

FINAL REPORT:

**THE DETERMINATION OF MINIMUM FLOWS FOR SULPHUR
SPRINGS, TAMPA, FLORIDA**

To:

Southwest Florida Water Management District
2379 Broad Street
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By:

SCIENTIFIC REVIEW PANEL

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The Determination of Minimum Flows for Sulphur Springs, Tampa, Florida

Scientific Review Panel Report

EXECUTIVE SUMMARY

The Southwest Florida Water Management District has created a draft minimum flows report for Sulphur Springs (draft date September 28, 2004). The District has decided to voluntarily request a peer review of the report entitled, "The Determination of Minimum Flows for Sulphur Springs, Tampa, Florida." A voluntary request means the review is facilitated solely by District staff. As this is not a legal process, the District staff is free to have open discussions with the review panel regarding the analyses and conclusions in the report. The review panel is comprised of chairman Dr. Paul Montagna, a marine ecologist from the University of Texas Marine Science Institute in Port Aransas, Texas who has experience with Sulphur Springs and the Lower Hillsborough River system; member Dr. Raymond Walton, a expert in hydrodynamic modeling from WEST Consultants in Bellevue Washington; and Dr. Bjorn Tunberg, a marine ecologist with the Smithsonian Marine Station in Fort. Pierce, Florida. This report has been generated by electronic correspondence among panel members and is a combined, synthesized report.

Sulphur Springs is an extremely disturbed, and manipulated artesian spring. The water quality of this spring has obviously deteriorated significantly over the past decades due to increased urbanization of this, and surrounding, areas. The disturbance to the spring has compromised the spring's ability to provide riparian habitat. Sulphur Springs now consists of an artificial and complicated system of concrete enclosures, barriers, pumps, pipes and valves, extremely far from natural conditions. Regardless, the law requires a minimum flow and level rule for this ecosystem, and every habitat is important for wildlife and is worth managing for maximum ecological benefit.

The approach to determining the minimum flow was to examine the relationship of inflow from Sulphur Springs to the salinity regime of the lower river, particularly as to how it maintains the ecology of the 500-ft. long spring run. Studies showed that excessive withdrawals from the spring pool can cause brackish water, 10 - 16 parts per thousand (ppt), from the lower river to migrate into the spring run. Biological studies showed that increasing salinity during low-flow periods has had a substantial impact on the composition and quantity of biological communities in the spring run and downstream. The ecological indicators of this effect are effects on the benthic macroinvertebrate community, which is comprised of a freshwater/oligohaline assemblage. The effects on biological communities of other potential stressors, especially low dissolved oxygen, must be separated from flow effects in future studies. However, the data presented indicates that communities during drought periods are substantially different from the communities found during higher flow periods.

Hydrological effects were studies with two numerical models. The model, LAMFE, was applied to simulate hydrodynamics and salinity, and the model, CE-QUAL-W2 was applied to hydrodynamics and water temperature. The theoretical development of LAMFE appears sound, the governing equations appear appropriate, and the few verification simulations compared to

analytical solutions show that the program functions as designed. The model seems to simulate water surface elevations acceptably. However, this is the easiest variable to match, and no comparisons with observed velocities were reported. The thermal effect of the spring discharge on the lower river was also evaluated using CE-QUAL-W2 for purposes of providing a thermal refuge for manatees during cold winter periods. During the coldest periods, when temperature drops below 15 °C, it is necessary to maintain a spring flow of 18 cfs to maintain temperature within a 2 °C change as recommended by FRMI.

The conclusions and recommendations of the report have been reached after an impressive, high quality and diversified study of the Sulphur Springs system. Implementing these recommendations should improve the ecology of the spring run and benefit the Hillsborough River system significantly.

The review panel makes the following recommendations. Additional monitoring should be performed after the rule is adopted to ensure management goals are met. Abiotic monitoring should focus on continuous measurements of flow, salinity, temperature, and dissolved oxygen. Biotic monitoring should continue to focus on benthic macroinvertebrates, but care should be taken to use standard methods in all sampling events and sample during similar seasonal conditions from year-to-year. Future modeling efforts should focus on developing and applying the CE-QUAL-W2 model, because it is more broadly accepted and it can model branched systems, and therefore could be easily extended to include the Spring Run in the model.

The Determination of Minimum Flows for Sulphur Springs, Tampa, Florida

Scientific Review Panel Report

INTRODUCTION

The Southwest Florida Water Management District (the District) is currently involved in the development of methods and rules for the establishment and implementation of minimum flows and levels (MFLs) for certain priority water bodies of the District, and is undertaking such effort as required by Sections 373.042 and 373.0421 of the Florida Statutes.

Chapter 373, Florida Statutes, directs the District to annually update a list of priority water bodies for which MFLs are to be established and to identify which water bodies the District will voluntarily undertake independent scientific peer review. Section 373.042 of the law provides that:

1. A minimum flow is the flow of a watercourse below which further water withdrawals will cause significant harm to the water resources or ecology of the area.
2. A minimum level is the level of water in an aquifer or surface water body at which further water withdrawals will cause significant harm to the water resources of the area.

