Establishment of Estuarine Water Clarity Targets for Sarasota County

Final Report

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FOREWORD

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Executive Summary

The Florida Impaired Waters Rule, or “IWR” (Chapter 62-303, Florida Administrative Code) includes guidelines for chlorophyll-A in surface water bodies. In accordance with the rule, a waterbody can be determined to be impaired if chlorophyll-A concentrations exceed a fixed value (11 µg/L) for an annual average and/or exceed a historical value by 50% or more, based on a multi-year trend analysis. Many of the estuarine waters in Sarasota County have chlorophyll-A concentrations that are near the thresholds described in the rule; and therefore, may have required pollutant load reductions assigned to them through the state’s Total Maximum Daily Load (TMDL) Program.

Portions of Sarasota Bay falling within Sarasota County (Roberts Bay – WBID 1968D and Blackburn Bay – WBID 1968F) are currently listed as impaired for historical increases in chlorophyll-A (excess nutrients). The tidal portion of Clowers Creek (WBID 1975AA) is listed as impaired for chlorophyll-A. Upper Lemon Bay (WBID 1983A) is also listed as impaired for chlorophyll-A (exceedence of the 11 µg/L threshold). The lower Myakka River (WBID 1991C) is also listed as impaired for historical increases in chlorophyll-A.

While chlorophyll-A can be a useful indicator of impaired conditions in an estuary, interpreting the causes and effects of varying chlorophyll concentrations is challenging. Chlorophyll-A is known to be highly variable and responsive to a variety of factors, including nutrient loads, rainfall, salinity, residence time, season, and even the time of day. In addition, factors other than chlorophyll, such as turbidity and color, may also affect water transparency.

Three major courses of action are available to Sarasota County, as regards the setting of water clarity goals. The first approach would be to accept the state’s determination that a chlorophyll a concentration of 11 µg / liter, and the water clarity that accompanies such conditions, is an appropriate target. If this approach is viewed as satisfactory, then only the tidal portions of Clowers Creek and Upper Lemon Bay would be viewed as having excessive phytoplankton abundance (other areas would be trending toward such an impaired condition), and only these areas would be viewed as having unacceptable water clarity. A second approach is to develop site-specific water clarity targets, without also establishing a link between those targets and any particular living resource. For example, the County could decide that maintaining water clarity of three feet, or six feet, or a value that would allow a person of a certain height to see their feet in waist-deep water, would be an appropriate goal. A third approach would be to try and determine a scientifically-defensible, site-specific water clarity goal that could be linked to a living resource. An approach such as this, using science-based management to protect the health of living resources, is basically the approach used by the Tampa Bay Estuary Program.

Using an extensive, locally collected data set, a major finding of this report is that phytoplankton biomass, as represented by the abundance of the main photosynthetic pigment chlorophyll-A (Chl-A) is positively correlated with light attenuation coefficients (negatively correlated with water clarity) for nearly all Sarasota County waters. The areas of Big Sarasota Bay, Roberts Bay, Little Sarasota Bay, Blackburn Bay, and Lemon Bay all show a relationship between increasing Chl-A values and decreasing water clarity. For the Dona and Roberts Bays system, there was no correlation between water clarity and Chl-A. And for the Lower Myakka River, an inverse relationship between light attenuation coefficients and Chl-A suggests that factors other than phytoplankton control water clarity, and that elevated light attenuation due to these other factors (i.e., dissolved organic matter) actually limits phytoplankton abundance.

Also, and important to making water clarity measurements meaningful for the public at large, there is a significant, non-linear relationship between light attenuation coefficients and Secchi Disk depths. This allows for the development of water clarity goals that might gain wider public acceptance. For instance, a Chl-A goal of 8 µg / liter (as a hypothetical example) could be the target for allowing sufficient light to support seagrasses in Roberts Bay, while simultaneously being the Chl-A maximum for allowing a water clarity goal of four feet of visibility to be achieved.

A potential course of action for Sarasota County is that it not accept a system-wide Chl-A target of 11 µg / liter for either an indicator of "impairment" or the Chl-A level that would be protective of living resources in the County's coastal waters. A potential course of action is for the County to not adopt water clarity and Chl-A goals that are entirely subjective, such as maintaining water clarity so that a person of a certain height would be able to see their feet in waist-deep water. This report outlines the steps necessary should the County consider the adoption of both water clarity and Chl-A goals that are: 1) segment-specific, 2) where appropriate, linked to the maintenance of health of an important living resource in local waters, and 3) scientifically-defensible.

Before this course of action can be acted upon, a significant data gap exists - determining the depth to which seagrass meadows grow in Sarasota Bay. With minimal effort, this information could be determined, allowing Sarasota County to propose to FDEP both water clarity and Chl-A target values that would be scientifically defensible, protective of the health of coastal waters, and able to be converted to terms (e.g., "four feet of visibility") that would allow for significant public understanding and support. In the absence of this information, a series of potential water clarity goals was developed based on hypothetical situations that mimic conditions that might occur in Sarasota County's waters.

