LOXAHATCHEE RIVER WATER QUALITY AND BIOLOGICAL MONITORING

TASK 4: FINAL REPORT
ASSESSMENT OF 2008-2009 LOXAHATCHEE RIVER WATER QUALITY

In Partial Fulfillment of Agreement No. 4600001638-A01

For the Period

October 2008 through September 2009

Respectfully Submitted by

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Loxahatchee River District

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Executive Summary

This report presents water quality data collected under the Loxahatchee River District's (LRD) RiverKeeper water quality monitoring program. This monitoring program evaluates nearly 30 water quality parameters at approximately 40 sites throughout the Loxahatchee River watershed and estuary. Ten sites are sampled every month, and the remaining sites are sampled bi-monthly (every other month). The purpose of this program is to identify long-term trends, assess compliance with established water quality targets, and establish baseline conditions prior to the modifications of freshwater inflows resulting from the Comprehensive Everglades Restoration Project (CERP) and the Northwest Fork Restoration Plan.

This report provides a simplified characterization and overview of the water quality conditions in Loxahatchee River for the reporting period October 2008 through October 2009. A stoplight analysis evaluating several key parameters to compare the 2009 water quality data to the established Target Period of 1998-2002 suggests there may be cause for concern because of possible impairment of these waters, particularly for the Wild and Scenic and Freshwater tributary segments of the river. However, more detailed analysis of these data is needed to determine if these are explicit trends. A more comprehensive and thorough temporal and spatial assessment by using box and whisker plots to compare water quality conditions among the following periods: the target period (1998-2002), the subsequent 5 year period (2003-2007), the calendar year 2008, and the calendar year 2009 (January-October). These plots reflect the findings in the stoplight analysis, but also provide summaries for the other water quality parameters. Lastly, we provide maps of all sampling sites in the watershed each symbolized by the average and maximum values of key water quality parameters for the reporting period. These maps illustrate the variation in water quality parameters throughout the watershed.

Introduction

Since 1971 the Loxahatchee River District (LRD) has been fulfilling its mission to preserve and protect the Loxahatchee River through an innovative wastewater treatment and reuse program and an active water quality monitoring program. LRD staff have monitored water quality in the surface waters of the Loxahatchee River and associated waters (see Figure 1) in an effort to document the condition and ecological health of the river and to determine the location and extent of water quality issues that need to be addressed. Over these past 35 years, the Loxahatchee River District has contributed significantly to the understanding of the ecology of this river (see http://www.loxahatcheeriver.org/reports.php). While numerous reports have been written regarding the Loxahatchee River, perhaps none are as comprehensive as the *Restoration Plan for the Northwest Fork of the Loxahatchee River* (SFWMD 2006). This document characterizes the watershed, discusses various restoration alternatives, and identifies the preferred restoration flow scenario. In particular, Table 10-1 of the restoration plan includes the water quality targets for the marine (salinity >30 ppt), polyhaline (salinity 18 – 30 ppt), meso/oligohaline (salinity 5 – 18 / 0.5 - 5 ppt), wild and scenic (salinity <5 ppt), and freshwater tributary (salinity <5 ppt) zones of the Loxahatchee River. These water quality targets (i.e., non-degradation standards) were established by LRD and SFWMD scientists using bi-monthly water quality data collected by LRD over the five year period 1998-2002.

Staff from the Loxahatchee River District's Wildpine Ecological Laboratory continues to collect water quality samples for nearly 30 parameters at approximately 40 sites located in the Loxahatchee River, its major tributaries, and associated waters (Figure 1). Ten sites are sampled every month, and the remaining sites are sampled bi-monthly (every other month). This water quality monitoring program, entitled RiverKeeper, was developed to identify long-term trends, and assess long-term compliance with the established water quality targets. Furthermore, on-going results from our water quality monitoring program are being used to establish baseline conditions prior to modification of freshwater inflows resulting from the Comprehensive Everglades Restoration Project and the Northwest Fork Restoration Plan (CERP 2001; SFWMD 2006).

The purpose of this report is to provide a simplified characterization and overview of the water quality conditions in Loxahatchee River. We first use a 'stoplight' approach to provide a high-level, thoroughly integrated assessment of observed water quality conditions relative to target water quality values for each of the five designated river reaches (See Appendix A for decision rules and data). Appendix B provides a more comprehensive and thorough temporal and spatial assessment by using box and whisker plots to compare water quality conditions among the following periods: the target period (1998-2002), the subsequent 5 year period (2003-2007), the calendar year 2008, and the calendar year 2009 (January-October). Appendix C provides maps that show all sampling sites in the watershed with each site symbolized by the average and maximum values of key water quality parameters for the period January through October 2009.

Study Area

The Loxahatchee River estuary encompasses approximately 400 ha and drains a watershed of approximately 700 km^2 located in northeastern Palm Beach County and southeastern Martin County, Florida, USA (Figure 1). Freshwater discharges into the estuary from the North Fork, the Northwest Fork, and the Southwest Fork of the Loxahatchee River. The hydrology of the basin has been substantially altered by flood control efforts since the 1950s. Historically (pre-1950), most surface water runoff reaching the estuary originated in the Loxahatchee and Hungryland Sloughs and flowed gradually to the Northwest Fork. In the 1930s the Lainhart Dam, a small fixed-weir dam, was constructed in the Northwest Fork at river mile 14.5 to reduce “over” drainage of upstream reaches of the Northwest Fork during the dry season. In 1958 a major canal (C-18) and flood control structure (S-46) were constructed to divert flows from the Northwest Fork to the Southwest Fork, which increased the intensity and decreased the duration of storm-related discharge to the estuary. Furthermore, since 1947 Jupiter inlet, the eastern link to the ocean, was expanded and made permanently open through ongoing dredging projects. These inlet modifications increased saltwater intrusion into the previously freshwater portions of Northwest Fork. Ongoing restoration efforts seek to increase base flows into the Northwest Fork, while not compromising the ecological integrity of downstream reaches (i.e., estuary) nor impairing valued ecosystem components of the estuary such as oysters and seagrasses (SFWMD 2006).

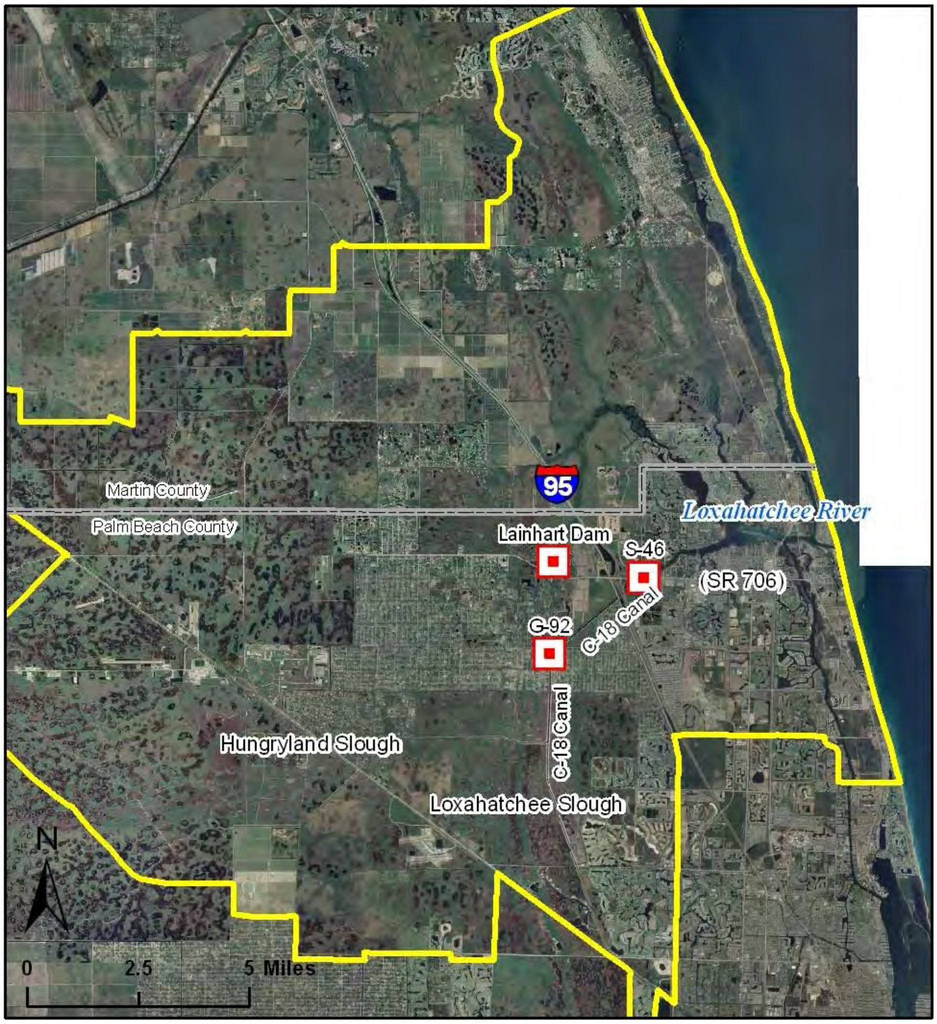


Figure 1. Loxahatchee River watershed and associated features.

Materials and Methods

Water quality samples were collected every other month at stations identified in yellow and monthly at stations identified in green in Figure 1 and summarized in Table 1. At each station, physical water quality conditions (e.g., temperature, pH, conductivity, salinity, and dissolved oxygen) were evaluated using a multi-probe water quality sonde at the surface (0.3 m depth). At stations 60 through 66, the river reach most likely to be stratified, we also sampled at mid-depth and approximately 20 cm above the river bottom.

Nutrient, bacteriological, chlorophyll *a*, turbidity, total suspended solids, and water color samples were processed following Standard Methods by the Loxahatchee River District's Wildpine Laboratory, which was certified under the National Environmental Laboratory Accreditation Program (NELAC) since 2000. Prior to 2000, the Wildpine lab was a state certified laboratory. The present certification (#E56026) is valid from July 1, 2009 through June 30, 2010. Analysis methods and detection limits are summarized in Appendix C. Photosynthetically active radiation (PAR) was assessed by taking at least 3 replicates of PAR using 3 LI-COR spherical sensors (4 π) simultaneously located at 20 cm, 50 cm, and 100 cm below the water surface. A complete list of parameters for each station is provided in Appendix D.

We used a 'stoplight' approach to provide a simplified, integrated assessment of observed water quality conditions relative to target water quality values for each of the five river reaches: marine (stations 10, 20, 30), polyhaline (stations 51, 60, 72), mesohaline (stations 62, 63, 64), wild and scenic (stations 67, 68, 69), and freshwater tributaries (stations 81, 95, 100). Analytical results for each river reach were divided into three categories (red, yellow, and green), which can be interpreted similar to the colors in a traffic signal (See Appendix A for decision rules and data). Green indicates good or acceptable conditions – no degradation is occurring. Yellow indicates caution should be observed – degradation may or may not be occurring (i.e., there may be cause for concern). Red indicates degradation likely is occurring, and resource managers should seek to identify the source of the problem and determine what actions might be employed to remedy the observed degradation in water quality.

One cautionary note must be addressed relative to comparing the results of the present study versus the target water quality values. Results presented for 2008 and 2009 were based on 12 and 10 months of sampling, while target water quality values were based on 5 years of samples. Analysis of results from a longer sampling period buffer extreme (both high and low) values, which provides a more conservative assessment. Nonetheless, the present assessment represents a thorough evaluation of ongoing water quality conditions in the watershed over the past year.

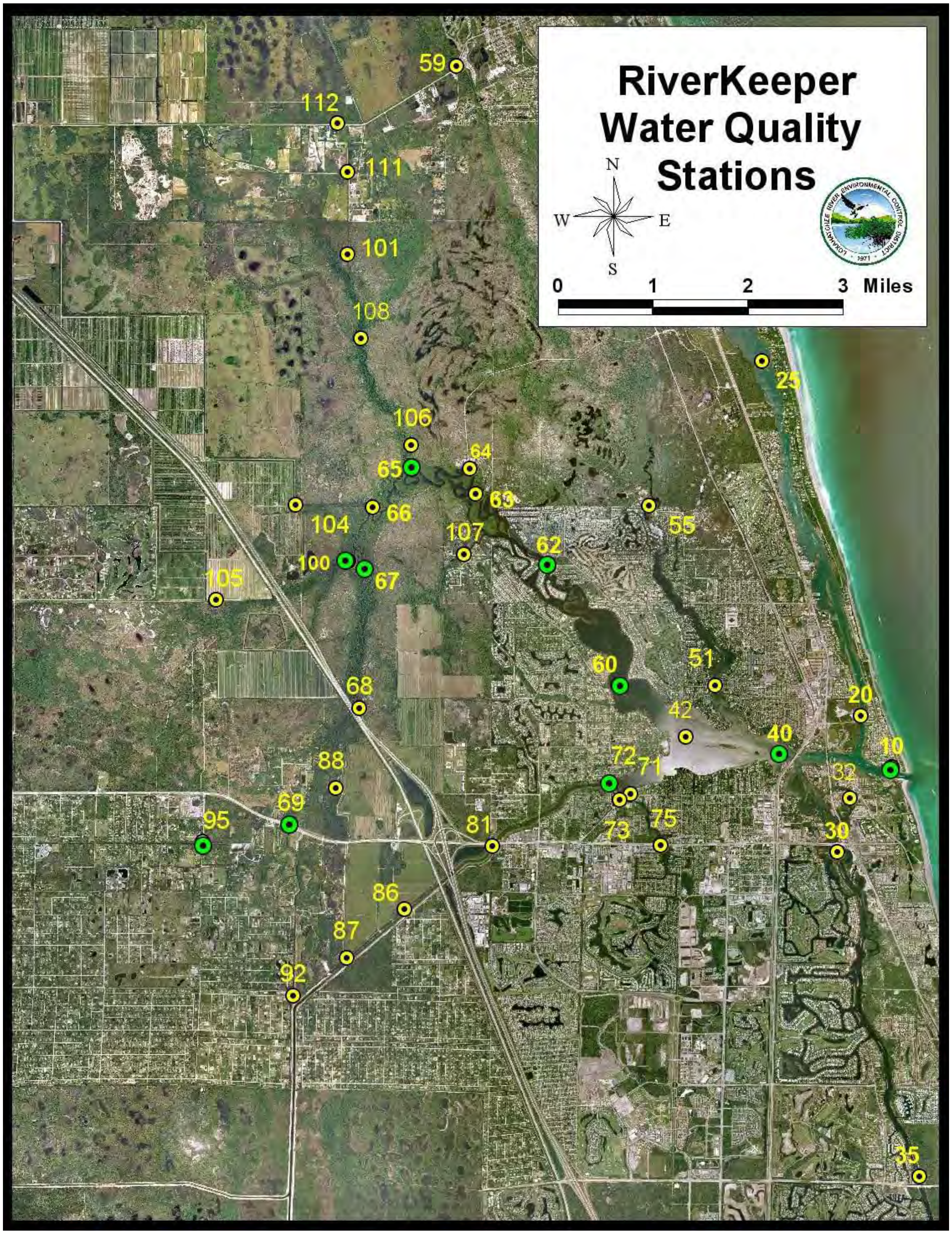


Figure 2. Loxahatchee River District's water quality monitoring stations in the Loxahatchee River and associated waters. Sites indicated in green were sampled every month, while yellow sites were sampled every other month.

Table 1. RiverKeeper sampling sites.

Station	Zone+	Sampling Frequency++	Northing*	Easting*	Latitude**	Longitude**
10	Marine	Monthly	950,408	957,903	26 56.7206	-80 04.4293
20	Marine	BM	953,238	956,193	26 57.1897	-80 04.7404
25		BM	972,837	950,720	27 00.4308	-80 05.7224
30	Marine	BM	945,745	954,896	26 55.9546	-80 04.9892
32		BM	948,686	955,606	26 56.4391	-80 04.8546
35		BM	927,816	959,468	26 52.9901	-80 04.1717
40		Monthly	951,108	951,709	26 56.8435	-80 05.5690
42		BM	952,109	946,497	26 57.0148	-80 06.5275
51	Polyhaline	BM	954,927	948,122	26 57.4780	-80 06.2246
55		BM	964,841	944,439	26 59.1185	-80 06.8901
59		BM	989,168	933,755	27 03.1456	-80 08.8280
60	Polyhaline	Monthly	954,920	942,739	26 57.4831	-80 07.2160
62	Meso/Oligohaline	Monthly	961,525	938,899	26 58.5776	-80 07.9148
63	Meso/Oligohaline	BM	965,503	934,848	26 59.2387	-80 08.6561
64	Meso/Oligohaline	BM	966,884	934,503	26 59.4670	-80 08.7179
65		Monthly	966,873	931,330	26 59.4687	-80 09.3025
66		BM	964,747	929,142	26 59.1202	-80 09.7082
67	Wild and Scenic	Monthly	961,353	928,662	26 58.5606	-80 09.8008
68	Wild and Scenic	BM	953,689	928,384	26 57.2960	-80 09.8613
69	Wild and Scenic	Monthly	947,259	924,583	26 56.2389	-80 10.5691
71		BM	948,947	943,456	26 56.4965	-80 07.0916
72	Polyhaline	Monthly	949,554	942,258	26 56.5981	-80 07.3114
73		BM	948,621	942,812	26 56.4434	-80 07.2106
75		BM	946,078	945,127	26 56.0211	-80 06.7876
81	FW Tributaries	BM	946,035	935,787	26 56.0246	-80 08.5075
86		BM	942,562	930,899	26 55.4568	-80 09.4118
87		BM	939,867	927,701	26 55.0155	-80 10.0039
88		BM	949,254	927,103	26 56.5654	-80 10.1026
92		BM	937,810	924,731	26 54.6793	-80 10.5531
95	FW Tributaries	Monthly	946,288	919,695	26 56.0839	-80 11.4703
100	FW Tributaries	Monthly	961,807	927,804	26 58.6365	-80 09.9583
101		BM	978,724	927,740	27 01.4285	-80 09.9494
104		BM	964,884	924,842	26 59.1475	-80 10.5002
105		BM	959,657	920,431	26 58.2895	-80 11.3190
106		BM	968,197	931,290	26 59.6873	-80 09.3082
107		BM	962,186	934,199	26 58.6920	-80 08.7798
108		BM	974,119	928,465	27 00.6677	-80 09.8215
111		BM	983,296	927,764	27 02.1831	-80 09.9395
112		BM	985,981	927,200	27 02.6268	-80 10.0401

Notes:

+ From Restoration Plan, (SFWMD, 2006)
++ BM - Bi-Monthly (Every other month)
* State Plane, Florida East, Ft
** WGS 1984, Degrees - Decimal Minutes

Results & Discussion

During the period October 2008 through October 2009 we collected and analyzed 414 water quality samples for approximately 25 parameters resulting in over 10,350 analytical results. When compared against the water quality targets (i.e., non-degradation standards), these results suggest there may be cause for concern for water quality in the Loxahatchee River for the period January through October 2009. Table 2 below shows a simplified interpretation of water quality results for the distinct river reaches. The chart immediately suggests that the Freshwater Tributaries and the Wild and Scenic areas may be most degraded and the best areas in which to conduct water quality improvement projects in the watershed. The Wild and Scenic area scored 'red' for chlorophyll *a* and dissolved oxygen values, and 'yellow' for total phosphorus and total nitrogen. The combination of these scores suggests possible impairment of these waters, relative to the 1998-2002 target values. Chlorophyll *a* concentrations also scored 'red' in the Meso/Oligohaline area of the river. A cursory review of Chlorophyll *a* over time suggests a trend of increasing concentrations. However, more detailed analysis of these data are needed to determine if these are definite trends, or artifacts due to changes in sampling frequency (monthly prior to 2007 vs. bi-monthly since 2007) or analysis periods (5 yr 1998-2002 vs. 10 months for 2009). It is important to note that the dissolved oxygen sample represents a single point in time and is subject to sampling artifacts by sampling a particular station early in the day. The forthcoming datasonde water quality monitoring report will provide additional, valuable detail on dissolved oxygen values from the near continuous sampling by the automated instrumentation located at Station 69 (Indiantown Road bridge) and 65 (mouth of Kitching Creek). The marine and polyhaline segments continue to show the greatest overall health. Semi-diurnal tides flush these downstream sites twice a day with relatively high quality (e.g., low nutrient concentrations) sea water flowing from the Atlantic Ocean in through the Jupiter Inlet.

