each cell.

The processed bathymetric data discussed in the previous section was then used to develop the model bathymetry for each cell. **Figure 3** shows the model grid with the resulting bathymetry for each cell.

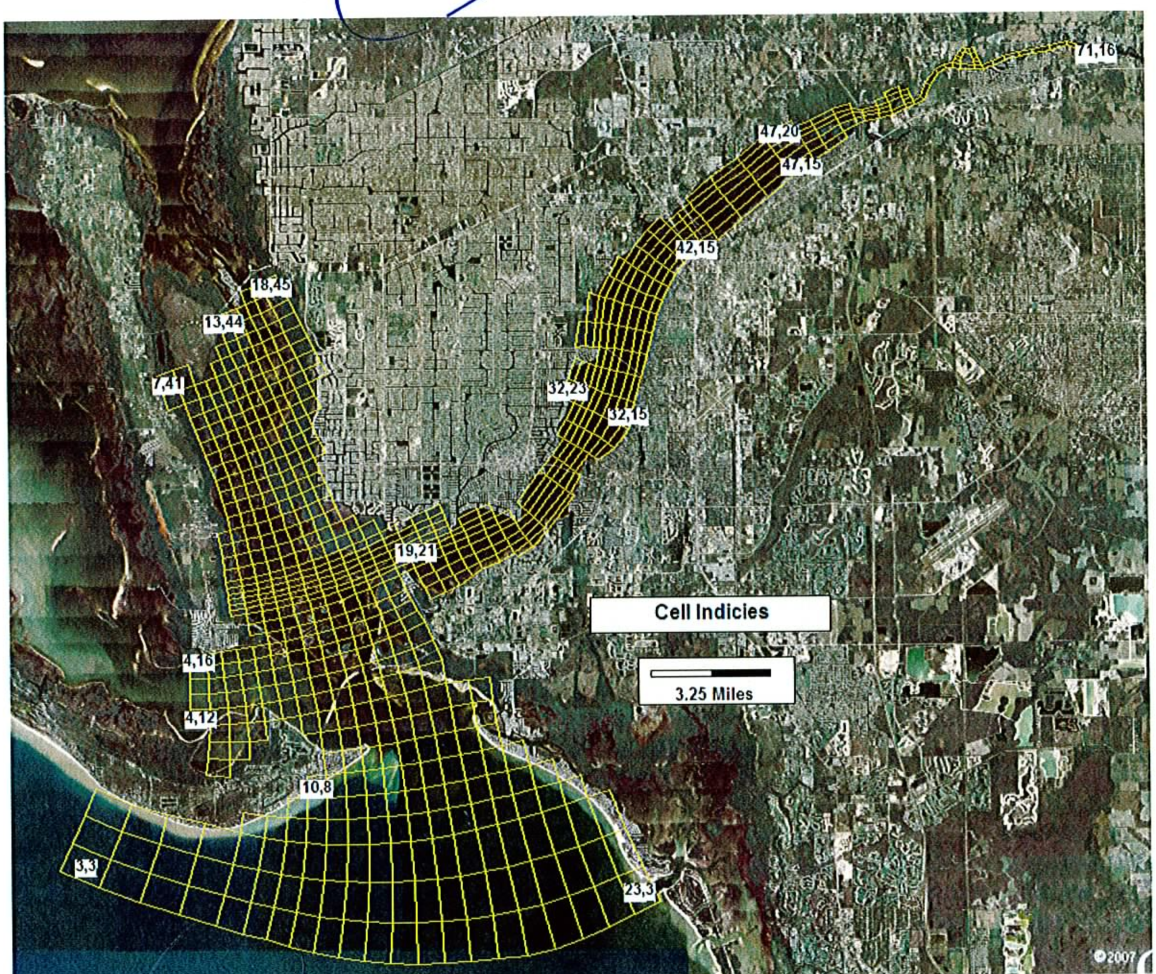


**Figure 8 Caloosahatchee model grid with representative cell indices.**

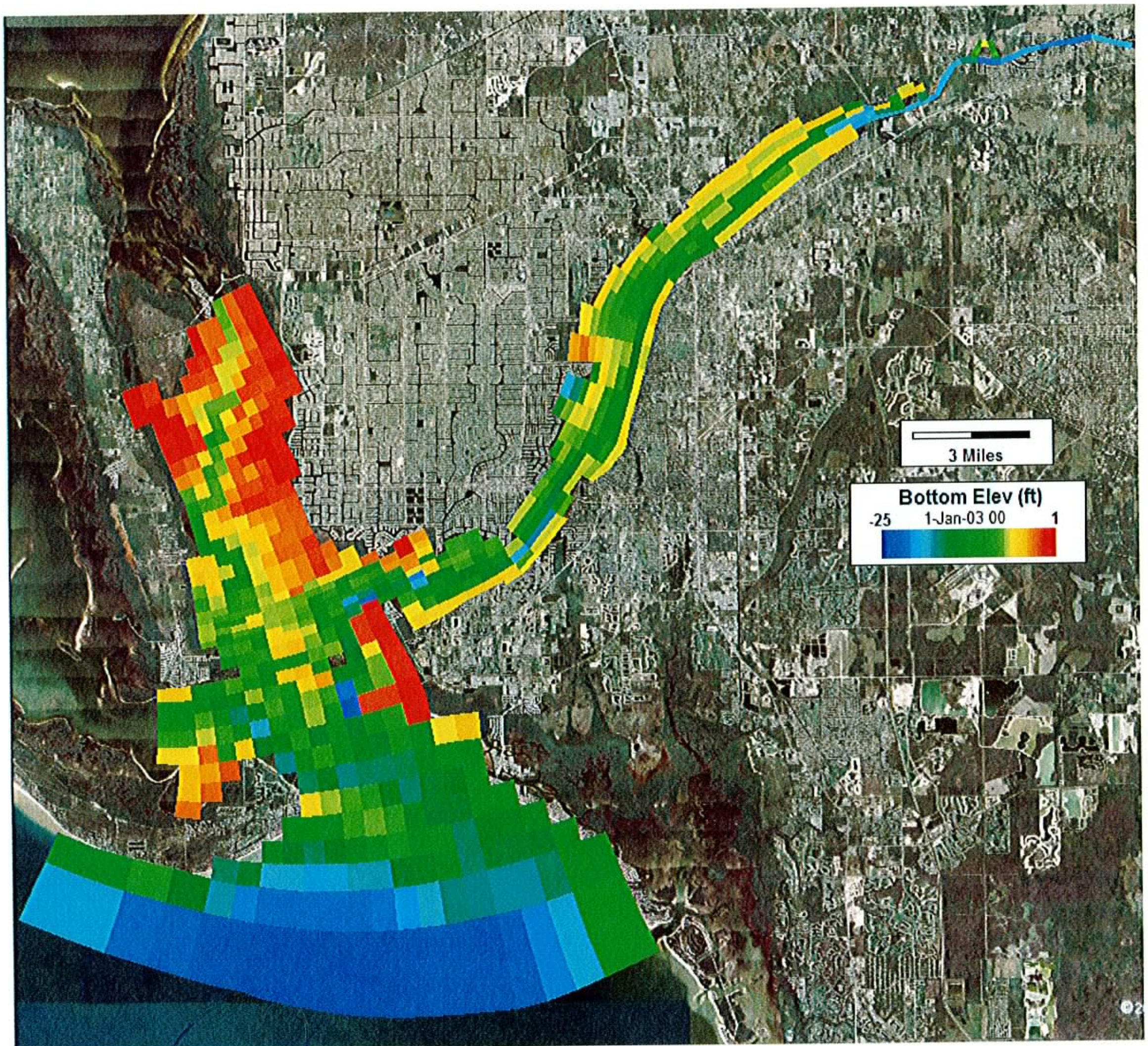


**Figure 9 Caloosahatchee model domain with model bathymetry.**

### *5.3.1.3 Parameters Simulated*

The parameters modeled for the Caloosahatchee Estuary water quality model are listed in Table 2.

**Table 2 EFDC parameters simulated.**

| Code | EFDC Parameter | EFDC Parameter Code | Used in Caloosahatchee Model |
|---|---|---|---|
| | Salinity | SAL | Yes |
| | Temperature | TEM | Yes |

water quality

*5.3.1.4 Model Simulation Period*

Based on the availability of time series of atmospheric forcing, tidal forcing and flow data needed for construction of the hydrodynamic Model, the period where the required data are the most complete and coincide with appropriate water quality data is the period from October 2002 through December of 2004. The model will be calibrated to one year of data for 2003. The validation period will be for the year 2004.

*5.3.1.5 Model Boundary Conditions*

The locations of the boundary conditions are shown in **Figure 4**. The Caloosahatchee model used two types of boundary conditions, flow and open boundaries. A flow boundary type is defined using a time series of flows and the water column parameters simulated. On open boundary is defined by a water surface elevation time series and the water column parameters. The flows at an open boundary are computed based on the water surface boundary condition specified and the adjacent water surface. This boundary allow for flows to enter and leave the model domain as required by the hydrodynamics.

