TETRA TECH

MEMO

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Date:	March 11, 2016 revised April 22, 2016, revised May 3, 2016, and Finalized May 5, 2016
Subject:	Caloosahatchee River Basin Watershed Model Review and Calibration Refinement – Final Task 4 EFDC Model Conversion

1.0 INTRODUCTION

Tetra Tech and AMEC were contracted by the Florida Department of Environmental Protection (department) to address department and stakeholder issues regarding the set up and calibration of the current versions of the Caloosahatchee River and Estuary Hydrologic Simulation Program – Fortran (HSPF) and Environmental Fluid Dynamics Code (EFDC) models. These models will be used to develop total maximum daily loads (TMDLs) for impaired freshwater bodies within the Caloosahatchee River Basin and to refine the Caloosahatchee tidal estuary TMDLs that the department adopted in 2010. The department provided the model files that contained data and ran from January 1, 2008 through December 31, 2010, as well as a report on the models developed by Dynamic Solutions and CDM in 2009 (2009 Model). However, the original EFDC model files developed by Dynamic Solutions and CDM that were used to prepare the 2009 report were not located or provided to Tetra Tech. The model files provided by the department were believed to be the department's updated model (2014 Model), which included modifications to the 2009 Model, such as extending the model simulation time and adjusting the delineation boundaries.

Task 4 of this project is to convert the existing EFDC model (DS-EFDC), which is a proprietary application, into a public domain application (PD-EFDC) and incorporate the light module from the existing proprietary model. For this task, Tetra Tech used the DS-EFDC input files for the period of 2008 through 2010, which were provided by the department. Tetra Tech updated and corrected these files for use in the PD-EFDC model, and this process is described in this memo. The PD-EFDC model has been tested for the 2008 – 2010 time period and was run at 15-, 30-, and 45-second time steps. Model results for the 45-second time step are displayed for the full simulation period in **Figure 1.**

A model can be unstable at larger time steps due to numeric instability, which produces a mass balance issue, either mass is created or removed resulting in a wide swing of the various modeled parameters and even negative concentrations. To ensure model stability at the 45-second time step, total phosphorus (TP) output was compared to the 30-second TP output at Cell 30, 30 (**Figure 2)**. If the outputs from the faster and slower time steps are similar, then the model shows no numeric instability and the model is considered stable. For the Caloosahatchee EFDC model, the model is stable at the 45-second time step because it produces similar results as when the model was run at the 15- and 30-second time steps. In addition, the latest EFDC1_4caloo.exe executable has been updated to stop if a negative concentration is produced, which can occur due to instability, and to close the BMD output file.

The PD-EFDC hydrodynamic and water quality models will be recalibrated to available data as part of Task 5 and Task 6, respectively. In addition to this memo, Tetra Tech has provided the PD-EFDC model code and executable file, as well as the hydrodynamic, water quality, and sediment input files.

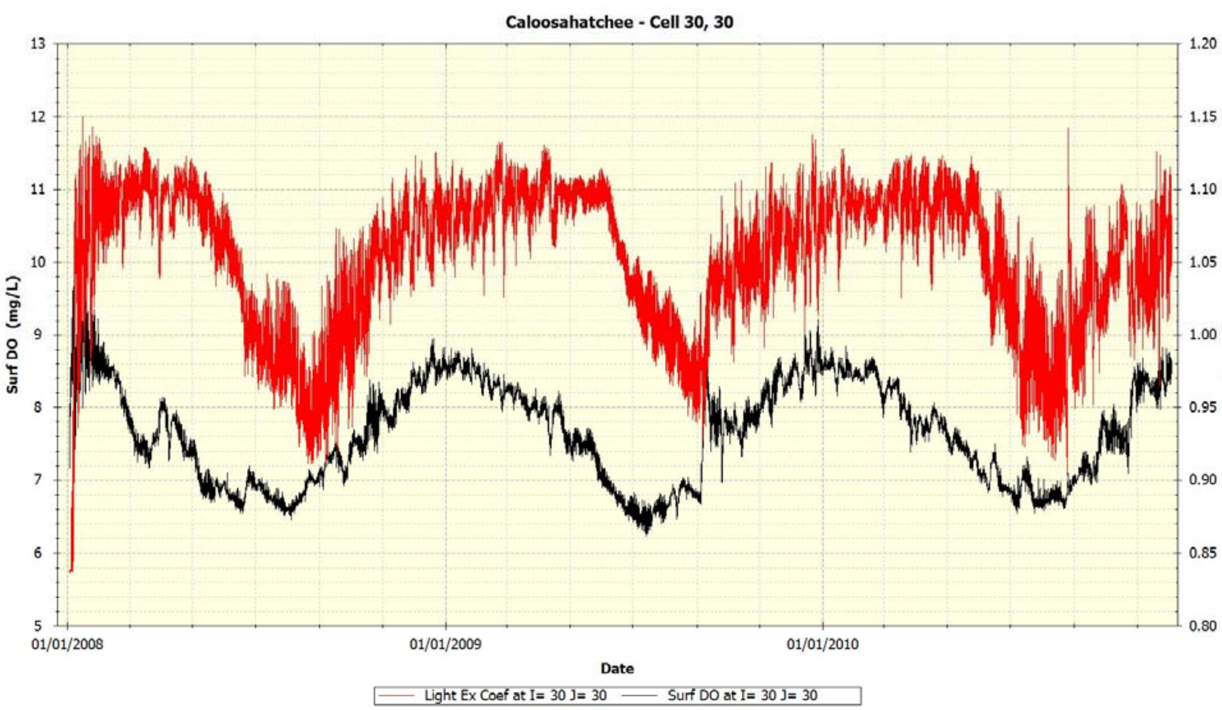

Figure 1: Caloosahatchee EFDC Model Results for Cell 30, 30 at the 45-Second Time Step for the Simulation Period January 1, 2008 through December 31, 2011

