# Memorandum

**To:** Lizanne Garcia

**From:** David Tomasko, Ph.D., Emily Keenan, M.S.

**Date:** 8/1/2018

**Re:** Task 2 Deliverable

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This Technical Memorandum is intended to meet the contractual obligations for Task 2 of the Agreement (No. 14MA0000047) between the Southwest Florida Water Management District (DISTRICT) and ESA SCHEDA to provide services in connection with the Charlotte Harbor Protection and Restoration Planning - Swim Plan Update.

Task 2 of this Agreement involved the identification of the primary Issues and Drivers affecting the Charlotte Harbor system. To fulfill this task, ESA SCHEDA focused on an assessment of the three identified major focus areas of 1) Water Quality, 2) Hydrologic Alterations, and (3) Natural Systems.

Each of these topics are reviewed, and results summarized so that the major stressors to the Charlotte Harbor ecosystem are identified, and projects or project “types” are summarized for potential inclusion in the updated Surface Water and Improvement and Management (SWIM) Plan for Charlotte Harbor.

**Issues and Drivers – Water Quality**

As outlined in the Agreement, ESA SCHEDA summarized the impairment status of water quality, as related to the guidance contained within the Numeric Nutrient Concentration (NNC) criteria listed in Rule 62-302.531, Florida Administrative Code (FAC). Water quality was evaluated for the latest impairment cycle (Cycle 3) which extends from January 1, 2009 to June 30, 2016. To ensure consistency with any assessments that could be conducted by the Florida Department of Environmental Protection (FDEP), ESA SCHEDA analyzed data provided by FDEP in their latest Impaired Waters Rule data set. This ensured that any data deemed suspect or not relevant by FDEP would not be used to characterize the status and trends (if any) in recent water quality, in keeping with the standard approach FDEP uses to determine the impairment status of waterbodies.

The NNC criteria evaluation was carried out for the Water Body Identification number waterbodies (aka WBIDs) listed in Table 1.

**Table 1 – List of WBIDs reviewed for NNC criteria status.**

| WBID Number | WBID Name |
|---|---|
| 2056A | PEACE RIVER ESTUARY (LOWER SEGMENT) |
| 2056D | ALLIGATOR BAY |
| 1991B | MYAKKA RIVER |
| 2018A | ROBERTS BAY |
| 2002 | DONL BAY |
| 2056C1 | PEACE RIVER ESTUARY (UPPER SEGMENT NORTH) |
| 1991C | MYAKKA RIVER |
| 2065C | CHARLOTTE HARBOR (MIDDLE SEGMENT2) |
| 2056B | MIDDLE PEACE RIVER ESTUARY (MIDDLE SEGMENT) |
| 2055 | TIPPECANOE BAY |
| 2065A | CHARLOTTE HARBOR (UPPER SEGMENT) |
| 1991E | MYAKKA RIVER (TIDAL SEGMENT) |
| 2065B | CHARLOTTE HARBOR (MIDDLE SEGMENT1) |
| 1983B | LOWER LEMON BAY |
| 1991G | MYAKKA RIVER BELOW BLACKBURN BRIDGE |
| 2060A1 | MYAKKA CUTOFF (WESTERN PORTION) |
| 1991A | MYAKKA RIVER |
| 2002A | LYONS BAY |
| 2075B | DON PEDRO ISLAND |
| 2065D | CHARLOTTE HARBOR (LOWER SEGMENT1) |
| 1983A1 | LEMON BAY (NORTH SEGMENT) |
| 1983A | UPPER LEMON BAY |
| 2075D | MANLSOTA KEY |
| 2075A | LITTLE GASPARILLA ISLAND |
| 2056C2 | PEACE RIVER ESTUARY (UPPER SEGMENT SOUTH) |

This evaluation of NNC criteria for Total Nitrogen (TN), Total Phosphorus (TP) and chlorophyll-a determined that there is a discrepancy between the boundaries of the areas used for the derivation of NNC criteria, compared to the boundaries of the WBIDs to which the NNC criteria could be applied. Figures 1 and 2 show a comparison of the boundaries of the regions from which NNC criteria were derived, compared to the boundaries of the WBIDs where the NNC criteria were applied for Lemon Bay and Charlotte Harbor, respectively. Although the expectation might be that NNC criteria developed at the regional level would not be applied at the smaller WBID level, this apparently was done in the Comprehensive Verified Impaired list from December 18, 2017.

**Figure 1 – Comparison of boundaries of regions from which NNC criteria were derived (left) vs. the boundaries of the WBIDs for which the NNC criteria were applied (right) for Lemon Bay.**

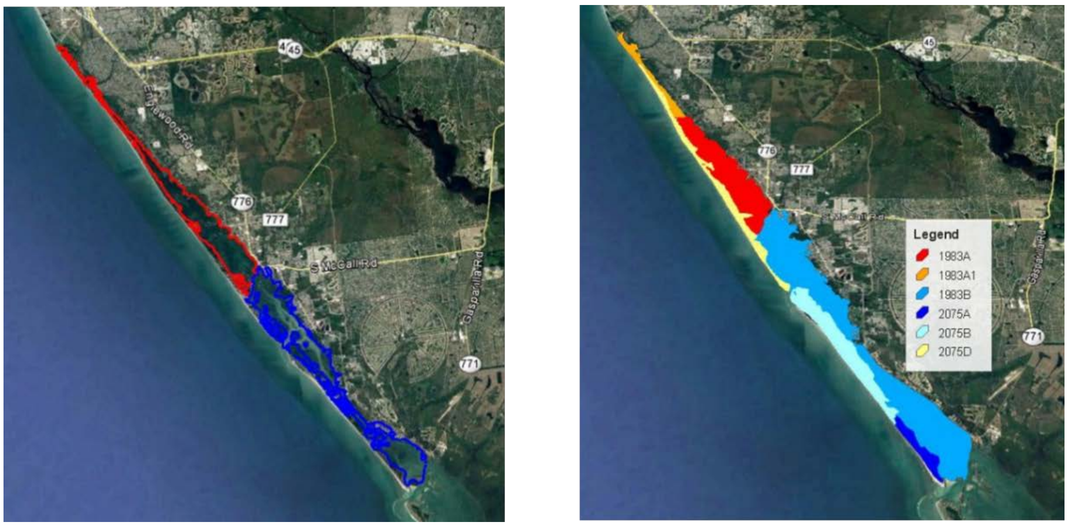



**Figure 2 – Comparison of boundaries of regions from which NNC criteria were derived (left) vs. the boundaries of the WBIDs for which the NNC criteria were applied (right) for Charlotte Harbor.**


For both Lemon Bay and Charlotte Harbor, individual WBIDs are in regions that would be expected to differ from the wider region from which NNC criteria were derived. The most significant example would be for Charlotte Harbor, where WBIDs 2065A and 2065B are closer to sources of freshwater inflow, and farther from the tidal flushing at Boca Grande Pass and Gasparilla Pass. As the NNC criteria for both Lemon Bay and Charlotte Harbor are single concentrations, rather than loads or salinity-normalized values, it would be expected that WBIDs 2065A and 2065B would be more likely to exceed NNC criteria than WBIDs 2065C and 2065D.

Table 2 displays results from the NNC criteria evaluation, with results shown for data aggregated at the regional scale, at which the criteria were derived, and the WBID level, at which the criteria were applied.

