Fenholloway River and Estuary TMDL Development
Taylor County, Florida

Gregory D. Sousa[1], J.M. Greenfield[2], S.J. Peene[1], and H.N. Rodriguez[1]

ABSTRACT

The Fenholloway River is located in Taylor County, Florida, along the Gulf Coast, 113 kilometers (70 miles) southeast of Tallahassee and 129 kilometers (80 miles) northwest of Gainesville. A paper mill discharges an average of 2.17 m^3/sec (50.0 mgd) of high color wastewater into the Fenholloway River 40.0 km (24.6 mi) upstream of the mouth of the river. The river typically has no flow in the vicinity of the mill as a result of the production well water withdrawal, with the paper mill discharge accounting for up to 90 percent of the flow in the river. From the paper mill effluent discharge point to the confluence of Spring Creek with Fenholloway River, 17.7 km (11 mi), there is little fresh water input to the system.

A three-dimensional grid, with two layers was setup to evaluate the color in the Fenholloway system as part of the TMDL process. The modeling approach was sufficient to properly represent stratification in the estuarine part of the system and color as a conservative substance.

[1]Water Resource Engineer, Tetra Tech, Inc., 2110-202 Powers Ferry Road, Atlanta, GA 30339.
[2]TMDL Coordinator, Environmental Protection Agency, Atlanta Federal Center, 61 Forsyth Street SW, Atlanta, GA, 30303.

INTRODUCTION

The Fenholloway River and Estuary are located near Perry in Taylor County, Florida, 113 kilometers (70 miles) southeast of Tallahassee and 129 kilometers (80 miles) northwest of Gainesville (Figure 1). A state law that was passed in 1947 allowed industrial wastewater discharges into the river. In 1954 a paper mill began production and discharge of high-color wastewater to the river. Water quality concerns in the Fenholloway River and Estuary began to be addressed around the passing of the Federal Water Pollution Control Act (Clean Water Act) 1972. Improvements to the wastewater treatment process reduced BOD loads. Presently, a phased TMDL modeling approach is under development for the Fenholloway River and Estuary. The model is being developed to address color, nutrients, and dissolved oxygen. This paper presents model development for color. Color levels in the Fenholloway River and Estuary inhibit light penetration. As a result of high color concentrations in the system, the submerged aquatic vegetation (SAV) in the estuarine and nearshore areas are significantly impacted (FDEP 1994).

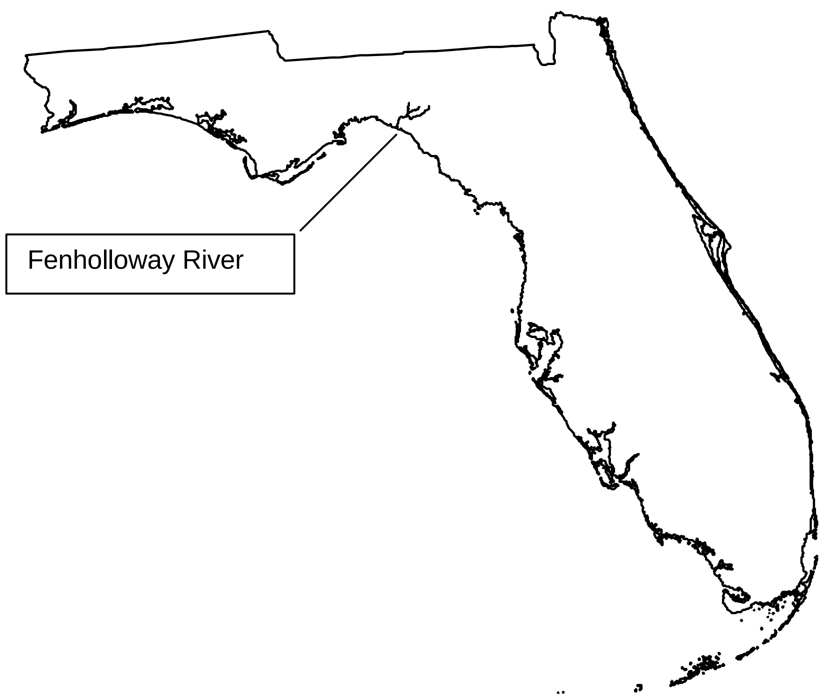

Figure 1. Location Map.

The Fenholloway Watershed contains wooded wetlands in the upland and coastal marshes in the lowland. The San Pedro Bay wetland area is the headwater for the system (Figure 2). San Pedro Bay contains manmade canals that were developed to drain the wetland for access to timber (Watts 1991). The area has little topographic relief. The elevations in the upland area are approximately 30 m, NGVD (100 ft, NGVD). Wetland and forested areas account for 40.5 and 44.0 percent of the drainage area, respectively.