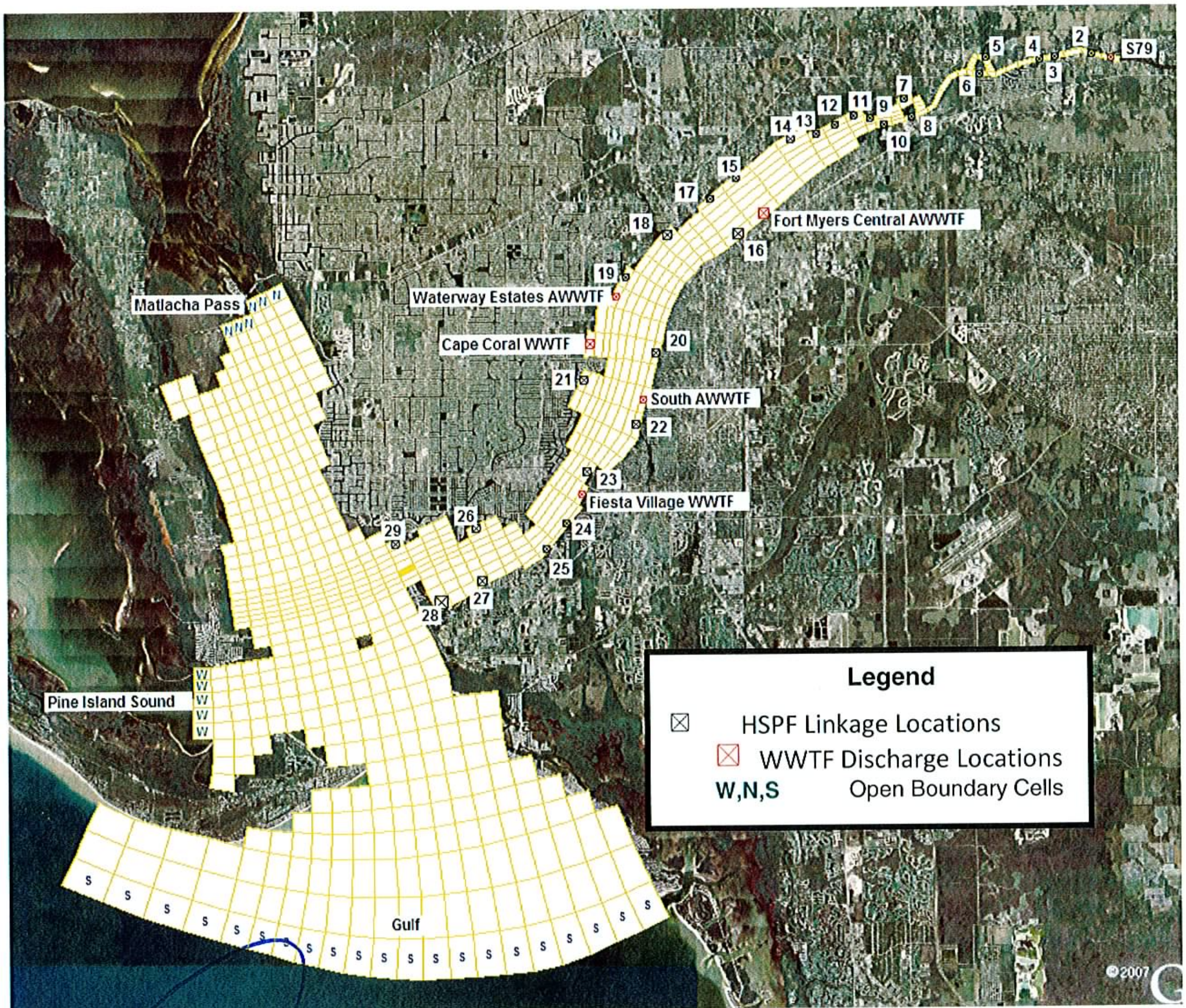


**Figure 10 Location of tidal and HSPF boundary conditions relative to the Caloosahatchee grid.**

#### *5.3.1.5.1 Fresh Water Flows*

The flow boundaries for the Caloosahatchee model came from two sources. The first type of flow boundaries were for the tributary network that drains to the Caloosahatchee Estuary. The second type of flow boundary condition was the permitted waste water treatment plants that discharge to the Caloosahatchee.

The tributary flow boundaries were defined using the flows and water quality results from the HSPF modeling efforts (see Section ??). The numbered points shown on **Figure 4** refer to the HSPF linkage ID corresponding to the HSPF sub-watersheds. The Linkage ID 1 has been renamed to "S79" as it corresponds to the discharge from the S79 structure. This is the primary source of fresh water into the Caloosahatchee River tidal system. For each sub-basin the flows, water temperature and water quality parameters were taken from the HSPF simulation results. A constant salinity of 0.25 ppt was used for all freshwater flows. As an example, the time series of the flows, salinity and temperatures assigned to the S79 structure for year 2003 are shown in **Figure 5**. The other smaller watersheds contribute about 25 percent of the total inflows. The annual average S79 flow contribution to the Caloosahatchee is shown in Table 3. Even though measured S79 flows were available, the ratios in Table 1 were derived from the HSPF simulated flows for all the tributaries and S79.

**Table 3 Annual freshwater contribution to the Caloosahatchee from S79.**

| Year | S79 Contribution (%) |
|---|---|
| 2001 | 71.9 |
| 2002 | 70.8 |
| 2003 | 75.8 |
| 2004 | 71.0 |
| 2005 | 82.3 |

The wastewater facilities that directly discharge to the Caloosahatchee Estuary are listed in Table 4. The flows and pollutant discharges for these facilities were taken from the monthly reporting for each facility.

**Table 4 Location of discharge for the Caloosahatchee WWTF's.**

| Discharge Location | | NPDES Permit | |
|---|---|---|---|
| Easting (m) | Northing (m) | Number | Name of Facility |
| 409905 | 2936047 | FL0039829 | Fiesta Village WWTF |
| 415536 | 2948171 | FL0021261 | Fort Myers Central AWWTF |
| 406740 | 2943193 | FL0030007 | Cape Coral WWTF |
| 409514 | 2946726 | FL0030325 | Waterway Estates Advanced WWTP |
| 412479 | 2941080 | FL0021270 | South AWWT Facility |