In summary, there is a relationship between algal biomass and water clarity in Sarasota County's tidal and estuarine waters, but not everywhere. Therefore, a statistically valid relationship can be established between Chl-A and water clarity. As such, it is unnecessary to rely upon a state-wide Chl-A goal to protect the County's water-related natural resources. However, determining goals for water clarity requires either the adoption of a subjective water clarity goal, or a resource-linked strategy, or a combination of the two, depending upon the area in question. For a resource-linked strategy, a potential approach is to aim for water clarity targets that would sustain the long-term health of seagrass meadows. There is practical precedence for such an approach, as the depth to which seagrasses grow (and thus their spatial extent) has been previously linked to water clarity in Sarasota Bay, Lemon Bay, and Tampa Bay. Additionally, seagrass health has been previously linked both to water clarity, and nutrient-related impacts to water clarity in both Tampa Bay and Lemon Bay.

The report outlines the steps necessary to develop the information needed to pursue such a strategy in Sarasota County's waters.

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Appendices

1.0 Introduction

Like many other coastal communities around the state and nation, Sarasota County's waterbodies are negatively impacted by excess nutrient pollution. Highly valuable bays and rivers may be declining in aquatic health, community recreation, and water clarity because of an increasing abundance of nitrogen-fed chlorophyll-A, an indicator of algal biomass.

Effective resource management requires targets to measure progress in achieving specific goals. From earlier work in the Tampa Bay estuary, it is clear that simple, universal water quality targets are not always appropriate. In Tampa Bay, chlorophyll-A targets vary by bay segment. These chlorophyll targets are based on empirically derived relationships between chlorophyll and water clarity. In turn, water clarity targets are based upon empirically derived relationships between water clarity and light availability at target depths, with target depths based upon a determination of the depth of penetration of historical seagrass coverage. Such an approach allows for the development of chlorophyll and water clarity targets that can be justified by specific living resource-related targets for bay segments, and they can reflect both public understanding of how to maintain healthy ecosystems, as well as a science-based approach to natural resource protection.

Sarasota County has been monitoring and classifying the chemical and biological water quality of its bay systems for several years. Fewer water quality data have been collected in the tidal creeks and rivers in the County's coastal waters. As TMDLs and other management activities (via the SBEP and CHNEP) are developed for the estuarine waters of the County, water quality target and compliance measures will be an important element of the prioritization process for management actions to improve and enhance these waterbodies.

Like many other coastal communities around the state and nation, Sarasota County's waterbodies are negatively impacted by excess nutrient pollution. Highly valuable bays and rivers may be declining in aquatic health, community recreation, and water clarity because of an increasing abundance of nitrogen-fed chlorophyll.

The Florida Impaired Waters Rule, or "IWR" (Chapter 62-303, Florida Administrative Code) includes guidelines for chlorophyll in surface water bodies. In accordance with the rule, a waterbody can be determined to be impaired if chlorophyll concentrations exceed a fixed value (11 µg/L) for an annual average and/or exceed by 50% or more a historical value based on a multi-year trend analysis. Many of the estuarine waters in Sarasota County have chlorophyll concentrations that are near the thresholds described in the rule; and therefore, may have required pollutant load reductions assigned to them through the state's Total Maximum Daily Load (TMDL) Program. These statewide chlorophyll targets appear to be too generalized to be scientifically applicable to the variety of water bodies in Sarasota County.

Chlorophyll is a useful indicator of impaired conditions in an estuary, but interpreting the data is challenging. Chlorophyll is known to be highly variable and responsive to a variety of factors that may include pollutant load, rainfall, runoff, salinity, residence time, the presence of red tide, season, time of day, and other factors. In addition, factors other than chlorophyll, such as turbidity and color, may affect water transparency. Therefore, the process of setting water clarity targets may need to account for multiple parameters that may not necessarily be the result of pollutant loads.

1.0 Introduction

Specific tasks performed for this project were:

- Review of determinations by FDEP of waterbody impairment in Sarasota County;
- Review of previous and relevant water quality/clarity target setting approaches;
- Exploratory data analyses of existing estuarine water quality data;
- Analysis of available data using an appropriate water quality target setting approach; and,
- Suggestion of a course of action by Sarasota County to fill existing data gaps and implement a resource-based approach to setting water clarity targets

Portions of Sarasota Bay falling within Sarasota County (Roberts Bay – WBID 1968D and Blackburn Bay – WBID 1968F) are currently listed as impaired for historical chlorophyll (excess nutrients). The tidal portion of Clowers Creek (WBID 1975AA) is listed as impaired for chlorophyll. Upper Lemon Bay (WBID 1983A) is also listed as impaired for chlorophyll (exceedence of the 11 ug/L threshold). The lower Myakka River (WBID 1991C) is also listed as impaired for historical chlorophyll.

This work assignment has been prepared to address the development of scientifically reasonable water quality targets for Sarasota County's natural water resources. These waterbodies primarily include Sarasota Bay, Lemon Bay, and the Myakka River.

2.0 Water Quality Target Setting Approaches

In response the issues outlined in the Introduction, the following scope of work was performed to address the activities stated above.

Task 1 – Data Compilation for Bay and Tidal Creek/River Water Quality Targets

The objective of this task was to gather existing water quality and living resource data for the County's bays and tidal influenced rivers and creeks. The County previously collected water quality data for several creek systems, however, this sampling effort ended in the early 1990s. Since that time, water quality data has also been collected in the lower Myakka River. Data were acquired from existing sources such as the FDEP IWR databases, STORET, Charlotte Harbor/Lemon Bay Volunteer Water Quality Monitoring Network, and Sarasota County.

Living resource data include seagrass coverages (SWFWMD SWIM Program), oyster bars (Sarasota County and SBEP/Florida Sea Grant), and limited shoreline mapping within the SBEP watershed.