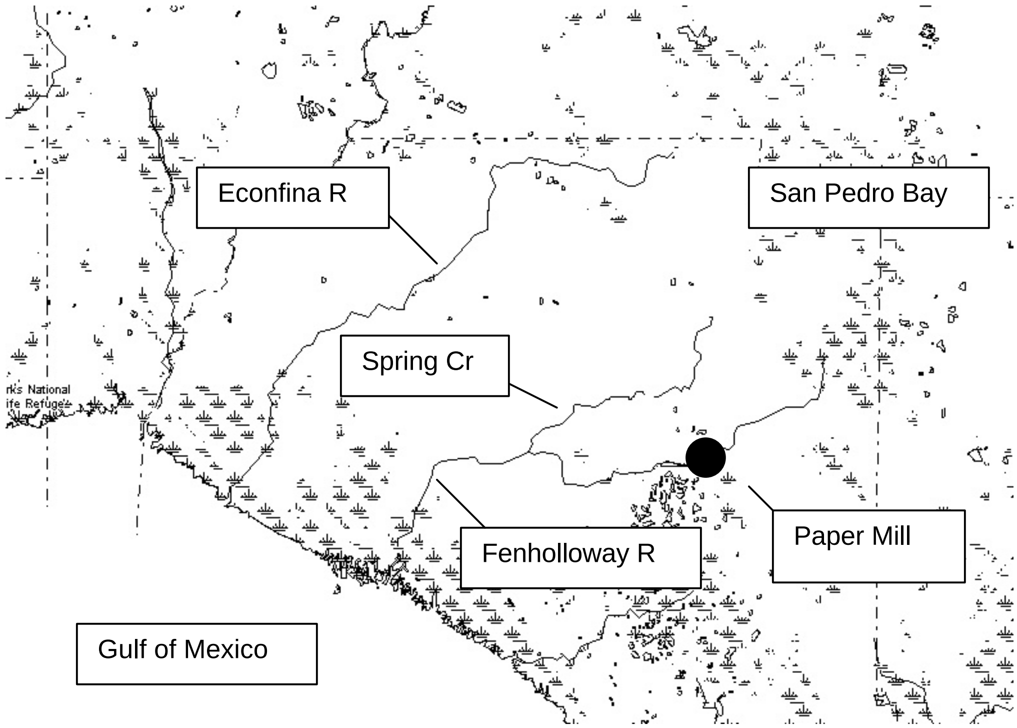

Figure 2. Fenholloway and Econfina Rivers.

The riverine portion of the system is characterized by flat slopes, shallow depths, and low velocities. The riverine bed slope is about 0.0004 meters per meter. Channel depths in the system are 0.3 m (1.0 ft) in the upstream reaches near the paper mill to approximately 1.0 m (3.3 ft) in the downstream reaches near the estuarine area. Characteristic velocities of 0.2 m/s (0.6 ft/s) have been observed in the upper reaches of the riverine system and velocities of approximately 0.1 m/s (0.3 ft/s) in the lower reaches (EPA 1989). The average flow at US19/98, just downstream of the paper mill's discharge, is 2.5 m^3/sec (88.3 cfs). The average flow at Cooey Bridge, a downstream location, is 13 m^3/sec (460 cfs). The travel time from the paper mill to the estuary of the river varies between 2.0 and 4.0 days (EPA 1989).

The estuarine portion extends to RK 4.2 (RM 2.6), a location known as Fish Camp (Figure 3). The estuary is characterized by shallow depths, about 1.0 m (3.3 ft), and a small tidal range, approximately 0.6 m (2.0 ft). There is a system of shallow oyster bars in the near shore area, just outside of the mouth of the Fenholloway River.

Two point sources discharge (eventually or directly) into the Fenholloway River. A sewage treatment plant that services the town of Perry discharges an average of 1.0 mgd (0.04 m^3/sec) into Spring Creek, a tributary of the river (Figure 3). A paper mill is located on the Fenholloway River and discharges effluent at RK 40.0 (RM 24.6). There are nine production wells that run across the Fenholloway River. The paper mill uses seven of the production wells to withdraw an average of 2.17 m^3/sec (50.0 mgd) from the Floridan aquifer (EP&A 2000). This is also the average flow that is discharged to the Fenholloway River. This process pumpage causes a cone of depression in the ground water that makes the river dry in the area immediately upstream of the plant. Under base flow condition, the effluent discharge is nearly 100 percent of the flow in the upstream section of the river. During baseflow conditions, the river downstream of the paper mill is largely mixed with interflow from the Floridan aquifer. The Floridan aquifer discharge to the Fenholloway River and Estuary is more clear than event based runoff (HydroQual 1993). The Floridan aquifer changes from being semi-confined to an unconfined condition near the location of the paper mill (Lee 1995).

MODEL GRID DEVELOPMENT

The model, Environmental Fluid Dynamics Computer Code (EFDC) (Hamrick 1996), was used for the simulation of hydrodynamics and transport. EFDC is a three dimensional (3D) hydrodynamic model that uses a curvilinear orthogonal grid in the horizontal and a sigma-stretched transformation in the vertical. The transport variables used in this application were salinity, temperature, and color, which was modeled as a conservative substance.

The model domain includes the riverine, estuarine, and near shore regions. The riverine portion is represented by a 2 layer grid (in the vertical) extending about 42 km (26 miles). The cross sectional representation in the model is rectangular, with widths determined from flow-width relations (HydroQual 1993) (Figure 3). The point source, Spring Creek confluence, measured data and model output locations are also noted in Figure 3.

