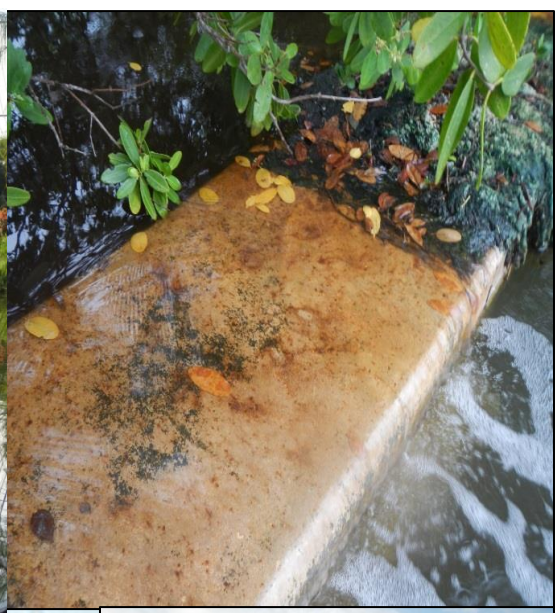
Sanibel-Captiva Conservation Foundation

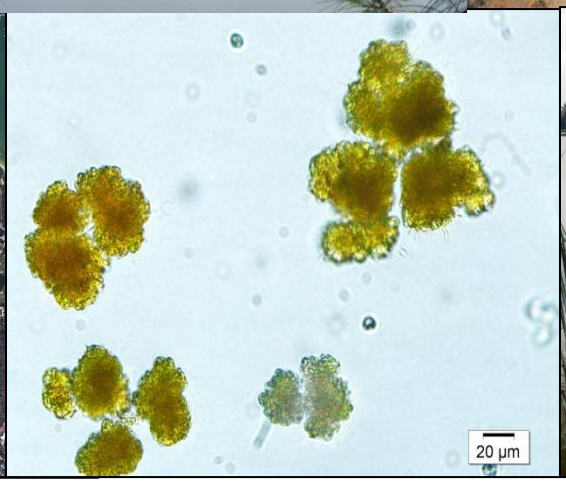
Water Quality in The Dunes Stormwater System: 4 Year Update

For Dunes Golf and Tennis Club, Sanibel FL

June 30, 2016

Mark Thompson, SCCF Marine Lab





Executive Summary

The SCCF Marine Lab began monitoring water quality for The Dunes stormwater system in 2012 at the request of The Dunes Golf and Tennis Club. SCCF currently monitors 4 of the 11 lakes within the stormwater system on a quarterly basis. The nutrients, nitrogen (N) and phosphorus (P) are the main focus of the monitoring. However, chlorophyll *a* and turbidity, salinity, pH and colored dissolved organic matter are also monitored due to their effects on aquatic organisms.

Past reports (July 2012, October 2012, December 2012, February 2013, December 2013, July 2014, December 2014, May 2015, February 2016) give in-depth discussion and background on The Dunes stormwater system monitoring results and conclusions. Please refer to those reports for more complete background. This update includes only new information obtained since the 42 month report.

Overall, the stormwater system would still be classified as impaired due to average trophic state index scores over 60 (TSI-used for evaluating the overall condition of a lake), and nitrogen and phosphorus concentrations consistently above state criteria (1.27 mg/l and 0.5 mg/l respectively) during a majority of sampling events. However, within the past 4 years, the system has gone through changes which can be attributable to implementation of best management practices (BMPs). Trend analyses show total nitrogen, inorganic nitrogen, and chlorophyll *a* (algae) are declining significantly, as is the TSI score. These positive results are attributable to BMP's implemented by The Dunes and The Dunes HOA.

BMPs such as establishment of aquatic vegetation (discontinuance of herbicidal treatments), development of a vegetated buffer zone around waterbodies, manual harvesting of macro-algae and some aquatic vegetation, reduced fertilizer application (extent unknown), native vegetation plantings, installation of floating island and exotic fish removal have all helped reduce nitrogen (and total phosphorus) concentrations in the stormwater system.

The effort to reduce phosphorus levels has not been successful to date. Phosphorus levels are actually increasing despite BMPs. The persistent excess phosphorus in the stormwater system is partly attributed to phosphorus loading from the use of reclaimed water for irrigation. Other studies have shown reclaimed water is potentially the main source of inorganic phosphorus to the Dunes landscape (Thompson and Milbrandt 2013, Thompson and Milbrandt 2014). Although phosphorus is readily adsorbed onto soil and used by terrestrial plants, any reclaimed irrigation water applied to impervious

surfaces such as driveways or directly to waterbodies adds phosphorus to the stormwater system. Calculations show if just 4% of the reclaimed irrigation water used is accidently applied to impervious surfaces or waterbodies, the loading is enough to keep the stormwater system in non-compliance with state phosphorus criteria. In other words, if 4% or more of the reclaimed water used for irrigation enters the stormwater system directly through improperly placed nozzles, spills or leaks, the system will fail to meet state water quality criteria. However preventing direct runoff of reclaimed water may be a relatively straightforward way to achieve significant reduction in phosphorus concentrations and effectively control algae biomass and gain compliance with state water quality criteria.

The level and rain monitoring equipment installed at the Lake 4 discharge weir is providing reliable real-time data on stormwater system level changes in response to rain events and evapotranspiration. It has provided a means for estimating storage capacity of the system, and provides discharge flow quantities that can be used with concentration data to estimate nutrient loading rates to Tarpon Bay. We recommend stakeholders read the Results and Discussion section to become more informed about stormwater discharges from The Dunes.

Introduction

This document summarizes data collected during 4 years (2012-2016) of stormwater system water quality monitoring by SCCF Marine Lab for The Dunes Golf and Tennis Club (DGTC). Included is all data available through June 2016 which was collected during 2 dry season and 2 wet season monitoring events each year. The Marine Lab monitors stormwater lakes within The Dunes on a quarterly basis per an agreement with DGTC. The primary goal of this monitoring program is to provide science-based information needed to understand the causes of poor water quality and offer potential solutions by encouraging development of a lakes management plan. Results from this program can be integrated into a lakes management plan and help measure the success of best management practices (BMPs) and other activities aimed at improving water quality. Implementation of a successful management plan can result in lakes suitable for recreational use, and provide aesthetically pleasing conditions, beneficial habitat and good water quality which will not degrade surrounding estuarine habitats.

Methods

Under the adaptive monitoring strategy, the number of sites monitored in the second year of this project was reduced from 8 to 4. The four lakes now monitored are a representative subsample of the larger stormwater system. Lake 4 is the most downstream lake and periodically exchanges water with estuarine waters over the discharge weir. Because this lake discharges to the estuary and receives flow from all upstream lakes as well as the estuary, it has unique characteristics. Its chlorophyll *a* and nutrient concentrations are typically lower due to dilution by estuarine waters while its salinity is highest amongst the lakes (3-20 PSU). Lake 5 is typical of the interior lakes of the stormwater system with high chlorophyll and nutrient concentrations and salinity between 2 and 4 PSU. The Lake 5 watershed includes golf course and residential land uses. Lake 9 is also surrounded by residential and golf course land classes and is very productive with a high biomass of fish and periodic phytoplankton blooms. Horseshoe Lake is completely surrounded by residential land use and its maintenance is the responsibility of the Dunes HOA. This lake is not directly connected to the other lakes in the stormwater system, and has had unique algae blooms in the past although its nutrient concentrations are relatively lower than other lakes in the system.

Sampling stations (Figure 1) are located near the discharge points of lakes which have existing discharge structures. For those lakes without discharge structures, monitoring sites were located based upon best professional judgment. Sampling was conducted per Florida DEP FS1000.

Sampling: Lakes (stormwater ponds) in the Dunes development are monitored seasonally. Sampling occurs twice during dry season and twice during wet season.

Event-driven Sampling: One sampling event per season is undertaken after a rain event of at least 0.5 inches (1.27 cm) in the previous 24 hours and one event per season occurs after a “dry” period of at least 7 days with no rain. Wet season is defined as those months which have greater than 5 inches (12.7 cm) of total rainfall (historically mid-June through mid-October, but often mid-May through late October).

All analyses were conducted using EPA-approved methods. Some analyses are contracted a State NELAC certified laboratory. Analyses results were entered into an Access relational database located at SCCF Marine Lab which is regularly backed up. Field and analyses logsheets are stored and archived at SCCF Marine Lab.

Data evaluation and analyses

For comparison purposes, raw data is presented in table form along with pertinent water quality criteria and 90th percentile values for all Florida lakes data. The 90th percentile values represent the value of a parameter for which 90 percent of all Florida lakes have a lesser (better) value (if measured values are greater than these values, the lake is in the worst 10 % of all monitored lakes in state for that parameter).

A trophic state index (TSI) was calculated for each lake using the methodologies described by Florida Department of Environmental Protection for assessing lakes (FDEP 1998). Since a lake's trophic state is associated with nutrient loading and phytoplankton concentrations, the TSI is calculated using phosphorus, nitrogen and chlorophyll *a* values. The greater these values, the higher the TSI and the more eutrophic (nutrient enriched) a system is thought to be. The TSI is used by the state for assessing impairment status of lakes. Values below 60 are considered "good" while above 70 is considered "poor" water quality. A lake may be classified as "impaired" with an annual average above 60 (at least one sample each quarter).

Seasonal Kendall trend analyses were performed on the available using Water Quality Stats® software. Results of trend analyses can be an indicator of how well BMP activities are working.

Results and Discussion

Kendal seasonal trend analyses found a significant downward trend in TN, IN, chlorophyll a and TSI for the system data taken as a whole (results from all lakes combined; Figures 2-4). Nitrogen has been trending downward for 4 years and the reductions may be starting to control phytoplankton growth (chlorophyll a). This is good news as reflected in the downward trend in trophic state index (TSI) which takes into account nitrogen, phosphorus and chlorophyll a. However, we are now able to see a significant upward trend in total and inorganic phosphorus since 2012. Freshwater systems such as lakes are commonly P limited, meaning the greatest potential for an increase in algae biomass will occur with the addition of phosphorus. However if we are more successful in reducing N than we are at reducing P, the amount of inorganic P in the water column may increase while the amount of total P, total N and inorganic N are decreasing. Modeling shows this to be the case at The Dunes with the system to currently have excess phosphorus at any nitrogen level.