**Table 2 – Results of NNC criteria evaluation for TN, TP, and chlorophyll-a at both regional and WBID levels. Results are based on analysis of data for the period of January 1, 2009 to June 30, 2016. WBIDs with insufficient data for comparison with NNC criteria are marked with "ID".**

| | | | Total Nitrogen | | Total Phosphorus | | Chlorophyll-a | |
|---|---|---|---|---|---|---|---|---|
| WBID | Nutrient Region | WBID Name | Region | WBID | Region | WBID | Region | WBID |
| 2065A | Charlotte Harbor Proper | CHARLOTTE HARBOR (UPPER SEGMENT) | Not impaired | Impaired | Not impaired | Not impaired | Impaired | Impaired |
| 2065B | | CHARLOTTE HARBOR (MIDDLE SEGMENT1) | | Impaired | | Not impaired | | Impaired |
| 2065C | | CHARLOTTE HARBOR (MIDDLE SEGMENT2) | | Not impaired | | Not impaired | | Impaired |
| 2065D | | CHARLOTTE HARBOR (LOWER SEGMENT1) | | Not impaired | | Not impaired | | Not impaired |
| 2002 | Dona and Roberts Bay | DONA BAY | Impaired | Impaired | Not impaired | Not impaired | Impaired | Impaired |
| 2002A | | LYONS BAY | | Impaired | | Not impaired | | Impaired |
| 2018A | | ROBERTS BAY | | Impaired | | Not impaired | | Impaired |
| 1983B | Lower Lemon Bay | LOWER LEMON BAY | Not impaired | Not impaired | Not impaired | Not impaired | Not impaired | Not impaired |
| 2075A | | LITTLE GASPARILLA ISLAND | | ID | | ID | | ID |
| 2075B | | DON PEDRO ISLAND | | Not impaired | | Not impaired | | Not impaired |
| 2075D | | MANASOTA KEY | | ID | | ID | | ID |
| 1991A | Tidal Myakka River | MYAKKA RIVER | Not impaired | Not impaired | Not impaired | Not impaired | Impaired | Not impaired |
| 1991B | | MYAKKA RIVER | | Impaired | | Not impaired | | Impaired |
| 1991C | | MYAKKA RIVER | | ID | | ID | | ID |
| 2055 | | TIPPECANOE BAY | | Not impaired | | Not impaired | | Impaired |
| 2060A1 | | MYAKKA CUTOFF (WESTERN PORTION) | | Not impaired | | Not impaired | | Not impaired |
| 2056A | Tidal Peace River | PEACE RIVER ESTUARY (LOWER SEGMENT) | Not impaired | Not impaired | Not impaired | Not impaired | Impaired | Impaired |
| 2056B | | MIDDLE PEACE RIVER ESTUARY (MIDDLE SEGMENT) | | Impaired | | Not impaired | | Impaired |
| 2056C2 | | PEACE RIVER ESTUARY (UPPER SEGMENT SOUTH) | | Impaired | | ID | | Impaired |
| 2056D | | ALLIGATOR BAY | | Not impaired | | Not impaired | | Impaired |
| 1983A | Upper Lemon Bay | UPPER LEMON BAY | Impaired | Impaired | Not impaired | Not impaired | Impaired | Impaired |
| 1983A1 | | LEMON BAY (NORTH SEGMENT) | | Impaired | | Not impaired | | Impaired |

The results shown in Table 2 suggest a disconnect between impairment determinations for TN and TP, compared to chlorophyll-a. In addition, there can be disconnects between impairment determinations at the regional vs. WBID levels. For example, Charlotte Harbor Proper is impaired for chlorophyll-a at the regional level, but it is not impaired for either TN or TP at the regional level. Within the Charlotte Harbor region, the two WBIDs in the lowest salinity portions of the estuary (WBIDs 2065A and 2065B) are both impaired for TN, while the two WBIDs in the highest salinity portions of the estuary (WBIDS 2065C and 2065D) are not impaired for TN.

When the data are examined at the spatial level at which the criteria were derived – the regional level – there is a disconnect between determinations of impairment for nutrients and chlorophyll-a for Charlotte Harbor Proper, the Tidal Myakka River, and the Tidal Peace River. For those three regions, the finding of impairment for chlorophyll-a is not matched with a similar finding of impairment for either TN or TP. This finding is consistent with prior work by McPherson and Miller (1987) who determined that the amount of colored dissolved organic matter (CDOM) was the primary light attenuator in Charlotte Harbor, and that levels of CDOM were sufficiently high as to reduce the ability of phytoplankton to assimilate incoming nutrient loads. The lack of a clear relationship between nutrient supply, chlorophyll-a concentrations and water clarity had previously been noted by Tomasko and Hall (1999) who suggested that seagrasses were not the best biological indicator of ecosystem health in Charlotte Harbor.

In response to the findings of McPherson and Miller (1987) that CDOM was the dominant light attenuator, and the determination by Tomasko and Hall (1999) that seagrass productivity was influenced mostly by salinity and levels of CDOM, rather than phytoplankton abundance, another approach to determine sensitivity to nutrient loads was undertaken. In a study completed by CDM (1998) it was determined that the phenomenon of bottom water hypoxia was mostly a natural event, driven by salinity stratification under conditions of high inflows. However, it was concluded increasing oxygen demand in bottom sediments over time could intensify and increase the duration of the natural hypoxic bottom water condition. To determine if there was any evidence of a potential increase in sediment oxygen demand (SOD) researchers from Louisiana State University tested the bottom sediments for potential increases in SOD, by looking for trends in the nitrogen and/or organic loads to bottom sediments over time. They determined that there was evidence of an increase in nitrogen and organic contents in more recent sediments in Charlotte Harbor, and that SOD levels could be higher in recent years, thus exacerbating hypoxic conditions during salinity stratification (Turner et al. 2006).

Based on the findings of Turner et al. (2006) and the Charlotte Harbor National Estuary Program (NEP) Policy Committee, the SWFWMD Governing Board supported adoption of a “hold the line” approach to nitrogen loads to Charlotte Harbor from the Peace River watershed. The determination of the need to hold the line on nutrient loads to Charlotte Harbor, and the basis for the SWFWMD projects developed to reduce impacts of nitrogen loads from Lake Hancock, was thus informed by the potential link between bottom water hypoxia and the apparent increase in organic loads to the sediments of Charlotte Harbor (Turner et al. 2006). This approach is very different than the nutrient management paradigm contained within the NNC criteria for determining impairment status, which is focused on water quality in surface samples and seagrass coverage, rather than SOD and bottom water hypoxia.

Based on the results shown in Table 2, and the issue of bottom water hypoxia, current NNC criteria may not provide adequate information to determine appropriate management actions to protect Charlotte Harbor. For example, if it is determined that the region-wide impairments for chlorophyll-a in Charlotte Harbor and the tidal Myakka and Peace Rivers require a management response, what should such a response be, if those same waters are not similarly impaired for either TN or TP? And since FDEP only uses surface water samples to determine impairment status, how is the link between nutrients, SOD and bottom water hypoxia to be accounted for?

To examine nutrient issues in greater detail, trend analysis was conducted using all available water quality data for TN, TP and chlorophyll-a at both the regional and WBID levels. To increase the sample size for trend analysis, data were examined for the years 2000 to 2017, using water quality data provided by DEP for WBID-level analyses. This period of record was chosen, as it corresponds to the period of record just after the last SWIM Plan was produced, and results here can be compared with findings from that plan. For chlorophyll-a, any values reported as “below minimum detection limit” were given a value equal to half the minimum detection limit, per FDEP protocol.

The water quality trends in the open waters of Charlotte Harbor, as outlined in the 2000 SWIM Plan include the following:

- TP concentrations declined significantly during the period of 1976 to 1996;
- There were no trends in Total Kjeldahl Nitrogen (TKN) over the period of 1976 to 1996;
- Chlorophyll-a concentrations displayed no trend over the period of 1976 to 1996;
- Salinity decreased over the years 1976 to 1996, which was concurrent with a positive trend in streamflow in the Lower Peace River over the same period;
- Dissolved oxygen values declined significantly during 1976 to 1996, which was thought to be linked to an increasing frequency of stratification-driven hypoxia, which would be expected under conditions of increased flow; and
- There was no apparent trend in the number of months with hypoxic conditions during the period 1975 to 1989 (Camp, Dresser & McKee, Inc. 1998).

To build on the trends identified in the 2000 SWIM Plan, two statistical tests were used for data from 2000 to 2017; linear regression and the Seasonal Kendall Tau test. Linear regression is an appropriate statistical test if the data set examined meets four requirements: 1) the relationship between time and the water quality data is linear, 2) the data points of time and water quality are measured independent of each other, 3) the data are normally distributed, and 4) the data sets display equal variation (they are homoscedastic). While these requirements were met for some of the data sets examined, they were not met for most of the data sets. In addition to linear regression, analysis was conducted using the Seasonal Kendall Tau test. This test does not require the data to be linearly correlated or normally distributed, as it uses ranks of data, compared to actual values. The Seasonal Kendall Tau test does not compare years against each other, it compares "seasons". In this way, all the Januarys between 2000 to 2017 are compared against each other, etc. After the ranks of each month are compared against each other, a weighted average value is derived that would determine, in effect, if "enough" months are changing in a similar enough fashion that one could conclude that the system as a whole is changing over time.