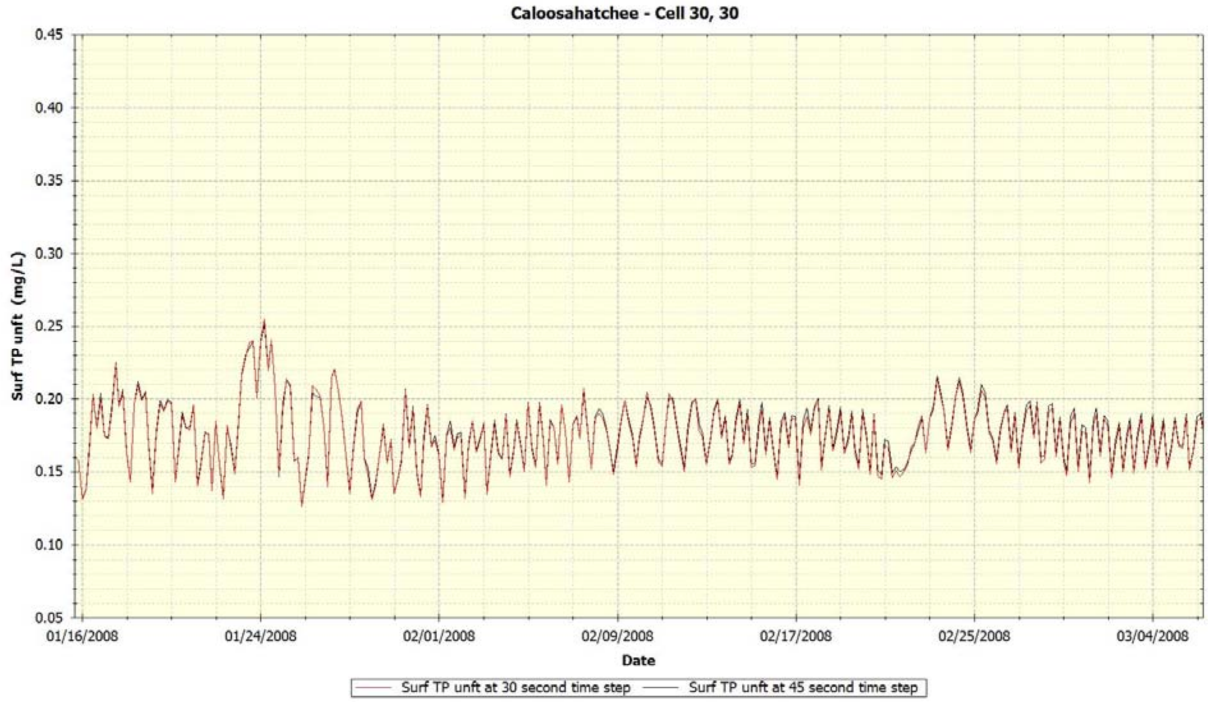

Figure 2: Caloosahatchee EFDC Model Stability Check at Cell 30, 30 for the 30-Second and 45-Second Time Steps

2.0 CONVERSION TO THE PD-EFDC MODEL

2.1 MODEL CODE UPDATES FOR THE LIGHT MODULE

Tetra Tech updated the existing PD-EFDC model to incorporate the light module from the DS-EFDC model. The existing PD-EFDC model included the following parameters:[1]

Ke(b) = background light extinction (m^{-1})

Ke(TSS) = light extinction coefficient for inorganic suspended solid (m^{-1} per g m^{-3})

TSS = inorganic suspended solid concentration (g m^{-3}) provided from the hydrodynamic model (all the cohesive sediment classes)

[1] Ke = Light extinction coefficient
TSS = Total suspended sediments
Chla = Chlorophyll-*a*
POC = Particulate organic carbon
DOC = Dissolved organic carbon
CDOM = Colored dissolved organic matter

Ke(Chla) = light extinction due to algae chlorophyll-*a* (m^{-1}), either self-shading equation or simple coefficient equation

The following parameters were added to the PD-EFDC model:

Ke(POC) = detrital particulate organic carbon (POC)

Ke(DOC) = colored dissolved organic matter (CDOM)

These parameters are located in Card 45, unless they are varied spatially in which case they will be in the file specified in Card 51. The present model specifies the spatial parameters are in the file: algrowth.inp.

The final light equation in the updated PD-EFDC model is:

$$Ke = Ke(b) + Ke(TSS) * TSS + Ke(Chla) * Chla + Ke(POC) * POC + Ke(DOC) * DOC$$

With the coefficients from DS-EFDC input file, the final equation is:

$$Ke = 1.12 + 0.052 * TSS + 0.031 * Chla + 0.078 * POC + 0.1 * DOC$$

These coefficients will be refined during model calibration, and the Ke(b) and Ke(DOC) coefficients can be varied by zone, if needed.

2.2 HYDRODYNAMIC MODEL INPUT FILES

Tetra Tech identified the proposed updates to the EFDC hydrodynamic model input files in the Task 1 memo. There were no major changes needed to the hydrodynamic code or the format of the input files before they were used in the PD-EFDC model.

2.3 SEDIMENT COMPONENT INPUT FILES

Tetra Tech determined that no changes were needed to the sediment component input files; therefore, these are the same as the department's 2014 Model.

2.4 WATER QUALITY MODEL INPUT FILES

Tetra Tech made several modifications to the water quality model input files, as summarized below.

The changes made to the WQ3DWC.inp file, which is the main water quality control file, were:

- The 2014 Model main control file format was modified to work with the PD-EFDC model.
- In the 2014 Model, Card 51 only included the spatial varying algal growth kinetics. In the PD-EFDC model, Card 51 now supplies the file names for spatially/temporally varying algal parameters.
- Card 51 was updated to include algal growth, algal settling, and the option for inputting benthic flux directly.

- The algal growth (algrowth.inp), algal settling (algalsettling.inp), and water quality kinetics (kinetics.inp) files were updated to be both spatially and temporally variable. The changes to these files provide the option to have seasonally varying kinetics, if needed.
- Card 02a was changed to include all three algal groups.
- The model output was modified from a time series text file output to a BMD (binary) hydrodynamic and water quality file. The BMD files are easier to graph and compare to water quality data.
- Card 10 through Card 29 include the same constant water quality and algal parameters as the 2014 Model. These parameters will be evaluated during model calibration (Task 6) to determine if any modifications are needed.
- The CWQSR01.inp through CWQSR21.inp files include the same boundary condition for the water quality parameters' concentration time series for the north and south boundaries as the 2014 Model. These will be evaluated during model calibration (Task 6) to determine if any modifications are needed.
- The point source time series was updated to use KSR=0, which evenly distributes the load among all the layers instead of dividing the load manually between the layers. This change reduced the number of point source inputs in the model from 136 to 34. The model will be updated in Task 6 to allow for the new point source time series to input as concentrations instead of loads.
- The atmospheric deposition in Card 49 and Card 50 will be updated in Task 6 to include direct atmospheric deposition of nutrients to the waterbody.
- Minor changes were made to the WQ3DWC.inp file to make direct editing and data entry easier and more understandable. Where there were three lines of data input for a given cell, such as in Card 33, now all the inputs per cell have been included on one line. These changes allow water quality parameters to be input on a single line instead of three separate lines, which makes editing the parameters much easier and inputs can be easily copy and pasted from a spreadsheet.
- The kinetic parameter and benthic flux mapping files were updated to include the changes to the north boundary grids. The north boundary grids were modified to eliminate the tidal inputs on the shallow marsh areas.
- The light attenuation kinetic inputs were updated to include the new light equations in Card 09, as described in **Section 2.1**.