Task 2 – Exploratory Data Analysis

The purpose of the data analysis task was to determine if statistically significant relationships existed between various water quality parameters that affect living resource targets. These parameters included both water clarity itself (quantified as light extinction coefficients), and also those water quality parameters capable of affecting water clarity (e.g., Chl-A, turbidity, color, etc.). The spatial unit of analysis for this task was the existing SBEP bay segmentation scheme developed by Mote Marine Lab (Estevez, 1990).

Task 3 – Evaluation of Bay and Tidal Creek/River Water Quality Targets

Based on the results of Task 2, a strategy for developing bay and tidal creek/river water quality targets was developed. Water quality targets were linked, where feasible, with living resource targets. Comparisons of water quality targets based on exploratory data analyses was compared with existing state water quality standards (including IWR/TMDL standards) and recommendations for alternative criteria were made, if warranted.

Task 4 – Recommendations for Developing Water Quality Targets

Using results from Tasks 1 through 3, develop a recommended course of action for Sarasota County to consider pursuing. These recommendations include a proposed technique to develop for determining resource-based water quality targets, and also a course of action to fill data gaps that presently exist that would prevent such a course of action from being followed.

2.0 Water Quality Target Setting Approaches

Background on TSI Values and the Impaired Waters Rule / TMDL Standards

To determine the appropriateness of using the IWR/TMDL standards in Sarasota County, it is important to know how the 11 µg / liter standard for Chl-A was derived. In an attempt to develop a state-wide assessment of the nutrient status of Florida's estuaries, the following equation was derived (FDEP 1996):

$$CHLA_{TSI} = 16.8 + [14.4 \times LN\ (CHLA)]$$

The same equation is used to calculate TSI values for both estuaries and lakes. However, a different scale is used for these waterbodies. For lakes, a TSI value of 0-59 is "good", 60-69 is "fair", and 70-100 is "poor". For estuaries, a TSI value of 0-49 is "good", 50-59 is "fair", and 60-100 is "poor". Therefore, if a lake and estuary were both to have a Chl-A value of 11 µg / liter, both would have $CHLA_{TSI}$ values of 51.3. However, a $CHLA_{TSI}$ value of 51.3 would result in a lake being classified as "good" while an estuary would be classified as "fair."

Even though a Chl-A concentration of 11 µg / liter for an estuary would be given a TSI value in the "fair" range, it would be classified under the IWR as "impaired" due to having phytoplankton biomass high enough that an annual average Chl-A value would be in excess of 11 µg / liter.

Clearly, the opportunity exists for developing more locally-relevant, biologically-based water quality criteria for Sarasota County's waters.

Locally-derived (Southwest Florida) Links Between Water Quality and Living Resources

Large declines in Florida seagrass beds have been documented in many locations including Tampa and Sarasota Bays, Charlotte Harbor, and the Indian River Lagoon. As many of these losses have occurred at the deep edges of the beds, reduced water clarity, and related increased light attenuation, has been considered one of the dominant causes of seagrass reductions. Gallegos (1996) reports that literature reviews comparing observed depth limits of submerged macrophytes with various estimates of water transparency have indicated that deep edges of grass beds extend to depths at which 13-42% of surface irradiance penetrates. This great variation in "minimum light requirements" may be due in part to variability in the amount of further light attenuation caused by epiphytic communities. Regardless of the reason for this variation in minimum light requirements estimates, this variation has great importance in determining an appropriate water clarity target. The attenuation of photosynthetically active radiation is quantified by the diffuse attenuation coefficient for downwelling irradiance, K(PAR). Light requirements for given grass beds as a fraction of surface irradiance can be determined from K(PAR) and the depth at the edge of the grassbed. Since K(PAR) cannot be directly regulated, light requirements of the seagrass beds must be translated into concentrations of water quality properties that meet the specified light availability target (Gallegos, 1996). Several studies in Florida have investigated the relationships between water quality parameters and light attenuation at the deep edge of seagrass beds.

McPherson and Miller (1987) determined the relative contribution of different components to the attenuation of PAR in Charlotte Harbor based on *in situ* and laboratory measurements. Non-chlorophyll suspended matter accounted for an average of 72% of attenuation coefficient (dissolved matter 21%; suspended chlorophyll 4%). Maximum light attenuation occurred near the mouth of tidal rivers due to the combined effects of dissolved organics and suspended matter.

Tomasko et al. (1992) determined that a statistically significant relationship existed between annual average light extinction coefficients and the depth to which seagrass meadows grow in Sarasota Bay. Also in Sarasota Bay, Tomasko et al. (1996) determined that there was an inverse power relationship between nitrogen loads to various bay segments and the biomass and productivity of seagrass meadows in those same segments.

Dixon and Kirkpatrick (1995) measured K *in situ* at various locations in Sarasota Bay, as well as in the laboratory under controlled lighting conditions. Laboratory attenuation was then partitioned into components attributable to water, phytoplankton, color, and non-chlorophyll suspended matter (NCSM) through the analysis of water quality parameters, and the measurement of the attenuation of both unfiltered and filtered samples. The study took place over a one year period (1993-1994). They found that seasonal patterns of water column attenuation reflected the composite effects of patterns of turbidity, chlorophyll, and color (coefficients low during winter, increased in summer). Annualized %PAR remaining at the bottom of the water column averaged near 42% for all sites except one. Regression models of *in situ* K_{dadj} (K_d adjusted for solar elevation angle) indicated that color, turbidity, and chlorophyll a accounted for nearly 86% of the variation in attenuation, with most of the attenuation produced by color. However, laboratory partitioning of attenuation (where attenuation due to color and water was measured directly) indicated that most attenuation was attributed to absorption and scattering of PAR by NCSM, not color. In addition to water quality parameters, epiphytes were found to reduce available light in Sarasota Bay by nearly 50% as a yearly average. The combined effects of water clarity and epiphyte coverage reduced the PAR available to the seagrass blade to an average of 21% on an annual basis with all stations combined.

