EVALUATION OF PHILLIPPI CREEK DRAFT HYDRODYNAMIC AND WATER QUALITY MODELING REPORT

Prepared for:

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1.0 INTRODUCTION

As required by Section 303(d) of the Federal Clean Water Act, the Florida Department of Environmental Protection (FDEP) has established criteria for evaluating water quality throughout Florida using a waterbody classification system and water quality standards for a host of water quality constituents (Florida Administrative Code (FAC) Chapter 62-302.530). The FDEP compiles surface water quality data collected throughout Florida using its STORET database. Each waterbody has been assigned a Waterbody Identification (WBID) and the data within the WBID are used to assess water quality impairment under the Impaired Waters Rule (IWR) (Florida Administrative Code (FAC) Chapter 62-302.530).

Phillippi Creek WBID 1937 is included on the 303(d) list of impaired waters, with impairments for low dissolved oxygen (DO) excess nutrients, and fecal coliform bacteria. After assessing the water quality data available, the U.S. Environmental Protection Agency (USEPA) is responsible for determining the Total Maximum Daily Loads (TMDLs) for Phillippi Creek, WBID 1937.

A TMDL is a scientific determination of the maximum amount of a given pollutant that a surface water body can assimilate and still meet its given water quality standards. The basic steps in the TMDL program are as follows:

1. Assess the quality of surface waters--are they meeting water quality standards?
2. Determine which waters are impaired--that is, which ones are not meeting water quality standards for a particular pollutant or pollutants.
3. Establish and adopt, by rule, a TMDL for each impaired waterbody for the pollutants of concern--the ones causing the water quality problems.
4. Develop, with extensive local stakeholder input, a Basin Management Action Plan (BMAP) that summarizes what actions will be taken by whom to correct impairments.
5. Implement the strategies and actions in the BMAP.
6. Measure the effectiveness of the BMAP, both continuously at the local level and through a formal re-evaluation every five years.
7. Change the plan and actions if things aren't working.
8. Reassess the quality of surface waters periodically.

2.0 SUMMARY OF PROPOSED TMDLS

Proposed TMDLs for DO, nutrients, and fecal coliforms were published for Phillippi Creek (WBID 1937) in September 2009 (USEPA, 2009a). The proposed TMDLs for DO and nutrients are stated as percentage reductions in loadings of total nitrogen (TN), total phosphorus (TP), and biochemical oxygen demand (BOD). The proposed reductions of 70% in loadings of these constituents are based on the reductions deemed necessary to maintain DO levels in the WBID above 5.0 mg/L at all times (USEPA, 2009a). This DO concentration minimum is that provided in the State of Florida's water quality criteria, which require that in no case shall the concentration of DO be less than 5 mg/L in freshwater streams. The basis for the percentage reductions is a hydrodynamic model and a water quality model of Phillippi Creek developed by USEPA (2009b). The models were used to relate DO to nutrient and BOD loads.

3.0 REVIEW OF HYDRODYNAMIC AND WATER QUALITY MODELS

This section provides a review of the hydrodynamic and water quality models developed by USEPA and utilized to set the TMDLs for DO and nutrients in Phillippi Creek WBID 1937. This includes discussion of the appropriateness of the model construct, discussion of the model calibration, and appropriateness of using the models to set loadings necessary for attaining DO targets.

3.1 Hydrodynamic Model

The hydrodynamic model DYNHYD was used to simulate transport and water surface elevation in a one-dimension construct (along the flow axis) of the Phillippi Creek system. Upstream and downstream boundary conditions of flows and water surface elevations, respectively, and flows to the system between the upstream and downstream boundary were provided as input. The model was run for the period January 2006 through December 2007, using best available data as input to represent real-world conditions, for calibration.

Observed water surface elevations from the NOAA Port Manatee site were used as the downstream boundary condition at the mouth of Phillippi Creek at Roberts Bay. Upstream inflow boundary conditions were based on gaged flows at USGS gage 02299780 and at Sarasota County station PH-5. Flows to the system between the upstream and downstream boundaries were from Sarasota County's SIMPLE model (USEPA, 2009b). The model utilized channel cross-section data from the Sarasota County ICPR hydrodynamic model, with bottom elevations from -1.4 m to 1.1 m NGVD (USEPA, 2009b).

The water surface, flow, and bathymetric data as boundary conditions and forcing functions for the model construct appear appropriate for the system. However, a one-dimensional model of the creek, with no vertical differences in flows, may not be the most appropriate model to adequately represent the dynamics of the system, especially in tidal areas. Density stratification is often found in tidal areas where freshwater inflows occur, resulting in typical estuarine circulation patterns of denser saltier water moving upstream in the lower water column and less dense fresher water moving downstream in the upper water column. If the combined hydrodynamic and water quality models were to be used to examine the system in the area downstream of the freshwater/saltwater interface, or in any area where vertical density differences exist, this could be problematic in simulating conditions comparable to those observed.

The calibration objectives for the hydrodynamic model were to "…adequately represent the physics of the system by propagating momentum and energy based upon freshwater inflow, and the downstream tidal water surface elevation" (USEPA, 2009a). However, no quantitative calibration criteria were provided, and no quantitative analyses of the relationships between predicted and observed water surface elevations or flows in the system were presented. Time series plots of observed and predicted hourly elevations over the entire two year period were provided for the mouth of Phillippi Creek, where the downstream elevation boundary was applied, and for two additional locations in the creek.