In addition, in the boundary concentration time series files, cwqsrNN.inp, Tetra Tech suggests updating the ISTYP flag to 1. The ISTYP flag indicates the time series format identifier. When ISTYP=0, the MCSER time data points must have a concentration value for each layer, and concentrations are read from the bottom to the top layer. When ISTYP=1, an additional line of data providing weight factors for concentrations for each vertical layer is read, and the time data lines have only one concentration value. Weight factors are read from the bottom to the top layer. By having the ISTYP flag equal 1, it allows for entering one string of time series data, instead of entering values for each layer. This minimizes the chance for errors, as was found in the QSER.inp file model inputs from the 2014 Model. It would also be helpful to update all similar fields to this format to help reduce errors.

3.0 COMPARISON TO PREVIOUS MODELS

A direct comparison to the 2009 Model could not be made as part of this project. The department was unable to provide the original 2009 Model files and the results from the 2014 Model were for a different time period than in the 2009 Model. Tetra Tech and the department determined that it would be best to compare the light extinction profiles in San Carlos Bay from the PD-EFDC model to results from the 2009 and 2014 Models to ensure the results in the PD-EFDC model fall within the ranges seen in the 2009 and 2014 Models. Tetra Tech provided comparison figures for a test run period of April 2009 through October 2009.

Figure 3 through **Figure 9** illustrate the EFDC model light related outputs from the PD-EFDC model for Cell I=30, J=30 in San Carlos Bay. These outputs were based on the light extinction parameters in the equation in Section 2.1. Figure 10 through Figure 12 illustrate the percent of light at bottom and the light extinction coefficient for cells I=18, J=22; I= 35, J= 24; and I=26, J= 22, which are located in different areas of San Carlos Bay.

For Cell I=30, J=30 in the San Carlos Bay, the current total nitrogen (TN) and TP concentrations are provided in **Figure 13**, and the dissolved oxygen (DO) and biochemical oxygen demand ($BOD_{5)}$ concentrations are provided in **Figure 14**. Water quality in the Caloosahatchee EFDC model will be compared to measured data and revised as necessary in Task 6. Nutrient concentrations are impacted by the Ke (light extinction coefficient), and the current Ke value may be adjusted during future tasks to improve model calibration.

Although the light at bottom is lower than the measured data, the results are similar (about 10%-50% different) to the results in the TMDL report. Therefore, the light module from the DS-EFDC model was correctly incorporated into the PD-EFDC model.

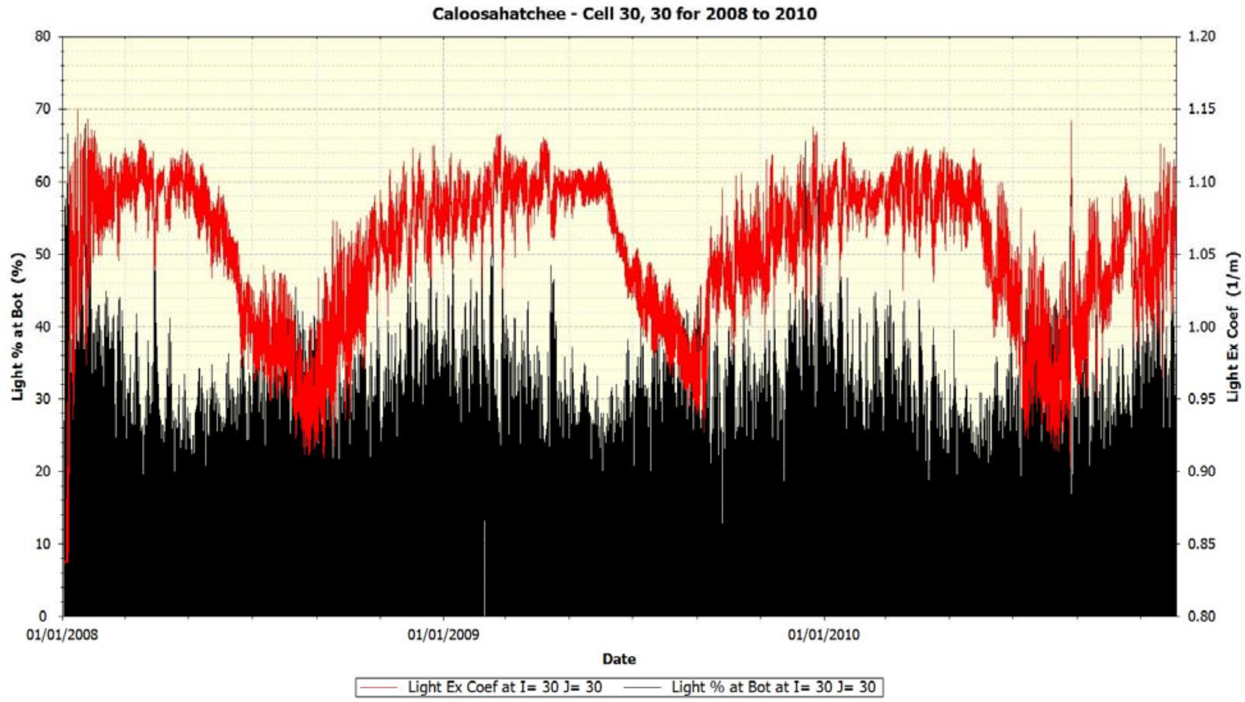

Figure 3: Caloosahatchee - San Carlos Bay (Cell 30, 30) Percent Light at Bottom and Light Extinction Coefficient for the Simulation Period January 1, 2008 through December 31, 2011