Dixon and Kirkpatrick (1999) also investigated the causes of light attenuation with respect to seagrasses in Charlotte Harbor over a one-year period (1997-1998). The authors found that the %PAR remaining at the bottom of the water column at the maximum depth extent of seagrass ranged from 13% to 29%. However, when epiphytic attenuation was accounted for, the %PAR actually available to the plant was reduced to annual averages of 11% to 16%. Water quality data from all stations were used as inputs to an optical model based on equations presented in Kirk (1994) and Gallegos (1993), in which vertical attenuation is a function of solar zenith angle, scattering, and total absorption. The model determined that chlorophyll, color, and turbidity accounted for 4%, 66%, and 31% of water column attenuation, respectively. The authors make the important note that the study occurred during a period of extraordinary rainfall and flows, with resulting decreases in both salinity and water clarity measured at almost all stations. Thus, the project year represented higher levels of attenuation following two years of comparatively better water clarity.

Christian and Sheng (2000) examined light attenuation by color, chlorophyll a and tripton in the Indian River Lagoon during April-June 1997. The calculated K from PAR measurements and partitioned K into components (seawater, color, chlorophyll a not corrected for pheophytin, and tripton which was calculated from total suspended solids and chlorophyll a data). Tripton had a dominant effect on attenuation in the IRL (60.5% of K compared to 25.2% from color and 9.6% from chlorophyll a). TSS, chlorophyll a and color were used as inputs for a numerical light attenuation model developed by Gallegos (1993). The results compared well with the collected data (calculated K from PAR measurements).

Dixon (2000) discussed issues related to the target %PAR (water column) of 20.5% in Tampa Bay. Monitoring programs have determined that this level of %PAR is present at depths desired for seagrass restoration for lower segments of the Tampa Bay system. She discussed possible reasons for this. First, 20.5% is an annual target which does not incorporate any seasonal light requirements. Continuous PAR data indicated that slightly depressed PAR levels during spring and early summer are associated with net biomass declines over the course of the year, even when annual average PAR was very near 20.5%. Sampling details may also contribute to the problem through measurement error. Dixon found that discrete monitoring, even weekly, can overestimate water column light levels by as much as 5.6% which is a large bias when compared to a target of 20.5%. Third, the light target does not represent the %PAR actually received by the grass blades. For lower Tampa Bay, epiphytic growths, on average, attenuated about 34% of all water column light penetrating to the deep edge of the grassbeds. Dixon states that it is possible that epiphytic attenuations are higher in the upper segments of Tampa Bay (with likely higher nutrient concentrations), in which case a water column target of 20.5% PAR at depth will be insufficient to even maintain grasses. Dixon also points out that other stresses, such as low salinity, have been seen in nearby systems in which biomass declines have accompanied light levels well in excess of 20.5%.

Tomasko et al. (2001) found that the depth to which seagrass meadows grow in Lemon Bay could be predicted based on annual average light extinction coefficients. However, areas close to passes and/or boating channels did not display this relationship, perhaps due to the higher wave energy at these locations. Excluding sites exposed to high wave and/or current exposure, the average percent sub-surface irradiance at the deep edge was determined to be ca. 18 percent.

Issues Associated With Optical Models

A number of researchers have attempted to develop optical models for understanding the relationships between various water quality parameters (e.g., phytoplankton, dissolved organic substances, non-chlorophyll suspended materials, etc.) and water clarity (see text above). Two basic approaches have been used.

One approach (e.g., McPherson and Miller 1987, Dixon and Kirkpatrick 1995) involves bringing water samples back to a laboratory, and then determining light loss through a set water column both prior to and then after filtering water through a standard filtering apparatus. In this approach, the difference between the two calculated light extinction coefficients is the difference between light attenuation due to dissolved versus suspended materials. Light attenuation due to suspended material is then further partitioned between that due to phytoplankton versus that not due to phytoplankton using empirically-derived partial attenuation coefficients.

A second approach, an empirically-based technique, has been utilized when the more manipulative types of studies used in the first approach were not used. In this approach, statistical correlations are sought by comparing, for example, light extinction coefficients versus various potentially significant water quality parameters (e.g., phytoplankton, turbidity, etc.). A concern with this type of approach is the potential for results to give rise to different conclusions based on the use simple regression techniques versus multiple regression techniques. For example, and using data from Sarasota County's waters within Sarasota Bay, chlorophyll A does not come out to be a statistically significant contributor to light extinction when a forward, step-wise multiple regression technique is used, yet chlorophyll A does come out to be a statistically significant contributor to light extinction when a simple correlation is tested. The difference in results is due to the fact that phytoplankton levels may vary in a predictable way with extinction coefficients, but they may not explain variation in extinction coefficients beyond the degree that "color" or "turbidity" already do when using a forward step-wise multiple regression.