Success of BMPs at reducing nitrogen runoff, coupled with the continued heavy use of reclaimed water for irrigation help explain the current phosphorus condition at The Dunes. BMPs implemented to date have helped reduce runoff of nitrogen-rich stormwater, while continued irrigation with phosphorus-rich reclaimed water, makes reductions in phosphorus more difficult (SCCF 2013).

Box and whisker plots show data from the most downstream to farthest upstream sites in the stormwater system (Figures 5-11). Obvious spatial gradients are noticed for salinity with the highest salinity occurring at Lake 4 (site farthest downstream and closest to the estuary; Figure 5). Concentrations of phosphorus and nitrogen are generally highest in the interior stormwater ponds and lowest nearest the estuary and in the "disconnected" Horseshoe Lake (Figures 6-9). "Interior" Lakes 5, 6 and 9 are the "worst case" for parameters of most concern (nitrogen, phosphorus, and chlorophyll *a*).

Trophic state indices (TSI) for the four lakes monitored throughout this study were above 60 for all sampling events (Tables 1-4). Values above 60 are defined as "poor" water quality by Florida DEP. The TSI score is calculated from nutrient and chlorophyll *a* levels. As described in the methods section, the TSI score is an average of three indices which use nitrogen, phosphorus and chlorophyll values as their basis. Although the TSI for The Dunes is trending downward, it is still classified as impaired due to nutrient loading (per FDEP criteria of a TSI of 60).

Loadings estimates for the entire Ladyfinger Lakes Basin (Thompson 2013, 2014), in which The Dunes is located, show reclaimed water in that basin accounts for the highest portion of phosphorus applied to the watershed (Thompson 2013, 2014). The Dunes golf course stormwater runoff was also found to have some of the greatest phosphorus (and nitrogen) concentrations on Sanibel (Thompson 2014). Phosphorus concentrations were shown to be greater in the dry season when the main source of runoff is reclaimed water irrigation. Groundwater testing also showed high levels of nitrogen and phosphorus immediately adjacent the stormwater system (Thompson and Milbrandt 2016). All evidence to date suggest reclaimed water used for irrigation is the main source of phosphorus loads from Sanibel, and that most of Sanibel's waterbodies have excess phosphorus so that little improvement in water quality will be seen until we reduce phosphorus inputs. Additional effort should be made to be sure phosphorus-rich reclaimed water does not flow directly into the stormwater system or other waterbodies. **All sprinkler heads should be adjusted to be sure they cannot spray directly into waterbodies or onto impervious surfaces such as roadways and golf cart paths. The reclaimed water system**

should also be rigorously and periodically checked for leaks and potential intermittent releases such as spills.

Since reclaimed water has high concentrations of P and N, users of reclaimed water should consider its fertilization qualities when irrigating. The application of 10000 gallons of reclaimed water to any landscape delivers 0.5 pounds of nitrogen and 0.2 pounds of phosphorus (Thompson 2013). These P and N loads should be accounted for when estimating fertilizer needs and when reporting fertilizer usage.

Currently, addition of either nitrogen or phosphorus to the stormwater system could cause significant increases in unwanted algae; however the increasing presence of aquatic plants due to cessation of herbicide usage will help tie up excess nutrients. The periodic manual thinning and removal of these plants will effectively remove nutrients from the system. The harvesting of significant numbers of the planktivorus fish present in the lakes (tilapia and cichlids) would also help reduce system nutrients and benefit the water quality in various other ways.

Nutrient saturation analysis revealed all monitored lakes in the system have excess phosphorus (see previous reports). Further reduction in phosphorus (and nitrogen) in these lakes is needed to reduce phytoplankton concentrations. As determined by the nutrient saturation model, a 50% reduction in current phosphorus levels is needed before any reduction in phytoplankton concentrations can be expected in The Dunes lakes. Lake 4, 5 and 9 are surrounded by landscapes irrigated with reclaimed water. Reduction in the runoff of reclaimed water from the watersheds of Lakes 4, 5 and 9 should be a top priority in trying to reduce their phosphorus. The reduction in the benthic foraging fish population (tilapia and Mayan cichlids) within these lakes would also be a prudent activity since their foraging directly releases P from bottom sediments. Other strategies for reducing phosphorus would include periodic harvesting of a proportion of the lakes' aquatic plants and irrigating landscapes with water from those lakes.

Research has shown that an excessive abundance of planktivorus fish (tilapia and cichlids) in stormwater ponds allow phytoplankton blooms to go unchecked by natural processes. Blooms of edible phytoplankton (micro-algae) in these lakes can be naturally controlled by zooplankton such as cladocerans. These zooplankton are a primary food source for tilapia and cichlids. Healthy aquatic plant populations in the lakes can provide refugia for zooplankton, allowing them to avoid predation by fish

resulting in algae reduction in the water column. Previous aquatic plant eradication efforts around lake edges and within the lakes significantly reduced zooplankton populations, resulting in increased algae in the water column. The large population of plankton-eating tilapia and cichlids can make re-establishment of healthy zooplankton populations difficult unless fish numbers are reduced.

Level, Flow and Rain Monitoring at Discharge Weir

In 2015, water flowed over the weir (in or out) at least 185 days. We estimate that net positive discharge from the stormwater system occurred on at least 85 days (more water flowed out of system than into it). **We also estimate that 5,128,000 ft^3 (38.4 million gallons) of water were discharged from The Dunes stormwater system in 2015 (Table5)**. As a result of these discharges an estimated 864 pounds of nitrogen and 45 pounds of phosphorus were released to Tarpon Bay in 2015 (Table 5). So far in 2016, 2,620,000 ft^3 and 384 pounds of N and 24 pounds of P have been discharged (Table 5). Discharges from the stormwater system were intended to be rare by design. However, sea level elevations are now often greater than the weir elevation on many higher tides. The stormwater system fills with estuarine water and from that point on, freshwater holding capacity is diminished or non-existent. The City of Sanibel is currently helping to design and install a tide flap gate at the Dunes stormwater weir to prevent high tides from filling the freshwater runoff collection system.

The rate of water level rises after rain events follows a linear relationship, and is thus predictable. The table below shows the expected water level in the stormwater system for given rainfall amounts.

Rain Amount (inches)	**Stormwater System Level Increase (inches)**
0.5	0.56
0.75	1.02
1	1.48
1.25	1.94
1.5	2.45
1.75	2.86
2	3.33
2.5	4.25
2.8	4.80
3	5.17
5	8.87

Example: On June 29th, 2016 the stormwater system level was at 1.47 feet. The discharge weir overflow is at 2.0 feet. There is 0.53 feet or 6.36 inches of storage capacity in system. From the table above it can be seen that a rain event of about 4 inches would bring the system to near overflow level. The city stormwater ordinance requires storage capacity of 2.8 inches of rain, thus at this point the system is operating within its design capacity.

The City of Sanibel stormwater control ordinance requires a development to provide capacity to retain runoff from a 2.8 inch rain event to prevent adverse water quantity and quality effects downstream. In the Dunes stormwater system, this would be equal to a stage of 4.8 inches (0.4 ft.) below the weir crest which is at 2 ft. NAVD. The Dunes stormwater system level required to absorb this rain event would be 1.6 feet or less. Any level above this will not provide storage capacity for the 2.8 inch design storm.

The dissipation of stormwater system water level after rain events has also been estimated from new level data for the dry season. An average decrease of 0.14 inches/day was noted after rain event level surges during the dry season. This rate was compared to SFWMD estimated potential evapotranspiration data and found to be the same (0.14 inches evapotranspiration/day). In effect, the rate at which the level decreases in the stormwater system is the evapotranspiration rate of this area.

A link to the real time level data at the Lake 4 discharge weir is provided below:

http://marinelab.sccf.org/research/dunes_weir/ .

Summary

The lakes in the Dunes stormwater system are still eutrophic due to nutrient levels and subsequent phytoplankton (algae) blooms. The TSI scores of lakes in the Dunes stormwater system are above the threshold value of 60 set by Florida DEP to classify a waterbody as "impaired". Nitrogen concentrations in all lakes are above the numeric water quality criteria established for Florida by USEPA and a majority of the phosphorus monitoring results exceed state water quality criteria. Modeling shows that the he lakes have excess concentrations of phosphorus in the water column at most times of the year, suggesting efforts should focus on controlling phosphorus through more efficient use of reclaimed water

Although still classified as impaired, the stormwater system is showing signs of improvement with a statistically significant downward trend in total nitrogen and chlorophyll (phytoplankton-algae). The discontinuance of herbicide treatment of aquatic vegetation within the stormwater system probably has had the greatest benefit to improved water quality conditions. Aquatic vegetation takes up nutrients which would otherwise be available to phytoplankton (micro-algae) and macro-algae (algal mats). Aquatic vegetation also provides habitat for zooplankton which consumes microalgae. More plants result in less algae and clearer water.

Other beneficial activities have included manual harvesting of a portion of aquatic plants and macro-algae in the lakes, development of a vegetated buffer around lake edges, possible reduction in fertilizer use (unknown if actual), installation of two floating islands, and removal of exotic bottom-foraging fish.

The four lakes currently monitored have excess amounts of inorganic phosphorus in the water column. In these lakes it was estimated that the phosphorus concentration must be reduced by 30-50% to effect a noticeable reduction in phytoplankton (chlorophyll). Before additional reduction in algae will be realized, phosphorus concentrations must be significantly reduced.

Reclaimed water used for irrigation on the golf course is likely the main source of phosphorus entering the stormwater system. Although the reclaimed water contains very significant concentrations of N, it is relatively high in P compared to most fertilizers used in the area. Any reclaimed irrigation water which runs off directly into a waterbody will add potential for more algae biomass. However, this may be one of the easiest sources of P to control by preventing direct application of irrigation water to water body surfaces, or other impervious surfaces such as driveways and roads. An irrigation system survey and sprinkler head adjustment/modification program may be able to have immediate beneficial impacts to water quality in the stormwater system.

To meet water quality criteria, total nitrogen currently within the stormwater system water column must be reduced by about 3200 lbs. and phosphorus by 70 lbs. Using plants (i.e. Cattails, rushes, floating islands) and animals (i.e. tilapia fish) to uptake nutrients then periodically harvesting 30-50% of the mass is an effective method to remove nutrients from the water column. Fertilizers used on lawn and golf courses should continue to be reduced. The inflow of fertilizer-based nutrients will continue to raise concentrations within the system until something can be done to effectively control transport during rain events, either by preventing water runoff or preventing fertilizer contact with rainwater (i.e. by reducing amount of fertilizer on grounds). The reduction in volume of direct reclaimed irrigation water runoff is the most efficient way to further reduce phosphorus concentrations. Prevention of direct irrigation spraying onto impervious surfaces and lakes should be top priority along with preventing and containing leaks or spills of reclaimed water.