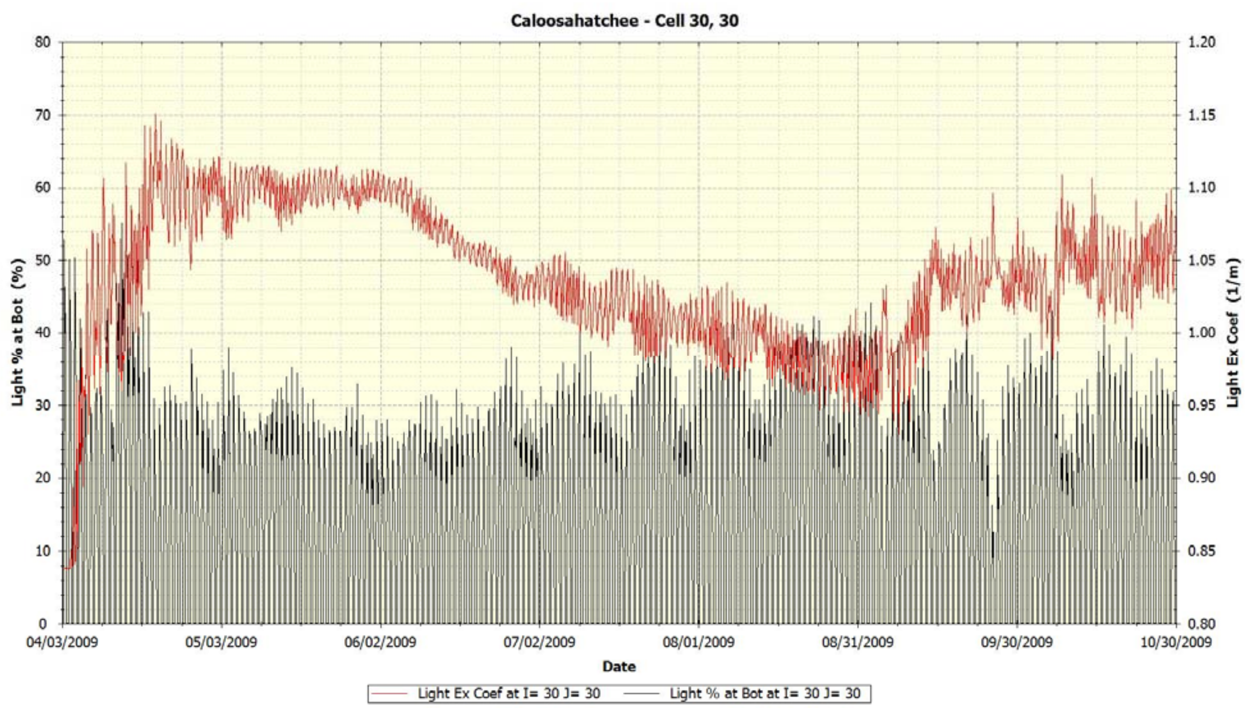

Figure 4: Caloosahatchee - San Carlos Bay (Cell 30, 30) Percent Light at Bottom and Light Extinction Coefficient for the for the April 2009 through October 2009 Test Run

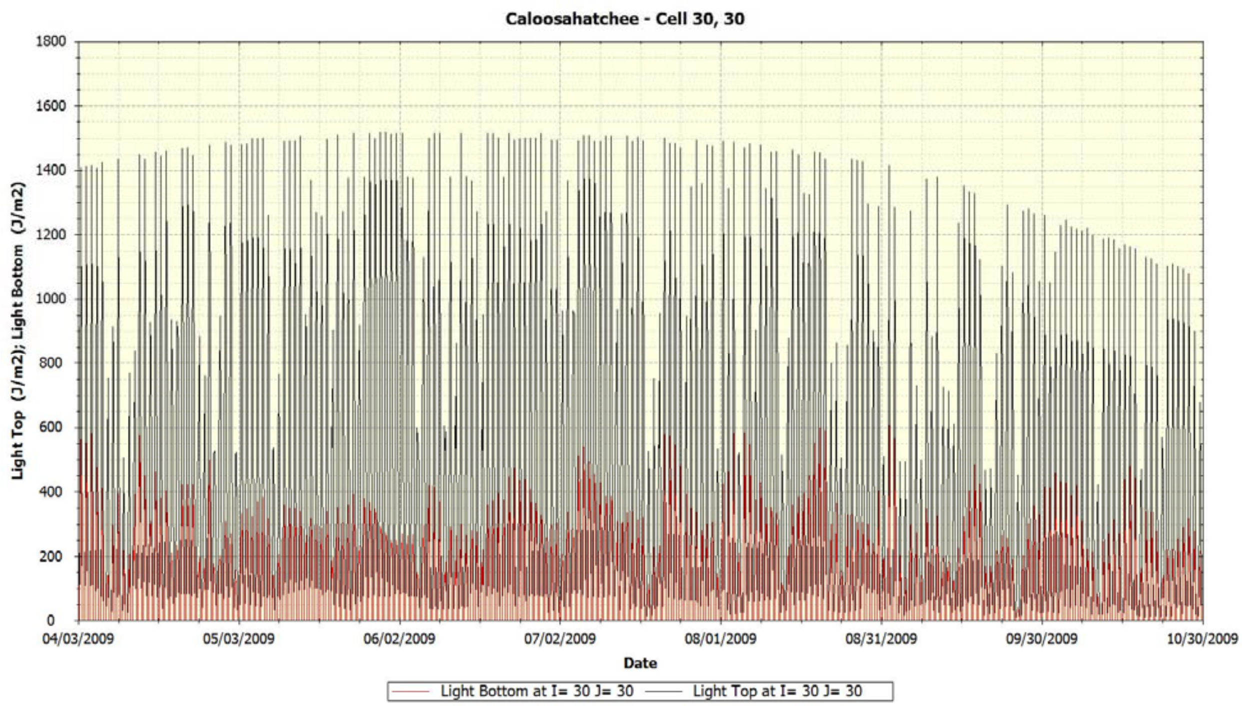

Figure 5: Caloosahatchee - San Carlos Bay (Cell 30, 30) Light at Bottom and Light at Top for the April 2009 through October 2009 Test Run

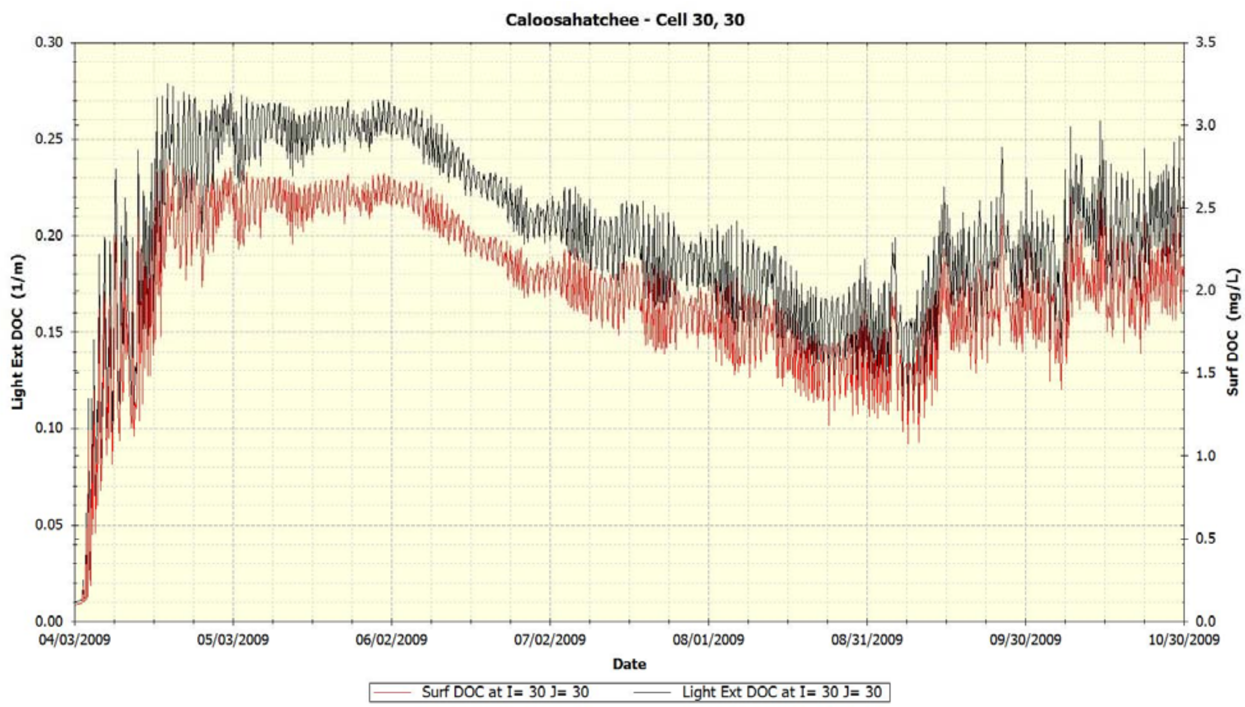

Figure 6: Caloosahatchee - San Carlos Bay (Cell 30, 30) Light Extinction for DOC for the April 2009 through October 2009 Test Run