Calibration statistics are typically expected to be presented as assurance that a model is reproducing observed responses to observed forcing conditions (i.e., winds, tides, freshwater inflows). No calibration statistics are provided for the hydrodynamic model. Appropriate calibration statistics, such as Root Mean Square Error, Mean Error, Relative Error, Absolute Mean Error, and r^2 relationships, should be provided for the hydrodynamic model water elevation and streamflow output. Additionally, plots of predicted versus observed values, and plots of residuals, would allow examination of potential biases in predictions. None of these quantitative calibration evaluations were completed for the hydrodynamic model, so that the status of the calibration cannot be evaluated.

3.2 Water Quality Model

The water quality model is an application of the Water Quality Analysis Simulation Program version 7 (WASP7) model. This model receives input from the DYNHYD hydrodynamic model for transport and water volumes, and simulates BOD, nutrients, algae, and DO. The model receives loadings of water quality constituents from the watershed, from Sarasota County's SIMPLE model, except for DO loads, which were estimated as 80 percent of saturation concentration. Meteorological conditions and temperature and salinity boundary conditions were provided to the WASP7 application as forcing functions as well.

One primary assumption influencing the water quality model construct was that observed low DO values in the system are a product of high algal production and respiration, despite water quality measurements of low BOD at or near detection limits, relatively low TN of 1.1 mg/L, and low chlorophyll-a values of 2.4 µg/L (USEPA, 2009b). The authors state that

> "Due to the lack of SOD [sediment oxygen demand] measurements, reaeration measurements, aquatic macrophyte and periphyton measurements the approach for developing this TMDL is based primarily on the water chemistry data and the evidence of low reaeration, high detrital loading, strong photosynthetic activity, and strong SOD" (USEPA, 2009b).

A statement is made that the greatest consumption of water column DO is through SOD, although no data are provided to support this.

The model does not contain vertical resolution, with the water column assumed to be well-mixed throughout. Vertical differences in water quality constituents in the real world are likely, given the varying sources of oxygen demand and production that are found between the surface and the bottom of the water column. Oxygen production during the daylight period is typically near the surface, and oxygen demand is nearer the bottom, where SOD exists. A vertically resolved model construct is likely more appropriate for simulating water quality dynamics in this system. However, no information is provided as to where in the water column the water quality samples were collected with which the model output was compared, so that the usefulness of a vertically resolved model construct cannot be determined.

The water quality model is parameterized with SOD and reaeration rates that yield DO values below 4 mg/L during some portion of the 1996-2007 time period in some portions of Phillippi Creek. The stated objective of the model is "…to demonstrate that this set of models adequately predicts water quality in the Phillippi Creek tidal river system…" (USEPA, 2009b). However, as for the hydrodynamic model, no quantitative calibration criteria were provided, and no quantitative analyses of the relationships between predicted and observed water quality constituents in the system are presented. Time series plots of observed and predicted DO, nitrogen species, and phosphorus species were provided for a site near Bee Ridge Road, and of oxygen demand for a site near the bridge on Fruitville Road.

The authors state that the "…model predicts each of these nutrient parameters well" (USEPA, 2009b), based solely on the time series plots provided, it appears, but do not provide any quantitative analysis of the calibration results. Examination of the time series plots provided does not provide assurance that the model is accurately simulating the water quality in the system, but rather that the model does not do a good job of simulating water quality. Examination of the time series plots provided do not provide assurance that the model predicts observed conditions during the 2006-2007 period, for any of the constituents examined. Appropriate calibration criteria should be selected that would allow discernment of responses to changes in forcing functions commensurate with the changes in response functions (water quality constituents) necessary to meet water quality rule requirements. Additionally, rather that the selected water quality sites where time series comparisons were presented for observed and predicted water quality, predictions for each of the 51 segments of the water quality model should be compared to existing water quality data as appropriate to evaluate the calibration. Comparisons of algal biomass predictions to observed data should also be made to aid in calibration.

Calibration statistics are typically expected to be presented as assurance that a model is reproducing observed responses to observed forcing conditions (i.e., nutrient loads, transport, oxygen demand, reaeration). No calibration statistics are provided for the water quality model. Appropriate calibration statistics, such as Root Mean Square Error, Mean Error, Relative Error, Absolute Mean Error, and r^2 relationships, should be provided for the water quality model constituents. Additionally, plots of predicted versus observed values, and plots of residuals, would allow examination of potential biases in predictions. None of these quantitative calibration evaluations were completed for the water quality model, so that the status of the calibration cannot be evaluated.

4.0 Conclusions

The proposed DO and nutrient TMDLs developed by USEPA in Phillippi Creek WBOD 1937 are based on a hydrodynamic and water quality model suite which indicates that 70% reductions in loadings of TN, TP, and BOD are necessary to achieve water quality standards with respect to DO. The model used to arrive at these reductions does not appear to be calibrated to correctly relate loadings to water quality in the system, although no calibration criteria or calibration statistical analyses for the hydrodynamic model or the water quality model are provided.

Loadings reductions of this magnitude are likely to be costly to achieve, in terms of both time and money. Prior to promulgating such reductions, there is a responsibility to ensure that the reductions are based on best available knowledge of the system. The model suite employed for this effort, and used to arrive at the proposed reductions, does not appear to be capable in its current state of simulating observed conditions given observed input data for forcing functions. This should be rectified before utilizing the model suite to examine loading reductions necessary to meet water quality standards.

5.0 References

United States Environmental Protection Agency (USEPA) 2009a. Proposed Total Maximum Daily Loads for Dissolved Oxygen, Nutrients and Fecal Coliforms in Phillippi Creek (WBID 1937).

United States Environmental Protection Agency (USEPA) 2009b. DRAFT Phillippi Creek: One Dimensional Hydrodynamic and Water Quality Modeling Report.