A probable scenario for lake restoration would be a comprehensive management plan which involves the following priority actions:

1. Elimination of herbicide and algaecide application to all lakes.
2. Allow re-establishment of native submerged aquatic vegetation (SAV) within in each lake.
3. Re-engineer discharge weir on Lake 4 to reduce the frequency of overtopping by high spring tides.
4. **Eliminate direct runoff of reclaimed irrigation water through adjustment and transfer of spray nozzles and prevention of leaks and spills**.
5. Encourage SAV growth through plantings of native SAV's.
6. Periodic harvesting (and off-site composting) of up to 30% of submerged and immersed vegetation to remove nutrients.

7. BMPs for watershed which reduce stormwater runoff and fertilizer application.
8. Significant reduction of non-native planktivorus fish populations through active removal.
9. Establishment of floating plant islands which are "periodically harvested" to increase nutrient uptake and removal from lake waters.
10. Re-establish zooplankton populations in lakes by re-establishment of SAV and fish removal and through possible introduction of native zooplankton.
11. Use of stormwater system water to irrigate golf course or at least salinity tolerant plantings around golf course. This would allow more nitrogen and phosphorus removal by plants in the uplands and reduce water column concentrations.

This document is intended as a data transfer and annual evaluation of results. Contact Mark or Eric at SCCF Marine Lab with any questions related to the data presented here. We would like to meet with your group to discuss questions and possible management actions which will impact the water quality of the Dunes stormwater system.

References

Jeppesen, E.; Søndergaard, M.; Meerhoff, M.; Lauridsen, T. L.; Jensen, J. P. 2007. **Shallow lake restoration by nutrient loading reduction - some recent findings and challenges ahead.** Hydrobiologia, Vol. 584, No. 1, 2007, p. 239-252.

Thompson, M. and E. Milbrandt, 2016. Nutrient loading from Sanibel's surficial aquifer. SCCF Marine Lab for the City of Sanibel. Sanibel FL.

Thompson, M. and E. Milbrandt, 2014. Sanibel nutrient management plan phase 2.development of stormwater runoff coefficients and nutrient concentration and loadings estimates for Sanibel Florida. SCCF Marine Lab for the City of Sanibel. Sanibel FL.

Thompson, M. and E. Milbrandt, 2013. Summary and evaluation of the surface water quality of Sanibel to guide development of a comprehensive nutrient management plan. SCCF Marine Lab. Sanibel FL.

Thompson, M. 2013. Year 1 Report – Dunes Lakes Water Quality. For Dunes Golf and Tennis Club, Sanibel, FL. SCCF Marine Lab. Sanibel, FL.

Thompson, M., R. Bartleson, E. Milbrandt and A. Martignette 2012a. Water quality and seagrass monitoring within the J.N. Ding Darling National Wildlife Refuge. Activity Report for the Period from July 2009- July 2012. USFWS Cost Share Grant 41540-1261-CS19.

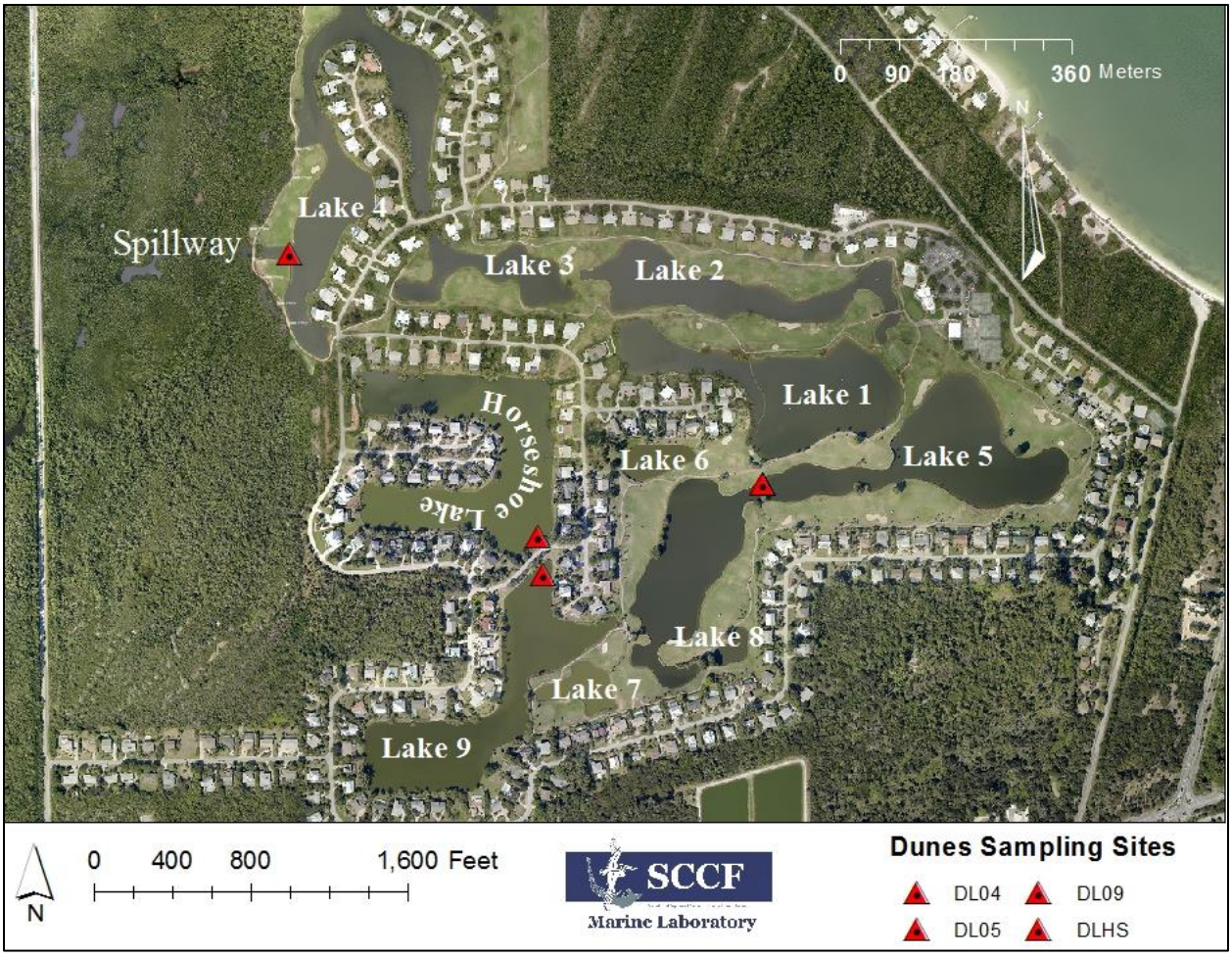


Figure 1. The four locations currently sampled 4 times each year at on the Dunes stormwater system. Samples are taken after a rain event of more than 0.5 inches in wet and dry season and after a dry period of at least 7 days in the two seasons.

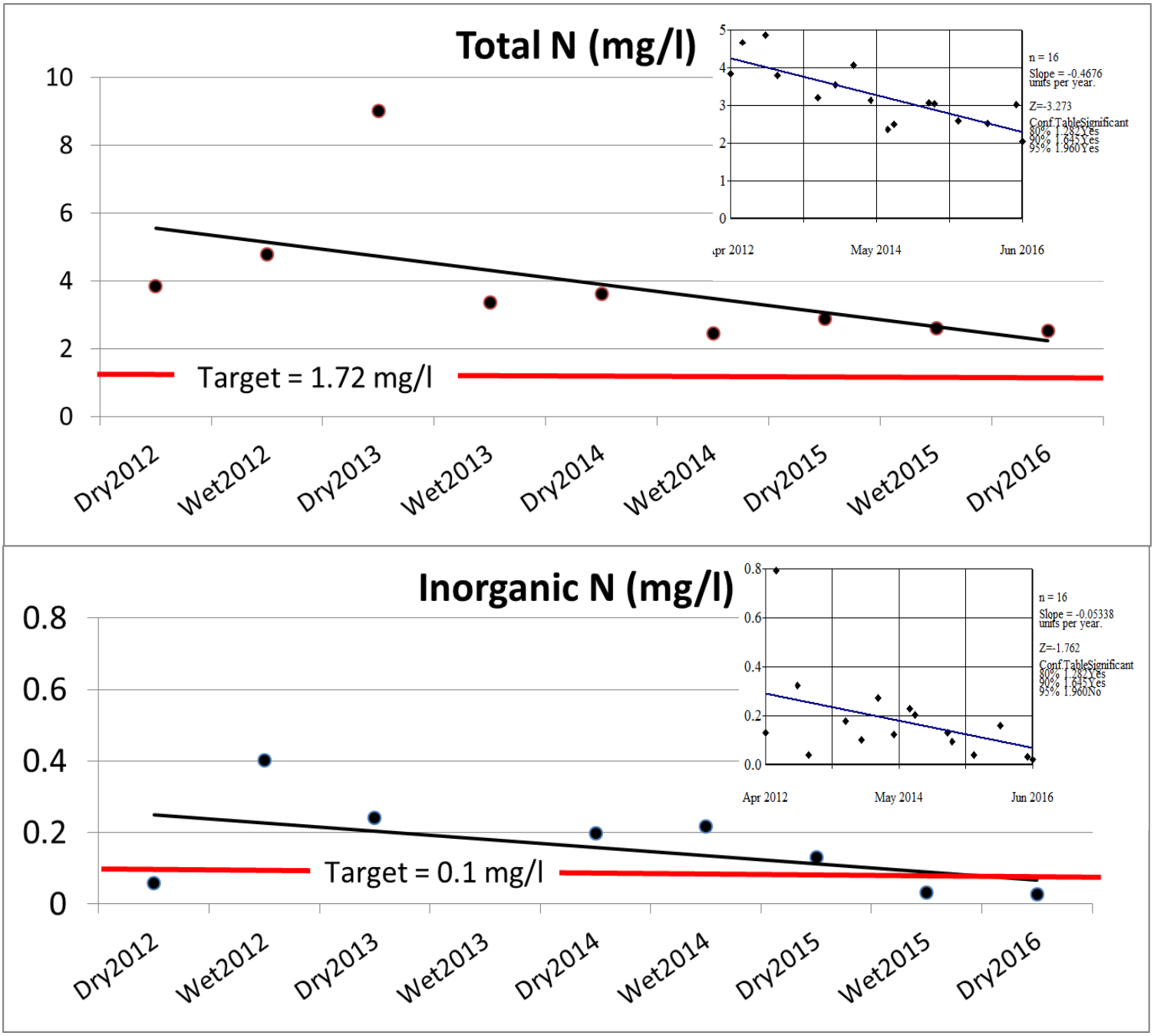


Figure 2. Mean nitrogen values verses time for pooled stormwater system data from The Dunes. TN and IN showsignificant downward trends using Kendall's Seasonal Trend analyses.