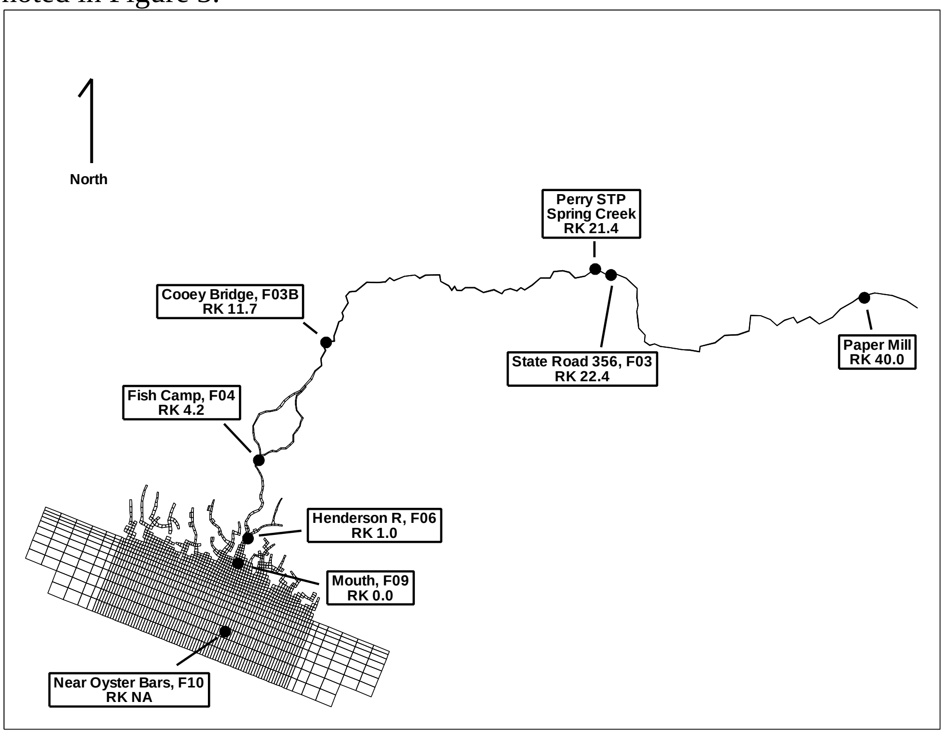

Figure 3. Model Grid With Point Source, Spring Creek, Measured, and Modeled Locations Noted.

The near shore section of the grid covers about 41 square kilometers (16 square miles). The grid cells in the estuarine and nearshore area are approximately 100 m by 100 m (328 ft by 328 ft). Cell size increases away from the mouth, to approximately 400 m by 400 m (1,312 ft by 1,312 ft). The southern edge of the grid is approximately 2.5 to 5.0 m (8.2 to 16.4 ft) in depth. The nearshore grid is shown in Figure 4.

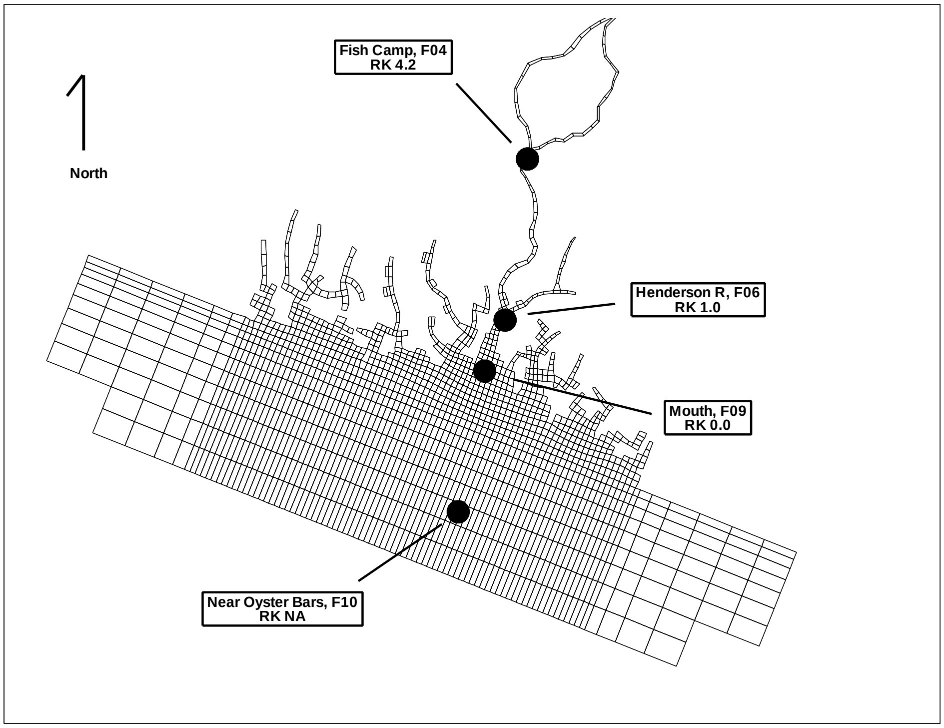

Figure 4. Nearshore Model Grid With Measured and Modeled Locations Noted.

COLOR LOADING

Color concentrations in the Fenholloway River and Estuary impair the growth of SAV (FDEP 1994). Color enters the system from the paper mill discharge and natural background loading. As a result of the paper mill processes, the discharge contains higher than natural color concentrations. The presence of these color concentrations is due to tannin and lignin derivatives (Smook 1992). Plant process improvements have reduced effluent color concentrations from approximately 2,300 platinum cobalt units (PCU) in the early 1990s to 1,300 PCU by the end of the decade. The large marsh and wetland areas of the Fenholloway River and Estuary contribute significant precipitation based natural color loading. Characterization of background color loading was developed from data collected in a surrogate system: the Econfina River and Estuary, just north of the Fenholloway (Figure 2). It also has its headwaters in the San Pedro Bay marsh area, and features similar landuse, riverine geometry, flow characteristics, but has no industrial discharge (EP&A 1998). The

Econfina River has been frequently studied to help develop an understanding of what the water quality of the Fenholloway River and Estuary would be like in the absence of point source contributions. Data collected in the Econfina River were used to develop background color concentration input values for the model. During the simulated period the Econfina River and Estuary were monitored on the same intervals as the Fenholloway River and Estuary. During periods of low rainfall, the primary dilution for the paper mill discharge occurs from spring inflow and ground water discharge to the Fenholloway River and Estuary. The area contains numerous sinkholes as it overlies karst geology. Ground water inflow to the system tends to contain much less color than the event based runoff. Color was modeled as a conservative substance, the color causing compounds are slow to biodegrade (Smook 1992). The short (2 to 4 day) travel time minimizes color reducing transformations. This model was developed with the intention of capturing long term trends.