For the Tampa Bay Estuary Program, target Chl-A values were derived from simple linear regression comparisons of extinction coefficients (K) as a dependent variable, plotted against Chl-A values as potentially significant independent variables. In fact, K values are not collected as part of the normal water quality monitoring program in Tampa Bay, but are actually calculated based on a conversion from field-collected Secchi disk depths.

Care must be taken to fully understand the approaches used when developing optical models, to correctly interpret results from these efforts

3.0 Exploratory Data Analysis

Water quality targets can be set for a variety of parameters to meet resource management or public health needs. In Florida, several approaches have been used to set water quality targets based on the protection of sensitive ecosystems or indicator species. Four water quality target setting approaches were evaluated for this report and include those that have been in the TMDL assessment process and also in the development of estuarine resource management plans (Comprehensive Conservation Management Plans). These targets are specifically related to nutrients and their ability to stimulate phytoplankton blooms, with the end result being increased turbidity or shading of the water column, thereby limiting light penetration to submerged aquatic vegetation (e.g., seagrass).

Historical water quality targets

This process involves selecting targets based on water quality conditions that existed prior to recent watershed disturbances. In the case of the FDEP Impaired Waters Rule (IWR), historical trend analyses are conducted on chlorophyll data for a given waterbody by averaging the lowest chlorophyll concentrations over a five consecutive year period. The specific language from Chapter 62-303 Identification of Impaired Surface Waters states:

"When comparing changes in chlorophyll a or TSI values to historical levels, historical levels shall be based on the lowest five-year average for the period of record. To calculate a five-year average, there must be annual means from at least three years of the five-year period…Estuaries or estuary segments shall be included on the planning list for nutrients if…data indicate annual mean chlorophyll a values have increased by more than 50% over historical values for at least two consecutive years.

Impaired Waters Rule (IWR)/Water Quality Standards

This approach was developed using existing state and federal research to develop broad regional standards. In this case, a single target is used across an entire geographic area, such as Florida estuaries. Targets for Florida waters are also described in Chapter 62-302 which states: "Estuaries or estuary segments shall be included on the planning list for nutrients if their annual mean chlorophyll a for any year is greater than 11 µg/l…"

In some cases such as coral reef systems or deep seagrass beds, this threshold may not be sufficiently protective of sensitive ecosystems. Conversely, in shallow bay systems, this may be an overly protective standard based on the ability for light to penetrate to the benthos regardless of chlorophyll concentrations.

Resource-Based or Reference System

The value of this type of approach is based on the relative strength of the following relationships: 1) the relationship between the depth distribution of seagrasses and water clarity, 2) the relationship between water clarity and "controllable" water clarity parameters (e.g., phytoplankton levels), and 3) the relationship between controllable water clarity parameters and specific management actions (e.g., nitrogen load reductions).

While this approach may seem to be the least subjective one, its appropriateness depends upon both the individual and cumulative strengths of each of the relationships described above.

This approach is built, in part, upon the Lambert-Beer Law, which is the basis for the equation:

$$I_z = I_o \text{ x } e^{-kz} \text{ ; where}$$

I_z = irradiance at depth z,
I_o = immediately sub-surface irradiance,
e = the base of the natural logarithm,
K = the light attenuation coefficient (per m), and
Z = depth in meters

This equation can be rearranged to calculate light attenuation coefficients:

$$K = -1/Z \;\; \ln(I_z / I_o))$$

By knowing two of the three elements in these equations, the third can be derived. Thus, if the depth to which seagrasses grow is known, and the light requirements are known (e.g., as a percent of sub-surface irradiance), then a target light attenuation value can be calculated. Also, if a target light attenuation value is developed, and a light requirement value is chosen, then the depth to which seagrasses should grow can be calculated.

The degree of confidence for pursuing this type of approach is built upon the appropriateness of values used for the depth to which seagrass meadows grow, the minimum light requirement value used, and the suitability of light attenuation measurement values.

Furthermore, water clarity itself is not usually an "actionable" water quality parameter by itself. That is, resource managers might be able to modify water clarity, but only through modifying the abundance of factors that contribute to water clarity. For example, if light attenuation was strongly affected by phytoplankton levels, and phytoplankton levels were related to nitrogen loads, then a reduction in nitrogen loads might be expected to reduce phytoplankton levels, which would in turn be expected to result in greater water clarity. This in turn might be expected to allow seagrass to grow to deeper depths, thus allowing for an expansion in their coverage.

The robustness of this approach is thus related to the dependence of water clarity on various parameters that can affect water clarity.

Data Collection

Existing water quality and living resource data were collected for the Sarasota County's bays and tidally-influenced rivers and creeks. The County previously collected water quality data for several creek systems, however, this sampling effort ended in the early 1990s. Since that time, water quality data has been collected in the Sarasota Bay, Lemon Bay, and the lower Myakka River. Data were acquired from existing sources such as Sarasota County, the FDEP IWR databases, STORET, and the Charlotte Harbor/Lemon Bay Volunteer Water Quality Monitoring Network.

Living resource data that were reviewed included seagrass coverages (SWFWMD SWIM Program), oyster bars (Sarasota County and SBEP/Florida Sea Grant), and limited shoreline mapping within the SBEP watershed. This data was acquired in GIS format and clipped to appropriate study area boundaries to assess temporal or spatial trends. A list of potentially useful or significant living resource targets was developed from this data collection effort. Coordination with an ongoing Sarasota County project to develop environmental indicators was conducted to ensure that the selected list of targets was acceptable to various technical review committee representatives.