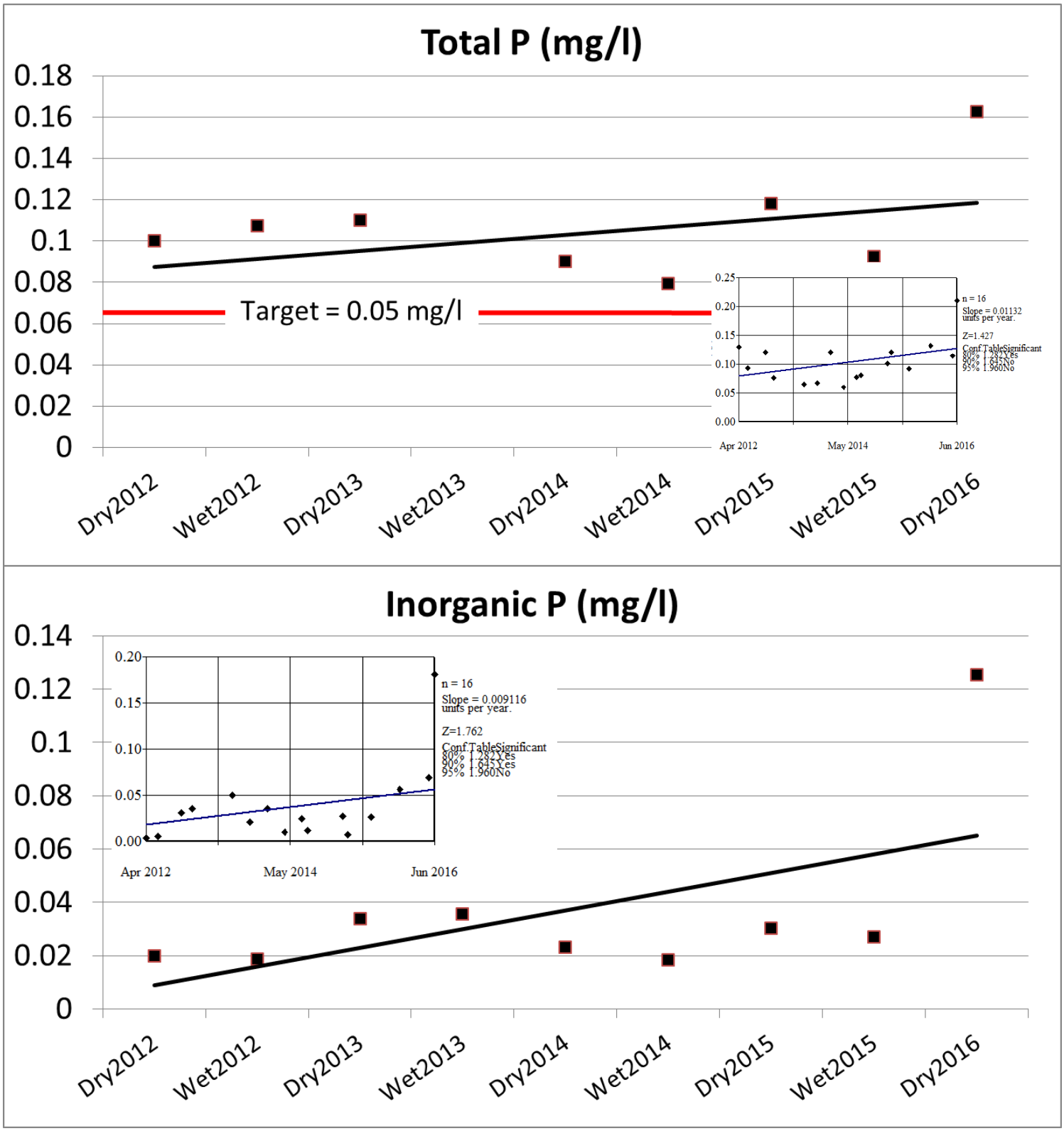
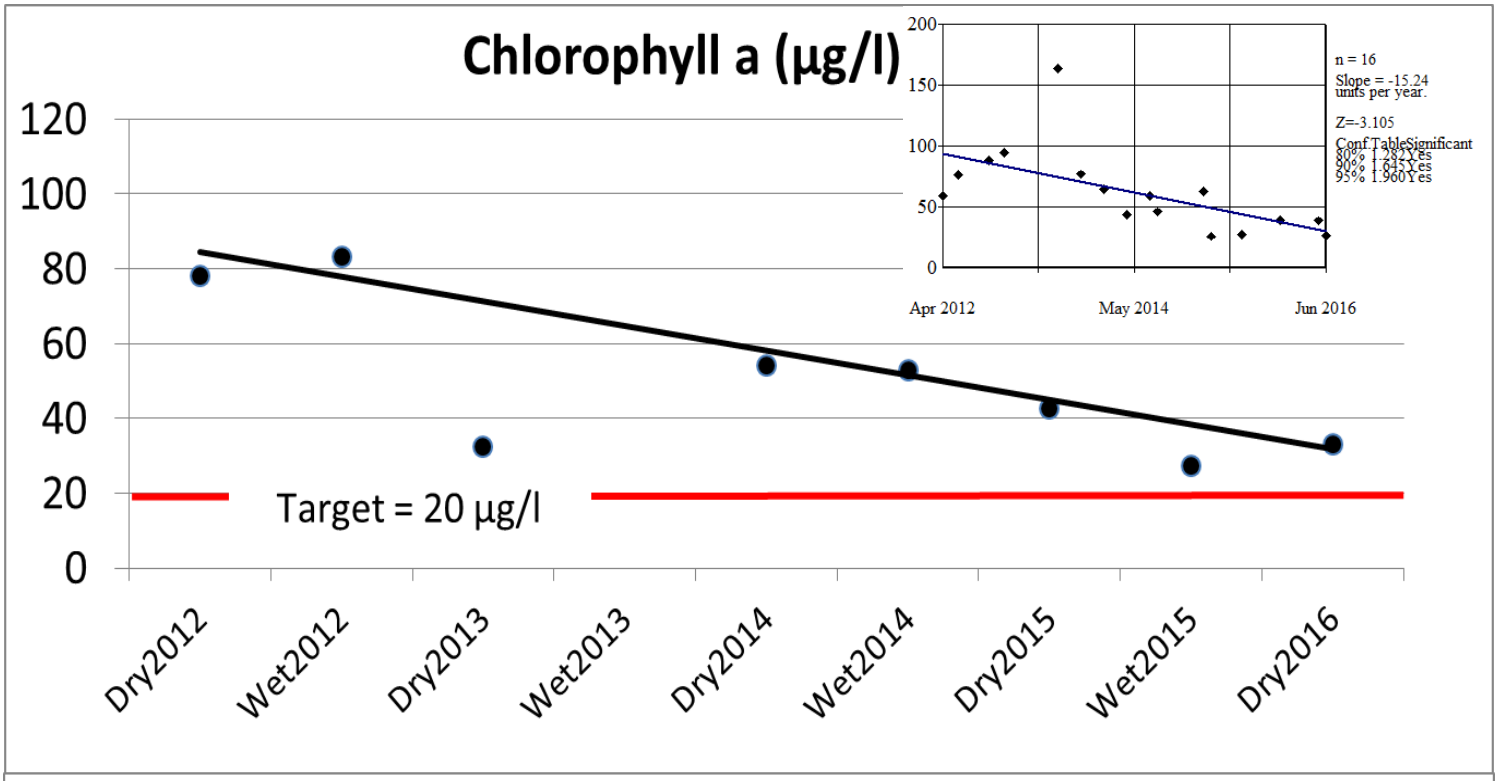


Figure 3. Mean phosphorus values verses time for pooled stormwater system data from The Dunes. Increasing trends in TP or OP were found using Kendall's test at 80 (TP) and 90% (OP) confidence levels.