INPUT AND BOUNDARY CONDITIONS

Input and boundary conditions are used to start model computations. These data include flow, salinity, temperature, color, and meterological conditions. Figure 5 shows the flow conditions for the model period. The flows were higher in the beginning, followed by a period of little or no rainfall. The dip in the line representing the paper mill discharge, reflects the annual plant shutdown for maintenance, October 9 – 15, 1998.

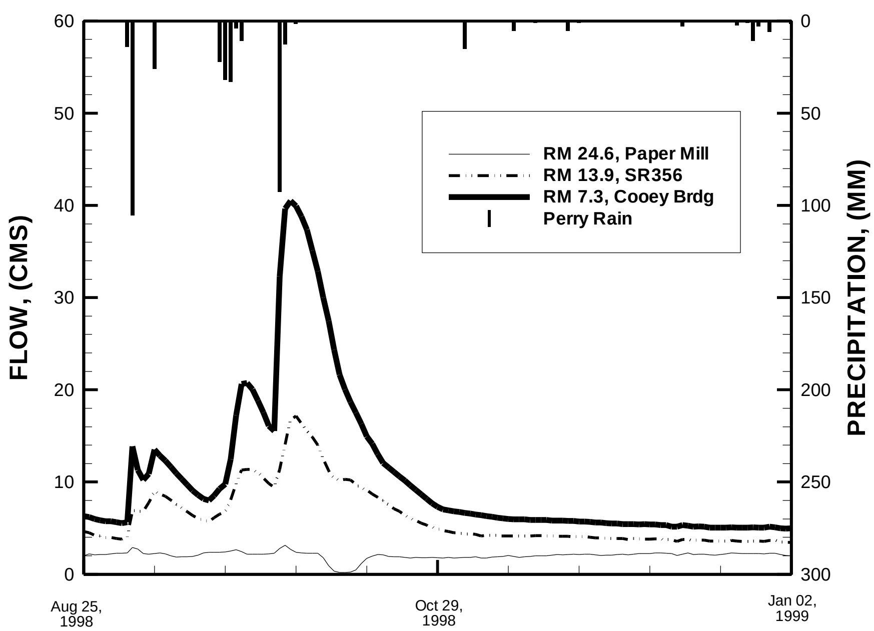

Figure 5. Flow and Precipitation During the Period of Study.

The flow input for the model was developed from the United States Geological Survey (USGS), paper mill discharge, and Suwanee River Water Management

District (SRWMD) data. Salinity concentrations for the nearshore boundaries were input from data measured every 4 to 6 weeks. Temperature input conditions for the paper mill discharge were provided by the paper mill. These data were typically provided on a daily basis. Riverine input values and nearshore boundary conditions were input from the measured data, typically on a four to six week time step.

MODEL RUN

The period evaluated was September through December 1998. The model run in this developmental stage was 130 days. The goal of this modeling is to represent the larger temporal and spatial scale trends. This is noted through comparison with the measured data, which was taken on a four to six week time step.

The long term trends in salinity are well captured by the model. Salinity intrusion can reach as far upstream as the Fish Camp location, RK 4.0 (RM 2.6) (Figures 6 and 7). The estuarine remains stratified most of the time as noted at the Henderson River confluence, RK 1.0 (RM 0.6) and mouth of the Fenholloway River, RK 0.0 (RM 0.0). The water column is well mixed at the nearshore location by the oyster bars.