The law also provides that MFLs shall be calculated using the best available information, that the Governing Board shall consider and may provide for nonconsumptive uses in the establishment of MFLs, and when appropriate, MFLs may be calculated to reflect seasonal variation. Revised in 1997, the law currently requires that when establishing MFLs, changes and structural alterations to watersheds, surface waters and aquifers shall also be considered (Section 373.0421, Florida Statutes). Current State Water Policy (Chapter 62-40, Florida Administrative Code) includes additional guidance for the establishment of MFLs, providing that “. . . consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows and levels, and environmental values associated with coastal, estuarine, aquatic, and wetland ecology, including:

- (a) Recreation, in and on the water;
- (b) Fish and wildlife habitats and the passage of fish;
- (c) Estuarine resources;
- (d) Transfer of detrital material;
- (e) Maintenance of freshwater storage and supply;
- (f) Aesthetic and scenic attributes;
- (g) Filtration and absorption of nutrients and other pollutants;
- (h) Sediment loads;
- (i) Water quality; and
- (j) Navigation.”

In October 1998, the District Governing Board approved a MFLs Rule (Chapter 40D-8, Florida Administrative Code) that included methodologies used to establish minimum levels in 15 lakes, 41 wetlands, and 7 wells in the Upper Floridan aquifer for saltwater intrusion in the northern Tampa Bay area. Following adoption of the rule, an independent scientific peer review of the

data and methods used to establish these levels was requested by Hillsborough County, Tampa Bay Water, and the Environmental Confederation of Southwest Florida. In accordance with statutory guidelines (Section 373.042, Florida Statutes), an independent scientific Peer Review Panel was assembled by the District and the requesters for this purpose. In their final report¹, which was submitted to the Governing Board in August 1999, the panel noted that “. . . the methodologies proposed by the District for the establishment of Minimum Levels are generally sound and reasonable.” Since this process, the District has committed to “voluntary” independent scientific peer review of its methodologies and MFLs.

The District empaneled an independent scientific peer review of methods used in the establishment of MFLs for Sulphur Springs. The peer review panel was given four charges:

1. Review the draft District document, entitled “The Determination of Minimum Flows for Sulphur Springs, Florida.”
2. Review, as appropriate, documents and other materials supporting the concepts and data presented in the draft District document.
3. Participate in an open (public) meeting at the District’s Tampa Service Office (or another site specified by the District) for the purpose of developing a written report as described in charge number 4 below.
4. By November 4, 2004, provide to the District, a written report that includes a review of the data, methodologies, analyses, and conclusions outlined in the document.

In conducting the review, the review panelists were asked to complete three tasks, and include responses or comments on each task in the written report as appropriate.

TASK 1. Determine whether the conclusions in the report are supported by the analyses presented.

TASK 2. If a proposed method is not scientifically reasonable, the panel should list and describe scientific deficiencies and, if possible, evaluate the error associated with the deficiencies; determine if the identified deficiencies can be remedied; describe the necessary remedies; or identify one or more alternative methods that are scientifically reasonable.

TASK 3. If a given method or analyses is scientifically reasonable, but an alternative method is preferable, the review panel should list and describe the method(s), and include a qualitative assessment of the effort required to collect data necessary for implementation of the alternative method(s).

¹ Bedient, P., Brinson, M., Dierberg, F. Gorelick, S., Jenkins, K., Ross, D., Wagner, K., and Stephenson, D. 1999. Report of the Scientific Peer Review Panel on the data, theories, and methodologies supporting the Minimum Flows and Levels Rule for the northern Tampa Bay area, Florida. Prepared for Southwest Florida Water Management District, Environmental Confederation of Southwest Florida, Hillsborough County and Tampa Bay Water.

BACKGROUND

Sulphur Springs is an artesian spring that lies within a small park in a highly urbanized setting in Tampa, Florida. The average flow of Sulphur Springs over the last 20 years is 34 cubic feet per second (cfs) or 22 million gallons per day (mgd). Sulphur Springs has been used to augment the City of Tampa's water supplies in the Hillsborough River Reservoir since the 1960's. The mineral content of Sulphur Springs has been increasing since the 1970's and it currently exceeds the potable water standards for several constituents. During water shortages, spring water can be blended with large volumes of reservoir water for limited periods of time. Withdrawals from the spring have been used only 11 percent of the days since 1991.

Sulphur Springs provides flows of low-salinity water that support downstream biological communities in the spring run and the Lower Hillsborough River. Prior to 2001, periodic withdrawals had a major effect on flows from the spring because the City's water pump operates at a rate (19.7 mgd), which is nearly as great as the average spring flow. Consequently, during periods of withdrawal, spring flows could be, or were, near zero. In 2001, the City modified the diversion facilities so that variable amounts of water could be diverted from Sulphur Springs. These modifications were part of a minimum flow rule, which requires 10 cfs (6.5 mgd) from Sulphur Springs be diverted to the base of the dam to meet minimum flows for the Lower Hillsborough River. The City now has the capability to simultaneously divert variable amounts of spring water into the reservoir, to the base of the dam, and to the spring run.