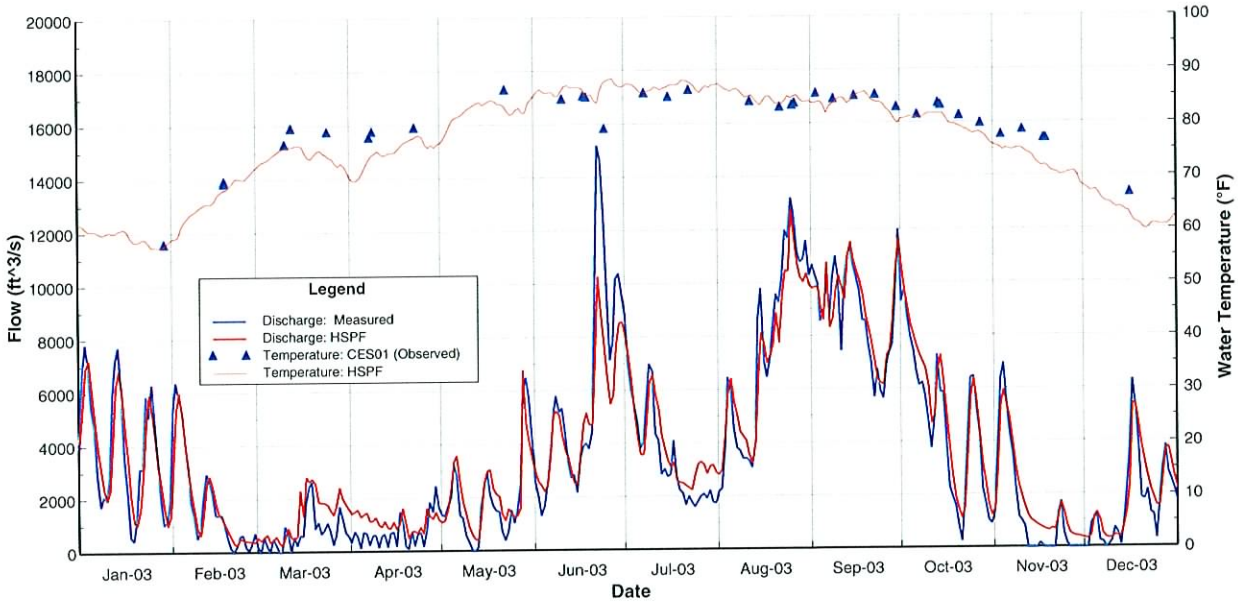


**Figure 11 Observed flows and temperature versus HSPF at S79.**

### *5.3.1.5.2 Use of HSPF versus Data*

The S79 structure on the Caloosahatchee River has on ongoing monitoring programs for discharge and water quality parameters. While the observed data could be used to define the boundary condition for the S79 inflows the decision was made to use HSPF simulation results for S79 instead. The rationale for this decision was:

- Most of the inflows to the Caloosahatchee Estuary are ungaged and/or have incomplete data sets.
- Using a rainfall/runoff simulator allows the modeler to "fill" the data gaps in infrequent data set. This enables the user to capture unusual rainfall events that measured data may miss.
- The use of HSPF simulation results allows for the "what if" scenario analysis required for the modeling study.

That said, in using simulated results there is an implicit acceptance of the impacts of model versus data discrepancies in the HSPF results on the receiving water quality model. While one goal of the modeling study is to minimize these discrepancies, they do exist. **Figure 5** also shows the measured S79 flows and temperatures compared to the calibrated HSPF results used for the water quality modeling of the Caloosahatchee Estuary for the year 2003. On average, the flow and temperature match is acceptable. The measured annual average discharge was 3572 cfs compared to 3724 cfs for the HSPF model (~ 4%). The observed water temperature was 79.7 °F compared to 76.3 °F for the HSPF model (~ -4%). On average the HSPF model does a good job. However, on a short term basis (i.e. March and April), the flows can be quite different.

#### *5.3.1.5.3 Open Boundaries*

The cells in **Figure 4** that have been labeled with a compass point direction indicate that those cells have been assigned as an open (i.e. tidal) boundary condition. Within the EFDC_Explorer modeling system, the boundary cells are managed as groups of cells that correspond to a physical boundary. For this application the cells along the northern edge of the model near the FL 78 bridge (labeled with a "N") make up the Matlacha Pass boundary group. The western open boundary of the model opens into the Pine Island Sound. The southern boundary represents the Gulf of Mexico conditions. The development of the tidal boundary conditions used for the Caloosahatchee water quality model is provided in the following section.

#### *5.3.1.5.4 Large Scale Model*

As mentioned above, the model domain and grid used for the Caloosahatchee water quality model is a balance of computational speed and required resolution. However, the computational constraints required the open boundaries (i.e. tidal boundaries) of the model to be limited to boundaries in Matlacha Pass and Pine Island Sound. There were insufficient data available at those locations to properly drive the tidal signal at those locations. Therefore, the approach used for this study was to develop a larger scale but coarser grid model of a large area in order to use regional/ocean data and approximate fresh water flows to compute the tidal, temperature and salinity series at the Caloosahatchee model boundaries. **Figure 6** provides a plot of the model bathymetry and grid of the large scale model. The USACE report (DSLLC, 2007) provides a more complete description of the model construction, calibration and application.

Time series of water surface elevation, temperature and salinity were then extracted from the model runs of the large scale model for the period(s) of interest. For the Caloosahatchee water quality model, the open boundaries at Matlacha Pass, Pine Island Sound and the Gulf of Mexico were configured with the corresponding time series from the large scale mode. One exception was for the Gulf boundary's salinity concentration. During the model calibration it was found that applying a constant salinity boundary salinity of 28 and 33 PPT at the surface and bottom, respectively provided better salinity results.