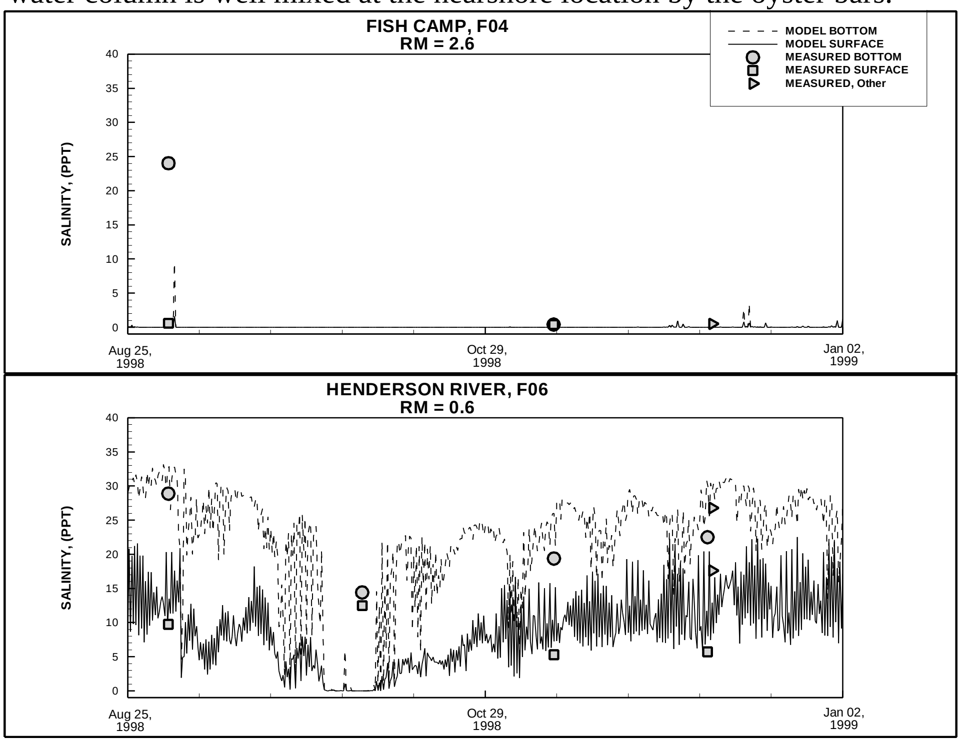

Figure 6. Salinity Time Series for Fish Camp and Henderson River.

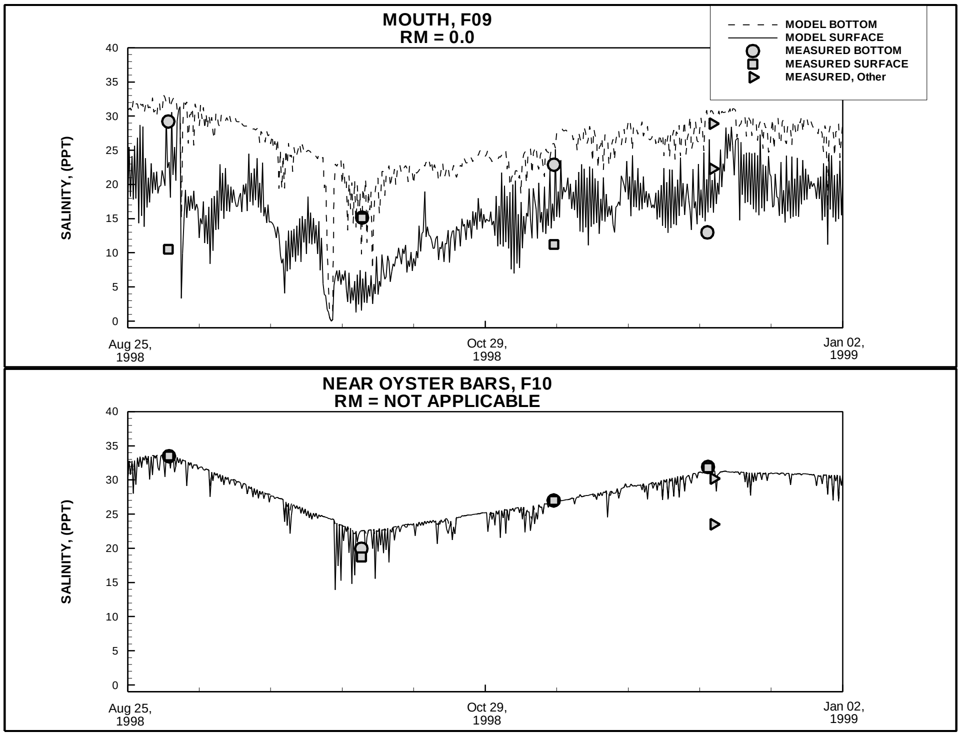

Figure 7. Salinity Time Series for the Mouth and Near Oyster Bars.

The temperature in the model runs compares well to the measured data (Figures 8 through 10). The cooling trend measured in the Fall/Winter months is shown in the model results. The riverine and nearshore portion of the system are well mixed with respect to temperature. The temperature stratification in the estuarine portion is notable, however, not too large.

Color time series data are presented in Figures 11 through 13. The effluent color concentrations are shown on all six figures for comparison. As in temperature, the color time series plots show that the riverine and nearshore portions are well mixed. The estuarine portion is stratified most of the time.

Figures 12 and 13, the Henderson River and Mouth locations, show the modeled data comparing well with the measured data. The stratification and destratification of the modeled data are within the range of the measured data. A tropical depression passed though the area during the end of September causing significant fresh water flows through the system and large destratification. This is most noted in Figure 12, the Henderson River location.