Using the modified diversion facilities, the District conducted experimental flow tests to examine downstream effects of a range of flows from the spring pool. Based on observed relationships between flows for the spring and ecological characteristics of the spring run and the lower river, the District established three management goals:

- Goal 1. Minimize the incursion of brackish water from the lower Hillsborough River into the upper spring run.
- Goal 2. Maintain low salinity habitats in the Lower Hillsborough River.
- Goal 3. Maintain a thermal refuge for manatees in the Lower Hillsborough River during cold winter months.

To meet these goals, the District proposes a minimum flow for Sulphur Springs of 18 cfs. The flow recommendation is based on flow tests that indicated the abundance and diversity of benthic macroinvertebrates in the upper spring run would be protected from incursion of high salinity water from the lower river at spring flows of 18 cfs. During water shortages, when the water level is 19 feet in the Hillsborough River Reservoir, the flow can be reduced to 13 cfs, which will result in brief salt water incursions during high tide. Because salinity incursions are tidally driven, the spring flow can be reduced to 10 cfs during low tide stages. This "18/13/10 cfs" minimum flow recommendation would be within acceptable limits to prevent significant harm.

REVIEW

Setting minimum flow rules requires several steps: 1) setting appropriate management goals; 2) identifying indicators to measure characteristics that can be mechanistically linked to the management goals; 3) reviewing existing data and collecting new data on the indicators; and 4) assembling conceptual, qualitative, and quantitative models to predict behavior of the indicators under varying flow regimes. The first two steps identified above represent the overall technical approach to setting the minimum flow rule. So, the first step in this review is to determine if the overall approach is sound by reviewing goals and indicators.

The District has three good, strong management goals for Sulphur Springs, which are stated above (Chapter 1). The goals were developed to address the needs of biological communities in the spring run and lower river. The purpose of Goal 1 is to protect macroinvertebrates communities in the upper spring run from adverse effects resulting from incursion of high salinity water from the Lower Hillsborough River during periods of low spring flow. The indicators for Goal 1 are frequency and duration of salinity incursions in the upper spring run. The purpose of Goal 2 is to provide a salinity gradient in the lower river that includes low salinity habitats to support diversity of characteristic plant, invertebrate and fish populations in that part of the ecosystem. The indicators for Goal 2 are volumes of water in the lower river with salinities less than 4 parts per thousand (ppt) and less than 11 ppt. The purpose of Goal 3 is to protect an endangered marine mammal that is stressed by cold water temperatures. The indicator for Goal 3 is to maintain the temperature changes within a thermal refuge to less than two degrees Celsius. The water flow indicators for these three goals are sound.

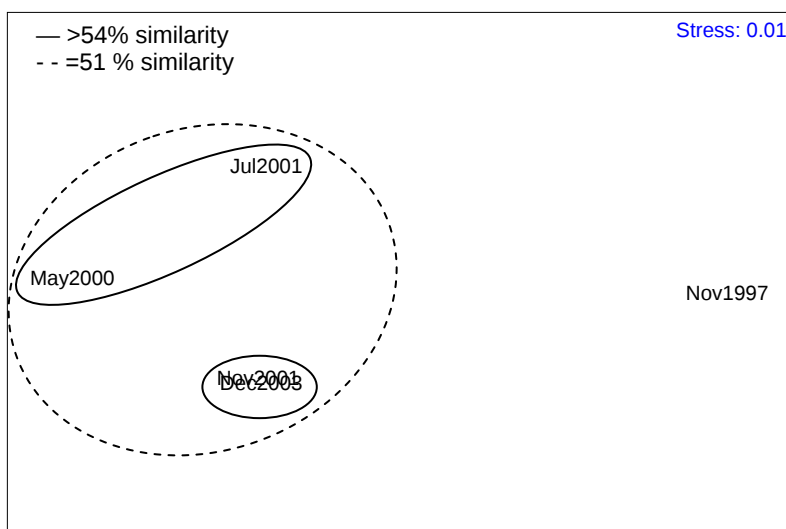
The next step is to review existing data (Chapters 2 and 3). The District is fortunate in that a very large database on flows, water quality, and biological communities exists. District staff has done an excellent job of reducing and presenting data. One of the most important findings is that salinity increases in the spring run when pumping rates are increased, thus a minimum flow rule would provide environmental benefit and protection.

Biological Characterization

Biological results are based on five qualitative and quantitative sampling events performed by WAR/SDI and HBMP. It is clear that the spring has a substantial impact on the composition and quantity of biological communities in the spring run and downstream.

A good way to analyze community composition over a sampling design is to perform multivariate analysis. This is true for both macrofauna and fish. There are many different multivariate approaches, but one of the easiest to interpret, and most accepted approach, is to perform non-parametric multidimensional scaling (MDS) and cluster analysis (Clarke and Warkwick, 2001), and one good software package for these kinds of analyses is Primer (Clarke and Gorley, 2001). The software creates a Bray-Curtis similarity matrix among all samples and then an MDS plot of the spatial relationship among the samples. A cluster analysis can be used to draw circles around samples in the MDS plot that are most alike at some specific level of similarity. Data can be transformed prior to analysis. The most severe transformation is presence or absence, which is exactly as the data appears in Appendix B. An analysis of data in Appendix B was run and is presented below.