Table 2. A 'stoplight' assessment of water quality among the five river reaches of the Loxahatchee River for the period January – October 2009 relative to the target levels of 1998-2002. See Appendix A for decision rules and data.

	Marine	Polyhaline	Meso/Oligohaline	Wild and Scenic	FW Tributaries
Chlorophyll *a*	Green	Yellow	Red	Red	Yellow
Dissolved Oxygen	Green	Green	Green	Red	Yellow
Fecal coliform	Green	Green	Green	Green	Yellow
Total Nitrogen	Green	Green	Green	Yellow	Yellow
Total Phosphorus	Green	Green	Yellow	Yellow	Yellow
Total Suspended Solids	Green	Green	Green	Green	Yellow

In addition to the stoplight assessment, in Appendix B we present water quality results using box and whisker plots for each parameter. These plots facilitate comparisons of water quality among four temporal periods: the target period (1998-2002), five years following the target period (2003-2007), the 2008 calendar year, and 2009 (January-October 2009).

The unusually dry conditions in 2009 (discussed below), and subsequent reduced freshwater discharge, likely affected several parameters including alkalinity, fecal coliform bacteria, percent light, pH, and salinity. Median temperatures in 2009 show new highs at all river segments but do not include November and December data. However, subsequent analysis for comparable periods (January through October) for each analysis group indicates new high temperatures for all areas except the marine. The 2009 median Chlorophyll *a* concentration reached new highs in the meso/oligohaline, wild & scenic, and freshwater tributary portions of the river. While these values are higher than the target period, and those established in the restoration plan, the majority of the concentrations are relatively low (below 10 µg/l). Nonetheless, the causes for these increases in algae (chlorophyll *a*) are unclear and warrant further study. Nutrient concentrations, described below and a logical contributor to the higher chlorophyll, are not notably higher in the upper portions of the river.

Because nutrient concentrations are key parameters to assess water quality, we present spatial and temporal changes in phosphorous and nitrogen concentrations among the five river segments (marine through freshwater tributaries) in Figure 2 and Appendix B. In the downstream reaches median phosphorous concentrations were quite comparable across the four time periods. However, in the wild and scenic and freshwater tributaries we recorded another slight increase in median phosphorus concentrations in 2009, relative to the target period and other years. The 2009 nitrogen concentrations were again lower in the downstream and middle reaches of the river compared to previous years, but were higher than the target period and 2008 in the wild and scenic and freshwater tributaries. This apparent trend in decreasing nitrogen concentrations at our marine sites (only) is due to a change in our analytical technique in January 2005, and does not represent a real decrease in total nitrogen concentrations. We found that in the saline waters the analysis technique using mercury provided inaccurate nitrogen readings, but these problems were remedied though the use of the analysis technique utilizing copper. This methodological artifact complicates analysis, however, it is fortunate the analytical issue was identified and remedied.

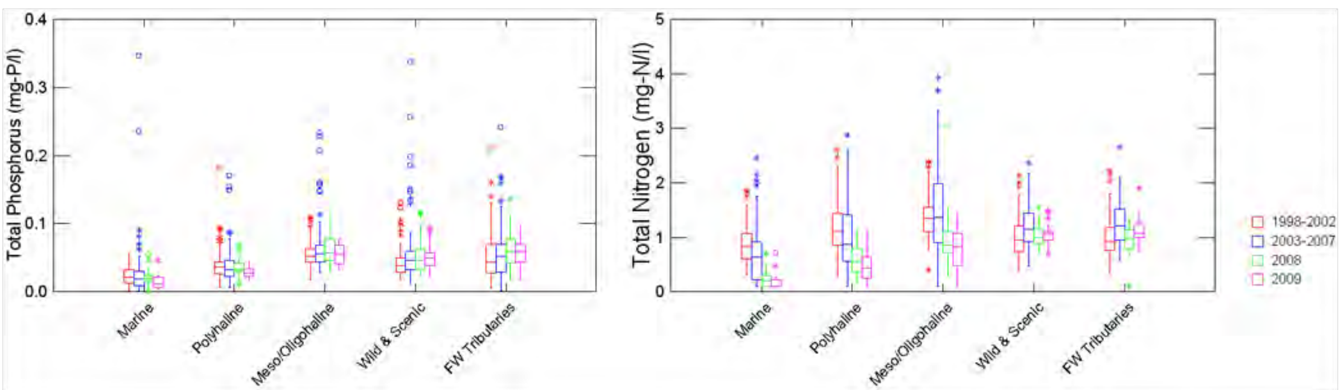


Figure 3. Box and whisker plots for Total Phosphorus and Total Nitrogen by river segment and analysis period. See Appendix B for larger sized plots.

Rainfall and subsequent flows were relatively low in the Loxahatchee from January through October 2009. During this period we recorded 46 inches of rain at LRD's treatment plant in Jupiter, compared to 53 inches and 61 inches for the same period (Jan-Oct) in 2008 and 2007. Average daily flows at Lainhart Dam during the same period were also lower at 66, 94 and 97 cfs for 2009, 2008 and 2007 (SFWMD-DBHYDRO). Daily flows over Lainhart Dam were less than 35 cfs for 54, 48, and 134 days during 2009, 2008 and 2007 (SFWMD-DBHYDRO). While the 2009 average daily flows were lower overall, the flows appear to be more consistent during the wet season with fewer extreme fluctuations compared to 2007 and 2008 (Figure 3).

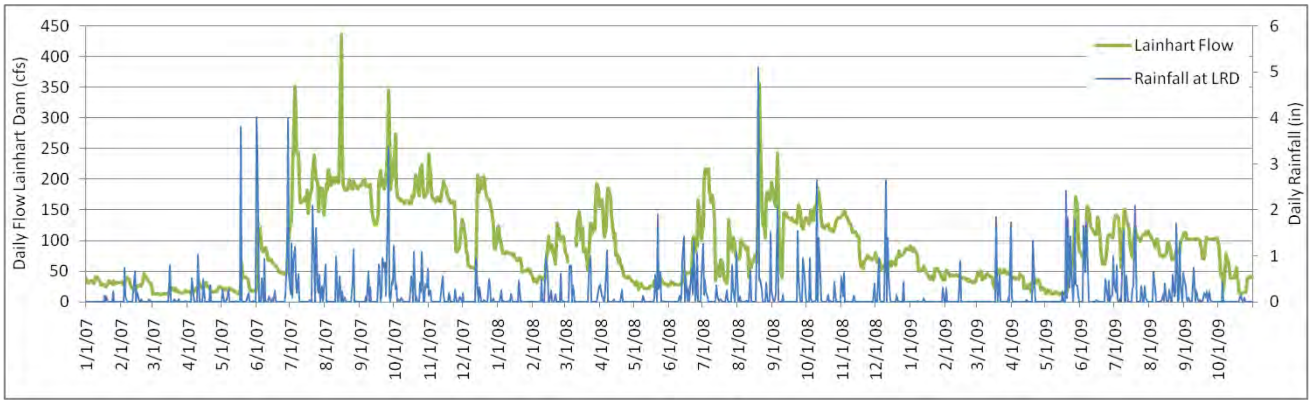


Figure 4. Plot of daily flow at Lainhart Dam and daily rainfall at LRD for the period of January 2007 through October 2009.

In an effort to better understand the relationships between rainfall, river flow and water quality, we performed some exploratory correlation analysis on rainfall, river flows and several key water quality parameters. For each day of water quality sample collection we computed the daily, prior 3-day, 7-day, and 14-day cumulative rainfall, and the daily, prior 3-day, 7-day, 14-day cumulative daily flow at Lainhart dam. For each of these variables we performed simple correlation analysis and assessed the resulting Pearson Correlation coefficients. As expected, statistically significant correlations were observed between Lainhart Dam daily flow and the 3-day cumulative rainfall. Flow measured at the time of water sample collection provides some of the strongest relationships to water quality for several parameters, and the prior 3-day cumulative rainfall showed some moderate relationships to water quality parameters as summarized in Table 3. As shown in previous stormwater reports (LRD 2007 and 2008), alkalinity and conductivity are conservative indicators that clearly show strong negative correlations with Lainhart Dam flow for most sampling stations. Total phosphorus and ortho-phosphorus showed some moderate, positive relationships to daily Lainhart Dam flows for many sampling stations. Surprisingly, total nitrogen was only weakly correlated with daily flows over Lainhart Dam. The prior 3-day cumulative rainfall showed moderately strong correlations with several water quality parameters at several stations. This analysis provides some cursory insight into general water quality conditions at various flow regimes in the river. Further investigation using more sophisticated analytical approaches would likely provide additional, valuable insights that can help to best manage flows and water quality in the Loxahatchee.

Table 3. Pearson Correlation coefficients of daily flow at Lainhart Dam (upper pane) and prior 3-Day cumulative rainfall at LRD's plant in Jupiter (lower pane) recorded for each sampling event, for each parameter (period of record: January 1998 and October 2009). Moderate correlation coefficients between 0.4 and 0.59 (or -0.4 and -0.59) are highlighted in yellow; stronger correlations, greater than 0.6 (or less than -0.6) in green.

Daily Flow at Lainhart Dam

	Station	Alkalinity	Turbidity	DO	NO2+NO3	Total Nitrogen	Total Phosphorus	Ortho-phosphorus	Conductivity
< Upstream - Downstream >	10	-0.11	0.18	-0.29	0.49	0.25	0.11	0.36	-0.42
	40	-0.41	0.04	-0.31	0.49	0.21	0.44	0.53	-0.49
	62	-0.77	0.21	-0.58	0.57	0.28	0.56	0.53	-0.71
	65	-0.84	0.21	-0.51	0.31	-0.16	0.42	0.45	-0.49
	69	-0.80	-0.07	-0.50	0.11	-0.02	0.56	0.57	-0.75
	92	-0.78	-0.25	-0.51	0.20	0.02	0.54	0.45	-0.70
	81	-0.81	-0.04	-0.49	0.21	0.05	0.45	0.13	-0.59
Tribs	75	-0.65	0.16	0.11	0.18	-0.01	-0.17	-0.06	-0.24
	104	0.07	-0.09	0.01	-0.10	0.04	0.52	0.23	0.08
	105	-0.77	0.07	-0.24	0.08	0.11	0.18	0.50	-0.77
	95	-0.54	-0.04	-0.42	-0.04	-0.06	0.39	0.64	-0.72

3 Day Cumulative Rainfall at LRD

	Station	Alkalinity	Turbidity	DO	NO2+NO3	Total Nitrogen	Total Phosphorus	Ortho-phosphorus	Conductivity
< Upstream - Downstream >	10	-0.14	-0.03	-0.19	0.36	-0.02	0.01	0.27	-0.14
	40	-0.22	0.00	-0.28	0.44	0.00	0.12	0.29	-0.29
	62	-0.24	0.67	-0.01	0.16	-0.14	0.13	0.06	-0.20
	65	-0.17	0.53	-0.04	0.10	-0.15	0.16	0.17	-0.11
	69	-0.14	0.24	-0.10	0.03	-0.10	0.31	0.37	-0.16
	92	-0.05	0.03	-0.14	-0.20	0.06	0.13	0.08	-0.04
	81	-0.15	-0.03	-0.13	-0.02	0.08	0.28	0.39	-0.09
Tribs	75	-0.31	-0.33	-0.48	-0.20	0.35	0.20	-0.40	-0.35
	104	-0.03	-0.14	-0.13	-0.14	0.12	-0.05	-0.09	-0.05
	105	-0.15	-0.16	-0.24	-0.23	-0.07	0.02	0.25	-0.13
	95	-0.34	0.25	-0.07	-0.08	-0.13	0.19	0.36	-0.37

In Appendix C we present maps that show the average and maximum values measured at all LRD RiverKeeper stations for total suspended solids, dissolved oxygen, total phosphorus, total nitrogen, chlorophyll *a*, and fecal coliform. These figures provide an interesting, spatial perspective of the various parameters throughout the watershed. All of the figures (except the fecal coliform bacteria figure) symbolize the concentration of each parameter using natural breaks (Jenks) classification used in ESRI's ArcGIS software. This classification system divides the data into natural groupings inherent in the data by creating breaks to best group similar values and maximize the differences between the classes (ESRI, 2009). As such it is important to take note the classifications when considering the data. We categorized fecal coliform concentrations by FDEP and EPA's thresholds for recreational waters. Particularly interesting is the distinct spatial gradation in nutrient concentrations (total nitrogen and total phosphorus) throughout the watershed from the freshwater tributaries downstream through the marine areas. The plot of fecal coliform bacteria concentrations shows generally good average concentrations through most of the watershed with high concentrations in a few tributaries. Maximum fecal coliform bacteria concentrations were generally found in the tributaries.

In conclusion, water quality in the Loxahatchee River during the period 2008 and 2009 suggests there may be some cause for concern, particularly in the wild & scenic portion of the river. Most water quality parameters in the downstream reaches of the river met or were better than established water quality targets. Nonetheless, water quality in the wild and scenic reach and the freshwater tributaries clearly suggest declining aquatic health in the river (i.e., water quality conditions did not meet non-degradation criteria).

We believe the RiverKeeper water quality monitoring program continues to be an excellent and efficient approach to monitor water quality in the Loxahatchee River watershed. Because of LRD's long standing commitment to assess water quality in the Loxahatchee River watershed, we have an excellent historical record against which present water quality conditions can be compared. As restoration efforts continue to move forward in the watershed, we will continue to assess current water quality conditions and compare them against the established target conditions (1998-2002) and the pre-restoration conditions, thereby providing a comprehensive measure of project success. Such across-time comparisons are invaluable when trying to adaptively manage our valuable resources. Finally, it should be noted that while much work has been done in the Loxahatchee River Watershed (e.g., the numerous LRPI projects) there continue to be water quality issues that need to be addressed.

Recommendations for future work:

1. Continue the RiverKeeper monitoring program to assess long- and short-term trends in water quality in the Loxahatchee River. This data provides essential information for adaptive management of restoration activities.
2. Perform comprehensive, sophisticated analysis of the RiverKeeper dataset with other environmental and physical parameters to further our understanding of the relationships between the variables. Water managers can then utilize this information to best manage flows into the Loxahatchee River.
3. Where water quality concerns are noted, resource managers should identify the source of the degradation, and develop and implement projects to remedy the source of water quality degradation.
4. The RiverKeeper data should be used to the greatest extent possible by the Department of Environmental Protection under their efforts to assess Total Maximum Daily Loads (TMDL) for the Loxahatchee River and tributaries.

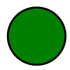
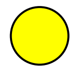
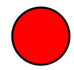
Literature Cited

Comprehensive Everglades Restoration Plan (CERP). 2001. Baseline Report for the Comprehensive Everglades Restoration Plan. South Florida Water Management District, West Palm Beach, Florida.

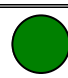
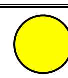
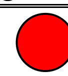
ESRI. 2009. ArcGIS Desktop Resource Help.

South Florida Water Management District (SFWMD). 2006. Restoration Plan for the Northwest Fork of the Loxahatchee River. South Florida Water Management District, West Palm Beach, Florida.

Appendix A - Stoplight Decision Rules & Data. Decision rules and data used in the 'stoplight' assessment. Because we assumed the observed conditions during the target period represent non-degradation conditions, we therefore scored conditions equal to or better than those conditions as green (good). Conditions slightly worse than the target conditions (i.e., between the 50th and 75th percentile) were scored yellow (caution). Observed conditions significantly worse than the target conditions (i.e., falling outside of the 75th percentile) were scored as red (cause for concern). In order to address the natural variability observed in the system, assessment was based on the median value for the parameter and period being assessed.

	≤ Median Target Value	> Median Target Value	>75th Percentile Target Value
Parameter			

Because higher dissolved oxygen concentrations are more desirable, the thresholds were reversed as shown below.