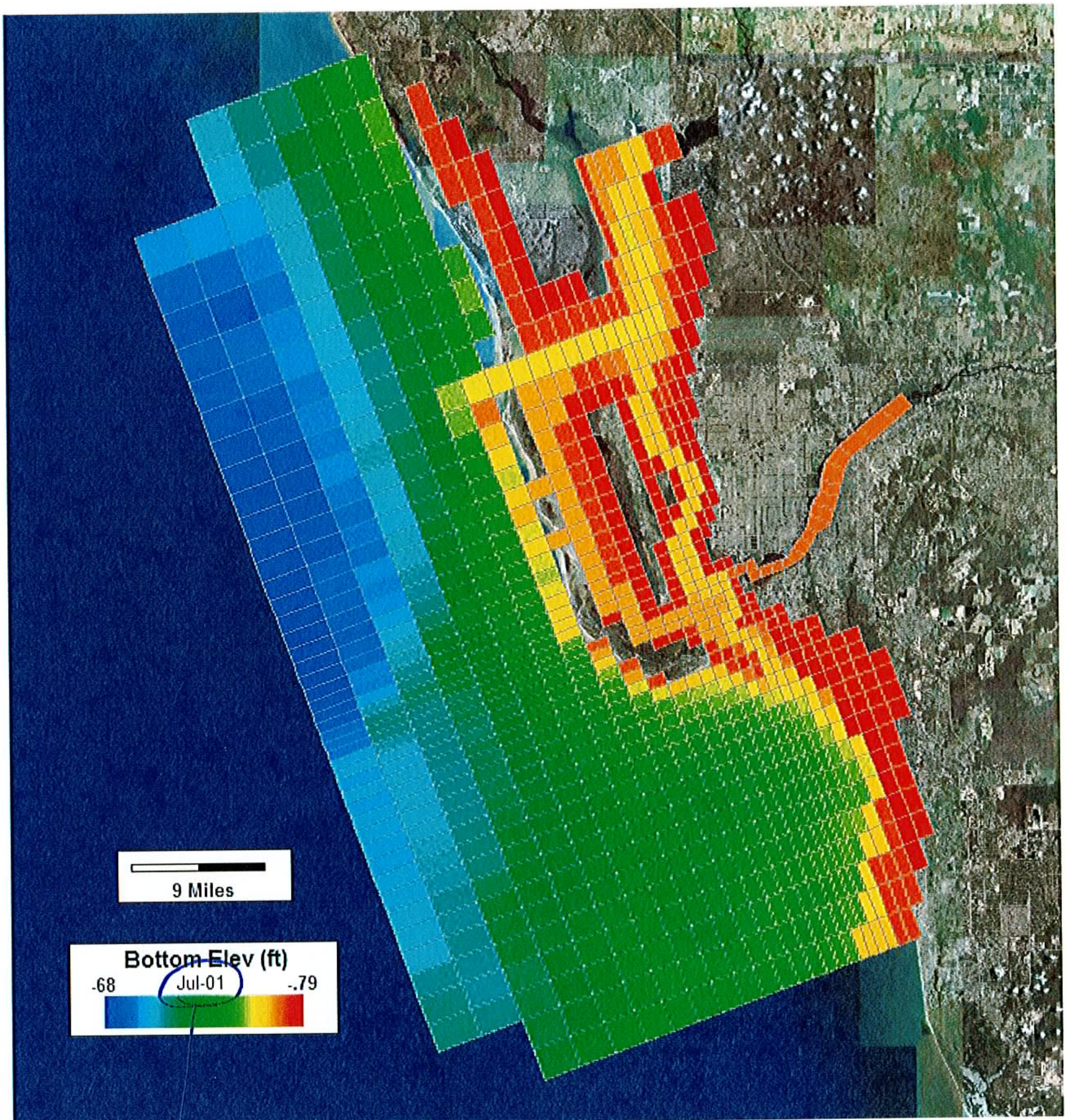


**Figure 12 Large scale model grid and bathymetry.**

### *5.3.1.6 Meteorological Data*

Atmospheric forcing data are used to model hydrodynamic processes and water temperature. Parameters include barometric pressure, air temperature, relative humidity, wind speed and direction, precipitation, evaporation, incident solar radiation and cloud cover. Atmospheric forcing data was available from historical archives maintained by NOAA NCDC. Hourly records of barometric pressure, air temperature, relative humidity, rainfall, wind speed and direction, and cloud cover were obtained from NOAA NCDC for the station located at the Ft. Myers International Airport (Page Field, WBAN ID 12835). During that process it was determined that the Page Field data had several significant data gaps in wind speed, direction and temperature. A search was conducted of the nearby meteorological stations that had the same period of record and the parameters needed. It was found that the Ft Myers SW Florida Regional Airport (WBAN ID 19894) provided the data required. The WSER and ASER files were generated using Page Field as the primary station and the SW Florida Regional airport as the "filler" station. **Figure 7** shows the wind rose for the period of 2003 and 2004.

### *5.3.2 Model Comparison Statistics*

The model-data comparison statistic selected for the calibration and validation was the Root Mean Square (RMS) error.

The RMS is calculated by the following:

$$RMS = \sqrt{\frac{\sum_{i=1}^{N}(O_i - X_i)^2}{N}}$$

Where:

O – The observed value,

X – The corresponding model value in space and time, and

N – The number of valid data/model pairs.