For chlorophyll-a examined at a regional level, linear regression was either not appropriate, or it failed to find a significant trend over time for Charlotte Harbor, Gasparilla Sound, Dona Bay, Lemon Bay, Lyons Bay, the tidal Myakka River, the tidal Peace River, and Roberts Bay. For those same regions, the Seasonal Kendall Tau test found only one trend – decreasing concentrations of chlorophyll-a for the tidal Peace River.

At a regional level, linear regression found evidence of decreasing values of TN for the years 2000 to 2017 for Gasparilla Sound and the Tidal Peace River, but no trends for any of the other regions. For those same regions, the Seasonal Kendall Tau test found evidence for decreasing trends for TN in Charlotte Harbor and the tidal Peace and Myakka Rivers, but an increasing trend of TN in Lemon Bay.

At the regional level, linear regression found evidence of decreasing values for TP in Charlotte Harbor, Gasparilla Sound and Lemon Bay. Using the Seasonal Kendall Tau test, decreasing TP values were found in Charlotte Harbor, Lemon Bay, and both the tidal Peace and tidal Myakka Rivers.

Water clarity was examined at the regional level, using data on Secchi disk depths. Linear regression was not found to be an appropriate test for most of the analyses, as data failed to meet requirements of normality and/or homogeneity of variance. Using the Seasonal Kendall Tau test, results indicated trends of improving water clarity (increasing Secchi disk depths) in Charlotte Harbor, Lemon Bay, and the tidal Peace and Myakka Rivers.

Overall, the results of trend analysis can be summarized as follows:

- There is no evidence of degrading water clarity over the period of 2000 to 2017 for any of the estuarine nutrient regions examined;
- There is evidence of improving water clarity over those same years for Charlotte Harbor, the tidal Peace and Myakka Rivers, and Lemon Bay;
- There is no evidence of increasing concentrations of chlorophyll-a over the period of 2000 to 2017 for any of the regions examined;
- There is evidence of declining concentrations of chlorophyll-a over those same years in the tidal reaches of the Peace River;
- There is no evidence of increasing concentrations of TN over the period of 2000 to 2017 for any of the regions examined except for Lemon Bay;
- There is evidence of declining concentrations of TN over those same years in the tidal reaches of the Peace and Myakka Rivers, Charlotte Harbor, and Gasparilla Sound; and

- There is no evidence of increasing concentrations of TP over the period of 2000 to 2017 for any of the regions examined.

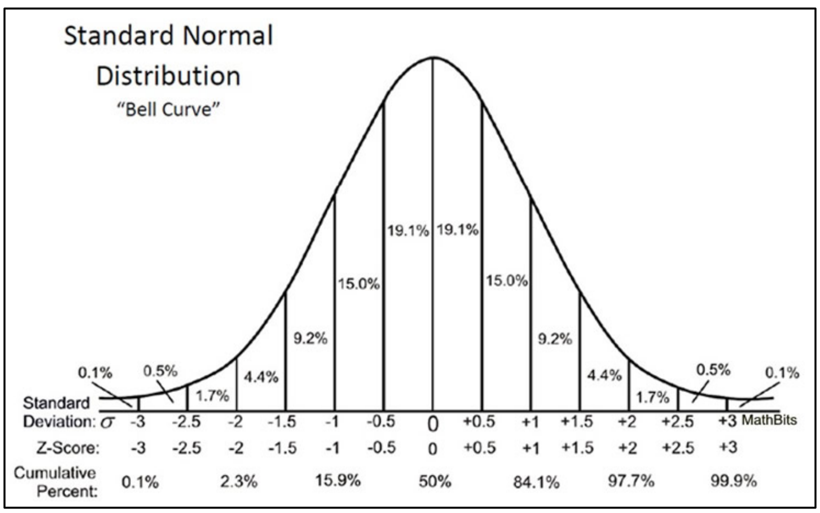
There is evidence of declining concentrations of TP over those same years in the tidal reaches of the Peace and Myakka Rivers, Charlotte Harbor, Gasparilla Sound, and Lemon Bay. With the exception of Lemon Bay, the results of the trend analysis suggest that water quality over the past 17 years is either non-trending or trending towards improvements across the region. These findings are somewhat in conflict with the assessment of the NNC criteria displayed in Table 2.

The reasons for the apparent disconnect between trend analysis and the NNC criteria analysis could be because the NNC criteria were based on a statistical distribution of data, rather than being tied to trend analysis and/or a dose-response assessment. In a report prepared for the Charlotte Harbor NEP (Janicki Environmental, Inc., 2010), the NNC criteria were developed to compare results to a “reference period” of 2003 to 2007. The reference period was selected based upon the determination that seagrass coverage during those years was similar to, or trending towards, the historical amount of seagrass in both Charlotte Harbor and Lemon Bay.

The NNC criteria (Janicki Environmental, Inc., 2010) were statistically based, in that the values chosen for TN, TP and chlorophyll-a represented the mean of annual means (n=5) plus one-half of the standard deviation of that mean of annual means, for both Lemon Bay and Charlotte Harbor.

As illustrated in Figure 3, values higher than one half of the standard deviation above the mean would be expected to occur approximately 31 percent of the time, by chance alone.

**Figure 3 – Distribution of data with various distances from the mean, in terms of standard deviations.**




For both Charlotte Harbor and Lemon Bay, the determination of impairment for chlorophyll-a could be a statistical artifact based on a combination of high variability (for chlorophyll-a) and a roughly one in three chance that criteria would be impaired in any given year, even if water quality was not degraded.

To assess the validity of NNC results, which suggested impairments for chlorophyll-a in Charlotte Harbor, the amount of seagrass coverage was analyzed, as seagrass coverage is the ecosystem feature that is intended to be protected by NNC. This assessment was conducted using data from SWFWMD seagrass mapping efforts (SWFWMD 2016).

**Seagrass Mapping Results**

For Charlotte Harbor, Figure 4 displays the trends over time for seagrass in Charlotte Harbor over the period of 1982 to 2016.

**Figure 4 – Seagrass coverage in Charlotte Harbor. Values are in units of acres of patchy, continuous and total (patchy plus continuous) seagrass. The area in the green box indicates the reference period of 2003 to 2007.**

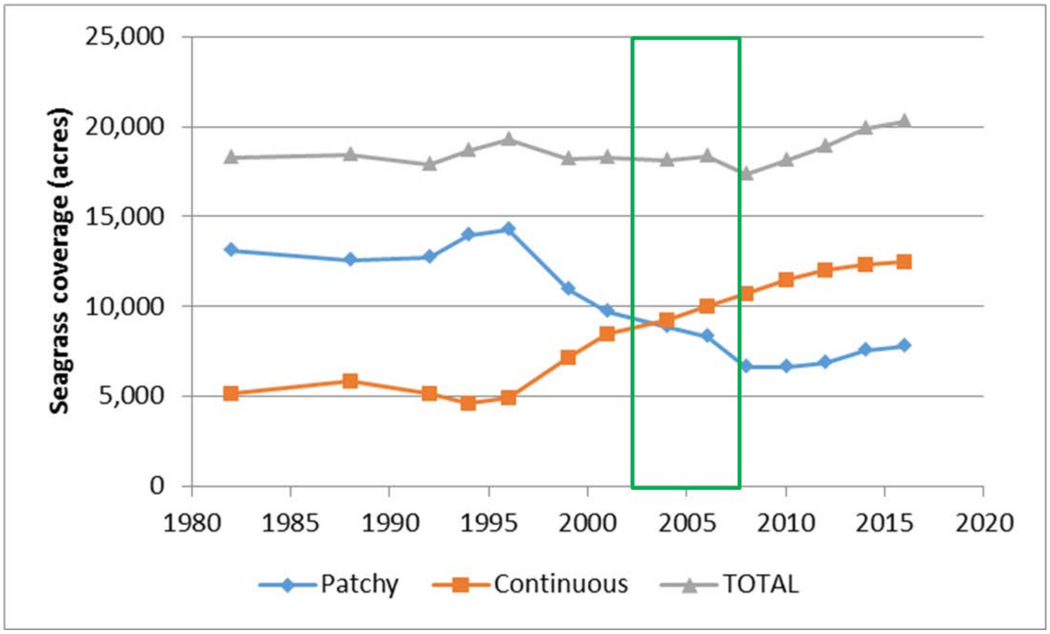



Figure 4 shows that there is currently more seagrass in Charlotte Harbor than in the 2003 to 2007 reference period and all previously monitored years. In addition to the positive trends in total acreage, a greater percentage of seagrass is mapped as continuous meadows, rather than patchy meadows. Polygons mapped as patchy seagrass have seagrass in approximately 25 to 75% of their boundaries, while polygons categorized as continuous have more than 75% seagrass coverage within their boundaries. The biomass of seagrass meadows increases as nutrient loads decrease (Tomasko et al. 1996) indicating that a transition from patchy to continuous seagrass coverage is indicative of improved water quality, which is consistent with the water clarity and nutrient trend analyses outlined above. The combination of increased coverage and a shift from patchy to continuous coverage suggests that water quality in Charlotte Harbor is not only as good or better than it was in the reference period of 2003 to 2007, it appears to be as good or better than it has been at any time since 1982.