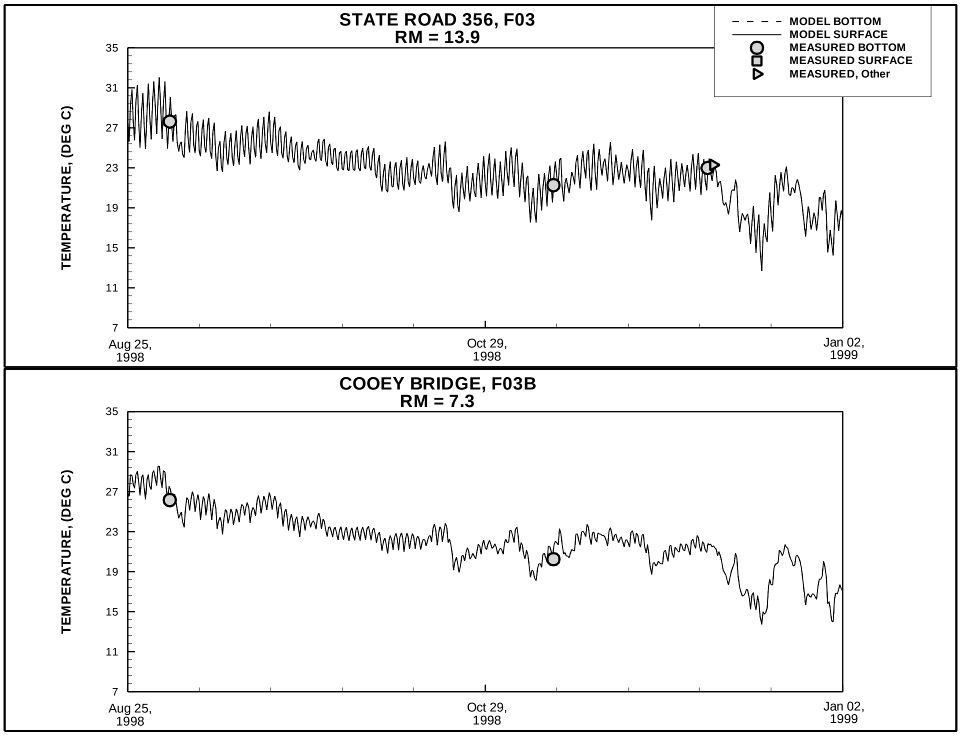

Figure 8. Temperature Time Series for State Road 356 and Cooey Bridge.

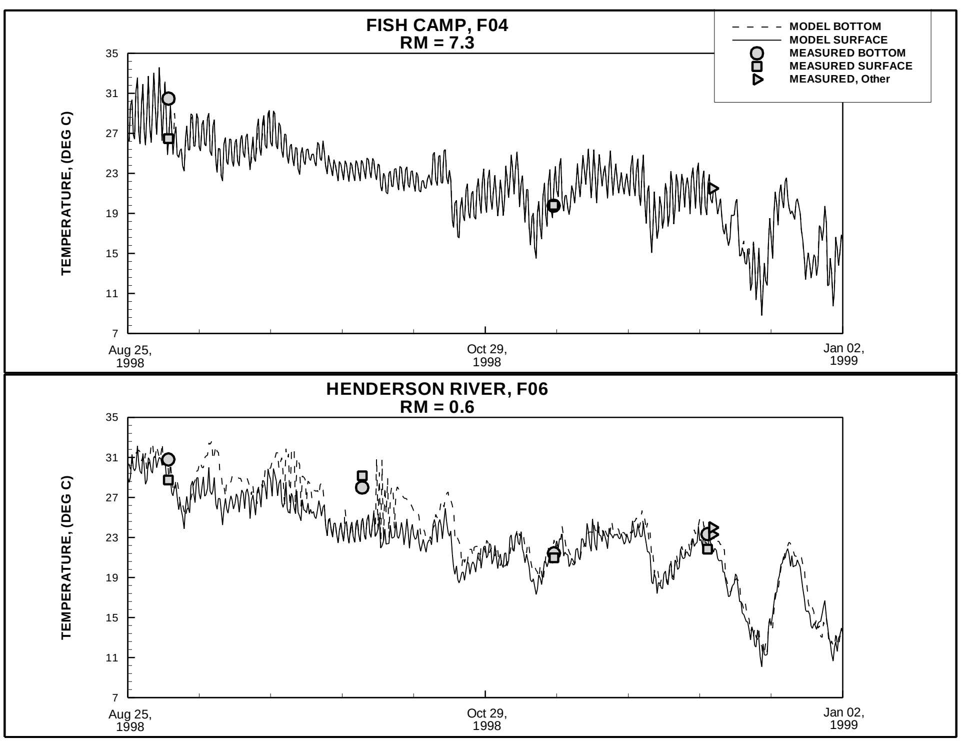

Figure 9. Temperature Time Series for Fish Camp and Henderson River.

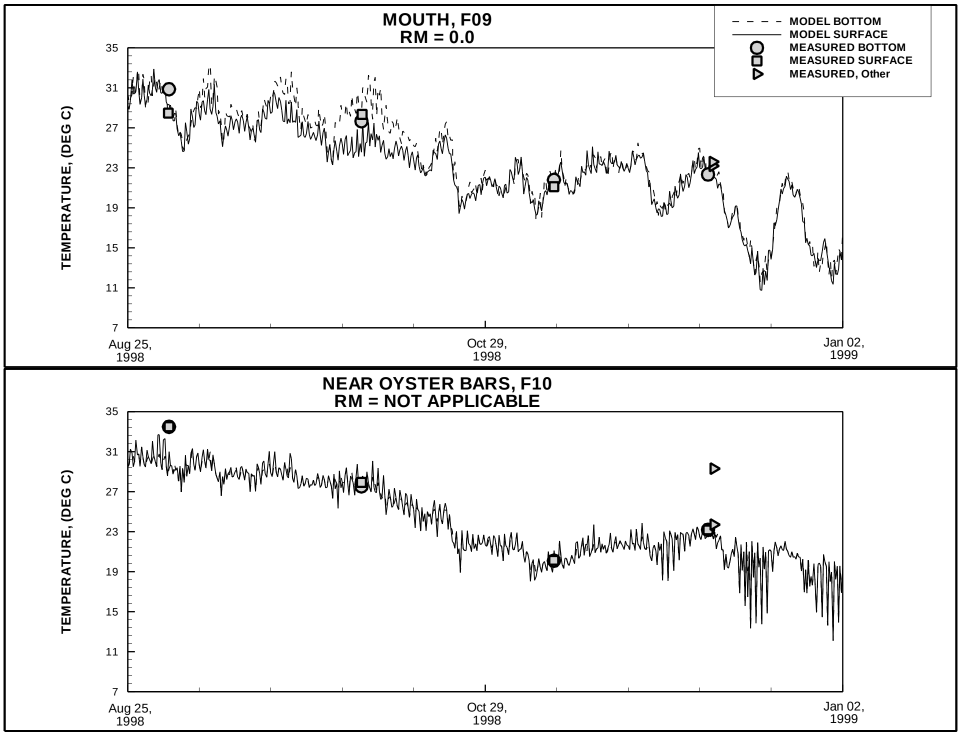

Figure 10. Temperature Time Series for the Mouth and Near Oyster Bars.