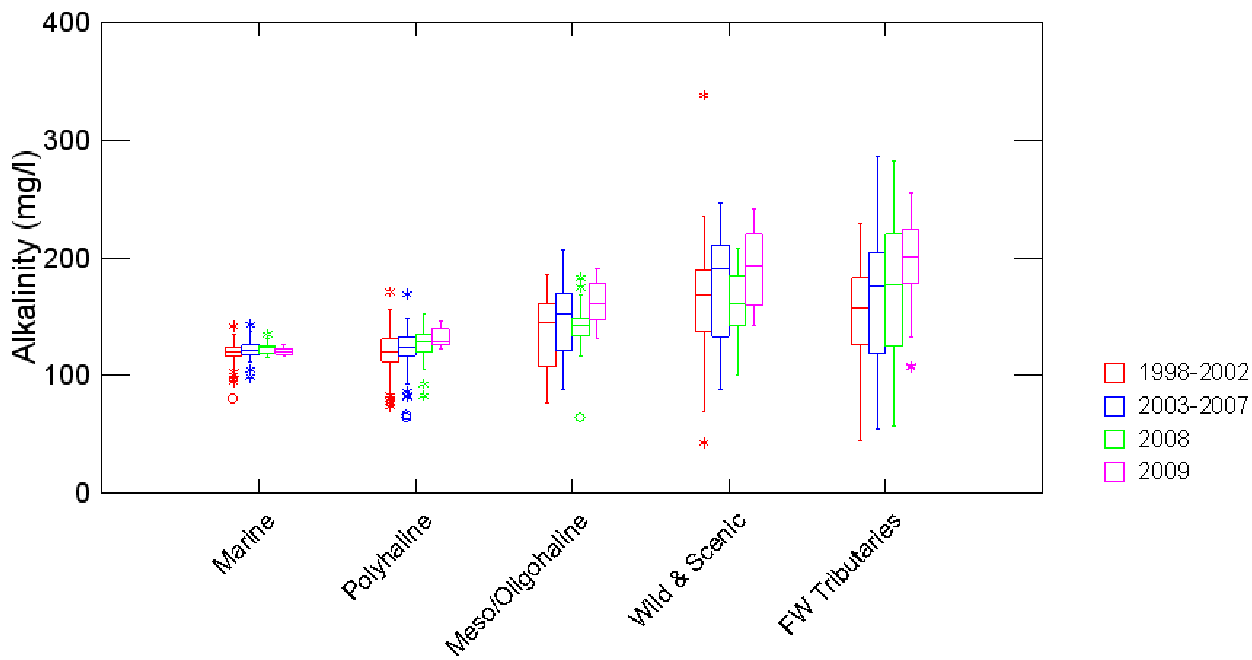
	≥ Median Target Value	< Median Target Value	< 25th Percentile Target Value
Dissolved Oxygen			

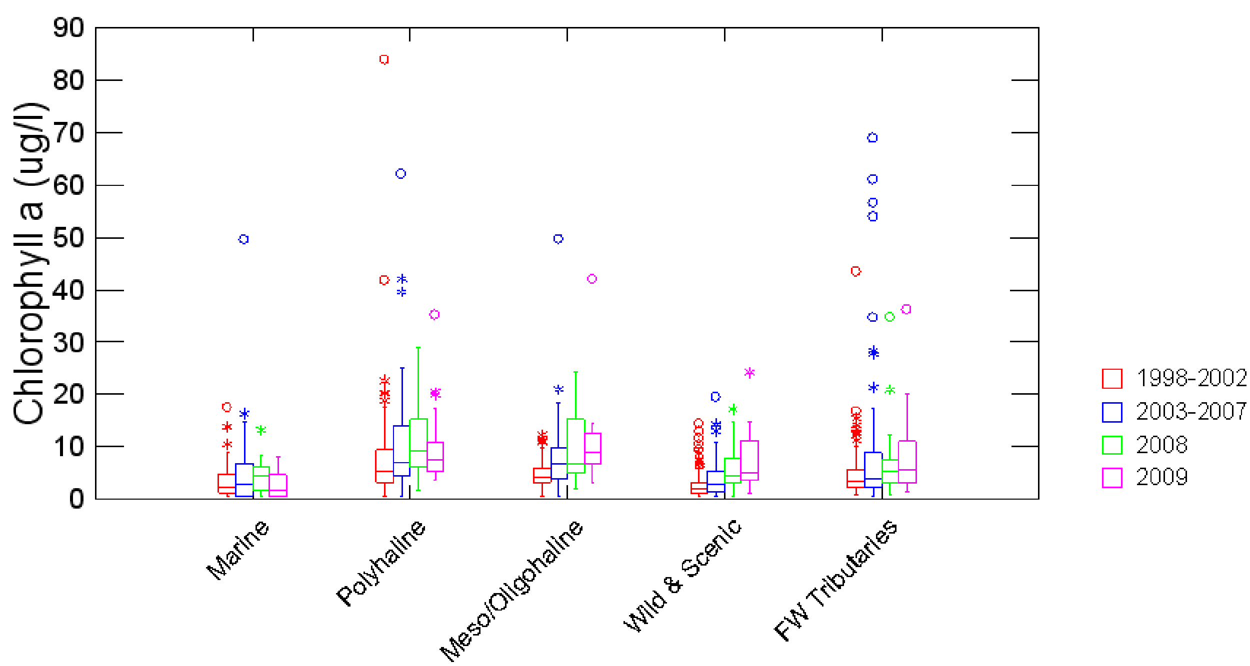
1998-2002 Targets	Marine		Polyhaline		Meso/Oligohaline		Wild and Scenic		FW Tributaries	
	Median	75th*	Median	75th*	Median	75th*	Median	75th*	Median	75th*
Chlorophyll *a* (ug/l)	2.35	4.86	5.36	9.57	4.29	5.95	2.00	3.22	3.27	5.72
Dissolved Oxygen (mg/l)	6.5	6.0	6.3	5.6	5.2	4.4	5.5	4.4	6.6	4.9
Fecal coliform (cfu/100ml)	6	18	31	70	88	128	110	230	100	180
Total Nitrogen (mg-N/l)	0.835	1.079	1.105	1.445	1.342	1.556	0.953	1.208	0.909	1.177
Total Phosphorus (mg-P/l)	0.021	0.033	0.036	0.044	0.052	0.064	0.039	0.050	0.043	0.069
Total Suspended Solids (mg/l)	5.3	8.0	5.3	7.0	4.3	6.0	4.0	5.3	4.0	5.3

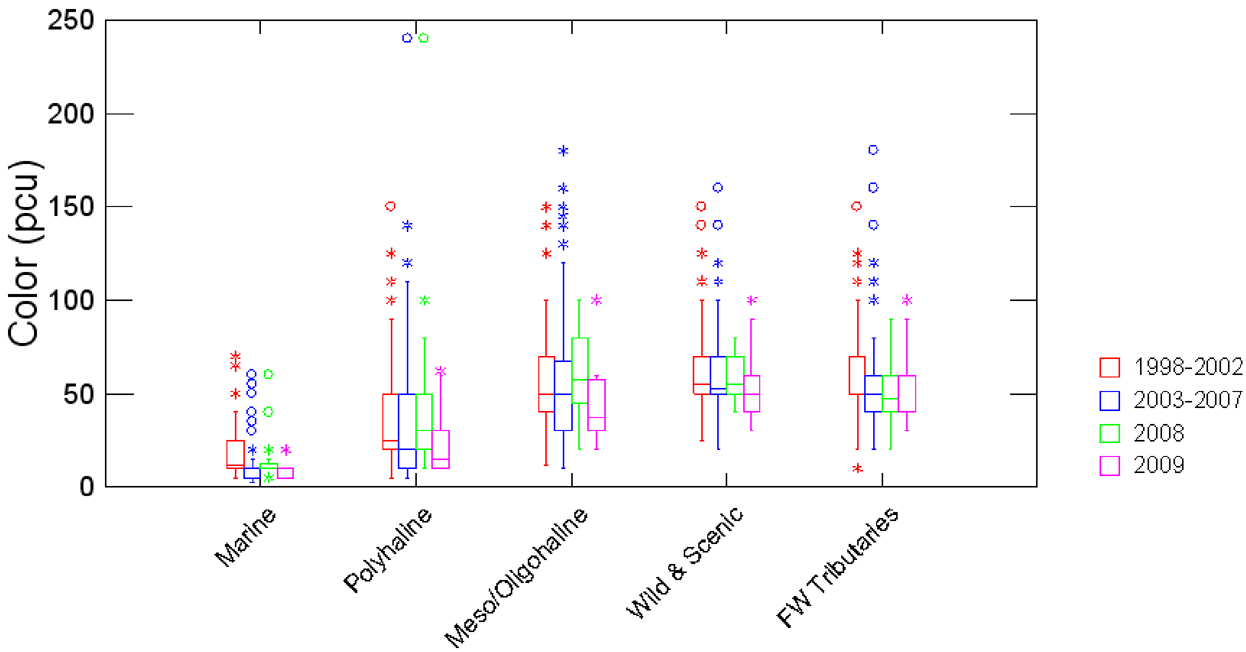
2009	Marine	Polyhaline	Meso/Oligohaline	Wild and Scenic	FW Tributaries
Chlorophyll a (ug/l)	1.60	7.60	9.08	5.16	5.66
Dissolved Oxygen (mg/l)	6.8	6.4	5.5	4.0	5.4
Fecal coliform (cfu/100ml)	1	16	49	68	111
Total Nitrogen (mg-N/l)	0.100	0.440	0.818	1.048	1.073
Total Phosphorus (mg-P/l)	0.012	0.027	0.055	0.050	0.060
Total Suspended Solids (mg/l)	2.0	3.8	3.0	3.0	4.4

*25th Percentile for Dissolved Oxygen

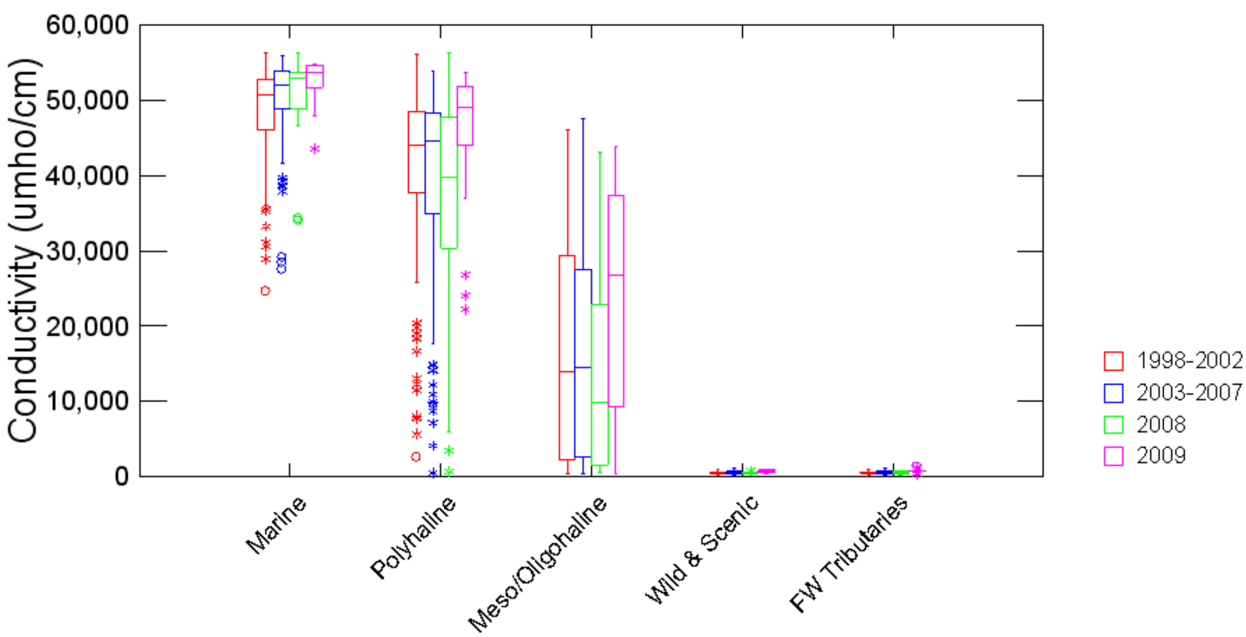
Appendix B – Box & Whisker Plots. Box and whisker plots of Loxahatchee River District's RiverKeeper data for the period 1998 through October 2009. See Figure 1 for a map of sample site locations.



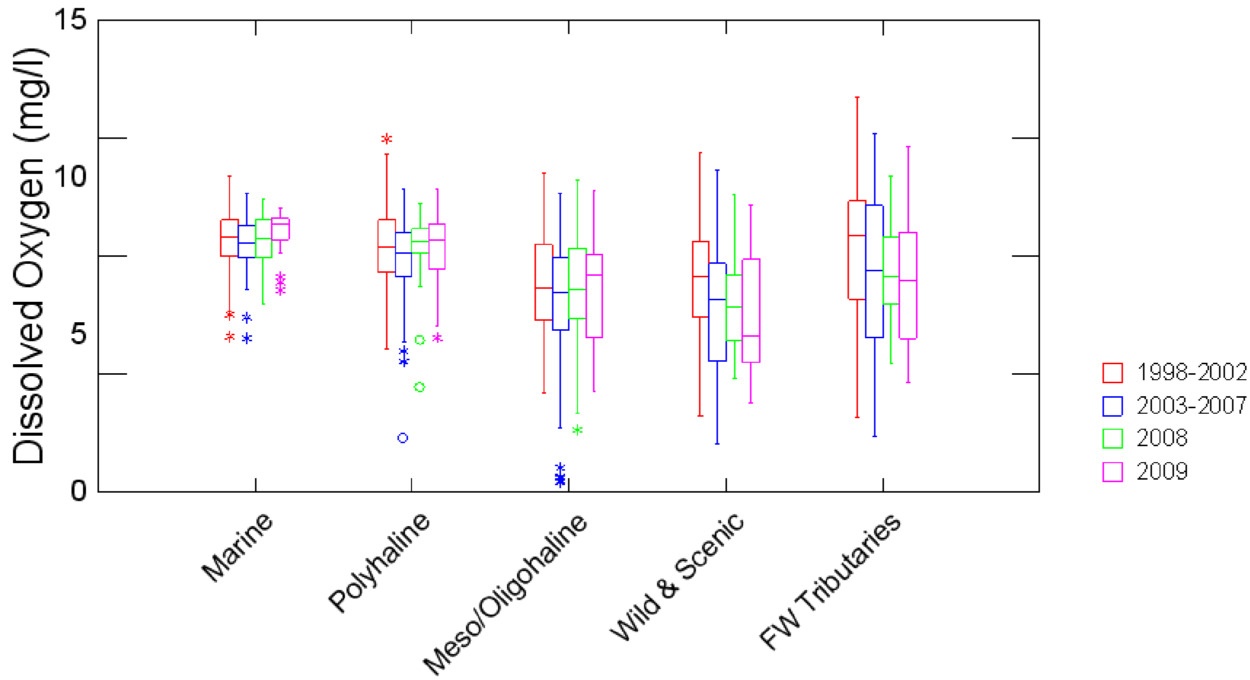




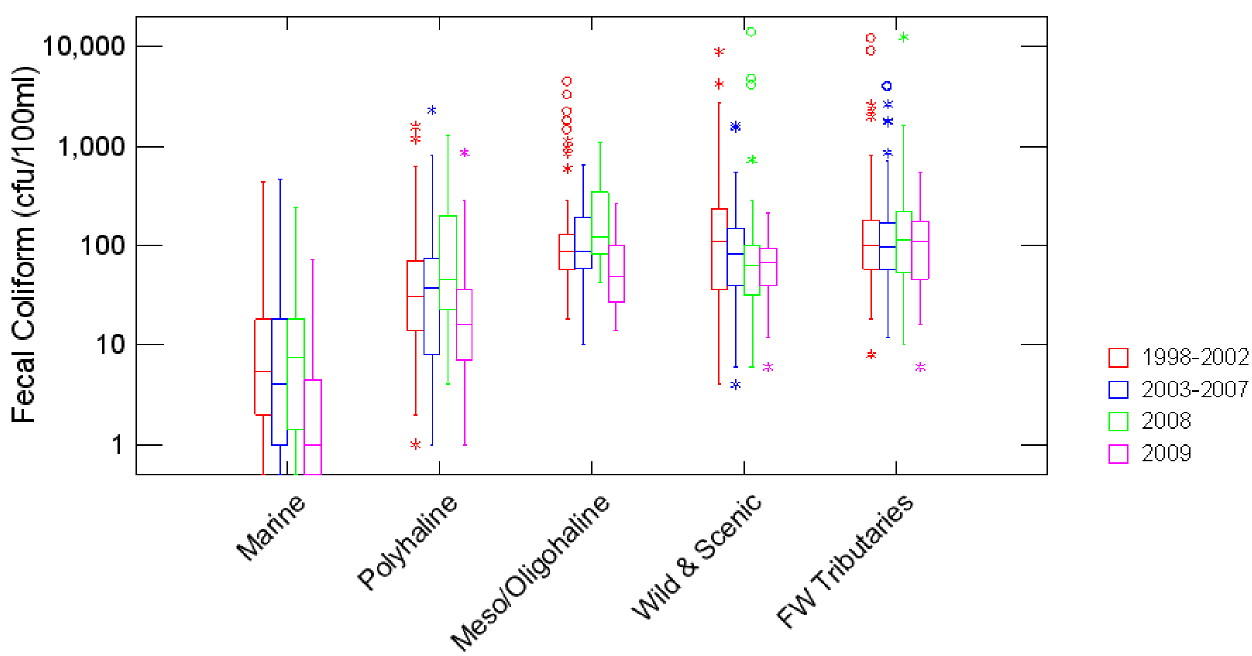
Color (pcu)
250
200
150
100
50
0
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009



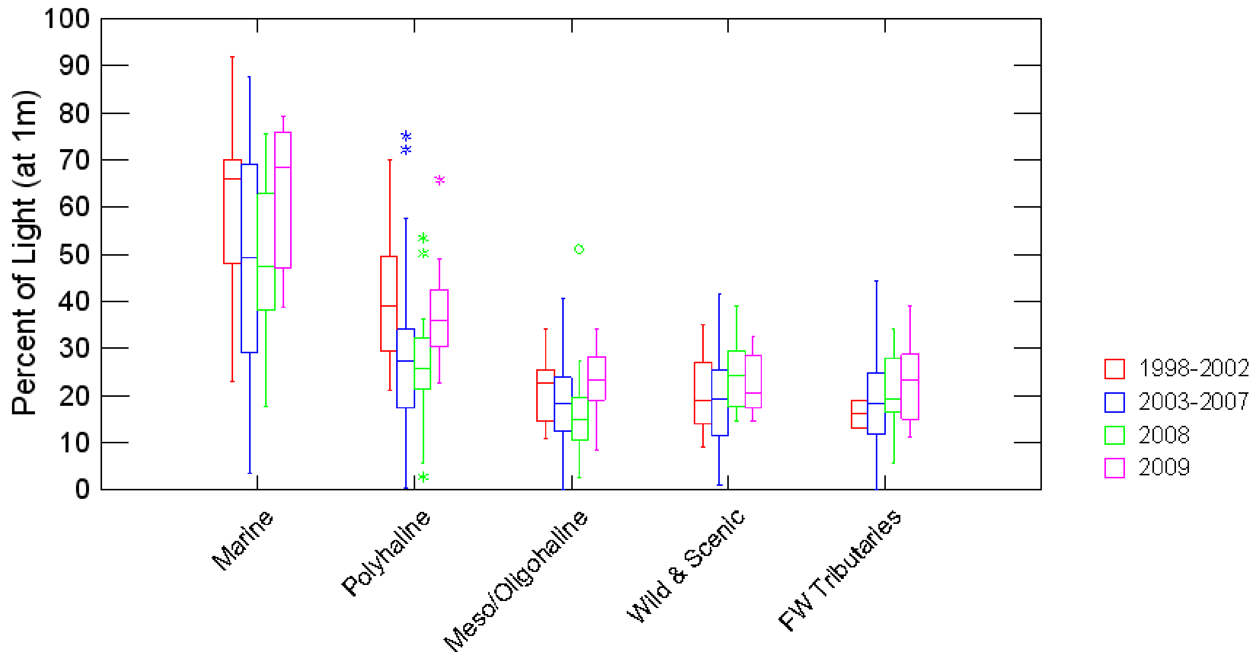
Conductivity (umho/cm)
60,000
50,000
40,000
30,000
20,000
10,000
0
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009