For Lemon Bay, Figure 5 displays the trends over time for seagrass in Lemon Bay over the period of 1988 to 2016.

**Figure 5 – Seagrass coverage in Lemon Bay. Values are in units of acres of patchy, continuous and total (patchy plus continuous) seagrass meadows. The area in the green box indicates the reference period of 2003 to 2007.**

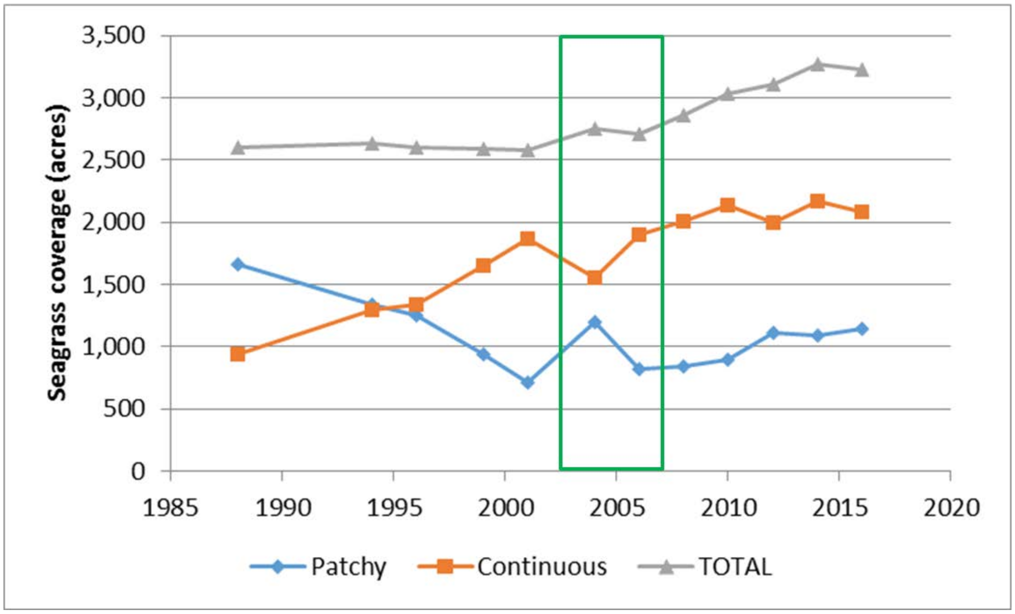



Figure 5 illustrates that there is currently more seagrass in Lemon Bay than in the 2003 to 2007 reference period, and more than in nearly all previously monitored years (total coverage was greatest in 2014). As was observed in Charlotte Harbor, there is now a greater percentage of seagrass mapped as continuous meadows. The combination of increased coverage and a shift from patchy to continuous coverage suggests that water quality in Lemon Bay is not only as good or better than it was in the reference period of 2003 to 2007, it appears to be as good or better than it has been at any time since 1988. As was found for Charlotte Harbor, these results suggest that the "intent" of the NNC guidance for Lemon Bay – the maintenance of water quality adequate for supporting seagrass coverage in Lemon Bay – has been met. Since phytoplankton were previously found to be the major cause of light attenuator in Lemon Bay (Tomasko et al. 2001) these results suggest that the finding of impairment for chlorophyll-a in Upper Lemon Bay (Table 2) is inconsistent with the results shown in Figure 5, where seagrass coverage is higher than at any time since 1988.

**Pollutant Loading Model**

To further aid in the interpretation of data on NNC impairments and seagrass, ESA SCHEDA completed an empirical pollutant loading model for the gaged Peace and Myakka River watershed for the years of 2009, 2010, 2011, 2012, 2013, 2014, and 2015. Results were compared between this effort and prior loading models conducted for both SWIM and the Charlotte Harbor NEP. The mean annual loads for TN, TP and Total Suspended Solids (TSS) were then compared to prior loading model values, as well as annual average values for chlorophyll-a for the tidal Peace River and Charlotte Harbor nutrient regions.

The pollutant loading model was completed using similar methods as had been previously used by the Charlotte Harbor Environmental Center (2001). Briefly stated, the loading model was constructed in the following manner:

- Flows and water quality data were compiled for gaged locations within the Peace and Myakka River watersheds. These stations included the following locations:

- Peace Creek at Wahneta
- Saddle Creek at P-11 structure
- Peace River at Bartow
- Peace River at Ft. Meade
- Peace River at Zolfo Springs
- Peace River at Arcadia
- Horse Creek near Myakka Head
- Horse Creek near Arcadia
- Charlie Creek near Gardner
- Joshua Creek at Nocatee
- Shell Creek near Punta Gorda
- Myakka River at Myakka City
- Myakka River near Laurel

For the Myakka River, the farthest downstream gage site (Myakka River at Laurel) only gages 42 percent of the river's 602 square mile watershed (Hammett 1990). Therefore, load estimates from the Myakka River do not represent as complete an assessment as is possible with the Peace River, where approximately 89 percent of the watershed is gaged. For these reasons, TN, TP and TSS loads from the Myakka River watershed are compared against values on an area-normalized basis, but they aren't included in the graphics shown below.

At each location, average monthly flow values were obtained from the U.S. Geological Survey (USGS), and the monthly (if available) water quality data from these same locations was then multiplied by the monthly average flow to derive a monthly average load for TN, TP and Total Suspended Solids (TSS). These monthly values were then summed for a given year to develop annual estimates of TN, TP and TSS loads for the years of 2009 to 2015. In addition, the average annual loads for each gaged location were then divided by the size of the watershed upstream from the gage, so that an area-normalized load could be developed for TN, TP and TSS. These area-normalized loads were then compared to prior estimates for Water Year (WY) 1998, WY 1999, and estimates of area-normalized loads based on results from Coastal Environmental, Inc. (1995) which developed loading estimates for the seven-year period of 1985 to 1991. Results from WY 1998 reflect the influence of the 1997 to 1998 El Niño event, during which rainfall in the Peace River watershed exceeded 60 inches. Rainfall in excess of 60 inches has been recorded 17 times during the past 100 years (data from watermatters.org). As such, results from WY 1999 represent a very high, yet not unprecedented, amount of rainfall.

Figures 6 and 7 show area-normalized TN loading rates for gaged locations in the Peace River watershed with and without, respectively, results from WY 1998.

**Figure 6 – Area normalized TN loads for the Peace River watershed by gaged location. Values are in units of pounds of TN per acre per year. Gaged locations are arrayed along the x-axis from upstream to downstream within the watershed.**