Sulphur Springs Macrofauna



The discussion of macrofaunal changes in the text (Section 3.7.3) is based on simply comparing highlighted species. A statistical analysis is preferred, and the MDS approach provides a less subjective and more robust analysis. When this analysis is performed, the 1997 community structure (after a prolonged drought and period of withdrawal) was different from the other four sampling times, and shares only 38% similarity with samples collected after May 2000. However, November 2001 and December 2003 (occurring during high flow) are very similar (57%), and the May 2000 and the July 2001 samples (occurring during low flow) were also very similar (54%). All four of these sampling dates shared 51% of species in common. This discussion above is similar to that presented in the text (pages 3-21 through 3-22), but it adds some statistical certainty.

Macroinvertebrates are strongly influenced by dissolved oxygen (as well as a suite of other potential stressors). It is very unfortunate that no dissolved oxygen measurements were made in the spring run when the gates were open, and it was not known to what extent that discharge from the pool became oxygenated in the spring run. In spite of this lack of data, it is, according to the report, “reasonable to conclude that variations in the salinity in the spring run over the period of study was a major factor affecting the species composition and abundance of many invertebrate taxa in the spring run.” This is a reasonable conclusion if increased flow does increase downstream dissolved oxygen concentrations. However, this relationship deserves further study.

There are also four methodological issues with regard to the macroinvertebrate sampling and analyses as detailed below:

1. Specific national guidelines exist that should be used for the field and laboratory procedures: DEP-SOP-001/01 (Department of Environmental Protection Standard Operating Procedures for Field Activities), DEP-SOP-002/01 (Department of Environmental Protection Standard Operating Procedures for Laboratory Activities) and DEP-QA-001/01 (New and Alternative Analytical Laboratory Methods). In those cases

where national guidelines may be missing, international standards established by e.g. ICES (International Council for the Exploration of the Sea) may be used. Apparently these standards have not been used for all the procedures within these studies.

2. In the current study, 95% ethanol was used to preserve animals. Ethanol dehydrates the specimens. Usually 4% to 5% formalin should be used first to preserve the animals, and later the animals are transferred to 70% ethanol for long-term storage.

3. The FWC qualitative samples were examined under a stereo dissecting microscope using different magnifications (according to the description on page 3-14). This is definitely not an acceptable approach. All the samples should be examined using the same magnification (usually 6X magnification). SWFWMD and FDEP used a 600 micron mesh dip net for the 1997 program while FWC used a 900 micron dip net for the 2000, 2001 and 2003 programs, which must have confound the comparative analyses.

4. Quantitative samples were collected on three dates; 25 May 2000, 8 November 2001 and 9 December 2003. To avoid seasonal differences each sampling should have been performed during the same time of the year. The 25 May 2000 study is presented in detail in (Allen et al., 2001). It is unclear why a 300 micron mesh was used (instead of a 500 micron).

Hydrological Characterization

As part of the Minimum Flow study (SWFWMD, 2004), two numerical models were applied to the Lower Hillsborough River:

1. The model, LAMFE, was applied to simulate hydrodynamics and salinity, and
2. The model, CE-QUAL-W2 was applied to hydrodynamics and water temperature.

The Minimum Flow study report (SWFWMD, 2004), however, contains only brief descriptions of the models and their development, calibration and applications to the River. Therefore, to supplement this review, a number of supporting documents were requested and reviewed (Chen, 1999; 2003; 2004a, 2004b, 2004c; Chen et al., 2000; Montagna et al., 1999; Pribble et al., 2003; Pribble and Janicki, 2003; and SWFWMD 1999).

LAMFE is a two-dimensional, laterally averaged hydrodynamic and salinity transport model. It was developed by District Engineer, X.J. Chen beginning in 1999 (Chen, 1999; 2003; 2004a, 2004b, 2004c; Chen et al., 2000). It uses a finite-difference scheme, including a z-vertical layer system in which the vertical grid is a series of fixed horizontal lines. As far as we know, the model has not been used outside the District, but it was subject to an independent scientific peer review (Montagna et al., 1999).

CE-QUAL-W2 is also a two-dimensional, laterally-averaged z-grid model. It simulates hydrodynamics and water temperature, and also has the capability to simulate the transport, fate and interactions of a wide range of water quality constituents, including salinity, dissolved oxygen, nutrients and algal kinetics. Its development began in the 1970's, and through the Corps of Engineers' Waterways Experiment Station (WES), it has undergone significant continued

development (Cole and Wells, 2000), numerous applications and extensive peer review. It is probably the most widely-used 2-D laterally-averaged model in the world today.

Neither the Minimum Flow study report nor other supporting documents explain why the District chose to develop LAMFE, in 1999, rather than simply use the already well-known and widely-used model, CE-QUAL-W2. In hindsight, this decision is even more puzzling because the District then elected to use CE-QUAL-W2 to model temperature. The Minimum Flow study report (SWFWMD, 2004) also suggests that future effort in looking at minimum flows in the Lower Hillsborough River might have to also look at dissolved oxygen – and can nutrient dynamics (algal kinetics) be far behind? Given the future outlook, we would suggest that the District focus future modeling effort on developing and applying the CE-QUAL-W2 model. An added advantage of using CE-QUAL-W2, it that it can model branched systems, and therefore could be easily extended to include the Spring Run in the model.