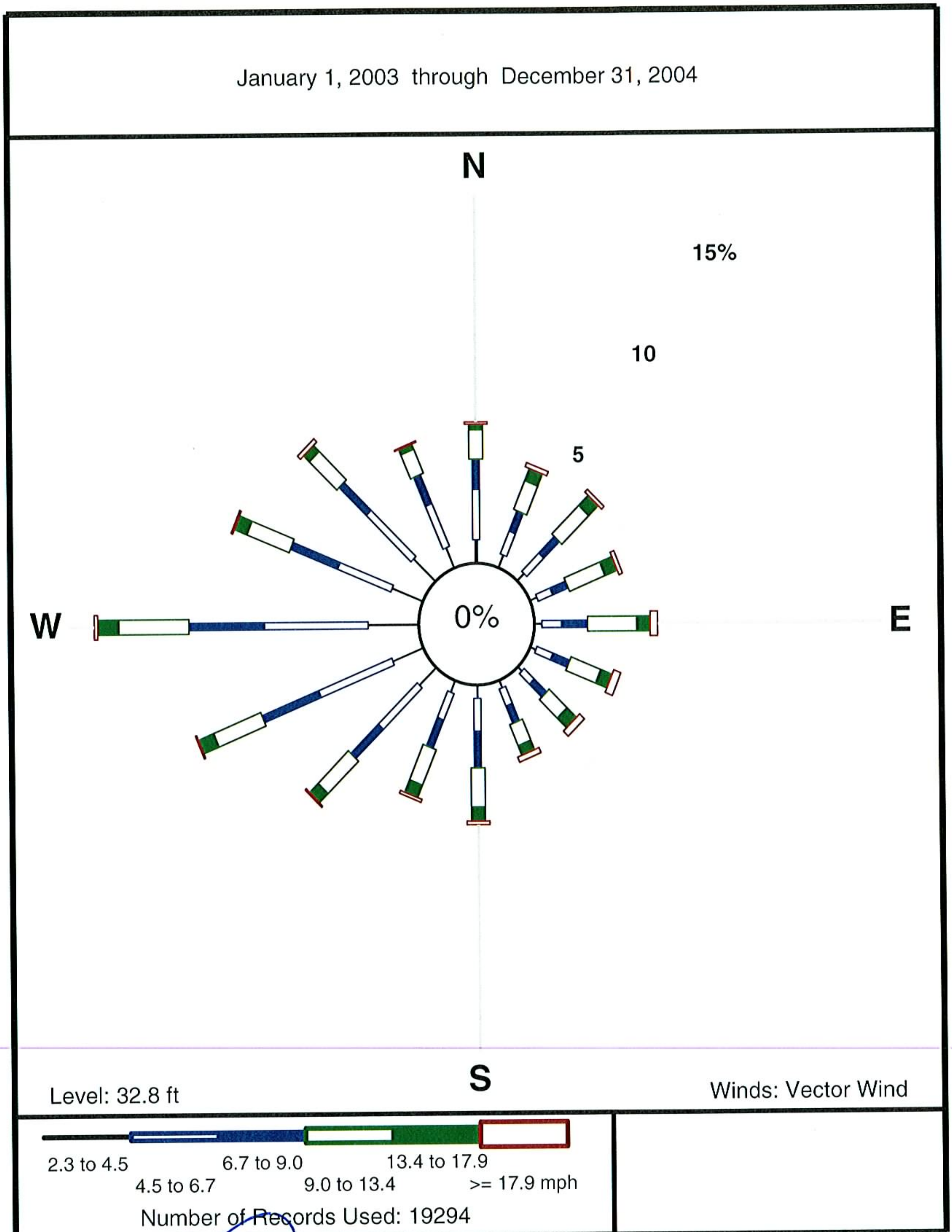


**Figure 13 Ft Myers International Airport wind rose for 2003-2004.**

### *5.3.3 Tidal Exchange and Boundary Flow Summary*

In general, the boundary condition impacts in the model are as follows:

- During the dry season (typically November through May), the hydrodynamics and water quality are largely controlled by the open ocean boundary. The small freshwater inflows from the surface drainage networks and wastewater dischargers have little impact on the hydrodynamics during this period.
- During the wet season and other wet-weather periods, the freshwater reaches (HSPF reaches) have greater impact in the tidal creek, from which S79 typically contributes more than 50% of the total freshwater flow.
- The tidal portion of Caloosahatchee is relatively long (about 150,000 ft). With a daily tide fluctuation magnitude of up to about 5 feet, the hydrodynamic regime of the tidal creek is somehow controlled by the tidal boundary as it is expressed through the following tidal prism ratio.

#### *5.3.3.1 Tidal Prism Ratio*

In order to understand the Caloosahatchee tidal dynamics and fresh/saline water mixing the tidal prism ratio (TPR) was computed. The TPR is defined as the change of water volume during one tidal exchange divided by the volume of water at high tide. The TPR can be computed using the following equation:

$$TPR_{Vol} = \frac{dVol_{Tide}}{Vol_{HighTide}}$$

The numerator is referred to as the tidal prism.

It is also possible to calculate the TPR from mass weighted concentrations in the area of interest. The TPR from concentrations is computed using the following:

$$TPR_{Conc} = 1 - \frac{C_{HighTide}}{C_{LowTide}}$$

The procedure is to assign an initial dye concentration to the area of interest of 100 mg/l. The area of interest is just the Caloosahatchee River and tidal estuary. The area outside of the Caloosahatchee is assigned an initial concentration of 0.0 mg/l. One tide cycle is then simulated. EFDC_Explorer is then used to generate a time series of the mass weighed dye concentrations of the Caloosahatchee. The dye concentration at low tide is then estimated from the time series and then the TPR is computed using the equation above.

For the Caloosahatchee a tidal range of 1.5 meters at the Gulf boundary (i.e. a typical large diurnal range) was used. **Figure 8** shows the tide data for several days around the period used for the TPR computations. The actual period used for the computation is shown in as the thick red line. The time series of the dye and water volume during the TPR simulation is shown in **Figure 9**. The resulting TPR is 0.16. In other words, without any fresh water input, the 16% of the water in the Caloosahatchee is exchanged with the water in Matlacha Pass. With fresh water inflows during storms, the flushing of the estuary will be higher.