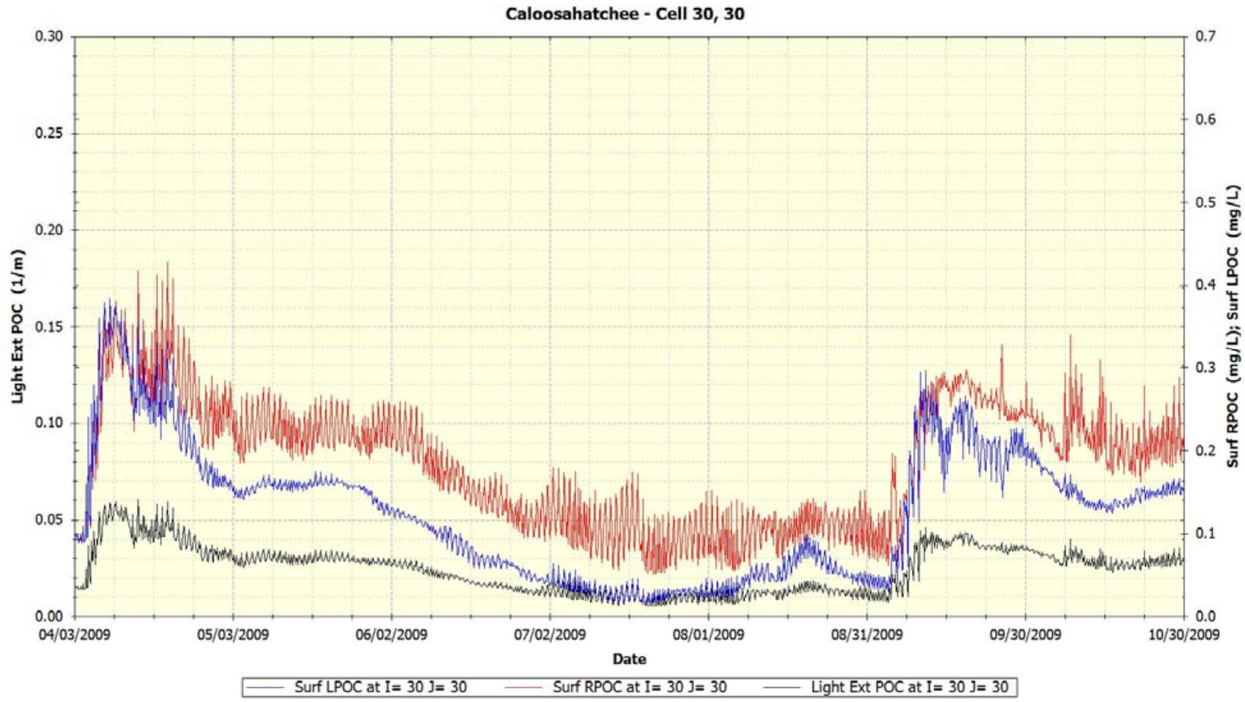

Figure 7: Caloosahatchee - San Carlos Bay (Cell 30, 30) Light Extinction for POC for the April 2009 through October 2009 Test Run

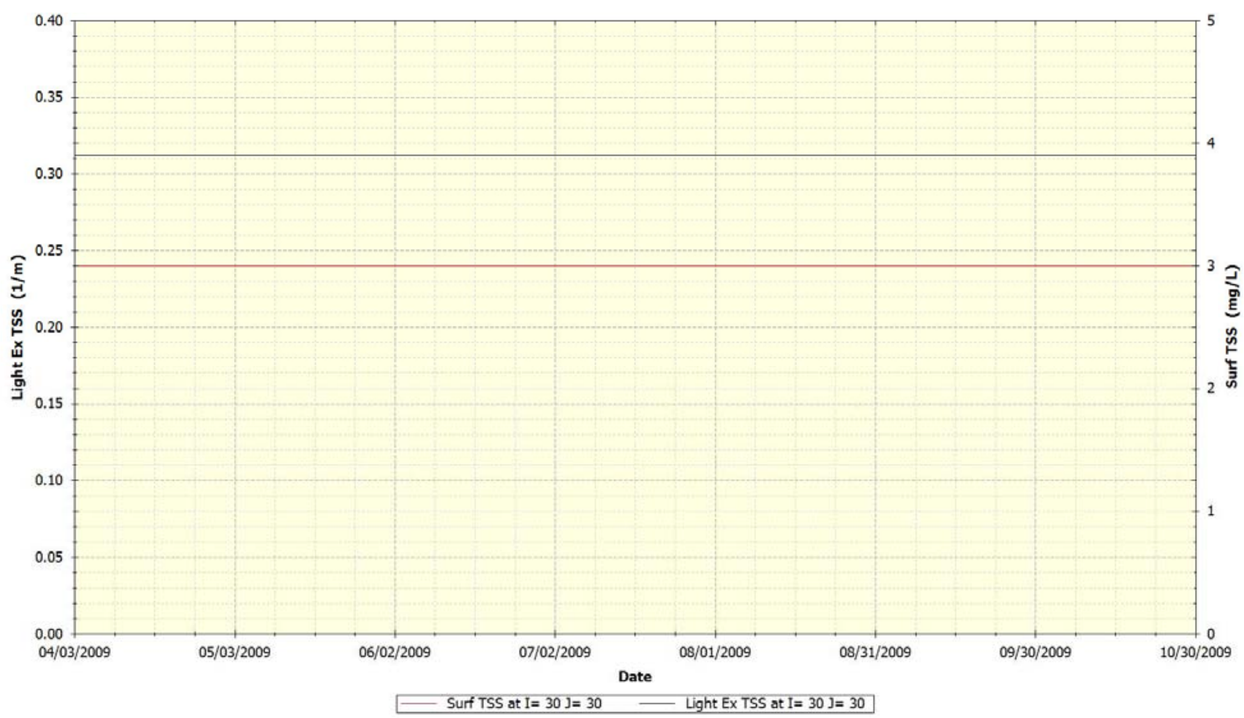

Figure 8: Caloosahatchee - San Carlos Bay (Cell 30, 30) Light Extinction Values and Surface TSS for or the April 2009 through October 2009 Test Run