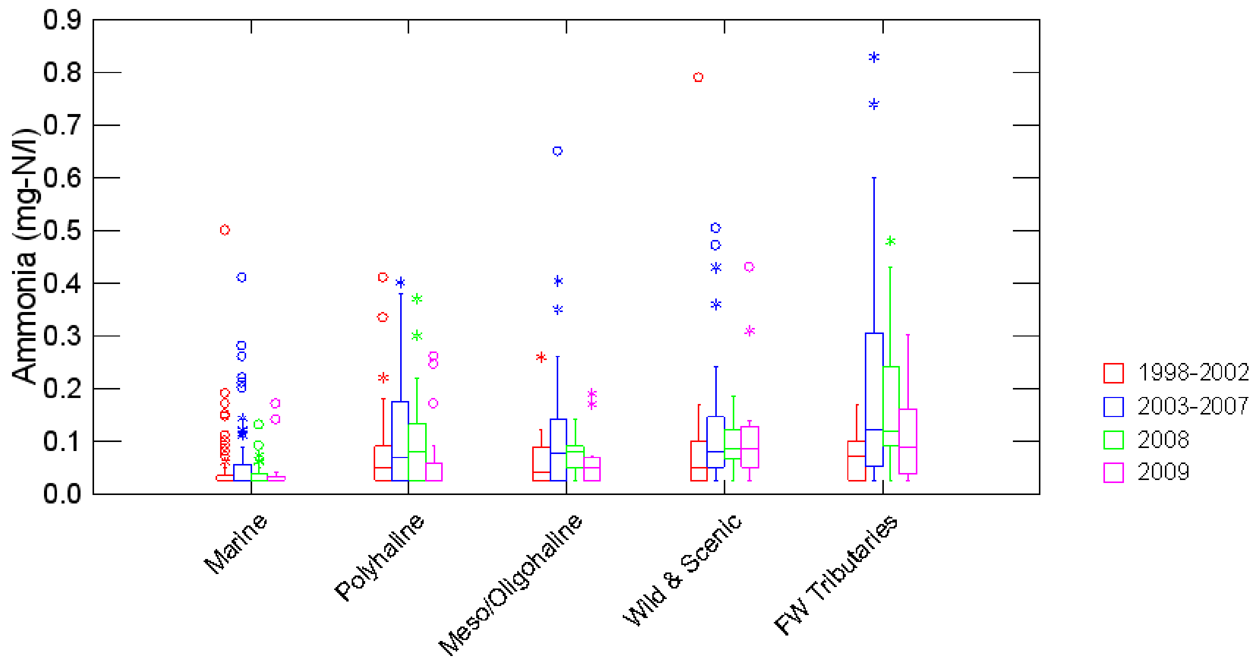
Dissolved Oxygen (mg/l)
15
10
5
0
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009



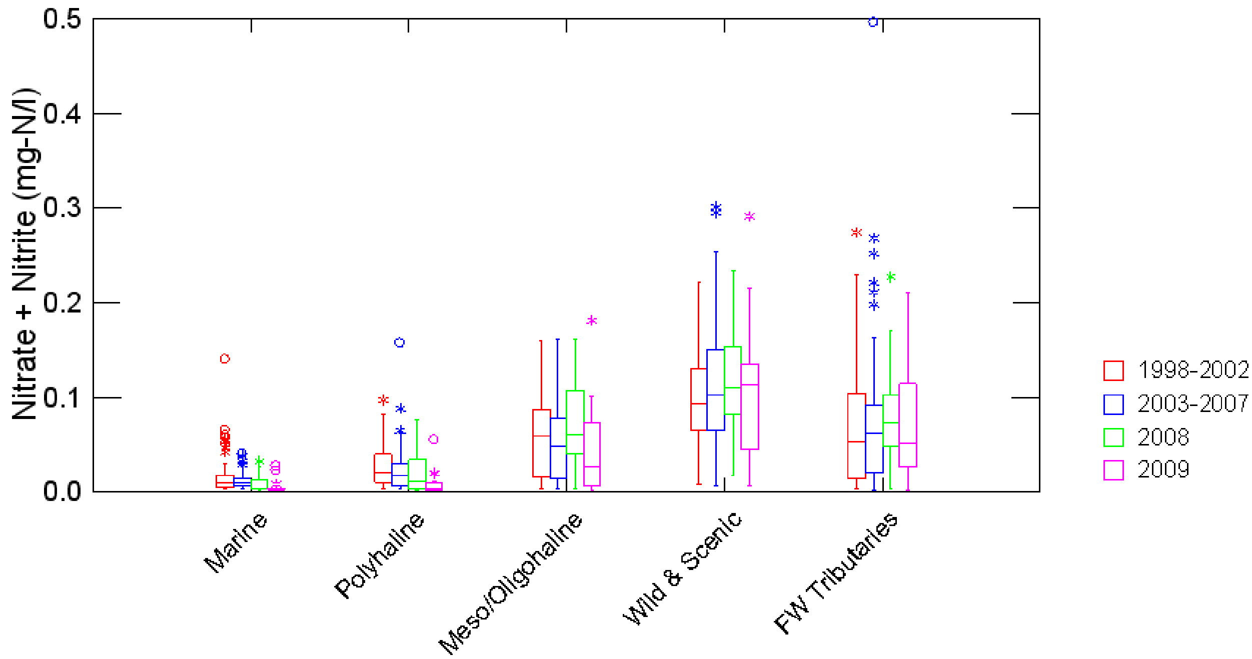
Fecal Coliform (cfu/100ml)
10,000
1,000
100
10
1
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009

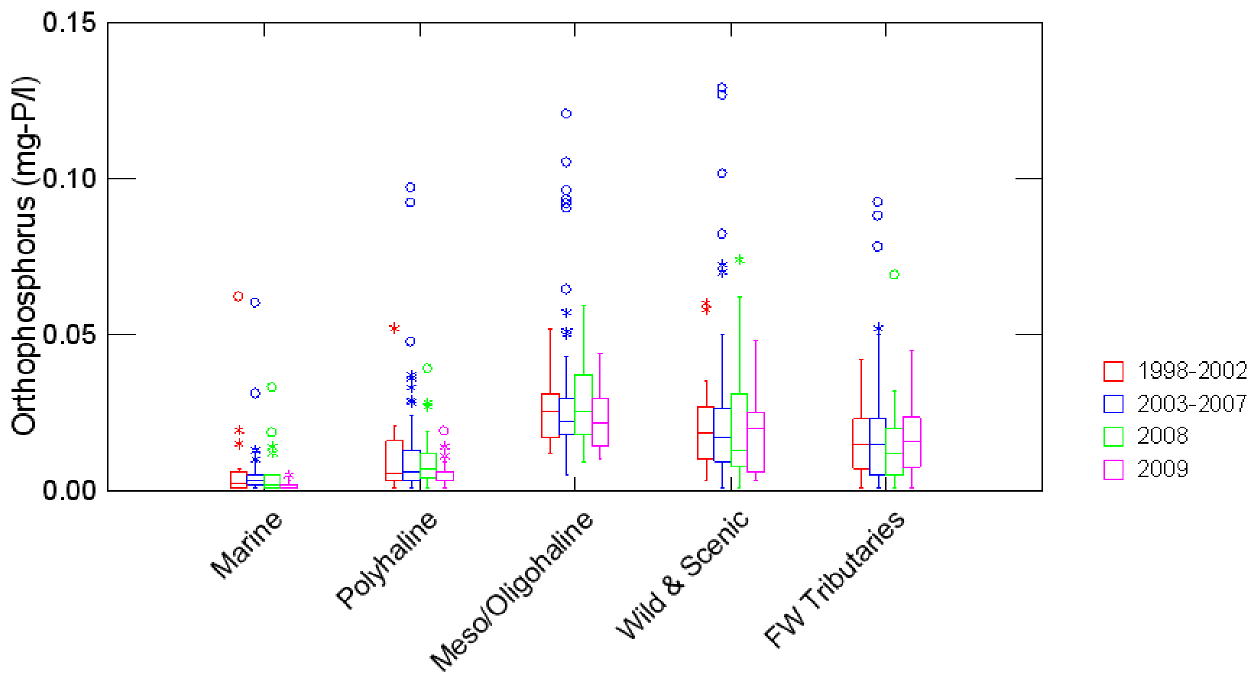


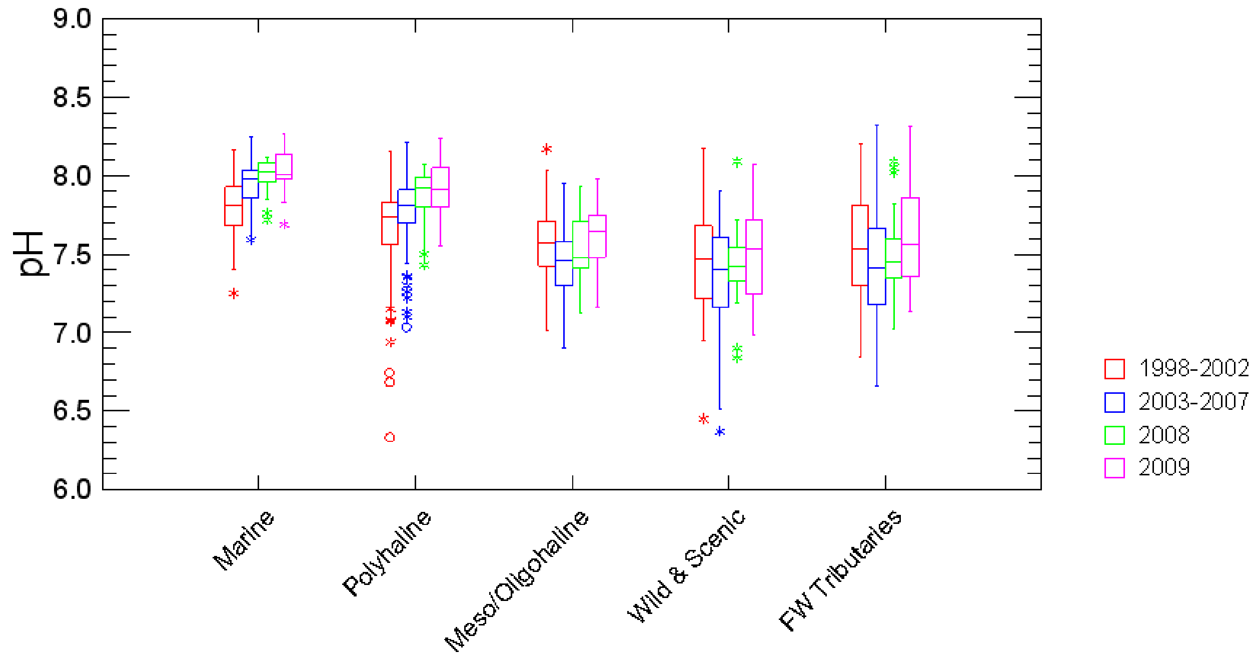
Percent of Light (at 1m)
100
90
80
70
60
50
40
30
20
10
0
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009



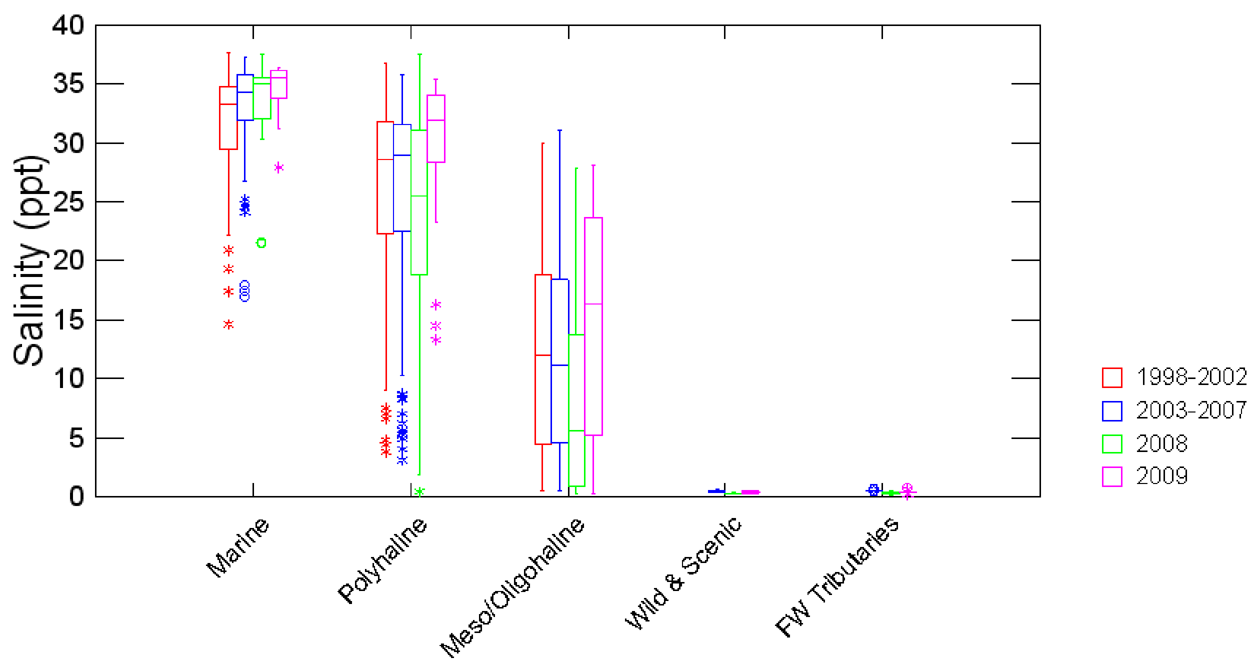
Ammonia (mg-N/l)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009


Nitrate + Nitrite (mg-N/l)
0.0
0.1
0.2
0.3
0.4
0.5
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009

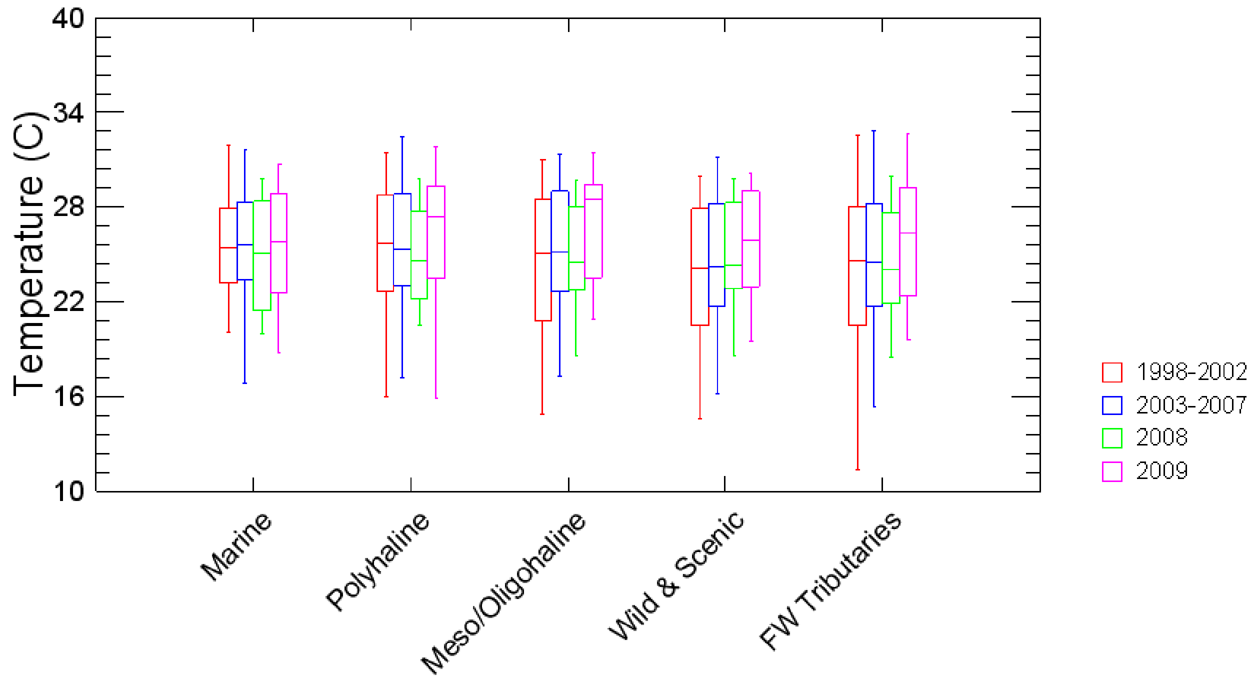

Orthophosphorus (mg-P/l)
0.00
0.05
0.10
0.15
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009