Having said this, the theoretical development of LAMFE seems sound. The governing equations seem appropriate, and the few verification simulations compared to analytical solutions seem to show that the program functions as designed. It is not clear from the supporting documents (1) why LAMFE is superior to CE-QUAL-W2 (assuming this is why a “new” model was developed) and/or (2) what features (solution methods, for example) it contains that make it a better choice for the Lower Hillsborough River. Perhaps the best response would be by showing that it does a superior job simulating river hydrodynamics or salinity distributions. However, the few comparisons between model simulations and observations do not show an impressive fit to observed salinities. Indeed, there seem to be periods when the agreement is generally poor. For example, Figures 57 and 64 in Chen (2004c) and Figures B-8 and B-9 in Chen (1999), show periods of relatively poor agreement between the model results and observations. As the salinity results are not shown for the CE-QUAL-W2 application for comparison, it is difficult to know if this is due to a poor model setup, poor data, or some other explanation. The model seems to simulate water surface elevations acceptably. However, this is the easiest variable to match, and no comparisons with observed velocities were reported.

In the Minimum Flow study report, the extent and depth of the LAMFE modeling is very brief (Section 3.9.2.2) – which is why we had to review other documents for information. The description of the LAMFE model setup, calibration, and application should be given a similar amount of space in the report as the description of the CE-QUAL-W2 model (Section 5.5). In addition, it would be useful to include other calibration metrics, such as (1) scatter plots of observed versus modeled salinity, and (2) time histories of the observations and model results comparing the differences between top and bottom salinities.

While the CE-QUAL-W2 model was intended, and used, to simulate water temperatures, for Manatee refuge evaluations, the Minimum Flow study report implies that salinity was also simulated. For example, the report discusses that salinity data were used (page 5-42) and several figures (5-26 and 5-27) show adverse thermal gradients that could only be offset by salinity gradients. It would have been useful if Section 5.5 had also shown the resulting salinity distributions, and compared them to both observations and the results of the LAMFE model. If the results of the two models, for salinity, are different, it would raise questions about which model does a “better” job, why, and what are the implications to adequately and accurately simulate water temperatures?

The various supporting documents that describe the CE-QUAL-W2 modeling show very little model calibration (Pribble et al., 2003). So the question of how well the model simulates temperature, or salinity for that matter, is not clear. The reports show scatter plots of observed versus model results for water surface elevations and temperatures, but none for salinity. The scatter plots seem to suggest that water surface elevations are often under predicted (e.g., at Rowlett Park Drive) and that temperatures at Rowlett Park Drive are often over predicted. It would be very useful to include time-history plots to illustrate whether these differences are related to amplitude (values too high or low) or phase (timing). The report should include both scatter plots and time histories of salinity, as the accurate simulation of salinity can influence the accurate simulation of temperatures, and the resulting vertical stability and mixing in the water column.

Throughout the report, there is a frequent conflict between SI and US Customary Units. Examples are Figures 3-16 and 3-17 show “elevation” versus “river kilometers” (SI units); Figure 5-6 shows flows in “cfs” (US units), etc. We suggest the report either uses one consistent system of units, or uses one system with the other in parentheses.

The development and application of both models do not include a sensitivity analysis that might address:

- What is the sensitivity of the downstream boundary condition (salinity or temperature) on the upstream results? Indeed, the development and variability of this boundary condition is not clear from the reports. The analysis should at least demonstrate at what point in the river the results are not sensitive to the vertical profiles selected at the boundary.
- What is the sensitivity of the grid resolution? The analysis should demonstrate that changing the horizontal and/or vertical resolution does not significantly change the model results in the region of interest.
- There are many other model parameters, such as bottom friction, eddy viscosity, etc. that could be varied to evaluate sensitivity.

No uncertainty analysis was performed for either model study. Therefore, it is not clear how “precise” the salinity or temperature results are, or what is their possible variability. For example, if the threshold refuge temperature is 15°C , is a temperature of 16°C reliably different that it can be considered warmer than the threshold?

The application of CE-QUAL-W2 simulates only zero flow from the upstream dam. However, it might be useful to simulate a range of winter flows, with “cool” releases to determine under what conditions (spring discharges along the Spring Run, or is partially diverted to the base of the dam) warmer waters from the Spring might sufficiently heat dam releases to provide manatee refuge temperatures along the Lower Hillsborough River.