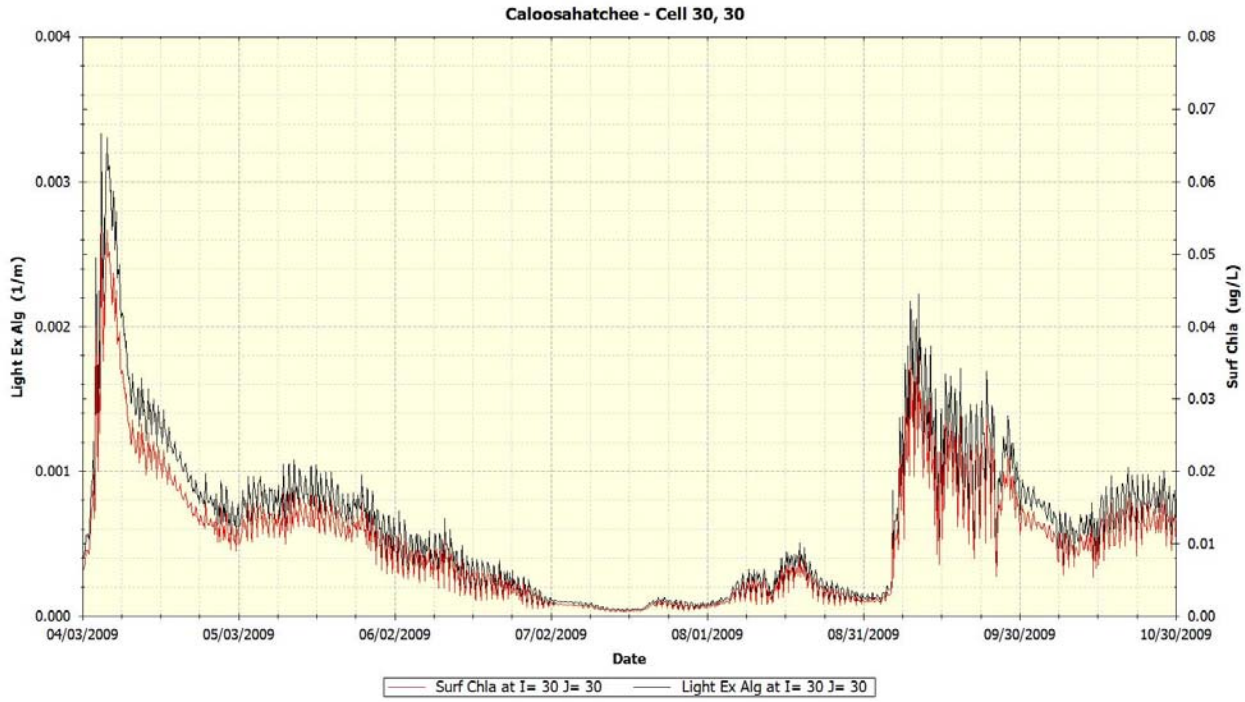

Figure 9: Caloosahatchee - San Carlos Bay (Cell 30, 30) Light Extinction for Chlorophyll for the April 2009 through October 2009 Test Run

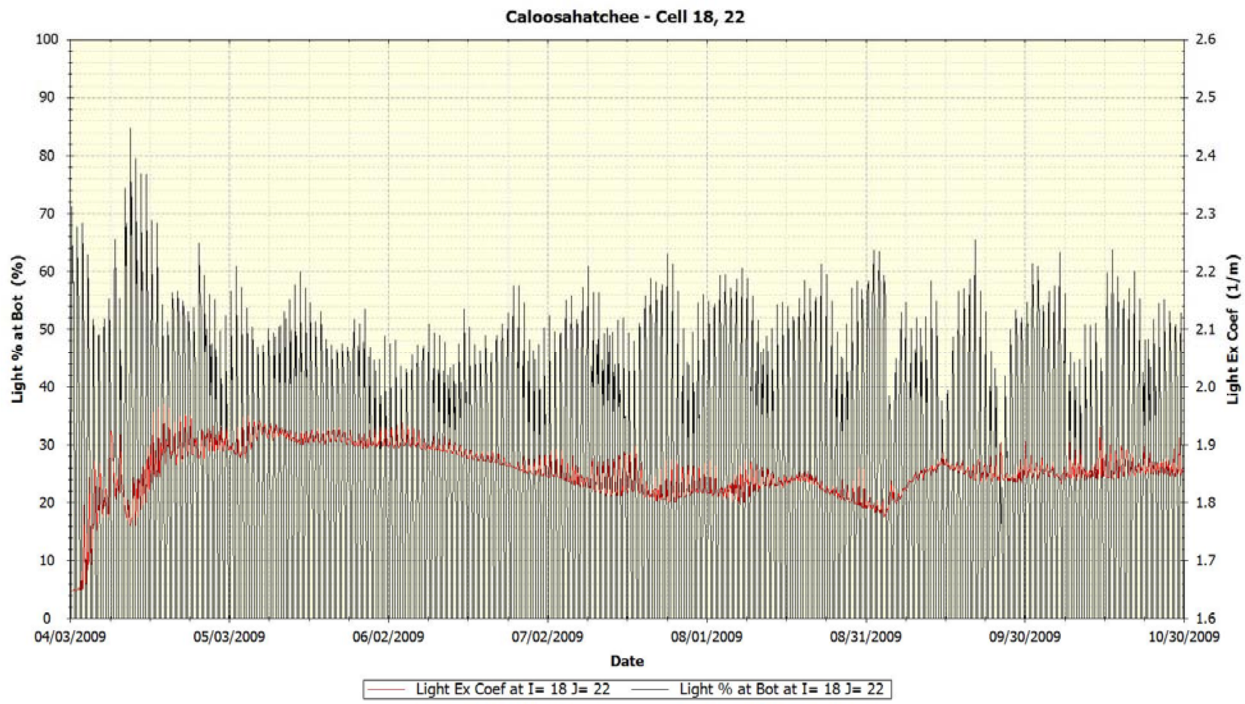

Figure 10: Caloosahatchee - San Carlos Bay (Cell 18, 22) Light at Bottom and Light Extinction Coefficient for the April 2009 through October 2009 Test Run