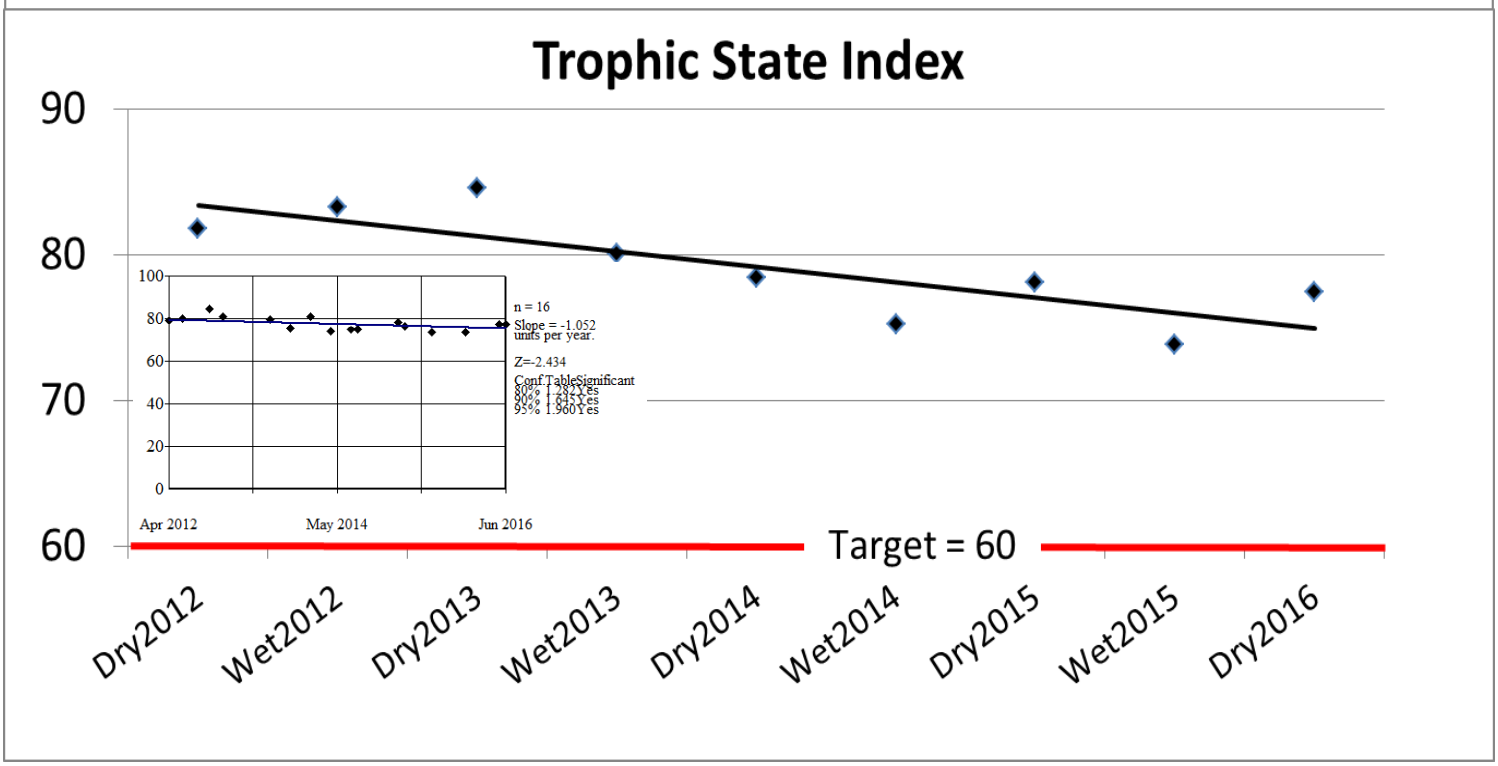


Figure 4. Mean chlorophyll a and TSI values verses time for pooled stormwater system data from The Dunes. Both are metrics of eutrophication and both show significant downward trends (Kendall's Seasonal Test) over the 4 year study period.

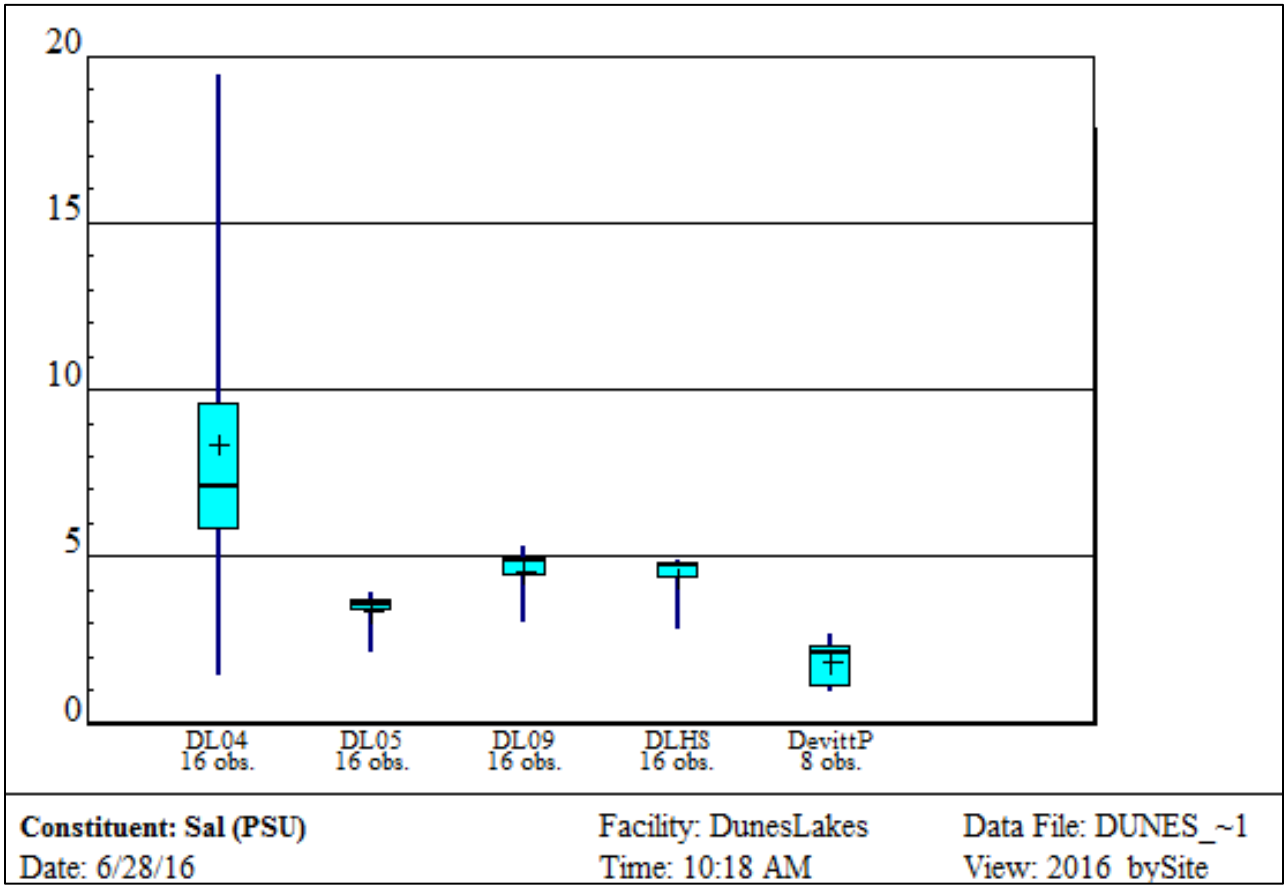


Figure 5. Mean salinity for four currently sampled lakes since inception of monitoring program in 2012. SCCF's Devitt Pond, which was newly dug on conservation land in 2014, is also shown for comparison. The number of sampling events is noted below each box and whisker plot. Box boundaries represent 25th and 75th percentile values and cross represents mean.

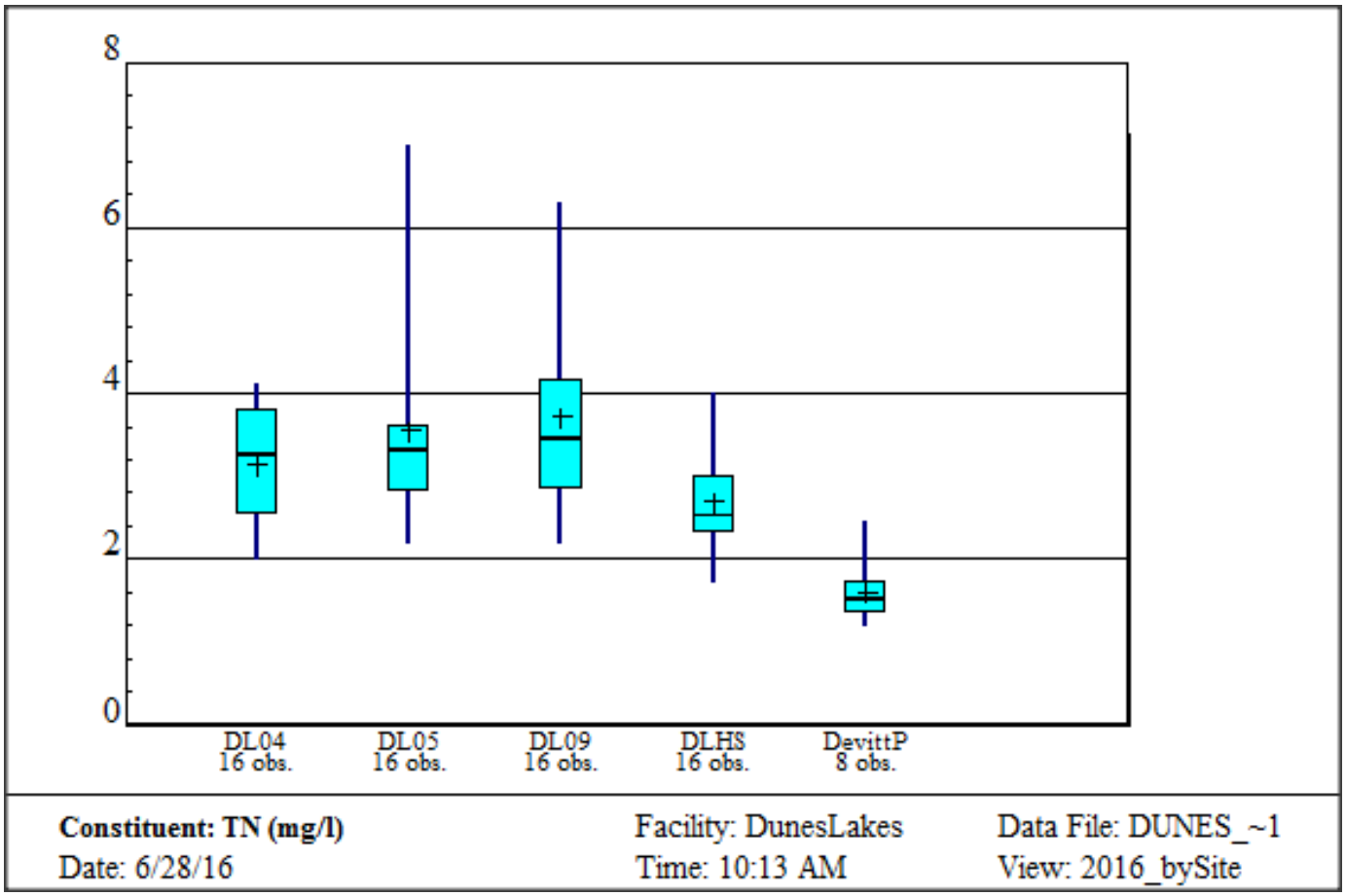


Figure 6. Mean total nitrogen (TN) for four currently monitored lakes since inception of monitoring program in 2012. SCCF's Devitt Pond, which was newly dug on conservation land in 2014, is also shown for comparison. The number of sampling events is noted below each box and whisker plot. Box boundaries represent 25th and 75th percentile values and cross represents mean.