Data Analysis

The purpose of the data analysis task was to determine the extent and quality of existing data and to examine statistically significant relationships among various water quality parameters that affect living resource targets. A memorandum describing this initial data analysis, conducted by Janicki Environmental, Inc., is presented in **Appendix A**. The spatial unit of analysis for this task was the existing SBNEP bay segmentation scheme developed by Mote Marine Lab (Estevez, 1990) along with newer designations for Dona and Roberts Bays, Lemon Bay, and Lower Myakka River developed by Sarasota County. Box plots of these parameters were prepared to determine the variability of these data for each bay segment (**Appendix B**).

Based on the conclusion in Appendix A that it can be appropriate (depending upon the location) to develop relationships between phytoplankton abundance and light extinction coefficients, an analysis of the data collected by Sarasota County between 1999 and 2003 was conducted. The data were examined to determine if relationships could be found between Chl-A and water clarity, with significance set *a priori* at $p < 0.05$. Results are summarized below.

Segment No.	Segment Name	Chl- A significant?	Linear Model
7	Upper Big SB – West Side	Yes – positive	K = 0.5695 + 0.0225 (Chl-A)
8	Upper Big SB – East Side	Yes – positive	K = 0.6067 + 0.0150 (Chl-A)
10	Lower Big SB – West Side	Yes – positive	K = 0.4782 + 0.0482 (Chl-A)
11	Lower Big SB – East Side	Yes – positive	K = 0.4928 + 0.0472 (Chl-A)
12	New Pass	Yes – positive	K = 0.4451 + 0.0238 (Chl-A)
13	Roberts Bay	Yes – positive	K = 0.6826 + 0.0415 (Chl-A)
14	Little Sarasota Bay	Yes – positive	K = 0.6294 + 0.0458 (Chl-A)
16	Blackburn Bay	Yes – positive	K = 0.5243 + 0.0606 (Chl-A)
	Lemon Bay	Yes – positive	K = 0.7220 + 0.0428 (Chl-A)
90	Upper Myakka River	Yes – negative	K = 3.3182 – 0.1081 (Chl-A)
	Dona and Roberts Bays	No	None
	Lower Myakka River	Yes – negative	K = 3.3259 – 0.0640 (Chl-A)

For the Upper and Lower Myakka River segments, increases in phytoplankton abundances correlate with decreases in water clarity. For these areas, extinction coefficients are very high to start off with (note the high y-intercept values), and phytoplankton levels are probably light-limited. For Dona and Roberts Bays, no correlation was found at all between water clarity and phytoplankton levels.

For all other segments, there are statistically significant correlations between water clarity and Chl-A, allowing for the prediction of water clarity based on phytoplankton abundances. However, factors other than Chl-A alone also contribute to variation in water clarity, so that variability exists in these relationships (as is also the case in Tampa Bay).

Using the entirety of the data set from all County waters, the following relationship was found to occur between Secchi Disk Depths and light extinction coefficients:

$$S.D. = -0.5228 \times \ln(K) + 1.2914;$$

Where,
S.D. = Secchi disk depth (meters),
ln = natural logarithm, and
K = light extinction coefficient (K / meter)

This relationship was significant at $P < 0.001$.

The value of this finding is that it can be used to convert extinction coefficients (which the general public may not be able to relate to) to water clarity measurements. An additional useful conversion would be from meters of visibility to feet of visibility, based on:

$$\text{Feet} = \text{Meters} \times 0.3048$$

The results shown in the table below are a first approach to develop “strawman” water clarity targets on a segment by segment basis. These targets were developed using the following approach. First, it was assumed that the percent sub-surface irradiance at the deep edge of seagrass meadows in Sarasota Bay was 25 percent (see Appendix A). Second, the three potential depths of 1, 2, and 3 meters (MSL) were target depths. These two numbers allowed for the calculation of example target water clarity goals. Third, the equations relating K to Chl-A shown above were used to convert these hypothetical water clarity goals to hypothetical Chl-A goals.

While the numbers calculated from this approach can be a useful tool for generating “strawman” water clarity goals, they are purely hypothetical. A relatively simple effort to determine the depth of penetration of seagrass meadows in various segments of Sarasota Bay would be needed to convert these hypothetical goals to realistic ones.

It should also be noted that target K values would not vary from segment to segment for the same depth target. That is, if 25 % of sub-surface irradiance is the target light level to achieve for a set depth, than the light attenuation coefficient to achieve that light level will not differ. Therefore, the only variation between segments would be for the amount of phytoplankton that would be “allowable” per segment, based on the segment-specific relationships between light attenuation and Chl-A.

3.0 Exploratory Data Analysis

Segment	1 m Depth Target K	1 m Depth Target Chl-A	2 m Depth Target K	2 m Depth Target Chl-A	3 m Depth Target K	3 m Depth Target Chl-A
7	1.386	36.3	0.693	5.5	0.462	NC
8	1.386	51.9	0.693	5.8	0.462	NC
10	1.386	18.8	0.693	4.5	0.462	NC
11	1.386	18.9	0.693	4.2	0.462	NC
12	1.386	39.5	0.693	10.4	0.462	NC
13	1.386	16.9	0.693	0.3	0.462	NC
14	1.386	16.5	0.693	1.4	0.462	NC
16	1.386	14.2	0.693	2.8	0.462	NC
Lemon Bay	1.386	15.5	0.693	NC	0.462	NC

Results from this data analysis of hypothetical goals show that existing water clarity in Sarasota County's waters would not be expected to be capable of allowing seagrass meadows to grow to a depth of 3 meters (NC = Not Calculated) in Sarasota Bay. The y-intercepts of all the light extinction coefficient vs. Chl-A equations derived from Sarasota County data are greater than the target K value of 0.462 / m.