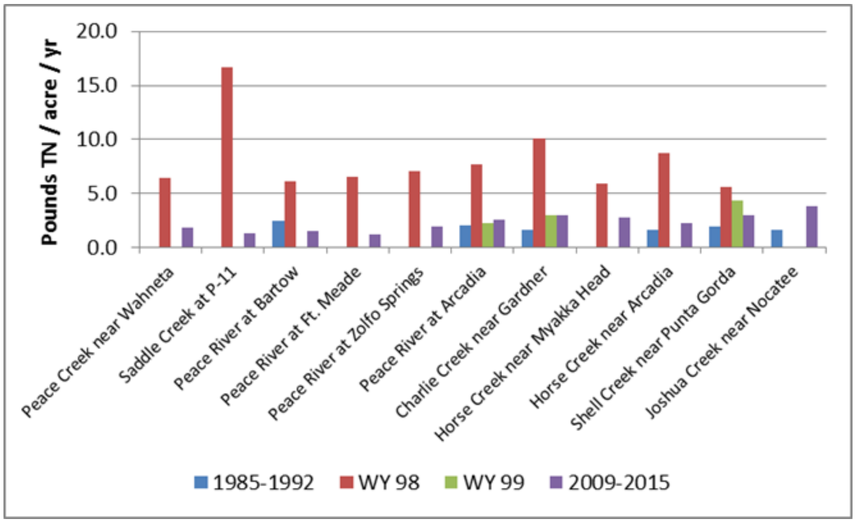
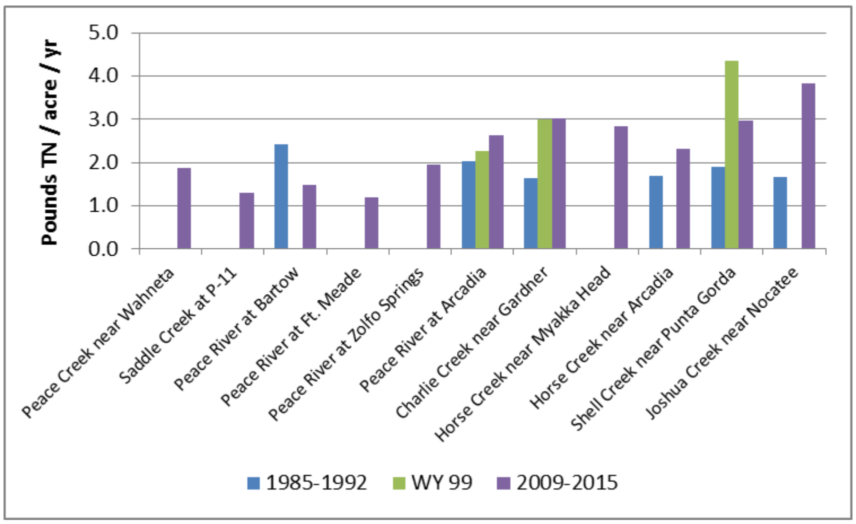



**Figure 7 – Area normalized TN loads for the Peace River watershed by gaged location, without showing results from WY 1998. Values are in units of pounds of TN per acre per year. Gaged locations are arrayed along the x-axis from upstream to downstream within the watershed.**




In WY 1998, the gage at Saddle Creek at the P-11 structure was clearly providing the highest loading of TN compared to all other stations along the Peace River. This location is the first station downstream of discharges from Lake Hancock into the Peace River basin. Results from WY 1998 showed the importance of focusing on discharges from Lake Hancock, which led to two District-sponsored projects, the Lake Hancock Lake Level Modification Project and the Lake Hancock Outfall Treatment Project. The Lake Level Project, completed in 2013 and operational in 2015, increases the control elevation at the lake outfall structure to store more water in the rainy season to increase discharges to the Peace River in the dry season. Recent data suggests the increased volume and depth of the lake has resulted in water quality improvements. Construction of the Lake Hancock Outfall Treatment Project was completed in 2014. Operation of the system has been limited to promoting growth and coverage of emergent wetland vegetation. Once fully operational, low flows from the lake (52 cubic feet per second and less) will be discharged from the treatment wetland.

Recent results (Figure 7) show that with the decreases in TN loading at the P-11 structure, the highest TN loadings are now occurring in basins farther downstream, with the highest area-normalized TN loading rates being found in Joshua Creek, Charlie Creek and Shell Creek. Results shown in Figure 7 suggest that TN loading rates may have increased over time in Joshua Creek, comparing prior estimates to values from 2009 to 2015.

Area-normalized TN loading rates for the Myakka River at Myakka City and Myakka River at Laurel averaged 3.67 and 2.78 lbs TN / acre / yr, respectively. These values would suggest that the Upper Myakka River generates more nitrogen per acre than farther downstream at Laurel. Based on yields at Laurel, the Myakka River watershed generates less nitrogen per acre than at Horse Creek at Myakka Head, Joshua Creek, Charlie Creek and Shell Creek.

Figures 8 and 9 show area-normalized TP loading rates for gaged locations in the Peace River watershed with and without, respectively, results from WY 1998.

**Figure 8 – Area normalized TP loads for the Peace River watershed by gaged location. Values are in units of pounds of TP per acre per year. Gaged locations are arrayed along the x-axis from upstream to downstream within the watershed.**

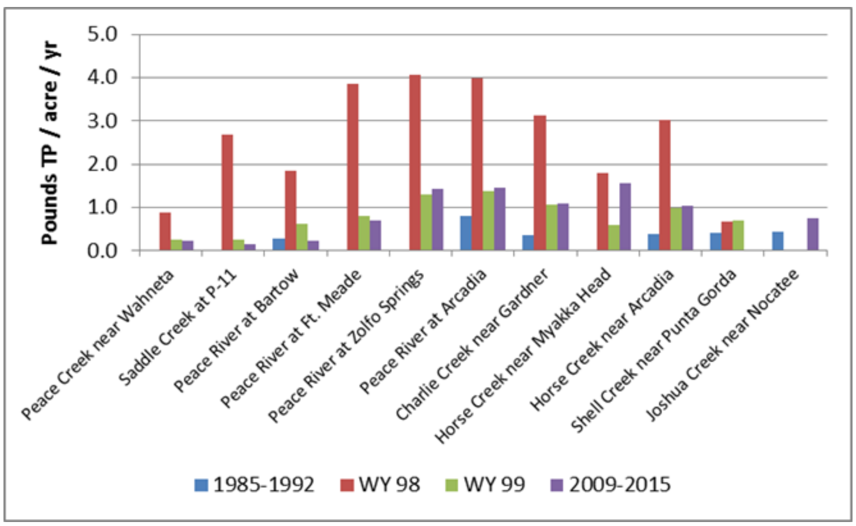
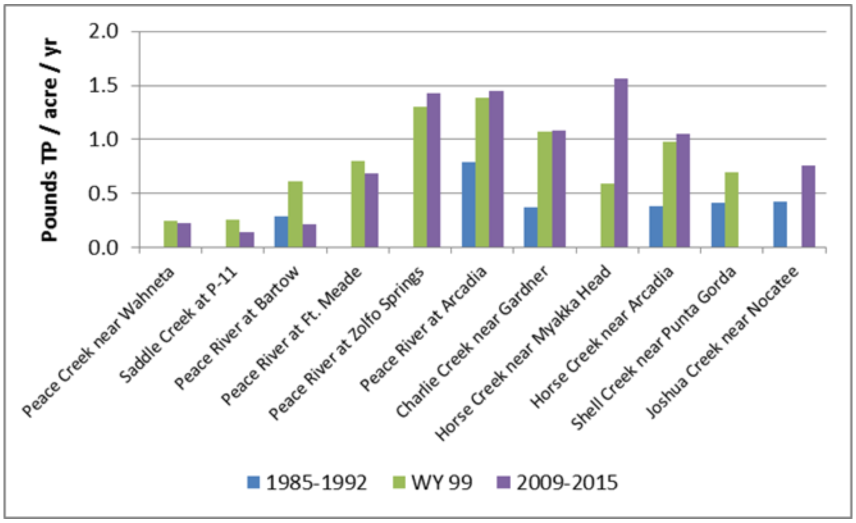


**Figure 9– Area normalized TP loads for the Peace River watershed by gaged location, without results from WY 1998. Values are in units of pounds of TP per acre per year. Gaged locations are arrayed along the x-axis from upstream to downstream within the watershed.**




In WY 1998 and in the most recent assessment, the highest values for area-normalized TP loading rates were generally in the Middle reaches of the Peace River watershed, at the Peace River at Ft. Meade down to the Peace River at Arcadia gages.

Area-normalized TP loading rates for the Myakka River at Myakka City and Myakka River at Laurel averaged 1.50 and 1.27 lbs TP / acre / yr, respectively. These values would suggest that the Upper Myakka River generates more phosphorus per acre than farther downstream at Laurel. Based on yields at Laurel, the Myakka River watershed generates less phosphorus per acre than at Horse Creek at Myakka Head, as well as the Peace River gaged locations at Zolfo Springs and Arcadia.

Figures 10 and 11 show area-normalized TSS loading rates for gaged locations in the Peace River watershed with and without, respectively, results from WY 1998.