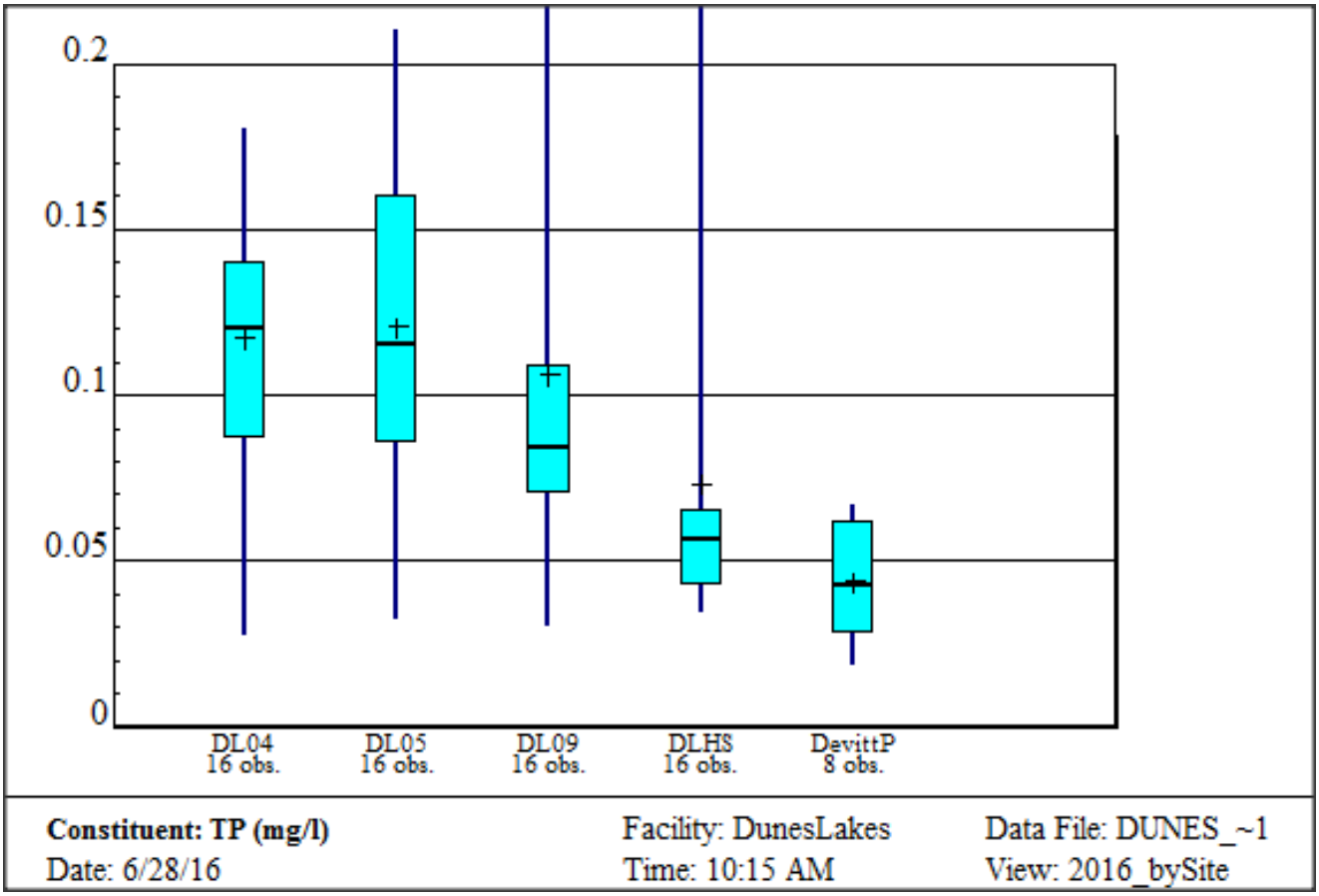


Figure 7. Mean total phosphorus (TP) for currently monitored lakes since inception of monitoring program in 2012. SCCF's Devitt Pond, which was newly dug on conservation land in 2014, is also shown for comparison. The number of sampling events is noted below each box and whisker plot. Box boundaries represent 25th and 75th percentile values and cross represents mean.

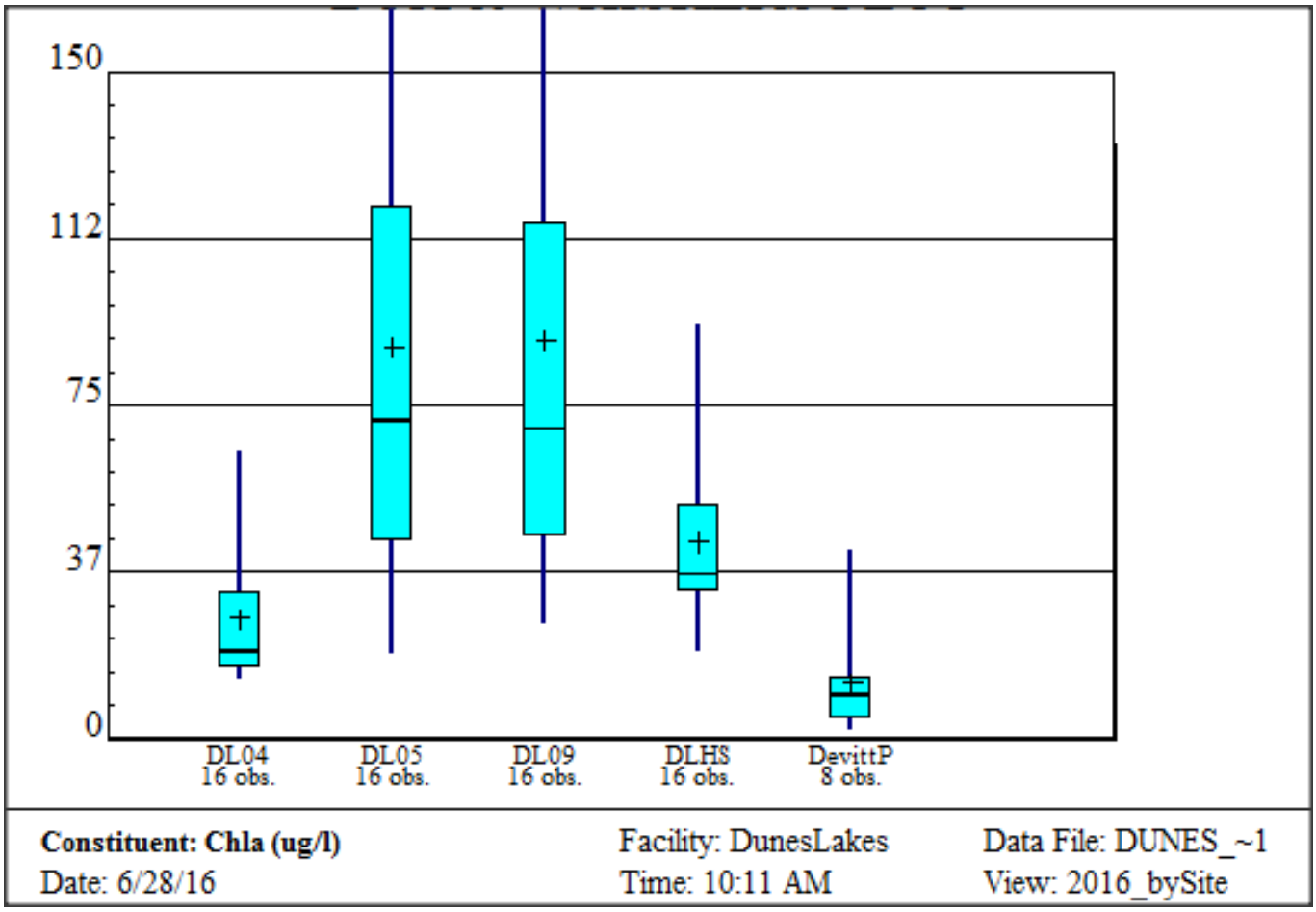


Figure 8. Mean chlorophyll *a* (chla) for currently monitored lakes since inception of monitoring program in 2012. SCCF's Devitt Pond, which was newly dug on conservation land in 2014, is also shown for comparison. The number of sampling events is noted below each box and whisker plot. Box boundaries represent 25th and 75th percentile values and cross represents mean.

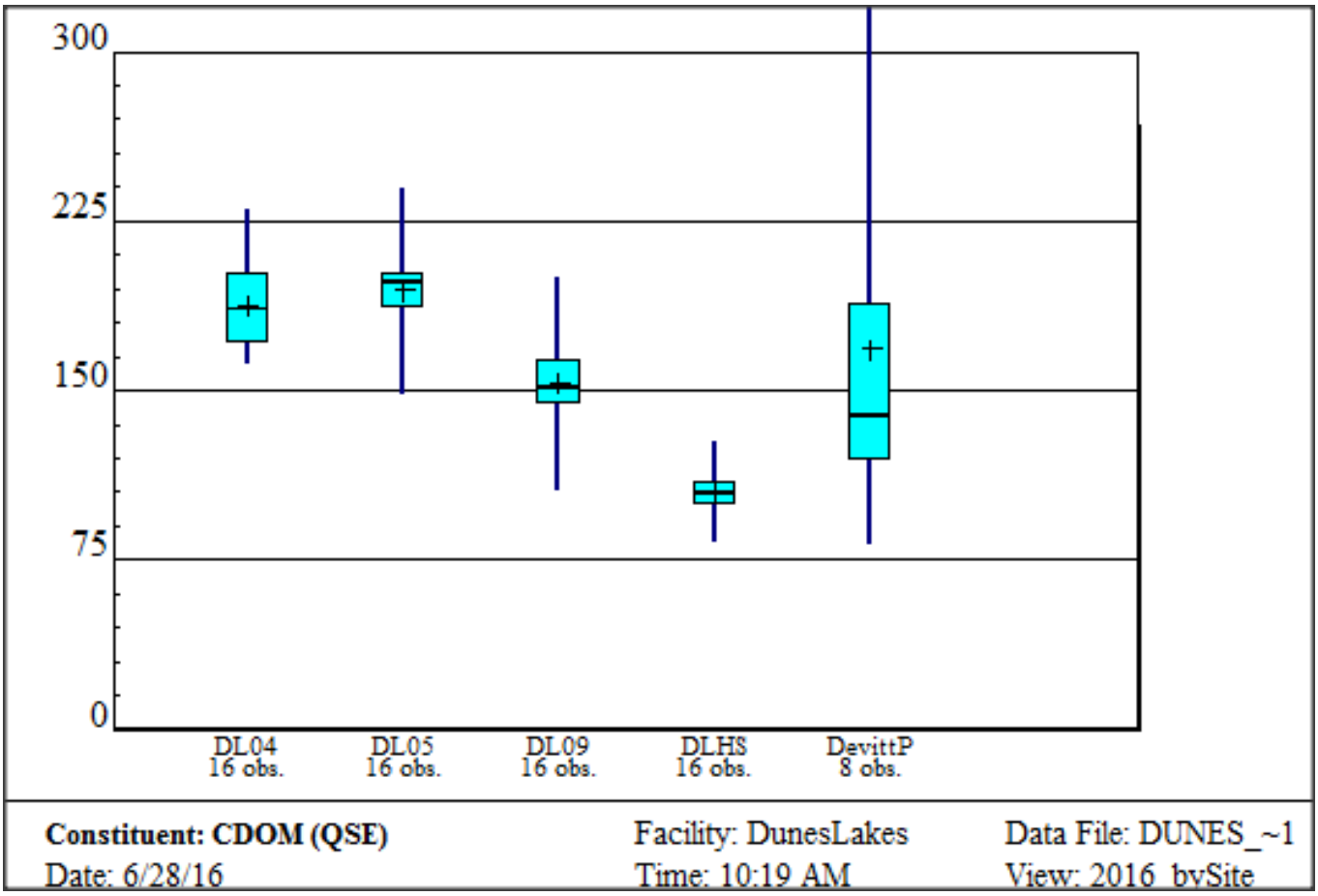


Figure 9. Mean colored dissolved organic matter (CDOM) for currently monitored lakes since inception of monitoring program in 2012. SCCF's Devitt Pond, which was newly dug on conservation land in 2014, is also shown for comparison. The number of sampling events is noted below each box and whisker plot. Box boundaries represent 25th and 75th percentile values and cross represents mean.