For seagrasses to grow to 1 m below MSL, Chl-A values would have to be below a range of ca. 14.2 to 51.9 µg / liter. Since all bay segments have annual average Chl-A values below that range, it is more than likely that seagrass meadows can grow to depths greater than 1 m (MSL).

For seagrasses to grow to depths of 2 m (MSL), Chl-A values would have to average between 0.3 and 10.4 µg / liter. It would appear that most of Sarasota County's water has Chl-A values low enough to allow seagrass meadows to grow to 2 m of depth; Lemon Bay may be close to not having sufficient light for this to occur. Based on the water quality data supplied from the County, and using a minimum light level requirement of 25 percent of surface irradiance, it does not appear that seagrass meadows could grow to depths of 3 m (MSL) in most of Sarasota County's waters.

Pollutant loading data were obtained from Sarasota County staff for total nitrogen, total suspended solids, and biological oxygen demand (BOD) and plotted on basin maps (**Appendix C**) to develop a general understanding of relative loads to each bay segment.

Recent work in Tampa Bay on nitrogen loads and rainfall have resulted in a relatively simple method of evaluating progress in achieving water quality targets. Nutrient loading data are required to develop this analysis. Alternative uses of this methodology were explored using other surrogates for nutrient loading (chlorophyll concentrations) and hydrologic load (rainfall) since annual nutrient (nitrogen) loads are not currently calculated for the Sarasota Bay or Myakka River systems.

4.0 Implementation of a Resource-based Approach

It is more likely than not that the state-wide Chlorophyll-a standard of 11 µg / liter is inadequate as a water quality goal for Sarasota Bay. It also seems that resource-based Chlorophyll-a goals for Sarasota County waters should be developed on a segment-specific basis, as opposed to a bay-wide standard. For purposes of discussion, the following would be the segments for which proposed standards would be developed: 1) Big Sarasota Bay [SBNEP segments 7, 8 {those portions within Sarasota County} , and also segments 10, and 11], 2) Roberts Bay [SBNEP segment 13], 3) Little Sarasota Bay [SBNEP segment 14], 4) Blackburn Bay [SBNEP segment 16], 5) Dona and Roberts Bays, 6) Lemon Bay [south to the Charlotte County line], and 7) the upper and lower Myakka River [that portion within Sarasota County].

With this in mind, the following is a proposed course of action to allow for the development of segment-specific resource-based Chlorophyll-a goals for Sarasota Bay.

Step One:

As a priority action, develop segment-specific targets for the deep edges for existing seagrass meadows. To implement a "hold the line" strategy, target depths could be based on maintaining current (i.e., year 2006) deep edges. For each of the seven segments, five to ten transects should be established to determine the farthest offshore occurrence of seagrass coverage. Using standard Braun-Blanquet techniques for estimating coverage, this "deep edge" should be defined as the approximate location where seagrass coverage drops below ca. 10 percent (i.e., Braun-Blanquet scores of 1 and higher). While seagrass can be found farther offshore than this location, these meadows would be part of a "zone of occurrence" that would not be needed for these purposes. Using basic surveying techniques modified for measuring depths, and taking into account tide stage, the depths of the offshore edge should be calculated to a resolution of 5 cm (i.e., 1.50 or 2.25 m) and corrected to mean sea level (MSL). These transects could be incorporated into a long-term monitoring effort, using techniques currently in use for both Tampa Bay and Charlotte Harbor. However, the primary purpose here would be to develop statistically robust estimates of the depth to which seagrass meadows grow per each basin.

Step Two:

Using existing and ongoing water clarity measurements, determine the mean annual light attenuation coefficient (K m^{-1}) for each segment. The ongoing water quality monitoring efforts for Sarasota County waters should allow for this mean to be derived from approximately 60 values. The percent of immediately sub-surface irradiance at the deep edge of meadows could be calculated for each segment based on the following equation:

$$\text{Percent PAR} = 100 \times e^{-kd} \text{ ; where}$$

Percent PAR = Percent of immediately sub-surface photosynthetically active radiation (400 to 700 nm wavelength),
e = base of the natural logarithm,
k = light attenuation coefficient, and
d = depth (m)

If calculations of the percent of immediately sub-surface irradiance at the deep edge of meadows fall within the range of ca. 20 to 30%, then these calculations would appear to be consistent with prior estimates of the “minimum light requirements” for most species of seagrasses.

However, if values are significantly outside this range, then the possibility exists that factors other than water clarity alone have an important influence on controlling depth distributions (e.g., current velocities, boat wakes, additional attenuation by epiphytic material). In such a situation, further work (Step 3) might not be that valuable an exercise.

Step Three

Using existing and ongoing water quality monitoring efforts, empirically-derived relationships between light extinction coefficients (K) and phytoplankton concentrations (Chl-A) should be established. While multiple regression techniques may be useful for determining the importance of factors other than phytoplankton, Chl-A was found to be significantly and positively correlated with extinction coefficients in all local waters except for Dona and Roberts Bays (where no relationship was found) and the Lower Myakka River (where an inverse relationship was found).

For the Tampa Bay Estuary Program, the relationship between water clarity and phytoplankton abundance is derived by a simple regression technique, with K as the dependent variable, and Chl-A abundance as the potentially significant independent variable.