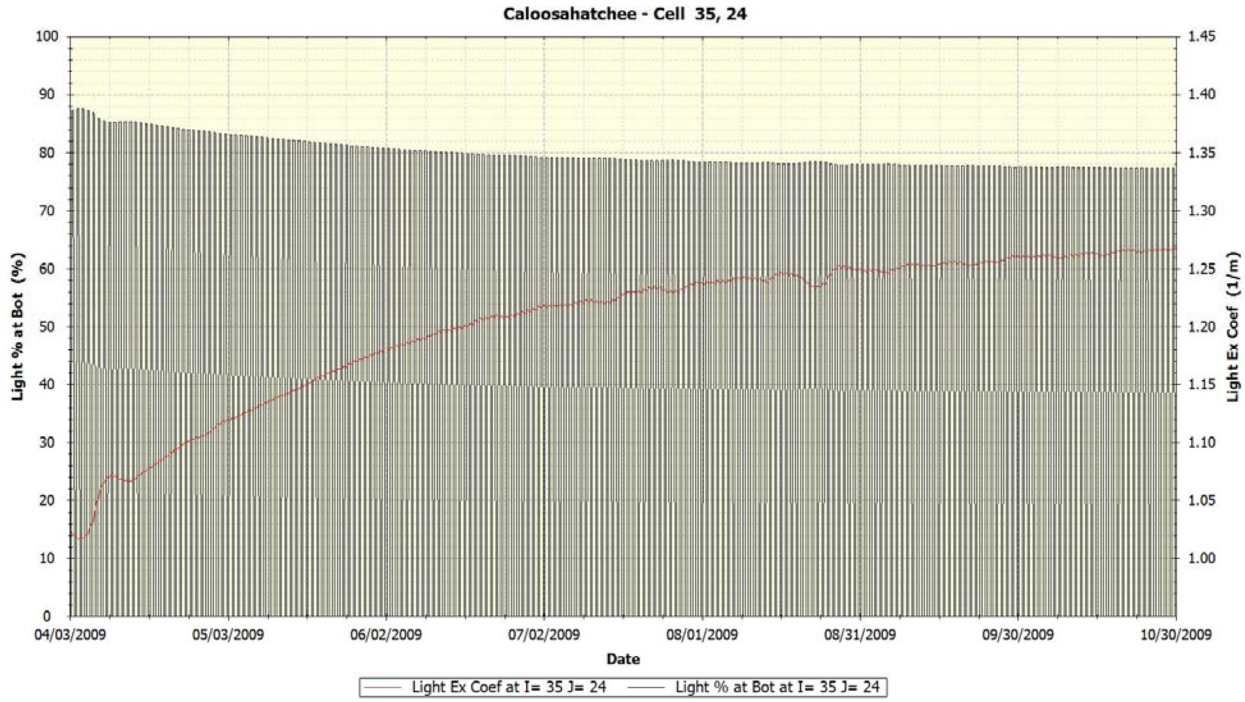

Figure 11: Caloosahatchee - San Carlos Bay (Cell 35, 24) Light at Bottom and Light Extinction Coefficient for the April 2009 through October 2009 Test Run

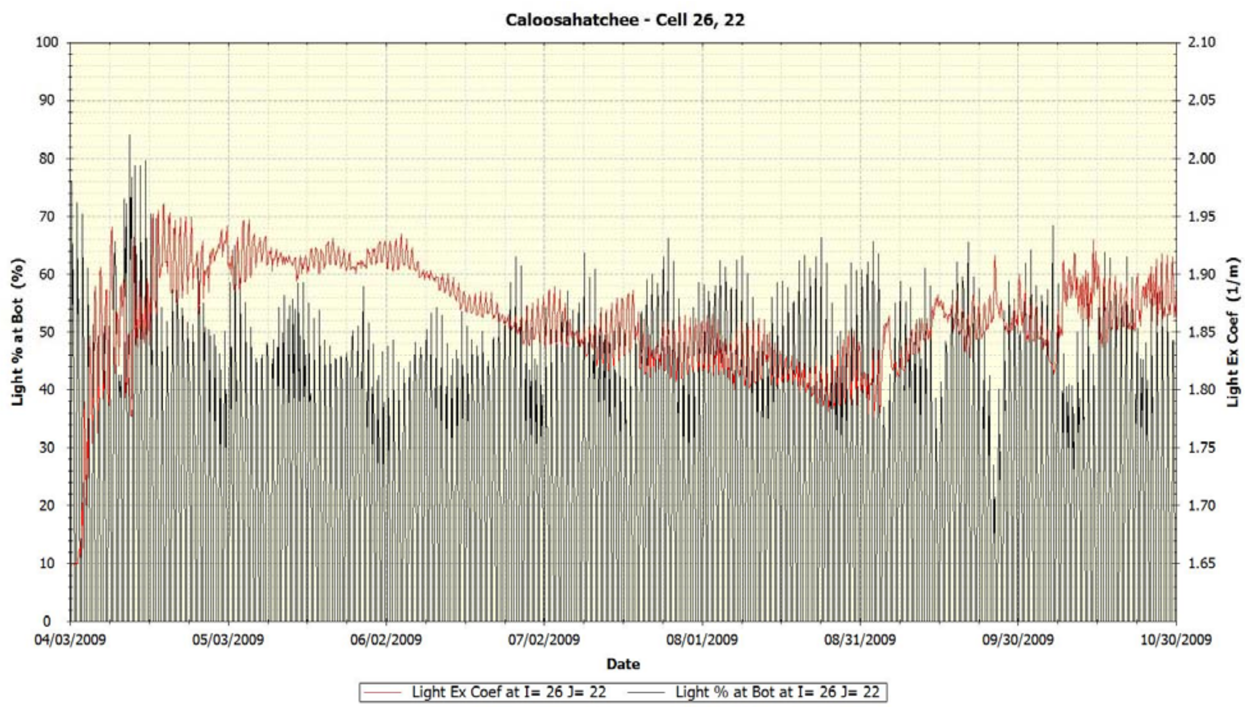

Figure 12: Caloosahatchee - San Carlos Bay (Cell 26, 22) Light at Bottom and Light Extinction Coefficient for the April 2009 through October 2009 Test Run