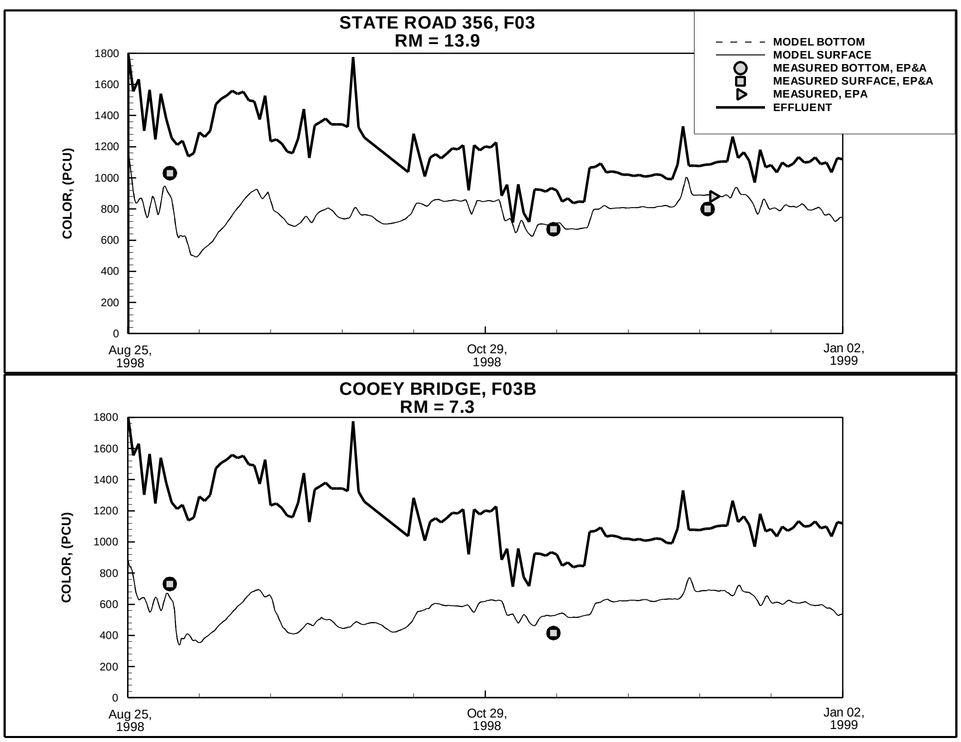

Figure 11. Color Time Series for State Road 356 and Cooey Bridge.

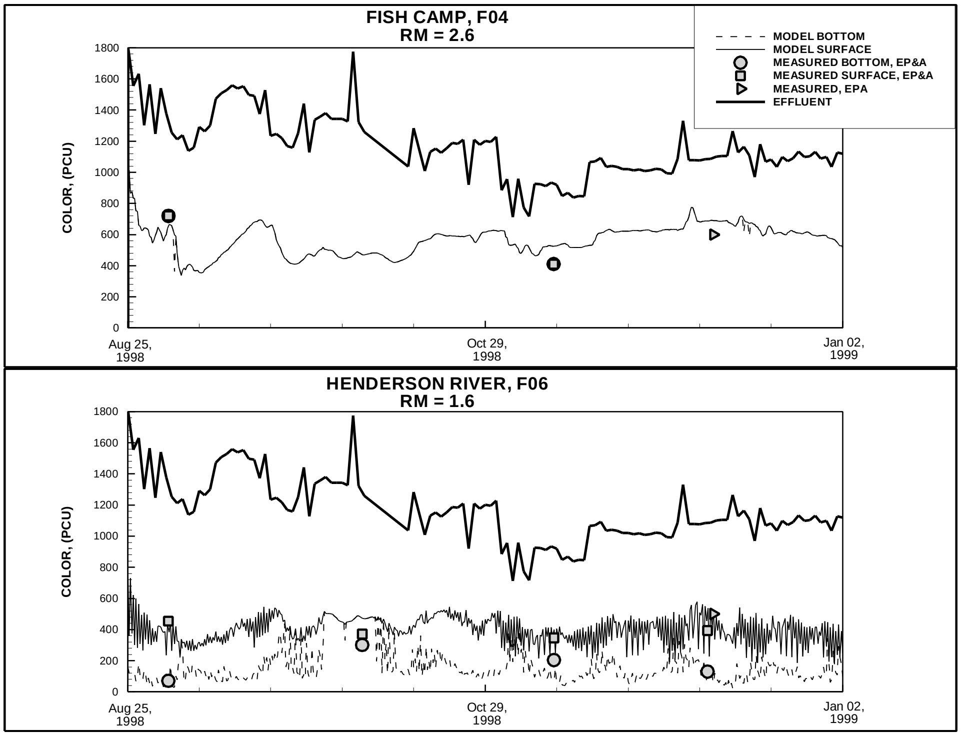

Figure 12. Color Time Series for Fish Camp and Henderson River.