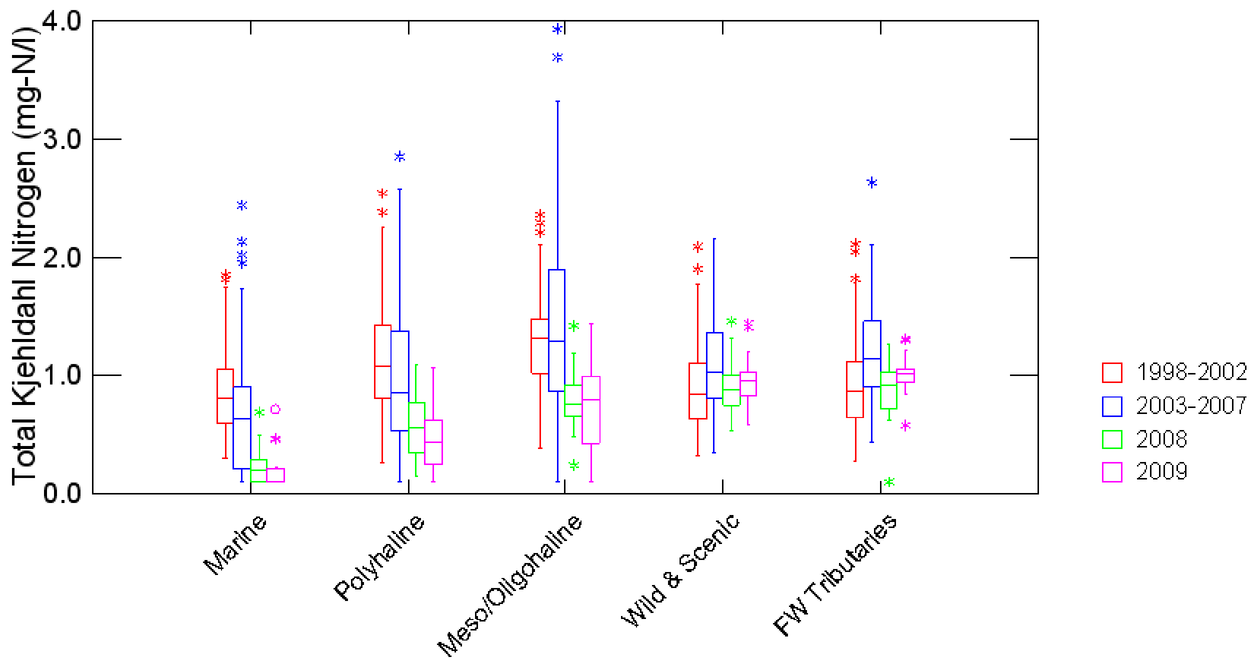


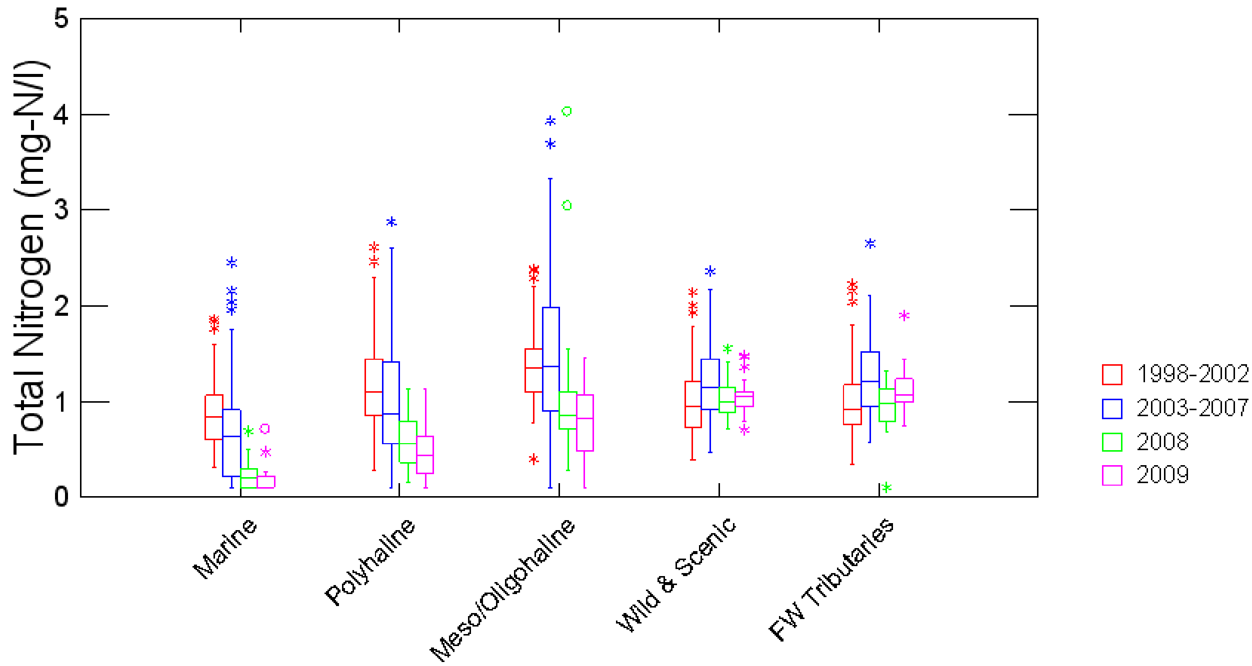
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009

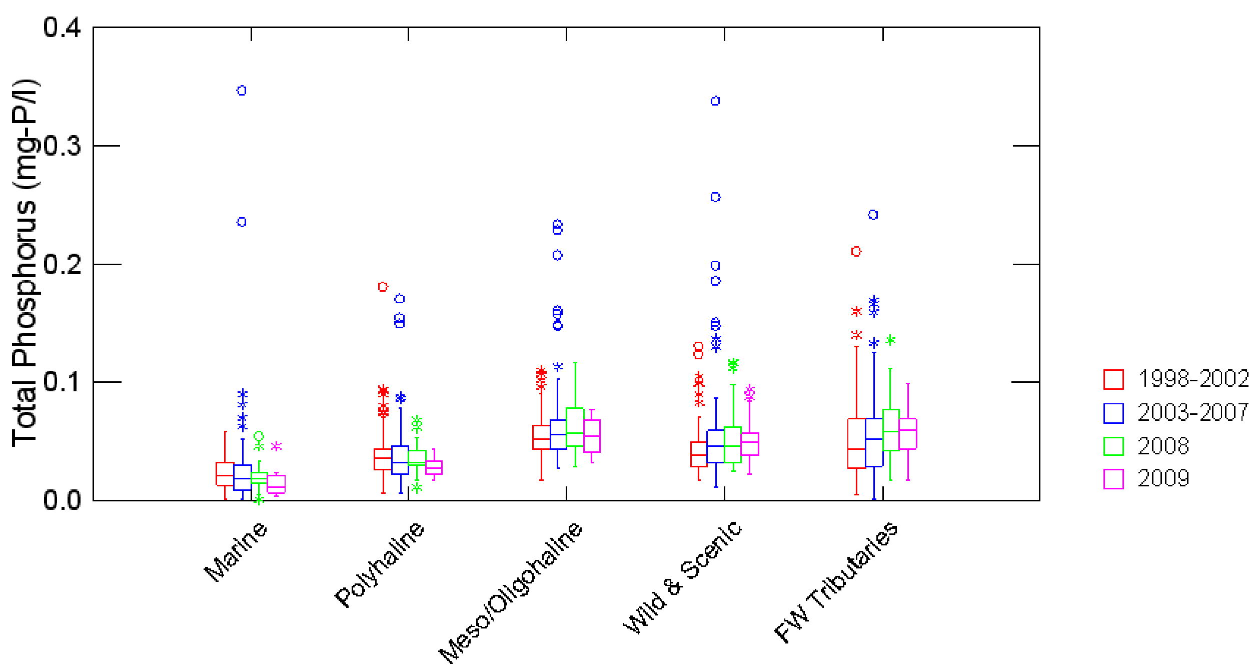


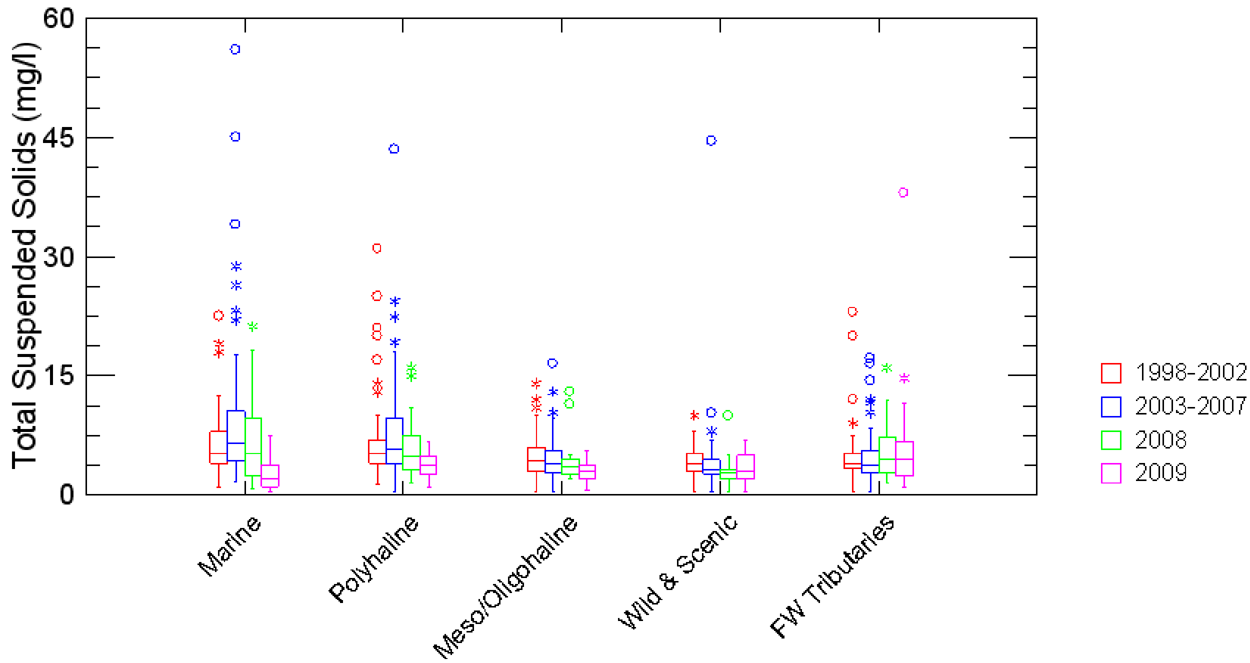
Salinity (ppt)
40
35
30
25
20
15
10
5
0
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009

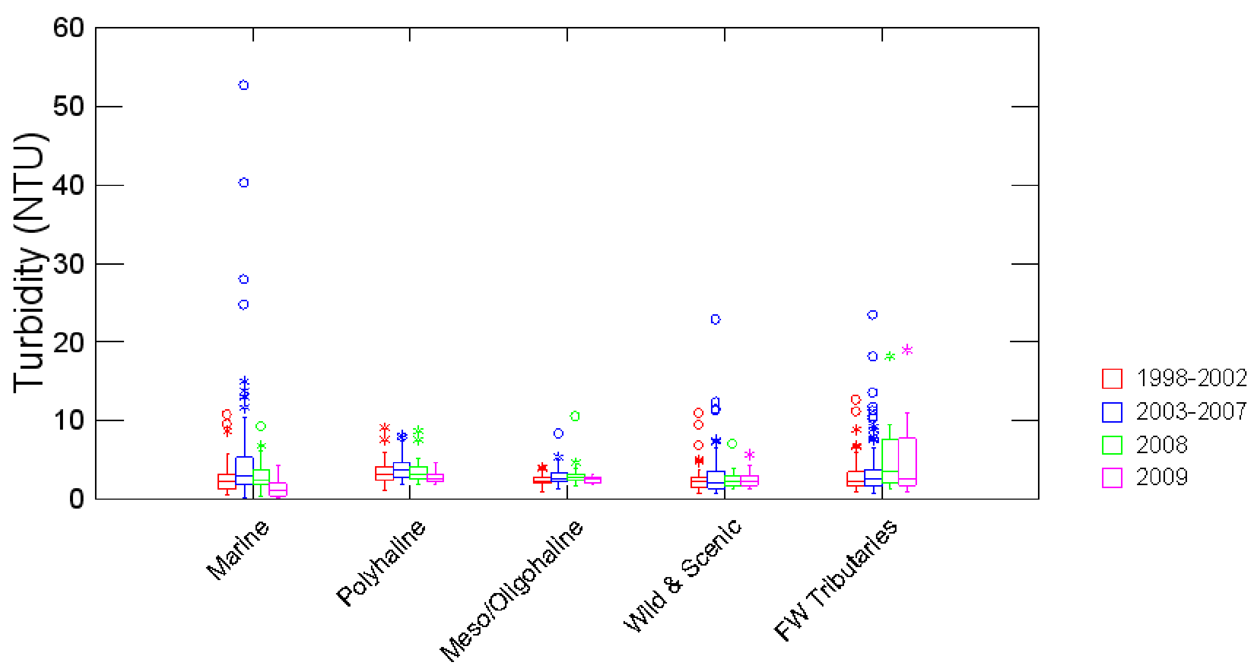

Temperature (C)
40
34
28
22
16
10
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009


Total Kjehldahl Nitrogen (mg-N/l)
4.0
3.0
2.0
1.0
0.0
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009

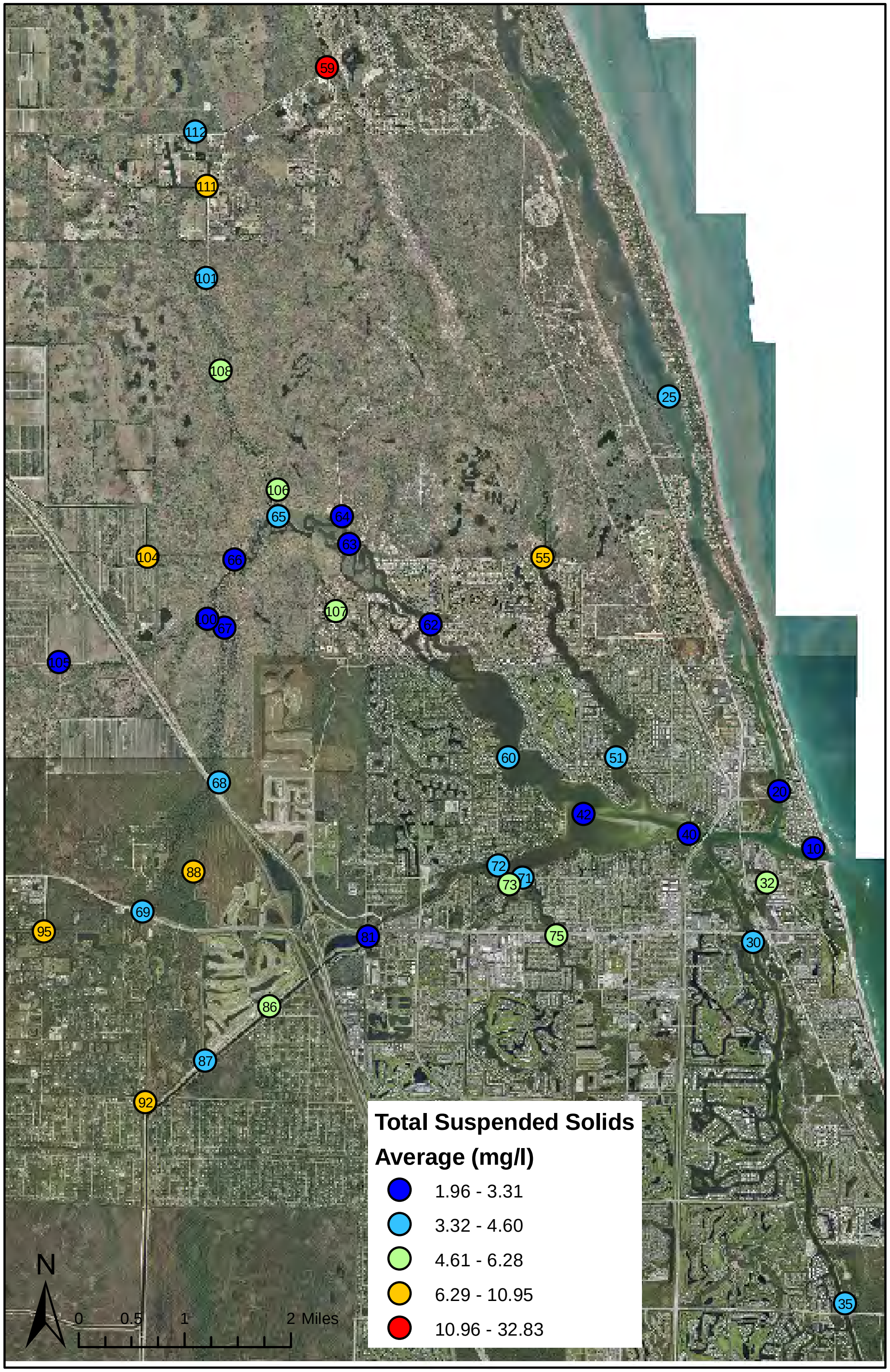

Total Nitrogen (mg-N/l)
0
1
2
3
4
5
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009

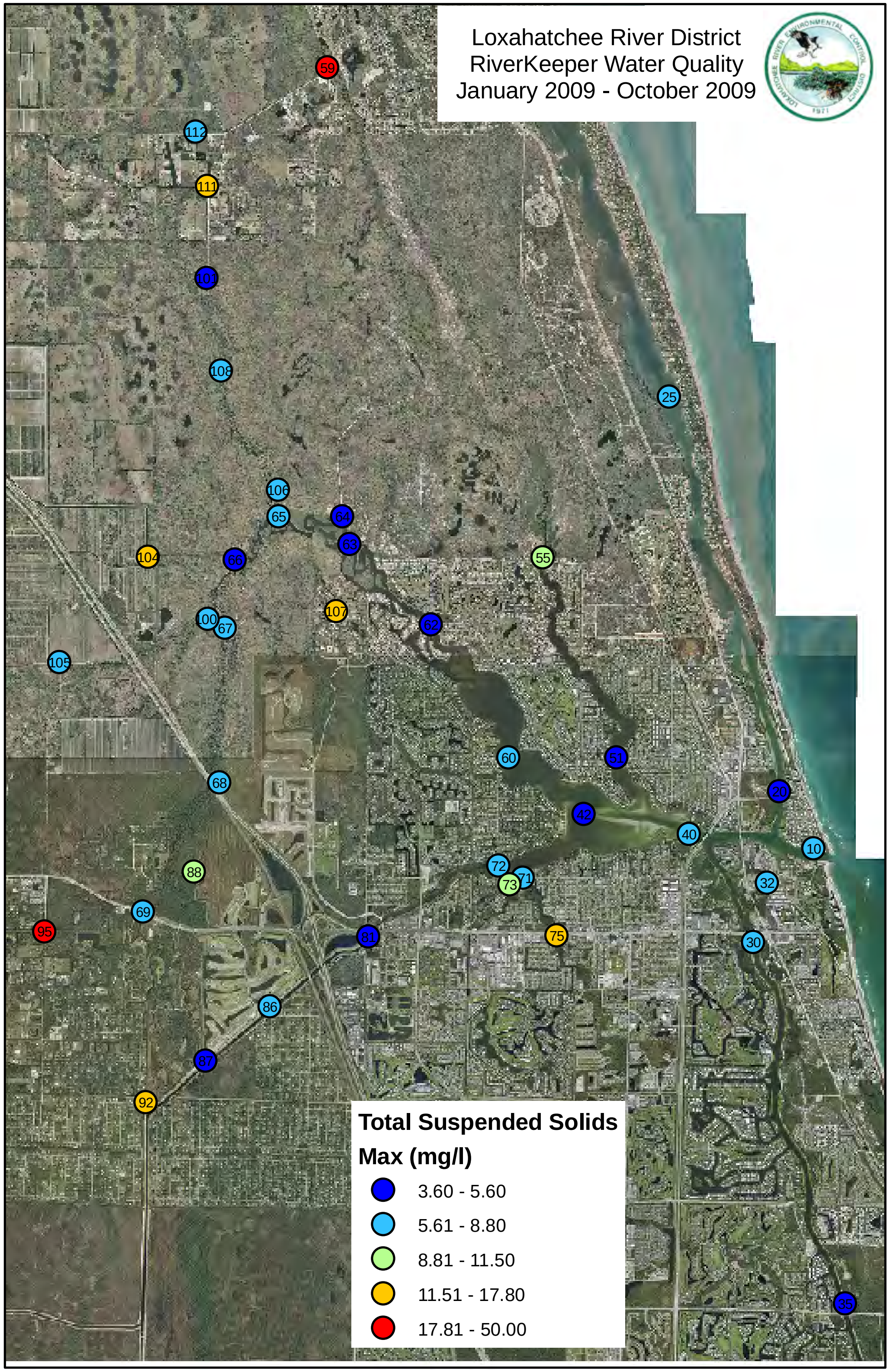

Total Phosphorus (mg-P/l)
0.0
0.1
0.2
0.3
0.4
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009