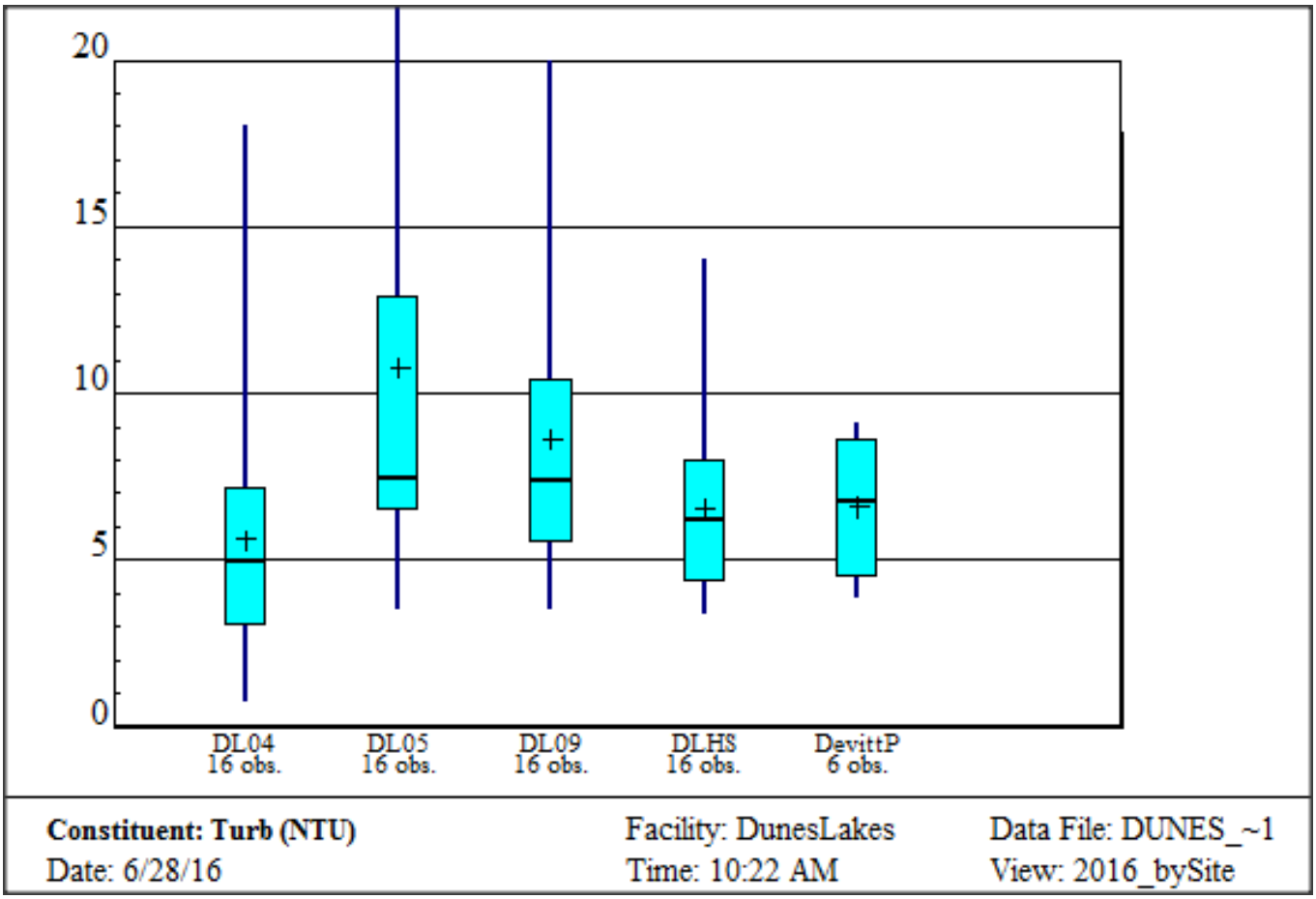


Figure 10. Turbidity for currently monitored lakes since inception of monitoring program in 2012. SCCF's Devitt Pond, which was newly dug on conservation land in 2014, is also shown for comparison. The number of sampling events is noted below each box and whisker plot. Box boundaries represent 25th and 75th

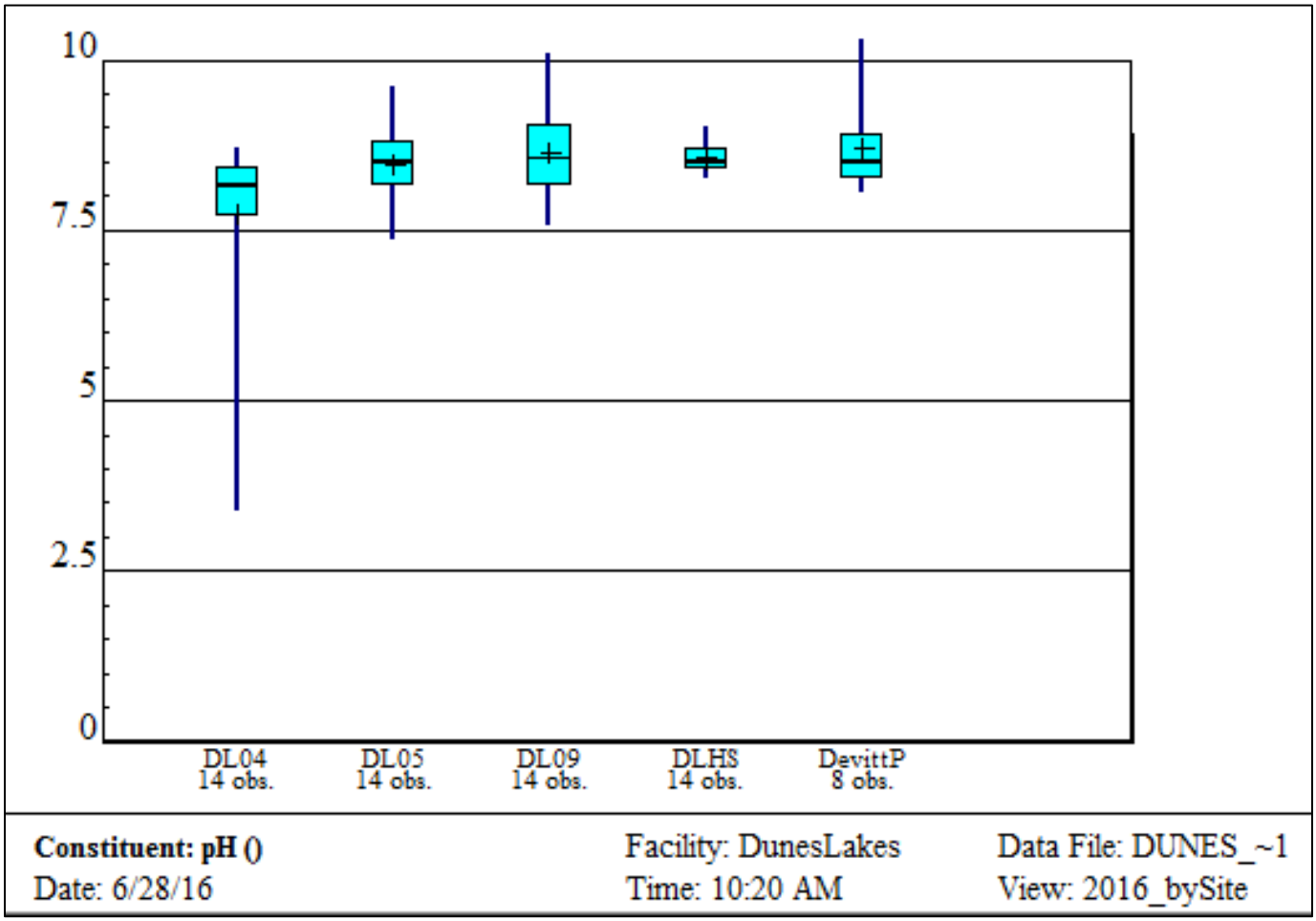


Figure 11. pH for currently monitored lakes since inception of monitoring program in 2012. SCCF's Devitt Pond, which was newly dug on conservation land in 2014, is also shown for comparison. The number of sampling events is noted below each box and whisker plot. Box boundaries represent 25th and 75th percentile

Table 1. Lake 4 water quality data summary. Values exceeding state water quality criteria are shown in bold.