The relationship between dissolved oxygen (DO) and flow rates is not clear (Figs. 3-22 and 3-23). There are inconsistencies in the text and the descriptions of the figures do not always match the trend in data. This could be partly a result of the figures not be clearly labeled as to which represents flow events and which does not. In any case, if the left box is no flow and the right box is flow, it is pretty clear that low DO conditions are more common when there is flow, yet

the text section (p. 3-42) concludes “... improvement of DO during flow conditions ...” In fact, many studies in other areas have shown that DO temporarily decreases during flood events, because of inorganic and organic matter inputs being respired, and that, in general, respiration processes dominate photosynthesis processes during times of high flow. It would be expected that this would be especially true in an urban estuary, where inputs during rain events could be substantial. Although low DO is always considered impairment by some agencies, this is not necessarily true, because in this case it indicates the system is working normally. The inorganic and organic inputs are simply stimulating respiration. The important question is: how long does that last? It is possible that the long-term average of these processes is in equilibrium, meaning the net balance of DO does not lead to low DO concentrations. However, it is also possible that the system is net heterotrophic and prone to DO impairments. The analysis of DO trends presented is empirical and subject to data selection and subjective interpretation. There are better ways to deal with DO changes, and that is to use DO production-consumption models and nutrient or organic matter loading allocations.

Approach To Determining Minimum Flows (Chapter 4).

The approach incorporates several important assumptions. The pool is hydrologically isolated from run habitats, so the pool itself was not considered. Much of the spring run is hardened and no longer functions as viable riparian habitats. The pool provides a fairly consistent discharge, so seasonal flow regimes were not considered. In fact, seasonality in pool flow rates is caused by withdrawals. Some spring flow has been routed to the base of the Hillsborough River dam to supplement the minimum flows for the river. These assumptions are very important and all appear to be appropriate. The implication of these assumptions is that the main management concern is during periods when there are no flows to the lower river.

Management Goals and Recommended Rule (Chapter 5)

Given the above assumptions, it is important to develop management goals and quantitative indicators that can be used to assess success of the management program. The District established three management goals and identified ecological indicators that are consistent with the above assumptions:

Goal 1. Minimize the incursion of brackish water from the lower Hillsborough River into the upper spring run. This goal is based on the effects of droughts on the macrobenthic communities. Indicators are salinity values between 1 ppt and 3 ppt in the spring run.

Goal 2. Maintain low salinity habitats in the Lower Hillsborough River. This goal is based on the Tampa Bay National Estuary Program recommendations that the communities of the river would benefit by a gradient of salinities ranging from fresh to polyhaline. Thus, the indicator is to maintain a distribution and volume of water less than 4 ppt and less than 11 ppt to provide salinity zones to benefit the freshwater biota and nursery function of the estuary. Seasonality is incorporated into the goal.

Goal 3. Maintain a thermal refuge for manatees in the Lower Hillsborough River during cold winter months. The indicator is to maintain temperatures in a reach 50 m from the spring

that is not reduced more than 2 °C as a result of spring flow diversions when water temperatures range from 15 °C to 20 °C.

The minimum flow recommendation for Sulphur Springs is 18 cfs. The flow recommendation is based on a series of experimental withdrawals that indicated the abundance and diversity of benthic macroinvertebrates in the upper spring run would be protected from incursion of high salinity water from the lower river at spring flows of 18 cfs. During water shortages, when the water level is 19 feet in the Hillsborough River Reservoir, the flow is recommended to be reduced to 13 cfs, which will result in brief salt water incursions during high tide. Between 1988 and 2003, this would have occurred on a total of 297 days, or 5% of the time. Because salinity incursions are tidally driven, it is recommended that the spring flow could be reduced to 10 cfs during low tide stages. The 18/13/10 cfs minimum flow recommendation would be within acceptable limits to prevent significant harm to the environment. The recommendation is well justified by the data presented in the report and appears to be scientifically sound.

Hydrologically, The Hillsborough River is a stressed environment (Figure 3-9). Since 1970, there are a significant number of days each year when there is no flow in the river. Consequently, small supplemental flows from Sulphur Spring are very important. During these times Sulphur Spring provides in excess of 80% of the inflow to the lower river (Figure 3-11).

Future monitoring is required to ensure that the recommended minimum flow rule is meeting stated management goals. The District proposal to maintain continuous data recorders for salinity and temperature is sound, but dissolved oxygen should be added to the list. Increased biological sampling would also be required to determine if the biological communities were responding as predicted. Biotic monitoring should continue to focus on benthic macroinvertebrates, but care should be taken to use standard methods in all sampling events and sample during similar seasonal conditions from year-to-year. One problem to resolve in a sampling design would be the combined effect of multiple stressors. Because the biological communities respond to many pressures (such as, fishing, low DO, pollutants, climate change, etc.) as well as flow, it is important to distinguish which of the stressors is likely responsible for community change. Future modeling efforts should focus on developing and applying the CE-QUAL-W2 model, because it is more broadly accepted and it can model branched systems, and therefore could be easily extended to include the Spring Run in the model.

EDITORIAL COMMENTS

General Comments:

U.S. Customary and Metric units should be used consistently, but this is not the case in this report. A typical example is page 2-17, line 7 from the bottom. Always present the U.S. Customary unit first and the metric equivalent in parentheses. Meters should be presented as “m” and degrees Celsius as °C. The graphs would also benefit if the metric equivalent is presented on the opposite axes. For example, see Figs. 2-15, 2-16 and 2-19 where m³/s could be added.