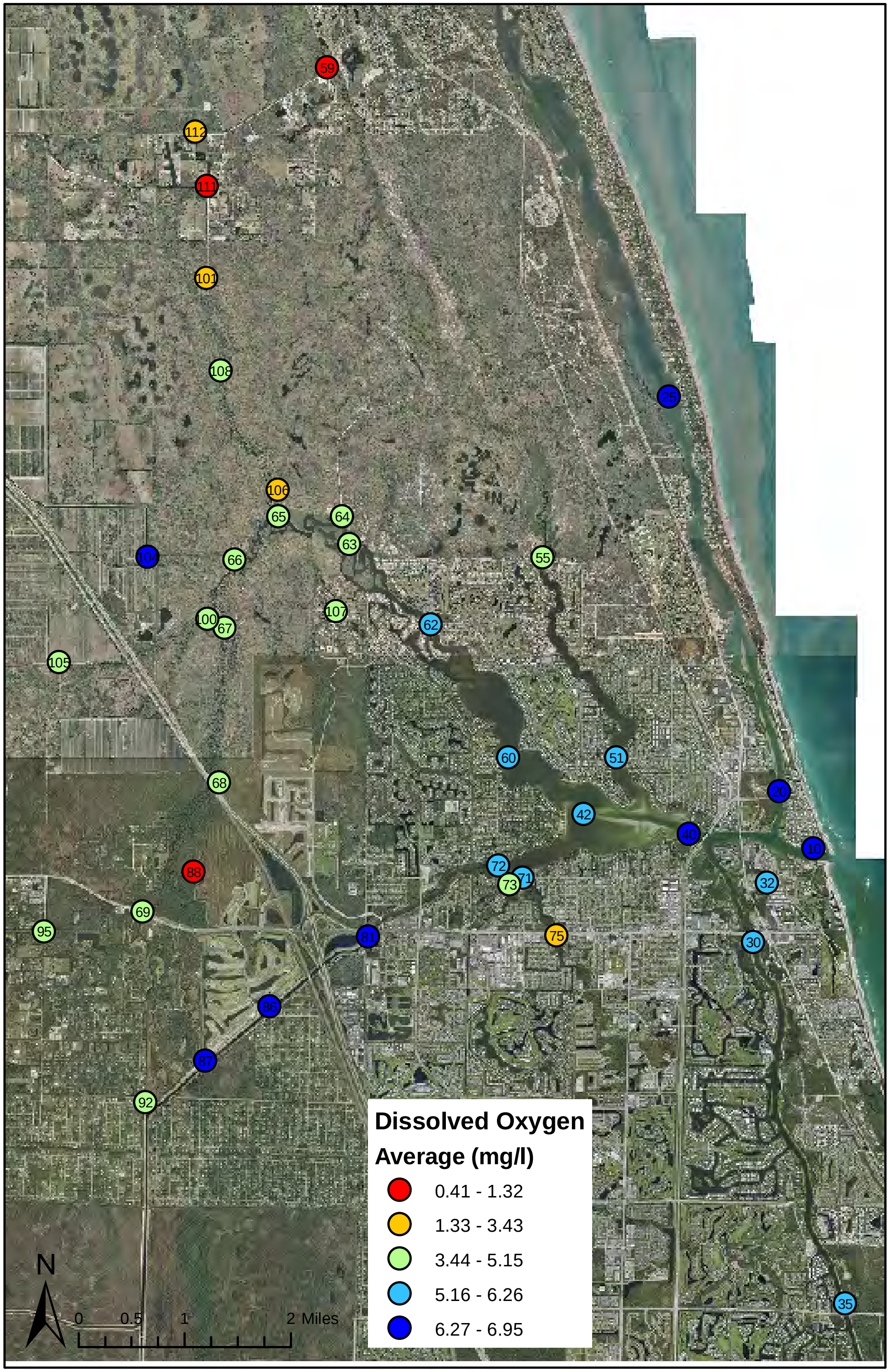

Total Suspended Solids (mg/l)
60
45
30
15
0
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009

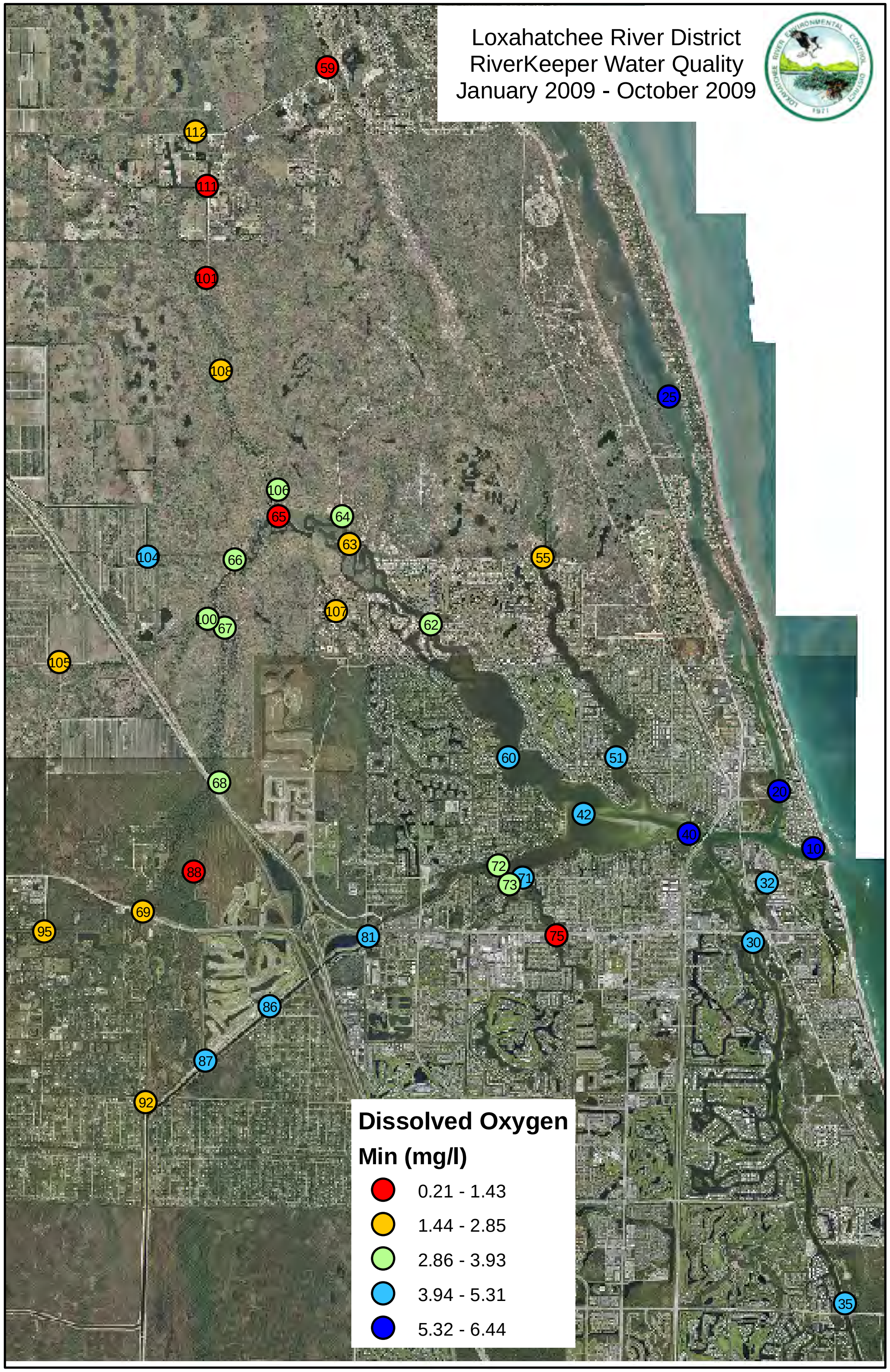

Turbidity (NTU)
60
50
40
30
20
10
0
Marine
Polyhaline
Meso/Oligohaline
Wild & Scenic
FW Tributaries
1998-2002
2003-2007
2008
2009

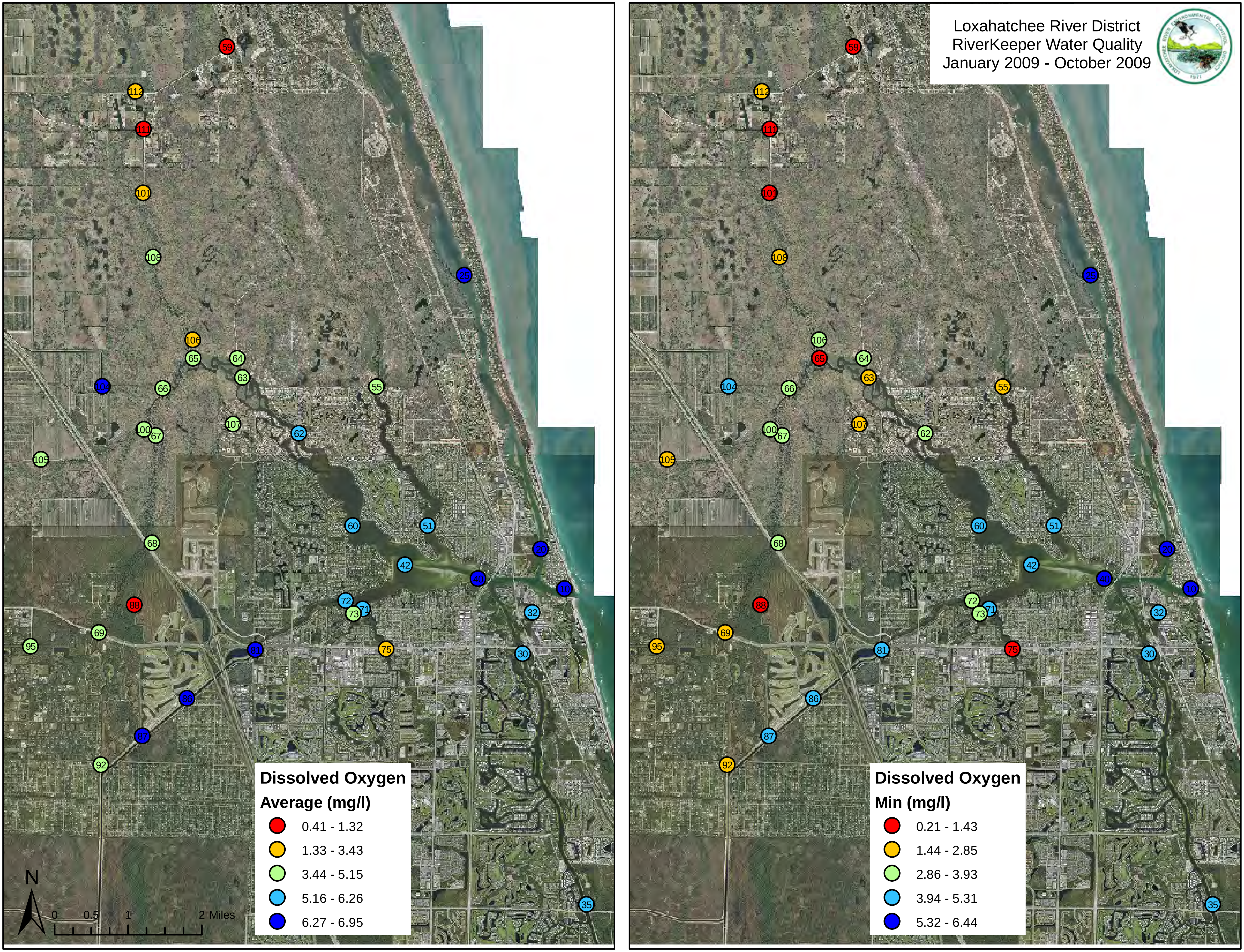
Appendix C – Spatial Plots. Spatial plots of select water quality parameters from the Loxahatchee River District's RiverKeeper data for the period January 2009 through October 2009.

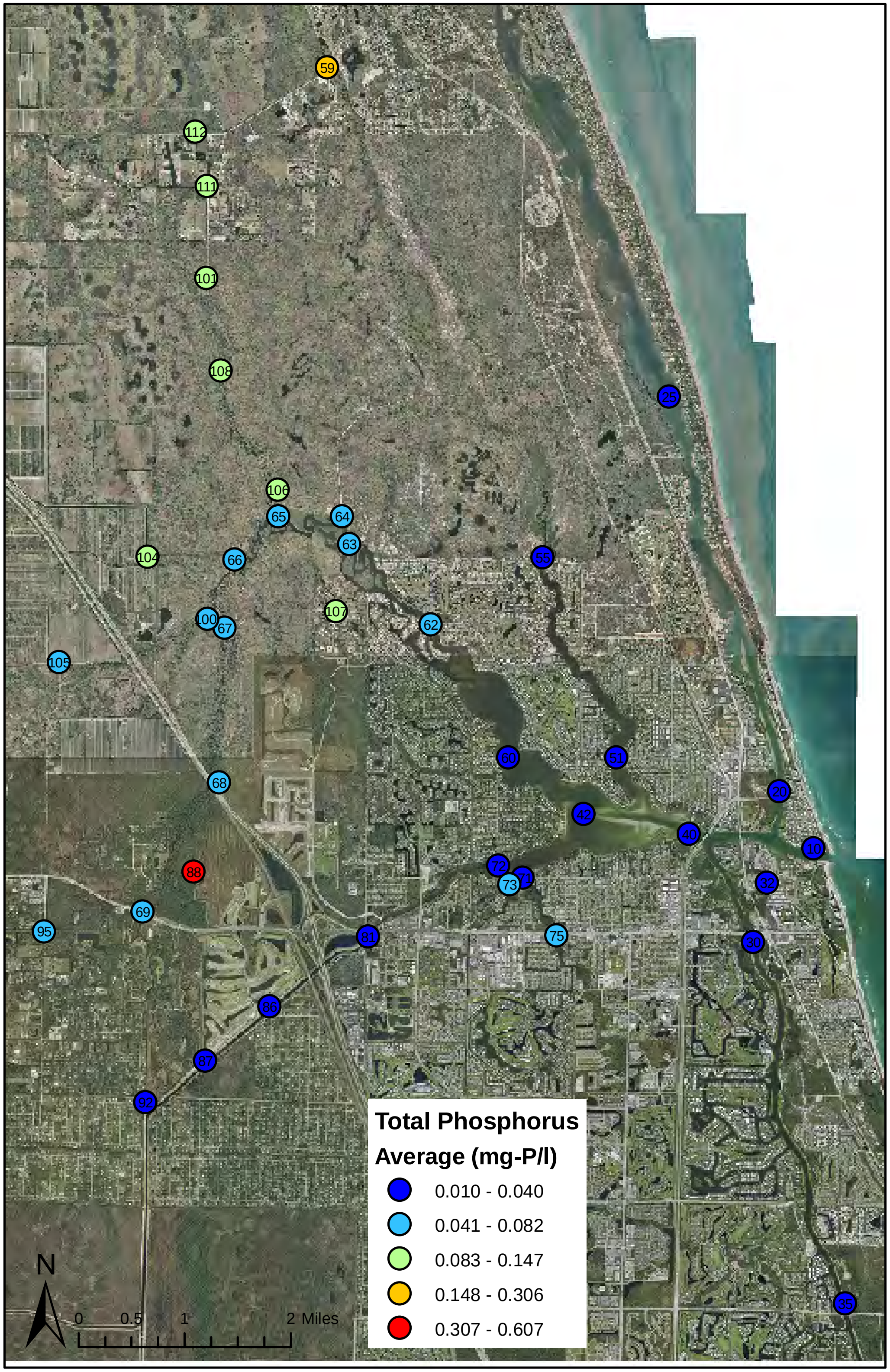

Total Suspended Solids
Average (mg/l)
1.96 - 3.31
3.32 - 4.60
4.61 - 6.28
6.29 - 10.95
10.96 - 32.83
N
0 0.5 1 2 Miles