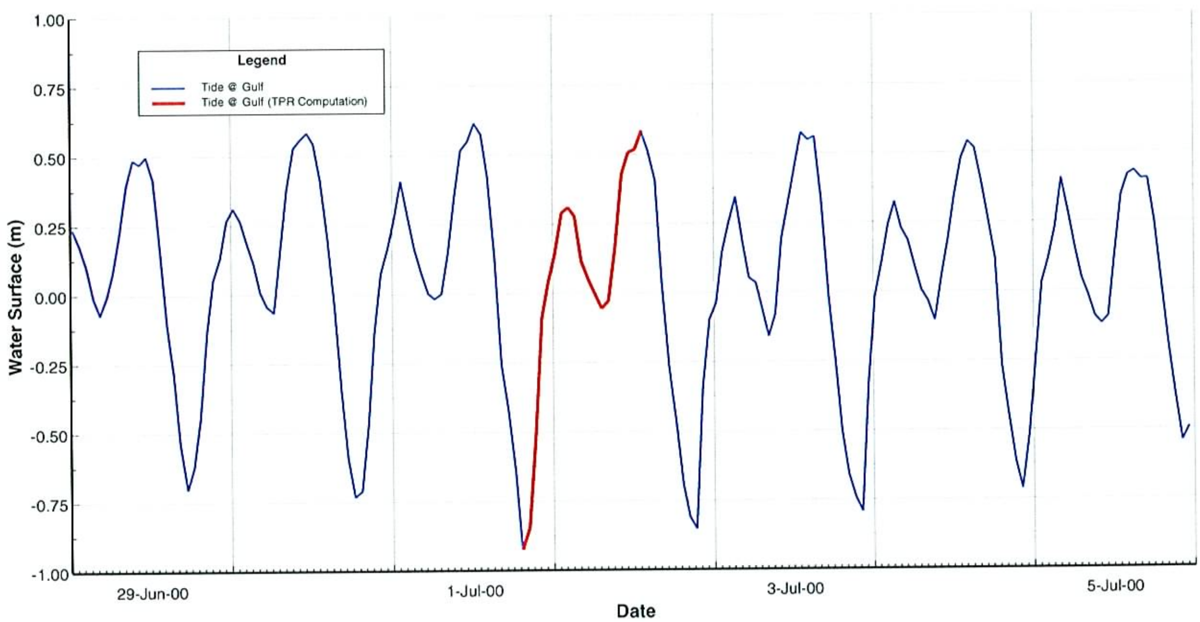


**Figure 14 Time series of the Gulf of Mexico tide data used for the TPR computations.**

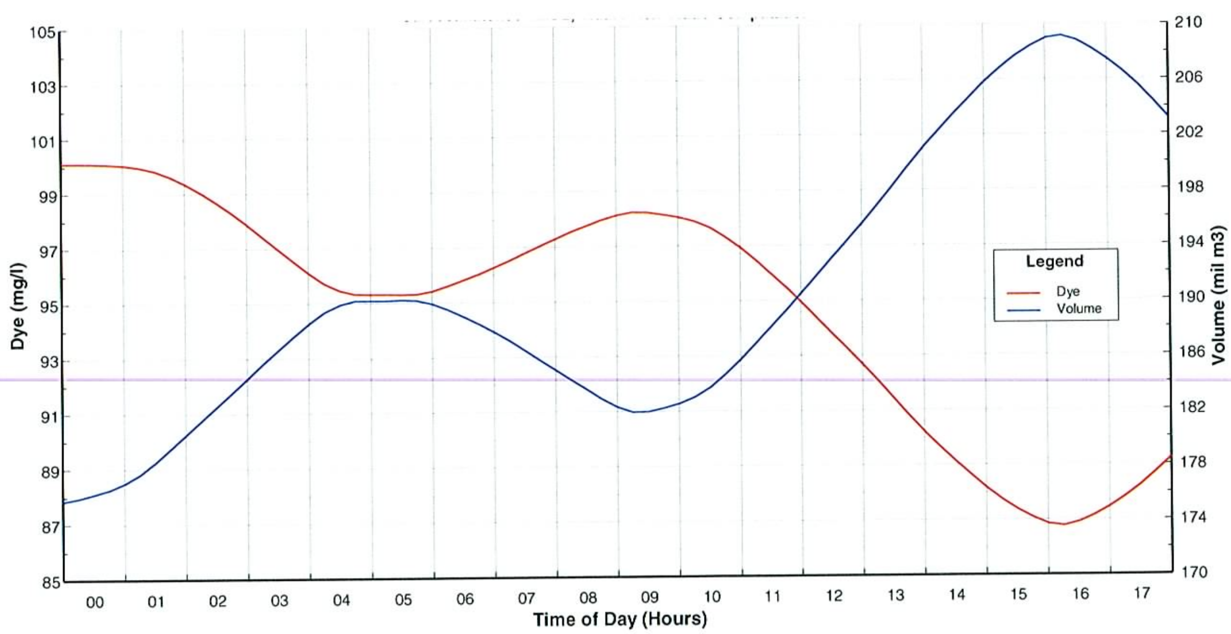


**Figure 15 Time series of dye and volume in the Caloosahatchee River during the TPR tidal cycle.**

### *5.3.4 EFDC Model Calibration*

#### *5.3.4.1 Model Simulation Period*

The period selected for hydrodynamic model calibration was from January 1, 2003 to December 31, 2003. This period has an adequate set of salinity, temperature, meteorology, and water quality data for setting boundary conditions and calibrating the model.

The model initial conditions and boundary conditions are discussed in Section 5.3.1. The EFDC hydrodynamic and water quality model calibration results are presented in Sections 5.3.4.3 for hydrodynamics and 5.3.4.3 for water quality. **Figure 10** provides a visualization of wind speed, direction and dry bulb temperature for the processed atmospheric data for the calibration period.