**Figure 10 – Area normalized TSS loads for the Peace River watershed by gaged location. Values are in units of pounds of TSS per acre per year. Gaged locations are arrayed along the x-axis from upstream to downstream within the watershed.**

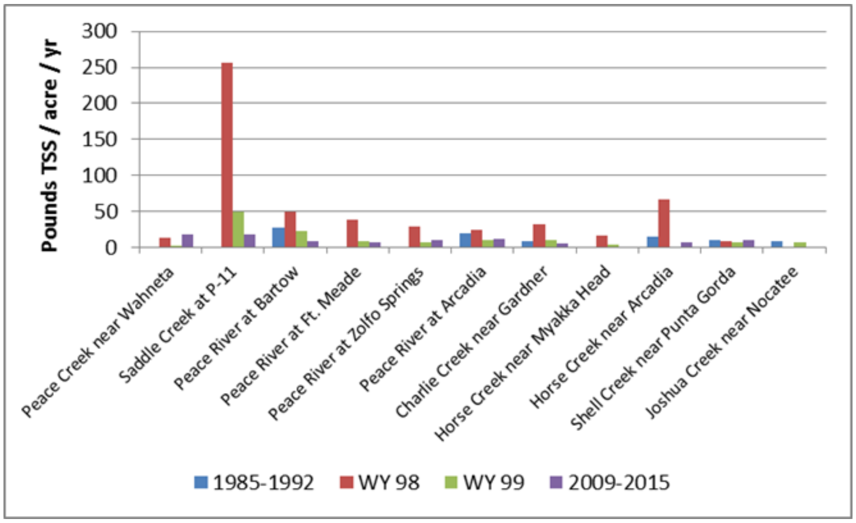
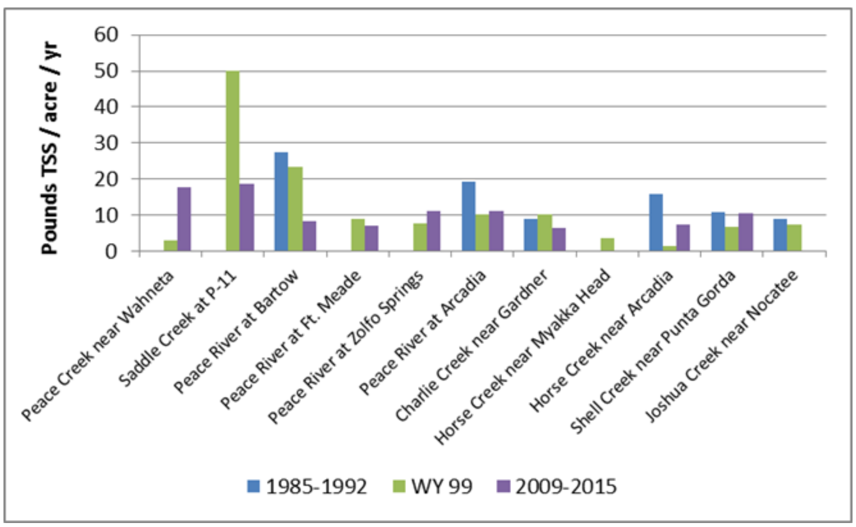



**Figure 11– Area normalized TSS loads for the Peace River watershed by gaged location, without results from WY 1998. Values are in units of pounds of TSS per acre per year. Gaged locations are arrayed along the x-axis from upstream to downstream within the watershed.**




In WY 1998 and in the most recent assessment, the highest values for area-normalized TSS loading rates were in the Upper Peace River watershed, particularly at the Saddle Creek at P-11 location. These results suggest that although discharges from Lake Hancock may have improved to the point that Lake Hancock is no longer the highest loading basin for TN to the Peace River, it is still a major source of TSS loads to the Peace River.

Area-normalized TSS loading rates for the Myakka River at Myakka City and Myakka River at Laurel averaged 12.94 and 14.51 lbs TSS / acre / yr, respectively. These values would suggest that the Upper and Lower Myakka River watershed generates similar rates of TSS per acre. Based on yields at Laurel, the Myakka River watershed generates less TSS per acre than at Saddle Creek, Peace Creek and Joshua Creek, but higher than values in most of the mainstem of the Peace River.

Table 3 summarizes the annual nitrogen load estimates for 2009 to 2016 for the following gages: Peace River at Arcadia, Horse Creek near Arcadia, Joshua Creek near Nocatee, and Shell Creek near Punta Gorda. When these gage sites are summed, they equal approximately 89 percent of the total Peace River watershed. These annual loads were then compared to annual average chlorophyll-a values for the same calendar years for the two NNC regions of Charlotte Harbor Proper and the tidal Peace River.

**Table 3 – TN loads (tons per year) for 2009 to 2016 for the gaged Peace River, and annual average chlorophyll-a values for the Charlotte Harbor and Tidal Peace River regions used to derive NNC criteria.**

| Year | TN Load estimates (tons / yr) | | | | | Annual Average Chl-a (µg / liter) | |
|---|---|---|---|---|---|---|---|
| | Peace River at Arcadia | Horse Creek near Arcadia | Joshua Creek near Nocatee | Shell Creek near Punta Gorda | Sum gauged Peace River | Charlotte Harbor Proper | Tidal Peace River |
| 2009 | 984 | 137 | 126 | 325 | 1,572 | 10.45 | 14.93 |
| 2010 | 1,090 | 158 | 213 | 241 | 1,702 | 7.63 | 16.75 |
| 2011 | 892 | 110 | 146 | 225 | 1,373 | 6.88 | 16.86 |
| 2012 | 1,006 | 188 | 170 | 369 | 1,733 | 6.75 | 11.44 |
| 2013 | 1,581 | 207 | 241 | 636 | 2,666 | 8.65 | 10.28 |
| 2014 | 1,017 | 115 | 65 | 306 | 1,504 | 7.23 | 12.01 |
| 2015 | 1,467 | 211 | 176 | 384 | 2,238 | 6.80 | 8.61 |
| **Mean** | **1,148** | **161** | **162** | **355** | **1,827** | **7.77** | **12.98** |

On average, the Peace River at Arcadia contributes more of the TN load than any of the other gaged locations within the basin, because its 1,367 square mile watershed is more than three time as large as the next largest sub-basin, the 373 square mile watershed for Shell Creek near Punta Gorda. The sub-basins of Horse Creek and Joshua Creek are similar in terms of their contributions to TN loads. However, Joshua Creek's higher than expected (for the Peace River) area-normalized TN loads (Figure 6) results in a similar load as Horse Creek, even though it has a smaller watershed.

The TN load from the gaged portions of the Peace River watershed, over the years 2009 to 2015, averaged 1,827 tons / yr. In comparison, the average TN load from those same locations, summed over the years 1985 to 1991, comes to 1,820 tons / year (Coastal Environmental Inc., 1995) a value less than 5 percent different.

The two-time periods of 1985 to 1991 and 2009 to 2015 represent seven years each, separated by 25 years. The two estimates were made using the same approach – combining measured flows and water quality data at four gages that combined equal 89 percent of the Peace River watershed. The fact that the average values of the two reports, separated by 25 years, are within 5 percent of each other indicates that the Peace River's TN loads have not trended over time. Based on the reduction of TN loads from Saddle Creek at the P-11 this basin may no longer require as much attention as 20 years ago. The focus can now be shifted to the basins that have been identified as higher TN loading sources, such as Joshua Creek.

As a final assessment, annual TN loads for the gaged Peace River were compared against the annual average chlorophyll-a values for the NNC regions of Charlotte Harbor and the Tidal Peace River in Figures 12 and 13, respectively. The results displayed here show no obvious relationship between TN loads and chlorophyll-a in either the open waters of the Harbor, or the tidal Peace River. These results are consistent with earlier work in

Charlotte Harbor, where it was determined that the nitrogen load – chlorophyll – water clarity – seagrass paradigm developed for Tampa Bay did not work for Charlotte Harbor (McPherson and Miller 1987, Tomasko and Hall 1999, CDM 1998). The results shown here, and the prior work noted above put into question the premise of the NNC for Charlotte Harbor, that there is a link between nutrient supply and seagrass coverage that is expected to function similarly as it does in Tampa Bay.