Step Four

Using the segment specific information from Steps 1 and 2, determine depth distribution and water clarity goals for meeting a “hold the line” strategy for seagrass coverage. Using the information from Steps 1, 2, and 3, determine a target phytoplankton level that, based on the empirical optical model, would allow for sufficient water clarity to allow adequate light penetration to the target depths for seagrass meadows on a segment by segment basis.

The following four scenarios were developed to illustrate the value of obtaining the necessary data required to implement a resource-based water clarity target for Sarasota County’s waters. While the County could decide to adopt a water quality target not linked to any particular living resource, data from Sarasota Bay, Lemon Bay, and Tampa Bay all have shown clear, statistically significant relationships can be developed between water clarity and living resources (i.e., seagrass depth distribution). Further, information contained in this report (p. 10 and Appendix A) show that statistically significant relationships exist between measures of water clarity, and measures of Chl-A.

Hypothetical Examples for Developing and Using Water Clarity and Chlorophyll Targets

Scenario One – Seagrass coverage is stable or increasing, with Chl-a $\leq$ 11 ug / liter

Under such a scenario, increased Chl-a levels are probably not appropriate, as they could likely cause decreases in biomass and/or productivity of existing meadows, or they could limit the amount of expansion that could occur for meadows that might be expanding their coverage. As these areas could obviously meet (perhaps not under all climatic conditions) a Chl-a target of 11 µg / liter or lower, the long-term average Chl-a level that was found under these conditions would be an appropriate target.

Scenario Two – Seagrass coverage is stable or increasing, with Chl-a > 11 ug / liter

Under such a scenario, documentation of stable or increasing seagrass coverage with sustained Chl-a levels greater than 11 µg / liter could be construed as evidence that the IWR standard was overly restrictive. In such a case, maintaining Chl-a levels at the long-term mean value would be protective of existing resources.

Scenario Three – Predicting losses with further increases in Chl-a levels

In Roberts Bay, the mean depth to which seagrass meadows grew in 2019, based on data from five transects, was 1.2 meters below MSL. For 2019 data, the mean attenuation coefficient (n = 60) was a K value of 1.13 m^{-1}.

Using the equations outlined in Step 2, the light at the deep edge calculates out to 25.7 percent of sub-surface irradiance. As this number falls within the range of expected “minimum light requirements” it is probable that water clarity is the dominant factor controlling the depth to which seagrasses can grow in this segment.

Also using 2017 water quality data, the mean Chl-a value for Roberts Bay was 20 µg / liter, and a regression of light attenuation vs. Chl-a found that variation in Chl-a values accounted for 12 percent of the variation in light attenuation, and that the attenuation coefficient for Chl-a was 0.038.

In such a scenario, a “hold the line” scenario for seagrass growth might be for Chl-a levels to be maintained at no more than 20 µg / liter, if seagrass mapping efforts and water quality monitoring efforts suggest seagrass coverage is stable with annual average Chl-a values of 20 µg / liter. If, however, Chl-a values were to increase to 30 µg / liter (with no change in color or turbidity), then light attenuation coefficients would be expected to increase from 1.13 to 1.51 (30-20 = 10; 10 x 0.038 = 0.38; 1.13 + 0.38 = 1.51).

With a long-term increase of Chl-a values from 20 to 30 µg / liter, and if the long-term minimum light requirement for seagrasses in Roberts Bay is 25.7 percent, then the deep edge of the grass bed would be expected to retreat from the observed 1.2 m (MSL) to a new deep edge of 1.1 m (MSL). Transect data from Roberts Bay could then be used to determine the average retreat toward the shoreline that would be expected with a reduction of seagrass meadows caused by this potential change in water clarity.

Scenario Four – Developing alternative Chl-a levels for segments losing seagrass coverage

In Roberts Bay, the mean depth to which seagrass meadows grew, based on data from five transects, was 1.2 meters below MSL. For 2019 data, the mean attenuation coefficient (n = 60) was a K value of 1.45 m^{-1}. Seagrass mapping data recorded losses of coverage between 2012 and 2016 of approximately 300 acres.

Using 2019 water quality data, the mean Chl-a value for Roberts Bay was 40 µg / liter, and a multiple regression of light attenuation vs. Color, Chl-a and Turbidity found that variation in Chl-a values accounted for 24 percent of the variation in light attenuation, and that the partial attenuation coefficient for Chl-a was 0.048.

From other segments with stable or increasing seagrass coverage, the average percent of light at the deep edge was 25.7 percent. For Roberts Bay in 2019, the mean percent of light at the deep edge (using 1.2 m depth and a mean K value of 1.45 m^{-1}) was only 17.6%.

To increase the light availability from 17.6 to 25 percent, the mean K value would have to decrease from 1.45 m^{-1} to 1.13 m^{-1}. For K values to change as such, mean Chl-a values would have to decrease to 33.3 µg / liter (1.45 – 1.13 = 0.32; 032 / 0.048 = 6.66; 40 – 6.66 = 33.3).

Thus, a reduction of Chl-a values from 40 to 33 µg / liter should allow for sufficient light for long-term survival of seagrasses at a depth of 1.2 meter (MSL) in Roberts Bay.

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Appendix A

Exploratory Data Analysis by Janicki Environmental

Appendix B

Box Plots of Available Water Quality Data by Segment

Appendix C

Pollutant Loading Maps