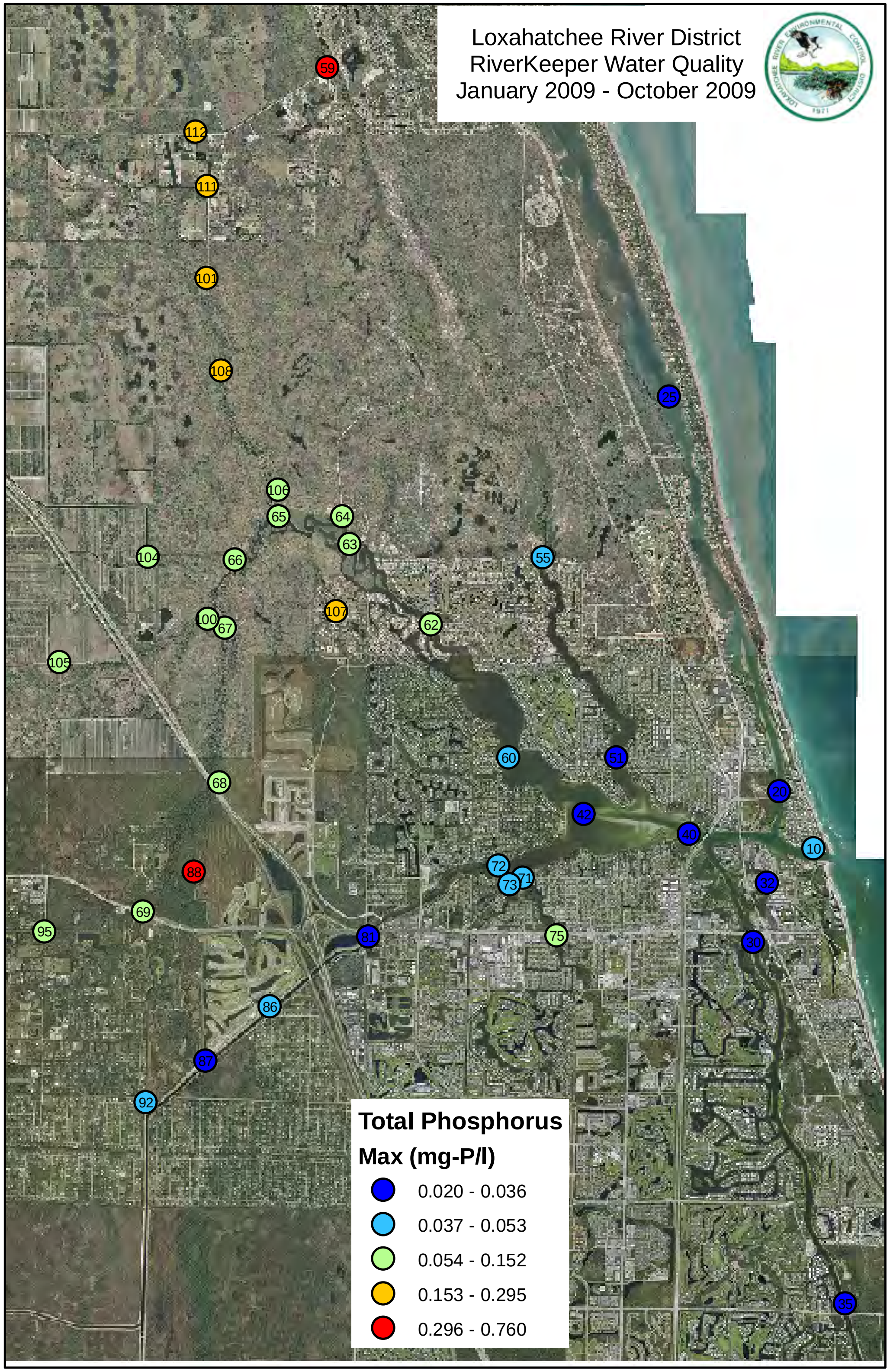

Loxahatchee River District
RiverKeeper Water Quality
January 2009 - October 2009
Total Suspended Solids
Max (mg/l)
3.60 - 5.60
5.61 - 8.80
8.81 - 11.50
11.51 - 17.80
17.81 - 50.00

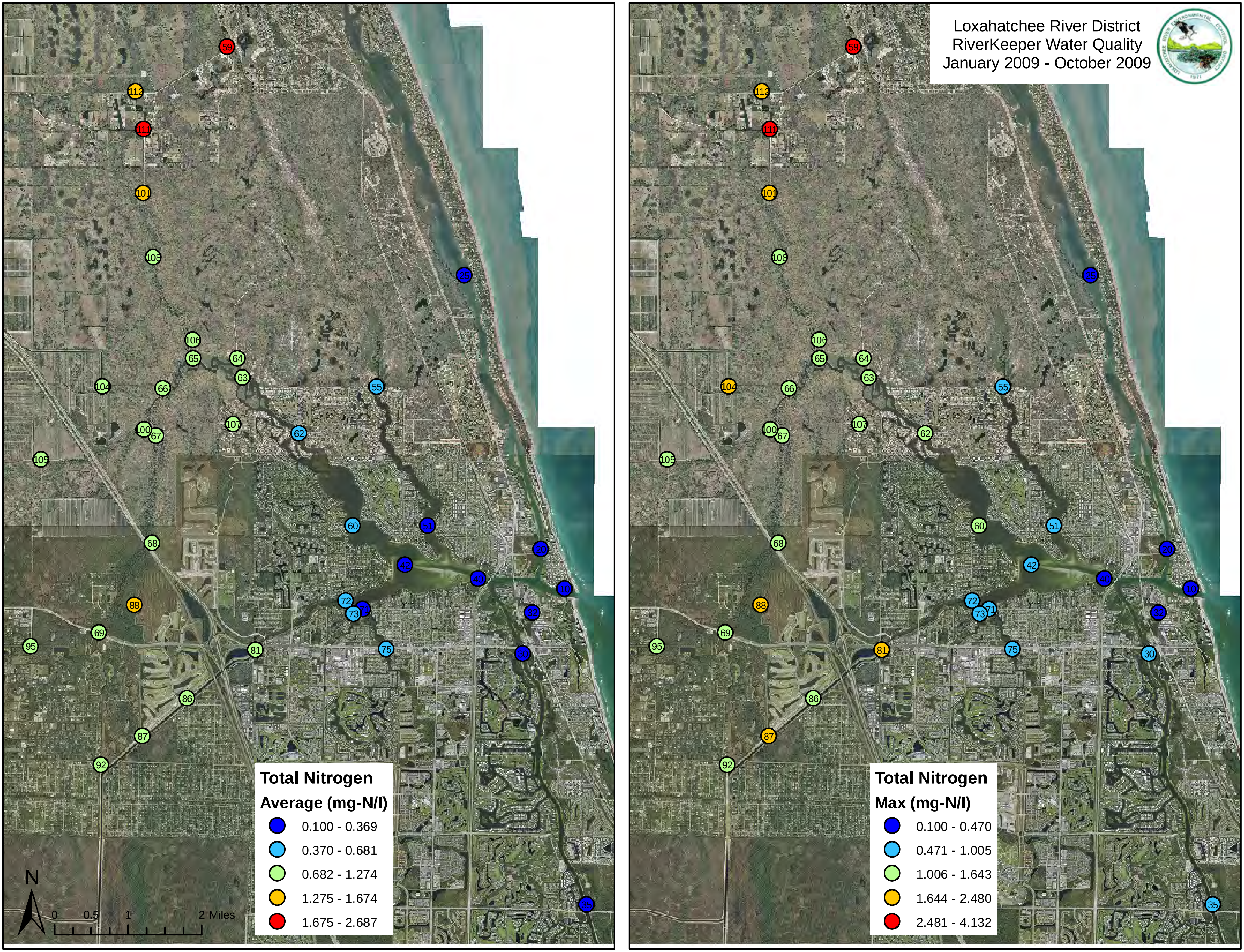

Dissolved Oxygen
Average (mg/l)
0.41 - 1.32
1.33 - 3.43
3.44 - 5.15
5.16 - 6.26
6.27 - 6.95
N
0 0.5 1 2 Miles


Loxahatchee River District
RiverKeeper Water Quality
January 2009 - October 2009
Dissolved Oxygen
Min (mg/l)
0.21 - 1.43
1.44 - 2.85
2.86 - 3.93
3.94 - 5.31
5.32 - 6.44

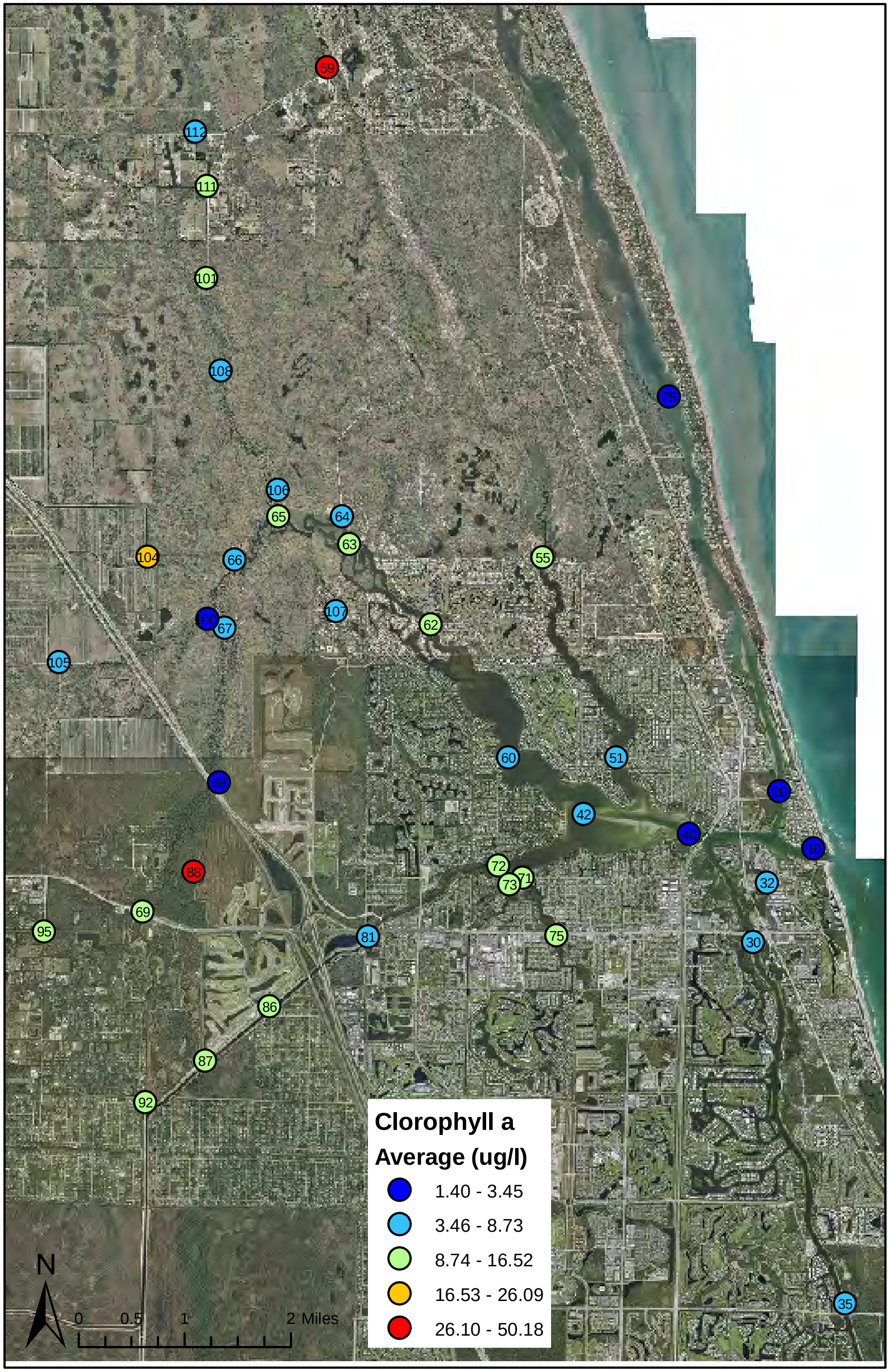

Loxahatchee River District
RiverKeeper Water Quality
January 2009 - October 2009
Dissolved Oxygen
Average (mg/l)
0.41 - 1.32
1.33 - 3.43
3.44 - 5.15
5.16 - 6.26
6.27 - 6.95
N
0 0.5 1 2 Miles
Dissolved Oxygen
Min (mg/l)
0.21 - 1.43
1.44 - 2.85
2.86 - 3.93
3.94 - 5.31
5.32 - 6.44

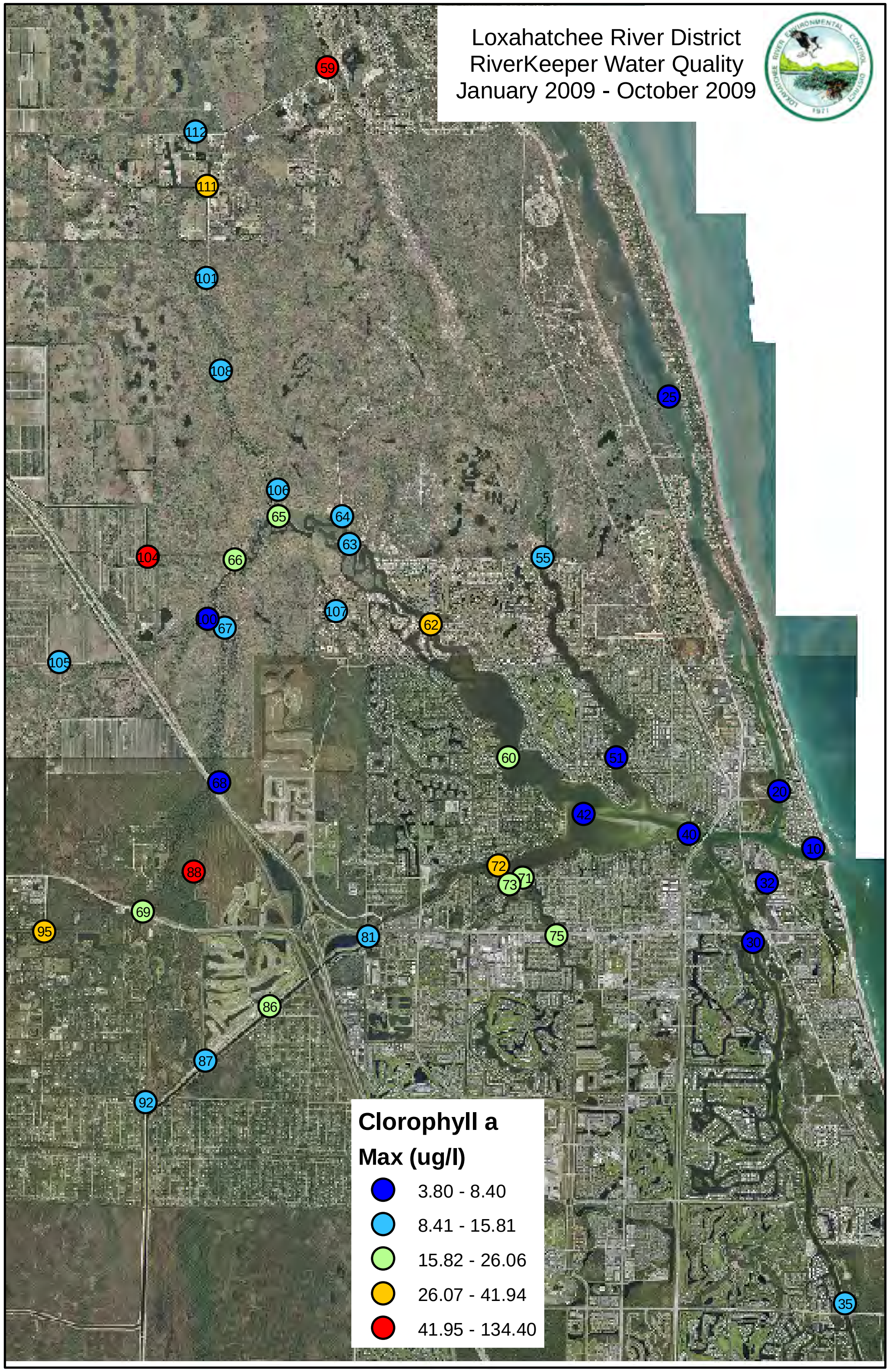

Total Phosphorus
Average (mg-P/l)
0.010 - 0.040
0.041 - 0.082
0.083 - 0.147
0.148 - 0.306
0.307 - 0.607
N
0 0.5 1 2 Miles

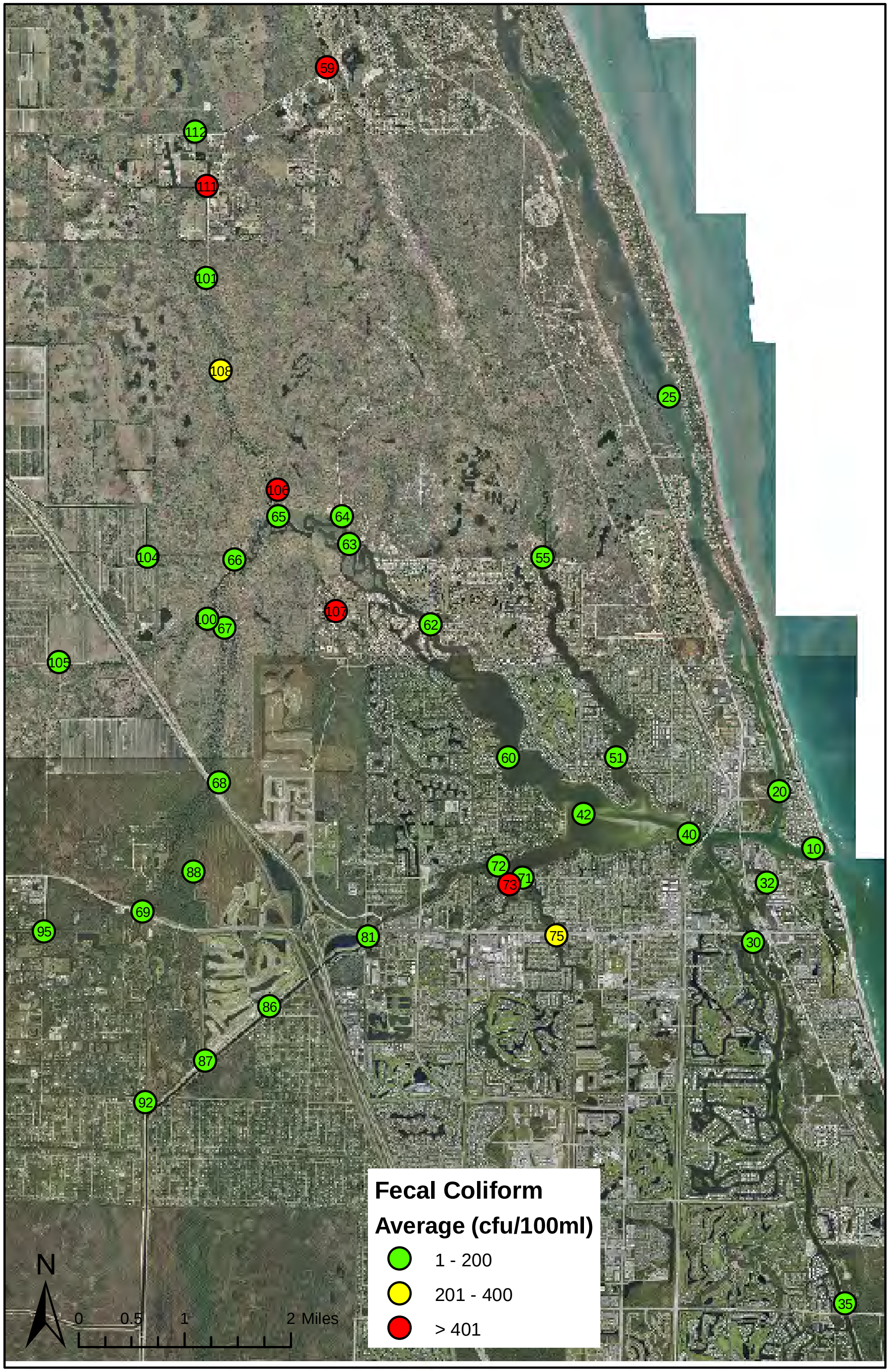

Loxahatchee River District
RiverKeeper Water Quality
January 2009 - October 2009
Total Phosphorus
Max (mg-P/l)
0.020 - 0.036
0.037 - 0.053
0.054 - 0.152
0.153 - 0.295
0.296 - 0.760