**Figure 12 – Plot of annual TN load from the gaged Peace River vs. annual average chlorophyll-a value for the same year for the Charlotte Harbor NNC region.**

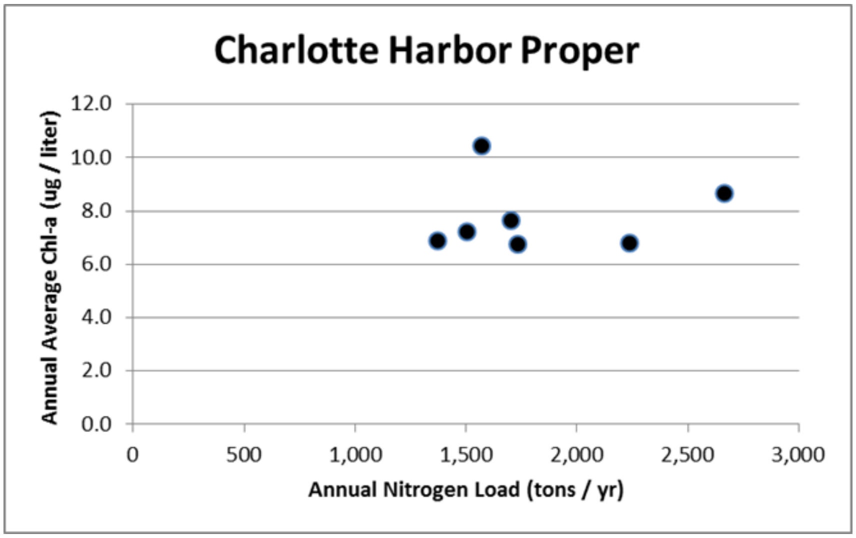
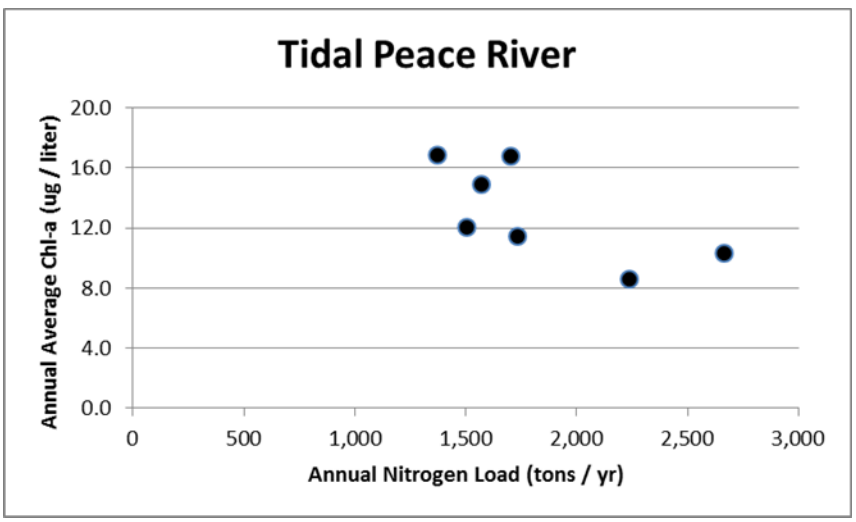



**Figure 13 – Plot of annual TN load from the gaged Peace River vs. annual average chlorophyll-a value for the same year for the Tidal Peace River NNC region.**



### Issues and Drivers – Hydrologic Alterations

Within the District's boundaries for the Charlotte Harbor watershed, there are a variety of documented alterations to hydrology. In the Upper Peace River, reductions in stream flow have been found to be greater than that which can be attributed to changes in rainfall alone (SWFWMD 2002). In the lower reaches of the Peace River, long-term trends in streamflow are more closely aligned with trends in rainfall (Basso and Schultz 2003). In the Upper Myakka River, an extensive die-off of trees in Flatford Swamp has been linked to increased excess flows, which have impacted the hydroperiod and water levels in the swamp (PBS&J 1998). Downstream, flows are not as impacted by excess dry season flows, and no similar stresses occur for the lower reaches of the Myakka River. The construction of the Cow Pen Canal in 1960 expanded the size of Dona Bay's watershed from 15 to 75 square miles. The five-fold increase in the size of the watershed has impacted Dona Bay due to excessive freshwater inflows, particularly during the wet season.

The 2000 Charlotte Harbor SWIM Plan identified several management actions, primarily related to the establishment of minimum flows, for hydrologic restoration of tributaries to the harbor. These actions are listed below along with relevant project and resource status updates.

- Establishment of minimum flows for the Upper, Middle and Lower Peace River including Shell, Horse and Joshua creeks
    - Technical work supporting establishment of minimum flows for the Upper Peace River was completed (SWFWMD 2002), and minimum flows were established for three upper river sites in 2006 (Rule 40D-8.041(7), FAC).
    - The minimum flows for the Upper Peace River are being met at the Zolfo Springs gage site, but not at the Ft. Mead and Bartow gages.
    - Technical work supporting establishment of minimum flows the Middle Peace River was completed (SWFWMD 2005a), and minimum flows were established in 2006 (Rule 40D-8.041(5), FAC).
    - The minimum flows for the Middle Peace River are being met.
    - Technical work supporting establishment of minimum flows the Lower Peace River was completed (SWFWMD 2010), and minimum flows were established in 2010 (Rule 40D-8.041(10), FAC).
    - The minimum flows for the Lower Peace River are being met.
    - A reevaluation of the Lower Peace minimum flow was completed in 2015 (SWFWMD 2015).
- Establishment of minimum flows for the Myakka River and continuation of efforts to reduce excessive dry season flows in the Upper Myakka River
    - Technical work supporting establishment of minimum flows for the Upper Myakka River was completed (SWFWMD 2005b), and minimum flows were established in 2006 (Rule 40D-8.041(6)(a)), FAC).
    - Technical work supporting establishment of minimum flows for the Lower Myakka River was completed (SWFWMD 2011), and minimum flows were established in 2012 (Rule 40D-8.041(6)(b)), FAC).
    - The minimum flows for the Upper and Lower Myakka River are being met.
- Assess the potential for hydrologic restoration of Cow Pen Slough

- Technical work supporting establishment of minimum flows for the Dona Bay/Shakett Creek System was completed (SWFWMD 2009), and minimum flows were established in 2010 (Rule 40D-8.041(14), FAC).

- The minimum flows for the Dona Bay/Shakett Creek System are being met.

A major District Initiative to address recovery of flows and levels in the Upper Peace River and the region is implementation of the Southern Water Use Caution Area (SWUCA) Recovery Strategy (SWFWMD 2006). The primary mechanism to meet the recovery strategy for the Upper Peace River is the recently completed Lake Hancock Lake Level Modification Project. This project included modifications to the P-11 structure that controls water levels in Lake Hancock to allow for increased wet weather storage and subsequent delivery of these stored quantities of water during the dry season.

For the Upper Myakka River, excessive amounts of inflow have led to hydroperiods associated with substantial wetland tree mortality (PBS&J 1999). Recovery of forested wetlands in the Flatford Swamp portion of the watershed will require a reduction in flows and the shortening of hydroperiods, which is expected to be accomplished through the Aquifer Recharge Project at Flatford Swamp for Saltwater Intrusion Minimum Aquifer Level Recovery. The goal of this District Initiative is to divert between 2 and potentially up to 10 mgd of flow out of the swamp. In addition to promoting more natural wetland hydroperiods in the swamp, the project is expected to reduce the rate of saltwater intrusion inland from the Gulf of Mexico.

In the Dona Bay Watershed Management Plan (KHA 2007) diversions of 5, 10 and 15 mgd were associated with benefits to water quality and natural systems in the receiving waters of Dona Bay. Currently, Sarasota County and the District are working to implement Phase II of the Dona Bay Restoration Project, which would divert 3 mgd of flows out of the Cow Pen Canal back toward their historical destination of the Myakka River.

The Charlotte Harbor Flatwoods Initiative (CHFWI) is a multi-stakeholder, multi-phased regional hydrologic restoration effort coordinated by the South Florida Water Management District (SFWMD), and the approximately 90-square mile project area spans both the South and South Florida Water Management Districts. The Southwest Florida Water Management District participates on the stakeholders group.

The SFWMD completed the Yucca Pens Hydrologic Restoration Plan (Plan) in January 2010, which is Phase I of the CHFWI. The goal of the Plan is to restore historic sheet flow to the Yucca Pens area. Development and topographic changes since the 1950s have blocked, constricted, and concentrated what were formerly sheet flow areas draining in a southeasterly or southerly direction. Restoration of the historic flow will reduce the amount of water that has been redirected to Gator Slough and lessen the impact of damaging point discharges through the Gator Slough Canal to Matlacha Pass and Charlotte Harbor.

In 2016, the SWFWMD collected LiDAR data over the project area to supplement water quantity and flow data collection efforts by other partners in the CHFWI. Ultimately, this improved topographic information can be used for modeling of potential restoration projects and strategies.

**Issues and Drivers – Natural Systems**

The District and the Charlotte Harbor NEP are cooperatively funding the Habitat Restoration Needs Update for the Charlotte Harbor Watershed. This fiscal year 2016 project is expected to be complete in late 2019. The purpose of the study is to identify habitat restoration acreage targets within the SWFWMD jurisdiction of the Charlotte Harbor watershed. Preliminary deliverables for the project include an assessment of land use and land cover changes within the watershed, the results of which are summarized in this section.