Specific Comments:

Page	Paragraph	Line	Comment
xi			Remove FMRI and insert FWRI
1-4	1	4	The expression: " for about half the days each year on average" is unclear, please revise.
2-3	1	3	in the 1999
2-8	Fig. 2-8		Mixed units.
2-10	Fig. 2-9 Fig. 2-10		Should use the same time ("x") axis for comparison, and make them the same width.
2-19	5	2	Remove "the" before "1945"
2-21	4	5	Change "(79 m)" to "(80 m)".
2-26	Fig. 2-23		Need to explain in the text what causes the long-term increase in specific conductance. Is it drought related?
2-27	4	6	Figure 2-25?
2-27	5	2	Change "shifted" to "lagged".
2-28	Legend	3	Remove space between line two and three in figure text. The "B" is missing in the lower graph.
2-29	Fig. 2-26		The lag should be explained in the text for this figure.
2-32	4	1	Statement “...indicate some nutrient enrichment..” inconsistent with text. The average total N was 0.72 mg/L, yet the median concentration for all Florida streams is 1.2. This appears as if Sulphur Springs water is nutrient depleted.
2-34	1	4	Statement not supported by tables, figures, or text. See above.
2-34	3	8	Why not use Log ₁₀ + 1 (or + 0.001) so zero values are not lost in the analysis?
2-35	Fig. 2-28		What kind of regression has been used in the graph?
3-2	Fig 3-1		Key (with o and x) does not match lines (blue and red)
3-3	Legend		Fig. 3-2. "Mouth" is misspelled in the 2 nd line of the figure text.
3-4	Fig. 3-3		The graph text says "<= 5 cfs" while the figure text says "< 5 cfs". Correct this!
3-4	Fig. 3-4		3-4. Red line (Hillsborough River) in graph is too thin
3-8	Table 3-1		The units used should be presented for every column.

Page	Paragraph	Line	Comment
3-9	2	3	The meaning of: "The median DO value for grab samples from the pool" is not clear. Describe what is meant by a grabsample and how it works.
3-10	Fig. 3-7		Where does regression line come from? How calculated? It looks like there are more points above the line than below.
3-11	5	3	" <i>Cladophora</i> " is misspelled.
3-12	2	3	"Caesar" is misspelled.
3-13	1	3	Space is missing at " <i>Laeonereis culveri culveri</i> ". Or should it only be: <i>Laeonereis culveri</i> ?
3-15	2	13	Is <i>Modiolus</i> really a euryhaline species? Same page: How is it possible to say that <i>Tanais</i> sp. is euryhaline because there are so many true marine tanaid species?
3-15	5	3	" <i>Stenonereis</i> " is misspelled.
3-16	3	5	"Pelecypod" is misspelled. Why not use "bivalve" instead? The same thing applies to line 18 from the bottom on page 3-17.
3-17	3	2	"species." not "species."
3-17	3	10	" <i>Pyrogophorus</i> " is misspelled.
3-17	4	9	Explain "snags" here instead on page 3-18.
3-18	1	1	Change "square meter" to "area unit".
3-18	2	13	Shouldn't "Tricoptera" be spelled "Trichoptera" here?
3-18	4	3	Change "dredge" to "grab".
3-19	2	4, 6	Change " <i>Pyrogophorus</i> " to "P".
3-19	4	9-10	Change "numbers per square meter" to "individuals per m ² "
3-20	4	2	Use "individuals per m ² ".
3-20	3	1	"A number of taxa". Does it mean "some", "several" or "many"? Vague expression.
3-20	3	2	" <i>Dero digitata</i> " is misspelled.
3-20	3	3	<i>Munna reynoldsi</i> is misspelled.
3-20	3	9	" <i>Pyrogophorus</i> " is misspelled.
3-20	4	1	Change "per sq. meter" to "per m ² ".
3-22	4	5	Update FMRI to FWRI (Fish and Wildlife Research Institute).
3-23	2	6	" <i>variegatus</i> " is misspelled.
3-23	2	14	"and two species of mojarras". Which ones? Was it not possible to identify these?
3-23	4	8	scientific name after "Seminole killifish" (<i>Fundulus seminolis</i>).
3-23	5	2	Delete "species".
3-27	Fig. 3-8		How are these average yearly flows calculated?
3-34	Fig. 3-13		Not sure what the "*" represent in many box and whisker plots. They are not defined.
3-36	4	3	The reference to Chen should be "2000".
3-36	4	4	How did you demonstrate that transients in the solution were removed from effects of initial conditions?
3-38	2	9	replace "to" with "do"