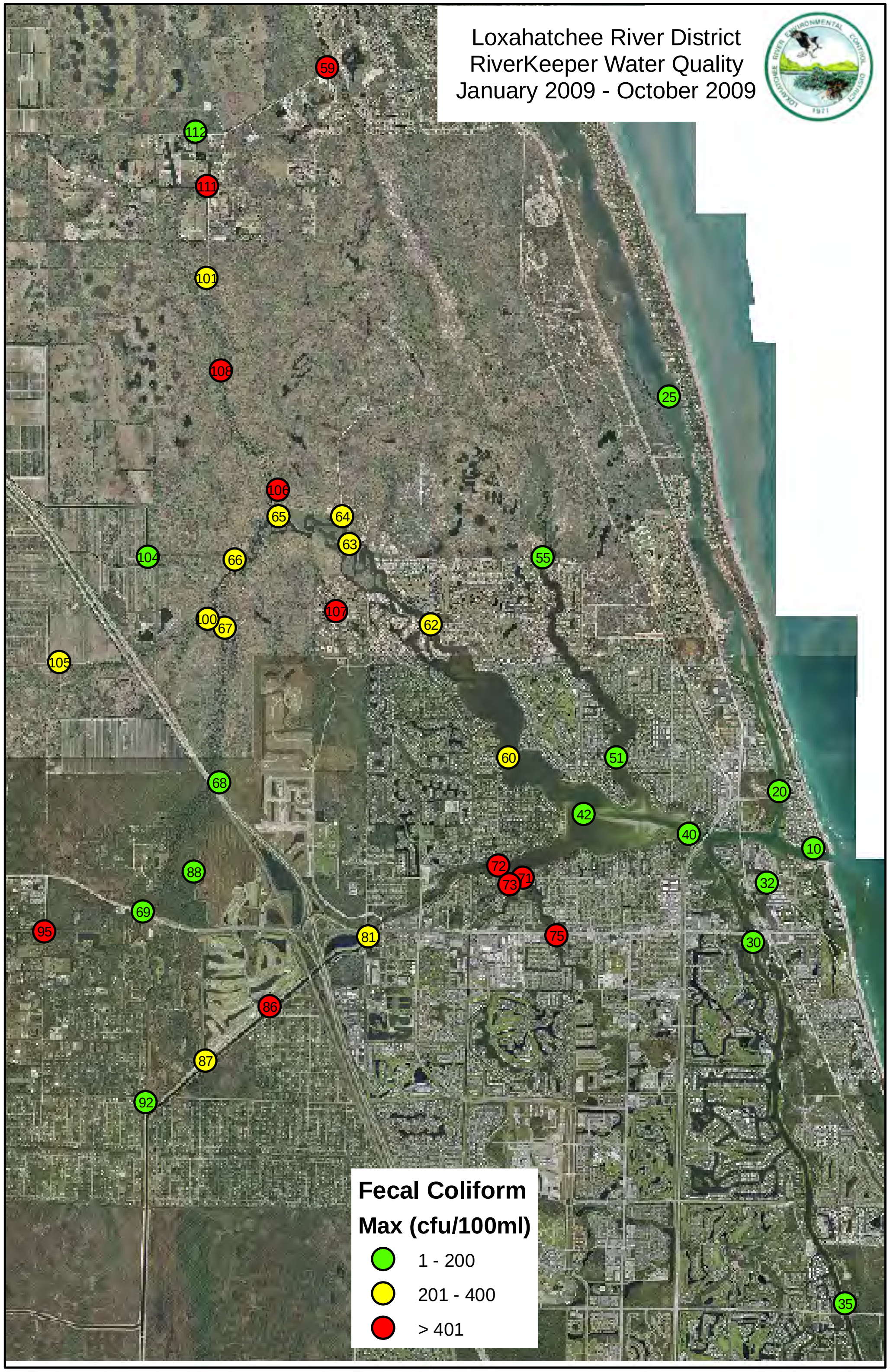


Loxahatchee River District
RiverKeeper Water Quality
January 2009 - October 2009
Total Nitrogen
Average (mg-N/l)
0.100 - 0.369
0.370 - 0.681
0.682 - 1.274
1.275 - 1.674
1.675 - 2.687
N
0 0.5 1 2 Miles
Total Nitrogen
Max (mg-N/l)
0.100 - 0.470
0.471 - 1.005
1.006 - 1.643
1.644 - 2.480
2.481 - 4.132


59
112
111
101
108
25
106
65
64
63
104
66
55
100
67
107
62
105
60
51
68
20
42
40
72
10
88
73
71
32
69
95
81
75
30
86
87
92
35
Clorophyll a
Average (ug/l)
1.40 - 3.45
3.46 - 8.73
8.74 - 16.52
16.53 - 26.09
26.10 - 50.18
N
0 0.5 1 2 Miles


Loxahatchee River District
RiverKeeper Water Quality
January 2009 - October 2009
59
112
111
101
108
25
106
65
64
63
104
66
55
100
67
107
62
105
60
51
68
20
42
40
72
10
88
73
71
32
69
95
81
75
30
86
87
92
35
Clorophyll a
Max (ug/l)
3.80 - 8.40
8.41 - 15.81
15.82 - 26.06
26.07 - 41.94
41.95 - 134.40


59
112
111
101
108
25
106
65
64
63
104
66
55
100
67
107
62
105
60
51
68
20
42
40
10
72
88
71
73
32
69
95
81
75
30
86
87
92
35
Fecal Coliform
Average (cfu/100ml)
1 - 200
201 - 400
> 401
N
0
0.5
1
2 Miles


Loxahatchee River District
RiverKeeper Water Quality
January 2009 - October 2009
59
112
111
101
108
25
106
65
64
63
104
66
55
100
67
107
62
105
60
51
68
20
42
40
10
72
88
71
73
32
69
95
81
75
30
86
87
92
35
Fecal Coliform
Max (cfu/100ml)
1 - 200
201 - 400
> 401

Appendix D – Analysis Methods & Calibration Criteria

LOXAHATCHEE RIVER DISTRICT WILDPINE LAB E56026

TABLE OF CALIBRATION ACCEPTANCE CRITERIA FOR LAB ACTIVITIES

Effective Date: 4/24/03 Rev. 7 on May 1, 2009

							[HISTORICAL VALUES]		
PARAMETER/	BLANK	LOD	# OF	INITIAL CALIB	2ND	CONTINUING	PRECISION	ACCURACY	SAMPLE
METHOD	(mg/L)	(mg/L)	INITIAL	CORR COEF	STD	CALIB (LCS)	OF DUPS	OF SPIKES	HOLD
			STDS	OR % R	% R	% R	% RPD	% R	TIMES
Fecal Coliform	1 pre-1 post +	1 cfu/	N/A	N/A	N/A	N/A	[0 - 50]	N/A	6 hours
SM9222D	every 10 samples	100 mLs					every 10 samples		
MF (20-60)	less than MDL						or matrix set		
Total Coliform	1 pre-1 post +	1 cfu/	N/A	N/A	N/A	N/A	[0 - 50]	N/A	6 hours
SM9222B	every 10 samples	100 mLs					every 10 samples		
MF (20-80)	less than MDL						or matrix set		
Ammonia-N	1 pre- +	0.05	6 to	>/= 0.995	90 - 110	80 - 120	[0 - 30]	[80 - 120]	28 days
EPA 350.2	every 10 samples		bracket		one prior	LCS in dup every	every 10 samples	every 10 samples	
low-Color, Nessler's	less than MDL		samples		to sample analysis	10 samples + end	or matrix set	or matrix set	
Ammonia-N	1 pre- +	0.2	4 to	>/= 0.995	90 - 110	80 - 120	[0 - 10]	[85-115]	28 days
EPA 350.2	every10 samples		bracket		one prior	LCS in dup every	every 10 samples	every 10 samples	
high-Titrimetric	less than MDL		samples		to sample analysis	10 samples + end	or matrix set	or matrix set	
TKN	1 pre- +	0.2	6 to	>/= 0.995	90 - 110	90 - 110	[0 - 20]	90 - 110	28 days
EPA 351.2	every 10 samples		bracket		one prior	LCS in dup every	every 10 samples	every 10 samples	
Block, AA	less than MDL		samples		to sample analysis	10 samples + end	or matrix set	or matrix set	
Nitrate+Nitrate-N	1 pre- +	0.005	6 to	>/= 0.995	90 - 110	90 -110	[0 - 20]	90 -110	48 hours
EPA 353.2	every 10 samples		bracket		one prior	LCS in dup every	every 10 samples	every 10 samples	
low-Cd Reduc, AA	less than MDL		samples		to sample analysis	10 samples + end	or matrix set	or matrix set	
Nitrate+Nitrate-N	1 pre- +	0.02	6 to	>/= 0.995	90 - 110	90 -110	[0 - 14]	90 -110	28 days
EPA 353.2	every 10 samples		bracket		one prior	LCS in dup every	every 10 samples	every 10 samples	
high-Cd Reduc, AA	less than MDL		samples		to sample analysis	10 samples + end	or matrix set	or matrix set	

PARAMETER/	BLANK	MDL	# OF	INITIAL CALIB	2ND	CONTINUING	PRECISION	ACCURACY	SAMPLE
METHOD	(mg/L)	(mg/L)	INITIAL	CORR COEF	STD	CALIB (LCS)	OF DUPS	OF SPIKES	HOLD
			STDS	OR % R	% R	% R	% RPD	% R	TIMES
Ortho-Phosphate	1 pre- +	0.002	6 to	>/= 0.995	90 - 110	80 -120	[0 - 20]	[90 - 110]	48 hours
SM4500-P F	every 10 samples		bracket	98 -102	one prior	LCS in dup every	every 10 samples	every 10 samples	
FIA	less than MDL		samples	published	to sample analysis	10 samples + end	or matrix set	or matrix set	
Ortho-Phosphate	1 pre- +	0.002	6 to	>/= 0.995	90 - 110	80 -120	[0 - 20]	[90 - 110]	48 hours
EPA 365.2	every 10 samples		bracket	98 -102	one prior	LCS in dup every	every 10 samples	every 10 samples	
Color, Ascorbic	less than MDL		samples	published	to sample analysis	10 samples + end	or matrix set	or matrix set	
Total Phosphorus	1 pre- +	0.002	6 to	>/= 0.995	90 - 110	80 -120	[0 - 10]	[85 - 115]	28 days
EPA 365.2	every 10 samples		bracket	98 -102	one prior	LCS in dup every	every 10 samples	every 10 samples	
low-Color, Ascorbic	less than MDL		samples	published	to sample analysis	10 samples + end	or matrix set	or matrix set	
Total Phosphorus	1 pre- +	0.005	6 to	>/= 0.995	90 - 110	80 -120	[0 - 20]	[85 - 115]	28 days
EPA 365.2	every 10 samples		bracket	98 -102	one prior	LCS in dup every	every 10 samples	every 10 samples	
high-Color, Ascorbic	less than MDL		samples	published	to sample analysis	10 samples + end	or matrix set	or matrix set	
BOD	1 dil. H20-	2.0	2 GGA	75 - 125	75 - 125	75 - 125	[0 - 30]	[70 - 130]	48 hours
EPA 405.1	1 seed Bk	published			one prior	every 10 samples	every 10 samples	every 10 samples	
5 day, 20 C	every 10 samples				to sample analysis	or at end	or matrix set	or matrix set	
NOTE: Must meet 2.0 mg/L minimum DO depletion (initial minus final) and 1.0 mg/L residual (final) DO for each test bottle.									
CBOD	1 dil. H20-	2.0	2 GGA	75 - 125	75 - 125	75 - 125	[0 - 30]	[70 - 130]	48 hours
SM5210B	1 seed Bk	published		published	one prior	every 10 samples	every 10 samples	every 10 samples	
5 day, 20 C	every 10 samples			in method	to sample analysis	or at end	or matrix set	or matrix set	
NOTE: Must meet 2.0 mg/L minimum DO depletion (initial minus final) and 1.0 mg/L residual (final) DO for each test bottle.									
Alkalinity	1 pre- +	1	min of 2	>/= 0.995	90 - 110	80 -120	[0 - 5]	[85 - 115]	14 days
EPA 310.1	every 10 samples		bracket		one prior	every 10 samples	every 10 samples	every 10 samples	
Titrimetric, pH 4.5	less than MDL		samples		to sample analysis	or at end	or matrix set	or matrix set	

PARAMETER/	BLANK	MDL	# OF	INITIAL CALIB	2ND	CONTINUING	PRECISION	ACCURACY	SAMPLE
METHOD	(mg/L)	(mg/L)	INITIAL	CORR COEF	STD	CALIB (LCS)	OF DUPS	OF SPIKES	HOLD
			STDS	OR % R	% R	% R	% RPD	% R	TIMES
Chloride	1 pre- +	2	min of 2	>/= 0.995	90 - 110	80 -120	[0 - 4]	[80 - 120]	28 days
SM4500Cl- B	every 10 samples		bracket		one prior	every 10 samples	every 10 samples	every 10 samples	
Argentometric	less than MDL		samples		to sample analysis	or at end	or matrix set	or matrix set	
Conductivity	1 pre- +	1	min of 2	95-105	95-105	95-105	[0 - 2]	N/A	28 days
EPA 120.1	every 10 samples	umhos/cm	to bracket		one prior	every 10 samples	every 10 samples		
Lab Meter	less than MDL		samples		to sample analysis	or at end	or matrix set		
TDS	1 pre- +	10	1	[93 - 103]	[93 - 103]	N/A	[0 - 6]	N/A	7 days
EPA 160.1	every 10 samples						every 10 samples		
Gravimetric, 180 C	less than MDL						or matrix set		
TSS low (AF, IjW)	1 pre- +	1	1	[80 - 120]	[80 - 120]	N/A	[0 - 45]	N/A	7 days
TSS high (Raw)	1 pre- +	1	1	[80 - 120]	[80 - 120]	N/A	[0 - 35]	N/A	7 days
EPA 160.2	every 10 samples						every 10 samples		
Gravimetric, 104 C	less than MDL						or matrix set		
NOTE: Choose sample size to yield between 2.5 & 200 mg residue and complete filtration time within 10 min.									
Sulfate	1 pre- +	5	12	>/= 0.995	90 - 110	90 -110	[0 - 20]	90 -110	28 days
EPA 375.2	every 10 samples		to bracket		one prior	LCS in dup every	every 10 samples	every 10 samples	
Color, MTB, AA	less than MDL		samples		to sample analysis	10 samples or end	or matrix set	or matrix set	
Turbidity	1 DI H2O	0.1 NTU	4 formazin	95 - 105	95 - 105	95 - 105	[0 - 5]	N/A	48 hours
EPA 180.1	every 20 samples		quarterly		2 gelex stds to	1 gelex every 10	every 10 samples		
Turbidimeter	less than MDL				bracket analysis	samples or at end	or matrix set		
pH	N/A	N/A	2 or 3 to	90 - 105	+/- 0.2 units	+/- 0.2 units	0 - 5	N/A	analyze
EPA 150.1			bracket	% efficiency					immediately
Lab Meters			samples	of electrode					
Chlorophyll a	1 pre	1	none	N/A	none	N/A	0 - 30	N/A	21 days
Color	1 pre	5	1	N/A	none	N/A	0 - 5	N/A	48 hours

Appendix E – Parameter & Station Listing

Parameters			***TOC***	***Ammonia***		
		Station		**Historical**	**Current**	
Date		10	*	*		
Time		20	*	*		
Sample Depth		25	*			
Tide Stage		30	*	*		
		32	*			
Alkalinity		40	*			
Ammonia		42	*			
Chlorophyll-a corrected		60	*	*	*	
Chlorophyll-a uncorrected		62	*	*	*	
Color		63	*			
Dissolved Oxygen		64	*	*		
Dissolved Oxygen % Saturation		65	*	*	*	
Fecal Coliforms		67	*	*	*	
Light % at 1 meter		68	*			
Light % at 2 meter		69	*	*	*	
Light Attenuation		72	*	*	*	
Nitrate+Nitrite		74			*	
Organic Nitrogen		75		*	*	
Orthophosphate		81	*	*	*	
pH		86	*	*	*	
Salinity		87	*	*	*	
Secchi Disk Depth		88	usually dry		*	
Specific Conductance		92			*	
Temperature		93			*	
Total Kjeldahl Nitrogen		95	*		*	
Total Nitrogen		100	*	*	*	
Total Organic Carbon		101		*		
Total Phosphorus		104	*			
Total Suspended Solids		105	*	*	*	
Turbidity		107		*	*	
Total Organic Carbon		108	*			
		111	*		*	
		112	*		*	
Notes:						
All the parameters listed are analyzed on all the samples except for TOC and Ammonia.						
In 2009 several ammonia stations were discontinued at the marine stations						
because occurance is rare; facilitated additional freshwater stations.						

Appendix F – Quality Control Summary

LOXAHATCHEE RIVER DISTRICT						
WildPine Lab		E56026				
Client:	SFWMD					
Project:	RIVERKEEPER PROJECT					
	QUALITY CONTROL SUMMARY - Sampling Subset					
Site #	Date		Analyte	Method	Code	Data Qualifier Issue
All	November 2008		TP	SM4500-P E	V	Analyte detected in the Field Blank and Equip Blank
Reporting Limit		0.002				
Field Blank		0.011				
Equipment Blank		0.009				
Contaminated glassware was predicted as the cause						
A more extensive acid wash on the glassware was initiated						
There were no repeated occurrences for this issue in 2009						
The other sampling issue would be when the samples were deliberately not taken, due to dry conditions, where there was no flow at the site.						
Station # 88 Not sampled			Station # 59 Not sampled			Station # 111, #112 Not sampled
November 2008			March 2009			March 2009
January 2009			September 2009			
March 2009						
May 2009						
September 2009						