Land use in the main sub-basins of the Peace and Myakka Rivers varies substantially. Table 7 summarizes the main land use / land cover classifications of the major sub-basins for the Peace and Myakka Rivers, based on mapping results from 2009.

**Table 7 – Land use / land cover (percent of sub-basin) for the main gaged sub-basins in the Peace and Myakka Rivers. Data from SWFWMD.**

| Sub-basin | Agriculture | Barren Land | Rangeland | Transportation and Utilities | Upland Forests | Urban and Built-Up | Water | Wetlands |
|---|---|---|---|---|---|---|---|---|
| **Saddle Creek at P-11** | 9 | < 1 | < 1 | 4 | 4 | 54 | 16 | 13 |
| **Peace River at Bartow** | 20 | < 1 | 1 | 3 | 4 | 43 | 14 | 15 |
| **Peace River at Zolfo Springs** | 39 | < 1 | 3 | 1 | 3 | 28 | 4 | 22 |
| **Peace River at Arcadia** | 53 | < 1 | 8 | 1 | 6 | 7 | < 1 | 25 |
| **Charlie Creek** | 55 | < 1 | 5 | < 1 | 8 | 7 | 1 | 24 |
| **Horse Creek** | 43 | < 1 | 11 | < 1 | 7 | 15 | < 1 | 24 |
| **Joshua Creek** | 71 | < 1 | 5 | 1 | 4 | 6 | < 1 | 13 |
| **Shell Creek** | 55 | < 1 | 13 | < 1 | 9 | 4 | 1 | 18 |
| **Upper Myakka River** | 41 | < 1 | 12 | < 1 | 10 | 14 | 1 | 22 |
| **Lower Myakka River** | 25 | < 1 | 13 | 1 | 16 | 19 | 3 | 23 |

The dominant land use in both the Peace and Myakka Rivers is agricultural land, especially if the category of "rangeland" is included. Upland forests are a small portion of the watershed, as are the categories of barren land and transportation and utilities (i.e., power line corridors). Urban and Built-up areas are the dominant land use category only in the uppermost portions of the Peace River watershed, in the sub-basins of Saddle Creek at P-11 and the Peace River at Bartow.

As part of the habitat restoration needs update, ESA SCHEDA completed an assessment of the amount of habitat loss between 1995 and 2009 for the major land use / land cover categories throughout the Charlotte Harbor watershed (ESA SCHEDA 2018). Table 8 shows the percent decline in coverage between 1995 and 2009 for the categories of Upland Coniferous Forest, Upland Hardwood Forest, Mangrove Swamps, Freshwater Marshes, Saltwater Marshes, and Salt Flats within five segments of the Charlotte Harbor system.

**Table 8 – Percent decline of various habitat types for different sub-basins in the Charlotte Harbor watershed, between 1995 and 2009. Data are based on GIS mapping efforts conducted for the SWFWMD. Analysis completed by ESA (2018) for the CHNEP. Habitat types are shown along with their FLUCCS codes. "NL" = no evidence of decline.**

| Sub-basin | Habitat Types | | | | | |
|---|---|---|---|---|---|---|
| | Upland Coniferous Forest (4100) | Upland Hardwood Forest (4200) | Mangrove Swamps (6120) | Freshwater Marsh (6410) | Saltwater Marsh (6420) | Salt Flats (6600) |
| **Charlotte Harbor Proper** | 81 | 54 | NL | NL | 25 | NL |
| **Coastal Lower Peace** | 89 | 90 | NL | NL | NL | NL |
| **Coastal Venice** | 50 | NL | NL | NL | 24 | NL |
| **Dona and Roberts Bay** | 89 | NL | 1 | NL | NL | NL |
| **Gasparilla Sound** | 56 | NL | NL | 64 | NL | NL |

The results shown in Table 8 suggest that habitat restoration strategies for the SWFWMD portion of Charlotte Harbor might consider including efforts to restore lost upland coniferous forests, as this is the habitat that has the most widespread and severe loss between 1995 and 2009. Each of the sub-basins listed in Table 8 have lost at least 50% of its Upland Coniferous Forests, during that 14-year time period. Declines in Upland Hardwood Forests were also found in the Charlotte Harbor Proper and Coastal Lower Peace sub-basins, also in amounts exceeding 50 percent.

Mangrove loss was detected in only one of the ten sub-basins (Dona and Roberts Bays) and was within the range of expected error for this type of mapping effort (1%). Freshwater marsh losses were substantial in the Gasparilla Sound sub-basin, while saltwater marsh losses were found in the Charlotte Harbor Proper and Coastal Venice sub-basins. The loss of saltmarsh in the Coastal Venice sub-basin (6.4 acres) was less than the 21-acre increase in mangrove forests in that same sub-basin, over the same time frame. Although more detailed analysis is required, these results could be suggestive of a replacement of salt marsh with mangroves, at least in some locations. No losses of salt flats were found in any of the sub-basins examined.

The substantial losses of uplands are indicative of the increase in development in the watershed, but results in Table 7 suggest that most of the "development" involved a shift from forested uplands (both coniferous and hardwood) to agricultural land uses. These results would support a focus on preserving and/or restoring upland features in the watershed, which have been lost at rates in excess of wetland systems, particularly estuarine wetlands. Since the final report is not expected prior to completion of the SWIM Plan, conclusions and recommendations from the final report of the Habitat Restoration Needs project will be incorporated by reference.

**Summary of Issues and Drivers**

The general findings of Task 2 activities include the following:

*Water Quality*

- NNC criteria are developed and applied at different spatial scales, resulting in a disconnect between the impairment status of local waters and the health of seagrass and trends of overall improving water quality.

- Even for waterbodies where assessments of impairment are consistent at regional and WBID levels (such as Upper Lemon Bay) positive trends in seagrass coverage suggest that impairment determinations based on NNC are not appropriate.

- The finding that nitrogen loads from the gaged Peace River have changed by less than 5% over the past 25 years suggests that the Pollutant Load Reduction Goal (PLRG) for Charlotte Harbor, which was based on a “hold the line” strategy, has been met.

- Combined, the results of the water quality, seagrass mapping and pollutant loading model efforts shown here suggest that Charlotte Harbor, as a whole, is not experiencing degraded water quality, nor is it showing signs of declining ecosystem health.

- However, attention should be paid to areas of above-normal nitrogen loading, such as Joshua, Shell and Charlie Creeks, to determine causes and management actions related to elevated area-normalized nitrogen loads.

- While improving water quality in Lake Hancock seems to be associated with the decreased nitrogen loads at the Saddle Creek at P-11 gage, that location continues to be an area of elevated area-normalized TSS loads, which would be expected to be addressed when the Lake Hancock Outfall Treatment Marsh becomes fully operational.

*Hydrologic Alteration*

- Minimum flows have been set for the Upper, Middle and Lower reaches of the Peace river, the Upper and Lower reaches of the Myakka River, and the Dona Bay/Shakett Creek watershed.

- In the Upper Peace River, the hydrologic alteration of greatest concern has been a decline in streamflow in the dry season.

- The Lake Hancock Lake Level project is completed and is assisting with restoring minimum flows to the Upper Peace River.

- In the Upper Myakka River, the hydrologic alteration of greatest concern has been an increase in streamflow in the dry and wet seasons, particularly in Flatford Swamp.

- Efforts are ongoing to reduce inflows into Flatford Swamp by between 2 and 10 mgd.

- In Dona Bay, the minimum flows allow for diversion of the totality of excess inflows brought about by the expansion of the bay’s watershed through the construction of the Cow Pen Canal.

- Efforts are ongoing to reduce inflows into Dona Bay, by diverting 3 mgd of flow away from Shakett Creek and Dona Bay, back towards the historical destination of the Myakka River.

*Natural Systems*

- The dominant land use throughout the Charlotte Harbor watershed is agricultural land such as row crops, citrus, and pasture land. The second most common land use is rangeland.
- Urban land uses are the dominant land use in the Upper Peace River, but not the Middle and Lower portions of the watershed.
- In each sub-basin examined, wetland coverage exceeds that of upland forests.
- Between 1995 and 2009, upland coniferous and hardwood forests have declined across more of the watershed than any other habitat type, mostly due to transitioning to agricultural land uses.

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