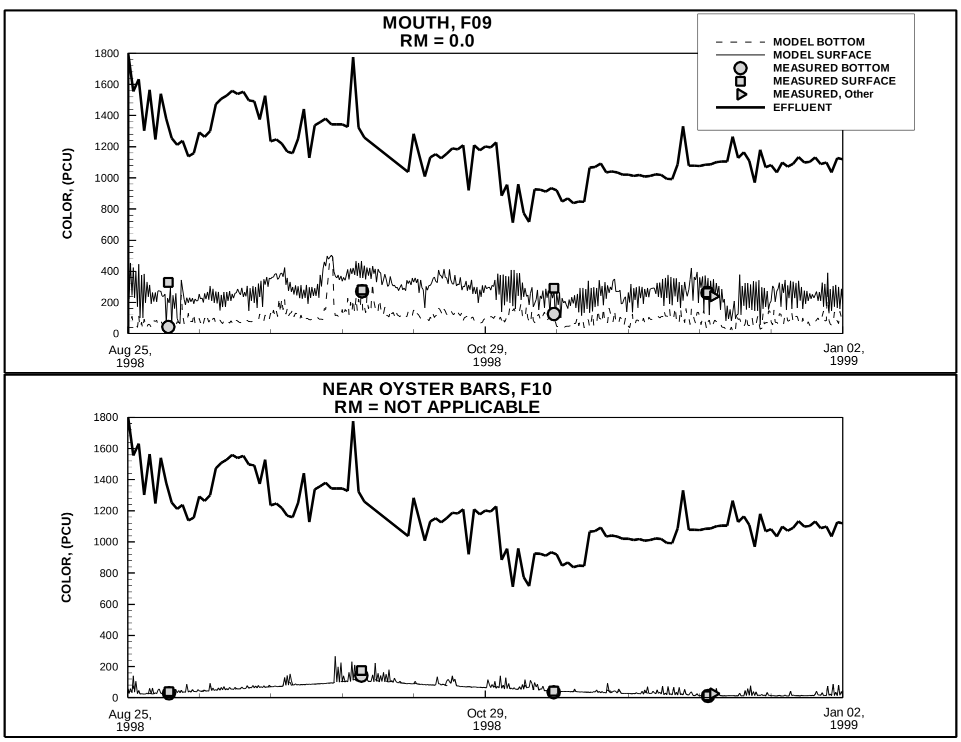

Figure 13. Color Time Series for the Mouth and Near Oyster Bars.

CONCLUSION

The model represents long term temporal and spatial color trends well. From the comparison with the measured data, the assumption of modeling color as a conservative substance is valid. The detail of the two- and three-dimensional grid resulted in representative simulation and stratification of the estuarine system. This is noted in the time series comparisons for salinity and temperature. The use of a dynamic model to evaluate color, among other constituents, provides utility in the TMDL development process. The use of a dynamic model enables the representation of the physical processes affecting the system.

ACKNOWLEDGMENTS

The authors would like to thank USEPA R4, USGS, FDEP, SRWMD, HydroQual Inc., and Buckeye Technologies, Inc. for their support.

REFERENCES

Environmental Planning & Analysis, Inc. (EP&A), (1998). "Study of the Fenholloway Estuary and Nearshore Receiving Waters." Environmental Planning & Analysis, Inc. (EP&A). Tallahassee, FL.

Environmental Planning & Analysis, Inc. (EP&A), (2000). "Two-Year Interim Report on the effects of Color Reduction on the Fenholloway River Coastal Reciving Waters." Environmental Planning & Analysis, Inc. (EP&A). Tallahassee, FL.

Environmental Protection Agency (EPA), (1992). "Fenholloway Nutrient Study: Perry, FL, Dec. 1998 - Sept. 1999." Environmental Protection Agency (EPA). Atlanta, GA.

Environmental Services Division, (1989). "Water Quality and Biological Assessment, Fenholloway River Near Perry, Florida." Environmental Protection Agency (EPA). Athens, GA.

Florida Department of Environmental Protection (FDEP), (1994). "Use Attainability Analysis Fenholloway River." Florida Department of Environmental Protection (FDEP). Tallahassee, FL.

Hamrick, J.M., (1996). "User's Manual for the Environmental Fluid Dynamics Computer Code." Virgina Institute of Marine Science, The College of William and Mary. Gloucester Point, VA.

Hydroscience, Inc., (1975). "Review of Fenholloway River's Water Quality – 1975." Hydroscience, Inc. Westwood, NJ.

HydroQual, Inc., (1993). "Water Quality Analysis of the Fenholloway River, Estuary and Adjacent Gulf of Mexico." HydroQual, Inc. Mahwah, NJ.

HydroQual, Inc., (1994). "Mixing Zone Analysis for the proposed Buckeye Discharge to the Fenholloway Estuary." HydroQual, Inc. Mahwah, NJ.

Lee, P.A. and Passehl, J., (1995). "Delineation of Ground and Surface Water Areas Potentially Impacted by an Industrial Discharge to the Fenholloway River of Taylor County, Florida." Florida Department of Environmental Protection (FDEP). Tallahassee, FL.

Smook, G.A., (1992). "Second Edition: Handbook for Pulp & Paper Technologists." Angus Wilde Publications. Bellingham, WA.

Watts, G.B. and Riotte, W., (1991). "Procter and Gamble Cellulose, Perry, Taylor County." Ground Water Investigation Report Number 91-05, Florida Department of Environmental Regulation. Tallahassee, FL.