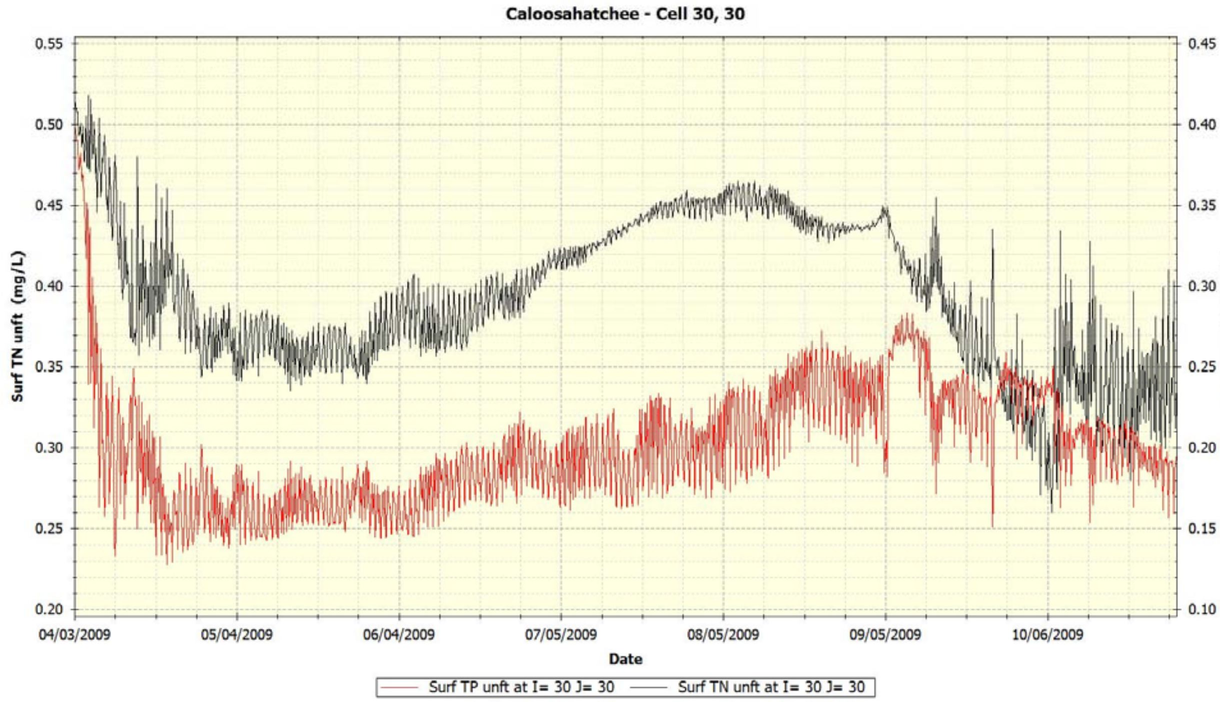

Figure 13: Caloosahatchee - San Carlos Bay (Cell 30, 30) TN and TP for the April 2009 through October 2009 Test Run

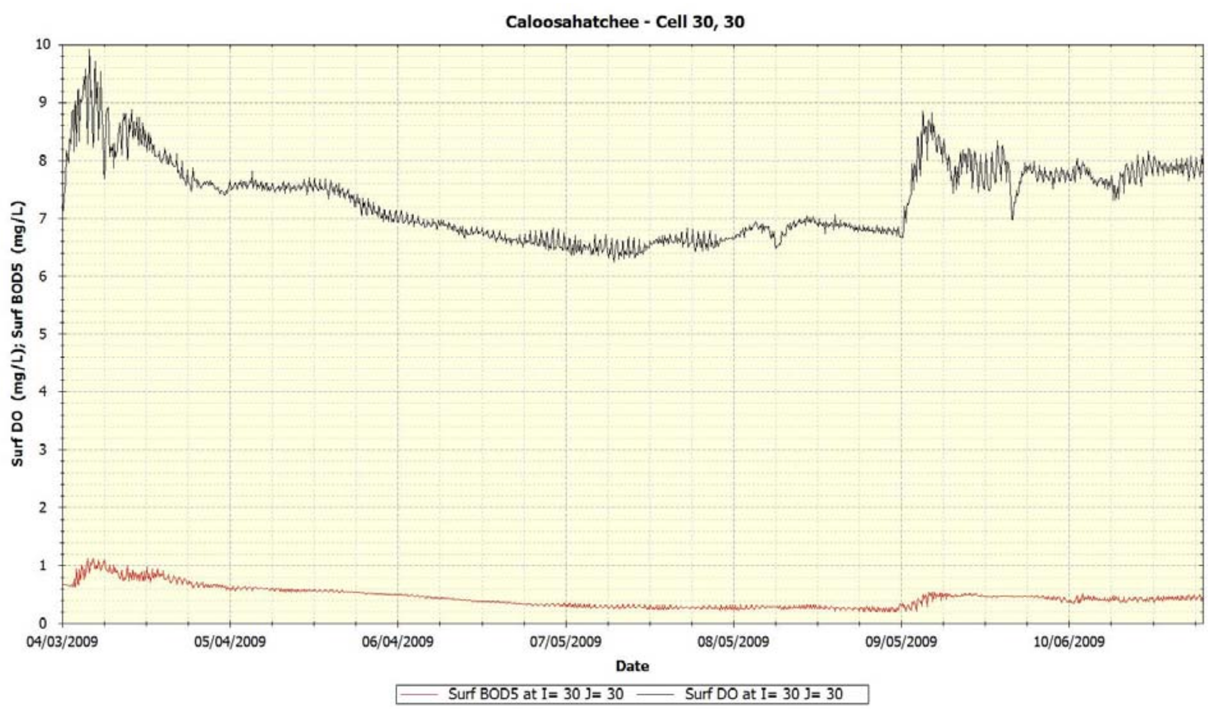

Figure 14: Caloosahatchee - San Carlos Bay (Cell 30, 30) DO and BOD_5 for the April 2009 through October 2009 Test Run

3.1 EFDC MODEL CODE

The following is the part of the EFDC model code that calculates the total light extinction coefficient, which is contained in the full EFDC model code that was provided to the department.

```
C ALGAL GROWTH: LIGHT, WQHT(K)=REAL(KC-K)/REAL(KC)
C IN C&C, F2IC=F2IC/FCYAN, FACTOR TO ALLOW CYANOBACTERIA MAT FORMATION
C
C MRM 05/12/1999 USE RILEY (1956) EQUATION TO COMPUTE LIGHT EXTINCTION
C     AS A FUNCTION OF CHL CONC. IF WQKECHL IS LESS THAN ZERO:
C
        XMRM = WQKECHL*WQCHL(L,K)
        IF(WQKECHL .LT. 0.0)THEN
          XMRM = 0.054*WQCHL(L,K)**0.6667 + 0.0088*WQCHL(L,K)
        ENDIF
        WQKESS = WQKEB(IMWQZT(L))+WQKETSS*SEDT(L,K) + XMRM
     # + wqkedye*dye(l,k)
     # + wqkedoc(imwqzt(l))*WQV(L,K,6)+wqkepoc*(WQV(L,K,4)+WQV(L,K,5))
        WQKESS1 = WQKESS
        IF(K.NE.KC)THEN
          XMRM = WQKECHL*WQCHL(L,KC)
          IF(WQKECHL .LT. 0.0)THEN
            XMRM = 0.054*WQCHL(L,KC)**0.6667 + 0.0088*WQCHL(L,KC)
          ENDIF
          WQKESS1=WQKEB(IMWQZT(L))+WQKETSS*SEDT(L,KC) + XMRM
     # + wqkedye*dye(l,kc)
     # + wqkedoc(imwqzt(l))*WQV(L,K,6)+wqkepoc*(WQV(L,K,4)+WQV(L,K,5))
        ENDIF
```