#### *5.3.4.2 Available Data for Hydrodynamic Calibration/Validation*

The data needed for calibration of a model is slightly different than that needed for definition of boundary conditions. The model boundaries must have data or a defensible approach (e.g. the HSPF simulation results used for this study) for all boundaries for the entire period of the simulation. However, for calibration, the data can be either sparse or robust, but it must be internal to the model domain, or at least not negatively impacted by a boundary condition.

##### *5.3.4.2.1 Hydrodynamic Calibration/Validation Stations*

For Caloosahatchee, there are 17 stations that meet the various data requirements for calibration and validation of the EFDC hydrodynamic model. The stations are MarkerH, CES02÷CES 11, 242, 350, MPV002, BR31, FMYER and CCORAL. Given these stations, three stations were selected as being representative of the overall system. These stations are described below and their positions are shown in **Figure 11**.

- BR31 is representative of the upper end of the Caloosahatchee Estuary.
- CCORAL is located roughly in the middle of the Caloosahatchee Estuary.
- CES09 representative of San Carlos Bay waters and the channel between the Caloosahatchee and the Gulf of Mexico.

The BR31 and CCORAL stations are SFWMD stations with continuous data collection at two fixed depths near the top and bottom of the water column are their respective sites. These high resolution data sets provide a better understanding of the salinity and temperature dynamics in the estuary than monthly data collection programs (e.g. the CES## stations). However, the monthly data programs can collect a much larger set of parameters.

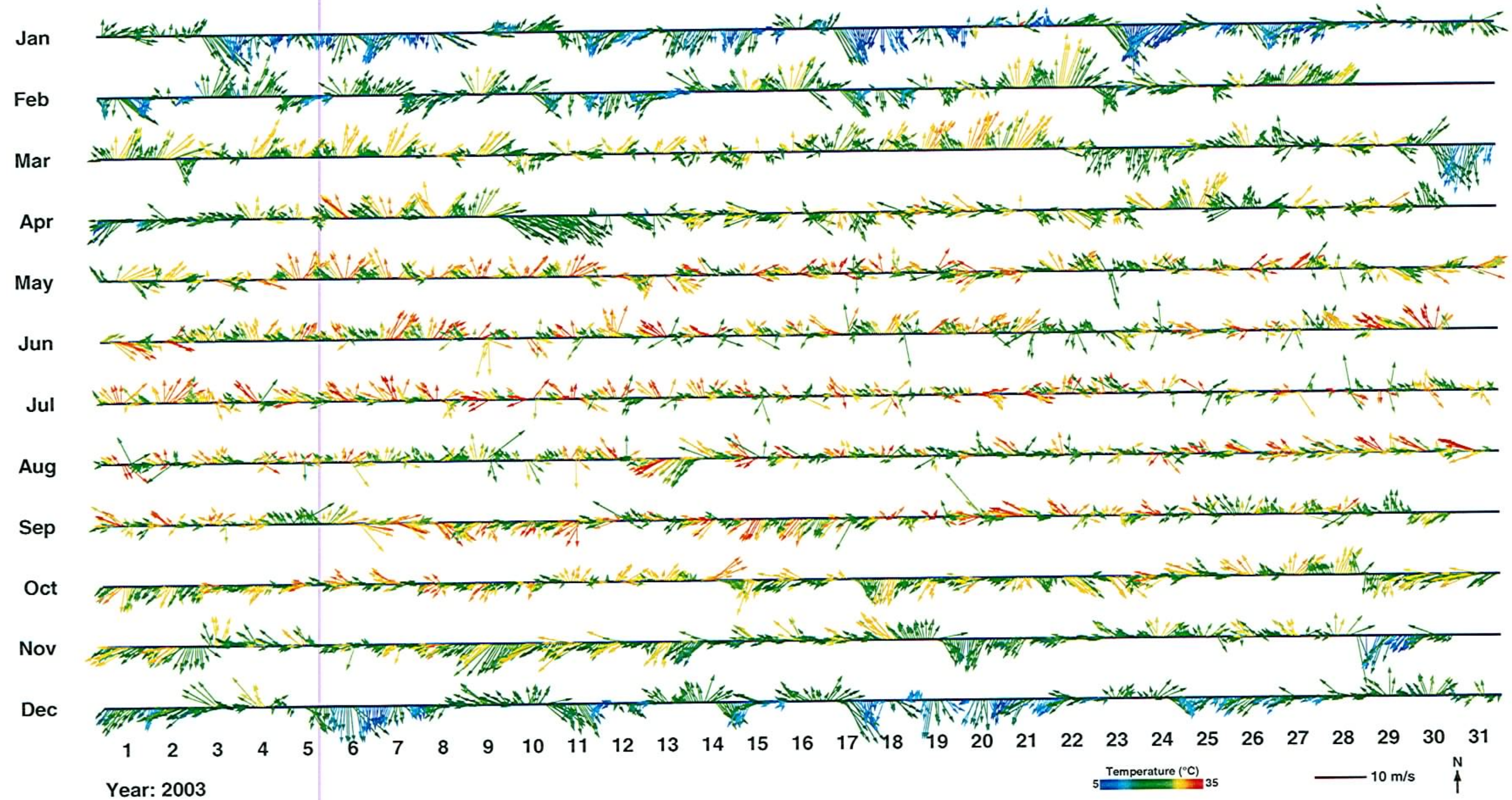


**Figure 10 Ft Myers wind stick plot for 2003.**