Parameter	Mean Value (n=2)										FL 90th%	FL WQ Criteria
	Dry2012	Wet2012	Dry2013	Wet2013	Dry2014	Wet2014	Dry2015	Wet2015	Dry2016	Wet2016		
Chlorophyll a (µg/l)	**38.8**	**36.2**	**32.5**	**39.4**	**24.2**	**25.3**	20.3	15.8	15.1		31.9	20
Total N (mg/l)	**3.55**	**3.7**	**9**	**3.45**	**3.85**	**2.4**	**2.96**	**2.7**	**2.35**		1.72	1.27
Inorganic N (mg/l)	0.124	0.152	0.241	0.1457	0.1865	0.258	0.1143	0.022	0.041		0.139	
Nitrate/Nitrite (mg/l)	0.011	0.010	0.010	0.010	0.017	0.020	0.032	0.010	0.005		0.08	
Ammonia (mg/l)	0.114	0.293	0.231	0.209	0.170	0.238	0.083	0.034	**0.037**		0.059	0.2
TKN (mg/l)	3.55	3.7	4.8	3.45	3.85	2.4	2.937	2.7	2.35		1.7	
Total P (mg/l)	**0.093**	**0.074**	**0.110**	**0.079**	**0.150**	**0.093**	**0.153**	**0.140**	**0.149**		0.095	0.05
Orthophosphate (mg/l)	0.022	0.019	0.034	0.034	0.056	0.018	0.057	0.056	0.137		0.04	
N:P	38.2	50.0	81.8	43.7	25.7	25.8	19.3	19.3	16.2		33.3	
ChlA:TP	0.4	0.5	0.3	0.5	0.2	0.3	0.1	0.1	0.1		0.3	
Limiting Nutrient	**None**	None	None	None	None	None	None	None	None		None	
Trophic State Index	**80.5**	**76.8**	**84.6**	**77.1**	**79.5**	**73.7**	**77.1**	**74.7**	**73.8**		72.7	< 60
Surface DO (mg/l)	4.5	4.0	3.5	5.9	5.4	2.9	6.9	4.7	2		5.12	> 5
Surface Salinity (PSU)	9.1	17.3	11.9	7.1	4.4	6.0	7.5	6.3	5.15			
Surface Temp (^{o}C)	25.4	26.8	28.4	29.1	21.6	30.6	23.5	30.6	29			
Turbidity (NTU)	4.5	6.6	*	4.5	4.5	7.1	3.4	2.2	10.7		9.35	
CDOM (QSE)	191.9	166.7	184.8	200.8	205.5	203.4	181.4	197.9	163			

Table 2. Lake 5 water quality data summary. Values exceeding state water quality criteria are shown in bold.

Parameter	Mean Value (n=2)										FL 90th%	FL WQ Criteria
	Dry2012	Wet2012	Dry2013	Wet2013	Dry2014	Wet2014	Dry2015	Wet2015	Dry2016	Wet2016		
Chlorophyll a (µg/l)	**133.8**	**146.5**	-	**168**	**46.3**	**67.8**	**67.8**	**43.4**	**30.6**		31.9	20
Total N (mg/l)	**4.15**	**6.3**	-	**3.5**	**3.2**	**2.65**	**3.14**	**2.6**	**2.62**		1.72	1.27
Inorganic N (mg/l)	0.026	0.857	-	0.244	0.196	0.3195	0.1597	0.028	0.019		0.139	
Nitrate/Nitrite (mg/l)	0.01	0.01	-	0.01	0.01	0.01	0.0207	0.01	0.007		0.08	
Ammonia (mg/l)	0.068	1.276	-	0.234	0.186	0.3095	0.139	0.018	0.012		0.059	0.2
TKN (mg/l)	4.15	6.3	-	3.5	3.2	2.65	3.127	2.6	2.62		1.7	
Total P (mg/l)	**0.0855**	**0.16**	-	**0.065**	**0.1065**	**0.125**	**0.1417**	**0.1**	**0.16**		0.095	0.05
Orthophosphate (mg/l)	0.02	0.0225	-	0.043	0.024	0.0185	0.0327	0.023	0.107		0.04	
N:P	48.5	39.4	-	53.8	30.0	21.2	22.2	26.0	17.0		33.3	
ChlA:TP	1.6	0.9	-	2.6	0.4	0.5	0.5	0.4	0.4		0.3	
Limiting Nutrient	None	None	-	P	None	None	None	None	None		None	
Trophic State Index	**84.7**	**91.8**	-	**83**	**79.3**	**80.9**	**82.8**	**77.2**	**78.3**		72.7	< 60
Surface DO (mg/l)	8.7	4.0	-	2.9	5.9	2.5	7.6	4.1	5.8		5.12	> 5
Surface Salinity (PSU)	3.5	3.6	-	3.5	3.6	3.7	3.2	3.6	2.3			
Surface Temp (^{o}C)	27.5	24.7	-	28.5	21.5	30.0	23.0	31.1	29			
Turbidity (NTU)	14.9	22.2	-	15.6	5.3	15.3	6.3	7.1	5.7		9.35	
CDOM (QSE)	183	194	-	202	218	200	196	192	154.5			

Table 3. Lake 9 water quality data summary. Values exceeding state water quality criteria are shown in bold.

Parameter	Mean Value (n=2)										FL 90th%	FL WQ Criteria
	Dry2012	Wet2012	Dry2013	Wet2013	Dry2014	Wet2014	Dry2015	Wet2015	Dry2016	Wet2016		
Chlorophyll a (µg/l)	**89**	**97.6**	-	**202**	**96**	**83.1**	**54.2**	**27.1**	**54.2**		31.9	20
Total N (mg/l)	**4.6**	**5.15**	-	**3.6**	**4.65**	**2.65**	**3.127**	**2.6**	**3.06**		1.72	1.27
Inorganic N (mg/l)	0.0477	0.507	-	0.0575	0.291	0.1595	0.1653	0.065	0.021		0.139	
Nitrate/Nitrite (mg/l)	0.0115	0.01	-	0.01	0.01	0.01	0.0153	0.01	0.005		0.08	
Ammonia (mg/l)	0.06	0.497	-	0.0475	0.281	0.1495	0.15	0.055	0.016		0.059	0.2
TKN (mg/l)	4.6	5.15	-	3.6	4.65	2.65	3.117	2.6	3.055		1.7	
Total P (mg/l)	**0.18**	**0.1455**	-	**0.085**	0.0545	0.0565	**0.0873**	**0.073**	**0.159**		0.095	0.05
Orthophosphate (mg/l)	0.0225	0.0215	-	0.043	0.0075	0.021	0.025	0.014	0.111		0.04	
N:P	25.6	35.4	-	42.4	85.3	46.9	35.8	35.6	22.0		33.3	
ChlA:TP	0.5	0.7	-	2.4	1.8	1.5	0.6	0.4	0.4		0.3	
Limiting Nutrient	None	None	-	P	None	None	None	None	None		None	
Trophic State Index	**88.1**	**87.9**	-	**85.7**	**81.1**	**76.9**	**78.7**	**73**	**81.5**		**72.7**	< 60
Surface DO (mg/l)	8.0	4.3	-	5.0	4.8	3.7	7.6	3.8	4.2		5.12	> 5
Surface Salinity (PSU)	4.9	4.8	-	4.5	5.0	4.8	4.4	4.9	3.2			
Surface Temp (^{o}C)	25.4	25.4	-	29.0	22.1	30.7	23.3	31.2	28.7			
Turbidity (NTU)	5.5	9.2	-	11.0	9.3	7.5	5.9	3.6	16.0		9.35	
CDOM (QSE)	153.3	149.4	-	154	175	144	172	150	119.5			

Table 4. Horseshoe Lake water quality data summary. Values exceeding state water quality criteria are shown in bold.

Parameter	Mean Value (n=2)										FL 90th%	FL WQ Criteria
	Dry2012	Wet2012	Dry2013	Wet2013	Dry2014	Wet2014	Dry2015	Wet2015	Dry2016	Wet2016		
Chlorophyll a (µg/l)	**50.7**	**52.3**	-	**72.2**	**50.5**	**35.1**	**28.7**	23	**31.95**		31.9	20
Total N (mg/l)	**3.1**	**3.95**	-	**2.95**	**2.75**	**2.1**	**2.3**	**2.5**	**2.13**		1.72	1.27
Inorganic N (mg/l)	0.04	0.092	-	0.044	0.115	0.133	0.082	0.012	0.033		0.139	
Nitrate/Nitrite (mg/l)	0.01	0.01	-	0.01	0.01	0.01	0.023	0.01	0.021		0.08	
Ammonia (mg/l)	0.066	0.128	-	0.128	0.105	0.123	0.059	0.014	0.012		0.059	0.2
TKN (mg/l)	3.07	3.95	-	2.95	2.75	2.05	2.3	2.5	2.11		1.7	
Total P (mg/l)	0.042	0.05	-	0.038	0.05	0.043	**0.091**	**0.057**	**0.184**		0.095	0.05
Orthophosphate (mg/l)	0.0145	0.012	-	0.023	0.005	0.016	0.007	0.015	0.147		0.04	
N:P	73.8	79.0	-	77.6	55.0	48.8	25.3	43.9	22.3		33.3	
ChlA:TP	1.2	1.0	-	1.9	1.0	0.8	0.3	0.4	0.2		0.3	
Limiting Nutrient	None	None	-	P	None	None	None	None	None		None	
Trophic State Index	**73.8**	**76.6**	-	**74.5**	**74**	**69.6**	**73.8**	**70.4**	**76.3**		72.7	< 60
Surface DO (mg/l)	8.3	6.1	-	4.7	7.9	5.3	6.5	4.8	6.2		5.12	> 5
Surface Salinity (PSU)	4.7	4.6	-	4.5	4.6	4.8	4.2	4.6	3			
Surface Temp (^{o}C)	24.4	25.6	-	29.3	21.7	31.1	23.3	30.7	29.1			
Turbidity (NTU)	9.5	7.8	-	8.7	7.2	5.5	4.8	5	5.5		9.35	
CDOM (QSE)	89	101	-	118	110	104	112	100	94			

Table 5. Discharge from The Dunes stormwater system at Lake 4 weir. Data for 2016 is given as of reporting date. Based on flowrates, nutrient loading from Dunes stormwater discharge to the Tarpon Bay estuary is also given.

Period	Mean Daily Flow (ft^3/day)	Total Discharge (1000 ft3)	Mean TN (mg/l)	Mean TN Loading (lbs)	Mean TP (mg/l)	Mean TP Loading (lbs)
Jan1 - Jun15 2015	0	0	2.96	0	0.153	0
Jun16 - Oct15 2015	1723	5,005	2.7	843	0.14	44
Oct16 - Dec31 2015	67	123	2.7	21	0.14	1
Total 2015		**5,128**		**864**		**45**
Jan1 - Jun15 2016	661	2,620	2.35	384	0.149	24
Jun16 - Oct15 2016						
Oct16 - Dec31 2016						
Total 2016 (to Date)		**2,620**		**384**		**24**