Page	Paragraph	Line	Comment
3-39	Fig. 3-16		The plots of LAMFE results would look better if the contour labels were removed. Each figure already contains a color key that is sufficient by itself
3-39			It would help the reader to include (at least once) plots at (1) low tide, (2) mid-tide and (3) high tide, to visualize the range of conditions.
3-43 3-44	Fig. 3-22 & 3-23		Figures are confusing because the same key appears in both sub-figures. Please put correct key in correct figure. Also, the figure legend does not distinguish between the two sub-figures.
3-45	3	4	"....at most upstream station (km 15.8) slowing increasing..." Is this good language? The same applies to Line 8 from the bottom on the same page, "....as far as freshwater or low salinity conditions are achieved."
3-47	Fig. 3-24		Doesn't it make more sense to have the graphs in chronological order instead of according to flows? If this is the case C and D should change places
3-48	4	5	"....in the most downstream 8 km of the lower river." Is this good language?
3-57	Fig. 3-28		Figures should be self explanatory. Therefore an explanation what the horizontal line at 20 °C and what the box plots express should be included in the figure text. This also applies to other figures in the report.
3-59	Fig. 3-30		The graphs should change places and an "A" and a "B" should be inserted. Why isn't the 20 °C line included in Figure 3-30 A?
3-60	3	5	In Section 3.11.3, it is hypothesized that occasional warmer bottom water would "... likely reflect the effect of short-term meteorological conditions on surface waters." This "unstable" thermal condition is more likely to be caused by a compensating higher salinity bottom waters that maintain denser water in the lower water column.
3-60	5	1	In Section 5.5, it is indicated that the CE-QUAL-W2 models used "cloud cover" to calculate atmospheric heating. Solar radiation data would be preferable as they give more reliable thermal loading to the water surface.
4-7	1	7	".....stenohaline (narrow salt tolerance)..." This should have been explained the first time that "stenohaline" was used. No explanation provided for "oligohaline" on the following line. Explain "euryhaline" too, the first time that it is being used.
4-8	1	1	Have the common names been presented for these four species earlier? " <i>americanus</i> " on line 2 should be in italics.
5-6 5-7	Fig. 5-3		Graphs and fonts are too small. Explain the box and whisker plots.
5-11	4	3	Change "depths" to "waters".
5-16	2	1	Please reference data be referred to.

Page	Paragraph	Line	Comment
5-19	Fig 5-9		According to the figure text Mean Daily Stage and Maximum Daily Stage should change places.
5-34	4	1	Please reference data be referred to.
5-40	2	5	In Section 5.5, it is indicated that the CE-QUAL-W2 models used "cloud cover" to calculate atmospheric heating. Solar radiation data would be preferable as they give more reliable thermal loading to the water surface.
5-42			In Section 5.5.5, it is not clear what meteorological data to simulate the November 1976-February 1977 "coldest period".
5-43			In Section 5.5.6, the report should explain why no cold-water releases from the reservoir were simulated. All the reported simulations had 0 cfs "flow from reservoir". The model needs to demonstrate whether the addition of warmer spring water could sufficiently increase overall river temperatures downstream.
5-44	1	2	In Section 5.5.6, it is not clear what " T" represents in a dynamic system. It is a maximum difference, and mean difference...?
5-44	3	1	The referenced figures are not "cumulative" distributions; they show "exceedance" distributions.
5-45 5-46			It would be better to combine the lines in the three parts of Figure 5-24 into one figure, with stronger line types and more-readable colors (perhaps varying line styles). The same holds for Figure 5-25.
5-48	Fig.5-26		Need to explain the periods (several days duration) where there appear to be vertical thermal instability. Is salinity compensating?
5-49	Fig. 5-27		These results look very strange. Please explain why the bottom waters are consistently warmer than the surface waters. I know this is only 5 days (the scales of Figs. 5-26 and 5-27 are deceiving), but little vertical mixing seems to be occurring. Are there observations that should this same set of processes?
5-48 5-49	Fig. 5-26 Fig. 5-27		A key should be added to define the "scenarios", rather than describing them as "A", "B", and "C", and making the reader revisit the text. Not clear where Figs. 5-26 and 5-27 are plotted. Need to explain why a 15 °C line is plotted (Figure 5-26) and a 20 °C line is plotted (Figure 5-27)

Chapter 6, Literature Cited:

Allen et al. Remove comma after "Murie"

Bulger et al. Remove comma after "Nelson" and add "and" here.

Clewell et al. Remove comma after "Flannery".

Gilmore et al. Remove comma after "Bullock".

HSW Engineering, Inc. "West" is misspelled.

Jaeger, J.E. Add space between J and E.

Knutilla, R. L. and M. A. Corral. Add space between R and L and between M and A. Tallahassee is misspelled.

McMahon et al. Remove comma after "Zale".

Montagna et al. Remove comma after "Palmer".

Poff et al. Remove comma after "Sparks".

Pribble et al. Remove comma after "Hackett". Do not use caps W for "water"

Shafland and Foote. Remove italics for "Northeast Gulf Science".

Tampa Bay National Estuary Program. Change the caps "R" in recommendations and correct the misspelling.

Appendices:

Appendix A

Remove some of the "out of range values" in many of the graphs and explain this in footnotes. The graphs are meaningless if these values are included. Please see e.g. TURBIDITY on page 3, BOD on page 4, NO₂-N on page 6, TKN on page 7 (this one is extra bad), OPO₄-P and TP on page 8 (the same here).

Why not start the Y-axis at 0.10 at TN on page 5?

Other graphs could also be improved by changing the values on the Y-axis. For example: The two bottom graphs on page 1 and pH on the same page.

Confusing Y-axes scales here, e.g. bottom left on page 1, upper left (TDS) on page 2, upper left (COLOR) on page 3.

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